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GROWING SEEDLINGS IN SAND

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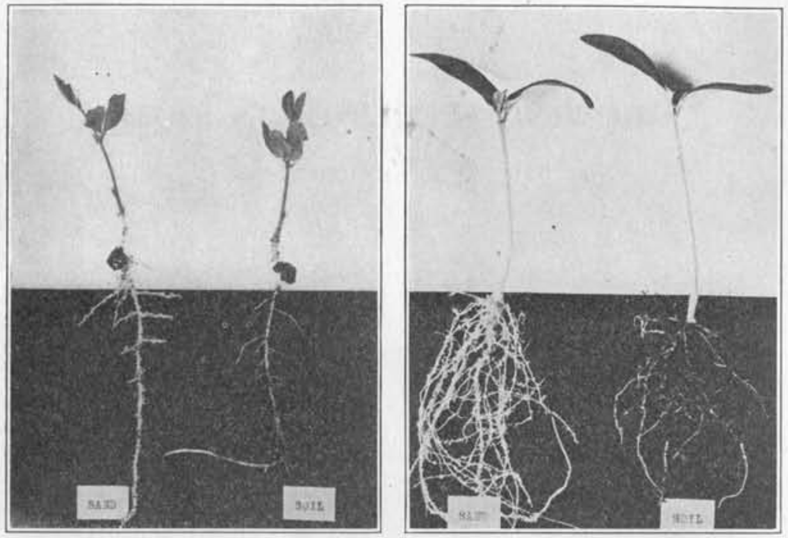

FIGURE 2. Root development of seedlings in sand and in soil, sweet pea at left, cucumber at right.

DIRECTIONS FOR PRACTICAL USE OF THE METHOD

1. Secure the desired amount of sand (as free from silt and loam as possible) from a sand pit, lake, river, seashore, or dealer in masons' supplies.

2. Wash the sand in several changes of hot water (160° F or above) until the water remains practically clean after stirring.

3. Place the sand in fairly tight, *clean*, wooden boxes or flats, or any sort of a container that will allow a little drainage. Level off the surface to about 2 inches or more in depth.

4. For each square foot of sand surface, dissolve about one-half teaspoonful of saltpeter (potassium nitrate) in about one-quarter pint of water and sprinkle over the sand. For a flat of ordinary size, this amounts to about 1 teaspoonful of saltpeter dissolved in a cup of water. For larger surfaces, add 1 ounce of saltpeter in 3 pints of water for each 10 square feet. (For other fertilizers, see Table 1.)

5. Drill or sow seeds and cover with the same washed sand.

6. Keep sand moist throughout its depth by occasional watering until the seedlings are grown.

7. After seedlings emerge, allow as much sunlight as possible on the cultures.

GROWING SEEDLINGS IN SAND

A. A. DUNLAP

SAND culture offers many advantages for growing seedlings under greenhouse conditions. Our experimental tests, as well as the experiences of certain commercial growers, show that this method provides for excellent seed germination and a high percentage of seedling survival. It insures a maximum number of healthy seedlings from a given quantity of seed.

The outstanding advantage of washed sand over soil lies in its freedom from damping-off fungi that are nearly always present in soil and which must be controlled by exacting soil treatments. Furthermore, this method enables the grower to regulate the development and size of the seedlings, to obtain "hard" seedlings with strong roots, and to keep them for indefinite periods without deterioration before transplanting—all desirable features favoring the use of sand.

Details of the sand culture method together with comparison of this with the usual soil methods were given in a bulletin[1] published early in 1936 but now out of print. It is the purpose of this circular only to give directions for starting plants from seed in sand. We also include certain cultural details that have been found of value since the first bulletin was written.

MATERIALS AND PROCEDURE

It is believed that seedlings of all kinds of plants may readily be grown in sand to an adequate size for transplanting. Owing to the fact that sand culture is somewhat different from the ordinary culture in soil, growers may require more or less practice before obtaining the best possible results.

Sand. Any sand that is fairly free from silt and loam may be used for growing seedlings. Seashore sand has been found most satisfactory. Sand from an inland pit is very useful especially if taken from the deeper portion of the pit. Surface sands from inland sources are undesirable on account of their fineness and organic content. A sand with a certain percentage of coarser particles produces stronger root growth than one having uniformly fine particles. The mineral impurities found in natural colored sands benefit seedling growth. Certain kinds of pure sand may be obtained on the market. Almost any dealer in masons' and builders' supplies has sand for making concrete which is also usually suitable for raising seedlings.

Washing the sand. In order to insure freedom from damping-off and to secure the best seedling growth, the sand should first be washed in

[1] Dunlap, A. A. Sand Culture of Seedlings. Conn. Agr. Exp. Sta. Bul. 380. January, 1936. (Out of print).

hot water. Obviously, a clean sand, like that from the seashore, is easier to wash than that from the usual inland sources. A safe rule to follow is to wash the sand in several changes of hot water (160° F or above) until the water remains practically clear after stirring. Many kinds of fairly clean, new sand may be used without washing for growing one crop of seedlings. A small amount of salt present in seashore sand is not usually detrimental to the growth of young plants. Occasionally inland sand contains damping-off fungi and must be thoroughly washed to avoid seedling loss. Any sand that has been used once in the greenhouse also should be washed before another planting.

As a substitute for the washing process, one grower passed the sand several times through the flame of a pressure weed-burner. Excellent results may be obtained by this method of sterilization. Another grower heated the sand for two hours under pressure in a steam autoclave with equally good results.

Containers. After washing, the wet sand is placed in containers in which the seedlings are to be grown. Ordinary wooden flats or clay crocks, such as are used for growing seedlings in soil, may also be used for sand cultures. The container should not allow the sand to dry out too rapidly, but at the same time it should provide for slight drainage. Wooden flats should be fairly tight except for a few small holes or narrow seams in the bottom. Glazed crocks are preferable to the usual unglazed, clay pots. If the latter are used, it is advisable first to coat them with paraffin, varnish or paint. Crocks should have the usual drainage hole left partially open. For small quantities of seed, leaky tin pans make useful containers.

Depth of sand. Obviously the depth of the sand depends on the type of container. In regular flats, about two and one-half to three inches of sand are used. In crocks, boxes, and greenhouse benches, sand to a depth of seven or eight inches may be used with excellent results. When the sand is four or five inches deep, it dries out less rapidly, conserves the added fertilizer better, and permits the seedlings to attain a larger size than the two- or three-inch bed.

Fertilizing the sand. As soon as the surface of the wet sand has been leveled off a little below the top of the container, the fertilizer may be added. This is dissolved in water and sprinkled over the bed immediately before sowing the seed.

Since certain amounts of nutrients are stored in the seed, and traces of plant food are present in the water and sand, it is only necessary to add a few elements to obtain satisfactory seedling growth. If plants were to be brought to maturity in sand, however, they would require the proper application of a more complex nutrient solution containing three or four different mineral salts. The addition of nitrogen and potassium is sufficient to bring most seedlings to the transplanting stage. Potassium nitrate (KNO_3, nitrate of potash, or saltpeter) furnishes both of these elements and is generally useful as a fertilizer. Sodium nitrate ($NaNO_3$, nitrate of soda, or Chile saltpeter) may be used, although the resulting seedlings are usually somewhat smaller than those grown with the potassium salt. Many combinations of two salts—one of which carries nitrogen and the other potassium, such as calcium nitrate and potassium chloride—also give excellent seedling growth. The additional application of phosphorus to the sand usually

results in the growth of somewhat larger seedlings, but this slight increase in size is not considered essential for seedling production. Magnesium added to the fertilizer solution also stimulates slight growth increase, but most seedlings do not respond to this element noticeably until after they have attained considerable size.

For practical purposes, saltpeter is the only fertilizer that is necessary in sand culture. This is especially true if the seedlings are to be transplanted into soil in the greenhouse, or if they are to be used in a small garden where more or less care will be given to the tender plants. If one desires the largest plants for transplanting directly into the field, it is better to add phosphorus and possibly magnesium salts to the saltpeter solution. Common chemicals containing phosphorus that may be used for this purpose are the acid phosphates of calcium and potassium. Commercial "superphosphate" used as an agricultural fertilizer contains from 20 to 25 percent of the water soluble calcium acid phosphate $CaH_4(PO_4)_2$. Mono-potassium acid phosphate (KH_2PO_4, biphosphate of potash) may be obtained in pure form and may be used in combination with certain non-potash nitrogen carriers, such as nitrates of lime, soda or ammonia, to make a very desirable fertilizer for seedlings in sand.

The following table shows some of the various types of nutrient solutions that may be prepared readily.

TABLE 1. FERTILIZERS FOR SEEDLINGS IN SAND.

Type No.	Name of Chemical	Formula	Essential Elements Supplied[1]	Approximate amounts in terms of teaspoonfuls: For each square foot of sand surface — before planting	Approximate amounts in terms of teaspoonfuls: For 1 quart of dilute nutrient solution for post-emergence feeding[2]
1	Saltpeter	KNO_3	N, K	½	1
2	Nitrate of Soda	$NaNO_3$	N, Na	½	1
3	Nitrate of Lime Muriate of Potash	$Ca(NO_3)_2$ KCl	N, K	½ ½	1 1
4	Saltpeter Superphosphate	KNO_3 $CaH_4(PO_4)_2$	N, K, P	½ ¼	1 ½
5	Nitrate of Lime Biphosphate of Potash	$Ca(NO_3)_2$ KH_2PO_4	N, K, P	½ ½	1 1
6	Nitrate of Soda Muriate of Potash Superphosphate	$NaNO_3$ KCl $CaH_4(PO_4)_2$	N, K, P	½ ½ ¼	1 1 ½
7	Saltpeter Superphosphate Epsom Salts	KNO_3 $CaH_4(PO_4)_2$ $MgSO_4$	N, K, P, Mg	½ ¼ ¼	1 ½ ½
8	Nitrate of Lime Biphosphate of Potash Epsom Salts Sulphate of Ammonia	$Ca(NO_3)_2$ KH_2PO_4 $MgSO_4$ $(NH_4)_2SO_4$	N, K, P, Mg	½ ½ ¼ ⅛	1 1 ½ ¼
9[3]	Nitrate of Ammonia	NH_4NO_3	N	½	1
10[3]	Sulphate of Ammonia Muriate of Potash	$(NH_4)_2SO_4$ KCl	N, K	½ ½	1 1

[1] N-Nitrogen, K-Potassium, P-Phosphorus, Na-Sodium, Mg-Magnesium.
[2] This treatment is usually unnecessary—see text, page 9.
[3] To prevent vigorous seedlings from growing too tall.

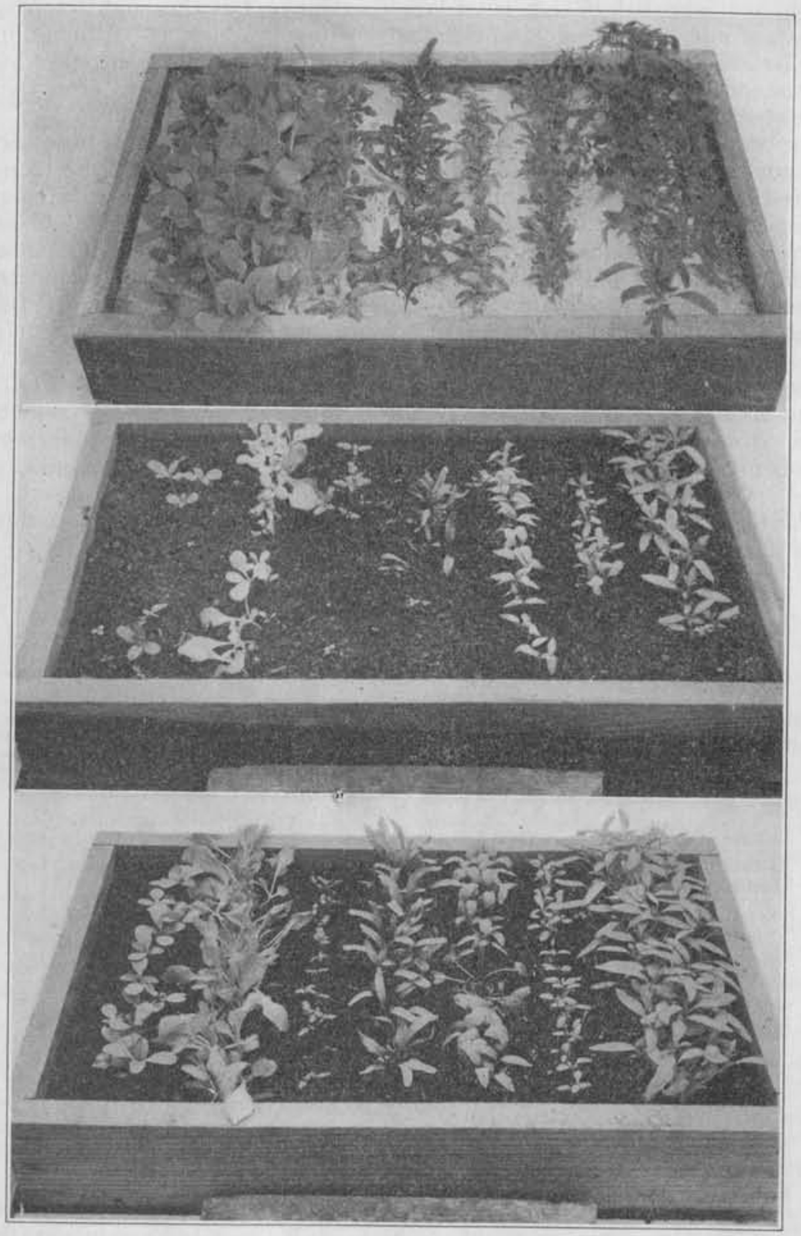

FIGURE 3

On these facing pages are pictured the results of seedling culture in sand and in soil. Each of the flats contained the same number of seeds of the following species: Zinnia, lettuce, clarkia, beet, eggplant, gypsophila and tomato.

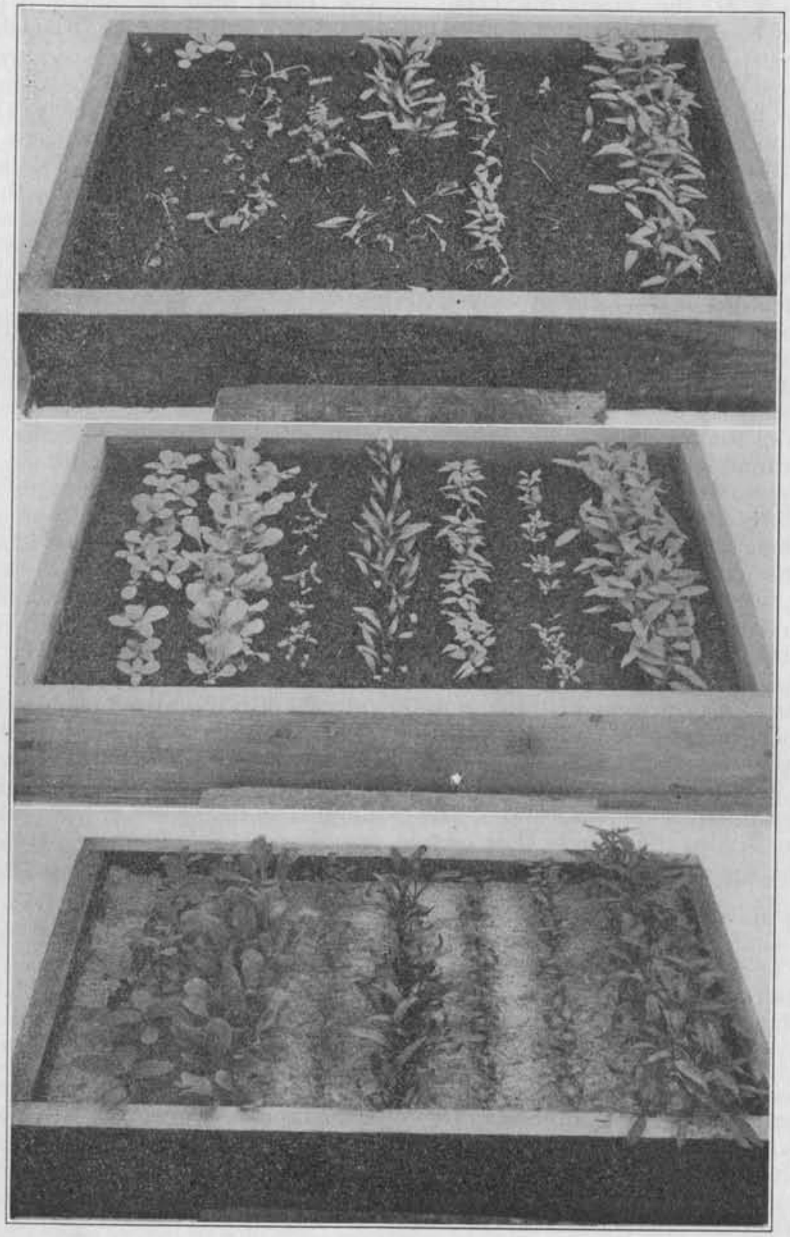

FIGURE 4

At the top of the left hand page, seedlings are shown growing in gray sand; center, untreated soil; and below, the formaldehyde-treated soil. On this page are shown from top to bottom: results when seed was treated with red copper oxide and planted in untreated soil; autoclaved soil, and brown sand.

Most of the chemicals listed in the table may be obtained as commercial products from dealers in agricultural fertilizers, or as purified chemicals from druggists. For the purposes at hand, the degree of purity of the nutrients is not important. The approximate amount of the chemical to be used is given in the next to the last column of this table. The amount is stated as a fraction of a rounded teaspoonful and is sufficient to nourish one square foot of seedlings to an ample size for transplanting. The last column presents the amounts of the same fertilizer salts that may be added to one quart of water for occasional watering of the seedlings. Such watering is not ordinarily necessary but may be employed when large seedlings are desired or when the fertilizer has been accidentally washed out of the sand by over-watering.

Each of the types of nutrients listed as Nos. 1 to 8 inclusive are satisfactory for growing almost any kind of seedlings in sand. As stated above, the more complex combinations of salts, as Nos. 7 and 8, are in most cases only slightly more desirable than a simpler type such as No. 1. It might be well for the grower to experiment with a few of the above types to determine which is the most satisfactory for his particular conditions.

Types of fertilization like Nos. 9 and 10 are designed to prevent vigorous seedlings such as cabbage and cucumber from producing stems that are too long for transplanting. The effects of these fertilizers depend somewhat upon the type of container in which the plants are grown. In wooden flats, the stems will grow longer than in glazed crocks. Sulphate of ammonia is more effective than nitrate of ammonia. The use of a potassium salt together with the ammonium salt tends to lessen the desired stunting of the plants caused by the latter.

Sometimes growers wish to use water extracts of ready-mixed plant foods or some brand of a complete fertilizer. These often give excellent results. They contain a diversity of materials, however, so that no definite amounts can be prescribed. Since such products carry considerable insoluble material, larger quantities would be required than in the use of pure salts. There is also the danger that certain organic materials in these extracts might encourage the spread of damping-off fungi among the seedlings.

Applying the fertilizer. The fertilizer is applied in solution to the wet sand just before the seeds are planted. The correct amount of fertilizer is determined according to the preceding table. This is dissolved in a small amount of water in order that it may be evenly distributed. About one-half cup of water for each square foot of sand surface is satisfactory. A syringe or clothes sprinkler is useful in applying the solution to the sand.

Seeding and covering. The seeds may be planted immediately after the fertilizer has been applied. They may be broadcast or sowed in shallow drills. It is possible to sow the seed thickly on sand and still obtain good results. If larger seedlings are desired, or if the species to be planted has a tendency to produce elongated stems, it is better to allow more space between the plants.

It is easier to cover the seeds with dry sand, which also has been washed. Larger seeds, however, may be covered with wet sand. Small seeds, such as petunia or snapdragon, require only a light sifting of sand, whereas most vegetable, tree, and larger flower seeds should be covered deeply enough to enable the seedling roots to obtain foothold. A light watering follows the planting.

The common practice of covering newly planted flats or crocks of soil with a glass plate, board, paper or some such material is also very helpful in sand culture. This keeps the upper portion of the sand in a moist condition that favors germination. Too much watering should be avoided at this period, because it tends to wash away the nutrients from the region of the young roots. However, covers should be removed as soon as the seedlings begin to emerge from the sand, allowing sufficient sunlight after the first stage.

Watering. Sand cultures should be watered only frequently enough to keep the sand thoroughly moist throughout its depth. Under ordinary conditions one watering a day will suffice for small seedlings, but as the plants grow they take up and evaporate increasingly larger amounts of water. A dry room, bright sunshine, and high temperatures tend to make more frequent waterings necessary. Shallow depths of sand dry out much more quickly than deeper ones, and on this account it is well to keep shallow crocks, flats, etc., on some damp surface such as wet peat moss or earth.

In watering sand cultures, the grower should keep in mind the fact that sand, unlike soil, does not "hold" plant nutrients but allows them to leach out if an excess of water is added. On the other hand, the sand should not be allowed to become too dry for extended periods. There are, however, very wide limits between a saturated condition of the sand and the point of dryness at which the seedlings show a tendency to wilt. With a little experience, the grower can easily adjust the watering to keep within these limits. During periods of high evaporation it is better to water more frequently, with less water being applied at each time. Some method of sprinkling the plants is more desirable than pouring the water on the sand.

Post-emergence feeding. Under certain conditions it may be necessary to water the cultures to such an extent that the nutrient salts will eventually be washed out of the sand. In such cases the seedlings will be small, pale green or yellowish in color, and there may be a tendency for the older leaves to drop. However, growth and vigor may be restored by watering the sand with one of the nutrient solutions listed in the last column of the table. This need be applied only about once a week in quantities as large as the sand will hold each time. Similar applications of this solution may be made to cultures of older seedlings after the plants have used up all of the fertilizers that were added at the time of planting. In this way large seedlings for transplanting into the field may be produced. In the case of certain seedlings that have tender foliage, it is better to apply the nutrient solution as closely to the sand as possible in order to avoid chemical injury when drops evaporate on the leaves. A light sprinkling of water after feeding also will prevent this injury.

Keeping seedlings in sand. Although sand-grown seedlings, with their well-developed roots, may be transplanted at even younger stages than those grown in soil, they may also be kept in a healthy condition for many weeks in the sand. This is a possible and extremely practical procedure with the majority of seedlings. Watering is the only attention required by the cultures in order to maintain them over a long period. Although the seedlings may become light in color, their stems grow very firm and the root systems strong and extensive under these conditions.

The plants may be made to renew growth at any desired time by merely saturating the sand with a dilute nutrient solution as previously described. It is believed to be beneficial to feed the plants in this manner about a week or more before they are to be transplanted. This seems to provide for quicker recovery from the shock of transplanting.

On a few occasions, seedlings have been retained in sand until premature flowers appeared on the diminutive plants. Upon transplanting into soil, these seedlings were found to resume vegetative growth and to develop into plants that were equal in every way to others produced from young, fresh seedlings transplanted at the same time.

In the case of a few species of plants, a certain percentage of the seeds apparently is infested with parasitic fungi which may cause serious losses in stands of seedlings which are being kept for future use. Beet and cabbage are examples of this and require special seed-treatments if the seedlings are to be kept for a long time. Soil-grown seedlings show the same evidence of seed-borne infection. Furthermore, seedlings in soil are likely to grow completely beyond a useful size if kept for only a few days, and they show no tendency to become hardened with age.

Transplanting. Sand-grown seedlings are easy to transplant and an exceedingly high percentage survive. If the sand is first loosened around the plants, they may be gently pulled up with the roots still intact. By placing both sand and seedlings in water, the sand will be washed away leaving the roots free. During the transplanting few plants need to be discarded. The uniformly good roots, evenness in size, and freedom from disease result in a large proportion of desirable seedlings.

Continued use of the sand. The same sand may be used many times for raising seedlings. It should be washed thoroughly, however, in hot water before each planting. This process is necessary to remove all contamination by fungi, decayed seeds, roots, and the green algae that sometimes grow harmlessly on the surface.

Supplementary Items

Seed treatment. With the majority of seeds, the best results have been obtained in sand culture when no seed treatment was used. Many seed treatments were designed to protect the seedling from soil fungi. Therefore little benefit is to be expected from the use of these methods when seed is grown in a fungous-free medium. In fact, most of the chemical treatments tested have done more harm than good when sand was used. More essential was the securing of fresh seed that had been carefully harvested from healthy plants. To date, the only treatment that has been found useful in this work is the hot water treatment of cabbage and other cruciferous seed. This consists in keeping the seed for 30 minutes in a vessel of hot water the temperature of which is maintained at 122° F. Such procedure has been found necessary when cabbage seedlings are to be grown with ammonium fertilization or when they are to be held in the seedling stage for a long time under any type of nutrition or culture.

Removal of diseased seedlings. Even under absolutely sterile conditions and the most careful attention, an individual seedling or small patches of seedlings may be killed either by seed-borne fungi or through contamination from the outside. Such seedlings frequently appear in sand cultures but there is seldom any spread of disease in the sand. Should any infection show signs of spreading to healthy seedlings, the infected areas, including both seedlings and sand, may be entirely removed from the culture, thereby preventing further loss.

Modified culture for slow-germinating seeds. Seeds that are small in size and which require two weeks or longer for germination, like Rhododendron, may be planted in washed sand to which no nutrient has been added. When the seedlings appear, they may be watered three or four times a week with a dilute form of one of the nutrient solutions listed in Table 1. In this case, however, the amount of salts given in the last column should be added to about two quarts of water instead of one. This special treatment prevents much green algal growth from forming on the surface of the cultures before the seedlings emerge. Since slow-growing seedlings must make considerable growth before they are large enough to transplant, it is better to use one of the more complete nutrient solutions, like No. 6, 7, or 8, listed on page 5. Many such seedlings grow considerably faster when kept in a very humid atmosphere, such as in a moist-chamber.

Exact amounts of nutrients unnecessary. The amounts of nutrients, as recommended in Table 1, are merely approximations of desirable amounts to use for the satisfactory growth of most seedlings. Either smaller or greater quantities of the fertilizer salts may often be used with practically identical results. If too small quantities of the nutrient are supplied, the seedlings may not attain a large size and they will usually be of a light, yellowish green color. The root systems, however, apparently become more extensive under such conditions. When too much fertilizer has been applied, the seedlings are usually stunted and rather dark green. Incidentally, vigorous, healthy seedlings are often lighter in color than less actively-growing plants.

Peat moss and sand mixtures. In a few experiments, clean, ground peat moss mixed with the washed sand has been found to increase the size of certain seedlings. This beneficial effect has been noted particularly in the case of some of the slower-growing species. The peat moss undoubtedly helps to retain both moisture and nutrients within the sand. No definite experiments have been performed to determine the best proportions of sand and peat moss, but mixtures of one part by volume of the latter to four or five parts of sand have been used. It has also been found beneficial to place a layer of peat moss in the bottom of the containers before filling with sand. A commercial product called "Sorbex" has been employed in these experiments.

Sand on soil. For some time growers have practiced covering seeds with sand after planting in soil to improve germination and to avoid damping-off. Since the soil in this case is in close contact with the young seedlings, damping-off frequently does occur. However, by using two inches of washed sand over the surface of soil, followed by fertilizing, seeding, and covering as previously described, a sterile culture medium is provided in which the seedlings may grow through the early danger period free from damping-off. Later the roots reach the soil below and vigorous growth will be made. Therefore, a one-half inch layer of new, rich soil in the bottom of a flat of sand may assist greatly in the nutrition of the older seedlings without necessarily encouraging damping-off.

Seed culture in cold frames. Although the most practical use of sand for growing seedlings may be made under greenhouse conditions, the method may be used in cold frames or hot beds with satisfactory results.

At the Station, sand culture was equally beneficial outdoors and indoors. The increased evaporation and drainage out-of-doors, however, make the problem of feeding and watering somewhat more difficult. This may be partly overcome by the use of fairly tight containers in the cold frame and by careful attention to the opening of the sash, or shading from bright sunshine. Rapid loss of nutrients from the sand into the underlying soil may be counteracted by watering every few days with a nutrient solution.