EFFECTS OF THE WEATHER ON GROWTH AND RADIATION INTERCEPTED BY FABA BEAN[1]

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ABSTRACT - The effects of the weather on growth and radiation intercepted by faba bean (*Vicia faba* L.) were studied in field grown plants throughout the summer of 1991 and 1992. At 7-day intervals, measurements of leaf area and plant dry weight were measured. The radiation intercepted by the crops and the values of air temperature, solar radiation and rainfall were collected throughout the season. Under the warmer summer of 1992 the plants had a greater rate of leaf expansion but a shorter period of growth. The weather also had an effect on the ability of a crop to capture and to use light for the growth process. The different weather prevailing during the 1991 and 1992 seasons brought large differences in the behaviour of the crops. A comparison of the classical and radiation approaches to analyse the effects of the weather on crop growth showed that both the classical and the radiation methods were not able to answer if the differences were due to physiological or morphological changes in the crops

Index terms: growth analyses, legumes.

EFEITOS DAS CONDIÇÕES METEOROLÓGICAS NO CRESCIMENTO E NA INTERCEPTAÇÃO DA RADIAÇÃO PELA FAVA

RESUMO - Foram estudados, em condições de campo, nos verões de 1991 e 1992, os efeitos das condições meteorológicas no crescimento e na quantidade de radiação interceptada pela fava (*Vicia faba* L.). A radiação interceptada pela cultura e os valores da temperatura do ar, radiação solar e precipitação foram medidos durante toda a estação. Plantas que cresceram sob o verão mais quente de 1992 obtiveram maior taxa de expansão foliar e menor período de crescimento. As condições meteorológicas também afetaram a capacidade da cultura de interceptar e utilizar a luz em seus processos de crescimento. As diferentes condições meteorológicas que prevaleceram em 1991 e 1992 trouxeram grandes diferenças no comportamento das culturas. Na análise dos efeitos do clima sobre o crescimento das plantas, concluiu-se que tanto o método clássico quanto o de radiação foram ineficazes para avaliar a diferença no comportamento das culturas quando decorrente de resposta morfológica ou fisiológica.

Termos para indexação: análise de crescimento, leguminosas.

INTRODUCTION

The effects of weather on growth, development and yield of crops have been the subject of extensive study. However, due to the complex interactions between environmental factors and crop behaviour, there is still a lack of understanding of how weather variables affect the performance of crops growing under field conditions (Monteith, 1981).

Whereas it is well known that weather can affect crop yield by affecting canopy development and the period needed for growth (Monteith, 1981; Skjelvag, 1981a, 1981b), and therefore the ability of a crop to capture resources from the environment (Monteith, 1994a), more studies are still needed to quantify the effects of the weather on the rate and duration of crop growth.

Quantitative studies of plant growth started more than 70 years ago from the work of Blackman (1919). Since then several methods, such as Relative Growth

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Rate (RGR; rate of growth by unit of mass), Net Assimilation Rate (NAR; rate of increase of biomass per unit of leaf area), Leaf Area Ratio (LAR; the leaf area per unit plant weight) and the Leaf Area Duration (LAD) have been developed to express plant growth. Those methods are today components of what is called The Classical Growth Analysis. The main hypotheses behind those methods is that the interception and use of light by plants is proportional to biomass.

Despite the great contribution of this work to the understanding of the relationship between plant growth and environment, several controversy have been brought about the use of such approach (Russel et al., 1989; Goudrian & Monteith, 1990).

Another approach to express the effects of environment on crop growth, The Radiation Method, was introduced by Monteith (1977). It is based on the relationship between the accumulated photosynthetically active radiation (PAR) absorbed by the crop and its accumulated dry weight. The use and validity of such a relationship has been discussed recently (Demetriades-shah et al., 1992; Monteith, 1994b).

Those two approaches which are, in essence, an attempt to understand how the environment affects crop growth, may have as a major weakness the fact that they have an implicit assumption that the size of the assimilatory component (leaves) is the major determinant for crop growth.

The main objective of this paper is to analyse the response of field crops to the weather.

MATERIAL AND METHODS

General introduction

The experiment was carried out at Sonning Farm, University of Reading (51° 27'N, 0° 57'W), during the summers of 1991 and 1992. In each year, Gobo, an indeterminate cultivar of *Vicia faba*, was sown, with an average density of 48 plants m^{-2}, in two plots of 8 x 6 m. The sowing date was 10th of April. The soil at the site was a sandy loam overlying gravel. Rainfall was supplemented with irrigation throughout the season.

Soil moisture content

Soil moisture content was monitored using a Neutron Moisture meter (Didcot Instruments Co. Ltd.). At 7-day intervals, and also before and after any irrigation, measurements were taken, in each plot, at 10 cm depth intervals down to a depth of 100 cm. The access tubes were installed in the middle of each plot.

Irrigation system

The irrigation was supplied using a trickle irrigation system. Fifteen tubes, linked to the main supply line were laid in each plot between every pair of crop rows. The rate of water application was about 15 mm h^{-1} and the pressure within the system was kept around 5 x 10^4 Pa. The amount of water applied was calculated taking into account two pieces of information: the crop potential evapotranspiration and the soil moisture measurements from the Neutron Probe. Irrigation was applied when the soil moisture content had decreased by 20% or more than the soil field capacity.

Meteorological data

Daily values of air temperature (minimum, maximum and mean), solar radiation and rainfall, were collected from an automatic weather station located 200 m from the experimental site.

Growth samples

At 7-day intervals 10 plants from each plot were harvested from a randomly selected area of 0.5 x 0.5 m. The samples were harvested at the centre of the area and the remaining peripheral area served as a buffer zone. After harvesting, the plants were separated into leaves, stem, roots and pods. Dry weights were determined after oven drying the samples at 80°C for 72 hours. The leaf area was measured using the Area Measurement System Mk2 (Delta-T Devices Ltd.).

Radiation intercepted

Solar radiation intercepted by the crops was measured by using tube solarimeters (Delta-T Devices Ltd.) installed in each plot at ground level and at the height of the crops. The solarimeters were individually calibrated against the Kipp + Zonen standard solarimeter. Using a Campbell CR7 datalogger (Campbell Scientific Ltd.), the output signals from the solarimeter were taken every thirty seconds and the average was recorded every hour.

In addition to these, PAR was measured by using a Sunfleck Ceptometer (Delta-T Devices Ltd.). Ten measurements were taken weekly at four different levels in the canopy: top, bottom, and at two intermediate levels.

Components of growth

The values of leaf area duration (LAD), in days, which is an indication of the persistence of the assimilatory surface of a crop (Beadle, 1985), were calculated by using the following relationship between the leaf area index (LAI) and time (t):

$$LAD = (LAI_1 - LAI_2)(t_2 - t_1)/2 \qquad \text{eq.1}$$

where:

LAI_1, LAI_2, t_1 and t_2 are respectively LAI and time (in days) at the moment of the imposition of the treatments and at the time of the maximum LAI.

The average net assimilation rate (NAR) (g m^{-2} (leaf area) d^{-1}) and leaf area ratio (LAR) (m^2 (leaf area) g^{-1} (total crop)) were calculated as:

$$NAR = (W_2 - W_1)(\ln LAI_1 - \ln LAI_2)/(LAI_2 - LAI_1)(t_2 - t_1) \qquad \text{eq.2}$$

$$LAR = (LAI_2 - LAI_1)(\ln W_2 - \ln W_1)/(W_2 - W_1)(\ln LAI_2 - \ln LAI_1) \qquad \text{eq.3}$$

where:

W_1 and W_2 are the dry weight (g) at the time considered and LAI_1, LAI_2, t_1 and t_2 are as defined in eq.1.

RESULTS AND DISCUSSION

The weather regime for 1991 and 1992 is summarized in Table 1. As a general point it can be seen that 1992 had more solar radiation during the early growth (May and June) of the crop. The season in 1992 also had more rainfall in March, April and May. Higher temperatures were also observed early in the season (April, May and June) in 1992.

Fig. 1 shows the variation in soil water content (1 m depth), as an average for the two replicates, for both 1991 and 1992 seasons. It can be seen that the plots were kept near the field capacity (300 mm) during most of the season.

The growth rate of a crop can be affected mainly by two components: i) the amount of photosynthate invested into the leaves, in comparison with the amount invested in other plant parts, and ii) by the efficiency of its assimilatory component. Therefore the values of LAD, NAR and LAR can give some insights on those components.

The results show that the crops growing in 1992 season had values of LAD and LAR around 35% smaller than the crops growing in 1991. Conversely, the 1992 crops had values of NAR around 40% greater than the 1991 crops (Table 2). The relative growth rate (RGR) of a crop can be described as NAR x LAR; therefore, the values of RGR at the time considered in this work were 0.050 g g^{-1} d^{-1} for the 1991 crop, and 0.063 g g^{-1} d^{-1} for the 1992 one. Those results indicated that the physiological component NAR had more influence on the behaviour of the crops than the morphological component LAR. In other words, the 1992 crop was able to have a greater RGR by compensating for a smaller LAR and LAD with a greater assimilatory component, NAR. Since both respiration and photosynthesis are components of the NAR, a further analysis indicates that the 1992 crop had a greater RGR by increasing gross photosynthesis or by reducing respiration in response to the weather conditions.

The total amount of PAR intercepted, the maximum LAI and the radiation use efficiency (ε; amount of dry matter produced per unit radiation intercepted)

TABLE 1. Monthly means of radiation, temperature and total monthly rainfall for the 1991 and 1992 growing season and for the decade (Dec.) 1980-1990.

Month	Radiation (MJ m^{-2} d^{-1})			Rainfall (mm $month^{-1}$)			Temperature (°C)		
	1991	1992	Dec.	1991	1992	Dec.	1991	1992	Dec.
March	7.5	6.9	7.8	34.0	43.8	59.0	8.5	8.0	6.2
April	12.5	11.7	13.1	63.0	61.0	43.7	8.6	8.8	8.2
May	13.5	20.0	16.4	9.0	43.4	55.2	11.5	13.8	11.7
June	14.5	19.0	17.2	84.0	24.4	55.1	12.7	15.1	14.8
July	18.2	14.2	17.2	84.0	64.0	37.5	17.4	16.3	17.1
Aug.	17.0	12.8	14.7	9.0	102.0	47.5	17.9	16.3	16.6

are presented in Table 3. They show that the 1991 crop was two times more efficient in converting radiation to dry matter (ε) than the 1992 crops. As the ability of converting radiation to dry matter indicates a greater efficiency of the photosynthesis apparatus (Monteith, 1977), those results are exactly the opposite of the results discussed above, as they indicate that the relation photosynthesis/respiration was more efficient in the 1991 crops than in the 1992 ones.

The answer to these contradictory results might be on the complex changes in the ratio photosynthesis/respiration with increasing LAI. As respiration is a major component of NAR, and about 50% of the photosynthate produced daily may be lost in the process of respiration, more studies are needed to verify the changes in the ratio photosynthesis/respiration with increasing LAI. Both the classical and the radiation approaches do not consider that an increasing LAI not only increases the ability of a plant to capture light, but also changes its growth and maintenance process (Costa et al., 1994).

The 1991 crops reached values of LAI around two times greater than the 1992 ones (Table 3). Those results were due to the higher temperature and

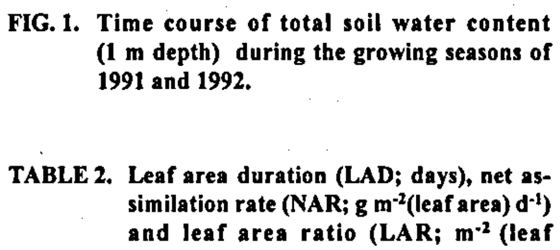

FIG. 1. Time course of total soil water content (1 m depth) during the growing seasons of 1991 and 1992.

TABLE 2. Leaf area duration (LAD; days), net assimilation rate (NAR; g m^{-2}(leaf area) d^{-1}) and leaf area ratio (LAR; m^{-2} (leaf area) g^{-1}(total crop)).

Year	LAD	NAR	LAR
1991	232	6.1	0.0083
1992	148	9.8	0.0064

TABLE 3. Seasonal amount of photosynthetically active radiation intercepted (A_p; MJ m^{-2}), the maximum value of leaf area index (MAX LAI) and the radiation use efficiency (ε;g MJ^{-1}) for the 1991 and 1992 crops.

Variables	1991	1992
A_p	450.6	651.2
MAX LAI	10.0	6.0
ε	5.0	2.5

radiation available through the 1992, which induced a greater rate of leaf expansion. However, the results showed that the 1992 crop, even with a smaller LAI, was more efficient in capture light (PAR intercepted). It is very likely that those results were affected by the measurements of radiation interception, which are subject to large error with increasing LAI. However, any morphological changes in leaf angle or leaf orientation can not be ruled out.

The different weather prevailing during the two seasons, brought large differences in the behaviour of the crops, but both the classical analysis and the radiation method were not able to answer if those differences were due to physiological or morphological changes in the crop or even due to measurements error. Therefore, whereas both the classical and the radiation approach can be used to assess the effect of the environment on crop growth they can lead to different interpretation for the same crop behaviour. The main reason for this controversy might be the complex interaction of NAR and ε with increasing LAI. Despite the fact that those approaches, mainly by their simplicity, can be a very useful tool to asses the effect of the environment on crop growth, their results should be seen with caution and would be more meaningful if followed by some physiological based studies (Lambers, 1987) or even by mechanistic models of crop growth.

CONCLUSION

The weather can affect the amount of radiation intercepted by a crop, and thus crop productivity, by changing its rate of leaf expansion and the duration of growth.

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