Alfalfa intercropping and competitive ability

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Abstract: Alfalfa is subjected to interspecific competition in two situations: (i) intercropping with a forage grass, where the required long-lasting equilibrium between species is frequently threatened by excessive alfalfa competitive ability; (ii) competition against weeds, which can be severe in monoculture and requires high competitive ability to avoid any chemical weed control. In both cases, competition for light interception is the main mechanism that drives the species proportion. Vegetative vigour and plant architectural traits can affect the alfalfa competition dynamics across successive harvests. Once completely unveiled, these traits could be selected for new varieties with improved adaptation to competition.

Key words: interspecific interference, legume-grass mixtures, organic agriculture, plant competition, weed competition

Introduction

Our focus on alfalfa competitive relationships is two-fold here, i.e.: (i) intercropping with a grass companion, to obtain a long-lasting, balanced mixture of the two components of the mixture; (ii) competition against weeds, to avoid any chemical weed control. Legume-grass mixtures are gaining new interest in Europe and elsewhere, owing to the energy and environmental costs associated with the synthesis and use of nitrogen fertilizer required for grass forage production and the quest for greatest self-sufficiency in feed proteins at the farm and the country levels. Legume-grass mixtures are currently grown over 70% of the sown grassland in France, exploited as hay, silage or grazed forage. Alfalfa monoculture is still prevalent in other countries, e.g. Italy, where it is the backbone of organic crop-livestock systems and contributes significantly to conventionally managed systems. Alfalfa competitive ability against weeds is crucial for organic systems and increasingly important for conventional ones, especially for the pure stand.

We briefly review alfalfa competitive relationships mainly with respect to their relevance to breeders. One major issue in this context is whether alfalfa varieties targeted to mixed cropping with grasses, or targeted to cropping under severe weed competition (as in most organic systems), could be successfully selected or recommended from testing trials carried out in the simpler condition of absence of competition. The response, which depends on the degree of genetic correlation between selection and target environments, has far-reaching implications, e.g. for the choice of phenotyping conditions in marker-assisted selection studies, or procedures for assessing the variety value for cultivation and use.

Competition

Alfalfa-grass intercropping and weed-invaded alfalfa crops are situations of interspecific plant competition which imply different targets. The target is maintaining a desirable legume-grass balance in the former case, and excluding the weeds in the latter. Competition for resources is one of the major processes controlling plant growth and explaining the dynamics of plant mixtures. Competition for light is of primary importance, because it determines the energy available for all physiological processes and partially drives the acquisition of other resources. Furthermore, as light availability declines exponentially with the distance from the top of the canopy, minor differences in plant size can have major effects on the relative yield of the intercropped species. The amount of captured light defines the potential growth rate and the nitrogen demand of the crops. Besides energy capture and photosynthesis, competition for water and nutrients is also critical in explaining the dynamics of plant mixtures.

Competitive ability and compatibility with grasses

The companion grass tends to be at competitive disadvantage and less persistent than alfalfa when associated with highly productive alfalfa varieties under favourable cropping conditions, while the reverse may occur when alfalfa is grown in shallow soils or suffers from poor establishment.

In alfalfa, traits related to growth habit, shoot development and branching (leaf area expansion), and internode length (vertical leaf area distribution) showed a prominent role in light interception, and mainly contribute to its advantage compared to grasses (4). For legumes

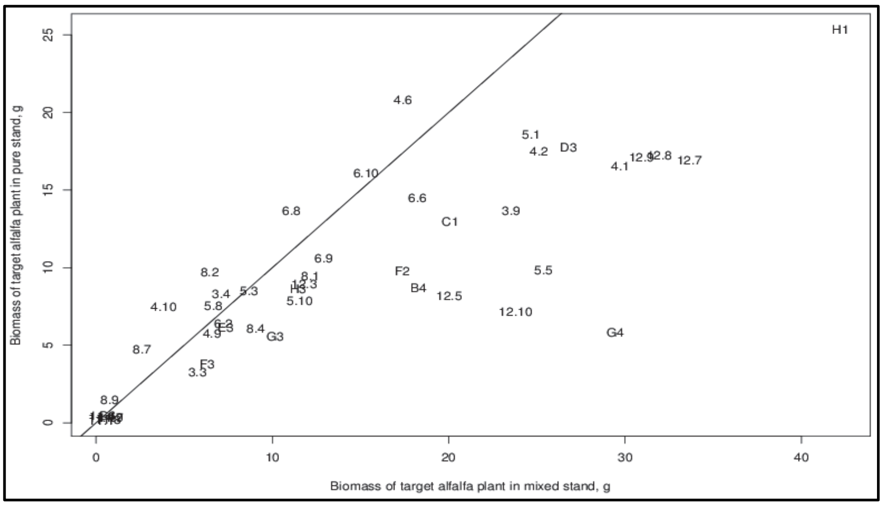

Figure 1. Biomass yield in the first harvest of 2011 of alfalfa genotypes grown in mixtures (one target alfalfa plant surrounded by 2 alfalfa and 4 tall fescue plants) and in pure stands (one target alfalfa plant surrounded by 6 alfalfa plants from the tall, erect cultivar Orca); the line is for equal biomass production in both stands

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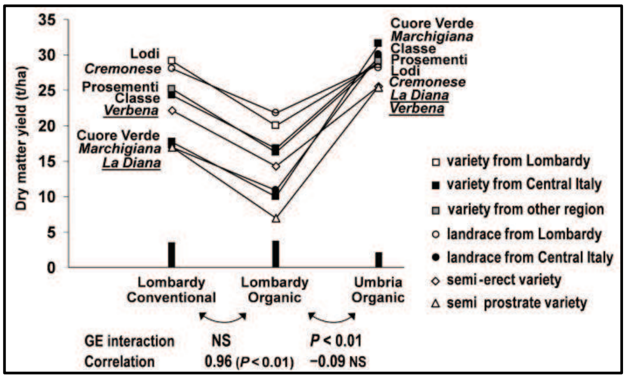

Figure 2. Forage yield of eight alfalfa cultivars across conditions reproducing organic or conventional cropping systems in two geographic areas (Lombardy, northern Italy; Umbria, central Italy), and genotype × environment (GE) interaction and phenotypic correlation for cultivar yield across environments; the graph pools results from the studies (2) and (3)

in mixture, intercepted light amount also determines the maximal amount of nitrogen that can be fixed by nodules (6), which can reach around 180 kg N ha^{-1} year^{-1} in alfalfa pure stands (9).

The root systems of grasses and alfalfa differ strongly in terms of architecture (fasciculate vs. taproot), root length density (high vs. low) and rooting depth (short vs. long) (7). Grasses are better competitors for water and most soil nutrients (mineral N, P and K in particular) than alfalfa, especially within the topsoil layers, but alfalfa explores deeper soil horizons.

However, alfalfa is little affected by soil N competition under conditions favourable to N_2 fixation, owing to its ability to fix atmospheric nitrogen (N_2). The proportion of N derived from fixation is even higher in mixtures than in pure stands as a consequence of the specialization of each species on a particular N resource (atmospheric N for alfalfa; soil N for grasses). N_2 fixation is intensively affected by water limitation, because this physiological process is one of the most sensitive to water stress. A drought event can thus quickly reduce the nitrogen autotrophy of alfalfa, changing drastically its ability to compete with grasses.

The relationships between species in a mixture are not only competitive: they may produce beneficial effects by modifying the environment of the other species. This is frequent is grass-legume mixtures, because a portion of the nitrogen fixed by legumes can be transferred to the associated grasses. Such effects tend to be more limited in alfalfa-grass than in clover-grass mixtures (10).

Maintaining a desirable balance between grass and alfalfa may be achieved by strategic choices at sowing (choice of alfalfa cultivars, grass species, date of seeding; density, seeding pattern) and by tactical management options (fertilisation, cutting). The selection of alfalfa varieties which are specifically adapted to mixed cropping because of greater compatibility with (hence, lower competitiveness against) grasses is also worth being investigated. A set of early studies in Lodi indicated the consistent ranking of alfalfa cultivars for biomass yield across pure-stand and mixed-stand conditions (11). However, preliminary results in Lusignan suggest at least some degree of genotype inconsistency between these conditions (Fig. 1). This experiment, which includes the observation of a number of morphological traits, will be used to test whether other alfalfa traits besides lower vigour may be associated with greater compatibility with associated grasses. We hypothesize that an alfalfa cultivar with lower stem height, more branching and good regrowth dynamics after cutting would have a reasonable high yielding ability in pure stand and would be a less aggressive companion crop for the grass in mixed stand, because of less competition for light interception. Breeding for all other traits that contributes to alfalfa persistency and quality would still be required for these new varieties. Choosing highly competitive grass companions can also be important to ensure more balanced associations.

Competitive ability with weeds

Weed density tends to be higher in alfalfa monocultures than alfalfa-grass mixtures. The false seeding technique, which is frequently adopted in organic agriculture, can be very useful to limit weed density and aggressiveness in the early, crucial stage of crop establishment. Weed competition after the first mowing is limited to species which are able to regrow.

The genetic variation for ability to compete with weeds has been poorly studied in alfalfa. One study whose results are partly summarized in Fig. 2 revealed substantially consistent responses of eight cultivars across conditions of high or almost nil weed competition (reproducing organic and conventional systems, respectively) which were established in one experiment in Lombardy (northern Italy). On average, landrace and variety germplasms showed comparable competitive ability against weeds. Competitive ability of the cultivars was strictly related to their forage yielding ability in the absence of weeds (2), with a semi-prostrate cultivar showing lowest values of both traits (Fig. 2). This relationship agrees with the crucial importance attributed to high relative growth rate for competitive success of genotypes belonging to erect, vigorous forage species grown in relatively favourable environments (5), when considering that high relative growth rate also implies high forage yield in the absence of competition. This relationship may be much looser in less vigorous, subordinate species such as white clover, whose genotype competitive ability mainly relies on the ability to make fine-scale exploitation of light and nutrients from undepleted zones through morphological plasticity (1). The high consistency of cultivar yield responses across high vs. negligible weed competiton conditions contrasts with the low consistency across two Italian cropping regions (northern vs. central Italy) (3; Fig. 2), suggesting that distinct material for each of these regions be bred with no specific selection for organic systems and/or higher competitive ability.

Compatibility with grass companions, and ability to outcompete weeds, likely inquire different optima of alfalfa competitive ability. They are associated with vegetative vigour and plant architectural traits yet to be discovered, which could eventually be selected for to produce varieties with improved adaptation to conditions of competition. ■

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