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Print publication: 01/01/2006

Document Version
Publisher's PDF, also known as Version of record

Link to publication

Citation for pulished version (APA):
Hoad, SP., Davies, DHK., & Topp, CFE. (2006). *Designing crops for low input and organic systems: Enhancing wheat competitive ability against weeds*. 157-168. Paper presented at Crop Protection in Northern Britain, United Kingdom.

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DESIGNING CROPS FOR LOW INPUT AND ORGANIC SYSTEMS: ENHANCING WHEAT COMPETITIVE ABILITY AGAINST WEEDS

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Summary: Weed suppression cannot be attributed to a single plant characteristic or trait. Instead the interaction between a series of desirable plant or crop characteristics has been shown to be important, with varieties compensating for weakness in certain areas with strengths in others. The balance between different characteristics for weed suppression will determine the value of the variety for early, late and season-long weed control, which will differ with the climatic zone. Generally, a high season-long crop ground cover is important. High shading ability, measured as fractional light interception, is also beneficial and selection for high yield does not compromise crop competitiveness. A description of general growth habits is based on an understanding the role of different characteristics in weed competition. These habits will be of value under different soil and cropping conditions or locations in low-input and organic farming.

INTRODUCTION

Development of new cereal varieties for competitiveness against weeds under low input and organic conditions requires identification of plant and crop characteristics, and development of routine methodologies to indicate their potential usefulness. Some varieties have higher weed suppression than others, but this is usually not attributed to a single characteristic. The interaction between a series of desirable characteristics is important in weed competition (Eisele & Köpke, 1997) and this will include strengths in some characteristics compensating for weaknesses in others. Certain key characteristics are indicated as generically desirable for organic wheat varieties to improve weed suppression, including (1) good establishment ability, (2) high tillering ability and (3) increasing plant height (Wicks et al., 1986; Didon & Hansson, 2002). Other characteristics such as (4) a planophile leaf habit and high leaf area index (Huel & Hucl, 1996; Seavers & Wright, 1999), (5) leaf inclination (Eisele, 1992; Lemerle et al., 1996) and (6) high yield potential may also be important. Many of the individual plant characteristics can be used to define general growth habits and determine whole crop measures such as leaf canopy size and light interception. For example, crop ground cover comprises a broad range of plant characteristics (e.g. Huel & Hucl, 1996; Ogg & Seefeltd); Didon & Hansson, 2002). This paper focuses on characteristics of winter wheat crops that may benefit weed suppression in low input and especially organic farming.

MATERIALS AND METHODS

A variety trial was carried out in each of four years (2000/01 to 2003/04) at an organic farm at Colstoun Mains Farm, Haddington, near Edinburgh. Varieties were supplied from four countries: Germany, Poland, Spain and UK. Each trial comprised of seven reference varieties used in all years (Batis, Isengrain, Malacca, Pegassos Rialto, Riband and Shamrock) and a selection of between eight to 18 other varieties (including Maris Widgeon, Marius, Option, Ramiro and Zyta). The trials also included a spring wheat (Chablis) and a winter oat (Gerald).

The experimental design was a randomised complete block with 4 replications. Each plot measured 24 m x 2 m. Measurements of crop and weed growth were observed throughout the crop life cycle. The key measurements were based on: (1) early growth habit, including plant number, tillering ability and % ground cover. (2) Canopy expansion and spring/summer growth including mean leaf angle/orientation and fractional light interception. (3) Weed growth and development, including % weed cover. Grain yield was also measured.

Results are presented from the EU-funded project on Strategies of Weed Control in Organic Farming (WECOF). Most of the data are for the growth stages between ear emergence and anthesis (i.e. EC 50-65). Regression analysis was used to examine relationships between crop growth and weed cover. Results are presented as general relationships between crop and weed across all genotypes and years. Weed growth varied significantly between years. Therefore weed ground cover is expressed as a weed score ranging from 0 to 1.0, where 1.0 represents the genotype with the maximum level of weed cover at the relevant growth stage in each year.

RESULTS

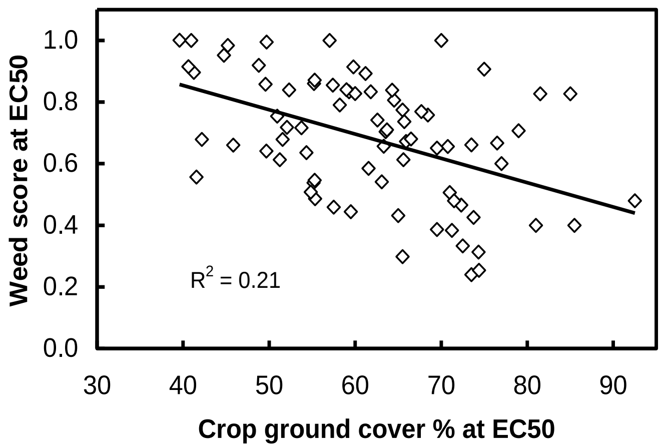
Table 1 indicates generalised growth habits in four contrasting varieties. These are defined as: (1) the continuous planophile, (2) the early season erectophile to late season planophile, (3) the early season planophile to late season erectophile and (4) the continuous erectophile. Although plant growth habit has influences on crop characteristics such as ground cover and fractional light interception, it can be a poor indicator of competitive ability, unless other factors such as speed of development, shoot population density and plant height are comparable across each of the types described (data not shown here).

Table 1. Leaf characteristics and general plant growth habit of selected wheat varieties. Leaf angles were measured from the stem at anthesis (i.e. a more erect leaf has a low angle). Plant growth habit refers to the change in leaf habit from pre-tillering to post-anthesis.

Variety	Flag leaf angle (^{o})	Mean angle of all leaves (^{o})	Plant growth habit
Chablis (SW)	76	52	Continuous planophile
Maris Widgeon	55	44	Erectophile to planophile
Rialto	31	35	Planophile to erectophile
Zyta	23	26	Continuous erectophile

SW = spring wheat.

Crop ground cover is comprised of several characteristics including percent crop establishment, shoot population density and leaf angle. Crop ground cover had the most consistent and negative effect on weed growth. Figure 1 demonstrates how crop ground cover at ear emergence across all genotypes and years was inversely (and significantly) related to weed ground cover at the same stage and at immediately post-harvest. Other data not shown in this paper demonstrates that crop ground cover at early growth stages has a significant impact on weed growth throughout the crop life cycle.



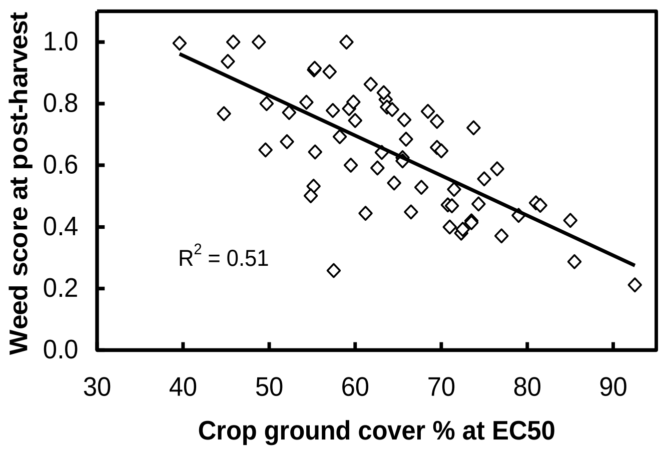


Figure 1. Relationship between crop ground cover (%) at ear emergence (EC50) and weed ground cover at EC50 (upper figure) and post-harvest (lower figure). Data represent all varieties across four seasons. Weed ground cover is scored as the percentage weed cover for each variety in each season expressed as a fraction of maximum weed cover at the relevant growth stage, thus enabling each season's data to be placed on the same scale.

The amount of light interception by the crop leaf canopy i.e. fractional light interception was significantly and negatively correlated with subsequent weed growth. Figure 2 (upper graph, $p < 0.001$) shows data for weed growth at post-harvest as a function of fractional light interception at ear emergence to anthesis. Light interception was influenced by crop height as well as crop ground cover. Generally, the plant and crop characteristics for weed suppression did not compromise grain yield. Thus, Figure 2 (lower graph, $p < 0.001$) indicates a significant negative correlation between yield and weed cover immediately post-harvest.

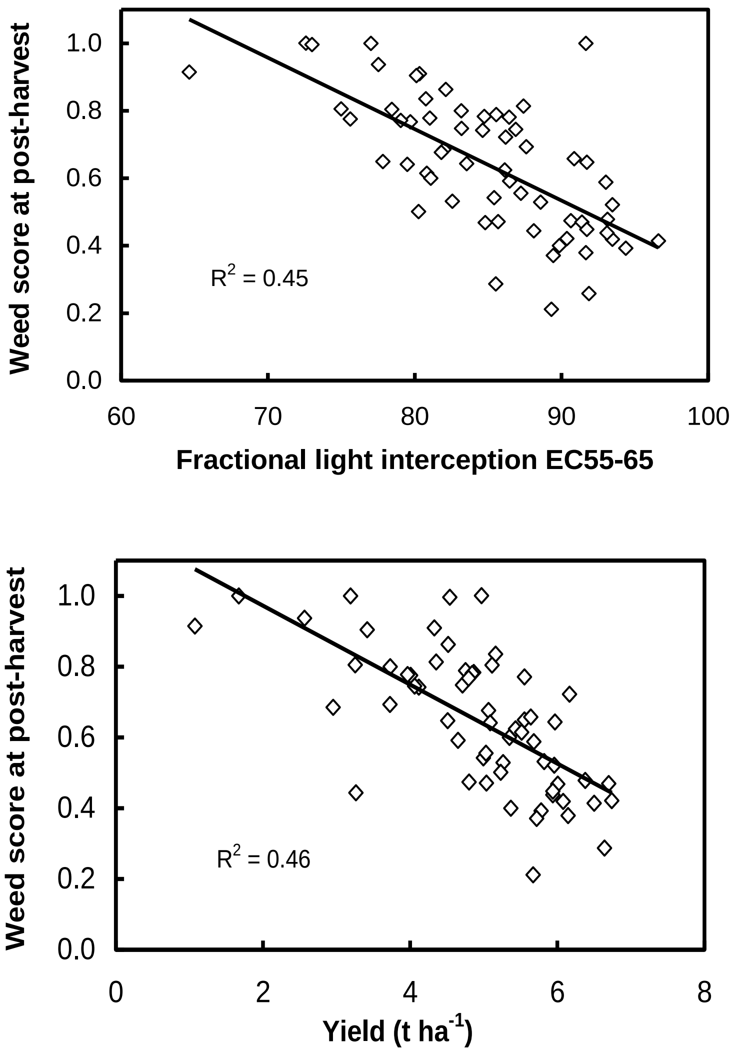


Figure 2. Relationships between (1) crop fractional light interception between ear emergence to anthesis (i.e. EC50-65) and weed ground cover at post-harvest (upper figure) and grain yield and weed ground cover at post-harvest (lower figure). Data represent all varieties across four seasons. Weed ground cover is scored as the percentage weed cover for each variety in each season expressed as a fraction of maximum weed cover at the relevant growth stage, thus enabling each season's data to be placed on the same scale.

DISCUSSION

Use of a wide range of genotypes enabled us to describe plant and crop characteristics and variety types that are best suited to weed suppression. This information is most useful in low-input crops where reduced herbicide inputs are desired and in organic crops where mechanical weed control could be minimised, but could improve herbicide performance in conventional crops. The balance between the characteristics determines the value of the variety for early, late and season long weed suppression, and for the climatic zone. For example, in cool, moist climates, season long weed suppression may be required and early prostrate habit and high tillering ability, because of greater establishment risks, are perhaps more important, with some added benefit of an increase in stem height. Our results suggest that crop ground cover is the most important crop feature for competing against weeds. This view is supported by other results from our EU-WECOF project (Drews, 2005, Davies et al, 2004) and other research (e.g. Lemerle et al., 1996). When a variety competed well against weeds this was associated with a relatively high fractional light interception. High weed suppression has also been linked with relatively high light interception in the upper leaf canopy of tall, planophile cultivars (Verschwele, 1994; Amesbaur & Hartl, 1999).

Seasonal variations in plant establishment and tiller production and/or tiller retention can make it difficult to group varieties into types that are consistently good or poor for competing against weeds. However, it is possible to describe four general growth habits in such a way that will benefit selection for weed suppression ability in new genotypes. (1) A continuous planophile habit has a clear advantage over the erectophile habit at a given plant or shoot population density. This habit appears to be particularly beneficial in shorter varieties and under circumstances where a crop requires sustained weed suppression, especially during the autumn and stem extension. (2) An early planophile to later erectophile habit can compensate better for lower crop establishment than early erectophiles, as rapid leaf development or large leaves would enable varieties of this type to take full advantage of their leaf habit. (3) The early erectophile to later planophile habit is a good model when crop establishment is high and if crops are sown in narrow rows. This structure can provide high fractional light interception throughout the season. The later planophile habit is the most beneficial habit where there is late weed growth i.e. from stem extension onwards. (4) The erectophile habit has been the long established ideotype for high yields in cereals for high-input agriculture and unlimited nutrient supply. This habit can be an advantage when weed levels are low, but it is a risky strategy when competition from weeds is high, especially early in the growing season. If an erectophile is desired then increased height may be of value. Shorter vartieties would benefit from an ability to produce and retain a high number of shoots per plant. All types benefit from good crop emergence. An early planophile type can provide earlier canopy closure and a degree of buffering against poor to moderate crop establishment.

A key factor is a robust consistency in weed suppression and yield, especially for organically-grown varieties. It is encouraging that yield benefits do not appear to be lost in identifying weed suppression in winter wheat. This has implications for plant breeding programmes, because the development of competitiveness against weeds does not exclude development of high yielding varieties. It is evident that some varieties are more robust than others, though it is not always clear why this is so. Our own results suggests that about 40% of the variation in ability to suppress weeds appears not to be linked to the measured characteristics. This leads to hypothesise what characteristics should also be assessed after suitable research. For example root competition and the potential for allelopathic differences between varieties (Didon, 2002;

Didon & Hansson, 2002). The balance between different characteristics for weed suppression will determine the value of the variety for early, late and season-long weed control. It is clear that selection for variety types should be considered in relation to climatic factors that affect both crop and weed growth.

ACKNOWLEDGMENTS

The authors are grateful for EU and SEERAD funding and would like to acknowledge the support of our partners from Bonn, Madrid and Warsaw in the EU funded project on Strategies of Weed Control in Organic Farming (WECOF).

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