Contribution of annual legumes pasture to the cereal in Mediterranean agriculture systems

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Introduction

The depletion of fossil fuels, the high demand of food for a constantly growing human population and, more recently, the strong expansion of biofuel crops, are causing sharp increases in the prices of fertilizers particularly nitrogen (N)(Crews and Peoples 2004; Jensen *et al*. 2011). Faced with this future scenario of high cost of N fertilizer, there is increasing interest in using legumes as N sources for sustainable agriculture and livestock. In the dryland (rainfed) cropping area of the Mediterranean climatic region of central Chile, bread wheat (*Triticum aestivum*) is predominantly grown in rotation with oats (*Avena sativa*); a system that relies heavily upon N fertilizers applied at sowing and tillering to support growth. The objectives of the study were to: (1) quantify the inputs of fixed N by two mixtures of annual legumes pastures; (2) determine the impact of including legume pastures in a cropping sequence on wheat N uptake and grain yield; and (3) compare the performance of wheat after legumes with standard farmer practice of applying N fertilizer to wheat grown following oats.

Methods

The study was conducted in two contrasting Mediterranean environments: interior dryland (granitic Alfisol, pH 6.2, organic matter (OM) 1.5%; 650 mm of annual rainfall) and Andean foothill (volcanic Andisol, pH 5.5, OM 13%; 1000 mm of annual rainfall), during 2008 to 2011. In each of the study sites, two annual legume pasture mixtures (M1 and M2) of varying length: 1, 2 and 3 years of the pasture in the crop sequence, were tested in rotation with wheat. The control treatment consisted of a cereal rotation (wheat follow by oat) with N fertilization. The above-ground biomass of the legume pasture and cereal grain yield were assessed. To estimate the percentage of Biological Nitrogen Fixation (BNF) derived from atmospheric N_2 (%Ndfa) the ^{15}N natural abundance method (Unkovich *et al.* 2008) was used. The legume pastures were grassed by sheep.

Results

In the interior dryland significant differences ($P \leq 0.05$) were obtained in pasture biomass production (Table 1). In the more intensive rotations, where the pasture and wheat had a 1:1 year sequence, pasture production was lower than the rotations where the pasture remained for two and three years in the rotation. In Andean foothills, the production of mixture M2 which included subterranean clover (*Trifolium subterraneum*), yellow serradella (*Ornithopus compressus*) and arrow leaf clover (*T. vesiculosum*) ranged between 8 and 17 t DM/ha/year.

The determination of BNF was performed using natural abundance of N^{15}. In the interior drylands the % Ndfa values were higher than in the Andean foothill due to higher mineralization potential of that volcanic soil. However, due to the higher biomass production of the legumes in this environment, the amount of N fixed was much higher, especially in the second and third season when fixation values ranged between 149 and 372 kg N/ha/year (Table 1)

Table 1. Shoot dry matter (DM), estimates of legume N derived from air (Ndfa) and fixed N of two legumes mixtures growing in the interior dryland and the Andean foothill of Chile (season 2011).

	Mixtures	Shoot dry matter (kg/ha)	Ndfa (%)	Ndfa (kg/ha)	N fijado (kg N/t DM/year)
Interior dryland	M1 (1 year)	2726 c	69 d	47 b	17 c
	M1 (2 year)	3352 a	84 b	87 a	26 a
	M1 (3 year)	1654 e	83 b	49 b	30 a
	M2 (1 year)	2450 d	87 a	54 b	22 b
	M2 (2 year)	2844 b	79c	83 a	29 a
	M2 (3 year)	1714 e	83 b	47 b	28 a
Andeanfoothill	M1 (1 year)	9072 d	75 d	176 c	19 bc
	M1 (2 year)	10849 c	83b	223 b	21 bc
	M1 (3 year)	8253 e	83 b	149 c	18 c
	M2 (1 year)	14827 b	87 a	384 a	26 a
	M2 (2 year)	17468 a	80 c	372 a	21 b
	M2 (3 year)	11100 c	83b	228 b	20 bc

Table 2. Wheat grain yields post-annual pasture in the Interior dryland and Andean foothill of Chile (season 2011).

Crop sequence	Wheat grain yields (kg/ha)	
	Interior dryland	Andean foothill
A. sativa (+N) – wheat (+N)	3393 a (100%)	6003 a (100%)
M1 (1 year) – wheat (nil N)	2200 d (65%)	4858 bc (81%)
M1 (2 year) – wheat(nil N)	3535 a (104%)	6060 a (101%)
M1 (3 year) – wheat (nil N)	2483 d (73%)	4100 c (68%)
M2 (1 year) – wheat (nil N)	2223 d (66%)	4505 bc (75%)
M2 (2 year) – wheat(nil N)	3113 bc (92%)	5128 b (85%)
M2 (3 year) – wheat (nil N)	1785 e (53%)	4598 bc (77%)

Interior dryland: M1= *T. subterraneum + Medicagopolymorpha + T. michelianum;* M2=*T.subterraneum + Biserrulapelicinus+ Ornithopus compressus.*Andean foothill: M1=*T. subterraneum+ T.incarnatum;* M2= *T. subterraneum + T. vesiculosum+ Ornithopus compressus.* Means followed by different letters in the same column differ significantly according to Duncan multiple test ($P \leq 0.05$).

Cereal yield in the interior dryland with a rotation sequence of two years of legume pasture followed by one year of wheat, was equivalent to between 92 and 104% of the wheat yield when fertilized with N (Table 2). The sequences of crop of one year of legume pasture follow by cereal and three years of legume pasture followed by cereal, resulted in lower wheat yields. In the first case this was due to insufficient time for legume to fix N whereas in the second case weed invasion caused a decrease in the contribution of the pasture legumes.

In the Andean foothills where the wheat yield potential is much higher (Table 2), cereal yields performed similarly to what was observed in the interior dry lands, *i.e.* higher cereal yields were obtained in the rotation comprising two years of legume pasture followed by wheat.

Conclusion

The crop rotation between annual legume pastures and cereals could provide a sustainable production system for Mediterranean rainfed areas of Chile based on increased pasture productivity and significant cost savings of N fertilization in the cereal crop phase.

Crops rotations comprising two year of pasture followed by wheat were more productive and made greater contributions of N to the cereal crop. Under this rotation sequence in Andean foothill, cereal yields varied between 82 and 101% of the yield of cereal monoculture with N fertilization whereas in the interior dryland this percentage varied between 92 and 104%.

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