

# CULTIVATION TECHNIQUES



## *Planning an optimum programme*

**In the first part of this two-part article we reviewed techniques in identifying soil physical problems. In this section, various means of correcting deficiencies will be explored and the pro and cons of each method will be evaluated.**

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### Introduction

Whilst turf managers use a diverse range of 'soil aeration equipment', few actually achieve the objective of 'effective soil aeration'. All too often, it is assumed that punching holes in a soil will automatically result in improved soil aeration. Not only is this assumption inaccurate, in many instances, it can be counterproductive and actually reduce soil aeration properties.

The term 'aeration equipment' is misleading. The vast majority of machines would be better categorised in a more general term of 'cultivation equipment'. Some of the machines may accomplish a degree of soil aeration but the majority have little effect. However, each has an alternative role to play in the many forms of 'cultivation'. Soil aeration is a specific objective and requires precise techniques to substantially improve the aeration porosity of a soil.

Each piece of equipment may perform one or more of the following 'cultivation' objectives:

1. Compaction relief
2. Rootzone aeration
3. Drainage improvement (both surface and sub-surface)

4. Thatch management
5. Soil modification (when accompanied by topdressing)
6. Improving irrigation efficiency
7. Pan busting
8. Layer disruption
9. Contour changing (allowing settlement after coring)
10. Enhancing fertiliser efficiency
11. Seedbed preparation
12. Stolon and rhizome pruning

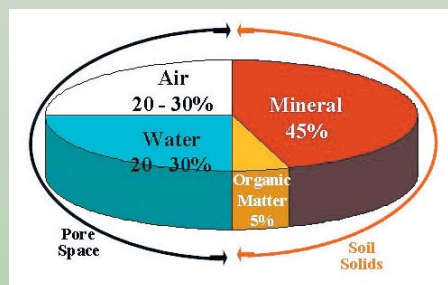
The first step in achieving success with a cultivation programme is to accurately identify the cause or causes of the problems and then determine the most appropriate corrective techniques for the prevailing conditions.

### The potential for soil aeration

On average, 50% of the soil is mineral/organic matter. The other half, the 'pore space', is occupied by air and water. Varying proportions of air and water can occupy the pore space or it may be entirely filled with water, i.e. saturated.

The proportion to which the soil pore

space contains water is referred to as the 'soil moisture content' and is expressed as a percent of the total soil volume. In a soil that consists of 50% mineral matter and which has a soil moisture content of 30%, the remaining 20% of the soil volume will contain air.



**Constituents of a well-managed soil shown as percentages of volume.**

The moisture status of a soil after drainage has ceased is termed 'field capacity' and is normally assumed to be at this point three days after saturation. It is not a quantitative measurement and the amount of water held at field capacity will vary in a soil, depending on its texture, structure, degree of compaction and soil temperature.



**Punching holes in the ground does not guarantee improved soil aeration**



**Machines serve different roles under the general term 'soil cultivation' and should not be automatically thought of as aeration implements**

## Balancing soil air and water

It is important for a soil to contain adequate moisture, but it is equally important that a soil contains adequate air-filled pore spaces. These air-filled pores provide routes for gas exchange with the atmosphere. This is termed 'soil aeration'. Adequate soil aeration is needed to create a healthy environment for turfgrass roots and plant-beneficial microbes living within the soil. Turfgrass roots and beneficial microbes are 'aerobic' organisms; that is, they require oxygen for respiration. They consume oxygen in their respiratory processes and generate carbon dioxide (CO<sub>2</sub>). Efficient soil aeration is necessary to prevent soil oxygen depletion and the accumulation of excessive CO<sub>2</sub> or other, toxic gases. As the rate of metabolic processes of organisms increase with a rise in temperature, the higher the temperature, the greater the demand for oxygen and soil aeration. Consequently, the demand for soil oxygen is at its highest during the summer months and at its lowest during the winter in the UK.

The ideal balance of water to air in the total pore space should be 70% water and 30% air. For adequate soil aeration, it is generally accepted that a soil should contain at least 10 to 20% air filled pore space for most of the growing season. If the air filled pore space is less than this for extended periods, the soil is considered to be depleted of oxygen, i.e. 'anaerobic'. Waterlogged and anaerobic soils will result in turfgrass decline by inhibiting root respiration. For example, a rootzone containing 20% air filled pores would become completely anaerobic (without free oxygen) after 24 to 48 hours if gas exchange did not occur. A rootzone with less than 10% air filled porosity can become anaerobic within 24 hours.

### Pore Size influences water and air movement

Soil pores are generally classified according to their size. And it is pore size, rather than total pore space, that strongly influences the water and air content of a soil at field capacity. Macropores, those larger than 75  $\mu\text{m}$  in diameter (1000  $\mu\text{m}$  equals 1 mm), will readily drain and mainly assist water infiltration, percolation and soil aeration or gaseous exchange.

General classification	Class (Brewer, 1964)	Diameter range ( $\mu\text{m}$ )	Characteristics and Roles
Macropores	Macropores	> 75	: water drains by gravity : accommodate roots : habitat for certain soil animals
	Mesopores	30 - 75	: retain water after drainage : water moves by capillarity : accommodate fungi and root hairs
Micropores	Micropores	5 - 30	: retain available water : accommodate most bacteria
	Ultramicropores	0.1 - 5	: retain unavailable water : exclude most micro-organisms
	Cryptopores	< 0.1	: exclude all micro-organisms : too small for large molecules

Classification of soil pores (adapted from Brewer, 1964)

Mesopores, those between 30  $\mu\text{m}$  and 75  $\mu\text{m}$  in diameter, will lose some of their water during the three day period leading to field capacity. Mesopores allow water to move more slowly. They enable capillary water to move to roots and soil moisture to be redistributed within the soil. However, the importance of capillary movement should not be exaggerated as the water moves very slowly and generally only over short distances.

Micropores, those less than 30  $\mu\text{m}$  in diameter, do not readily assist water to move through the soil but retain water within it and serve as a storage reservoir. They will only lose their water through root absorption. Therefore, a soil that is dominated by micropores will retain far more water than the desirable 70 % of total pore space. A soil that is totally dominated by micropores smaller than 30  $\mu\text{m}$  in diameter may have 100% of its total pore space occupied by water at field capacity. In such an instance, the soil water content at field capacity will equal saturation.

### There must be an extensive and continuous network of macropores

Oxygen diffuses through water 10,000 times slower than it does through air. Consequently, water-filled pores such as micropores and many mesopores can easily become deficient in oxygen, causing problems to turfgrass roots and microbes. Macropores, on the other hand, are the major aeration pores and it is essential that a soil has an extensive and continuous network of these larger pores to ensure adequate soil aeration.

### What is soil compaction?

Soil compaction is defined by an increase in bulk density and a reduction in total porosity. However, compaction does not affect all pores equally. Principally, there is a loss of macropores and a proportionate increase in micropores. By reducing the proportion of macropores in a soil, the potential for drainage and aeration are reduced. In all but the sandiest of soils, severe compaction can eliminate all macropores.

Understandably, the most compacted layer within a soil is found in the top 100 mm where foot and vehicular traffic is most intense. It is this zone that most severely restricts gaseous exchange.

### Choosing the most effective equipment

Any mechanical 'soil aeration' operation must increase the total macroporosity of a soil to be effective. All too often, equipment that is prescribed as an 'aeration treatment' fails to increase the number and extent of macropores.

A primary concept that is often overlooked is that any implement, on entry into a soil, will cause compaction and reduced aeration potential. Soil particles are pushed downward and laterally to accommodate the implement, thereby increasing the bulk density of adjacent soil and causing compaction.

Simultaneously, macropores are reduced to micropores and aeration porosity diminishes. It is inevitable and unpreventable. The extent of the damage will depend on the diameter of the tine or, as in the case of a hollow tine, the thickness of metal.



Many so-called 'aeration machines' only enhance surface drainage by creating a hole. They do little to increase the number or frequency of macropores.

An implement can only have a positive effect on the soil, either during its brief period in the soil or during its removal from it. So, let us consider the various options and their effects. Also, let us consider how different soils and their moisture contents might influence the outcomes.

### Vertical entry and removal tines

Any machine that is designed so that its tines enter and leave the soil in a vertical direction must rely entirely on the withdrawal sequence to disrupt the soil particles and produce macropores. In a moist to wet state, a soil is well lubricated and, in such a condition, any implement is going to withdraw with minimum friction and, therefore, minimal upheaval. Consequently, no compaction relief will occur.

The drier a soil is during withdrawal of the tine; the greater will be the upheaval and potential for compaction relief. However, even where friction on removal of a tine causes a degree of 'heave', the disturbance is generally restricted to horizontal planes of weakness within the soil, e.g., at interfaces between soil layers or along rootbreaks. These types of implements are of limited value in achieving an improvement in soil aeration. Instead, they may produce holes that merely enhance surface drainage by providing a by-pass route through surface layers down which surface water can escape to lower horizons. The holes created will also accelerate evaporation from the soil and result in drier surfaces. But, the destruction of macropores on entry of the tine will have an adverse effect on soil aeration porosity.

The most effective machines of these types in achieving a degree of soil aeration are those fitted with needle tines that create a large number of small diameter holes at very high frequency. Generally though, this type of implement should be considered as 'surface drainage enhancement' cultivation systems; not soil aeration machines.

### **Trailed, rigidly fixed-tine spikers and slitters**

Let us now consider pieces of equipment in which the tines are fitted rigidly to a drum, plate, or bar. As before, if a soil is well lubricated; minimal disruption will occur and the tine will merely create a slit in the soil, causing varying degrees of compaction and smearing. It is unlikely that soil aeration is enhanced. If a soil is in a drier state and friction is present; upheaval is likely but, again, there is a tendency for the soil to fissure along horizontal planes of weakness. It is for this reason that the turf tends to peel off at the depth of rooting. These implements may be effective in disrupting compacted layers or pans within the soil but are not very efficient at enhancing overall soil aeration.

### **Forking action: popularly referred to as verti-draining**

We now turn to machines with a forking action, such as the Verti-drain, Soil Reliever, etc., that are designed to heave the ground. These can be effective if used when the soil moisture content is relatively low. Maximum heave and fissuring will occur in a dryish soil. The extent and direction of soil fissuring, and subsequent soil aeration, will be regulated by many factors; soil texture, structure, depth and expanse of rooting, and previous cultivation operations. However, a dry soil can cause unacceptable surface disruption and many turf managers choose, instead, to carry out the operation when the soil is in a moist to wet state.

Under those circumstances, the effects are very different. The heaving action now becomes a subsurface compaction action where soil particles are compressed together. A relatively large void may be formed but it is at the expense of surrounding soil macropores. If a soil is very wet, the implement will, at best, only produce surface drainage holes and soil aeration is minimal. In

some cases, it can severely decrease the potential for extensive soil aeration. These



**Above: Verti-Drain tines. Right: The DryJect is a recent introduction to the European market.**

implements have proved very popular because of their potential to dramatically increase surface drainage rates. However, there is a major risk of achieving surface drainage at the expense of good internal aeration.

### **Air, water and amendment-injection implements**

A number of machines are designed with very different principles in mind. Rather than relying on mechanical cultivation, they use either air- or water-injection to fashion a macropore system. The Sisis Aer-Aid System injects air; the Toro HydroJect blasts water; and a more recent introduction to the European market, the DryJect, uses water, followed by sand or another soil amendment, to modify the soil texture. Each of these machines is more effective in establishing a network of macropores and are, therefore, more deserving of the term 'aeration' equipment.

The Aer-Aid has the potential to increase a soil's macroporosity by preserving existing macropores and enlarging some mesopores. Theoretically, the mode of action pushes air through the existing pore system, thereby relieving compaction and encouraging an extensive and continuous network of macropores. The number and extent of macropores formed will depend on various soil characteristics. Nevertheless, such a machine is a dedicated aeration implement.

The HydroJect, that injects fine bursts of water into the soil at the depth of penetration, will also create macropores and enhance soil aeration. It is generally more effective in coarse textured soils where few fine particles will migrate and clog pores. The machine can also be effective in the treatment of localised dry spots and general soil hydrophobicity.

The DryJect combines the benefits of water-injection and soil modification. After establishing a hole and enlarging surrounding pore spaces by means of a powerful jet of water, the machine introduces dry sand or other amendments to stabilise the macropore system that has been created.

Preservation of existing macropores and the creation of additional ones should be the aims of good soil aeration. The network of macropores must be extensive and continuous so that oxygen can readily diffuse to roots and soil microbes. As turf managers we must aid air movement uniformly throughout the rooting zone and not just limit it to sporadic vertical holes.

Each type of implement must be carefully considered and a knowledgeable selection can then be made to adequately correct the deficiency. Think hard about the problem and even harder about the remedy.