I. INTRODUCTION

(1) The importance of soil physical condition to plant growth

In the early investigations into the factors affecting plant growth, the attention of the majority of workers was focused either on the chemical or bacteriological aspects. The first man who clearly saw the importance of soil physics appears to have been Sir Humphrey Davey who in a series of lectures called "The Elements of Agricultural Chemistry" stressed the importance of this branch of Soil Science. However before this aspect was taken up, the brilliant work of Lawes and Gilbert came to the fore and it wasn't until the expansion of arable agriculture took place in America and created problems in the physical conditions of the soil that attention was once again directed to soil physics. By the end of the nineteenth century soil physics was recognised as a branch of Soil Science and the need for trained research physicists was realised and filled, with the consequence that soil physics has now been put on a sound theoretical basis.

(2) Difficulties of definition of soil physical conditions

With this advance in soil physics has come the realization that the relations of the plant to the soil are highly complex and that no simple explanation is adequate in describing the optimum conditions for plant growth. This fact becomes immediately apparent when one asks the question "what is the optimum soil physical condition for plant growth". The farmer calls this condition tilth, but as yet no satisfactory scientific explanation has been given to this term.

Russell (1945) points out that although many farmers firmly believe in the importance of tilth for plant growth and ease of management of land, crop development doesn't seem to be anything like as sensitive to quite wide variations in tilth. This might be dependent on whether the tilth is mellow or raw (Russell 1952), which from Russell's definition conforms to what Milne (1938) terms

consistence. There are however certain properties of a good tilth which are of undoubted importance to plant growth. Among other things a good tilth implies that there is a suitable air and water regime existent in the soil for plant growth. This condition can, according to Russell, be described in terms of the distribution of pore space (the air pockets in the soil) and the mechanism for ensuring the permanency of this distribution.

The air and water conditions in a soil are controlled by two factors, first the texture of the soil, which involves the type and size of both mineral particles and organic matter present, and secondly the structure, that is the arrangement of these textural particles in relation to one another. The structural arrangement of particles is probably the one which will best give us an idea of how water and air relations are controlled. In clay and loam soils, where the textural particles are small, there is the tendency for these particles to be grouped together under certain circumstances. These groups, or aggregates, have fine pore spaces within them, termed capillary and colloidal micropore spaces. Between these aggregates are larger pore spaces which are termed non-capillary pores. The fine pores hold their water against the gravitational pull, and some of the water is available to plant roots. The larger pores act as drains for the water and facilitate gaseous exchange between the soil air and the atmosphere. When a soil has a good structure, the soil particles are arranged in such a manner that optimal air and water relations are ensured. Russell (1938) points out that while it is important that a soil should have a good structure, it is of even greater importance that this structure should have stability which should resist through the growing season of the crop and, where possible, over a number of years. This stability may be either mechanical or water stability. Mechanical stability infers the resistance of the structure to purely mechanical forces such as are exerted by cultivation, strong winds or the impact of raindrops. In general, this is assured if there is enough colloidal material present,

whether it be from organic or inorganic sources or both. Water stability infers the ability of the soil crumbs to retain their individuality when wetted and although little can be found in the literature which gives the factors which are conducive to this stability, it would appear to have something to do with the ions adsorbed on the colloidal particles (Keen 1942).

(3) The place of cultivation implements in the maintenance of soil physical condition

The farmer and the soil scientist are both primarily interested in getting the soil into and maintaining it in a condition of good structure. Russell (1938,1952) puts forward four groups of factors which are available for controlling and improving structure. They are the proper use of cultivation instruments, of climate, of manures and of growing crops. After working on the cultivation in Ceylon, Eden (1931) came to the conclusion that mechanical cultivation has a bigger burden to bear in tropical than in temperate climates in maintaining the soil in a reasonable state of tilth because of the absence of the frost factor in causing the breakdown of the soil mass into crumbs.

Milne (1938) points out that in countries with an established agriculture, the type of system of soil management which maintains a good tilth, has been found by trial and error. In pioneer agriculture however mistakes are easily made which are often costly and at times irreparable. It is therefore of great importance that, if possible, we should rationalise the tillage operations, so that by application of our knowledge, such mistakes can be avoided.

It is the purpose of this paper to try various methods of tilth measurement and see what the effect of the different tillage implements on the soil is at the same time the problem of tilth endurance was observed.