## I. INTRODUCTION

The question of shading in cacao cultivation is an old and long-discussed one, and it can be said that no definite universal answer has been arrived at, though it is doubtful if such an answer exists. In spite of controversy different cacao growing areas adopt their own methods and retain them, e.g., in Trinidad and parts of the Gold Coast cacao is grown under shade, whereas in Grenada cacao is more closely planted and grown without shade. However, in all cacao growing countries the necessity for shade in the establishment of new plantations is recognised, and in the West Indies a varied mixture of food crops is usually used to provide shade for young cacao. This includes tannia, cassava, banana, plantain, etc., and is known as "temporary shade" - its composition and concentration seems very variable and the planting of temporary shade follows no definite plan - different planters use different methods and mixtures of crops. But in all cases the natural conditions under which wild cacao grows are simulated, i.e. the humid, shaded lower canopy of tropical rain forests.

The effect of the shade has not been at all fully investigated. Different views have been put forward, as outlined below, but it is probable that the importance of shade trees lies in their protection of the soil, conserving water by reducing evaporation losses, and also in their effect on the plants by reducing transpiration losses and maintaining a humid atmosphere at a fairly even temperature about the plants. It would seem that a careful investigation into the exact effects of shading on cacao, young cacao especially, would yield profitable results in that it would assist planters to attain the optimum shading necessary for good growth of young cacao cuttings, particularly since the work of the College Cacao Propagation Programme will probably lead to more and more planters using cuttings of selected trees as a source of material for new cacao fields.

The effect of light on any plant is not fully understood, but may be regarded as acting in two ways:

1. A direct effect on the growth rate.

Light is not one of the essential factors in order that a plant shall grow. Practically all plants can grow in darkness, although under such conditions they do not appear normal and are termed "etiolated": being characterised by essentially elongated stems, entire lack of chlorophyll and under-developed leaves. Maximov (7) has suggested that under the influence of light there arise in the plant substances of the nature of hormones which lead to changes in the character of growth of leaves and stems. These substances have a definite retarding effect on the rate of growth of plants, and the higher the intensity of light the greater the retardation. This may be partly explained by the suggestion that, under the influence of light, plants pass more quickly through the grand period of growth, and the period of elongation terminates early, resulting in smaller plants. Consequently shoots that have grown under shade are longer than those grown in light. This is also borne out by the fact that during the night plants grow more quickly than during daylight. Whatever the explanation may be the effect of light on the growth rate is definitely one of retardation. Thus, were growth the only factor determining the state of a plant, the heavier the shade the more successful would be the plant. But light has a second effect on a plant.

2. Light is the source of the necessary energy required for the production of organic matter in the leaves of plants, and thus light is essential for nutrition. In general the rate of assimilation increases as the intensity of light increases, but not in all cases. In the case of shade plants, including cacao, the assimilation rate increases until the light intensity has reached a fairly low value and any further increase in light intensity has no effect on the assimilation rate, but has an adverse effect on the plant. Myers (8) and Ducke (2) have described

the natural habitat of the cacao plant as being that of the lower canopy of trees in tropical rain forests, where it is rather heavily shaded throughout its life history. It is logical to assume that cacao has been so adapted, or has so evolved that its maximum assimilation rate is reached at the light intensity of such a locality, and it is this light intensity which should be simulated in cultivation practices. Excess light would show no increase in assimilation rate, but result in an adverse effect on the plant owing to the fact that increasing light intensity retards the growth rate. Thus it follows that up to a point increased light intensity is beneficial to a shade plant since nutrition increases, but beyond this point the retarding effect on the growth rate is felt.

It has been impossible as yet to find a numerical expression for the amount of radiant energy required by the plant for its normal development, but for all plants, and for shade plants particularly, there must be some definite "optimum light intensity" at which development is a maximum. This value may change as the plant matures. It is possible that it increases as the plant grows since in the natural habitat of a tree such as cacao the amount of light received by a young tree or seedling is less than that received by the adult - during growth the plant rises from the canopy of the ground vegetation to a higher canopy.

The question of the effect of shade is further complicated by the fact that restriction of sunlight means restriction of radiant energy and a consequent fall in temperature. Temperature is one of the principal factors affecting growth, and again, an optimum temperature is known for each plant, above or below which growth is retarded. It is possible that for cacao the sun temperature of the tropics is above the optimum growth temperature, and it seems feasible to state that cacao has so evolved that the shade temperature it experiences in its natural habitat is its optimum growth temperature.

The erection of shade for cacao trees diminishes the

radiant energy reaching the trees, and also diminishes the radiant energy reaching the soil. The effect of shading the soil may be more important than that of shading the trees. In the present investigation all these aspects were borne in mind, and rather than treat the trees, or the soil, or the atmosphere separately, these three were regarded as components of one composite system, soil-plant-air, and it was the effect of shade on this system that was investigated. It must be stressed that the investigation was carried out on young cacao cuttings up to the age of one year, and the light requirements of such plants may bear little relation to those of more mature trees, and still less to questions of yield.