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Bio-economic analysis of dual-purpose management of winter cereals in high and low input production systems

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ABSTRACT

Dual-purpose (DP) management of cereals holds promise to reduce the feed gap and to better integrate crop and livestock systems especially in drylands where forage deficit is severe. However, there is limited information on which cereal species and type of management would be most optimal for both forage and grain production in dry highland environments. A two-year field study (2013–2015) in the Central Anatolian plateau of Turkey investigated the effect of spring defoliation of barley, triticale and wheat varieties at tillering and stem elongation stages and a no-cut (grain-based) system under low- and high-input management on yield and quality of forage, straw and grain. Overall, barley had greater ($P < 0.01$) forage DM accumulation within the winter-spring season, relative to wheat and triticale with the exception of low-input system in 2014 when all cereal species and varieties had similar DM yield for both defoliation stages. Differences in straw yields favored barley over triticale and wheat for low-input system in 2014 ($P < 0.09$) but not 2015 and for high-input system for 2014 ($P < 0.05$) and 2015 ($P < 0.07$). Most frequently, cutting at stem elongation had the lowest total DM production. Similarly, grain yield was lower when cut at this stage for both years and input management systems. Total crude protein was greater in the systems with cut forages compared to the no-cut. Bioeconomic modelling indicated that growing cereals only for grain led to higher profits when the precipitation was lower than average, while DP management based on defoliation at tillering led to higher profits during an average year. Also cultivation of barley led to higher profits in all periods. The findings provide a convincing case for dual-purpose management of cereal forages both under low and high input systems for improved efficiency and profitability in crop-livestock farming.

1. Introduction

Winter cereals, grown for forage and grain, canintensify the animal and crop production from the same area of land, hence improve both food and feed security (Dove and Kirkegaard, 2014). As such, dual-purpose (DP) management of cereals has been shown to be an alternative and sustainable management practice in the south central USA (MacKown and Carver, 2005), Australia (Bell et al., 2014) and northern Mediterranean countries (Francia et al., 2006). Small grain winter cereals are extensively grown on over 42 million hectares in Central and West Asia and North Africa (CWANA) region where approximately 22% of the world's sheep population exists (FAO, S., 2016). Wheat and oats are grown under both rainfed and irrigated areas, while barley and triticale are commonly grown under rainfed conditions for grain, as well as hay, silage and spring grazing (Rakeih et al., 2010; Keles et al., 2016). Cereal forages in spring and stubble and straw represent the most important feed source for sheep during summer and winter seasons in the region (Annicchiarico and Pecetti, 2003; Ryan et al., 2008). Therefore, DP management of cereals holds a significant promise to reduce the feed gap and to better integrate crops and livestock (Moore, 2009). Especially in areas of CWANA receiving more than 300 mm of annual precipitation, DP management can significantly reduce forage deficit and improve forage quality (Harrison et al., 2011). As such, aside from the grain yields, more attention should also be paid to spring forage production and straw yield and quality of cereals to reduce the feed gap.

Years of DP cereal research in different parts of the world have shown that the stem elongation stage is the critical threshold for

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grazing in order to avoid undesirable tradeoffs between yield and animal gains (Epplin et al., 2000; Virgona et al., 2006; Jacobs et al., 2009). The second most important factor for DP success appears to be matching crop phenology to environment (Harrison et al., 2011). A few studies reported on the positive effect of spring defoliation on the chemical characteristics of small grain cereal forages (Francia et al., 2006; Jacobs et al., 2009; Keles et al., 2013) and straw (Ates et al., 2017). Limited research in the CWANA on DP management comparing the effects of cultivars and stages of cutting confirmed the importance of single grazing systems before stem elongation stage to avoid yield penalties (Yau et al., 1989; Celen and Soya, 1999; Balkan et al., 2011). Most DP research has been on minimizing the tradeoffs between forage and grain yields disregarding the fact that animals are in need of high quality feed during summer months from cereal stubble. None of the studies conducted in CWANA reported the effect of input management or investigated financial implications of DP management. This situation emphasizes the necessity for a better understanding of crop-livestock interactions within farming systems, in particular the impact of crop grazing on grain production and nutritional value of crop by-product and residues.

The overall objective of this study was to screen commonly grown cereal species and cultivars as potential DP crops under high and low input management, especially relevant to dry, highland regions of the CWANA region. We hypothesized that because of different phenological characteristics of the species and cultivars, there will be significant differences among the cereals in terms of the tradeoffs between grain yield and forage productivity. It was also hypothesized that the yield response and economic returns may significantly differ depending on the stage of defoliation and other DP management options. Information generated from this study will enhance our understanding of management of DP cereals and provide opportunity to optimize the benefits from commonly grown cereals in the dry highland regions.

2. Material and methods

2.1. Site, establishment and experimental design

The study was conducted at Bahri Dagdas International Agricultural Research Institute research field (37° 51′ N, 32° 33′ E, 1008 m a.s.l.), Konya, Turkey from 2013 to 2015. The site was on a clay–loam soil with slightly alkaline characteristics. Soil tests indicated the site had an organic matter content of 2.2%, high available P 250 kg ha^{-1} (Olsen et al., 1965), Ca 446 kg ha^{-1} and K 244 kg ha^{-1}, soluble salt 0.05 dS/m, and that soil pH was 7.8.

The research farm, located in the Central Anatolian highlands, has a continental climate with 322 mm long term mean (LTM) annual precipitation and 11.6° C LTM annual air temperature. Average mean temperature and monthly rainfall are shown in Fig. 1. Total annual precipitation in 2013 and 2014 was lower than the LTM by 138 and 21 mm, respectively. Precipitation in 2015 was similar to the LTM. In most cases, the mean monthly air temperature was similar to the LTM. Of note was that the mean temperature was 1.7–3.2 °C higher than the LTM in winter months except the mean monthly air temperature was 3.2 °C colder than the LTM in December 2013.

Plot size was 1.4 × 5 m with 20 cm row spacing. Cereals were planted on November 13, 2013 and November 14, 2014 at the rate of 550 seeds m^{-2}. An herbicide mixture of florasulam (Dow AgroSciences, LLC) and 2, 4-Dichlorophenoxy was applied for weed control in each plot at tillering stage of the cereal forages. Treatments were arranged in a randomized crisscross design with four replicates. Cereal crops (bread wheat cv. Bayraktar2000, Dagdas94 and Sonmez2001; triticale cv. Alperbey, Melez2001 and Mikham2002; and barley cv. Aydanhanım, Larende and Tarm92) were the main plot factors and the cutting stages (at tillering, at stem elongation and No-cut) were the cross plot factors. The experimental design and establishment procedures were the same in both high and low input conditions, which were in the adjacent field simultaneously. Cereal species and cultivars were selected based on their common regional usage or phenologic and physiological characteristics (i.e., early germination and growth, harvest and maturity index) that were deemed to be advantageous for DP management.

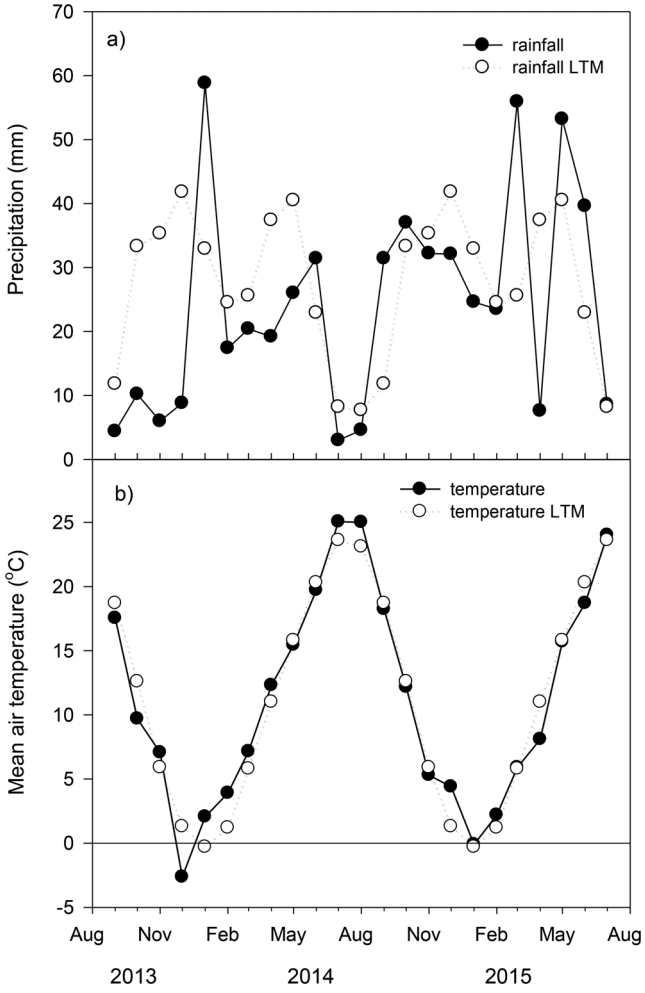

Fig. 1. Monthly rainfall and mean daily air temperatures during the experimental period (2013/15). LTM: Long-term means of air temperature and precipitation are for the period of 1975–2010.

2.2. Fertilizer application and irrigation

Low input management (LIM; rain fed, low fertilizer): In both years, fertilizer was applied at a rate of 70 kg N ha^{-1} and 70 kg P ha^{-1}. While the entire amount of P was applied at sowing, the N was applied at a rate of 27 kg N ha^{-1} at sowing in the form of $(NH4)_2HPO_4$ and at the rate of 43 kg N ha^{-1} in the form of NH_4NO_3 in March. Low input management represented the rainfed systems of central Anatolia, where input of fertilizers are less than the irrigated systems.

High input management (HIM; irrigation, high fertilizer): In this system, fertilizer was applied at the rate of 140 kg N ha^{-1} and 90 kg P ha^{-1}. The entire amount of P was applied at sowing, and N was applied at a rate of 36 kg N ha^{-1} at sowing in the form of ammonium and at the rate of 80 kg N ha^{-1} in the form of nitrate in March. Another 24 kg ha^{-1} N in the form of nitrate was applied in May with irrigation. Additionally, 90 mm water was applied in both years following the fertilizer application in May. This was after the sampling at the stem elongation stage. High input management systems is representative of irrigated cereal production systems in central Anatolia, where cereals may be cultivated for grain and straw, as well as, spring grazing intended for dual purpose management.