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Dual-purpose use affects phenology of triticale

Francesco Giunta[a], Agnese Cabigliera[a], Adriana Virdis[b], Rosella Motzo[a,*]

[a] Dipartimento di Agraria, Sez. Agronomia, Coltivazioni erbacee e Genetica, Via de Nicola 1, 07100 Sassari, Italy
[b] Agris Sardegna, Dipartimento per la ricerca nelle produzioni vegetali, Viale Trieste 111, 09123 Cagliari, Italy

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ABSTRACT

Treating cereals as a dual-purpose crop (grazing and grain production) can modify the timing of anthesis, but which among the main determinants of the timing of anthesis – namely leaf number, the phyllochron and the length of the flag leaf emergence to anthesis interval – are affected is unclear. Eight field experiments conducted in triticale, designed to vary both sowing date (October through January), growth habit (vernalization requiring vs non-requiring) and to simulate grazing by clipping at the terminal spikelet stage (TS), were performed to monitor plant development. Clipping delayed anthesis by 2–7 days in four cultivar/environment combinations. The slower rate of leaf emergence after clipping delayed the appearance of the flag leaf ligule (FLA). When a delayed FLA was not accompanied by a proportional reduction in the duration of the FLA-anthesis interval, anthesis occurred later. The impact of an increase in the phyllochron can be expected to be wider than just a delay to anthesis. A higher phyllochron can also result in a slower recovery of leaf area, with a knock-on effect on the duration of the most critical period for grain number determination.

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1. Introduction

Growing dual-purpose cereals – i.e., those which are initially grazed by animals, but later are allowed to recover and produce grain – can promote farm diversification of crop-livestock systems, can enhance farm incomes and can reduce risk (Bell et al., 2014). In the Mediterranean environment, one of the most frequently used dual-purpose cereals is triticale (Epplin et al., 2000). Phenology is critical for the success of a dual- purpose crop as it determines both the duration of the grazing period and affects the timing of anthesis (Giunta et al., 2015). Reaching flowering outside the optimal period has profound negative consequences on grain productivity (Harrison et al., 2011). Achieving a satisfactory grain yield requires that grazing is not continued beyond the emergence of the apex from the soil (Harrison et al., 2011), and the best predictor of apex emergence is the timing of the terminal spikelet stage (TS) (Giunta et al., 2015). The period between TS and anthesis therefore represents the time available for the plant to re-grow an adequate canopy after grazing has been terminated. Both genotype and sowing date exert a major influence on the timing of both TS and anthesis. With respect to the former, triticales are highly variable, ranging from spring types in which the developmental rate is responsive to temperature and photoperiod, to cultivars also responsive to vernalization in an obligate (winter types) or facultative (intermediate types) way (Loomis and Connor, 1992). Spring cultivars are typically sown later than winter ones, although both tend to reach anthesis around the same time (Virgona et al., 2006).

Most attempts to determine the effect of grazing on phenology have contrasted the anthesis dates of grazed and non-grazed plants (Harrison et al., 2011), but no attention has been paid to the relationship between the timing of TS and that of anthesis. The effect of grazing on anthesis date lies in the range zero to eleven days (Nicholson, 2006; Virgona et al., 2006) but information is lacking on the way by which anthesis date should be affected. Anthesis date is the result of the final leaf number (FLN) set and of the rate of leaf emergence – which together determine the time of appearance of the flag leaf ligula (FLA) – and of the time elapsed between FLA and anthesis (Jamieson et al., 1998). According to this framework, anthesis date can be modelled irrespective of TS, a developmental moment of key importance for dual-purpose cereals, because it coincides with when the apex of the main stem, which has until then lain 2–3 cm below the soil surface, is brought to the surface by the elongating stem (McMaster, 2009; Giunta et al., 2015). Interrupting grazing at this stage prevents removal or damage to the developing spike on the shoot apex and potential loss of grain yield (Scott and Hines, 1991). The strong relationship between FLN and the number of leaves emerged at TS (Jamieson et al., 2007; Giunta et al., 2015) has established an association between anthesis date

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[*] Corresponding author. Fax: +39 79229222.
E-mail address: motzo@uniss.it (R. Motzo).

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and TS, at least for the proportion of variation in anthesis date due to the corresponding variation in FLN. Giunta et al. (2015) have proposed a developmental ideotype for a dual-purpose small-grain cereal based on these relationships. The intention of the present research was to attempt an experimental validation of the effect of grazing on the phenology of triticale.

2. Materials and methods

Eight field trials were conducted across two locations in Sardinia, Italy (Ottava, 41°N, 80 m asl, and Ussana, 39°N, 97 m asl) (Table 1). Rainfall and air temperature were recorded at a meteorological station situated close to the experimental fields. Ottava has a long-term mean annual precipitation of 552 mm and Ussana of 441 mm. Two triticale cultivars with similar photoperiodic sensitivity but different vernalization requirements were contrasted. Cultivar Oceania, with no vernalization requirement, can be classified as 'spring type' according to Loomis and Connor (1992), whereas cv. Bienvenu, with a quantitative response to low temperature, can be classified as 'intermediate type' according to the same Authors. The optimum planting dates in this environment range from mid-November to mid-December for spring types, and from beginning of October to mid-December for intermediate types. To simulate grazing, in five of the eight trials the plants were clipped at TS with a lawn mower, so that their height above the ground did not exceed 2 cm; control plots were left unclipped. TS was used to decide when to cut because it always happens before the internode elongation begins, bringing the apex to the surface. A factorial combination of cultivar × clipping treatment was arranged in a randomized complete block design with four replications. Each plot was formed by eight 10 m long rows, separated from one another by 15 cm. The soil was dressed with 100 Kg ha^{-1} P_2O_5 and 100 Kg ha^{-1} N at sowing. Weeds, pests and diseases were chemically controlled, and the quantity of rainfall up to anthesis was sufficient at each site and year to avoid the imposition of any significant degree of water stress. The Haun stage (HS) (Haun, 1973) of the main stem was recorded on a set of five plants per plot every 3-4 days until the flag leaf had completely emerged and its ligule had become visible (DC 39, Zadoks et al., 1974). Destructive sampling was performed every 3–4 days on five plants per plot in order to pinpoint the timing of TS (Bonnett, 1936). The timing of the 'beginning of anthesis' stage (DC61) was fixed as when at least 50% of the spikes in a given plot had reached this stage. Thermal time was calculated from the measured maximum and minimum air temperatures, assuming a base temperature of 0 °C (Ewert, 1996). Linear regressions were calculated between HS and thermal time to estimate the phyllochron as the inverse of the slope of the regression equations for each plant both prior to ($\mathrm{PHY_{before}}$) and post ($\mathrm{PHY_{after}}$) TS. The number of vernal days which had elapsed between sowing and TS of cv. Oceania plants was calculated according to Weir et al. (1984) assuming that full vernalization is obtained between 3 and 10 °C and reduced amounts between −4 and 3 °C and 10 and 17 °C. Regressions where both the x and the y were measured with an error (Figs. 1 and 2) were subjected to model II regression, OLS method, via the 'lmodel2′ package of R (R Core Team, 2014). Data from each of the eight environments were subjected to a separate analysis of variance.

3. Results

The average daylength between sowing and TS was around 10 h in all the environments except OTTJAN12, where it reached 11 h (Table 1). The number of vernal days was minimum in the earlier sowings of October and November and particularly low in OTTOCT13. This sowing was characterized by the highest average temperature over the sowing-TS period, and by the lowest average temperature over the subsequent TS-anthesis period.

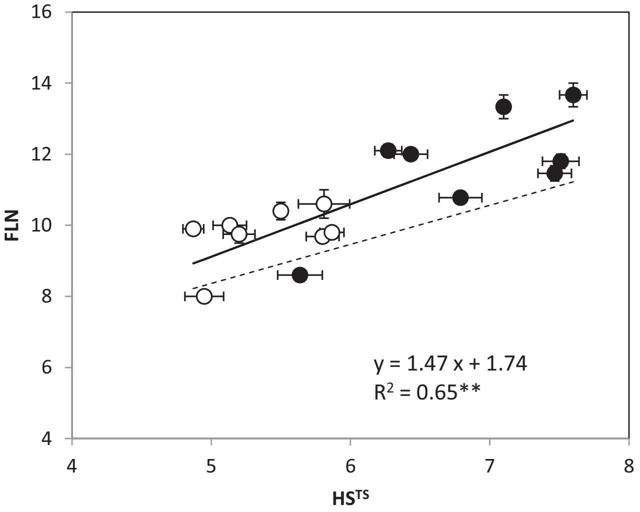

Fig. 1. FLN, as related to Haun stage at TS (solid line). Empty symbols: cv. Oceania, full symbols: cv. Bienvenu, bars: standard errors of the mean. The dashed line relates to wheat, taken from Brown et al. (2013).

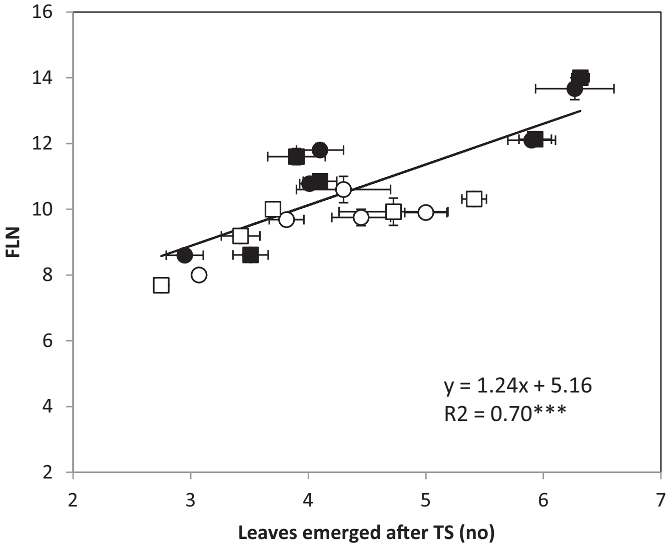

Fig. 2. FLN, as related to the number of leaves which emerged after TS. Empty symbols: cv. Oceania, filled symbols: cv. Bienvenu, circles unclipped treatment, squares: clipped treatment, bars: standard errors of the mean.

The variation in the duration of the sowing-TS period imposed by the combination of sowing date, location and cultivar was between 38 and 89 days (Table 2). For both cultivars, a December sowing resulted in the longest sowing-TS period in terms of actual days. The cultivars' performance differed within the environments for all developmental traits associated with the length of the sowing-TS period, with the sole exception of the phyllochron. Cultivar Bienvenu had always a later TS compared to cv. Oceania, particularly from the October sowings, when a one-month difference in TS between cultivars was observed. Overall, the earlier the sowing, the greater the differences in the time needed to reach TS between the intermediate and the spring cultivar ($r = -0.97^{***}$). A negative association was calculated between the number of vernal days recorded in the sowing-TS period of each environment and the differences in the number of days needed to reach TS between the intermediate and the spring cultivar ($r = -0.82^{*}$). Cultivar Bien-

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