Frontispiece

A Study of the effect of Plant Density on Growth and Yield in two varieties of Grain Barley.

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AGROMONY THESIS:

Topic:

The effect of Plant density on growth and yield in two varieties of Grain Barley.

CHAPTER I.

INTRODUCTION:

As a thesis topic, I have chosen to work with a temperate cereal viz: Barley (Hordeum distichum) and to examine in two varieties; Zephyr and Kenia:-

(1) The physiological and growth characters of two Barley varieties differing in grain yield potential.

(2) The effect of plant density on growth and development and on grain yield and its components.

In cereals, as in many crops, an increase in plant density leads to an increase in total dry matter until a level of yield is reached after which increase in density does not lead to a further increase in yield. The data upon which this statement is based often refers to shoot dry matter only. Grain yield on the other hand reaches a maximum with increasing density, after which a further increase in density leads to a fall in grain yield (Holliday, 1960; Donald, 1963). Crop growth, leaf area, tiller initiation and tiller death and other parameters are modified by plant density. Attempts have been made to relate these parameters with grain yield in studies envolving the physiological basis of varietal and fertilizer effects upon grain yield. Watson et al have made very full studies and have suggested that high grain yield is dependent upon having high values of leaf area and leaf area duration, especially after ear emergence (Watson, Thorne and French, 1963).

METHODS OF STUDY:

The problem of accounting for variation of yield in terms of growth and development of the crop plant is obviously very complex, for ultimately it involves the effect of external factors on all the physiological processes of the plant, the interrelation between different processes, and their dependence on internal factors determined by the genetical constitution of the plant. There are three main methods of study used by experimenters in sorting out such problems.

(1) Controlled environment with either whole plants or plant parts.

(2) Field studies using Growth Analysis techniques.

(3) Field studies using the energy balance concept.

To discover the physiological basis for variation in crop yield it is necessary to supplement laboratory studies by direct observation on field grown crops, measuring those attributes that are capable of relatively simple physiological interpretation. The disadvantages of any field study is that high variability in the plant population necessitates repetition of each observation on a large number of samples or a smaller number of samples with more frequent sampling intervals.

Growth Analysis is used as a technique in the field of studying related growth parameters in order to give some picture of the effects of density on grain yield, and is based on the principal that the increase in dry weight of plants in a given period is a measure of net photosynthesis. Full analysis of yield requires consideration of the distribution of dry matter and leaf area between the different parts of the plant as well as the total dry weight and leaf area accumulated. Physiological techniques appropriate for laboratory studies are, in general, not suitable for investigations on crops growing in field conditions. One reason for this is that such techniques may themselves change the environment; for example although it is possible to measure directly the gas exchange of plants growing on a field plot, this involves enclosing the plants in an airtight chamber inside which the environmental factors of light temperature, CO_2 concentration and water supply may differ in intensity from those outside.

In early experiments with cereals (Engledow and Wadham, 1923), the procedure followed was to make a census of the growing crop recording at intervals the number of plants/unit area, number of tillers/plant shoot height, and at harvest the number of ears/plant, grains/ear and grain weight; the plant characters assumed to be related to yield. These census studies did not succeed in defining easily measured yield controlling characters that the cereal breeder can use as a basis for selection as the different yield attributes are sometimes inversely correlated. The yield of a field crop is the weight/unit area of the harvested produce or some specific part of it, hence it is more logical to base an analysis of yield on the weight changes that occur during growth than on changes in morphological characters. The first step in developing a procedure for analyzing growth in terms of dry weight change was made by Blackman (1919). Blackman showed that increase in dry weight can be regarded as a process of continuous compound interest, the increment produced in any interval adding to the "capital" for growth in subsequent periods. The rate of interest, or relative growth rate;

$$R = \frac{I}{W} \times \frac{dw}{dt}$$

where R = growth rate
W = dry weight
t = time interval

i.e: $$\frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

The dry matter yield of a plant was considered as dependent on (1) the initial capital, i.e: the seed weight, (2) The relative growth rate, and (3) the length of the growth period and variations in yield can be analysed in terms of these three quantities.

However, the dry weight of a plant is not all productive capital, for a considerable part of it consists of skeletal material not active in growth. As dry matter increase is attributable to photosynthesis, a better measure of the productive capital or "growing material" of the plant is leaf size. The rate of increase of dry weight per unit leaf area, (I/L) (dw/dt) where L is the total leaf area of the plant, is a measure of the excess of the rate of photosynthesis over the rate of dry matter loss by respiration. Gregory (1917) suggested the use of this function in the analysis of growth and called it Net Assimilation Rate (NAR), and Briggs, G., Kidd, F. and West, C. developed E (Unit leaf rate) as an 'efficiency index'. The relative rate of plant growth at any one time, may be taken as an expression of the efficiency of the plant at that time in producing dry matter, or the difference between rates of assimilation and respiration/100 gm dry weight at that time.

Thus NAR and E is the rate of increase of dry weight per unit leaf area. N.A.R. is capable of relatively simple physiological interpretation, while leaf area is the result of many physiological and environmental processes:- genetics of the plant, age, nutritional status, temperature and moisture status, etc. LAI (Leaf area index) is often taken as a measure of the size of the Photosynthetic System, but it is not a perfect measure because parts of the plant other than the leaf laminae are capable of photosynthesis and may sometimes account for an appreciable fraction of the dry matter production. Thus total annual photosynthesis is a function of the size, duration and efficiency of the photosynthetic system. Growth analysis envolves sampling or harvesting whole plants at different growth stages over time from a population of similarly treated plants at intervals, in this case weekly intervals were used. Watson (1947) has shown that while E varies between species grown in the same environment, between varieties of the same species, and between seasons for the same crop in the same place, variation in E within and between species and between seasons is accompanied by relatively greater variation in leaf area, so that measurement of leaf area is important in the study.

Thus it is clear that the relative growth rate (R.G.R.) is the product of N.A.R. and the ratio of leaf area to total dry weight; this ratio (L/W, leaf area ratio) may be regarded as an index of the amount of 'growing material' per unit dry weight of the plant. Consequently, the progress of dry matter accumulation and its end point yield at harvest can be completely described in terms of the two attributes NAR and leaf area.

It is not practicable to make a continuous record of the changes with time in total dry weight and leaf area; instead, they are measured by taking samples from a population of similarly treated plants at intervals, usually a week or multiples of a week. RGR and NAR are then estimated as mean rates over the successive intervals. Fisher (1921) showed that, if W_1 and W_2 are the total dry weights at times t_1 and t_2 respectively, the mean value of R.G.R. for the time interval $t_2 - t_1$ is given by:-

$$\frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

and following Gregory (1926) it has been usual to calculate N.A.R. as

$$\text{NAR} = \frac{(W_2 - W_1)(\text{Log}_e L_2 - \text{Log}_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

For short intervals (1-2 weeks) it appears that this condition is approximately satisfied, and the errors introducted are negligibly small for field crops, in comparison with those due to sampling variation in W and L.

Limitations to the concept of N.A.R:

It is important to bear in mind that N.A.R. is not a pure measure of photosynthesis, but it depends on the excess of dry matter gain by photosynthesis over loss by respiration. Some of the limitations to the concept of N.A.R. are :-

(1) Photosynthesis occurs mainly in the leaves whereas respiration proceeds throughout the whole plant.

(2) N.A.R. is often estimated from plant tops only as roots are difficult to obtain. This will result in an under-estimation of N.A.R., at the times when the root system is increasing in dry weight, i.e: the error introduced may be large in the very early growth stages, later decreasing and becoming negligible.

(3) Another limitation of the NAR concept arises from the fact that photosynthesis is not entirely restricted to the leaf lamina, but occurs also in other parts of the plant difficult to measure, e.g: in stems and petioles, and in the leaf sheaths and ears of cereals.

(4) Photosynthesis may occur at a greater rate in different parts of the plant, e.g: nearly half the dry weight increase of Barley plants after ear emergence is the result of photosynthesis in the ears (Watson and Norman, 1939; Porter, Pal, and Martin, 1950).

(5) NAR varies with changes in the external climatic factors, viz: light and temperature. Weekly values for increase in Dry Weight/Unit leaf area vary more or less about a mean - fluctuations attain increasing amplitude as age of the plant increases e.g: after 8 weeks in maize - (Briggs, Kidd and West, 1920) when sampling errors are largely responsible.

Watson (1952) points out that there can be no ideal basis of reference for N.A.R. that will render it wholly independent of the 'internal factor' or 'growing material' of the plant since NAR depends on both photosynthesis and respiration. The best course seems to be to use a basis of reference appropriate for photosynthesis, since this must be the dominant process whenever increase in dry weight is taking place. Williams (1939) preferred to express N.A.R. on the basis of leaf protein-nitrogen E_p although this envolves elaborate analytical procedures and it is doubtful of its superiority. Hence it is better to continue to use the leaf area basis for the sake of uniformity.