Effect of temperature, photoperiod and rainfall on the phenological development of different cultivars of oilseed rape (*Brassica napus* L. var. oleifera DC.)

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ABSTRACT
The objective of the research was to assess the validity of relationships that emerged during the course of a five-year study in two environments of southern Italy between a number of weather variables and the phenological development of two varieties of canola with differing earliness. Data was used from 16 field experiments conducted during the period 1993-96. The duration of the intervals between sowing, emergence, onset of flowering and physiological maturity was estimated using regression equations calculated in the previous five-year period, using the mean values of temperature and photoperiod and rainfall recorded during the same intervals. The level of reliability of these functions was assessed by studying the correlations between estimated and observed values. Results obtained could possibly lead to the use of readily available climatic data in the territory with the aim of developing simple quantitative models which allow an assessment of the adaptability of different genotypes in the cropping area.

Key words: oilseed rape – varieties - phenology – weather variables

INTRODUCTION

Southern Italy could represent a potential new area for canola production. It is important to identify cultivars and sowing date suited to the local climate. However, the management of sowing date is difficult because of the highly variable rainfall distribution in these environments: the prolonged summer droughts or, conversely, heavy autumn rainfall have often led to the postponement of seeding until the beginning of January (Santonoceto and Anastasi, 1993). With reference to cultivars, it has been noticed on different occasions that, in the Mediterranean climate, earliness represents one of the most valid means for many winter grain crops of avoiding, at least partially, end-of-season high temperatures and water deficit (Santonoceto, 1997). The effect of earliness is heightened if associated with a balanced duration of the main phenological phases: a shorter time to flowering, yet sufficient to allow adequate vegetative growth of the crop, would guarantee an increase in the subsequent grain filling phase, whose duration has been found to be closely associated with grain yield. Familiarity of the quantitative relationships between crop phenology and agro-meteorological factors represents the first step in the development of simple quantitative models to help in identifying cultivars better adapted to local conditions. However, in order to extend these models on a territorial level they must be founded on readily available climatic variables such as temperature and rainfall or calculable like photoperiod.

A previous paper (Santonoceto and Anastasi, 1999) quotes the results of a research conducted for five years in two localities in Calabria in order to quantify phenological development in response to variations in temperature (minimum, maximum and mean), photoperiod and rainfall of two varieties of canola: Activ, annual, and Ceres, biennial, representative of early and mid-late maturing cultivars respectively. Crop phenology was divided into three phases: sowing to emergence, emergence to flowering, flowering to physiological maturity. The relationships between each phase duration and temperature, photoperiod and rainfall, recorded during each phase and cultivar, were studied by backwards multiple regression. In the event of two or more values from minimum, maximum and mean temperature being found to be significant, the value with the highest level of significance was chosen. Minimum temperature was the only factor which influenced the duration from sowing to emergence. The relationship highlighted that the phase tends to gradually stabilise as, on average, the minimum temperature approaches 15°C. The duration from emergence to flowering of the two cultivars was determined by mean temperature and daylength. Temperature, however, accounted, on average for the two cultivars, for only 9% of the variation in A-F1. Significant responses to quadratic photoperiod indicates that the response to this variable is progressively smaller with the increase in daylength. Maximum temperature and rainfall were determinant in regulating the duration from flowering to physiological maturity of both cultivars. The objective, in this second phase of research was to examine the validity of the relationships outlined previously using data recorded in a series of trials conducted in the same localities with the same varieties mentioned earlier.

MATERIALS AND METHODS

Data was used from 16 field experiments conducted in three consecutive growth seasons (1993/94-1995/96) at S.Marco Argentano (39°33'N, 16°07'E, 232 m a.s.l.) and Rocca di Neto (39°05'N, 18°08'E, 40 m a.s.l.) on the varieties Activ (annual) and Ceres (biennial). Sowing dates varied, irrespective of growth season, between 6 October and 7 January. Development stages were recorded according to the CETIOM (1978) growth stage key and symbology. Dates were recorded for sowing (S), emergence (A), start of flowering (F1) and physiological maturity (G5): the duration of each phase was estimated using the cited regression equations (Santonoceto and Anastasi, 1999) on the basis of the mean values of the climatic variables recorded within each interval. Daylength was calculated from Keisling (1982). The level of reliability of these equations was assessed by studying the correlations between estimated and observed values in each phenological phase of the two genotypes.

RESULTS AND DISCUSSION

On average for the three years and for the two localities, the mean temperature progressively decreased from 16.5 (±0.6 s.e.) to 8.2°C (±0.6), from October to February then increased, reaching 20.9°C (±0.4) in June. During the winter, minimum temperatures frequently dropped to values below 0°C; the highest maximum temperatures only exceeded 30°C in June, corresponding to the final maturing phases of Ceres in a number of trials sown later. The amount of rainfall, from October to June, was considerable, on average greater than that of the previous five years and equal, by year, to 741, 435, and 953 mm at Rocca di Neto and 943, 652, and 514 mm at S. Marco Argentano. The distribution of rainfall was typical of a Mediterranean environment: indeed, almost 90% of rainfall was concentrated between October and March.

Table 1. Mean values and ranges of variation of the climatic variables recorded within each phase of the two varieties in the trials conducted in 1988-93 (n=23) and 1993-96 (n=16).

Phase	Variables	ACTIV		CERES	
		1988-93	1993-96	1988-93	1993-96
S-A	Min t ± s.e. (°C)	5.1 ± 0.8	8.6 ± 0.7	5.1 ± 0.8	8.6 ± 0.7
	Range	0.2 ÷ 13.8	3.8 ÷ 13.2	0.2 ÷ 13.8	3.8 ÷ 13.2
A-F1	Mean t ± s.e. (°C)	8.9 ± 0.3	10.3 ± 0.3	9.6 ± 0.3	10.7 ± 0.3
	Range	6.8 ÷ 11.2	6.7 ÷ 11.9	7.6 ÷ 12.0	7.3 ÷ 12.0
	Photoperiod ± s.e. (hr.min)	11.36 ± 0.09	11.18 ± 0.06	12.06 ± 0.10	11.48 ± 0.08
	Range	10.48 ÷ 13.06	10.54 ÷ 12.18	11.12 ÷ 13.36	11.12 ÷ 12.48
F1-G5	Max T ± s.e. (°C)	20.5 ± 0.5	20.4 ± 0.5	23.4 ± 0.5	23.8 ± 0.6
	Range	16.2 ÷ 24.6	15.2 ÷ 24.0	20.2 ÷ 28.5	18.1 ÷ 27.3
	Rainfall ± s.e. (mm)	118 ± 11	116 ± 14	86 ± 8	61 ± 9
	Range	16 ÷ 249	14 ÷ 223	27 ÷ 155	12 ÷ 163

Table 1 shows the mean values of the climatic variables used in the regressions. Irrespective of variety, in the latter three-year period, higher mean values of minimum temperature were recorded compared with the previous period during the S-A phase; higher mean temperatures and lower mean photoperiod during the A-F1 phase; fairly similar mean values of maximum temperature and rainfall during the F1-G5 phase. However, it is important to emphasise that in this final phase, the earliest variety intercepted a greater amount of rainfall (118 and 116 mm, Activ, against 86 and 61 mm, Ceres, in 1988-93 and 1993-96, respectively) and lower maximum temperatures (20.5 and 20.4°C, Activ, against 23.4 and 23.8°C, Ceres, in 1988-93 and 1993-96, respectively).

Figure 1 shows: the 1:1 line, calculated using the regression equations previously cited; the observed values of the duration of the phases S-A, A-F1, F1-G5 of Activ and Ceres in the period 1993-96; the correlations between these latter values and those calculated in the same three-year period. The correlation coefficients, all highly significant, indicate the high level of association of the two variables; the slope (b) of each correlation line compared to the 1:1 line, provides further indications of possible divergences in evaluation between the trend of observed values in the final three-year period and the regression equations adopted; divergences that are wider the more the value of b moves away from 1.

The calculated duration of the S-A phase is slightly underestimated at higher values observed of the same phase. An explanation for this situation is found both in the highest temperatures recorded in this phase during the latter three-year period and in the reduced range in variability of the same temperatures (from 3.8 to 13.2°C) (Tab. 1). With similar sowing dates, this caused an anticipation of emergence, compared with the previous five-year period, and, in the curvilinear relationship emerged between the two variables, delimited the values of the phase duration in the part of the curve wich tends to stabilise.

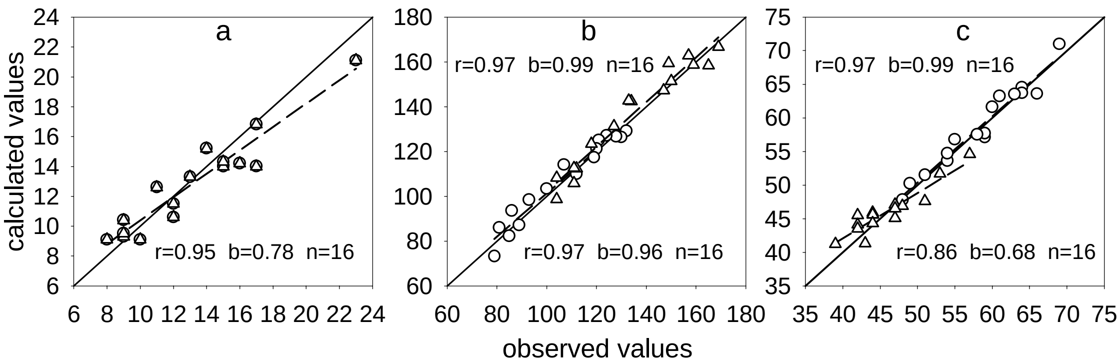

Fig.1. Observed and calculated values of the S-A (a), A-F1 (b) and F1-G5 (c) phases in Activ (circle) and Ceres (triangle) in the three-year period 1993-96. The dash line represents the correlation between the two variables in the three year period. The 1:1 line is shown.

In Ceres, the calculation of the duration of the F1-G5 phase is underestimated, at the highest observed values and overestimated at the lowest observed values of the same phase. This phenomena is attributable to a greater reactivity to rainfall recorded in Ceres in the latter three-year period; in other words, compared with the first five-year trial period, a longer duration of the F1-G5 phase was witnessed, with higher amount of rainfall and a shorter duration in the opposite case. Apart from these easily rectifiable differences, the satisfactory correlation between the trend of observed values in the three-year period and the regressions adopted, found in the remaining phases, with values of b close to 1, leads to the assumption that readily available climatic data within the region may enable simple quantitative models to be developed allowing an assessment to be made of the adaptability of different genotypes in the cropping area.

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