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Forage and seed yield response of lucerne cultivars to chemically weeded and non-weeded managements and implications for germplasm choice in organic farming

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ABSTRACT

Organic livestock production is steadily increasing in Europe. Lucerne (*Medicago sativa* L.) can play a key role in organic crop-livestock systems of southern Europe, owing to its positive attributes of adaptation, forage quality and nitrogen provision. This study tackled the unprecedented question on whether specific variety recommendation and, possibly, specific breeding are necessary for lucerne in organic systems. In lowland of northern Italy, where competition against weeds is expected to be the main determinant of success in organic farming, eight cultivars were evaluated in one environment under a chemically weeded management and an 'organic' management mimicked by no weed control, with the objectives of: (i) assessing the extent of cultivar × management interaction for dry matter (DM) and seed yield traits; and (ii) comparing different germplasm types for competitive ability and suitability to organic farming. The experiment was designed as a split-plot holding managements on main plots and cultivars on sub-plots. The test germplasm encompassed varieties bred under conventional or organic management and landraces from northern and central Italy, as well as germplasm with semi-erect or semi-prostrate habit. The recorded traits were lucerne DM yield over 3 years (13 harvests), DM yield over the first harvest of both the fourth and fifth year (as a measure of persistence), seed yield and its components assessed in the third year, and competitive ability against weeds as expressed by lucerne proportion under 'organic' management. Weed competition caused a severe reduction of DM yield and lucerne proportion in the 'organic' management but just a slight, non-significant reduction of seed yield, for which the greater stand thinning in this management relative to the chemically weeded one was largely compensated by increases in racemes per stem and seed weight. No cultivar × management interaction was observed for 3-year DM yield, seed yield and persistence ($P > 0.05$), suggesting that specific variety testing under organic management is not necessary. Greater relative growth rate, implying both better DM yield in the absence of severe weed competition and greater competitive ability under organic management, was inferred as the main reason for the consistency between managements for response of best-performing germplasm. The low competitive ability of semi-prostrate germplasm reflected its low vigour. The results did not suggest any specific adaptation to organic conditions of landraces or material bred under organic management. Specific adaptation to the region of evaluation was the main driving factor for cultivar adaptation to both managements.

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1. Introduction

Organic farming, which is carried out with no use of mineral fertilisers or synthetic chemicals for pest and weed control, has gained considerable interest in Europe because of growing concern about healthy food and environment protection. Eurostat data for EU in 2005 indicated that about 4% of the total farming land was organically managed, Italy being the second-ranking country for organic farming area with over 1 million ha (about 8% of the total national agricultural area).

Organic livestock production is steadily increasing in Europe (Rahmann and Böhm, 2005). Lucerne (*Medicago sativa* L.) can play a key role in organic crop-livestock systems, owing to its suitability to low input, rainfed conditions, its positive effects on soil fertility and nitrogen balance, and the high protein content and quality of its forage (Campiglia et al., 1999; Entz et al., 2001; Huyghe, 2003). Furthermore, lucerne cropping can enhance the energy balance and, hence, the sustainability of organic systems (Hoeppner et al., 2006). In countries where lucerne is a basic forage species, such as Italy, its introduction in organic systems is already remarkable. Organic

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farming employed over 5% of the Italian certified seed of lucerne in 2008 (ENSE, 2009). Information is lacking, however, on the possible need of different variety recommendations for organic and conventional systems. For instance, two recent extension guides on organic lucerne production do not mention actual performance under organic farming as a pre-requisite for the choice of varieties (Guerena and Sullivan, 2003; Fuerst et al., 2009). Likewise, specific selection programmes for organic systems are very rare for lucerne (Falcinelli and Torricelli, 2001) or other forage crops (Baert et al., 2007).

The current and foreseeable development of organic farming may justify the implementation of specific variety recommendation and even specific breeding for this production system, in the presence of sizeable interaction of crossover type between cultivar and production system (organic or conventional). Specific adaptation to organic farming may derive from differences among varieties for traits such as competitive ability against weeds, tolerance to major biotic stresses or nutrient use efficiency (Casler et al., 2007). Genetic variation in competitive ability is expected to have overwhelming importance as a specific trait for organically grown lucerne in lowland of northern Italy, as: (i) the lack of chemical pest control also under conventional farming makes pest tolerance equally important in conventional and organic systems; and (ii) chemical soil fertility for P, K and microelements (enhanced by the return of nutrients as manure or slurry) is usually sufficient in organic systems of this region, thereby reducing the importance of nutrient efficiency relative to areas characterised by less fertile soils or less intensive crop-livestock systems.

Investigations on grain crops have provided inconsistent evidence for specific adaptation to organic systems (e.g., Annicchiarico and Filippi, 2007; Murphy et al., 2007; Przystalski et al., 2008; Lorenzana and Bernardo, 2008; Annicchiarico et al., 2010), while revealing genetic variation in crop competitive ability mainly due to greater competitive advantage provided by taller stature (e.g., McDonald, 2003; Vandeleur and Gill, 2004). While displaying greater competitive ability, old cultivars of these crops failed to outperform modern, shorter varieties under organic farming because of their lower yield potential (Carr et al., 2006; Mason et al., 2007). One study concerning forage grasses revealed the occurrence of cultivar × production system interaction in ryegrass (*Lolium* spp.) mainly in relation to ploidy level, owing to the trend of tetraploid varieties towards relatively better response under organic management (Boller et al., 2008). Conversely, cultivars of cocksfoot (*Dactylis glomerata* L.) or tall fescue (*Festuca arundinacea* Schreb.) displayed largely consistent responses across conventional and organic production systems in that study. The interaction of cultivar with these systems has not been investigated in lucerne. Likewise, it is not known whether landrace germplasm of this species, still representing a valuable genetic pool for Italian breeding programmes (Russi and Falcinelli, 1997; Annicchiarico, 2006), or non-conventional semi-erect or semi-prostrate lucerne germplasm recently developed for enhanced grazing tolerance (Brummer and Bouton, 1991; Pecetti et al., 2008), have better competitive ability against weeds than modern conventional germplasm.

Also seed production can be an issue for organic lucerne growers, in the perspective of higher seed price relative to conventionally produced seed and the possible compulsory adoption of organically produced seed in organic systems. The use in these systems of conventionally produced seed has been allowed so far to the extent that it was necessary to keep pace with the demand for seed. Its share has represented about 94% of the lucerne seed employed in Italian organic farming in 2008 (ENSE, 2009), and its possible ban in the near future would lead the whole organic lucerne chain to collapse because of the lack of organically produced seed.

In this study, dry matter (DM) yield, competitive ability against weeds, persistence and seed yield of lucerne cultivars of different origin and plant type were evaluated during 5 years in northern Italy under a chemically weeded management and an 'organic' management mimicked by no weed control, with the objectives of: (i) assessing the extent of cultivar × management interaction, and (ii) comparing different germplasm types (landraces vs. modern varieties; varieties bred under conventional and organic management; erect vs. semi-erect or semi-prostrate plant type) for competitive ability and suitability to organic farming.

2. Materials and methods

The tested germplasm included eight cultivars, namely: (i) the improved varieties Classe, Lodi and Prosementi, bred under conventional conditions in northern Italy; (ii) the variety Cuore Verde, selected under organic management in central Italy (Falcinelli and Torricelli, 2001); (iii) one farm landrace each of the traditional cultivars Cremonese from northern Italy and Marchigiano from central Italy; and (iv) the candidate varieties La Diana and Verbena, with semi-prostrate and semi-erect growth habit, respectively, selected for grazing tolerance in northern Italy. The cultivars were evaluated in Lodi, northern Italy (45°19′N, 9°30′E, 81 m elevation, 802 mm average annual rainfall) in a field with no previous experience of organic farming (as the evaluation in an actual organic system would have prevented the comparison with a chemically weeded management). Phosphorous fertiliser approved for organic agriculture was applied to all treatments prior to sowing at the rate of 94 kg/ha of P_2O_5. The 'organic' and chemically weeded managements were allocated to main plots and the cultivars to sub-plots of a split-plot design with four replications, leaving 6 m wide border areas under 'organic' management between the two managements. Elementary plots were 1.5 m × 4.0 m. Sowing took place in mid-March 2005 at the rate of 35 kg/ha. The chemically weeded management implied the application of Benfluralin (4.5 L/ha) prior to sowing, Imazamox (0.75 L/ha) in spring of the first year, Fluazifop-p-metile (2 L/ha) once in every summer, and Propyzamide + Diuron (2.5 L/ha) in winter. No weed control was applied to the 'organic' management. Both managements received one irrigation of 40 mm per year at the end of July, implying moderate drought stress during summer (long-term June–August average of 179 mm rainfall and 393 mm potential evapotranspiration).

Lucerne DM yield and lucerne proportion on total DM were recorded: (i) over three cropping years, encompassing four harvests both in the first and third year and five harvests in the second year; (ii) over the first harvest of both the fourth and fifth year, in which DM yield was considered as a measure of cultivar persistence. Lucerne proportion over the first 3 years in the 'organic' management was considered as a measure of competitive ability of the cultivars. The lucerne proportion was assessed on a dry matter basis after separating and oven-drying lucerne and weeds in a random sample of about 1 kg fresh herbage for each plot. Lucerne DM yield was estimated from total plot fresh yield and lucerne DM content and proportion in the subsample.

The second harvest of the third year was only performed on half of each plot, while allowing the plants of the other half to blossom and set seed for evaluating seed yield and its components. It is a traditional habit of Italian lucerne growers to consider seed production as a by-product of the forage production, harvesting seed on the second or third regrowth of the third or fourth cropping year (Annicchiarico et al., 2007). At seed maturity, the number of fertile (i.e. pod-bearing) stems per square meter was estimated by counting the stems in a 30 cm × 30 cm representative sample area per plot. The numbers of racemes per stem, pods per raceme and seeds per pod were estimated across a random sample of five stems per plot. The whole half plot was combine-harvested to assess the seed yield, expressing it on a dry basis after oven-drying a subsample

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