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Choice of Cultivars in Organic Farming: New Criteria for Winter Wheat Ideotypes

Sortenwahl im Organischen Landbau: Neue Kriterien für Winterweizen-Ideotypen

II: Weed Competitiveness of Morphologically Different Cultivars

II: Unkraut-Unterdrückung morphologisch differenzierter Sorten

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Summary

The effect of differing ground shading resulting from cultivar selection on natural weed cover and defined seeded model weeds was tested in field trials in 1989, 1990 and 1995 at the organically managed experimental farm Wiesengut near Bonn, Germany. Cultivars with planophile leaf inclination could reduce weed growth significantly, especially at wide row spacings and north-south direction of the drilling row. Morphology and seed production of weeds were also influenced by shading ability of the selected winter wheat cultivars.

The effect of morphological features of different cultivars on ground shading exceeded the effect of increased N-fertilization of 40, 120 or 160 kg N ha^{-1}, given as farmyard manure to the precrop potato.

By optimizing and combining cultivar selection, row spacing and direction of rows, the competitiveness of a winter wheat stand in Organic Farming might be so much enhanced, that hoeing is not necessary in stands of relatively low weed density.

Keywords: winter wheat, weeds, morphology, cultivars

Zusammenfassung

Der Effekt unterschiedlicher Bodenbeschattung von morphologisch verschiedenen Winterweizensorten auf die natürliche Verunkrautung und definiert ausgesäte Modellunkräuter wurde in Feldversuchen 1989, 1990 und 1995 auf dem Versuchsbetrieb für Organischen Landbau Wiesengut bei Bonn getestet. Sorten mit planophiler Blatthaltung konnten, vor allem bei weiten Reihenabständen und Drillrichtung Nord-Süd, den Unkrautaufwuchs deutlich vermindern. Auch die Morphologie von Unkräutern wurde beeinflußt, und die Samenproduktion bei hoher Beschattung deutlich gemindert.

Der Beschattungseffekt der Sortenmorphologie übertraf bei weitem den Effekt einer Stickstoffdüngung von 40, 120 oder 160 kg N ha^{-1} als Stallmist zur Vorfrucht Kartoffel.

Durch die optimierte Kombination von Sortenwahl, Reihenweite und Drillrichtung kann die Konkurrenzkraft eines Bestandes so gesteigert werden, daß bei vergleichsweise geringem Unkrautdruck auf den Einsatz der Maschinenhacke verzichtet werden kann.

Schlüsselworte: Winterweizen, Unkraut, Morphologie, Sorten

Introduction

Weed control in Organic Farming has to depend mainly on the use and optimization of the natural competitive relationships between crop and weeds (KÖPKE 1991). The competitiveness of the crop is influenced by row spacing, plant density and the morphology of the cultivar (HOLT 1995, WICKS et al. 1994). Elements used in conventional farming to increase the competitiveness of the stand, such as nitrogen-fertilization, high plant densities and narrow row spacings, are not easy to realize in Organic Farming. Narrow row spacings prevent the option of mechanical hoeing and N-fertilization may increase the growth of weeds in light stands with a high light penetration to the soil surface (EISELE 1995a). High plant densities are difficult to realize:

a) due to the non-use of chemical seed dressings and thus uncertain field emergence
b) because of limited soil nitrogen, especially in spring leading to reduced tillering

(SCHAUDER et al. 1995). Results of EISELE & KÖPKE (1997) showed that the proper choice of cultivar can decisively influence light competitiveness, especially under organic farming conditions. Higher shading can lead to decreased weed density, biomass and reduced weed reproduction.

Our investigations were undertaken to clarify the effects of different levels of genotypically determined shading by winter wheat cultivars on weed growth, to determine how these effects are influenced by N-fertilization, row distance and row direction and how much they can contribute to a weed control strategy in Organic Farming.

Materials and Methods

Field trials were conducted in 1989, 1990 and 1995 on Wiesengut-Experimental Farm for Organic Agriculture, University of Bonn (Germany), on precisely mapped homogeneous areas of a fluvisol (HAAS 1995). In four different experiments a range of morphologically different German winter wheat cultivars with different leaf inclination (as described by GARDNER et al. 1985) and different plant height were tested: Carolus (planophile leaves) and Apollo (erectophile leaves), both with short straw, and the cultivars Sperber (erectophile leaves), Obelisk, Reiher and Granada (planophile leaves), having long culms (Tab. 1).

Tab. 1: Winter wheat cultivars, factors and seeding date of 4 different winter wheat experiments

Experiment	year	cultivars	factors	seeding date
1	1989	Apollo, Granada, Obelisk, Sperber	row spacing: 13.5 and 22.5 cm	October 26, 1988
2	1990	Apollo, Carolus, Granada, Obelisk, Sperber	row direction: north-south, east-west	October 28, 1989
3	1990	Apollo, Carolus, Reiher, Sperber	N-fertilization of 40, 120 and 160 kg N ha^{-1}, applied on April 10, 1989 as composted farmyard manure[1)] to the previous crop potatoe	October 28, 1989
4	1995	Carolus, Sperber	row direction: north-south, east-west row spacing: 12 and 24 cm N-fertilization of 0, 80, 160 and 240 kg N ha^{-1} [2)], also given as composted manure[3)] to the previous potato crop	October 21, 1994

[1)] manure of a deep litter stable, composted for 12 month on a heap, with 3.03% N_t (dry-weight basis). Nitrogen availability is described in detail by (Stein-Bachinger (1993).
[2)] only two variations (0 and 240 kg N ha^{-1}) were analysed.
[3)] manure of a deep litter stable, composted for 2.5 month on a heap, with 2.05% N_t (dry-weight basis).

Photosynthetically active radiation (PAR) was measured simultaneously above the canopy and on the soil surface using a line quantum sensor (Li-COR Inc., USA), which integrates PAR over a length of 100 cm. Two measurements per plot were averaged at each sampling period. Measurements were performed under conditions of clear sky every two weeks in experiment 1–3 and at EC (Decimal code for growth stages, ZADOKS et al. 1974) 26–30, EC 30/31, EC 37/38 and EC 68/69 in experiment 4. Interception of sunlight is presented as percentage shading calculated from these measurements.

The effect of shading was recorded either by estimating natural weed cover (3×0.1 m^2 per plot) or with model weeds as 'biological indicators'. In experiments 1 and 2 *Lepidium sativum* L. was sown with an exactly defined number of seeds and grown in irrigated plastic boxes of 100 cm length and 10 cm width. Two of these boxes were placed in each plot between the wheat rows and shoot dry matter was harvested at different stages of growth. The development of particular weed species *(Apera spica-venti, Galium aparine)* and the model weed *L. sativum* was described by morphological parameters (height, leaf area, branching rate) and seed reproduction. These parameters were measured on ten individual plants per plot.

Experiments 1 and 2 were run as randomized split-plot treatment arrangement with four replicates (blocks). Main plots were row directions and row spacing; sub-plots were cultivars. Individual plots were 1.5 by 7 m^2 (experiment 1) and 1.5 by 10 m^2 (experiment 2).

Experiment 3 was a randomized block design with four replicates and an individual plot size of 1.5 m by 10 m.

Experiment 4 was performed as a randomized block design with two split-plot treatments and four replicates. Main plots were row direction, sub-plots were row distance and sub-sub-plots were cultivars and N-fertilization. The individual plot size was 1.5 m by 8 m.

All data were statistically analysed using analysis of variance. Treatment means were compared using the Bonferroni-Holm test (HOLM 1979).

Results

Between 68 and 90% of the incoming PAR from growth stages EC 25 to EC 80 were absorbed or reflected by the plant canopy and could not be used by the weeds (Tab. 2).

Tab. 2: Averaged total ground shading (=percentage reduction of the incoming PAR) from tillering to milky ripe stage of six different winter wheat cultivars. Different letters show significant differences within each column ($\alpha = 0.05$, Bonferroni-Holm-Test)

	% total ground shading			
cultivar	Exp. 1 EC 25–75	Exp. 2 EC 25–80	Exp. 3 EC 25–72	Exp. 4 EC 26–69
Reiher (tall, planophile)			90.38 a	
Carolus (short, planophile)		84.42 a	89.69 a	86.90 a
Apollo (short, erectophile)	68.16 a	82.96 a b	88.79 a b	
Granada (tall, planophile)	66.02 a	82.43 b		
Obelisk (medium tall, planophile)	68.73 a	80.38 c		
Sperber (tall, erectophile)	66.05 a	79.49 c	87.33 b	81.66 b
culms m^{-2} (averaged)	415	498	441	492

Planophile cultivars with a fast canopy development before stem elongation, such as Carolus and Reiher, showed a relatively high shading efficiency, whereas Sperber with erectophile leaves shaded significantly less in all experiments. The cultivars Apollo, Obelisk and Granada could not be clearly assigned and showed a different shading ability in 1989 and 1990: Obelisk showed a delayed growing and covering in experiment 2. Under Granada shading was reduced, caused by problems due to leaf diseases in experiment 1 (*Puccinia recondita, Puccinia striiformis*). In 1989 (experiment 1) ground shading was comparatively lower because the stands were thinner and allowed more light to penetrate to the ground. The number of culms did not differ significantly between cultivars, except in expe-

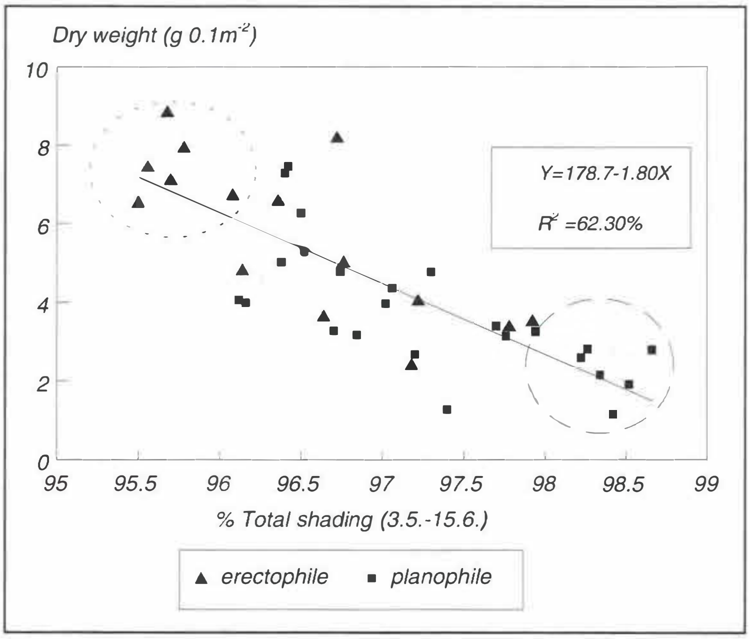

Fig. 1: Dry weight production of *Lepidium sativum* L. in relation to total shading at growth stages EC 30–70 (Experimental site Wiesengut 1990, experiment 2)

riment 4, where Carolus had significantly more culms m^{-2} (507) than Sperber (476).

The differences in shading ability appeared to be very small, but an increase in total ground shading by 3–4% above the 95% level between EC 30 and EC 70 caused by morphologically different cultivars reduced dry matter yield of the model weed *Lepidium sativum* by 75%. Cultivars with planophile leaf inclination shaded more efficiently than did the erectophile cultivars (Fig. 1, experiment 2). *Lepidium sativum* was seeded at wheat-growth-stage EC 30 and harvested at EC 70. Since it was grown in separate boxes with irrigation, the competition was wholly due to the light factor.

In experiment 1 the correlation between *Lepidium* dry matter yield and shading was also significant (r = –0.562**), but only the growth stages between EC 61 and EC 82 could be evaluated, because the *Lepidium* boxes were not irrigated correctly in the earlier growth stages. The number of generative parts of *Lepidium* (blossoms, seeds) was also reduced by higher shading (r = –0.624**).

Model weeds were used in 1989 and 1990, because natural weed cover did not exceed 5% and was too low to find out differences between the cultivars. In 1995 weed ground cover was much higher. The dominant species were *Viola arvensis*, *Matricaria spp.*, *Veronica hederifolia* and *Ranunculus repens*. Fig. 2 shows, that natural weed ground cover increased with wider row spacings and higher N-fertilization. Compared to erectophile Sperber, Carolus (planophile) could nearly level out the disadvantage of wider row distance and increased N-fertilization.

Compared to east-west rows weed ground cover was always higher in north-south direction (experiments 2 and 4) and compared to narrow row spacings always higher with wide row spacings (experiments 1 and 4).

Interactions between morphology of the cultivar and drilling direction could be examplarily shown for *Apera*

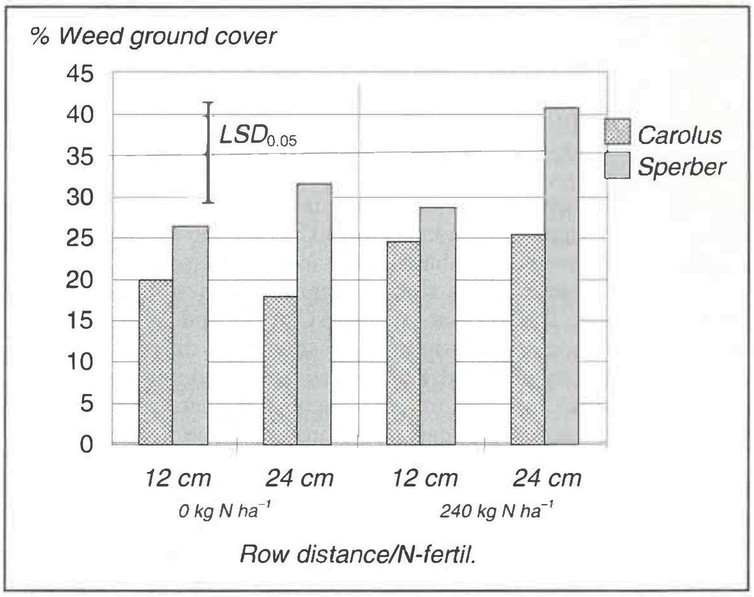

Fig. 2: Weed ground cover under two winter wheat cultivars depending on row distance and N-fertilization (composted farmyard manure, given to the precrop). Experimental site Wiesengut 1995, experiment 4)

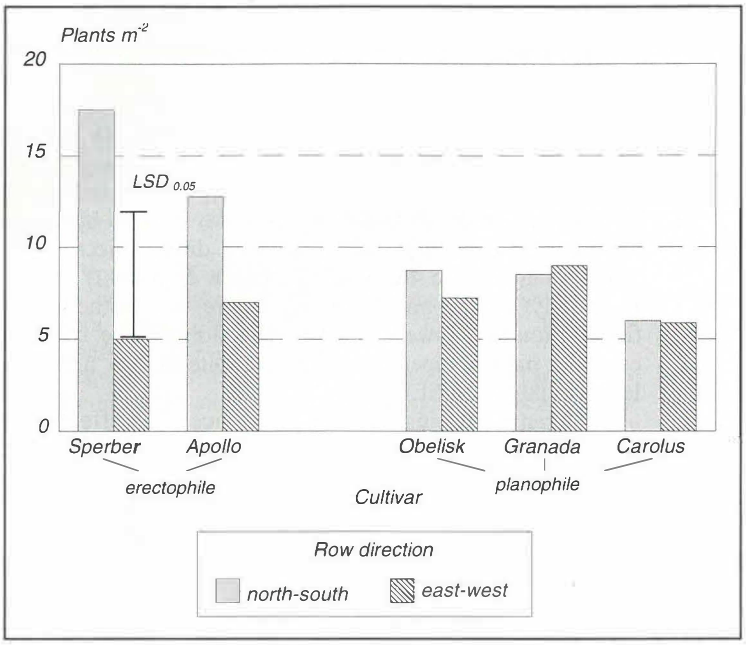

Fig. 3: Weed density (*Apera spica-venti*) associated with five winter wheat cultivars at two row directions (Experimental site Wiesengut 1990, EC 72, experiment 2)

spica-venti. Weed density was significantly higher in north-south direction under erectophile cultivars whereas planophile types were able to suppress weed growth in both directions (Fig. 3).

Higher weed ground cover in stands with increased availability of nitrogen, especially at wide row spacings, showed that the given nitrogen could be used efficiently by weed plants, if the morphology of the cultivar allowed a sufficient amount of light penetrating to the soil surface. Increasing N-fertilization led to higher shading of all cultivars, but the influence of the cultivar on ground shading greatly exceeded the effect of nitrogen supply (Fig. 4). The two planophile cultivars, Carolus and Reiher, shaded more efficiently at the lowest N-level than the erectophile types, Sperber and Apollo, at any of the N-levels tested.

These results could be corroborated with those from experiment 4 (Tab. 3).

There was a significant relationship between morphology (leaf area index) and shading at low N-levels

Tab. 3: Total ground shading of two winter wheat cultivars at two N-fertilizer levels (composted farmyard manure, given to precrop potato. Experimental site Wiesengut 1995, experiment 4. Different letters show significant differences ($\alpha = 0.05$, Bonferroni-Holm-Test)

Cultivar	0 kg N ha^{-1}	240 kg N ha^{-1}
Carolus (planophile)	85.41 (b)	88.27 (a)
Sperber (erectophile)	78.72 (c)	84.59 (b)

($r = 0.80^{**}$ at 40 kg N ha^{-1}) but not at high N-fertilization ($r = 0.14$ at 240 kg N ha^{-1}). Similar significant correlations between weed cover and ground shading were calculated at low nitrogen fertilization level (Tab. 4).

Not only weed density or weed ground cover, but also morphology and reproduction of weeds were influenced by shading of different cultivars. *Galium aparine* showed a decreased branching rate and seed produc-

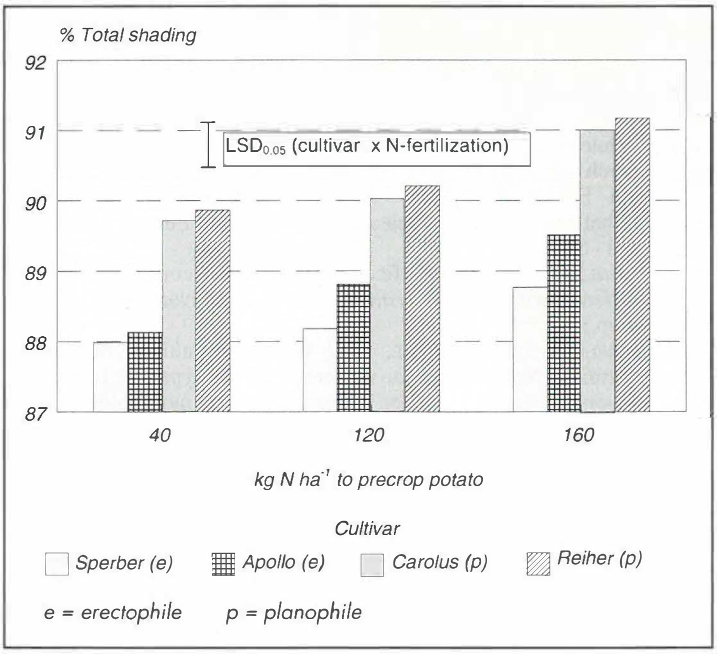

Fig. 4: Total ground shading of four winter wheat cultivars at 3 N-fertilizer levels (composted farmyard manure, given to precrop potato. Experimental site Wiesengut 1990, experiment 3)

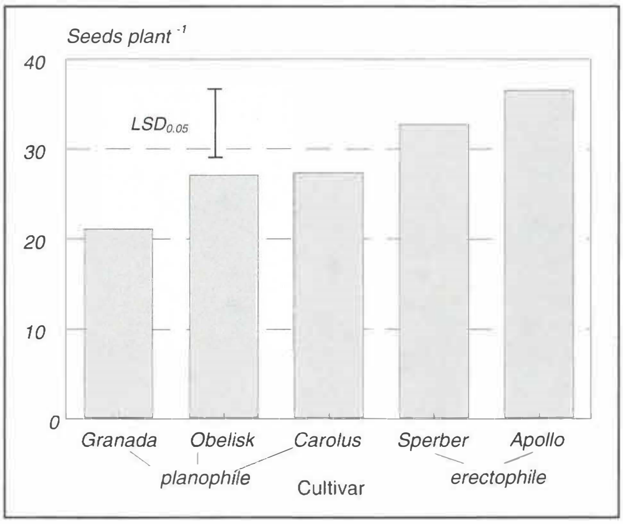

Fig. 5: Seed formation of *Galium aparine* in five winter wheat cultivars (Experimental site Wiesengut 1990, experiment 2)

tion under planophile cultivars compared to erectophile types (Fig. 5). The correlation between ground shading and seed production of *Galium aparine* was significant with $r = -0.52$ ($\alpha = 0.05$). Also *Lepidium sativum* reacted with increased blossom and seed production to a higher amount of solar radiation. The close relationship between ground shading and weed seed reproduction shows the importance of competitiveness even in later growth stages.

Tab. 4: Coefficients of correlation (r) between ground shading and weed cover at EC 25–27 and EC 30 at two different N-fertilization levels, experiment 3 (significance level α: *=0.05 **=0.01).

growth stage	40 kg N ha^{-1}	240 kg N ha^{-1}
EC 25-27	–0.664**	0.021
EC 30	–0.603*	0.132

Discussion

Access to light is the most important factor in weed competitiveness. It could be shown, that growth habit and thus shading ability can determine the competition power of a wheat cultivar (EISELE & KÖPKE 1997). The results obtained in these investigations showed, that higher ground shading caused by cultivar selection led to decreased weed growth. Not only weed yield could be reduced by high competitive cultivars, as reported by WICKS et al. (1986) for some summer annual weeds or CHALLAIAH et al. (1986) for *Bromus tectorum,* but also weed morphology and seed reproduction were influenced by shading. Similar results have been reported by BENVENUTI et al. (1994). Especially the differences in ground shading ability after stem elongation may not be relevant for actual weed competition but for the weeds reproduction potential. Thus shading over the whole vegetation period is an important factor of competition.

It was not possible to compensate a lack of competitiveness by increased nitrogen fertilization. VALENTI & WICKS (1992) reported decreasing weed densities caused by increased nitrogen fertilization, but with plant densities between 554 and 660 culms of winter wheat m^{-2}. In Organic Farming plant densities and leaf area index are generally much lower (1989: 415 culms m^{-2}, 1990: 498 culms m^{-2}). Consequently, comparatively more light can penetrate to the soil surface. If sufficient light is available, N-fertilization can be efficiently used by weeds (KORR et al. 1996). FRANZ et al. (1990) showed significantly higher seed production and plant height of *Galium aparine* and *Viola arvensis* due to increased N-application. Stimulation of weed growth by N-fertilization can be reduced by using appropriate spreading techniques like direct injection of liquid manure into the soil (SCHENKE & KÖPKE 1995). Especially in Organic Farming, where no synthetic N-fertilization is allowed, cultivar selection can be used to establish high competitive stands in spite of low nitrogen levels (EISELE 1995 b).

In Organic Farming Systems the choice of an effectively shading cutlivar can contribute decisively to the weed management strategy. Plant densities are comparatively low and hoeing is a common practice for mechanical weed control, especially if wet wheather in spring prevents effective harrowing. However, hoeing needs row spacings of more than 17 cm, which leads to an unfavourable plant distribution. The aim of organic weed management must be a stand of high competitiveness in spite of low plant densities which allows the farmer to realize narrow row spacings by doing without the option of hoeing. Methods for quantifying the competitiveness of different winter wheat cultivars to optimize cultivar selection were described by EISELE (1996).

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