STUDIES ON SOME LOCAL PROPAGATION MEDIA

By

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This thesis is my original work and has not been presented for a degree in any other University.

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To My Parents

for allowing me to work in their laboratory and for their assistance and useful suggestions.

I am greatly indebted to the following persons of the Department of Horticulture, Agricultural University, Wageningen, Holland: Prof. Bierhuizen, Head of the Department for accepting me in the department and for giving me a very useful talk on germination problems; Dr. Ir. Hopmans and his Assistant for their advice and assistance during the determination of some physical properties of the materials studied, and Miss Wagenvoort for her diligent assistance during the determination of some chemical properties of the materials studied, for making it possible for me to obtain results from the [illegible] Institute for Land and Water

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SUMMARY

The main objective of this study was to investigate the possibility of using locally avilable materials as additives in propagation mixtures for vegetable seedlings production in containers so as to find subsitutes for the imported ones.

Three trials with capsicum seedlings were carried out in a plant-house at the Horticultural Unit at the Field Station of the Faculty of Agriculture, University of Nairobi. The objective was to find suitable additive(s) to basal media, which were various mixtures of top red soil and compost, to make suitable potting mixture(s) for the production of the capsicum seedlings. In the first trial the following local and imported additives were tested: local - sand, coir-dust, charcoal dust, saw-dust, coffee parchments, leaf mold, peat moss and sisal waste; imported - Irish peat and vermiculite. In the second trial the following were tested: coir-dust, sisal waste, charcoal dust, saw-dust, sand and vermiculite; while in the third trial the tested additives were sisal waste, coir-dust, charcoal dust, saw-dust and vermiculite.

In order to explain the results of the three trials, some physical and chemical properties of the additives were determined. The determinations were carried out at the Department of Horticulture of the Agricultural University,

and at the Institute for Land and Water Management - both of Wageningen, Holland; and at the Department of Soil Science of the Faculty of Agriculture, University of Nairobi.

The additives were also tested for suitability as germinating media.

Results from the trials and the determined physical and chemical properties indicate that sisal waste, coir-dust and charcoal dust, locally available materials, can give better results than or as good results as vermiculite and Irish peat (imported materials). Sisal waste has a high total pore space percentage but low water-holding capacity. The material has a high cation exchange capacity but low concentration of soluble salts. It has a pH of about 7.6 and contains exchangeable calcium, potassium and magnesium. Coir-dust has also a high total pore space percentage but has relatively low volume percent air at 10 cm water tension. The coir-dust has good water-holding and cation exchange capacities, and has high exchangeable potassium, calcium and magnesium. Coir-dust has a pH of 5.4. Charcoal dust has very low total pore space percentage but high volume percent solid matter. The charcoal dust has relatively low volume percent air at 10 cm water tension and low water-holding capacity. It has a very low cation exchange capacity and low concentration of soluble salts. It has a pH of about 7.5.

The results also indicate the unsuitability of saw-dust and coffee parchments as additives to propagation mixtures. The two seem to be too acidic for good plant growth and could be containing some phytotoxic properties which could retard plant growth.

Charcoal dust and local peat moss could be suitable as germinating media. The local peat moss has high total pore space percentage and water-holding capacity.

It has been recommended that further work with mixtures of sisal waste, coir-dust, charcoal dust and local peat moss with top soil and compost, and/or fertilizer, should be undertaken in order to find out suitable propagation mixtures for raising various vegetable seedlings and other horticultural crops for various parts of the country.

CHAPTER I

INTRODUCTION:

As the demand for consumption of fresh fruits and vegetables in Kenya is increasing, especially in the expanding urban areas, the supply of these commodities should also increase. Also Kenya's economy being dependant on Agriculture, the export demand for the fruits and vegetables, including cut flowers, is of importance. Increasing the supply of the fruits, vegetables and cut flowers depends partly on the production techniques employed by the growers, and partly on other factors like market feasibilities, production costs, etc, etc. Propagation is a production technique which is of utmost importance as it contributes positively to the final yield of any given crop.

There are many propagation techniques, as can be gathered from the literature review given in the next chapter. In Kenya the traditional way of propagating especially vegetable and fruit seedlings is by raising them on a raised seedbed and then transplanting them to their final stand in the field. Commercial nurseries, which mainly raise ornamental plants and cut flowers, are the only places where containers, such as pots and seed-flats, are intensively used. These days also, containers are being used in raising tea and coffee but not much experimental work has been done yet. The need for intensive production of vegetable seedlings has not yet been realized in this country, except in few large farms near Naivasha. However, as it has been mentioned above, the intensification of seedling production is of importance in helping to increase the continuous production (or supply) of vegetable and fruits so as to meet the increasing local and export demands.

It is essential to use good propagation medium in whatever container being used. Various organic and inorganic materials in various proportions have been used elsewhere, especially in Europe and America, to replace top soil for various given reasons as can be seen in the literature review. Information obtained from the commercial nurseries in this country indicates that the important components used in formulating their propagation media (mixtures) mainly include imported materials such as vermiculite (but now obtainable locally), perlite and peat, and other local materials like top soil, sand, manure of various types, charcoal, leafmold, wood chippings and broken clay bricks and old pots - all of which have not been scientifically tested in Kenya.

A material such as peat has been universally accepted as a very good material for use in formulating propagation media because of its good physical properties. The problem is that such a material is not available in experimental work has been done yet. The need for intensive production of vegetable seedlings has not yet been realized in this country, except in few large farms near Naivasha. However, as it has been mentioned above, the intensification of seedling production is of importance in helping to increase the continuous production (or supply) of vegetable and fruits so as to meet the increasing local and export demands.

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A material such as peat has been universally accepted as a very good material for use in formulating propagation media because of its good physical properties. The problem is that such a material is not available in this country and indeed in the whole of the African continent. Nevertheless substitute organic materials could be used successfully and Kenya could thus stop importing materials like peat.

The study undertaken was aimed at testing such locally available organic materials, namely coir-dust, charcoal dust, saw-dust, coffee parchments, sisal waste, local peatmoss and leafmold, in the propagation of vegetable seedlings in containers. However, information got from this study could be useful in formulating propagation media for other horticultural crops.

The objectives of the study are:

(a) Determination of some chemical and physical properties of the locally available organic materials.

(b) Identification of suitable local materials to be used in mixtures for raising vegetable seedlings in containers.

CHAPTER II

LITERATURE REVIEW

Vegetable Seedling Production for Transplanting

1. Advantages and Disadvantages

In the production of vegetable seedlings, the economic use of space is very important (Knott, 1957; Denisen, 1958) in that a number of plants can be grown in a small area thus reducing the cost of production per plant. Other reasons include the simplification of irrigation, weeding and control of insects and disease in the seedling stage (Winters, 1967), it also enables the growing of long season crops in a short growing season (Shoemaker and Teskey, 1955 ; Denisen, 1958) by producing seedlings in a nursery and later transplanting them to the garden. Denisen (1958) claims that by controlling the environmental conditions surrounding the seedlings being produced, percentage establishment is increased because losses due to disease, insect pests and other adverse conditions are reduced.

However, Korodi (1966) has observed that there are difficulties in the production of vegetable seedlings especially in large scale nurseries, due to the great labour demand. Kopetz (1956) regards direct sowing as superior to any kind of transplanting. He found out that six week old tomato and pepper plants transplanted at an age of twenty days had only 28% and 49% of the dry weight of direct sown plants respectively. Another disadvantage of transplanting seedlings is that transplanting checks growth (MacGillivray, 1953; Knott, 1957). The severity of the check depends on the following:

(a) the number of times the plants are transplanted;

(b) the size of the plant - the larger the plant the greater the check;

(c) length of time the plants operate on a reduced water supply;

(d) environmental conditions that affect transpiration;

(e) proportion of the root system that is retained;

(f) ability of the older roots to absorb water;

(g) the rate at which new roots are formed;

(h) previous rate of growth - as slow growing plants suffer less than rapidly growing ones;

(i) the conditions of transplanting - whether the plants have roots free of soil or have a ball of soil around them.

MacGillivray (1953) has observed that the advantages and disadvantages of transplanting as opposed to direct sowing vary according to climate of the area and the skill used by the grower. He listed the following considerations as important before deciding on what method to use:

Consideration	Transplanting	Direct Sowing
(a) Cost of seed	Low	High
(b) Transplanting/ Sowing cost	High	Low
(c) Thinning cost	None	High
(d) Check of growth	Some	None
(e) Germination condition	Usually good	Variable to poor
(f) Weeding	Low	High

There are therefore no hard and fast rules. The choice between the two methods (transplanting or direct sowing) should be made by the grower himself, depending on prevailing conditions. However, the following crops are commonly and successfully transplanted: broccoli, cabbage, cellery, egg-plant, lettuce, onion, parsley, tomato, cauliflower, pepper and kohlrabi. (MacGillivray, 1953; Winters, 1967).

2. Methods Used in the Production of Vegetable Seedlings for Transplanting

Vegetable seedlings can be produced in any one of the following three methods: in containers, on shaded nursery beds or in soil blocks.

A. Containers

Plant containers can be used to raise plants in groups or individually (Edmond, 1964). For group production the mostly used containers are flats which are shallow trays or seedboxes. Broccoli, cabbage, cauliflower, cellery, eggplant, kohlrabi, lettuce, onion, pepper and tomato can be raised in flats or seedboxes (Winters, 1967; Tindall, 1965). Raising plants individually involves the use of pots or bands (Edmond, 1964). The pots can be either porous (clay) or non-porous (metal, plastic, polythene tubings), while the bands can be either of wood or paper. In raising plants in pots or bands water and nitrogen supply have to be carefully regulated. Investigations have shown that plants in no-porous pots require less moisture than in porous pots (Edmond, 1964). Consequently failures through the use of non-porous pots are likely to be due largely to over-watering whereas failures through the use of porous pots are likely to be due to excessive drying out or under-watering. However, if the pots are regularly watered, either type of pot should be equally satisfactory. New clay pots, peat fibre pots and paper bands absorb nitrates (Edmond, 1964). Nitrogen should therefore be supplied when using these containers. Pepper, tomato and eggplant can be raised in pots or bands (Tindall, 1968). Curcubits have been also raised successfully in clay or peat pots, or in thin wood or paper bands. Nylund (1956) recommended that growing plants in 3inch (about 8cm) pots instead of flats, prior to transplanting to the field, could increase early yields of tomato.

The containers used should have adequate holes at the bottom to allow surplus water to drain through the medium or soil (Tindall, 1968).

B. Soil Blocks

Raising of vegetable seedlings in soil blocks is a new method which works very well especially in mass seedling production (for example in Holland - personal communications). The blocks are made by compacting a suitable growing medium using a machine. Blocks of various sizes can be made depending on the type of vegetable to be raised. In Holland, 5 x 5 x 5 cm blocks are used for lettuce, 7 x 7 x 7 cm blocks for sweet pepper and 10 x 10 x 10 cm blocks for tomatoes. In Dahomey and Ivory Coast (Anonymous) 5 x 5 x 4 cm or 4 x 4 x 5 cm blocks are used for cucumber, eggplants, peppers and tomatoes.

In Holland, the blocks consist of 95% peat, 3 - 5% sand and some fertilizer. In Ivory Coast the best formulations that have given best results are:

(a) 20% coffee peels (coffee berry skins) of an age of a minimum of 3 years.

60% forest top soil

10% sand

10% compost with short and well decomposed stables.

(b) 90% forest top soil mixed with clay sandy soil.

10% well decomposed coffee peels.

In Dahomey, the black-humus clay sandy soil, often available in the moors which are periodically flooded, is suitable for making the soil blocks. In the same country (Dahomey), well decomposed compost mixed fifty fifty with grey loam or clay forest top soil is also used. In Uganda (Will, 1972) soil blocks consisting of 3 parts by volume well-rotted coffee peels, 1 part by volume sand and 1 part by volume garden compost produced strong, healthy and well established plants free from nematodes and which suffered no transplanting checks. It is also understood that Prof. Huxley described similar mixtures at Makerere, Uganda, in early sixties (Gurnah, personal communication).

Seeds can be sown directly in the blocks or pricked-out into them (as in Holland, Dahomey and Ivory Coast, and Uganda).

For the production of seedlings which have to be transported over a long distance, soil blocks can be of great help.

C. Structures

Cold frames, hot beds and slatted frames have been used for the production of vegetable seedlings

(Andriance and Brison, 1955; Shoemaker and Teskey, 1955; and Edmond, 1964). These are usually used to start plants at seasons when outside conditions are unfavourable, or to raise plants that require special treatments or shade.

In Kenya, the traditional way of producing vegetable seedlings is by use of raised nursery beds over which shade is sometimes provided. Most of the transplanted crops can be raised in this way (MacGillivray, 1953). The pre-requisite for this method is that the beds should be close to the final planting beds or garden so as to minimize transportation costs and drying out of plants thus reducing check of plant growth (Tindall, 1965).

Whichever method mentioned above is used there are factors of management that should be borne in mind. A successful operation depends very much upon good management - regular watering, adequate nutrition, control of insect and disease pests, the use of good growing medium or soil, and the practice of a sound technique (Adriance and Brison, 1956).

3. <u>Growing Medium or Soil</u>

A good growing medium is the first essential for any successful crop productions (Gallagher, 1973). However, its quality varies considerably depending upon the properties of the constituent used in its formulation (Matkin et al, 1957). Matkin et al have advocated that if a well formulated growing medium is used then soil conditions can be disregarded when siting a nursery. The well formulated medium can also give more rapid and uniform growth of plants. Adriance and Brison (1955) have written that the use of appropriate type of soil or medium is one of the most important factors of good management in plant growing. The medium may determine whether the plants will be stocky or spindly, vigorous or stunted, normally developed or excessively luxuriant. The medium also directly influences the vigour of plants up to maturity. Knott and Deacon (1967) have indicated that a selection of a good medium for growing transplants in seedflats, seedbeds and any other container is highly important.

A good soil mixture must be friable, fertile, fairly retentive of moisture and free from disease causing organisms especially nematodes and damping-off (Adriance and Brison 1955; Winters, 1967; Knott and Deacon 1967). Ordinary soil, as it exists in gardens or fields, is usually not a satisfactory growing medium in seedflats, beds or containers, since it lacks the ideal soil structure, water holding capacity and texture (Shoemaker and Teskey, 1955). Hartmann and Kester (1968) have also indicated that most loam soils alone are unsatisfactory for use as potting media because they are either heavy and poorly aerated, thus become sticky after watering, and on drying they shrink forming a hard and cracked surface or they may have a low water-holding capacity. However, a good loose fertile top soil free from nematodes is most desirable for growing seedlings on raised seed-beds and flats (Winters, 1967).

Knott and Deacon (1967) indicated that the best soil mixtures consist of compost, sand and ordinary garden soil. The proportions may vary according to the type of the garden soil. 1 part by volume compost, 1 part by volume sand and 1 part by volume garden soil have given most sturdy and vigorous seedlings of tomato and subsequently the heaviest fruits and largest yield per hectare (Knott and Deacon 1967). Tindall (1965, 1968) recommended fertile top soil and well decayed compost mixed in equal proportions for seedling production. Coarse sand should be added if the top soil is likely to retain more moisture than required due to high percentage of clay. Heavy soil can be improved by mixing it with one-third well-rotted manure to two parts of soil (Winters, 1967). Adriance and Brison (1955) have also recommended a mixture of compost, sand and loam soil for use in seedbeds or for potting.

Compost is the most important constituent of recommended mixtures for raising vegetable seedlings for two main reasons. Firstly, the volume of soil in a container and especially a pot, is generally so small that the root system is greatly restricted and the natural essential elements supply is limited, and the necessity for frequent watering is conducive to the leaching of nitrates and possibly other essential ions; both these problems can be overcome if the potting mixture is reinforced with heavy applications of well decomposed compost (Edmond, 1964). Secondly, finely divided forms of organic matter increase the capacity of the mixture to hold the available water and exchangeable essential cations and also promote good drainage and aeration (Edmond, 1964) Compost is however very variable in its physical and chemical properties depending upon its origin (Chroboczek, 1963). It is therefore difficult to standardize potting media using compost. To overcome this problem other materials with less variable properties such as peat and vermiculite can be used provided fertilizer is applied. Shoemaker Teskey (1955) proposed that a good mixture for flats, beds and containers should contain 7 parts by volume top soil, 3 parts by volume peat and 2 parts by volume sand; since this type of mixture has a low nutrient content, it should be chemically analysed in order to find out how it can be enriched with fertilizer.

A. Preparation of Growing Medium (Mixture)

In preparing a soil mixture, the ingredients should be thoroughly mixed to obtain consistent uniform the root system is greatly restricted and the natural essential elements supply is limited, and the necessity for frequent watering is conducive to the leaching of nitrates and possibly other essential ions; both these problems can be overcome if the potting mixture is reinforced with heavy applications of well decomposed compost (Edmond, 1964). Secondly, finely divided forms of organic matter increase the capacity of the mixture to hold the available water and exchangeable essential cations and also promote good drainage and aeration (Edmond, 1964) Compost is however very variable in its physical and chemical properties depending upon its origin (Chroboczek, 1963). It is therefore difficult to standardize potting media using compost. To overcome this problem other materials with less variable properties such as peat and vermiculite can be used provided fertilizer is applied. Shoemaker Teskey (1955) proposed that a good mixture for flats, beds and containers should contain 7 parts by volume top soil, 3 parts by volume peat and 2 parts by volume sand; since this type of mixture has a low nutrient content, it should be chemically analysed in order to find out how it can be enriched with fertilizer.

A. Preparation of Growing Medium (Mixture)

In preparing a soil mixture, the ingredients should be thoroughly mixed to obtain consistent uniform plant growth. Any type of soil/material used should be sieved to eliminate large particles or aggregates. Any dry material like peat, charcoal or barkwaste should be moistened before mixing because in a mixture such materials, if dry, do not easily absorb all the necessary water even after watering. When mixing, the ingredients are placed in a pile which is arranged in layers and turned with a shovel or spade. The mixture should be prepared at least a day prior to use and it should be just slightly moist at the time of use so that it does not crumble, and that the mixture should not be so wet as to form a ball when squeezed in the hand. (Hartmann and Kester, 1968)

B. Sterilization of Growing Media

Sterilization of soil mixtures, especially potting mixtures, is of importance. The mixtures can be either heat sterilized or chemically treated. Heat treatment by steam is preferably applied after the mixture has been placed in the container (but not in plastic containers, as these might be damaged) so that there is no recontamination hazard from further handling. When using a dry source of heat, uniform sterilization is difficult to obtain because of poor distribution of the heat in the mixture/ material. Steam, on the other hand sterilizes uniformly because it penetrates the entire mass of the mixture/

material being sterilized. Another advantage of steam is that it may be used near living plants without injuring them. (Baker, 1957).

Chemicals like chloropicrin, vapam, formaldehyde, methyl bromide, etc, can also be used. Materials chemically sterilized have to be aerated for several days before they can be used, for example when chloropicrin is used, aeration takes 7 to 8 days. (Baker, 1957).

The equipment used for sterilizing soil varies greatly. The following have been used for heat treatment of propagation mixtures in California, U.S.A.: mobile bin, steam box, a tank, inverted pan and rotating screw. For chemical fumigation hand injectors can be used. (Baker, 1957).

C. Use of Artificial Media for Propagation of Seedlings

a. Need for Artificial Media

Composts, as already discussed above, vary in their constituents and also in their properties. Garden soils may be infected with plant pathogens or may be imbalanced in respect to their plant nutrient content, and their physical properties may be unfavourable for optimum growth of young plants in containers. The best way to overcome these shortcomings of compost/soil mixtures is to use artificial media (Chroboczek, 1963).

Furthermore, good top soil is increasingly difficult to find. Artificial media could be readily available, easy to handle and can produce uniform plant growth. Sterilization of artificial media is usually unnecessary, unless it is used several times, and nutrients can be added according to the predetermined nutrient requirements of the crop. Thus use of standardized artificial media of known composition can eliminate variability of compost/soil mixtures (Sheldrake and Boodley, 1966).

Growing young plants in well directed substrate in Europe and U.S.A. is becoming standard practice because mineral nutrition and the physical root environment can be controlled to give optimum crop growth (Chairman of Symposium on peat in Horticulture, 1975).

Verwer (1975 a) pointed out that in the pot-in-pot system, repotting can be mechanized in the same way that planting in soil blocks can be. This is important where labour is expensive. He however pointed to some disadvantages in the use of artificial media. He thinks that since most substrates such as perlite and sand have no buffering capacities nutrient imbalances in the media can be disastrous. He has also mentioned that controlling moisture in the media could be another problem. But these problems can be overcome by the understanding of the physical and chemical properties of the medium in question.

b. General Properties of Media

The growing medium must have the following characteristics for good results (Richards, Warneke and Aljibury, 1964; Hartmann and Kester, 1968):

(i) It must be sufficiently firm and dense to hold cuttings, seeds, or seedlings in place during rooting, germinating or growing.

(ii) It must have a volume which is fairly constant when either wet or dry as excessive shrinkage after drying is undesirable.

(iii) It must be sufficiently retentive of moisture that watering does not have to be too frequent.

(iv) It must be sufficiently porous to allow water to drain away thus permitting adequate aeration.

(v) It must be free from weed seeds, nematodes, and various noxious disease organisms.

(vi) It must not have an excessive salinity level.

(vii) It must be capable of being sterilized with steam without deleterious effects.

To obtain optimum result in potting, van Dijk and der Boon (1971) advocated that the properties of the potting medium for vegetables should be within the following limits:

(i) percentage moisture and air, by volume at $_{p}F$ of 1.5 should be at least 40% and 40% respectively;

(ii) organic matter content should be at least 20% on dry-matter basis;

(iii) pH (water) for a medium with 20 - 40% organic matter should be 5.5. - 7.0, while that with over 40% organic matter should be 5.0 - 6.5.

(iv) percentage water soluble salts should be at most 0.05 x % organic matter, while the percentage chloride should be at most 0.004 x % organic matter (- on dry-matter basis)

(v) water soluble nitrogen should be 1.0 x % organic matter (mg per 100g of dry matter)

(vi) water soluble potassium should be 0.8 - 2.5 mg per 100 g of dry matter;

(vii) water soluble phosphate, as P_2O_5, should at least be 20 mg per 100 g of dry matter;

(viii) water soluble iron (Morgan Solution) should be at most 6 mg per 100 g of dry matter.

However, these limits are only proposals for classification standards for potting soils in the Benelux.

De Boodt and Verdonck (1972) and de Boodt and de Waele (1968) have defined a good medium as that having a high capacity of available water, a high air volume, a sufficiently high base exchange capacity, a high heat capacity and low salt content and heat conductivity. Puustjarvi (1974) is of the opinion that a good medium should provide the following:

(i) mechanical anchorage and support

(ii) adequate storage and supply of water

(iii) good aeration to the root

(iv) adequate storage and supply of mineral nutrients essential to growth.

C. Physical Properties to be known

(i) Air and Water Economy

Water enters the plant on an energy gradient which depends partly on the water-absorbing capacity of the medium. This is determined by the medium's physical properties and principally the attractive forces which determine the free movement of water. Puustjarvi (1974) observed that water content corresponding to a specific energy value varies from substrate to another, being greater in fine-textured substrates than in coarse ones. When the energy value is at 0 cm, the water space equals the total pore space (TPS). The difference between the TPS and water space is the air space (de Boodt and Verdonck, 1972; Puustjarvi, 1974). The water-sorption curve, water-release curve and $_pF$ curve ($_pF$ being the log cm water tension applied to a medium) provide the basic data on the water and air economy of a substrate (de Boodt and Verdonck, 1972; Puustarvi, 1974). A $_pF$ curve reflects pore size distribution which controls the air/water ratios by volume at any given energy value (Arnold, 1973).

The importance of a $_pF$ curve was discussed by de Boodt and Verdonck, 1972). They observed that the drier the substrate the greater the energy to be expended by the plant to get water held by pores. For water to move into the plant, there must be a downward gradient of free energy from the medium to the plant. Thus in a dry soil the plant itself will contain water at high free energy values which will itself retard growth. Water, therefore, should be available at energy levels as low as possible consistent with there being enough air available in the pores within the root zone. Moisture between 10 and 100 cm suction pressure (or water tension) is thought to be useful for characterizing a medium as one which could hold enough water. The highest moisture tension that will not inhibit plant growth under nursery conditions is thought to be 100 cm (Arnold, 1973).

The following are illustrated by a $_{p}F$ curve (Figure 1 - after de Boodt and Verdonck, 1972):-

- Volume of solid matter; at 0 cm water tensions.
- Volume air; given by the difference in volume percent between the corresponding point on the curve and the point where the curve crosses the ordinate.
- Volume percent air after watering; the difference in volume percent between TPS and moisture content at 10 cm water tension.
- Easily available water (EAW); the quantity of water released between 10 and 50 cm water tensions. In a good medium this should be 75% - 90% of the total amount of available water which is the amount of water released between 10 and 100 cm water tensions.
- Water buffering capacity (WBC); that quantity of water released between 50 and 100 cm water tensions; it is a measure of water reserved when sudden heat waves occur resulting in very intensive transpiration;

Aeration in potting substrates can be improved by modifying their physical properties (Arnold, 1973). The aim should be to increase the large sized pore spaces to achieve larger air content at lower water tension.

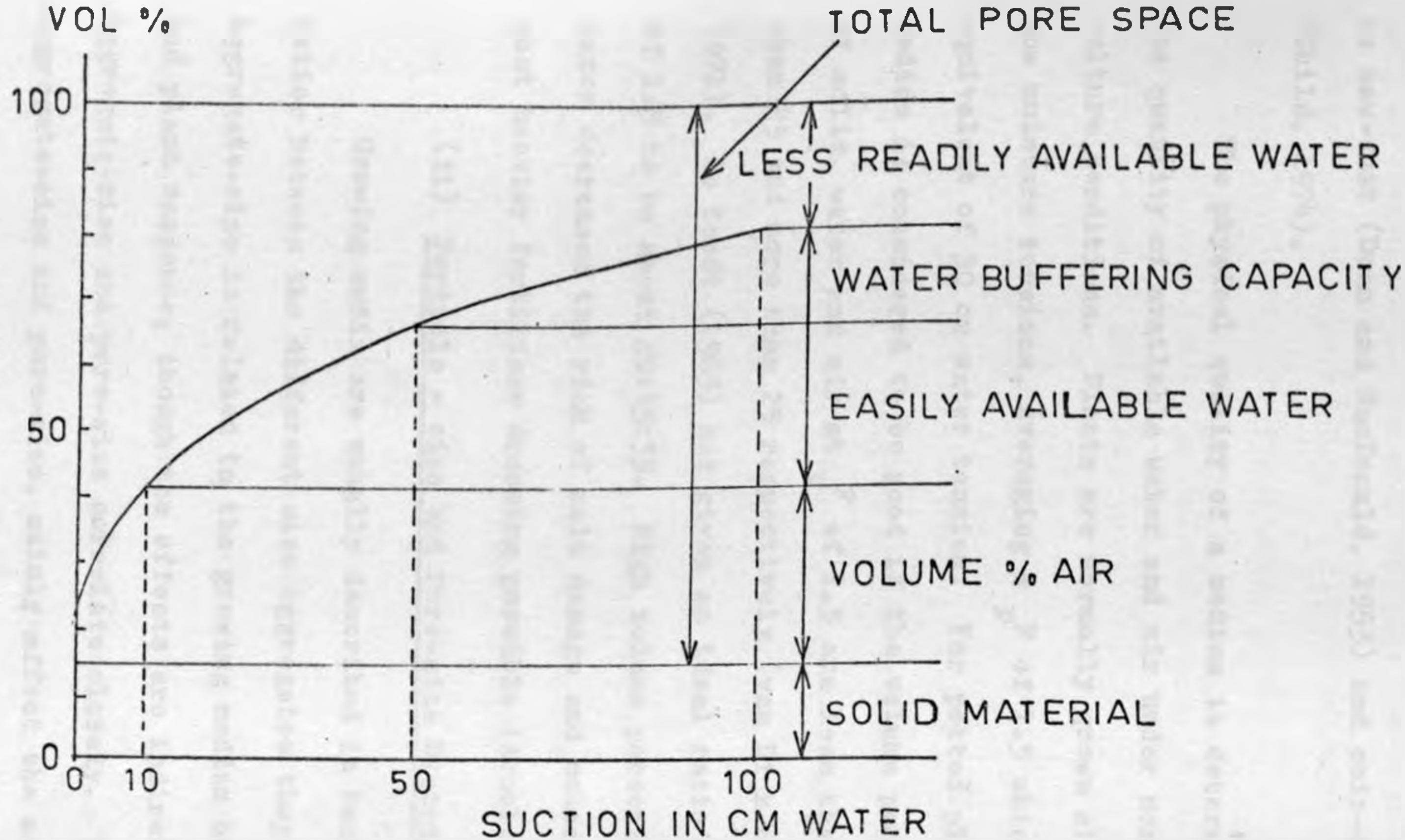

FIGURE 1 A pF — CURVE

Source : M. deBoodt and O. Verdonck
Acta Hort. 26. 1972, p 43.

Changes may be made in the physical properties of a substrate by mixing it with some soil conditioners such as saw-dust (Dunn and MacDonald, 1953) and coir-dust (Child, 1974).

The physical quality of a medium is determined by the quantity of available water and air under normal culture conditions. Plants are normally grown at fairly low moisture tensions, averaging a $_{p}F$ of 1.5 which is an equivalent of 30 cm water tension. For potted plants, a medium is considered to be good if the volume percentage of solid, water and air at $_{p}F$ of 1.5 are less than 25, more than 45 and more than 25 respectively (van Dijk and der Boon, 1971). De Boodt (1965) had given an ideal ratio at a $_{p}F$ of 1.5 to be about 20:45:35. High volume percentage of water decreases the risk of salt damage and makes a somewhat heavier fertilizer dressing possible (Arnold, 1961).

(ii) Particle - size and Pore-size Distributions

Growing media are usually described in terms of ratios between the different size aggregates they contain. Aggregate-size is related to the growing medium behaviour and plant response, though the effects are indirect. Aggregate-size and pore-size correlate closely. The two, aggregate-size and pore-size, mainly affect the aeration of the medium. Not all large particles are primary particles. Some are secondary particles (or aggregates). The aggregates have their own built in micro-structure.

Therefore, there are pore-spaces between aggregates as well as within them. General findings are that aggregates with size of 0.5. to 1.0 mm are most suitable for plant production. (Puustjarvi, 1974).

Pore-size can be calculated from a $_{p}F$ curve of a growing medium in question.

(iii) Bulk Density (BD)

BD is defined as the mass or weight of a unit volume of dry soil or growing medium (Buckman and Brady, 1969), dried usually at 105°C. For potting mixtures, low BD mixtures are disliked by growers because tall plants are then much more liable to topple over especially if the mixture is partially dried and light-weight plastic pots are being used. If heavy clay pots are used, this problem does not arise. The widely accepted BD is thus between 0.4 to 0.5 g cm^{-3}. (Bunt, 1973)

For vegetable seedling production however, low BD growing media are acceptable because the plants are not allowed to grow too tall to topple over. During the vegetable seedling production operations, the containers are usually lifted or moved around during the growing period, in which case light - weight media are convenient (Baker, 1957).

d. Chemical Properties to be Known

These include $_{p}H$, Base Exchange Capacity (BEC) or Cation Exchange Capacity (CEC), Buffering Capacity (BC) and available nutrients (van Dijk and der Boon, 1971; Verdonck, Cappaert, de Boodt, 1974; Penningsfeld, 1974). These properties can be determined in any soil laboratory. Available nutrients can be determined also by a biological method (Bouma, 1965; Janssen, 1970).

To make a growing medium more acid or alkaline, either sulphur or calcium carbonate is added.

B E C indicates the ability of a growing medium to retain the nutrients for a certain time in a form available to the plants. Inert materials, used as growing media, have high BEC if mixed with organic materials. If plants are grown in the inert materials alone, daily or weekly replenishing of nutrients is required.

BC of a growing medium is also an important chemical property. Whether the medium is acid or alkaline, nutrients are to be added to it; the $_{p}H$ should not then change very much, which then will imply high BC. The BC is usually low for inert materials as compared to organic materials.

Cation absorption capacity of a substrate, a property related to BEC or CEC, needs mention. High cation absorption capacity of a growing medium allows heavier addition of nutrients without damaging the plants (Penningsfeld, 1974). The absorbed nutrients do not increase the osmotic pressure of the soil solution.

Such growing media give better protection against nutrient deficiency and over fertilizing.

Penningsfeld (1974) advocated that micro-biological activity in growing media should be low. The reason he gave is that as expected there will be uncontrolled decomposition of organic matter and mobilization of nutrients. The respiration that occurs during the decomposition of organic matter will cause oxygen deficiency to the plant roots. There will also be a greater risk of infection. Therefore materials which are low in microbial activity are desirable when formulating a growing medium.

It is important to know the nutrient status of any given growing medium. This will indicate how much more nutrients should be given to the plants. There are great differences between plants in respect to nutrient demands and potting soils should contain an amount of nutrients sufficient for the first stage of the plant growth (van Dijk and der Boon, 1971). The nutrients should be either supplied by the materials used in formulating the potting soil, or should be added when mixing the potting soil.

D. Materials Used in Europe and U.S.A.

a. Organic

(i) Sphagnum Moss:

This is from dehydrated remains of acid - bog plants in the genus Sphagnum. The material is acid with a $_{p}H$ of 3.5 and very deficient in most nutrients

(Gallagher, 1973). However, it can be made suitable for plant growth by treating it with small amounts of limestone and if nutrients are added (Nolan, 1969). It is light in weight and has very high water - holding capacity; it can hold 10 - 20 times its weight of water. It has also a specific fungistatic substance(s) which accounts for its ability to inhibit damping-off of seedlings germinated in it (Hartmann and Kester, 1968). Thus it is relatively sterile. Before it is used in propagation media, it is generally shredded and moistened.

(ii) Peat

Composition of peat varies depending on vegetation from which it originated, state of decomposition, mineral content and degree of acidity. It originates from remains of aquatic, marsh, bog or swamp vegetation which has been preserved under water in a partially decomposed state. Therefore, there are several types of peat (Hartmann and Kester, 1968). There is a yellowish brown or light brown fibrous type which is usually referred to and baled as peat moss. This is the most important type used in horticulture. It has a high water-holding capacity and about 1% (dry basis) nitrogen. It is shredded and moistened before it is used in mixtures. Other types include the brown to black peat, which is partially fibrous; the surface or cultivated peat, which is so advanced in decomposition that plant remains are difficult to identify; and the white peat. When the white peat is adequately supplied with plant nutrients, it can be successfully used in the raising of ornamental and vegetable seedlings (Wille, 1968).

(iii) Barkwaste

This has been used in Canada, Belgium and U.S.A. (Gartner, Still and Klett, 1974; Verdonck, Cappaert and de Boodt, 1974; Maas and Adamson, 1975). It is a by-product of paper industries. Barkwaste from hardwood species has so far shown good results. When used fresh, it has shown to decrease production because it has too low nitrogen. Therefore, it must be composted with nitrogen (Verdonck et al 1974). The composting process influences largely the physical properties of the bark. The increase of the finer particles in the composted bark has an influence on the water and air economy of the material. It has been reported that during the decomposting process, the bulk density of bark increases from 0.22 to 0.26, volume percent air is reduced from 37.8 to 10.9 and easily available water increases from 17.8 to 29.0% by volume (Cappaert, Verdonck and de Boodt, 1974). As for particle size, good results have been obtained where there is 20 to 40% particles below 0.8 mm. The material absorbs water slowly. It has also been found out that composted bark does not contain enough available nitrogen for plant growth, and therefore there is need for the addition of nutrients for optimal plant growth (Cappaert et al, 1974). But it has sufficient micro-nutrients.

When bark is kept moist with distilled water pH increases from 5.2. to 6.2 after 30 days (Gartner et al, 1974); this could be due to the fact that the bark is high in calcium averaging 4.5% on a dry weight basis. It is therefore not necessary to add lime as this will increase the pH to a level which is too high for plant growth. Bark from a large number of tree species, has been found to have some phytotoxic properties which inhibit plant growth (Gartner et al, 1974). But after composting for over 30 days these properties disappear. The degree of inhibition varies with species of wood. Mixture containing bark should therefore be stockpiled for a minimum of 30 days to overcome the inhibition.

(iv) Leafmold

Leafmold consists of partially decomposed fallen leaves in the forests or it can be made by composting layers of leaves mixed with thin layers of soil to which small amounts of nitrogen compound are added. The mixture should be well watered to aid decomposition. This is then ready for use 12 to 18 months after preparation (Hartmann and Kester, 1968). This mixture may however contain nematodes as well as weed seeds and noxious insects and diseases. It therefore needs sterilization. In modern large-scale propagation establishments, leafmold is rarely used.

(v) Parts of Coconut Palm

The use of these materials has been developed in Western Samoa (Reynolds, 1974). Fibre is removed from the husk of the coconut fruit and chopped until individual fibres are less than 2.5 cm in length. This fibrous materials is then used. Water holding capacity is related to the size of the fibre, and is generally high.

The other material that is used is the wood-chips of the palm. These are prepared from fallen coconut trunks which have undergone very little or no decay so that the chips produced are hard and compact. From preliminary trials it was found that chips prepared from partly rotted logs decomposed quickly, become rather acid and biological and chemical activities increased which is/was undesirable. Hard chips are therefore preferable.

The $_{p}$H of the fibre decreases from 6.9 to 6.7, that of hard chips from 6.6 to 6.3., and while that one of partly rotted chips decreases from 6.4. to 5.0. after 70 days while in use. Other physical or chemical properties of the used parts of coconut palm have not been mentioned.

Coir-dust, a by-product of coir manufacture, has been used as a soil ameliorant in Ceylon and India (Child, 1974). The dust has been found to be high in potassium content. Nathanael (1968) found percentages of: moisture 11.7, Nitrogen 0.18, Phosphorus 0.034, Potassium 1.17, Calcium 0.15 and Magnesium 0.16, in air dried coir-dust.

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(vi) Saw-dust

This material consists of small wood fragments obtained when sawing any wood.

Pure saw-dust of any wood, whether rotted or fresh, does not produce as good tomato yields as soil does, even when abundant plant nutrients are present (Dunn and MacDonald, 1953; Wolfe and Dunn, 1953). Water relation may be a primary factor as the retention of water by either fresh or rotted pure saw-dust is not as great as that of soil (Dunn and MacDonald, 1953; Wolfe and Dunn, 1953). Wolfe and Dunn (1953) found out that soil amelioration with saw-dust is not effective. However, better results could be achieved by composting the saw dust with manure for over a year (Dunn and MacDonald, 1953).

b. Inorganic

(i) Vermiculite

This is a micaceous material that has been heated to 1400°F. It weighs about 6 pounds per cubic foot (about 96 kg per cubic metre) and is insoluble in water. It has relatively high cation exchange capacity and therefore, holds nutrients in reserve and releases them slowly. Its buffering capacity is good and it has a neutral reaction. The material contains a certain amount of potassium and magnesium which are available for plant growth. It comes in four grades:

grade 1 - particles from 5 to 8 mm in diameter.

grade 2 - particles from 2 to 3 mm in diameter.

grade 3 - particles from 1 to 2 mm in diameter.

grade 4 - particles from 0.75 to 1 mm in diameter.

Grades 2 and 4 are usually referred to as the horticultural grades. Grade 4 is most useful as a seed germinating medium. (Sheldrake and Boodley, 1966; Hartmann and Kester, 1968).

(ii) Perlite

Perlite is a volcanic rock and is used in propagation media after it has been expanded by heating it to 1800°F. It weighs 6 to 9 pounds per cubic foot (about 96 to 144 kg per cubic metre) and does not decay or deteriorate when being used. The material has neither cation exchange capacity nor buffering capacity. It is neutral in reaction with pH 7.0 to 7.5. It holds water on its irregular surfaces. Particle-size used is approximately a tenth to an eighth of an inch (about 2.5 to 3.2. mm) in diameter. (Sheldrake and Boodley, 1966; Hartmann and Kester, 1968). Though it has no mineral nutrients it has been found to be a stable medium for nutrient culture(Morrison, MacDonald and Sulton, 1960).

(iii) Pumice

This is gray or white volcanic rock originally frothed by gases to give it a spongy-like, highly porous character. It is chemically inert and has a neutral reaction. The particles tend to be sealed at one end making many pores within each particle, which tend to trap air rather than becoming completely water-saturated. The propagation grade is usually a tenth to an eighth of an inch (about 2.5. to 3.2. mm) in diameter. (Hartmann and Kester, 1968).

(iv) Sand

Washed sand of 0.5. and 0.05 mm in diameter can be used. It is the heaviest material used in propagation and this is its major disadvantage. It may contain quantities of weed seed and fungi that may cause damping-off. Therefore it should be sterilized before use. It contains no available nutrients and has no buffering capacity. Sheldrake and Boodley, 1966). It is extensively used in sand culture or hydroponics (Biekart, 1930; Hewitt, 1966).

c. Synthetics

(i) Styromull

Styromull is a material consisting of expanded polystrene flakes. It is odourless and chemically neutral. It is extremely light (1 m^3 weighs about 15 to 20 kg), does not rot and does not absorb water and therefore holds very little moisture. The material has no adverse effects on plants. Therefore, it is mainly useful in improving soil drainage and aeration, and in helping in permanent loosening of the soil. (Werminghausen, 1972)

(ii) Hygromull

This consists of ureaformaldehyde foams. It has a high nitrogen content which is liberated slowly on decomposition in the soil. The material must not be used fresh because of the strong smell of formaldehyde, which should be allowed to dissipate first. If heated above 90°C, it decomposes to some extent. It soaks up water and has a good cation exchange capacity. The moisture capacity is about 50% by volume. (Wermïnghausen, 1972)

(iii) Styropor-Wool

This is also a foam. It consists of strips of expanded polystyrene 6 mm x 2 mm in size. Its fibrous structure makes it easy to work into soil, and it improves the cohesion of the root ball. (Werminghausen, 1972)

(iv) Nutri-Foam

This is a culture substrate based on polyurethane foam and has been developed in America by Dow Chemicals. It is a spongy, rubber-like material and is enriched with nutrients. The nutrients can be given up to the plant but cannot be washed out in the ordinary way. It is usually supplied in the form of flakes or potshaped moulds from 5 to 25 cm in diameter. (Werminghausen, 1972)

(v) Baystraat

This is also a material from polyurethane foam cut with vertical pores. It is light, soft and sterile.

When saturated with water, about 50 to 70% of the pores are filled with water. In moist condition the $_pH$ is slightly acid to neutral. It is mainly used for cuttings. (Verwer, 1975b)

(vi) Br - 8

This material has been developed in U.S.A. It is made from wood pulp to which acrylate is added by means of a catalytic process. By polymerization the acrylate is bound to the wood fibre. Since it is usually in blocks, holes are pressed in and nutrients added when it is being produced. It has a $_pH$ of 6.5 and a good buffering capacity. Its cation exchange capacity is about 75 m.e per 100 g material. It is firm and remains so after use. (Verwer, 1975b)

(vii) Jiffy-7 and Jiffy-9

These have been developed in Norway. They are made from young peat moss. The materials are made into blocks or tablets which are 4.5 cm in diameter and 9 mm in height with a maximum of 20% moisture. When the tablets are used they absorb as much as 60 to 70 ml of water and thus swell up. At markets, the $_pH$ is 5.5. to 5.9. and 6.0. to 6.3. During the production of the materials, nutrient is added. (Verwer, 1975b)

The difference between the two is that Jiffy-7 tablets are encircled by a synthetic net made of polyethylene. Without the net the blocks are not stable and thus can disintegrate after swelling. In Jiffy-9 addition of bitumen product makes the blocks firm after swelling. (Verwer, 1975b)

(viii) Quecee Sure-Start

This is a material produced by Floralife Inc. Chicago Illinois. It is a plant-formaldelyde foam compound. The medium is sterile. (Verwer, 1975b)

(ix) Rock-Substrat

Rock-Substrat has been developed by Hartmann International in West Germany. It consists of any given foam, organic or inorganic manuring and peat. It is very variable. Usually it is pressed to blocks. (Verwer, 1975b)

(x) Rock Wool

This has been developed in Denmark. It consists of 60% diabase, 20% limestone and after adding 20% coke it is melted at a temperature of about 1500 to 2000°C. The molten substance is extruded to threads of 0.05 mm in diameter and pressed into sheets weighing 80 kg per m^2. During cooling off, a phenol resin is added when the temperature is about 200°C. After adding the resin, the material can take up water. The percent pores is about 96 and all pores have the same size. It is sterile. New material has a pH of over 7.0, and by watering before use for some hours, the pH decreases rather quickly. By adding some acid it is easy to attain a $_pH$ of 6.0. The sheets can be used for cuttings and glass house crop production (Verwer, 1975b).

E. Materials used in Kenya

The organic materials used by some commercial nurseries, which mainly deal with ornamental plants, include sludge, wood chippings, charcoal dust, coir dust, leafmold, peat and farm yard manure. Sludge is a treated sewage prepared by Nairobi City Council; the peat is imported. A suitable particle size of charcoal dust has not yet been defined. The leafmold used is from forests and leaves are partially decomposed to become humus. (Personal Communication)

Inorganic materials that have been used by the same commercial nurseries include gravel, sand, broken clay bricks and old used clay pots, and vermiculite, which used to be imported but now locally produced, imported perlite and pumice. The sand and gravel used are usually the building type. Coarse sand and fine sand are also used for different operations - coarse for cuttings and fine as a germinating medium (personal communication)

Forest top soil is mainly used as a germinating medium while top red soil, low in humus, is used in mixes for general potting media. (Personal Communication)

4. Sowing

Vegetable seeds can be sown in seedboxes/flats, in pots or in nursery beds/seedbeds. (Tindall, 1965, 1968; Knott and Deacon, 1967)

Sowing in seedboxes or pots in advantageous in that watering is easy and the seedlings can be transported later without damage. Several holes should be in the bottom of the box or pot for drainage facility. To further assist drainage, a thin layer of stones is used to cover the bottom - the stones prevent soil particles from blocking the holes. The box or pot is then filled with the germinating medium and the surface firmed by pressing with hands or a piece of board of a suitable size. There should be a space of about 1.3 cm from the top of the box or the box or pot to the firmed surface to allow watering. The top of medium should be level so that fine seeds will not be washed to one side during watering. Seeds can be then broadcast over the surface of the germination medium and covered with a thin layer of sifted and fairly sandy soil, or they can be drilled into the medium. The drills, generally about 1.3 cm deep, are made by a pointed stick and should be equally spaced to provide equal share of light, water and nutrients, to the germinating seeds. Seeds are then dropped into the drills, the seeds approximately touching one another, and then covered with a layer of fine soil. (Tindall, 1965; Knott and Deacon, 1967)

Depth of sowing varies according to the size of the seed. Knott and Deacon (1967) have recommended generally a depth of 0.5 to 1.0 cm while Tindall (1965) recommends a depth of about 1.3 cm though he also thinks that as a general rule a seed should be sown at a depth equal to its diameter. Seeding rate should be varied according to the medium temperature and the resulting probable germination (Knott and Deacon 1967). Seeds that are expected to give a poor germination should be sown rather thickly (Tindall, 1965). Thick seeding however, should be avoided so that spindly seedlings are not produced (Knott and Deacon, 1967).

After sowing, either by broadcasting or drilling, the surface of the germinating medium should be lightly firmed so that roots can obtain a good hold in the medium when germination begins. The medium is then well watered by using a watering can with a fine rose. Subsequent watering should be at a regular intervals but care should be taken not to apply excessive amounts of water since this will encourage the spread of those diseases, such as damping-off, which are particularly liable to attack young seedlings. The seedboxes or pots should then be sheltered from direct sunlight. (Tindall, 1965; Knott and Deacon,1967)

When sowing in seed-beds, the same procedure as described above, is used.

Sowing of seeds should be adjusted to provide proper-sized plants for field setting at the most favourable period (Knott and Deacon, 1967). Generally this should be 1 to 1½ months before field setting.

5. Pricking-out

Not much information can be found in literature in respect to usefulness of pricking-out of vegetable seedlings. Knott and Deacon (1967), however, have written that thinning seedlings by transplanting them into other flats or beds (i.e. pricking-out) so as to give them more space before the final field setting, is useful. The seedlings are usually pricked-out when they have developed the first two to three true leaves; and the seedlings should be transplanted with as many roots as possible.

Alvey (1955) observed that there was evidence that early pricking-out is of advantage in different seasons and under a variety of propagation treatments. He observed that pricking-out was most advantageous when the cultural conditions favour rapid development of the plants in the early stage. He concluded that it paid to prick-out tomato seedlings as early as two days after germination.

6. Stage of Transplanting

The stage of transplanting vegetable seedlings varies with different crops (Tindall, 1965, 1968). Tomato seedlings can be transplanted when they are about 8 to 10 cm high or when the seedlings have developed 2 to 3 true leaves. Winters (1967) recommended that tomato seedlings should be transplanted when they are about 15 to 20 cm high. Knott and Deacon (1967) on the other hand suggested that well grown tomato and pepper seedlings should be set out in the field at the age of 4 to 6 weeks after sowing and at age of 6 to 8 weeks in the case of eggplants.

Opinion therefore differ as to the age seedlings should be transplanted, but as a general rule (Tindall, 1965, 1968) transplanting should be done as soon as the seedlings can be conveniently handled since late transplanting often leads to a check of growth, and that early transplanting is generally beneficial in the later growth of plants.

However, other workers have observed that there is a positive correlation between the seedling size at transplanting and the total final yield. Spithost (1969) observed that heavier transplants of tomato made a better crop and produced a higher early and total yield. Large (1965), working on the spacing of tomato seedlings on a propagation bench, observed that significant increases in early yield were obtained from the heaviest plants. Knott and Deacon (1967) also observed that the sturdiest and most vigorous tomato seedlings gave the heaviest fruits and largest yield per hectare. Very little or no information is available on other vegetable crops in this respect.

CHAPTER III

MATERIALS AND METHODS

The objective of experiments ONE, TWO and THREE was to try and identify suitable combinations of local materials (henceforth referred to as local additives), top red soil (low in humus) and composted Farm Yard Manure to be used in raising capsicum (*Caspsicum grossum* var. Yolo Wonder) seedlings in perforated polythene bags, each measuring 10 cm in diameter and 18 cm in depth.

1. Description of the Proposed Local Additives

a. Charcoal dust:

Charcoal is prepared by burning wood in a limited supply of oxygen. Thus leaving mainly carbon. The charcoal is used as a fuel for cooking and heating rooms. The material to be used for propagating is powdered charcoal, thus the charcoal dust. The dust can be obtained cheaply as sweepings from charcoal sellers.

b. Coffee Parchments:

These are the inner white and tough skins that cover the coffee beans, and are removed before the beans are roasted and ground.

c. Coir-dust:

This is a by-product of coir manufacture. It consists of the pith or binding material, separated during processing, and variable amounts of fibre.

d. Peat Moss:

This is a peat-like material obtainable at Ondiri swamp in Kikuyu Division of Kiambu District, Central Province. The swamp is surrounded by relatively steep slopes with mainly Kikuyu red soil. The slopes are used for production of vegetables, such as cabbages, onions and tomatoes, after taking measures against soil erosion which can occur during heavy rains. If there is any soil erosion, the washed top soil is deposited in the swamp.

The peat-like material forms a layer about 60 cm thick and floats on the swamp water. One can walk on the layer without trouble. There are sedges, Typha species, commonly growing on the swamp and it has been assumed that the material has resulted from dead parts of the plants. After the material has been dug out, it is left to dry out and then could be used as an additive to potting mixtures.

e. Saw-dust

This refers to the fine wood fragments produced when sawing wood or timber; the saw-dust studied was from Cypress (a coniferous tree with dark foliage) wood.

f. Sisal waste

This is the waste effluent from sisal leaves decortication. The material had stayed in the dump at Kalimoni Factory near Thika for about six months before the start of the study.

2. **Trial ONE.**

The objective of this experiment was to find a suitable additive to basal media, which were mixtures of top red soil and compost, to make suitable potting media (or mixtures) for raising capsicum seedlings in containers.

One part of each of the additives (local and imported) was mixed with three combinations (or levels) of the basal media. The additives used were sand, charcoal dust, coir-dust, saw-dust, coffee parchments, leaf mold, peat moss, Irish peat, vermiculite and sisal waste. The three levels of the basal media were Top red soil: Compost in the following combinations: 1½: 1½; 2:1, and 1:2. Mixtures of these levels of basal media with the ten additives gave thirty treatments (Table 1, treatments 1 - 30). Treatments 31 - 34 (Table 1) which are commonly used potting mixtures in some nurseries in Kenya, were the controls. The trial thus had thirty four treatments (or mixtures) as detailed in Table 1.

The thirty-four treatments were arranged in a Randomized Complete Block Design with six blocks. The blocks corresponded to benches (Plate 1) in the plant-house (Plate 2) at the Horticultural Unit, Field Station of the Faculty of Agriculture. Each plot had thirty seedlings planted separately in the perforated polythene bags.

Seeds of capsicum were sown in seed-boxes filled

Table 1: Composition of propagation media tested. The materials were mixed in proportion, by volume, as shown down the columns

(Trial ONE)

ADDITIVES	PARTS BY VOLUME																																	
	Sand			Coir-dust			Char-coal dust			Saw-dust			Coffee parch-ments			Leaf-mold			Local peat moss			Irish peat			Vermi-culite			Sisal waste			CONTROLS			
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
BASAL MEDIA: Top Soil (Low in Humus)	1½	2	1	1½	2	1	1½	2	1	1½	2	1	1½	2	1	1½	2	1	1½	2	1	1½	2	1	1½	2	1	1½	2	1	-	-	-	1
BASAL MEDIA: Compost	1½	1	2	1½	1	2	1½	1	2	1½	1	2	1½	1	2	1½	1	2	1½	1	2	1½	1	2	1½	1	2	1½	1	2	-	-	-	-
Top soil (High in Humus)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	3	1	-
Sand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-
F.Y.Manure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	1
Charcoal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	½	-
Treatment Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

Plate 1: Arrangement of boxes containing the perforated polythene bags in which the capsicum seedlings are growing, to give blocks (or replicates). In the photograph, two blocks, on the raised benches in the plant-house, can be clearly seen.

Plate 2: Part of the plant-house at the Field Station of the Faculty of Agriculture, University of Nairobi, where the three trials were conducted.

with forest top soil, as it is practised at the Field Station. Pricking-out into the perforated polythene bags was done when the seedlings had developed one to two true leaves. Care was taken to select uniform seedlings.

The following observations were made at pricking-out time and subsequently at an interval of every four days for thirty-six days: height of the plants; number of true leaves; and fresh and dry weights of roots, stem and leaves plus petioles. For the observations, two plants per plot were sampled at random and their heights taken. The plants were carefully removed from the polythene bags and the roots were washed clean of soil. The plants were then divided into roots, stem and leaves plus petioles, their fresh weights taken, dried separately in the oven at about 80°C for twenty four hours, and their dry weights taken.

The analysis of variance of the results was done as follows:

(a) Total Dry Weights at every Sampling Date:

Source of Variations	Degrees of Freedom
Treatments	33
Blocks	5
Additives (A)	9
Basal media (B)	2
Interaction (A X B)	18
Among controls	3
Control vs Rest	1
Error	165
TOTAL	203

(b) Uniformity of the plants at the last Sampling Date:

The variances between plants within each additive were calculated as follows:

Source of Variation	Degrees of Freedom
Plants between plots	5
Plants within plots	6
TOTALS	11

Bartlett 's test was then employed to test the homogeneity of the variances (plants within plots). Any two additives were compared by F-test (at P=0.05) where

$F = \frac{X_a}{X_b}$ or $\frac{X_b}{X_a}$ whichever X was bigger as numerator; X_a and X_b being variances of additives

3. Trial TWO

Combinations of Enriched top red soil (one part compost to four parts top red soil, by volume) with the following additives (local and imported) were tested: Vermiculite, saw-dust, sisal waste, coir-dust, charcoal dust and sand.

The Enriched top red soil was tested with three levels of each of the additives as detailed in Table 2. This gave 18 treatments (1 - 18, Table 2). Treatment 19 - 21 (Table 2) were the controls for the entire experiment while the vermiculite gave a control for comparison of additives.

The twenty-one treatments were also arranged in a Randomized Complete Block Design in a plant-house at the Field Station, as in experiment ONE, with six blocks. Each plot had also thirty seedlings planted separately in the perforated polythene bags.

As in the first experiment, seeds of capsicum were sown in seed-boxes filled with top soil and pricking-out was done when the seedlings had developed one to two true leaves. The same observations were made as those in the first experiment. Unlike the first experiment, the sampling interval was seven days for thirty-five days. After

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The twenty-one treatments were also arranged in a Randomized Complete Block Design in a plant-house at the Field Station, as in experiment ONE, with six blocks. Each plot had also thirty seedlings planted separately in the perforated polythene bags.

As in the first experiment, seeds of capsicum were sown in seed-boxes filled with top soil and pricking-out was done when the seedlings had developed one to two true leaves. The same observations were made as those in the first experiment. Unlike the first experiment, the sampling interval was seven days for thirty-five days. After

Table 2: Composition of the propagation media tested. The materials were mixed in Proportions, by volume, as shown down the columns (Trial TWO)

ADDITIVES	PARTS BY VOLUME																				
	VERMICULITE			SAW-DUST			SISAL WASTE			COIR-DUST			CHARCOAL DUST			SAND			CONTROLS		
	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4			
ENRICHED TOP SOIL	6	5	4	6	5	4	6	5	4	6	5	4	6	5	4	6	4	5	1	-	-
TOP SOIL (Low in humus)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
COMPOST	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TREATMENT NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

pricking-out, subsequent random samples were made as follows: the first two sampling dates - one plant per plot; and the rest of the sampling dates - two plants per plot.

The analysis of variance of the results was done as follows:

(a) Total Dry Weights at every Sampling date:

Source of Variation	Degrees of Freedom
Treatments	20
Blocks	5
Additives (A)	5
Levels of Additives (B)	2
Interaction (A X B)	10
Among Controls	2
Control vs Rest	1
Error	100
TOTAL	125

(b) Uniformity between plants:

As in experiment ONE

4. Trial THREE

Two parts of each of the additives were mixed with four combinations (or levels) of the basal media (Top red soil mixed with Compost). The additives used were sisal waste, coir-dust, charcoal dust, saw-dust and vermiculite (as a control for comparison of the additives). The four levels of the basal media were Top red soil: compost in the following combinations by volume: 3:1, 2:2, 1:3 and 0.4. The four levels of the basal media with the five additives gave twenty treatments (Table 3, treatments 1 - 20). Treatments 21 - 24 (Table 3) were the controls for the treatments (or mixtures). Hence the experiment had twenty-four treatments as detailed in table 3.

The twenty-four treatments were also arranged in a Randomized Complete Block Design with five blocks in the plant-house at the Field Station. Each plot had twenty-four seedlings planted separately in the perforated polythene bags.

As in experiments ONE and TWO, seeds of capsicum were sown in a seed-box filled with forest top soil and pricking-out was done when the seedlings had developed one to two true leaves. Seven days after pricking, random samples, a plant per plot, were taken for observation. Observations made were as those made in experiment ONE and TWO except that the plants were not divided into roots, stem and leaves. The same sampling procedure was repeated at an interval of one week for five weeks, though in the last sampling date, two plants per plot were sampled to make it possible for the analysis of the uniformity between plants within each material.

Table 3: Composition of the propagation media tested. The materials were mixed in proportions by volume as shown down the columns (Trial THREE)

		PARTS BY VOLUME																							
ADDITIVES		VERMICULITE				SISAL WASTE				COIR-DUST				CHARCOAL DUST				SAW-DUST				CONTROLS			
		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2				
BASAL MEDIA	COMPOST	2	1	3	0	2	1	3	0	2	1	3	0	2	1	3	0	2	1	3	0	1	1	1	-
	TOP SOIL (Low in humus)	2	3	1	4	2	3	1	4	2	3	1	4	2	3	1	4	2	3	1	4	-	1	2	1
TREATMENT NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	16	18	19	20	21	22	23	24

The analysis of variance of the results using the Total Dry Weights was done as follows:

(a) Total Dry Weights at every Sampling Date:

Source of Variation	Degrees of Freedom
Treatments	23
Blocks	4
Additives (A)	4
Basal media (B)	3
Interactions (A X B)	12
Among Controls	3
Controls vs Rest	1
Error	92
TOTAL	119

(b) Uniformity between plants

As in experiment ONE and TWO

5. Physical and Chemical Properties Determinations

Most of these determinations were done at the Department of Horticulture of the Agricultural University in Wageningen, The Netherlands. The materials (additives) studied were: coir-dust, peatmoss, charcoal dust, sisal waste , coffee parchments and saw-dust.

A. Physical Properties

For the determinations of Bulk Density, Total Pore Space and deriving the Moisture Retention Curves, the Sand

Valk and Harst

Basin method (Stakman, 1969; de Boodt, Verdonck and Cappaert, 1973) was used and is briefly described below.

(a) Bulk Density and Total Pore Space

The samples were put in double rings (Diagram 1 & Plate 3) At the bottom of the lower ring a nylon tissue was attached using rubber bands before the rings were filled with the samples. Five samples of each of the materials studied were used. The samples in the double rings were brought to saturation with water by putting them in a container and slowly filling the container with water up to the upper ring (Diagram 2) for twenty-four hours after which the double rings with the samples in them were put on the sand basin (Diagram 3 and plate 4) at zero water tension.

The water table (also water tension) in the sand basin can be altered by altering the levelling bottle (B) which is connected to the sand basin as shown in the diagram. When the levelling bottle is at level D the water tension in the sand is zero. The tension is increased by lowering the levelling bottle for example to level H to give 10 cm water tension. When this is done excess water drains through overflow C.

During the determinations, the water tension was adjusted to 10 cm. The samples were then left on the basin for six days to attain equilibrium after which the upper ring was removed and a broad bladed knife was passed over the top of the lower ring to leave a sample of known volume

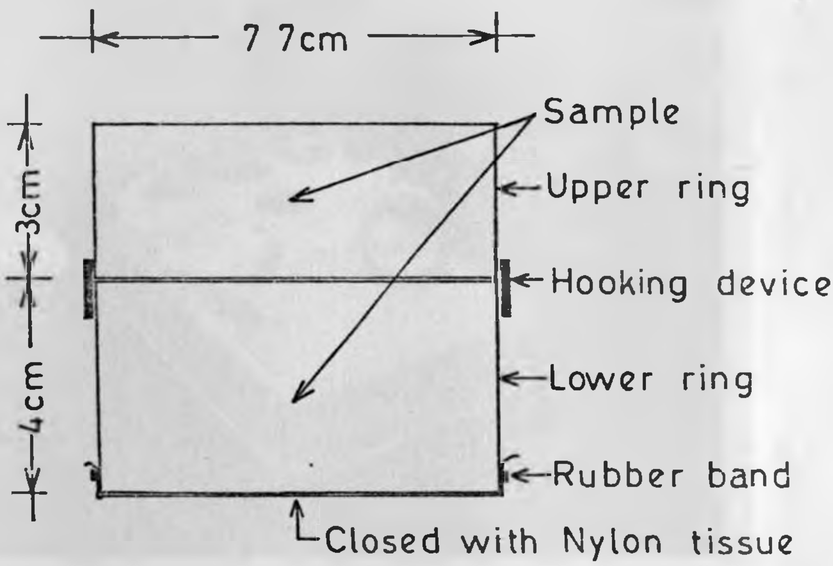

Diagram 1. The double rings (core 1 and core 2).

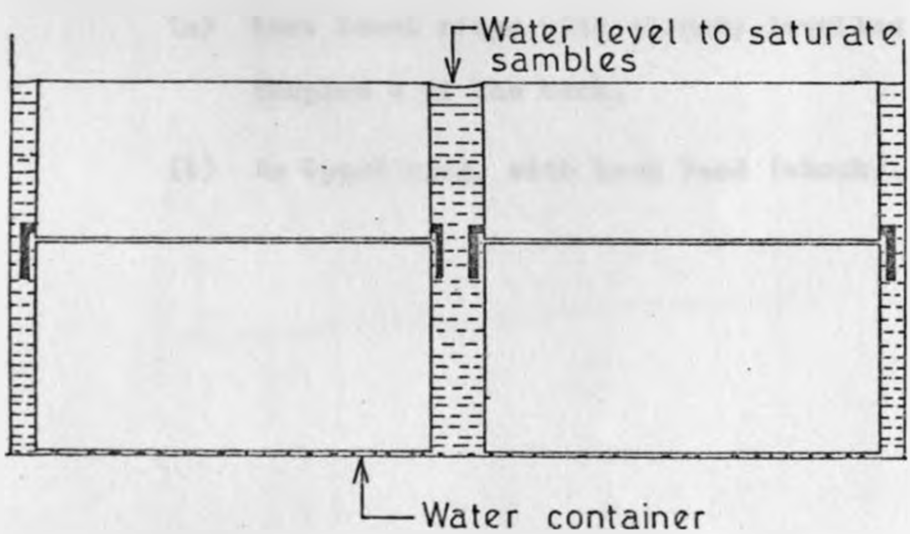

Diagram 2. Saturation of substrate.

Plate 3: Some of the rings, on the inverted green tray, that were used.

(a) Some lower rings with already levelled samples - at the back.

(b) An Upper ring, with back band (=hook).

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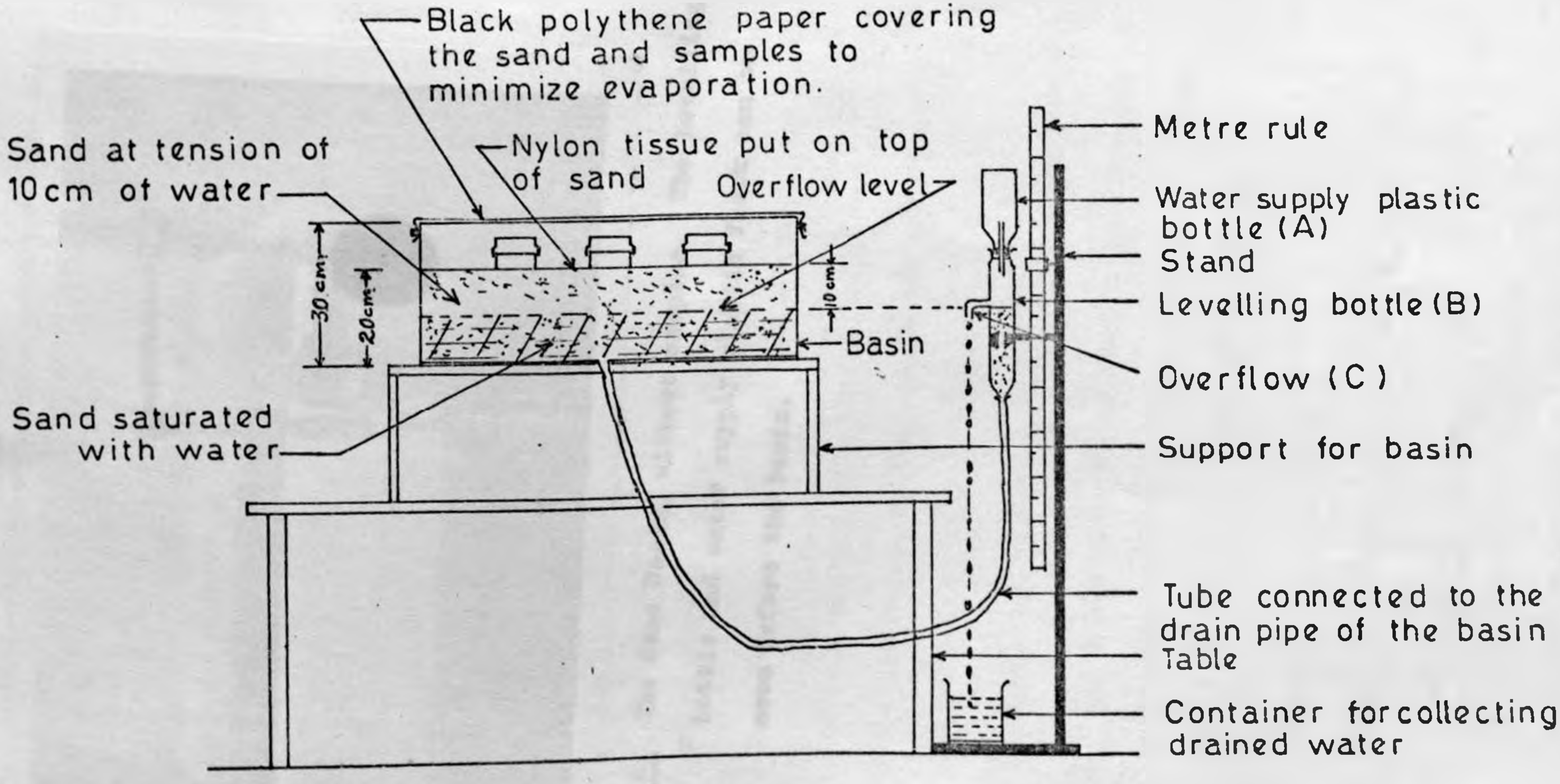

Diagram 3 The sand basin

Plate 4: The Sand Basin, without samples. The levelling bottle and water supply plastic flask can be seen before the basin.

($V = 190\ cm^3$) with standardized compaction in the ring. The rings with humid samples were then put in an oven and dried for twenty-four hours and weighed. The drying and weighing was repeated daily until the weights of the samples and the rings with nylon tissues were constant.

Calculations:

(i) The weight of the lower ring with the nylon tissue (determined before the experiment started) was say X g.

(ii) The dry weight of the sample plus the ring with nylon tissue was say Y g.

(iii) Therefore the dry weight of the sample was (Y-X) g.

(iv) The Bulk Density (BD) of the sample was $\frac{Y-X}{V}$ where V is the volume of the sample and was equal to $190\ cm^3$.

(v) Therefore the total pore Space in percentage was $(1 - \frac{BD}{PD}) \times 100$ where PD is the Particle Density of the organic material (and is usually approximated to be 1.45 cm^3 - de Boodt et al, 1973).

b. Moisture Retention Curves

The sand basin method, as described above was used.

After saturation, the samples were put on the sand basin at 0 cm water tension. The levelling bottle was lowered to give 5.0 cm tension and the samples were left

($V = 190\ cm^3$) with standardized compaction in the ring. The rings with humid samples were then put in an oven and dried for twenty-four hours and weighed. The drying and weighing was repeated daily until the weights of the samples and the rings with nylon tissues were constant.

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b. Moisture Retention Curves

The sand basin method, as described above was used.

After saturation, the samples were put on the sand basin at 0 cm water tension. The levelling bottle was lowered to give 5.0 cm tension and the samples were left on the sand basin for one week so that there was an equilibrium between the moisture in the sample and in the sand. After the one week the double rings were separated and the lower rings given a flat surface and weighed, and the weight of the sample plus the water retained recorded. After weighing the lower rings with wet samples, they were put back on the sand basin and levelling bottle lowered to give 10 cm tension. The samples were again left on the sand basin for one week and weighed. The same procedure was repeated subsequently at 30, 50 and 100 cm tensions. After the last tension, 100 cm, the rings were transfered to an oven and dried until each sample had a constant weight. The water retained at 5, 10, 30, and 50 and 100 cm water tensions was thus determined.

Calculations:

(i) The weight of ring and nylon tissue was say X g.

(ii) The weight of ring plus nylon tissue plus the wet sample at a given water tension, was say Y g.

(iii) The weight of ring plus nylon tissue plus the dry sample was say Z g.

(iv) The weight of water in the sample at a given water tension was therefore (Y - Z) g.

(v) The weight of the dry solid water in the ring was therefore (Z - X) g.

(vi) Therefore the water content per unit dry weight (WCW) was $\frac{Y - Z}{C - A}$

(vii) The water content per unit of sample volume (WCV) in g cm^{-3} is WCW X BD (Bulk Density).

(viii) Substituting g of water by cm^3 of water and multiplying by 100 gave the volumetric water content in percentages (i.e. volumetric water content percent is equal to WCV X 100).

The volumetric water content value of a sample with a given water tension value gave a point for the graphical relation of water tension and volumetric water content (hence the water retention curve, or water release curve, or the $_pF$ curve).

The volumetric water content values of samples for each material were calculated and their average, at a given water tension, was taken and plotted. Available water, easily available water, water buffering capacity and air content were calculated using the data for the water retention curves:

(i) Available water = Volume % of water released from the material when the suction/tension increases from 10 to 100 cm.

(ii) Easily available water = volume % of water released from the material when suction/tension increases from 10 to 50 cm.

(iii) Water Buffering Capacity = volume % of water released from the material when the suction/ tension increases from 50 to 100 cm.

(iv) Air content = the difference in volume % between the TPS and the moisture content at 10 cm suction/ tension.

B. Chemical Properties

a. pH

The Potassium Chlorate Method was used. This method is extensively used in United States Salinity Laboratories (Agriculture Handbook No. 60, 1969). 1.0 g of each of the material was mixed with 10.0 ml of 1 molar KCl. The mixtures were left to stand for 24 hours after which measurements were done using a pH - meter. The same procedure was repeated at the Institute for Land and Water Management, at Wageningen in Holland, and results compared to those obtained at the Department of Horticulture.

b. Electrical Conductivity (estimation of Soluble Salts)

This was done at the Institute for Land and Water Management. The method used was as described in Agriculture Handbook No. 60 of U.S. Salinity Laboratories (1969). The estimation of the electrical conductivity, expressed in mhos (reciprical ohms) was done by using , material-water extracts. The extracts were made by mixing 1 g material with 5 ml demineralized water. The mixtures were left to stand for 24 hours filtered and measurement done by using Direct Indicating Bridge (electrical conductivity meter).

c. Chloride Concentration

The method used was the one being used at the Department of Horticulture. Material-water extracts were made by mixing 1 g material with 10 ml demineralized water. The mixture were thoroughly stirred and left to stand for 24 hours, filtered and measurements done by measuring the electrical resistance by Direct Indicating Bridge and using meter readings to read the chloride concentration from a control curve. The same procedure was followed at the Institute for Land and Water Management and the results compared.

The control curve was constructed by using the following chloride concentrations, and their measured electrical resistances; 0.02, 0.04, 0.06, 0.08, 0.1, 0.2, 0.3, 0.4, 0.5, 0.7, 0.9, 1.0, 3.0 and 5.0.

d. Cation Exchange Capacity and Exchangeable Bases

These were done at the Department of Soil Science of the Faculty of Agriculture, University of Nairobi, using their method of Analysis (Ahn, 1973). The materials analysed, in duplicates, were coir-dust, charcoal dust, sawdust, sisal waste, peat moss, Irish peat, vermiculite and top red soil. 5.000 g of air dry samples were weighed out and shaken, using a reciprical shaker, with 50 ml normal ammonium acetate adjusted to exactly pH of 7.0, for one hour. The samples were then centrifuged at 1500 r.p.m. for 20 minutes and the supernatant ammonium acetate decanted off-but kept for the determination of the exchangeable bases namely Sodium, Potassium, Magnesium and Calcium.

I. Determination of Cation Exchange Capacity

After the decanting off the supernatant ammonium acetate as mentioned in (d) above, the remaining acetate was removed from the samples by repeated washing with methyl alcohol followed by centrifuging as follows:

(i) material plus remaining ammonium acetate solution were shaken by hand with 50 ml. methyl alcohol and then centrifuged at 1500 r.p.m. for 20 minutes and the supernatant solution decanted off carefully.

(ii) (i) was repeated until the test by Nessler's reagent (added to a portion of the supernatant solution) was negative.

When the samples were clean of ammonium acetate solution, distillation was done. The alcohol washed samples with about 250 mls of distilled water were transfered to 500 ml round bottom flasks. The flasks were

were connected, via splash heads, to Liebig Condensers leading into 250 ml conical flasks each containing 20 ml of 2% Boric acid and a few drops of mixed indicator. (prepared by dissolving 0.12 g methyl red and 0.08 g methylene blue in 100 ml of 95% methanol). The splash heads were disconnected from the flasks and 2 spatulas of light Magnesium Oxide were inserted into each flask. The contents of the flasks were then heated and distillation continued until about 150 ml had distilled over and been collected in the receivers. The system was then disconnected and the green contents of the receivers titrated with 0.1 normal HCl to a pink end point in order to determine the milli-equivalents of ammonia in the distillate.

Calculation:

Each ml of 0.1 N HCl used in the titration was equivalent to 2 m.e. per 100 g material sample (the samples were weighing 5.0 g).

II. Determination of Exchangeable Bases

(1) Calcium and Magnesium by E.D.T.A. (versanate titration)

(i) Determination of Calcium

5 ml aliquots of ammonium acetate leachate (the supernatant ammonium acetate solution from (d) above) containing the cations displaced from the material samples

were taken. 10 ml of 10% KOH were added to each sample (this was to raise the pH to 12.0 or slightly higher). Then 1 ml of triethanolamine and three drops of 10%. (weight per volume) KCN were added in order to chelate and therefore suppress interfering metallic ions. Finally 5 drops of calcon indicator were added and the resulting red solutions were titrated from the red to blue end point with a standardized EDTA solution.

Calculation:

Using 10 ml aliquot and 50 ml of Ammonium acetate and 5.0 g sample, each ml of EDTA used was equal to 1 m.e calcium per 100 g material. Since 5 ml aliquots were used, the results were multiplied by 2.

(i) Determination of Magnesium (plus Calcium)

When EDTA is used to titrate against ammonium acetate solution containing both calcium and magnesium, it reacts preferentially with the calcium, so that the calcium is complexed first. It is only after the complexing of all calcium ions that it begins to complex the magnesium ions. This is why in the determination of magnesium, the magnesium and calcium are determined together and the exchangeable magnesium therefore being obtained by subtracting the m.e. exchangeable calcium obtained in the first titration from the m.e. echangeable calcium plus magnesium in the second.

As in the first titration (i) above, 5 ml aliquots of ammonium acetate leachate were taken and 5 ml of ammonium chloride (ammonium hydroxide buffer solution) added. 1 ml of triethanolamine and three drops of 10% (weight per volume) KCN solution were then added. Finally three drops of Eriochrome Black, T-methanol-hydroxylamine hydrochloride, solution were added and resulting red solutions were titrated with a standardized EDTA solution to a blue end point.

Calculation:

Similar to that used for exchangeable calcium as (i) above. To get the m.e. of exchangeable magnesium, the figures for calcium obtained in (i) above, were subtracted from the figures for calcium plus magnesium obtained in (ii).

(2) Determination of Echangeable Potassium and Sodium by EEL Flame Photometer

(i) Potassium:

Normal Ammonium acetate was used as a blank and therefore used to set the O reading, and a solution of 0.2 N KCl was used to set the 100 reading. The operation was therefore set to read between 0.0 and 0.2 normal KCl. To obtain a standard curve the following normalities were used: 0.025, 0.05, 0.10, 0.15 and 0.20 of normal KCl. Samples to be analysed were diluted 25 times and after every determination the blank was used to wash out the previous solution from the tube and to make sure that the blank still read 0. The normality of solutions with potassium from the samples was read from the standard curve.

Calculation:

The normality of the solution with respect to potassium indicates the amount of exchangeable potassium present in the 10.0 g samples. If 10.0 g sample is shaken with 100 ml of ammonium acetate and if the normality of the solution is 0.001 N, then there is 1 m.e. of potassium per litre of ammonium acetate or 0.1 m.e of potassium per 100 ml, which in turn is equal to 0.1 m.e. of potassium in the 10 g sample. During the determinations 50 ml of ammonium acetate were used. Therefore the results obtained were multiplied by ½. To be expressed as m.e per 100 g of material, the results of exchangeable potassium in the used 5.0 g samples were also multiplied by $\frac{100}{5}$ i.e. by 20. Lastly the results were also multiplied by 25 (the dilution factor).

(ii) Sodium:

As in (i) above, normal ammonium acetate was used as a blank and therefore was used to set the 0 reading. To set the 100 reading 0.IN NaCl was used. For constructing the standard curve, the following normalities were used: 0.0125, 0.025, 0.05, 0.075 and 0.1. Samples to be analysed were diluted 25 times. During the determination, same procedure as in (i) above was followed.

Calculation:

As in (i).

e. Nutritional Status of the Materials

This was carried out at the Department of Horticulture of the Agricultural University in Wageningen, Holland. The availability of phosphorus, potassium, magnesium and iron was determined by using a Biological method for the assessment of Nutritional Status of a soil (Bouma, 1965; Janssen, 1970). The apparatus used were small 250 ml cylindrical plastic pots, whose original bottoms have been removed and replaced by gauzes, 600 ml plastic pots, and hardboard rings (Plates 5 & 6). The materials, analysed were coir-dust, peat moss, saw-dust, charcoal dust, sisal waste and coffee parchments. Five different types of nutrient solutions (-Phosphorus, -Potassium, -Magnesium, -Iron and Complete) were prepared as detailed in Table 4. The five types of solutions therefore gave 5 treatments for each material under study.

Five 250 ml cylindrical pots were filled, three-quarters full, with each of the materials. Five 600 ml plastic pots were filled with the five different types of solutions (Table 4), the extra volume being made of demineralized water. Then the 250 ml cylindrical pots were placed on top of 600 ml plastic pots by means of the hardboard rings, (Diagram 4). This was repeated for each of the materials under study. The treatments for each

Plate 5: Dismantled pots at the end of the experiment.

(a) The 600 ml plastic pots with the cardboard rings (support of the cylindrical pots) - at the back in the photograph.

(b) The cylindrical pots, some with roots that had grown through the gauze into the nutrient solutions - lying on sides at the centre of the photograph.

(c) A cardboard ring - left-bottom corner of the photograph.

Plate 6: Some of the pots used in the determination of the nutritional status of the materials studied.

Table 4: Volumes of 1 molar stock solutions that were transferred to pots to prepare, using demineralized water, 600 ml volumes of -K, -P, -Mg, -Fe and Complete nutrient solutions

	MILLITRES OF STOCK SOLUTION USED				
STOCK SOLUTIONS	COMPLETE	-P	-K	-Mg	-Fe
$Ca(NO_3)_2 4H_2O$	3.6	3.6	3.6	3.6	3.6
KNO_3	1.2	1.2	-	1.2	1.2
NaH_2PO_4	-	-	1.2	-	-
NaCl	0.6	0.6	-	0.6	0.6
$MgSO_4 \cdot 7H_2O$	0.9	0.9	0.9	-	0.9
$KH_2 PO_4$	1.2	-	-	1.2	-
EDTA[1]	0.6	0.6	0.6	0.6	-
Trace Element[2] Solution	0.6	0.6	0.6	0.6	0.6

[1]The EDTA contained Fe, Mn, B, Zn, Cu & Mo

[2]The Trace Element Solution was also the EDTA Solution but without Fe.

Table 4: Volumes of 1 molar stock solutions that were transferred to pots to prepare, using demineralized water, 600 ml volumes of -K, -P, -Mg, -Fe and Complete nutrient solutions

	MILLITRES OF STOCK SOLUTION USED				
STOCK SOLUTIONS	COMPLETE	-P	-K	-Mg	-Fe
$Ca(NO_3)_2 4H_2O$	3.6	3.6	3.6	3.6	3.6
KNO_3	1.2	1.2	-	1.2	1.2
NaH_2PO_4	-	-	1.2	-	-
NaCl	0.6	0.6	-	0.6	0.6
$MgSO_4 \cdot 7H_2O$	0.9	0.9	0.9	-	0.9
KH_2PO_4	1.2	-	-	1.2	-
EDTA[1]	0.6	0.6	0.6	0.6	-
Trace Element[2] Solution	0.6	0.6	0.6	0.6	0.6

[1]The EDTA contained Fe, Mn, B, Zn, Cu & Mo

[2]The Trace Element Solution was also the EDTA Solution but without Fe.

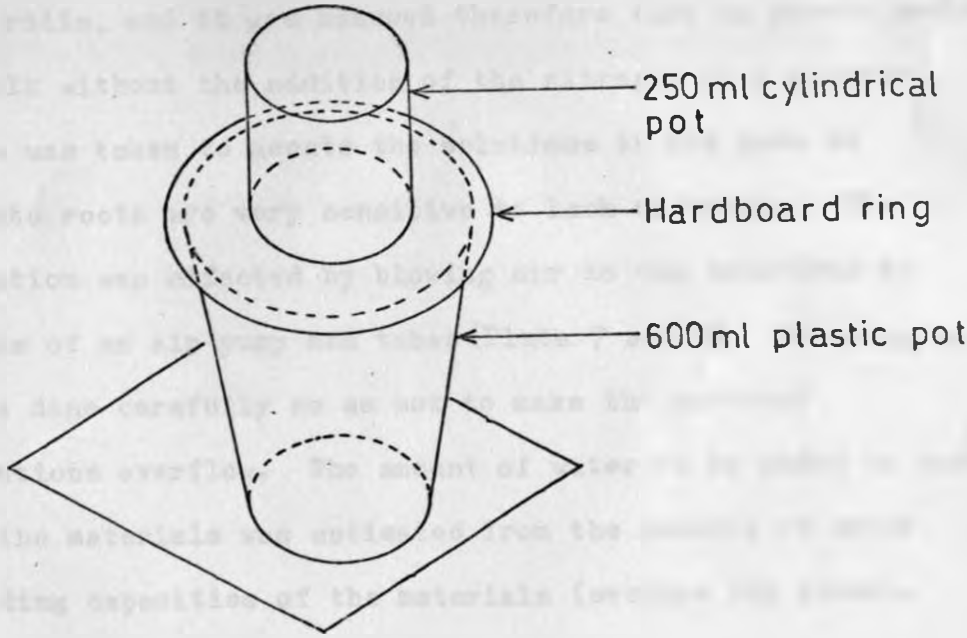


Diagram 4 Arrangement of cylindrical pot, hardboard and plastic pot.

material were replicated twice and were completely randomized within each material.

Tomato, (L. esculentum var. Money maker) was used as the test plant. Young seedlings, 17 days old, were pricked-out into the various pots, prepared as described above. Before the pricking-out, Nitrogen in the form of Urea was added to the materials at a rate of 70 mg Nitrogen per 200 cm^3 of the material. This was inevitable due to the fact that the materials had been assumed to have a high C/N ratio, and it was assumed therefore that no growth could result without the addition of the nitrogen as a starter. Care was taken to aerate the solutions in the pots as tomato roots are very sensitive to lack of oxygen. The aeration was effected by blowing air to the solutions by means of an air pump and tubes (Plate 7 and 8). Watering was also done carefully so as not to make the nutrient solutions overflow. The amount of water to be added to each of the materials was estimated from the results of water holding capacities of the materials (section 5Ab above).

After the seedlings had grown in the various materials for 4 weeks i.e. when the seedlings were 45 days old, their tops were cut off and their fresh weights taken immediately after which the tops were transfered to an oven and their dry weights taken two days later.

Plate 7: Air pressure pump (left-bottom corner) which was used to pump air through tubes to the nutrient solution in the lower 600 ml pots, to provide aeration.

Plate 8: Aeration of solutions by means of orange tubes leading into the bottom 600 ml pots.

Analysis of variance, using dry weights, was done as follows:

Source of Variation	Degrees of Freedom
Treatments	29
Replicates	1
Nutrient Solutions (A)	4
Materials (B)	5
A X B (Interaction	20
Error	29
TOTAL	59

6. Germination Trial

Five 600 ml plastic pots were filled with each of the materials under study (coir-dust, sisal waste, saw-dust, charcoal dust, peat moss, and coffee parchments). A germination medium (consisting of 95% peat, 5% sand, 2kg/ m^3 calcium of ammonia, 1kg/m^3 Thomasslakkenmeal - rich in calcium and sulphur, 1 kg/m^3 Dolomite, ½kg/m^3 superphosphate and 100g/m^3 trace elements) for tomato seeds at the Department's Greenhouses was used as a control. Therefore there were seven treatments which were replicated five times and thus giving 35 pots (Plate 9) of sown tomato seeds.

The pots were observed everyday and germinated seeds were counted. Seedlings with their cotyledons spread were regarded as 'germinated'. They were pulled out as they were being counted. The counting was continued until all the 50 seeds had germinated or no more seeds germinated.

Plate 9: Arrangement of the germination trial. From front to back of the photograph: 1st row - sisal waste, 2nd row - saw-dust, 3rd row - local peat moss, 4th row - coir-dust, 5th row - coffee parchments, 6th row - charcoal dust and 7th row - control.

CHAPTER IV

RESULTS

1. Total Dry Weights

A. Treatments

(i) Trial ONE

The treatment means and standard errors are presented in Table 8. Table 5 summarises the analysis of variance at different sampling dates. It can be seen that the following mixtures were not significantly different (P of 0.05) from mixture 34, which was a control; 10, 25, 27, 23, 19, 29, 4, 24, 12, 28, 26 and 22, especially at the last four sampling dates (see also plates 10, 11 and 12). The following mixtures performed worst throughout the experimental period: 13, 14 and 15 (Plate 13)

(ii) Trial TWO

The treatments means and standard errors for the sampling dates when the F-tests were highly significant are given in Table 9. A summary of the analysis of variance is given in Table 6. It can be observed (Table 9) that at the third week after pricking-out, the following mixtures were best: 9, 8, 7, 1, 19, 21, 4, 15, 12 and 18, while at the fourth week the following were best: 21, 9, 8, 19, 1, 7, 13, and 12. At the last sampling date, mixture 21 was superior to others but not statistically significantly different from mixtures 9 and 7. It can also be seen that treatment 20, top soil alone, (Table 2), performed worse than any treatment (mixture) throughout the experiment.

(iii) Trial THREE

The treatment means and standard errors for the sampling dates when the F-tests were highly significant are presented in Table 10, and Table 7 summarises the analysis of variance at various sampling dates. It can be seen that in the second week after pricking-out, treatment 11 was the best performer, in the third week treatments 3, 11, and 5 were best performers, in the fourth week treatment 5 was the best mixture and in the last sampling date treatment 7 was the best mixture though it was the worst performer one week after pricking out. Treatment 24, top soil alone, was amongst the worst performers throughout the experimental period (Table 10).

B. Additives

(i) Trial ONE

The main effects of the additives in terms of total dry weight are presented in Table 11. It can be seen that sisal waste and saw-dust were as good as vermiculite and Irish peat at the later sampling stages. In the first three sampling dates almost all additives had the same performance; and the differences showed up later. Coffee parchments performance was an exception in that seedlings in mixtures with the coffee parchments were very poor throughout the experimental period; the seedlings were unhealthy, dwarfed and their stems and

Table 5: Summary of Analysis of Variance. (Trial ONE)

		DAYS AFTER PRICKING OUT								
		4	8	12	16	20	24	28	32	36
	d.f	MEAN SQUARES								
Treatments	33	7.32NS	49.14**	157.48**	1508.85NS	7819.44**	26367.97**	72150.79**	213956.57**	525196.65**
Additives(A)	9	9.09NS	79.24**	304.56**	4707.17**	24505.32**	82791.66**	243402.07**	736410.49**	1821752.89**
Basal media(B)	2	108.26**	30.34NS	40.20NS	43.59NS	210.22NS	6792.18NS	2497.48NS	24205.58NS	60441.53NS
Interaction (AXB)	18	6.90NS	43.64**	93.86NS	165.04NS	1836.56NS	3451.90NS	8364.10NS	12838.41NS	35844.79NS
Among controls	3	4.54NS	19.86NS	217.64*	522.15NS	1331.29NS	13714.82*	10387.13NS	17090.26NS	45155.27NS
Control vs Rest	1	0.53NS	2.73NS	32.89NS	540.66NS	21.58NS	8155.00NS	3647.22NS	102099.25**	34158.21NS
Blocks	5	75.06**	41.52*	141.22*	824.65NS	4788.98**	28028.60*	8412.54NS	13942.32NS	30396.54NS
Residual	165	5.81	17.56	56.47	1685.91	1087.2	4770.62	9139.80	19985.77	31899.80

NS - Not significant

* - Significant at p = 0.05

** - Significant at p = 0.01

df - Degrees of Freedom

Table 6: Summary of Analysis of Variance (Trial TWO)

		WEEKS AFTER PRICKING-OUT				
		1	2	3	4	5
	d.f.	MEAN SQUARES				
Treatments	20	36.45 NS	32.76 NS	227.97**	2632.00**	15095.36**
Additives (A)	5	31.55 NS	131.97 NS	255.92**	2434.63**	27107.69**
Levels of Additives (B)	2	62.04 NS	66.81 NS	58.94 NS	2501.23**	992.89 NS
Interaction (AXB)	10	28.40 NS	53.28 NS	136.34**	1210.91**	4713.34**
Among Controls	2	27.74 NS	658.76*	885.97**	16672.03**	58531.44**
Controls vs Rest	1	107.67 NS	11.41 NS	26.49 NS	11.29 NS	186 .76 NS
Blocks	5	166.83*	499.18*	150.09**	453.81 NS	1763.15 NS
Residual	100	52.32	67.06	44.41	421.25	1208.23

NS - Not significant
* - Significant at p = 0.05
** - Significant at p = 0.01
df - Degrees of Freedom

Table 6: Summary of Analysis of Variance (Trial TWO)

		WEEKS AFTER PRICKING-OUT				
		1	2	3	4	5
	d.f.	MEAN SQUARES				
Treatments	20	36.45 NS	32.76 NS	227.97**	2632.00**	15095.36**
Additives (A)	5	31.55 NS	131.97 NS	255.92**	2434.63**	27107.69**
Levels of Additives (B)	2	62.04 NS	66.81 NS	58.94 NS	2501.23**	992.89 NS
Interaction (AXB)	10	28.40 NS	53.28 NS	136.34**	1210.91**	4713.34**
Among Controls	2	27.74 NS	658.76*	885.97**	16672.03**	58531.44**
Controls vs Rest	1	107.67 NS	11.41 NS	26.49 NS	11.29 NS	186 .76 NS
Blocks	5	166.83*	499.18*	150.09**	453.81 NS	1763.15 NS
Residual	100	52.32	67.06	44.41	421.25	1208.23

NS - Not significant

* - Significant at p = 0.05

** - Significant at p = 0.01

df - Degrees of Freedom

Table 7: Summary of Analysis of Variance (Trial THREE)

		WEEKS AFTER PRICKING - OUT				
		1	2	3	4	5
	d.f.	MEAN SQUARES				
Treatments	23	43*	347**	2993**	21577**	122784**
Additives (A)	4	19 NS	143*	2220**	28205**	211330**
Basal media (B)	3	92*	1242**	14125**	92878**	436006**
Interaction (A X B)	12	50*	160**	547**	4120**	29230**
Among controls	3	6 NS	536**	3587**	17620**	102673**
Controls vs Rest	1	11 NS	153 NS	260 NS	2522 NS	11908**
Blocks	4	41 NS	48 NS	932**	5760**	15712**
Residual	92	23	52	244	833	2712

NS - Not significant
* - Significant at p = 0.05
** - Significant at p = 0.01
df - Degrees of Freedom

Table 8: Mean Total Dry Weights (mg) at various sampling dates (Trial ONE)

Days after pricking	8	12	20	24	28	32	36
Treatment Number	Mean Weights (mg)						
1	18.86 efghi	38.64 ab	145.28 abcdefg	190.18 efg	314.98 fghi	628.57 abcdef	906.40 def
2	23.78 abcd	36.32 abcd	122.40 efgh	181.06 efg	351.23 cdefghi	528.08 ef	963.33 cdef
3	18.28 efghi	24.83 fgh	155.34 abcdef	201.44 cdefg	393.66 abcdefgh	638.12 abcdef	892.02 ef
4	20.71 bcdef	36.28 abcd	165.27 abcd	218.91 abcdefg	365.74 bcdefghi	689.41 abcd	1062.13 abcd
5	20.70 bcdef	34.55 abcd	121.88 efgh	196.18 defg	347.85 defghi	565.08 def	980.77 bcdef
6	14.90 hij	29.12 cdefg	138.23 cdefg	196.44 defg	316.78 fghi	576.22 def	941.90 cdef
7	16.40 fghij	34.60 abcde	132.34 defg	202.18 cdefg	354.97 bcdefghi	556.93 def	913.83 def
8	19.86 defg	36.37 abcd	124.82 efgh	234.70 abcdefg	378.22 abcdefghi	589.73 cdef	1004.14 bcdef
9	18.43 efghi	36.12 abcd	147.02 abcdefg	199.63 cdefg	333.92 defghi	620.93 bcdef	1017.31 bcde
10	20.38 bcdefg	35.11 abcde	133.67 defg	291.48 a	336.23 defghi	700.42 abcd	1231.67 a

Cont. /86a

Table 8: Mean Total Dry Weights (mg) at various sampling dates (Trial ONE) contd..

Days after pricking	8	12	20	24	28	32	36
Treatment Number	Mean Weights (mg)						
11	17.35 efghij	34.40 abcde	158.36 abcde	193.78 efg	359.77 bcdefghi	641.83 abcdef	993.49 bcdef
12	15.91 ghij	31.13 bcdef	123.00 efgh	231.98 abcdefg	396.72 abcdefgh	664.19 abcdef	1044.62 abcde
13	14.47 ij	19.76 h	33.70 i	26.38 i	23.37 j	23.55 g	27.43 g
14	17.80 efghi	28.58 defg	45.31 i	47.93 i	37.33 j	48.13 g	59.48 g
15	13.03 j	20.80 gh	27.84 i	19.78 i	23.62 j	22.61 g	27.25 g
16	18.04 efghi	28.99 cdefg	117.68 gh	214.93 abcdefg	435.50 abcd	606.97 bcdef	1006.33 bcdef
17	18.82 efghi	26.76 efgh	94.77 h	203.44 cdefg	280.93 i	630.99 abcdef	945.91 cdef
18	20.83 bcdef	34.48 abcde	147.38 abcdefg	187.53 efg	350.19 cdefghi	645.34 abcdef	979.79 bcdef
19	20.28 cdefg	29.40 cdef	139.53 bcdefg	234.47 abcdefg	309.72 hi	683.88 abcde	1105.20 abc

Cont. /86b

Table 8: Mean Total Dry Weights (mg) at various sampling dates (Trial ONE) contd...

Days after pricking	8	12	20	24	28	32	36
Treatment Number	Mean Weights (mg)						
20	19.66 defg	36.82 abcd	156.65 abcdef	175.89 fg	346.98 defghi	600.80 bcdef	873.78 ef
21	27.78 a	33.98 abcde	147.98 abcdefg	220.28 abcdefg	342.89 defghi	510.30 f	825.78 f
22	19.74 defg	31.56 bcdef	157.84 abcde	210.33 bcdefg	399.22 abcdefgh	655.53 abcdef	1033.26 abcde
23	19.48 defgh	35.03 abcde	128.46 efgh	181.96 efg	420.63 abcdef	608.39 bcdef	1140.28 ab
24	25.03 ab	39.44 ab	133.57 defg	254.98 abcde	418.22 abcdefg	663.01 abcdef	1061.92 abcde
25	20.20 cdefg	37.48 abc	171.22 abc	282.58 ab	462.66 ab	750.57 ab	1230.96 a
26	24.71 abc	38.63 ab	180.23 a	259.03 abcde	431.03 abcde	697.79 abcd	1038.14 abcde
27	19.33 defgh	38.64 ab	176.37 ab	285.66 ab	477.64 a	742.34 abc	1178.50 ab
28	19.15 defghi	34.94 abcde	131.37 defg	292.15 a	458.07 abc	780.99 a	1039.99 abcde

Cont. /86c

Table 8: Mean Total Dry Weights (mg) at various sampling dates (Trial ONE) Contd..

Days after pricking	8	12	20	24	28	32	36
Treatment Number	Mean Weights (mg)						
29	19.91 defg	32.84 bcdef	173.47 abc	277.23 abc	381.68 abcdefghi	785.50 a	1093.61 abcd
30	19.75 defg	37.01 abcd	146.89 abcdefg	248.13 abcdef	372.82 abcdefghi	686.22 abcde	981.08 bcdef
31	18.42 efghi	31.53 bcdef	153.38 abcdefg	249.29 abcdef	376.78 abcdefghi	673.39 abcde	906.51 def
32	21.36 bcde	26.68 efgh	120.12 fgh	163.07 g	311.32 ghi	576.76 def	867.83 ef
33	18.00 efghi	28.78 defg	128.17 efgh	214.40 abcdefg	327.20 efghi	667.70 abcdef	1017.18 bcdef
34	21.33 bcde	40.37 a	124.68 efgh	273.16 abcd	400.20 abcdefgh	698.89 abcd	1049.18 abcde
Standard error	±0.72	±1.29	±5.65	±11.85	±16.40	±24.24	±30.63

Treatments with same letter(s) within each sampling date are not significantly different (P of 0.05)

Table 8: Mean Total Dry Weights (mg) at various sampling dates (Trial ONE) Contd..

Days after pricking	8	12	20	24	28	32	36
Treatment Number	Mean Weights (mg)						
29	19.91 defg	32.84 bcdef	173.47 abc	277.23 abc	381.68 abcdefghi	785.50 a	1093.61 abcd
30	19.75 defg	37.01 abcd	146.89 abcdefg	248.13 abcdef	372.82 abcdefghi	686.22 abcde	981.08 bcdef
31	18.42 efghi	31.53 bcdef	153.38 abcdefg	249.29 abcdef	376.78 abcdefghi	673.39 abcde	906.51 def
32	21.36 bcde	26.68 efgh	120.12 fgh	163.07 g	311.32 ghi	576.76 def	867.83 ef
33	18.00 efghi	28.78 defg	128.17 efgh	214.40 abcdefg	327.20 efghi	667.70 abcdef	1017.18 bcdef
34	21.33 bcde	40.37 a	124.68 efgh	273.16 abcd	400.20 abcdefgh	698.89 abcd	1049.18 abcde
Standard error	±0.72	±1.29	±5.65	±11.85	±16.40	±24.24	±30.63

Treatments with same letter(s) within each sampling date are not significantly different (P of 0.05)

Table 9: Mean Total Dry Weights (mg) at the 3rd, 4th and 5th Weeks after Pricking-Out

(Trial TWO)

Week 3			Week 4			Week 5		
Tr. No.	Weight	SS	Tr. No.	Weight	SS	Tr. No.	Weight	SS
9	50	a	21	111	a	21	233	a
8	48	a	9	100	ab	9	214	ab
7	48	a	8	98	abc	7	205	ab
1	48	ab	19	97	abc	8	183	bc
19	47	ab	1	96	abc	10	182	bc
21	47	abc	7	90	abcd	14	169	cd
4	44	abcd	13	89	abcd	19	159	cde
15	42	abcd	12	88	abcd	1	158	cde
12	42	abcd	14	87	bcde	13	154	cde
18	42	abcd	16	86	bcde	3	133	de
16	41	bcd	18	85	bcde	12	131	de

Cont. /87a

Table 9: Mean Total Dry Weights (mg) at the 3rd, 4th and 5th Weeks after Pricking Out

(Trial TWO) Cont...

Week 3			Week 4			Week 5		
Tr. No.	Weight	SS	Tr. No.	Weight	SS	Tr. No.	Weight	SS
10	41	bcd	10	83	bcde	2	131	de
2	41	bcd	11	79	bcdef	4	128	e
14	39	cd	2	76	cdef	15	128	e
5	39	cd	3	70	defg	16	127	e
11	39	cd	17	67	defg	17	122	e
13	38	d	15	64	efg	18	121	e
17	38	d	5	57	fg	11	120	e
3	37	d	4	51	gh	5	77	f
6	27	e	6	31	hi	20	38	f
20	26	e	20	27	i	6	37	f
SE	± 1			± 4			± 8	

Tr No = Treatment Number   SE = Standard Error   SS = Statistical Significance

Treatments with same letter(s) within each week are not significantly different (P of 0.05)

Table 10: Mean Total Dry Weights (mg) at the 1st, 2nd, 3rd, 4th and 5th Weeks After Pricking-out (Trial THREE)

Week 1			Week 2			Week 3			Week 4			Week 5		
Tr. No	Wt	SS	Tr. No	Wt	SS	Tr. No	Wt	SS	Tr. No	Wt	SS	Tr. No	Wt	SS
19	27	a	11	50	a	3	102	a	5	241	a	7	537	a
5	26	a	13	45	b	11	99	a	11	210	b	5	487	b
11	25	ab	23	43	bc	5	95	a	3	193	b	3	474	b
1	24	abc	22	41	bcd	1	83	b	7	193	b	11	338	c
9	24	abcd	15	39	cde	21	82	b	15	173	c	22	338	c
3	22	bcd	1	37	def	7	78	bc	9	171	cd	21	334	cd
6	21	cde	9	36	ef	15	77	bcd	22	164	cd	9	322	cde
14	21	cde	3	35	efg	13	75	bcde	1	160	cde	1	321	cde
23	21	cde	7	35	efg	23	75	bcde	21	155	de	6	304	def
4	20	def	10	35	efg	22	72	cde	6	154	do	10	300	ef
13	20	def	17	35	efg	2	70	cde	23	148	e	15	292	ef
24	20	def	21	35	efg	6	69	cde	13	123	f	23	287	f

Cont. /88a

Table 10: Mean Total Dry Weights (mg) at the 1st, 2nd, 3rd, 4th and 5th Weeks After Pricking-Out (Trial THREE) Cont..

Week 1			Week 2			Week 3			Week 4			Week 5		
Tr. No	Wt	SS	Tr. No	Wt	SS	Tr. No	Wt	SS	Tr. No	Wt	SS	Tr. No	Wt	SS
2	19	defg	6	34	fgh	17	68	de	10	106	fg	13	251	g
10	19	defg	14	31	ghi	9	66	e	2	99	gh	2	164	h
17	19	defg	19	31	ghi	14	52	f	17	87	hi	17	147	h
18	19	defg	2	30	i	19	50	f	14	76	i	14	124	h
21	19	defg	18	28	ij	10	44	f	19	72	i	8	90	i
22	19	defg	20	28	ij	8	34	g	8	47	j	19	81	ijk
12	18	efg	5	27	ij	12	32	gh	18	42	j	12	56	jk
15	18	efg	12	25	jk	18	32	gh	12	38	j	18	51	jk
20	18	efg	8	22	kl	4	30	ghi	24	38	j	4	42	k
8	17	fg	16	21	kl	16	24	hi	4	34	j	24	37	k
16	17	fg	24	20	l	24	24	hi	16	31	j	16	34	k
7	16	g	4	15	m	20	21	i	20	31	j	20	33	k
SE	±1			±1			±3			±6			±11	

S.E. = Standard Error   Tr No = Treatment Number   Wt = Weight   SS = Statistical significance
Treatments with same letter(s) within each week are not significantly different (P of 0.05)

Table 11: **Main Effects of Additives on Dry Weight (mg) (Trial ONE)**

Days after pricking / Additives	8	12	16	20	24	28	32	36
Vermiculite	21a	38a	89a	176a	276a	457a	730ab	1149a
Irish peat	21a	35ab	70a	139b	216bc	412ab	642b	1078ab
Sisal waste	20a	35ab	82a	151b	273a	404abc	751a	1038abc
Coir dust	19a	33ab	67a	142bc	204bc	343cd	610c	995bc
Saw dust	18ab	34ab	69a	138b	239ab	364bcd	669ac	1090ab
Charcoal dust	18ab	36a	68a	135b	212bc	356bcd	589c	978bc
Leaf mold	19a	30b	67a	120c	201bc	356bcd	628c	977bc
Local peat moss	22a	33a	73a	148b	210bc	332d	598c	935c
Sand	20a	33a	77a	141b	191c	353bcd	598c	921c
Coffee parchments	15b	23c	28b	36d	31d	28e	34d	38d
Standard Error	±1	±2	±13	±10	±22	±30	±45	±56

Additives with same letter(s) within each sampling period are not significantly different at (P of 0.05)

Plates 10. 11 and 12

Size of capsicum seedlings, at the last sampling date, growing in some treatments, shown below, compared to those seedlings growing in treatment 34 (the control):-

4 - 1 part sand: 1½ Top red soil: 1½ parts Compost										
8 - 1	"Charcoal dust:	2 parts	Top	red	soil:	1 part		Compost		
23 - 1	" Irish peat	: 2	"	"	"	"	:	"	"	"
24 - 1	" " "	: 1	"	"	"	"	:	2 parts		"
26 - 1	" Vermiculite	: 2 parts	"	"	"		:	1 part		"
28 - 1	" Sisal waste	: 1½	"	"	"	"	:	1½ parts		"

These treatments were not statistically significantly different in performance, from the control (P = 0.05).

Plate 10

Plate 11

Plate 12

Plate 13: Very poor growth of capsicum seedlings in mixtures with the coffee parchments (treatments 13, 14 and 15) as compared to the growth in treatment 34 (1 part Compost to 1 part Top red soil) which was the control. The photograph was taken at the last sampling date.

leaves were purple in colour at first but turned yellow towards the end of the experiment. The local peat moss performed well up to about sixteen days after pricking-out when its performance started to deteriorate; Vermiculite and Irish peat, as expected, had good performance all through.

(ii) Trial TWO

The main effects of the additives in terms of total dry weight are presented in Table 12. From the table it can be seen that sisal waste was significantly better (P of 0.05) than the rest of the additives including vermiculite throughout the experiment except that it was not significantly different from coir-dust at the fourth week after pricking out. From the same table, it can be seen that saw-dust had the poorest performance throughout, and also that during the third and fifth weeks after pricking-out, the following were not significantly different from each other: vermiculite, coir-dust, charcoal-dust and sand.

(iii) Trial THREE

The main effects of the additives in terms of total dry weight are presented in Table 13. The table shows that sisal waste performed very well during the experiment. In the third week after pricking-out the sisal waste showed the same performance as vermiculite and coir-dust, while in the fourth week the sisal waste

Table 12: The Main Effects of Additives on Dry Weight (mg) (Trial TWO)

Weeks after pricking-out Additives	3		4		5	
Sisal waste	50	a	96	a	201	a
Vermiculite	42	b	81	b	141	bc
Coir dust	40	bc	83	ab	144	bc
Charcoal dust	40	bc	80	b	150	b
Saw-dust	37	c	60	c	81	d
Sand	40	bc	80	b	123	c
Standard Error	± 3		± 12		± 14	

Additives with same letter(s) within each sampling period are not significantly different at (p of 0.05)

Table 13: The Main Effects of Additives on Dry Weight (mg) (Trial THREE)

Weeks after pricking Additives	3	4	5
Vermiculite	68 ab	121 b	250 b
Sisal Waste	69 a	159 a	355 a
Coir dust	60 abc	131 ab	254 b
Charcoal dust	57 bc	81 c	175 c
Saw dust	43 c	58 c	78 d
Standard Error	± 7	± 13	± 23

Additives with same letter(s) within each sampling period are not significantly different at P of 0.05

Table 13: The Main Effects of Additives on Dry Weight (mg) (Trial THREE)

Weeks after pricking Additives	3	4	5
Vermiculite	68 ab	121 b	250 b
Sisal Waste	69 a	159 a	355 a
Coir dust	60 abc	131 ab	254 b
Charcoal dust	57 bc	81 c	175 c
Saw dust	43 c	58 c	78 d
Standard Error	± 7	± 13	± 23

Additives with same letter(s) within each sampling period are not significantly different at P of 0.05

was better than vermiculite(P of 0.05) but not coir-dust. In the last sampling date the sisal waste excelled all the other additives. Charcoal dust and saw-dust had relatively worse performance than the rest of the additives throughout the experimental period with the saw-dust registering the worst performance at the end of the experiment.

C. Basal Media or Levels of Additives

(i) Trial ONE

As can be seen from Table 5, the main effects of basal media were not significantly different (for instance Plates 14 and 15) except in the second sampling date.

(ii) Trial TWO

The main effects of levels of additives and the enriched top soil were not significant throughout the experiment except in the second last sampling date (Table 6).

(iii) Trial THREE

The main effects of the basal media in terms of total dry weight are presented in Table 14. It can be observed that basal media 1 and 3 (2 parts compost; 2 parts top soil; and 3 parts compost: 1 part top soil, respectively) had the best performance throughout the experimental period and the performances were not statistically different. Basal medium 2 (1 part compost: 3 parts top soil) was better than basal medium 4 (0 part

Plates 14 and 15

The Plates , taken at the last sampling date, show that there were no significant differences on the effects of basal medium levels on the size of the plants. Treatments 1, 2 and 3 contained sand and different levels of basal medium, and treatments 4, 5 and 6 contained coir-dust with different levels of basal medium.

Plate 14

Plate 15

Table 14: The Main Effects of Basal Media on Dry Weight (mg) (Trial THREE)

Weeks after pricking-out Basal Media	2	3	4	5
1 2 parts compost: 2 parts top soil	36a	77a	156a	306a
2 1 part compost: 3 parts top soil	30ab	53b	95b	189b
3 3 parts compost: 1 part top soil	38a	78a	168a	345a
4 0 part compost: 4 parts top soil	22b	28c	36c	51c
Standard Error	±4	±8	±14	±26

Basal media with same letter(s) are not significantly different at P of 0.05

compost: 4 parts top soil) which had the worst performance all through.

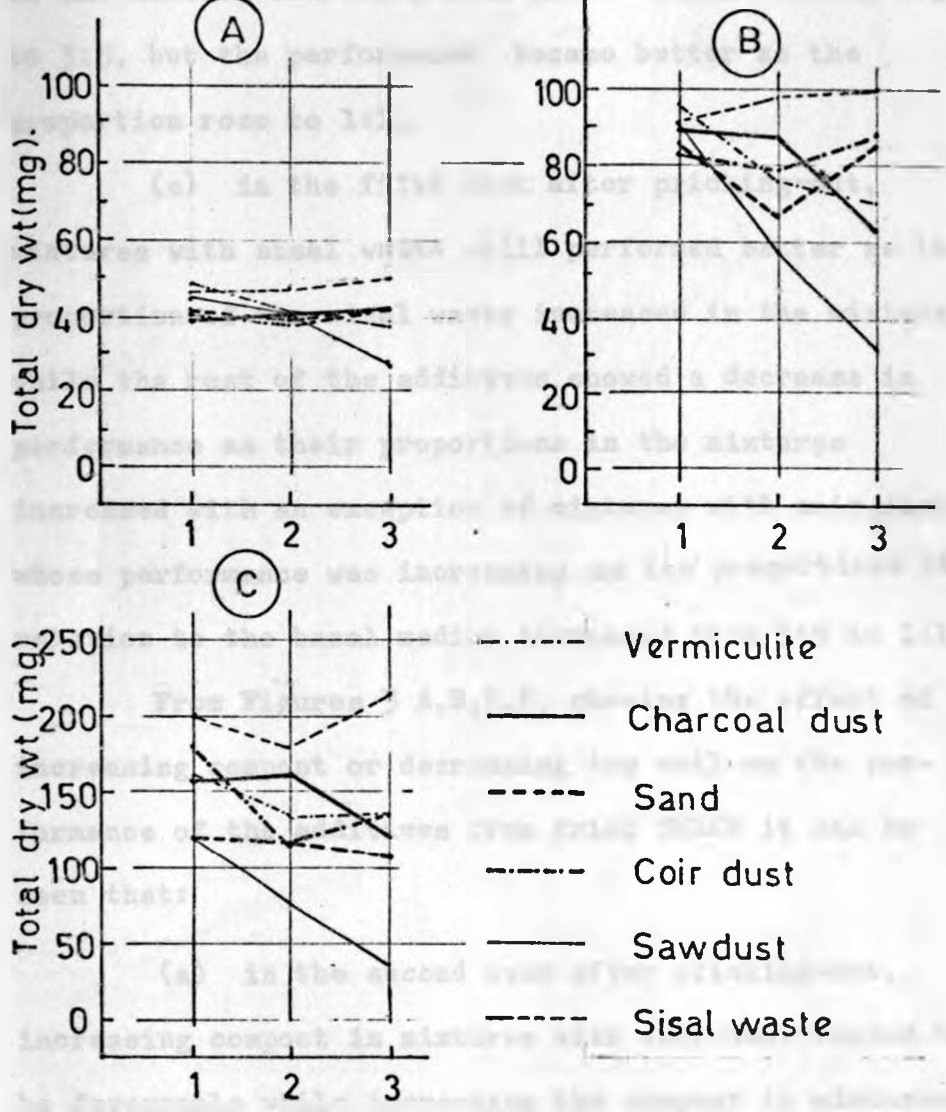
D. Interaction Between Additives and Basal Media

There were no significant interactions in Trial ONE, except in the third sampling date. However, in both trial TWO and THREE, there were highly significant interaction between additives and basal media. These significant interactions occured when the main effects of treatments and additives were also highly significant.

Figures 2 A,B,C, show the effect of increasing the amount of additive, in relation to the basal medium, on overall performance of the mixtures in trial TWO. It can be observed that:

(a) in the third week after pricking out, mixtures with sisal waste, charcoal dust, coir-dust and sand performed better as their proportions in the mixtures increased; while the performance of mixtures with vermiculite and saw-dust deteriorated as their proportions in the mixtures increased.

(b) in the fourth week after pricking out, mixtures with sisal waste and coir-dust still performed better as their proportion in the mixtures increased; while mixtures with charcoal dust, vermiculite and saw-dust performed poorer as their proportions in the mixtures increased; mixtures with sand had their performance getting poorer as the proportion of the sand



Additive : Basal medium A-3 weeks after pricking
1— 1 : 3 B-4 " " "
2— 3 : 5 C-5 " " "
3— 1 : 1

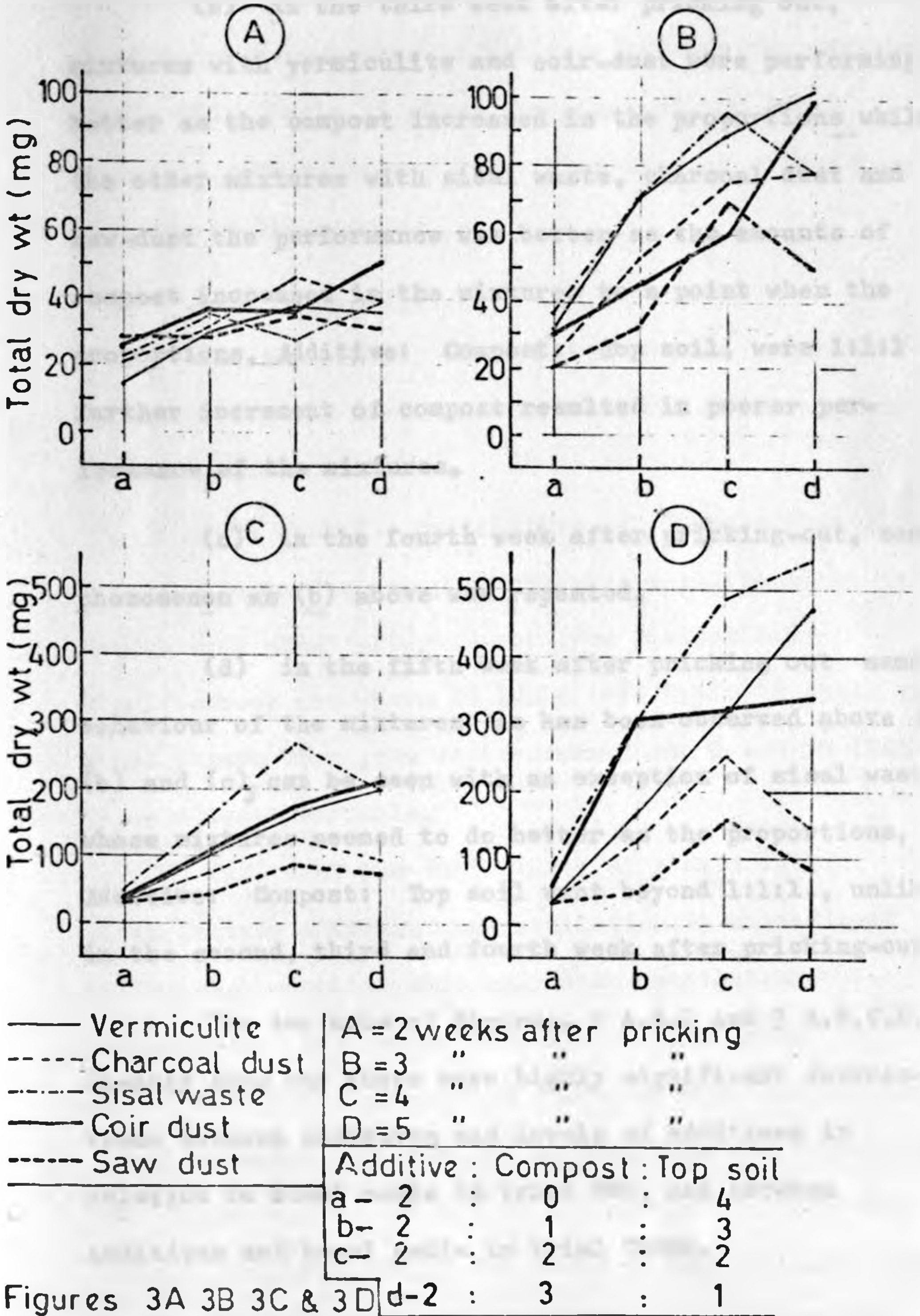
Figures 2A 2B & 2C
Effect of increasing the amount of additive in relation to the basal medium on overall performance of mixtures.

in the mixture increased from sand: basal medium, 1:3 to 3:5, but the performance became better as the proportion rose to 1:1.

(c) in the fifth week after pricking-out, mixtures with sisal waste still performed better as the proportion of the sisal waste increased in the mixtures while the rest of the additives showed a decrease in performance as their proportions in the mixtures increased with an exception of mixtures with coir-dust whose performance was increasing as its proportions in relation to the basal medium increased from 3:5 to 1:1.

From Figures 3 A,B,C,D, showing the effect of increasing compost or decreasing top soil on the performance of the additives from trial THREE it can be seen that:

(a) in the second week after pricking-out, increasing compost in mixtures with coir-dust tended to be favourable while increasing the compost in mixtures with charcoal dust, vermiculite, and saw-dust was also favourable to a point when the proportions, by volume, of Additive: Compost: Top Soil were 1:1:1 - increasing the compost further resulted in poor performance of the mixtures; increasing compost in mixtures with sisal waste was favourable to a point when the proportions, Additive: Compost: Top Soil, was 2:1:3 - further increment of the compost seemed not to be more effective.



Figures 3A 3B 3C & 3D Effect of increasing compost or decreasing topsoil on performance of the additives.

(b) in the third week after pricking out, mixtures with vermiculite and coir-dust were performing better as the compost increased in the proportions while the other mixtures with sisal waste, charcoal dust and saw-dust the performance was better as the amounts of compost increased in the mixtures to a point when the proportions, Additive: Compost: Top soil, were 1:1:1 - further increment of compost resulted in poorer performance of the mixtures.

(c) in the fourth week after pricking-out, same phenomenon as (b) above was repeated.

(d) in the fifth week after pricking out same behaviour of the mixtures as has been observed above in (b) and (c), can be seen with an exception of sisal waste whose mixtures seemed to do better as the proportions, Additive: Compost: Top soil went beyond 1:1:1., unlike in the second, third and fourth week after pricking-out.

The two sets of figures, 2 A,B,C and 3 A,B,C,D, clearly show why there were highly significant interactions between additives and levels of additives in relation to basal media in trial TWO, and between additives and basal media in trial THREE.

E. Uniformity of Plants

(i) Trial ONE

Bartlett's test was used to test the homogeneity of variance of the plants using the additives with and without coffee parchments. In the two cases, there were significant differences in variance between the additives (Table 15). Table 15 shows that many of the local materials gave variances lower than that of either vermiculite or Irish peat.

(ii) Trial TWO

The homogeneity of variance between treatments and additives was tested as in the first trial and the following were observed:-

(a) that the variability of plants within plots between treatments was statistically significant at the fourth week after pricking-out (the statistical significances are shown in Table 16). Table 16 shows that those plants that grew in treatments 20, 6 and 17 (Table 2) were least variable.

(b) that the variability of plants within plots between additives was statistically significant at the last sampling date only (the statistical significances are shown in Table 17). The table 17 shows that plants growing in mixtures with saw-dust were least variable. It can also be seen from the same table that there was no statistical difference in uniformity between plants growing in mixtures containing sand, coir-dust, vermiculite and charcoal dust, and in mixtures containing coir-dust, vermiculite, charcoal dust and sisal waste.

Table 15: Variances and Coefficients of variation(%)for plant dry weights on the last sampling date (5 weeks after pricking) - Additives. (Trial ONE)

Additive	Variance (mg)		CV %
Sand	14531	a	13
Coir_dust	16931	a	13
Sisal waste	21281	ab	14
Charcoal dust	23563	ab	15
Peat moss (local)	27466	abc	17
Saw-dust	31283	abc	16
Vermiculite	49406	bcd	18
Irish peat	58648	cd	21
Leaf mold	80308	d	28
Coffee parchments	128	e	27

$F_{17,17}$ = 2.29 for 5% level of significance

Additives with same letter(s) are not Significantly different

Table 16: Variances and C.V% for plant dry weight (4 weeks after pricking-out). - Treatments (Trial TWO)

Treatment number	Variance (mg)		Coefficient of variation %
20	25	a	17
6	31	a	18
17	70	ab	12
3	128	bc	16
5	193	bcd	24
15	195	bcd	35
10	305	cde	21
12	327	cde	21
16	344	cdef	21
2	397	defg	26
13	457	defgh	24
18	489	defgh	26
4	509	defgh	25
7	553	defgh	26
14	600	efgh	28
21	672	efgh	23
8	783	efgh	29
11	885	efgh	38
9	921	fgh	30
19	1044	gh	33
1	1192	h	36

$F_{5,5}$ = 5.05 at 5% level of significance

Treatments with same letters are not significantly different

Table 17: Variances and C.V % for plant dry weights at the last sampling date - Additives.
(Trial TWO)

Additive	Variance (mg)	Coefficient of Variation (%)
Saw-dust	215 a	18
Sand	760 b	20
Coir-dust	1326 bc	25
Vermiculite	1777 bc	27
Charcoal dust	1803 bc	29
Sisal waste	2990 c	27

$F_{17.17}$ = 2.29 at 5% level of significance

Additives with same letter(s) are not Significantly different

To indicate whether the proportional variability between treatments and between additives was statistically significant, a log transformation was used. Analysis of the transformed data showed no statistical significant differences by Bartlett's test. This meant that the coefficient of variations for both treatments and additives did not differ significantly which means that the standard deviations could be proportional to the means.

(iii) Trial THREE

The homogeneity of variance, at the last sampling date, between treatments and between additives was also tested by using Bartlett's test. The test showed that there were significant differences in uniformity of plants growing in the different treatments (statistical significances are shown in Table 18) and also in the different additives (statistical significances are shown in Table 19). Table 18 shows that treatments 24, 12, 16, 4, 18, 19 and 20 (Table 3) had plants which were least variable. Table 19 shows that there were

significant differences between the uniformity of plants growing in mixtures containing vermiculite, coir-dust and charcoal dust, and that plants growing in mixtures with sisal waste were most variable while those growing in mixtures with saw-dust were least variable.

Table 18: Variances and Coefficient of variation(%) for plant dry weights on the last sampling date (5 weeks after pricking) - Treatments (Trial THREE)

Treatment Number	Variance (mg)		Coefficient of variations(%)
24	35	a	16
12	38	ab	11
16	54	abc	22
4	113	abcd	25
18	165	abcde	25
19	248	abcde	19
20	281	abcdef	51
2	352	bcdefg	11
14	441	cdefgh	17
7	611	defghi	5
17	710	defghi	18
3	839	defghij	6
11	935	defghij	9
13	1381	efghijk	15
23	1404	efghijk	13
8	1485	efghijk	43
10	2662	fghijk	17
9	2801	ghijk	16
1	3544	hijk	19
22	5544	ijk	22
15	7419	jk	29
21	9067	k	29
6	9272	k	32
5	10672	k	21

$F_{4,4}$ = 9.49 at 5% level of significance

Treatments with same letter(s) are not significantly different.

Table 18: Variances and Coefficient of variation(%) for plant dry weights on the last sampling date (5 weeks after pricking) - Treatments
(Trial THREE)

Treatment Number	Variance (mg)		Coefficient of variations(%)
24	35	a	16
12	38	ab	11
16	54	abc	22
4	113	abcd	25
18	165	abcde	25
19	248	abcde	19
20	281	abcdef	51
2	352	bcdefg	11
14	441	cdefgh	17
7	611	defghi	5
17	710	defghi	18
3	839	defghij	6
11	935	defghij	9
13	1381	efghijk	15
23	1404	efghijk	13
8	1485	efghijk	43
10	2662	fghijk	17
9	2801	ghijk	16
1	3544	hijk	19
22	5544	ijk	22
15	7419	jk	29
21	9067	k	29
6	9272	k	32
5	10672	k	21

$F_{4,4}$ = 9.49 at 5% level of significance

Treatments with same letter(s) are not significantly different.

Table 19: Variances and C.V% for plant dry weights on the last sampling date (5 weeks after pricking) - Additives (Trial THREE)

Additive	Variance (mg)	Coefficient of variation (%)
Vermiculite	1212 b	14
Sisal waste	5510 c	21
Coir dust	1609 b	16
Charcoal dust	2324 b	28
Saw-dust	351 a	24

$F_{19,19}$ = 2.21 at 5% level of significance

Additives with same letter(s) are not significantly different.

2. Physical and Chemical Properties

A. Physical Properties

The $_pF$ curves for the materials under study and an Ideal Substrate (de Boodt and Verdonck 1972), - a theoretical substrate whose figures show what a good substrate should be like, are presented in Figure 4 and Appendix 1. It can be observed that the $_pF$ curves for the materials studied are not better, as far as moisture retention is concerned, than that of an ideal substrate except for coir-dust, especially at moisture tensions above 10 cm. Sisal waste and coffee parchments had the worst $_pF$ curves.

From Table 20 it can be seen that:

(i) all materials are of low bulk densities, with coir-dust and sisal waste having the lowest.

(ii) all materials except charcoal dust had higher Total Pore Space percentage and less volume percent solid matter than an ideal substrate.

(iii) all materials had higher volume percent air, at 10 cm water tension, than an ideal substrate; the sisal waste having as high as 70%.

(iv) all materials except coir-dust had less volume percent available water.

(v) all materials except coir-dust and peat moss had less volume percent Easily Available Water than an ideal substrate, with coffee parchments having as low as 2%.

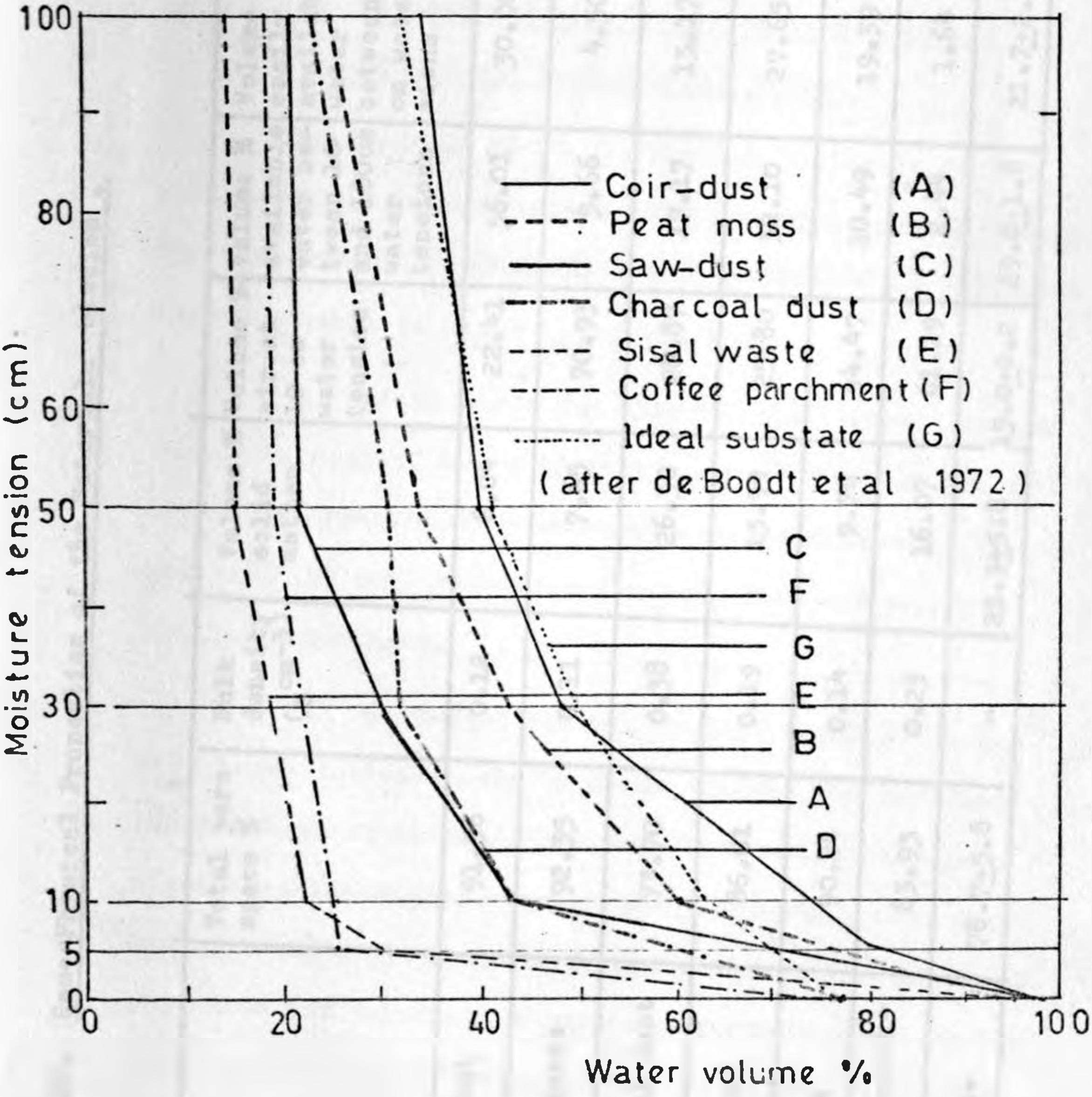


Figure 4 Moisture retention (pF) curves of the material studied.

Table 20. Some Physical Properties of the Materials studied.

	Total pore space %	Bulk density ($g cm^{-3}$)	Volume % solid matter	Volume % air at 10 cm water tension	Volume % available water between 10 and 100cm water tensions	Volume % easily available water between 10 cm water tensions	Volume % water buffering capacity between 50cm and 100cm water tensions
Coir dust	91.96	0.12	8.04	22.41	36.01	30.06	5.95
Sisal waste	92.35	0.11	7.65	70.93	5.66	4.50	1.16
Charcoal dust	73.70	0.38	26.30	28.87	17.17	13.17	4.00
Peat moss	86.01	0.19	13.99	25.80	32.10	27.65	4.45
Saw dust	90.24	0.14	9.76	44.47	20.49	19.39	1.10
Coffee parchments	83.93	0.23	16.07	61.29	2.44	1.64	0.84
Ideal substrate	76.7±5.8	-	23.3±5.8	15.0±0.2	29.0±1.8	21.7±2.5	7.3±0.7

(vi) all materials had less volume percent Water Buffering Capacity than an ideal substrate.

B. Chemical Properties

(a) pH, Electrical Conductivity, Chloride Concentration, Cation Exchange Capacity (CEC) and Exchangeable Bases.

The results of pH, Electrical Conductivity (an estimation of soluble salts), CEC and Exchangeable bases, for the materials studied are summarised in Table 21. From the table it can be observed that:

(i) sisal waste and charcoal dust were alkaline while the rest of the materials were acidic: saw-dust, coffee parchments and peat moss having the lowest pH; and that the soil reactions for coir dust and top red soil were the same.

(ii) coir-dust had the highest total exchangeable bases followed only by sisal waste; the coirdust had the highest exchangeable potassium while the sisal waste had the highest exchangeable calcium. Coir dust had also the highest exchangeable sodium while the local peat moss had the highest exchangeable magnesium for the local materials; vermiculite had the highest exchangeable magnesium. Coir-dust, sisal waste and peat moss had higher total exchangeable bases than both the imported materials (vermiculite and Irish peat) and the top red soil.

(vi) all materials had less volume percent Water Buffering Capacity than an ideal substrate.

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Table 21. P^H, Exchangeable Bases, CEC, Base Saturation, Electrical Conductivity and Chloride Concentration of the Materials studied.

	P^{H}KCl.		K	Ca	Mg	Na	CEC	Total Exchange Bases	Base Saturation (%)	Electrical Conductivity at 25°C (mmhos) at I.C.W.	Chloride Concentration g/100g of sample	
	DoH	ICW	Exchangeable Bases (me/100g material)				(me/100g material)				DoH	ICW
Coir-dust	5.4	5.4	40.8	10.9	8.1	12.5	55.4	72.3	130.5	4.000	0.352	0.990
Sisal waste	7.2	8.0	14.9	23.3	7.7	2.2	134.6	48.1	35.7	-	0.010	0.009
Charcoal dust	6.9	8.1	2.7	5.7	0.3	0.6	6.2	9.3	150.0	1.180	0.0072	0.008
Peat moss	4.7	4.7	2.2	3.7	11.0	7.0	43.6	23.9	54.8	0.354	0.0232	0.027
Saw-dust	4.1	3.7	2.4	4.2	1.2	0.7	20.5	8.5	41.5	0.168	0.009	0.010
Leaf mold	5.4	5.6	-	-	-	-	-	-	-	1.200	0.0256	0.027
Coffee parch-ments	4.4	4.4	-	-	-	-	-	-	-	0.240	0.0064	0.007
Top red soil	5.4		1.3	7.5	4.7	0.7	19.8	14.2	71.7	-	-	
Vermi-culite	-		0.9	4.0	11.6	0.8	12.4	17.3	139.5	-	-	
Irish peat	-		0.3	3.5	4.1	1.2	82.4	9.1	11.0	-	-	

DoH = Department of Horticulture) at Wageningen, Holland
ICW = Institute for Land and Water Management)

Table 21. P^H, Exchangeable Bases, CEC, Base Saturation, Electrical Conductivity and Chloride Concentration of the Materials studied.

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Coir-dust	5.4	5.4	40.8	10.9	8.1	12.5	55.4	72.3	130.5	4.000	0.352	0.990
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Saw-dust	4.1	3.7	2.4	4.2	1.2	0.7	20.5	8.5	41.5	0.168	0.009	0.010
Leaf mold	5.4	5.6	-	-	-	-	-	-	-	1.200	0.0256	0.027
Coffee parchments	4.4	4.4	-	-	-	-	-	-	-	0.240	0.0064	0.007
Top red soil	5.4		1.3	7.5	4.7	0.7	19.8	14.2	71.7	-	-	
Vermiculite	-		0.9	4.0	11.6	0.8	12.4	17.3	139.5	-	-	
Irish peat	-		0.3	3.5	4.1	1.2	82.4	9.1	11.0	-	-	

DoH = Department of Horticulture) at Wageningen, Holland
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(iii) sisal waste had the best cation exchange capacity followed by Irish peat,coir-dust and peat moss respectively. Charcoal dust had the lowest cation exchange capacity.

(iv) coir-dust, charcoal dust and vermiculite showed a base saturation of more than 100%. While Irish peat and sisal waste were least saturated with bases. Same results were found after repeating the determination.

(v) the electrical conductivity and chloride concentration were reasonably low in all materials under study except coir-dust.

(b) <u>Nutritional Status of the Materials</u>

The dry weights of the test plants after growing in the materials for four weeks (Plates 5 & 16) are presented in Table 22. Analysis of variance for each material, analysed separately, showed that the differences in weight between the treatments were not statistically significant. However, from the visual observations during the experiment it could be seen that there was a phosphorus deficiency in plants growing in -P treatments of peat moss and saw-dust, and in all plants growing in all treatments of coffee parchments and charcoal dust. It was also noted that plant growth in coffee parchments was so poor that no roots grew into the nutrient solutions. During the short time the trial was conducted the nutrients in the seed and seedlings may have sustained the growth. It is possible

Plate 16: Size of the tomato plants after four weeks growth in the materials and nutrient solutions.

that the deficiency of the elements may have given quantitative differences in dry weights if the trial was conducted for a longer period.

Since the materials had received the same treatments in all other aspects surrounding the experiment, and since the differences between treatments within each material were not statistically significant, analysis of variance between the materials was conducted. The F-test was highly significant. Plants in peat moss and coir-dust did best (Table 22).

3. <u>Germination Trial</u>

Results from the germination trial have been summarized in Table 23 (see also Plate 17). From the table it can be observed that there was no significant difference between days to the emergence of the first seed between seeds sown in peat moss, charcoal dust and the control; but the differences between these materials (peat moss, charcoal dust and control) and the rest were statistically significant, with seeds sown in saw-dust and coffee parchments taking the longest period to emerge. It can be seen from the table that as far as the percentage total emergence was concerned, the differences between coffee parchments and the rest of the materials, including the control, were statistically significant. The coffee parchments had the poorest percentage total emergence while charcoal dust had 100% total emergence. From the that the deficiency of the elements may have given quantitative differences in dry weights if the trial was conducted for a longer period.

Since the materials had received the same treatments in all other aspects surrounding the experiment, and since the differences between treatments within each material were not statistically significant, analysis of variance between the materials was conducted. The F-test was highly significant. Plants in peat moss and coir-dust did best (Table 22).

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Table 22: Dry Weights (g) of the test plants after four weeks growth in the materials and nutrient solutions

TREATMENTS	COMPLETE	-P	-K	-Mg	-Fe	AVERAGE
Peat moss	1.130	0.635	1.015	0.800	0.990	0.914 a
Coir-dust	1.035	0.920	0.960	0.670	0.585	0.834 a
Sisal Waste	0.405	0.435	0.360	0.410	0.170	0.356 b
Charcoal dust	0.185	0.095	0.325	0.170	0.195	0.212 b
Saw-dust	0.455	0.100	0.645	0.315	0.310	0.365 bc
Coffee parchments	0.060	0.055	0.185	0.105	0.105	0.102 c

Averages with same letter(s) are not significantly different at P of 0.05

Table 23: Germination Results

	Days to Emergence of the first seed	Days to 50% Emergence	Percentage Total Emergence
Peat moss	7 a	9.22 a	98 a
Charcoal dust	7 a	9.40 a	100 a
Coir-dust	8 b	11.54 c	90 a
Sisal Waste	8 b	11.70 c	86 a
Saw_dust	9 c	15.90 d	82 a
Coffee Parchments	9 c	-	38 b
Control	7 a	10.44 b	90 a

Materials with same letter(s) are not significantly different at P of 0.05..

Plate 17: 'Germinated' seeds.

Note: (a) that there were no germinated seeds on saw-dust (2nd row from right) and coffee parchments (3rd row from left) when the photograph was taken.

(b) that the local peat moss (3rd row from right) and charcoal dust (2nd row from left) had relatively high numbers of 'germinated' seeds, as compared to the rest, when the photograph was taken.

same table it can be noted that peat moss and charcoal dust took shortest period to have 50% emergence , while saw-dust took the longest period.

CHAPTER V

DISCUSSION

Physical Properties:

From the literature review (Chapter two above) it can be gathered that the organic and inorganic materials (additives) used in propagation media are to essentially improve the physical state of the media so that the media have fairly constant volumes when either dry or wet, can sufficiently retain moisture so that watering is not frequent and are porous to permit good drainage and aeration. The physical properties of all the materials tested could improve the porosity of propagation mixtures as the materials had relatively high total pore space percentages (Table 20). Therefore as far as improving the porosity, and therefore provide good aeration and drainage, of a propagation medium is concerned, the materials had equal chances of giving good results during the trials. However, this was not the case as there were remarkable differences between the performances of the various materials (additives) - Tables 11, 12 & 13. These differences could then be attributed to other physical or chemical properties of the materials (additives).

Looking at the results of volume percent air at 10cm water tension and the results of available water (between 10 and 100 cm water tensions - Table 20) it can be seen that indeed there were notable differences between the various materials (additives). Sisal waste which had the best results during the three trials, had the highest volume percent air but very low volume percent available water. Coir-dust, whose results were second to those of sisal waste, had the highest volume percent available water but low volume percent air. Therefore the superiority of these two materials or additives (sisal waste and coir-dust) to others, as far as the determined physical properties were concerned, could have been due to the two mentioned properties (i.e. ability to give best aeration - sisal waste, and the ability to hold more water - coir-dust). The differences in performances between the sisal waste and coir-dust according to physical properties could have been due to the lack of good aeration in mixtures with coir-dust. During the trials, watering was done daily and therefore plants growing in sisal waste, which had poor water-holding capacity could not have suffered from shortage of water. Charcoal dust, whose performance in the trials was next to those of sisal waste and coir-dust, had a higher volume percent available water than sisal waste, and higher volume percent air than coir-dust. Since saw-dust had a high volume percent air and had good water-holding capacity, it could have been expected to give better results than it did. This poor performance of saw-dust could be attributed to the fact that the saw-dust could be having some phytotoxic properties (due to presence of resins) which could retard growth - as is the case for barkwaste which is also a woody product (Gartner et al, 1974). Furthermore, other workers (Dunn and MacDonald, 1953; Wolfe and Dunn, 1953) found that pure saw-dust, whether fresh or rotted does not give good results as either a potting medium or soil ameliorant. They did not give reasons as to why the saw-dust gave poor results - except for poor water-holding capacity of the material; but they found that better results could be achieved if the saw-dust was composted with any type of manure for over one year. In the trials the poor performance of saw-dust could not have been due to poor water-holding capacity and hence lack of water, as watering was done daily and other materials (additives) such as sisal waste, with poorer water-holding capacities gave better results. Coffee parchments had also a very high volume percent air (in fact second only to that of sisal waste) but had the lowest volume percent available water (followed by sisal waste). Therefore all other factors being equal, it could be expected that the coffee parchments should have performed better than or as well as coir-dust. However, the results from the first trial showed that the coffee parchments had the worst performance. Investigating the influence of saturated fatty acids on the germination of seeds and growth of seedlings of higher plants, Hasler (1974) showed that dry leaves and twigs of the coffee plant contained saturated fatty acids which he thought delayed seed germination and retarded seedling growth of tomato and wheat when they (the leaves and twigs) were used in either a germination medium or a potting or growing medium. Coffee parchments may contain the same or similar saturated fatty acids. This could explain the poor performance of the coffee parchments in the first trial.

Chemical Properties:

The results showed that coir-dust, saw-dust and coffee parchments with $_{p}$Hs of 5.4, 3.9 and 4.4 respectively are acidic and that sisal waste and charcoal dust with $_{p}$Hs of about 7.6 and 7.5 respectively are alkaline. Experiences of the United States Salinity Laboratory Staff (1969) and suggestions by Buckman and Brady (1969) indicate that a medium with a $_{p}$H within the range of 5.0 to 8.0 is apt to be trouble free; that a medium with a $_{p}$H of less than 5.0 will be deficient of the following nutrient elements: calcium, magnesium, phosphorus, molybdenum and boron, or may have the following nutrient elements in toxic amounts: zinc, manganese, aluminium and nickel - due to increased solubility; and that a medium with a $_{p}$H of more than 8.0 will have free calcium which will be toxic to plants. Therefore, it can be noted that since the $_{p}$H of the top soil used in the mixtures, during the trials, was 5.4, addition of saw-dust or coffee parchments could have made the mixtures more acidic while the addition of sisal waste or charcoal dust could have increased the $_pH$ of the mixtures; and the addition of coir-dust could not have altered the $_pH$ of mixtures. This then could explain further the poor performances of mixtures with saw-dust and coffee parchments, and good results of those mixtures with sisal waste, coir-dust and charcoal dust. The presence of coffee parchments or saw-dust in the mixtures could have resulted in the unavailability of the nutrient elements calcium, magnesium, phosphorus, molybdenum and boron and in the production in toxic amounts of zinc, manganese, aluminium, and nickel, due to the low $_pH$ which could have been produced. The presence of coir-dust, sisal waste or charcoal dust in the mixtures probably had no effect on the $_pH$. Unfortunately the $_pH$ of the mixtures was not determined.

It is important for any propagation medium to have an adequate cation exchange capacity. If cation exchange capacity is too low any nutrients either added or released by decomposition of the ingredients in the mixture could very quickly be washed away during the daily watering. A material with a high cation exchange capacity could thus be expected to retain more of the released or added nutrients thus resulting in better plant growth. It is hardly surprising then that materials with high cation exchange capacity viz. sisal waste and coir-dust (Table 21) showed the best results in the trials. On the other hand charcoal dust which in the trials did quite well has a low cation exchange capacity. The registered low exchange capacity for charcoal dust could be due to the fact that the charcoal is a very good ion absorbent. But it should be borne in mind that a high cation exchange capacity of a material does not necessarily mean that nutrients absorbed by the material could be easily available to plants. This is because of several factors which could retard the release of the sorbed nutrient elements (Buckman and Brady, 1969). Some of these factors include the proportion of cation exchange capacity of the material that is occupied by the nutrient cation in question, the effects of the other ions held in association with the cation in question; and the tenacity with which the material holds the specific cation.

Vermiculite was found to have a cation exchange capacity of about 12 m.e which is much lower than the cation exchange capacity of about 150 m.e quoted by Buckman and Brady (1969). This difference may be partly due to difference in the grade of the vermiculite and partly due to the unsuitability of the method used in determining the exchange capacities. The method used in these studies is usually for the analysis of natural mineral soils. Another reason why the determined exchange capacity for vermiculite was too low to be acceptable could have been due to the fact that during the determinations, the materials were analysed in the same physical state, as far as particle/ aggregate size was concerned, as they were when they were used in the mixtures during the three trials. This could then mean that the particles of the materials, like vermiculite, used were too large to be hit more effectively by the reagents used.

The above reasons (unsuitable methods and large particle/aggregate size of the materials) could also help in explaining the anomalies that can be seen when looking at the base saturation percentages results (Table 21). Some materials namely coir-dust, charcoal dust and vermiculite had base saturation percentages of more than 100. This could mean that the figures of total exchangeable bases for these materials were too high or that the cation exchange capacities were too low to be considered relaible. Even after the repetition of the determination of the two chemical properties (exchangeable bases and cation exchange capacity) using the same methods as used before, the same results were obtained. This then confirmed that the anomalies observed in the results could not have been due to experimental errors. However, since the materials received the same treatments during the determinations, the results could only give a slight indication of the differences in chemical properties of the materials but cannot be used to compare the results to previous work, if any, on the same materials say vermiculite; as far as the properties in question are concerned. Further work on this could perhaps give a better picture of the chemical properties.

The electrical conductivity and chloride concentration of the materials studied were not very high except in the case of coir-dust whose figures were the highest recorded, for organic or inorganic soils, at the Institute of Land and Water Management at Wageningen in Holland (personal communication) where also these two properties were determined. It should however be remembered that different plants are differently sensitive to various concentration levels of soluble salts in a growing medium. Therefore more trials with vegetable seedlings could indicate the tolerable concentrations of the soluble salts and chloride that could be produced by the materials under study when they are used in mixtures. However, from the results of the nutritional status of the materials (Table 22), it can be seen that despite the fact that the coir-dust had the highest concentrations of soluble salts and chloride, the coir-dust produced heavier plants, in the short period the experiment was conducted, than the rest of the materials except local peat moss. The results of exchangeable bases show that coir-dust had the highest total bases even though the results are not very reliable as it has been mentioned before, with very high figures on exchangeable potassium and sodium. The high level of exchangeable potassium showed by coir-dust was also observed by Nathanael (1968). The high figure of total bases shown by coir-dust could explain the high recorded electrical conductivity. However, it can be said that the materials studied have reasonably low soluble salts and chloride concentrations which will not adversely affect plants that could be grown in mixtures containing any of the materials.

Nutritional Status

Results of the nutritional status of the materials studied were inconclusive. As mentioned earlier (chapter four) the experiment to determine the lack or the availability of phosphorus, potassium, magnesium and iron in the materials, might have been conducted in too short a period to bring out conclusive results. The fact that plants growing in coir-dust had higher dry weights than plants growing in the other materials, could be explained by coir-dust's good physical properties which are nearing those of an ideal substrate (see Table 20). Further work should be undertaken.

Use of Compost in Mixtures

It can be observed from the results of the third trial that compost was important in the mixtures. The results of the second and third trials confirm the views of Shoemaker and Teskey (1955) and Hartmann and Kester

(1968) that ordinary soil is usually not a satisfactory growing medium in seedflats or containers. However, if ordinary soil is mixed with some compost the results can be good (see treatments 19 and 21 of the second trial, and treatment 21 of the third trial). The results further indicate that mixtures of top soil and compost could be sufficient in formulating a propagation medium. The Oserian Estate at Naivasha, here in Kenya, indeed use a mixture of their local top soil (not the same top soil used during this study) and well-rotted cow manure for raising capsicum seedlings in polythene tubes (personal communication). As mentioned earlier in the literature review (chapter two), it is difficult, due to the given reasons, to use compost in a standardized medium. However, the use of compost in a potting medium can be of importance in that it helps in supplying some natural essential elements, instead of the addition of fertilizer to the medium, as well as improving the physical state of the potting media (Edmond, 1964). However further work, also using added nutrients to the mixtures, could show whether the compost is indeed useful in supplying nutrients or it just improves further the physical state of the mixtures when it is used in mixtures with other organic materials.

Uniformity of Plants grown in Mixtures containing the Local materials Under study

From the results of the three trials it can be seen that plants that could be raised in mixtures containing some local materials (additives), namely sisal waste and coir-dust, could be as uniform as those plants raised in mixtures containing the imported materials such as vermiculite. It can however be observed from the results that the heavier the plants were in dry weight the higher the variance was. This can be seen by looking at the variances of sisal waste and saw-dust in the second and third trials (Tables 17 and 19). In any case the average dry weights of the plants compared were not statistically significant. Sisal waste and coir-dust could thus be used in standardized media because they can produce as uniform plants as those produced by imported materials such as peat which are already being used in standardized media.

Use of the Local Materials as Germination Media

The results from the germination trial indicate that the local peat moss and charcoal dust could be used as germination media. These two materials had relatively higher volume percent solid matter and bulk densities than the other materials except coffee parchments. The coffee parchments also had a high volume percent solid matter and a high bulk density but had the lowest germination percentage. This could be due to the saturated fatty acids the material could be having which affect, negatively, germinating seeds of higher plants (Hasler, 1974).

Further work should be undertaken to show what particle sizes of say charcoal dust could be best when the material is to be used as a germination medium and also to confirm the results of this study.

General Summary

Of the local materials studied, sisal waste ranked first in performance while the coir-dust was second. Charcoal dust and local peat moss were fair while the coffee parchment ranked last. It can be seen from Figures 2A, 2B and 2C that the more of the sisal waste in the propagation medium the better the plant growth whereas other additives tended to reduce growth. This could be due to the fact that the material (sisal waste) improves further the drainage and aeration of the medium. This could indicate that the material (sisal waste) has a wide safety margin as far as its quantity in a propagation medium is concerned. Another observed characteristic which qualifies further the suitability of sisal waste and coir-dust in propagation media is that these two materials combine very well with compost. Increasing the compost in relation to the materials (sisal waste and coir-dust) indicate better plant growth (Figures 3A, 3B, 3C and 3D).

This suggests that these materials can be mixed with high amounts of the compost with low amounts of top soil to give a good plant growth.

Sisal waste, coir-dust and charcoal dust, mixed with other ingredients, have all the good physical properties which Hartmann and Kester (1968) think a good propagation medium should have. Different combinations of these three materials with others could therefore form a good medium for rooting cuttings. At Thika Research Station, coir-dust is indeed used for rooting cuttings while in the Nairobi City Park nurseries, charcoal has been used successfully as an ingredient when formulating rooting media for cuttings. It is therefore also suggested that more work should be done to try and find out the suitability of these materials (sisal waste, coir-dust and charcoal dust) in propagation mixtures for other vegetable seedlings and other horticultural crops, like fruit trees, in Kenya.

A fourth material which should be given more attention as a germinating media, along with charcoal dust, is the local peat moss.

CHAPTER VI

CONCLUSION

The present study has shown that there are a number of locally available materials which have the same or even better properties than the imported ones as ingredients in a propagation mixture. Sisal waste, coir-dust and charcoal dust performed better than or as well as vermiculite and Irish peat as additives in mixtures for propagating vegetable seedlings in containers. Charcoal dust and local peat moss did well as germinating media.

Sisal waste which produced the best results is a light material (bulk density of 0.11 g cm^{-3}) and has a high total pore space percentage for good aeration and drainage but has low water-holding capacity. The material has a high cation exchange capacity and low concentration of soluble salts. It contains exchangeable calcium, potassium and magnesium which could be available to plants. Though alkaline, its $_pH$ (of about 7.6) is within the acceptable $_pH$ range for good plant growth.

Coir-dust also has a high total pore space percentage, as high as that of sisal waste, but has relatively low volume percent air at 10 cm water tension. However, the material has good water-holding and cation exchange capacities. The material contains high exchangeable potassium, calcium and magnesium which could also be available to plants. It is acidic (pH of about 5.4) but its acidity does not seem to affect plant growth. Coir-dust is also a light-weight material (bulk density of 0.12g cm^{-3}).

Charcoal dust is the heaviest of the local organic materials studied - it has a bulk density of 0.38 g cm^{-3}. It has the lowest total pore space percentage but the highest volume percent solid matter (of about 26% - Table 20). The material has also relatively low volume percent air at 10 cm water tension and water-holding capacity. It is alkaline (pH of about 7.5) but its pH is within the acceptable range for good plant growth. Charcoal dust has a very low cation exchange capacity and a low concentration of soluble salts.

Local peat moss has good total pore space percentage and water-holding capacity, but has low volume percent air at 10 cm water tension. As expected, the material is acidic (pH of 4.7) but has a relatively good cation exchange capacity. It also has high exchangeable magnesium and sodium.

The other locally available organic materials namely saw-dust and coffee parchments seem to be too acidic for plant growth and could be containing some phytotoxic properties which could inhibit plant growth.

A summary of the physical properties and relative performance of the materials studied is given in Table 24. There seems to be no definate relationship between the properties and the performance of the materials.

It is obvious that further studies have to be made on sisal waste, coir-dust, charcoal dust and local peat moss, particularly in mixtures of different proportions with soils from various parts of the country and with different combinations with compost and/or with fertilizer depending on the type of soil. It would also be advisable to find the physical and chemical properties of the various mixtures (as distinct from the pure additives) in order to fully explain possible differences in performance of various mixtures. Such studies would lead to recommendations on standard propagation mixtures for various parts of the country which are based on scientific findings.

Table 24: Summary of the physical and chemical properties and relative performance of materials studied[1]

	Volume % solid matter	Bulk Density gcm^{-3}	Total Pore Space %	Volume % air at 10cm water tension.	Volume % available water between 10 and 100 cm water tension	pH[2] KCl.	Cation exchange capacity m.e./100 g	Total exchangeable bases. me/100g	Performance
Sisal waste	7.65	0.11	92.35	70.93	5.66	7.6	134.6	48.1	Very good
Coir dust	8.04	0.12	91.96	22.41	36.01	5.4	55.4	72.3	Good
Charcoal dust	26.30	0.38	73.70	28.87	17.17	7.5	6.2	9.3	Fair
Local peat moss	13.99	0.19	86.01	25.80	32.10	4.7	43.6	23.9	Fair
Saw-dust	9.76	0.14	90.24	44.47	20.49	3.9	20.5	8.5	Poor
Coffee parchments	16.07	0.23	83.93	61.29	2.44	4.4	-	-	Very poor
Vermiculite	-	-	-	-	-	-	12.4	17.3	-
Irish peat	-	-	-	-	-	-	82.4	9.1	-
Top red soil	-	-	-	-	-	5.4	19.8	14.2	-
Ideal substrate[3]	23.3±5.8	-	76.7±5.8	15.0±0.2	29.0±1.8	-	-	-	-

1 - Determinations done during the study
2 - Averages of results obtained at both the Department of Horticulture and Institute for Land and Water Management in Wageningen, Holland.
3 - After de Boodt and Verdonck, 1972.

CHAPTER VII

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Appendix 1 : Volume Percent Soil Moisture Retention at Different Tensions

Tension (cm)	5	10	30	50
Coir-dust	78.46±0.92	69.55±3.08	46.03±1.60	39.49±0
Sisal waste	30.11±2.16	21.42±1.13	18.83±0.74	16.92±0
Charcoal dust	50.48±2.79	44.83±2.11	35.57±1.64	31.66±1
Peat moss	70.54±2.03	60.21±2.99	38.55±1.10	32.56±0
Saw-dust	67.27±1.93	45.77±1.85	29.54±0.48	26.38±0
Coffee parchments	25.08±1.12	22.64±0.68	21.83±0.62	21.04±0
Ideal substrate	-	61.7±5.6	46.7±3.3	40.0±3.