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Clover as a cover crop for weed suppression in an intercropping design I. Characteristics of several clover species

N.G. den Hollander*, L. Bastiaans, M.J. Kropff

Group Crop and Weed Ecology, Wageningen University, P.O. Box 430, 6700 AK Wageningen, the Netherlands

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Abstract

Weeds often form a major problem in weakly competitive vegetable crops, particularly in low input systems. Undersown cover crops can be used to suppress weeds, but often put too high a competitive pressure on the main crop. Cover crop selection is one of the potential means that can be used to design or optimize these intercropping systems. The objective of the current research was to investigate the variability among a range of clover species in morphological and physiological traits that are considered relevant for interplant competition. To this purpose, field experiments with pure stands of eight clover species (2001) and a selection of three clover species (2002) were conducted, in which regular observations and periodic harvests were taken. Clear differences in the time in which full soil cover was obtained, total accumulated biomass, growth duration, height development and N-accumulation were observed. Persian clover (*Trifolium resupinatum* L.) and subterranean clover (*T. subterraneum* L.) were the two most contrasting species in this study, particularly differing in the period in which full soil cover was obtained. Persian clover's faster soil cover could not be attributed to a single trait, but resulted from a number of intrinsic characteristics, like light extinction coefficient, light use efficiency and specific leaf area that together determine the relative growth rate. The study also demonstrated the importance of differences in relative starting position, caused by, for instance, seed size, seeding rate and fraction establishment, for the analysis of early growth characteristics. Alsike clover (*T. hybridum* L.), berseem clover (*T. alexandrinum* L) and crimson clover (*T. incarnatum* L.) developed slower than Persian clover, but all produced a higher amount of accumulated dry matter, due to a longer growing period. Clear differences in height and height development between species were observed. These differences were not associated with dry matter accumulation, as the tallest (red clover; 80 cm) and the shortest species (subterranean clover; 12 cm) produced similar amounts of dry matter. A strong positive correlation between early soil cover development and N-accumulation was observed. The large variability among clover species indicates that species selection is a very important aspect of the development of cropping systems that include clover as a cover crop.

Keywords: Clover; Undersown cover crop; RGR; Living mulch; Light interception; Soil cover; LUE; LAI; SLA

1. Introduction

The primary objective of weed management is to reduce the negative effects of weeds on crop production. Herbicides have proven to be a reliable and highly effective method to control weeds at relatively low cost. Consumers of the industrialized world however, increasingly demand food products that are safe, of high quality and have been produced with a minimum use of synthetic inputs. For that reason, weed management has to rely on other control measures. Achieving an adequate weed control without the use of herbicides is often reported to be difficult (Whitworth, 1995; Kropff and Walter, 2000). Mechanical weed control is often less effective, and moreover a heavy reliance on mechanical control is undesirable, because of damage to soil structure, increased risk of frost damage and the strong dependency on weather conditions. Removing weeds manually is often restrained by labour availability and is above all costly. Prevention of weed problems is another alternative, for which three mechanisms can be distinguished (Bastiaans et al., 2002). Firstly, the number of seeds that are present in the weed seed soil bank can be reduced. This can be achieved through increased seed mortality or a reduced seed production. Secondly, the fraction of seeds that develop into a weed seedling can be reduced through prevention of germination or emergence. Thirdly, growth and development of weed seedlings can be retarded to reduce the competitive ability of the weed relative to that of the crop, leading to a reduced negative effect on crop production.

* Corresponding author. Tel.: +31 70 3440638; fax: +31 70 3852045.
E-mail address: HollanderN@NWO.NL (N.G. den Hollander).

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Undersown cover crops may potentially reduce weed infestation through each of the discerned mechanisms (Phatak, 1992). The effects of the cover crop are achieved by a rapid occupation of the open space between the rows of the main crop, which prevents germination of weed seeds and reduces the growth and development of weed seedlings. Germination of weed seeds may be inhibited by complete light interception (Phatak, 1992) by the cover crop or by secretion of allelo-chemicals (White et al., 1989; Overland, 1966). After establishment of weed seedlings, resource competition becomes the main weed suppressing mechanism of the cover crop (Teasdale, 1998).

The use of undersown cover crops for weed management is particularly relevant for crops that are not very competitive. Slow growing crops like leek and onion, with upright leaves, hardly form a closed canopy and are therefore not able to suppress weeds adequately (Baumann et al., 2001). Clover possesses good potential as a weed suppressor and apart from that has other advantages, like nitrogen fixation and the reduction of pests and diseases in a number of crops (Finch, 1993; McKinlay et al., 1995; Theunissen and Schelling, 1996). Ideally, the main crop and the cover crop should differ to a high degree in the way they explore resources, thus avoiding competition between both species to at least some extent (Vandermeer, 1989). The addition of clover as a cover crop, however, has often been reported to result in severe competition between the cover crop and the main crop (Bottenberg et al., 1997; Brandsaeter et al., 1998; Lotz et al., 1997; Weber et al., 1999). The subsequent yield losses are regarded as a serious constraint for using clover as an undersown cover crop (Liebman and Dyck, 1993; Brandsaeter et al., 1998; Hartwig and Ammon, 2002).

In conclusion, the beneficial effect of clover as a cover crop with respect to pest, disease and weed management can only be exploited if yield reduction resulting from competition can be reduced. Several attempts have been made to reduce the competitive strength of the undersown clover while maintaining its weed suppressing ability. Brandsaeter and Netland (1999) focused on temporal complementarity by separating periods of vigorous growth of the cover crop (subterranean clover) and the main crop, while Vrabel (1983) used chemical control of the cover crop to reduce yield losses. Brainard et al. (2004) evaluated different options, particularly, cover crop species, time of seeding, use of supplemental nitrogen and herbicide regulation. Ross et al. (2001) conducted mechanical control of the cover crop and combined this with a screening of different cover crops, including clover species. The screening revealed clear differences in the ability to suppress weeds among cover crops. Brandsaeter et al. (1998) demonstrated clear differences in competitive ability between different cultivars of subterranean and white clover and found that yield reduction of the main crop was positively correlated with biomass production of the clover species. To aid the selection of species for a particular crop and aid decisions about crop–weed management, Ross et al. (2001) remarked that a greater understanding of the growth characteristics of clover species is required. In this respect, several studies have indicated at the importance of (early) soil cover development (e.g. Brandsaeter and Netland, 1999; Brandsaeter et al., 1998; Baumann et al., 2000; Nelson et al., 1991). In crop–weed competition research early growth, particularly early leaf area development (e.g. Kropff et al., 1992), early height growth rate and final plant height (e.g. Bastiaans et al., 1997) have been identified as important characteristics determining the competitive ability of species. It is obvious that these traits are similarly important for strengthening the weed suppressive function of cover crops. Simultaneously, these characteristics determine the potential yield loss of the main crop resulting from competition with the introduced cover crop.

The current study focussed on a comparison of clover species. Main objective was to determine the variability in morphological and physiological traits that are considered relevant for interplant competition. If sufficient variation is available, species selection is likely to be one of the important means to optimize intercropping systems that contain clover for weed suppression. Competitive ability and the relation between the presented characteristics and competitive ability are covered in a second paper.

2. Materials and methods

In 2001, an experiment with eight clover species was conducted. Based on the results of this experiment three contrasting clover species were selected for further study in the 2002-experiment (Table 1).

2.1. 2001-Experiment

A screening experiment with eight clover species was laid out on a heavy clay soil, in Wageningen, the Netherlands. The site was fertilized with 300 kg ha^{-1} 12–10–18 NPK 2 weeks before sowing. The experimental design was a fully randomized complete block design in six replicates and treatments consisted of eight clover species. On May 7, the clovers were sown at a rate of 20 kg ha^{-1} in plots of 6 m × 7 m. Seeds were sown with a seed drill of which the pipes were positioned 30 cm above the soil surface to mimic broadcast sowing. After sowing, the soil was rolled with a Cambridge roller to compress the soil. Hand weeding of the clover plots was carried out at the end of June.

In each plot, the number of emerged clover plants was counted daily in two squares of 0.50 m × 0.50 m until no further increase in plant number was observed. Soil coverage was assessed weekly by estimating the soil cover in each of the 16 squares (0.125 m × 0.125 m) of a frame of 0.50 m × 0.50 m. Canopy height was determined weekly, at three positions per plot. Starting from 1 month after sowing, two squares of 0.50 m × 0.50 m were harvested weekly from each plot. The clover plants were cut just above soil level. A sub-sample was taken and used to determine the fraction leaf and stem. Leaf area was measured using a LI 3100 Area Meter (LI-COR, Lincoln, NE, USA). All samples were dried for 24 h at 70 °C and weighed subsequently. Leaf area index (LAI) was used to calculate the fraction light interception according to:

$$\frac{I}{I_0} = e^{(-k\,\mathrm{LAI})} \quad (2.1)$$

where I/I_0 is the fraction intercepted light, k the extinction coefficient (determined in a separate experiment; see below) and