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The effects of forage removal on biomass and grain yield of intermediate and spring triticales

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ABSTRACT

The dual-purpose use of cereals can be a convenient management option if grain yield (GY) is not significantly reduced. The effects of clipping at the terminal spikelet stage on biomass and grain production of an intermediate ('Bienvenu') and a spring ('Oceania') triticale cultivar grown at two sowing rates (300 and 600 seeds per m^2) were analysed in terms of the changes induced on radiation and water capture and use and biomass partitioning in five different Mediterranean environments with no additional N application following clipping. Clipped crops were able to recover completely in terms of the fraction of radiation interception (FIPAR) before anthesis, but the period in which plants exhibited a smaller leaf area resulted in a severe reduction – from 20 to 26% depending on the environment- in the total amount of radiation intercepted (IPAR, MJ m^{-2}), and consequently, in biomass at anthesis (from 14 to 30%). Radiation use efficiency (RUE) between clipping and anthesis ranged from 0.89 to 1.42 g MJ^{-1}, and only contributed to the decrease in biomass when leaf nitrogen levels were reduced as a consequence of clipping. Evaporation increased (by 13 mm on average) and transpiration decreased (by 11 mm on average) following clipping, with contrasting but quantitatively small effects on evapotranspiration. Transpiration efficiency decreased by about 20% following clipping in most environments because clipping decreased biomass production more than evapotranspiration in environments that did not allow the triticale crops to reach leaf area index values greater than 3–4. GY varied from about 300 to 850 g m^{-2} and was only affected by clipping in the two environments with favourable post-anthesis conditions where unclipped crops showed a higher harvest index (HI, 0.38 unclipped vs 0.36 clipped crops on the average of the two environments). In the environments where a severe water stress (transpiration lower than 18% of reference evapotranspiration) following anthesis led to similar amounts of IPAR under the two treatment conditions, the lower biomass at anthesis of clipped crops lead to a higher HI and no reduction in GY. No interaction between clipping and cultivar was observed for FIPAR. Cultivar differences derived from their different phenologies and were mainly expressed before clipping; the longer duration of the phase prior to clipping (from 0 to 18 days depending on the environment) resulted in the intermediate cultivar being superior in terms of winter forage production (193 vs 135 g m^{-2} on average). On the other hand, the intermediate cultivar was less advantageous in terms of GY (270 vs 357 g m^{-2}) in the environments presenting the most severe terminal water stress. Sowing rate was only relevant in the pre-clipping period when the higher sowing rate produced, on average, 40% more biomass than the lower sowing density. Dual-purpose triticale can be a convenient management option in Mediterranean environments subjected to severe terminal water stress because GY is not affected and a variable amount of winter forage may be obtained.

1. Introduction

Dual-purpose use of cereals (in which the cereal is grazed by animals and harvested for grain in the same season) is common where livestock and cereal crops are managed in the same area. Triticale (*x Tricosecale* Wittmack) is one of the cereal species grown for dual-purpose use in Mediterranean environments. This type of utilisation is particularly interesting under Mediterranean conditions,

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Abbreviations: GY, grain yield; FIPAR, fraction of intercepted photosynthetically active radiation; IPAR, cumulated photosynthetically active intercepted radiation; RUE, radiation use efficiency; TE, transpiration Efficiency.

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Table 1
Long-term weather data (means ± standard deviations) for the two sites, and weather data for the emergence-anthesis (EM-ANT) and anthesis-maturity (ANT-MAT) periods of the five experiments. VPD, Vapor Pressure Deficit; T, transpiration; ETo reference evapotranspiration.

Site or environment	Period	Duration (d)	Maximum temperature (°C)	Minimum temperature (°C)	VPD (KPa)	Rainfall (mm)	ETo (mm d^{-1})	T/ETo
Ottava (58 years)	Oct–May		17.2 ± *1.0*	8.8 ± *1.0*	0.76 ± *0.21*	473 ± *111*	2.5 ± *0.4*	
	Apr–May		20.1 ± *1.4*	10.4 ± *1.3*	0.90 ± *0.28*	83 ± *46*	4.0 ± *0.5*	
Ussana (40 years)	Oct–May		18.9 ± *1.1*	7.8 ± *0.7*	0.60 ± *0.11*	381 ± *123*	2.2 ± *0.3*	
	Apr–May		22.4 ± *1.8*	9.6 ± *1.1*	0.83 ± *0.21*	72 ± *40*	3.6 ± *0.5*	
OTTOCT	EM-ANT	154	15.4	7.6	0.9	444	2.5	0.82
	ANT-MAT	101	20.3	11.1	1.2	148	4.6	0.38
OTTNOV	EM-ANT	143	15.5	7.7	0.9	185	2.7	0.56
	ANT-MAT	68	22.3	12.2	1.4	107	5.4	0.21
OTTJAN	EM-ANT	87	16.3	6.9	0.9	78	3.4	0.35
	ANT-MAT	61	25.0	14.7	1.7	80	6.0	0.28
USSDEC12	EM-ANT	107	16.7	3.9	0.6	187	2.5	0.53
	ANT-MAT	53	27.7	11.8	1.2	50	5.8	0.15
USSDEC13	EM-ANT	119	15.8	5.4	0.5	314	2.2	0.71
	ANT-MAT	54	24.2	11.8	0.9	18	4.8	0.18

because it guarantees a source of forage in a period when animal food requirements are high (Royo et al., 1997) and crop growth rates are low (Harrison et al., 2011a,b,c) with low or no reduction in grain production. It offers a wide range of varieties, from spring types, whose developmental rate responds to temperature and day length, to winter and intermediate types, which are also responsive to vernalisation. The phenological differences that exist among triticale cultivars, including different times to maximum leaf area index (LAI), different rates of dry matter accumulation (Royo and Blanco, 1999) and different growth habits (erect or prostrate), influence their aptitudes to dual purpose use.

Any change in grain yield (GY) following grazing/clipping can be viewed as the results of clipping affecting the ability of crops to capture radiation and water, and/or the ability to convert them into biomass (Bonachela et al., 1995a,b; Harrison et al., 2011b,c). A rapid and full recovery of photosynthetic activity after the removal of aboveground biomass is important for obtaining a good GY (Winter and Thompson, 1987). Given the same biomass, the GY of dual-purpose triticale can also be affected by the altered partitioning of biomass into grain and straw (Bonachela et al., 1995a,b) because clipping affects dry matter accumulation in stems (Royo and Romagosa, 1996) and green area duration (i.e., amount of biomass produced after anthesis) (Winter and Thompson, 1987).

Most studies that have discussed the effects of grazing/clipping on the GY of small grain cereals have reported dissimilar results with regard to the environmental conditions, management or crop/cultivar (Harrison et al., 2011a and papers cited therein). As underpinned by Harrison et al. (2011a), those papers lacked an approach that could be broadly applied (i.e., an analysis based on a framework that allowed an interpretation of mechanisms by which leaf area removal affects yield). Harrison et al. (2011b,c) performed such an analysis on bread wheat to analyse the effects of different intensities and duration of grazing, thereby obtaining a useful dataset for modelling the effects of grazing on GY (Harrison et al., 2012). In this paper, we adopted a similar type of analysis for triticale, based on the capture and use of resources. We focused our analysis on the most critical period for dual-purpose cereals, i.e., the period of leaf area recovery, from clipping to anthesis, and evaluated the interaction between clipping and phenology. The aim of this study was to analyse the effects of clipping on biomass and grain production of winter and spring triticales with regard to clipping-induced changes on the capture and use of radiation and water, as well as on biomass partitioning.

2. Materials and methods

2.1. Experimental design

Five field trials were conducted across two locations in Sardinia, Italy (Ottava, 41°N, 80 m asl, and Ussana, 39°N, 97 m asl) in the 2011–2012 and 2012–2013 seasons, representing a subset of the experiments used to analyse how dual-purpose use affects the phenology of triticales by Giunta et al. (2015). The soil at Ottava consisted of a sandy- clay-loam that was overlaid on limestone (Xerochrepts), with a soil water content of 31% on a volume basis at field capacity and of 13% at the wilting point. The soil at Ussana consisted of loam, with a soil water content of 33% on a volume basis at field capacity and of 17% at the wilting point. According to long-term data, the climate at both Ussana and Ottava is typically Mediterranean, although the two sites differ in rainfall and thermal regime. There is 19% less rainfall at Ussana than at Ottava, and the temperature range is wider because of the higher maximum and lower minimum temperatures that occur during the whole year (Table 1).

Two triticale cultivars with similar photoperiodic sensitivities but different vernalisation requirements were compared. Cultivar Oceania, which does not have vernalisation requirements, can be classified as 'spring type' according to Loomis and Connor (1992), whereas cultivar Bienvenu, which has a quantitative response to low temperature, can be classified as 'intermediate type' according to the same authors. These plants were chosen among the most productive and well-adapted cultivars to the Mediterranean environment of Sardinia. During the 2011–2012 season, sowing was performed on 15 November 2011 and on 18 January 2012 at Ottava ('OTTNOV' and 'OTTJAN' environments), and on 28 December 2011 at Ussana ('USSDEC12'). During the 2012–2013 season, sowing was carried out on 9 October at Ottava ('OTTOCT') and on 19 December ('USSDEC13') at Ussana.

Two seed-rate treatments were compared in each of the environments: 300 seeds per m^2, the common sowing rate for triticale in this type of environment, and 600 seeds per m^2. Seed density was calculated for each cultivar from thousand-grain weight and percentage of germination. Half of the plots were clipped at the terminal spikelet stage with a lawn mower ('clipped' treatment), so that their aboveground height did not exceed 2 cm. In each environment, a factorial combination of cultivar × clipping × sowing rate treatment was arranged in a randomised 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