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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

1: Light Conditions in Stands of Winter Wheat Affected by Morphological Features of Different Varieties

1: Lichtverhältnisse in Winterweizen-Beständen in Abhängigkeit von morphologischen Sorteneigenschaften

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Summary

Light penetration in stands of five morphologically different winter wheat cultivars was measured at various growth stages in field experiments on two organic farms during 1989 and 1990. Wheat was sown in two row spacings (13.5 and 22.5 cm) and two row directions (east-west and north-south). Results revealed that shading ability depended on morphology of the variety especially at low leaf area index, wide row spacing and north-south direction. Compared to modern wheat types with erect leaves, cultivars having planophile leaves shaded more efficiently. Increased shading ability of taller varieties could be shown only in an east-west drilling direction. Ideotypes best adapted to organic farming should combine an early covering of the soil surface with long and large leaves, with long leaf area duration due to reduced susceptibility to fungal diseases.

Keywords: light, wheat, cultivars, morphology

Zusammenfassung

In Feldversuchen auf zwei organisch wirtschaftenden Betrieben wurde 1989 und 1990 die photosynthetisch aktive Einstrahlung unter 5 morphologisch unterschiedlichen Winterweizensorten alle zwei Wochen während der Vegetationsperiode erfaßt. Drillrichtung (13,5 und 22,5 cm Reihenabstand) und Exposition der Drillreihe (Ost-West, Nord-Süd) wurden zusätzlich variiert. Die Abhängigkeit der Bodenbeschattung von der Sortenmorphologie zeigte sich vor allem bei niedrigem Blattflächenindex, weitem Reihenabstand und Drillrichtung Nord-Süd. Verglichen mit erectophilen Weizentypen beschatteten planophile Sorten unter diesen Bedingungen wesentlich effizienter. Eine erhöhte Beschattung höherwüchsiger Sorten konnte nur bei Ost-West Drillrichtung nachgewiesen werden. Für den Organischen Landbau geeignete Ideotypen sollten eine frühe Bodenbeschattung mit langen Blättern und eine lange Blattflächendauer mit geringer Anfälligkeit gegen Blattkrankheiten aufweisen.

Schlüsselworte: Licht, Weizen, Sorten, Morphologie

Introduction

The exploitation of light is regarded as the most decisive factor of competition between crops and weeds. The inter- and intraspecific competition for this growth factor in stands of small grains is determined by the arrangement of crop plants (row spacing, seeding rate, drilling direction) and the morphology of the individual plant. The light relations in plant communities can be described by the equation

$$I = I_0 \, e^{-kF} \quad \text{(MONSI \& SAEKI 1953)} \qquad (1)$$

where I is the intensity of light within the stand below a given layer of leaves or leaf area index (LAI) F with a light intensity I_0 above the canopy. The extinction coefficient k depends on the architecture of the canopy i.e. its leaf inclination (ANDERSON 1966, MONTEITH 1973). e is the base of natural logarithm (2.178). According to this relationship ground shading is influenced by LAI and leaf inclination of a cultivar and its spacing (SPITTERS & AERTS 1983, LOTZ et al. 1991, KROPF & LOTZ 1992). After EISELE & KÖPKE (1991) & DUNAN (1991) LAI is the most sensitive measure for light competitiveness. Both morphological features are genotypically fixed but can be influenced by agricultural measures such as nitrogen fertilization (LEDENT & RENARD 1982, KIRKHAM 1984).

The influence of morphological features on light regime and thus weed competition in stands of cereals has been described by several authors (BALYAN et al. 1991, BENVENUTI et al. 1994, WICKS et al. 1994, EISELE 1995), but it is not clear, under which conditions morphological features can be relevant as a criterion for varietal choice. In Organic Farming systems especially this question is of particular interest, because weed control has to depend mainly on the use and the optimization of the natural competitive relations between crops and weeds (KÖPKE 1991). Direct mechanical weed control should only be an additional measure. In stands of winter wheat, for example, mechanical hoeing is more effective compared to the use of the harrow, but requires unfavourable row spacings of more than 17 cm distance (SCHENKE 1993).

The following investigations were performed to determine the relevance of morphologically determined shading ability for weed control and whether this criterion should become an aim for breeding cultivars adapted to the conditions of Organic Farming and other types of extensified farming systems.

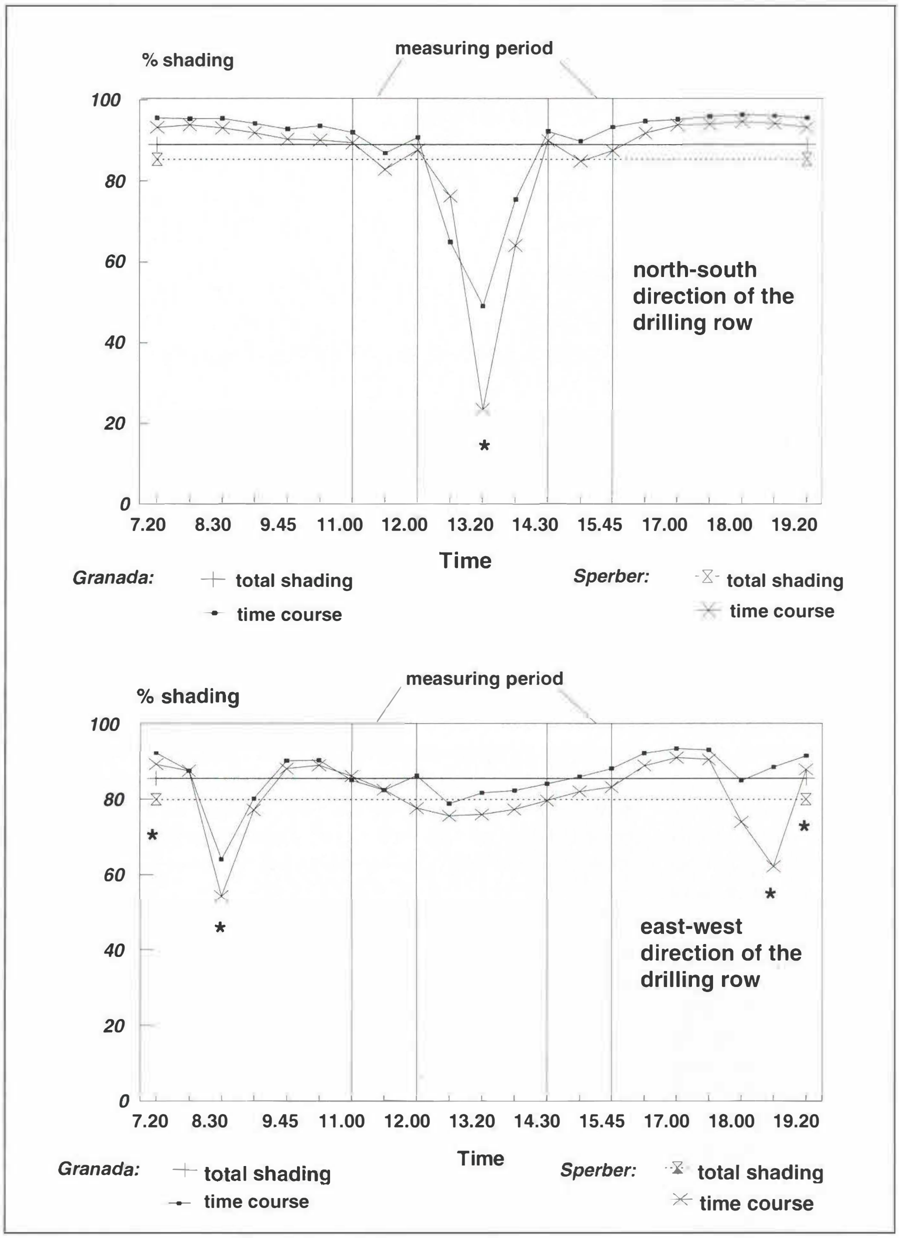

Fig. 1: Daily course of relative shading and averaged total shading of the day depending on cultivar (cv. Sperber with erected leaves, cv. Granada with planophile leaves) and row direction (north-south, top; east-west, bottom) at 22.5 cm row spacing (experimental site Wiesengut 1989). *: Significant differences with $\alpha = 0.05$.

*Tagesverlauf der relativen Beschattung und Gesamtbeschattung des Tages in Abhängigkeit von der Sorte (Sperber mit erectophiler, Granada mit planophiler Blatthaltung) und Drillrichtung (Nord-Süd, oben; Ost-West, unten) bei 22,5 cm Reihenabstand (Versuchsgut Wiesengut 1989). *: Signifikante Unterschiede mit $\alpha = 0.05$.*

Material and Methods

Field trials were conducted in 1989 and 1990 on Wiesengut-Experimental Farm for Organic Agriculture, University of Bonn (Germany) on exactly mapped homogeneous areas of a fluvisol (HAAS 1995). A range of morphologically different German winter wheat varieties 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 varieties Sperber (erectophile leaves), Obelisk and Granada (planophile leaves) having long culms. In addition, two different row spacings (13.5 and 22.5 cm, only in 1989) and two row directions (north-east, south-west, only in 1990) were tested. Winter wheat was sown with 400 seeds m^{-2} at October 26, 1988 and October 28, 1989.

Morphological parameters such as plant height, leaf area index (LAI) and leaf inclination were measured on ten individual plants per plot. Plant height was measured eight times between tillering and harvest. Leaf area was determined at growth stages tillering, stem elongation, anthesis and ripening with a LI 3100 Areameter (LI-COR inc., USA). The angle between the base of the leaf blade and the stem was measured and the percentage of lax leaves was estimated. 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, measurements being taken every two weeks when the sky was clear. Interception of sunlight is presented as percentage shading calculated from these measurements. During the morning light came in at an angle of 40–50° to the drilling row, and at noon, for the east-west-rows and for the north-south-rows respectively, at an angle of 90° or at 0°. Sample measurements were taken every 30 minutes during the course of the day to determine the optimum time for comparable light measurements. They showed that the morning and the afternoon readings accurately predicted the total shading for the day (i.e. integration of the daily course-curve). Accordingly the measuring period for the light measurements was between 11:30 h and 12:30 h or from 14:30 h to 15:30 h, respectively as illustrated in Fig. 1.

From the data obtained by morning measurements, a shading-course curve over the vegetation period was derived. By integration of this curve total shading of a certain

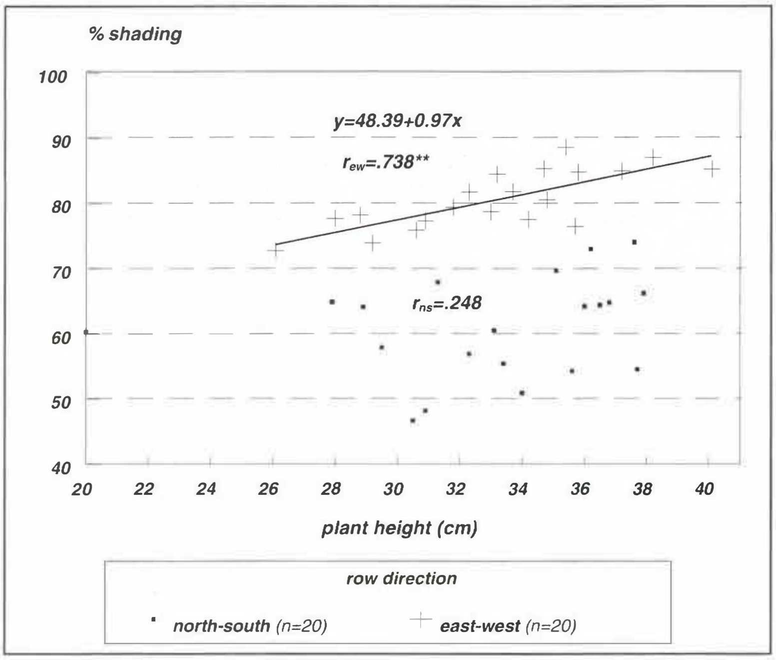

Fig. 2: Ground shading depending on plant height of 5 winter wheat varieties (cv. Apollo, Carolus, Granada, Obelisk, Sperber) drilled in north-south and east-west direction, respectively (experimental site Wiesengut 1990, EC 30)

Bodenbeschattung in Abhängigkeit von der Wuchshöhe bei 5 Winterweizensorten (Apollo, Carolus, Granada, Obelisk, Sperber) bei Drillrichtung Nord-Süd, beziehungsweise Ost-West (Versuchsgut Wiesengut 1990, EC 30).

period could be calculated. In addition, measurements were taken at noon to show the differences in shading during the period of maximum radiation.

The vertical light distribution and interception was examined by measurements in four different layers of the canopy (0, 30, 60 and 80 cm, respectively). The LAI of each layer was recorded separately for calculating the corresponding extinction coefficients.

The experiments were laid out as randomized block designs with a split-plot treatment arrangement and fourreplicates. Main plots were row directions and row spacing; subplots were cultivars. Individual plots were 1.5 by 7 m in 1989 and 1.5 by 10 m in 1990. All data were subjected to an analysis of variance. Treatment means were compared using the Bonferroni-Holm test.

Results

The light conditions in stands of winter wheat were remarkably influenced by genotypically determined morphological features of the varieties. Plant height, LAI and leaf inclination proved to be the determining factors. These effects were modified by plant spacing (row distance) and drilling direction .

Average culm density was 415 ears m^{-2} in 1989 and 498 ears m^{-2} in 1990. No significant differences between the treatments could be proved.

Plant height

No relationship was found between maximum straw length (= plant height at EC-stage 60, decimal code for growth stages, ZADOKS et al. 1974, which is the criterion for the characterization of a variety as 'tall' or 'short') and total ground shading ($r^2 = 0$). Maximum length did not correspond at all with plant height at earlier growth stages. However, the plant height at different EC-stages showed a significant correlation to actual ground shading (Tab. 1), especially at EC 45-55 (ear emergence).

The relationship between height and shading ability also depended on the angle of light penetration to the drilling row.

Tab. 1: Coefficients of correlation between plant height and actual ground shading at different growth stages (significant at α: * = 0.05, ** = 0.01)

*Korrelationskoeffizienten zwischen Wuchshöhe und aktueller Bodenbeschattung bei unterschiedlichen Wachstumsstadien (signifikant bei α: * = 0.05, ** = 0.01)*

EC-Stage				
30/31	32/33	45–55	65–75	80–85
0.525**	0.536**	0.628**	0.39*	0.315

A significant increase in ground shading under tall cultivars at the highest daily radiation (noon) was obtained only with the east-west drilling direction (Fig. 2).

In contrast to north-south direction increased ground shading of taller varieties grown in east-west direction could be shown at all growth stages after tillering (Fig. 2, Tab. 2).

Tab. 2: Coefficients of correlation between plant height and ground shading as affected by drilling direction (Significant at α: * = 0.05, ** = 0.01; experimental site Wiesengut 1990)

*Korrelationskoeffizienten zwischen Wuchshöhe und Bodenbeschattung bei unterschiedlichen Drillrichtungen (signifikant bei α: * = 0.05, ** = 0.01, Versuchsgut Wiesengut 1990)*

Exposition	EC 30	EC 32/33	EC 70-75	EC 80-85
north-south (n = 20)	0.248	0.380	0.382	0.357
east-west (n = 20)	0.738**	0.757**	0.531*	0.557*

Leaf Area Index (LAI) and leaf inclination

We found that LAI and leaf inclination were the most important morphological features that influenced light penetration and distribution in the canopy. At low levels of LAI a small increase of LAI caused a major increase in shading. When average LAI increased from 0.5 to 3.0 during the period between tillering and stem elongation, the shading increased from 40 to more than 75% ($r^2 = 0.382$). After stem elongation an increase in LAI from 3.3 to 6.1 caused only a slight increase in ground shading from 95 to 98% ($r^2 = 0.424$).

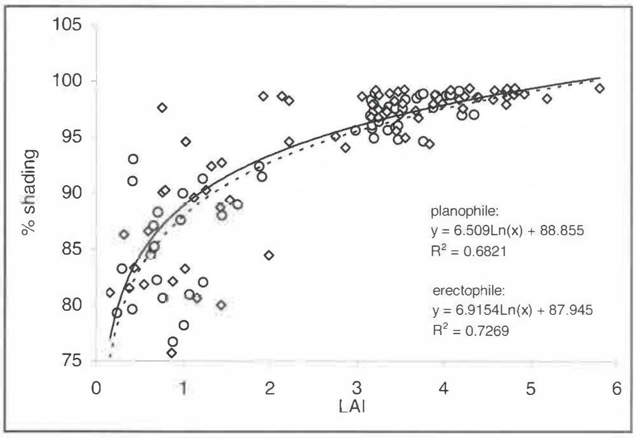

Fig. 3: Ground shading as a function of LAI in winter wheat cultivars with planophile (◇, —) or erectophile (O,---) leaf inclinations (experimental site Wiesengut 1989 & 1990, EC 65-75).

Bodenbeschattung in Abhängigkeit vom Blattflächenindex unter Winterweizensorten mit planophiler (◇,—) oder erectophiler (O,---) Blatthaltung (Versuchsgut Wiesengut 1989 & 1990, EC 65-75).

Fig. 3 shows the diminishing effect of increasing LAI on ground shading at EC 65-75. The highest values of shading were reached by planophile varieties with high LAI.

At the same LAI the planophile cultivars tended to shade more efficiently than did the erectophile cultivars. These differences between varietal types gradually diminished at LAI greater than 3.5. Accordingly an early realisation of high LAI was decisive for the competitiveness of a genotype.

The relationship between LAI and shading was closer at wide row spacing ($r^2 = 0.3^{**}$ at 22.5 cm) compared to narrow row spacing ($r^2 = 0.01$, n.s. at 13.5 cm).

The vertical distribution of light in the canopy could be described by the extinction coefficient k, which could be derived from equation (1). k is determined by the leaf angle α and the angle of light penetration β (ANDERSON 1966). If $\alpha < \beta$, k can be used as a measure for the leaf angle (MENZI 1988). The cultivars Apollo and Carolus, having nearly the same plant height, shaded the soil surface more than 95% (Fig. 4). However, in spite of lower LAI, Carolus shaded significantly more than Apollo in the upper layers. The shading of Carolus was more efficient because of its planophile leaf inclination, especially of the flag leaf. Thus the extinction coefficient k increased in inverse proportion to the leaf angle.

After ANDERSON (1966), k increases as long as $\alpha < \beta$. Thus a higher shading caused by planophile leaves ($\alpha <$ 30–40°) could be expected only around noon, also depending on the orientation of the drilling row and the row spacing. Figure 5 shows a consistently higher ground shading under the planophile cultivar Granada especially in north-south-direction between 11:00 h and 13:00 h.

Discussion

The results obtained here have shown that morphological features can influence light conditions significantly in winter wheat stands and thus competition between crop and weeds. Similar results have been shown by VERSCHWELE & NIEMANN (1992) and BALYAN et al. (1991). However, the effects of different varieties on ground shading ability depend on the general conditions of the stand. Ground shading can be increased by using cultivars with planophile leaves especially under conditions of wide row spacings and low LAI. Due to a limited soil nitrogen supply, thin stands of winter wheat with relatively low LAI are typical for organic growing conditions.

The measured differences in ground shading between cultivars with erectophile and planophile leaf inclination seemed to be very small, but even these differences can lead to significant effects. In investigations by PATTERSON (1979), a reduction of PAR by 98% led to reduced weed growth whereas no effects could be shown by 75% ground shading. KORR et al. (1996) showed, that 98% ground shading in summer wheat stands was not sufficient to prevent weeds from taking advantage of increased N-fertilization. With high N-fertilizer rates, weed biomass decreased only if no light reached the soil surface.

A higher degree of shading by long strawed cultivars compared to short cultivars as described by WICKS et al. (1994) could not be proved. Characterization of the influence of cultivar-determined plant height on ground shading did not depend on maximum straw length but on height development throughout the vegetation period. Similar results have been described by MOSS (1985) for some winter wheat varieties.

Comparable light measurements to describe the competitiveness of different cultivars have to be related to the drilling direction and time of day. Not only the angle of light penetration to the soil surface (time of day) (ANDERSON 1966) but also the angle of light penetration to the drilling row determines the shading effects of morphological features. The effects of cultivar morphology on ground shading was greatest in a north-south direction of the drilling row. Several authors have described higher yields in stands of winter wheat sown in north-south direction compared to an east-west direction (DONALD, 1963; SHEKLAWAT et al., 1966). A careful choice of variety can optimize the competitiveness of the stand and thus use the potential yield advantage of north-south orientation.

The increasing number of organic farms and the expected trends towards extensified farming systems will lead to an increased acceptance of susceptibility to weed competition as a criterion for choosing winter wheat cultivars. It seems prudent to consider these findings in future wheat breeding programs. The most decisive morphological characteristics found in our investigations were early covering of the ground by fast canopy development with long and large leaves. Genotypes with planophile leaf inclination in the upper leaf layers and, most importantly, those having a long leaf area duration combined with little susceptibility to diseases, proved to be the most competitive after stem elongation. Genotypes with a combination of early ground covering and planophile leaf inclination just above the ground, but leaves vertically inclined at the top becoming more horizontal closer to the ground would be most favourable. With plants of this type shading of the lower leaves is diminished and thus assimilation of the plant potentially increased (AUSTIN et al. 1976). Nowadays numerous modern cultivars of winter wheat representing erectophile plant types bred for intensive agriculture with stands of high plant density are available. Since only a few planophile cultivars with higher shading ability in less dense stands are available, further investigations should reveal whether the competitiveness of a stand can be optimized by using mixtures of morphologially different cultivars which can additionally combine shading ability during early and late development.

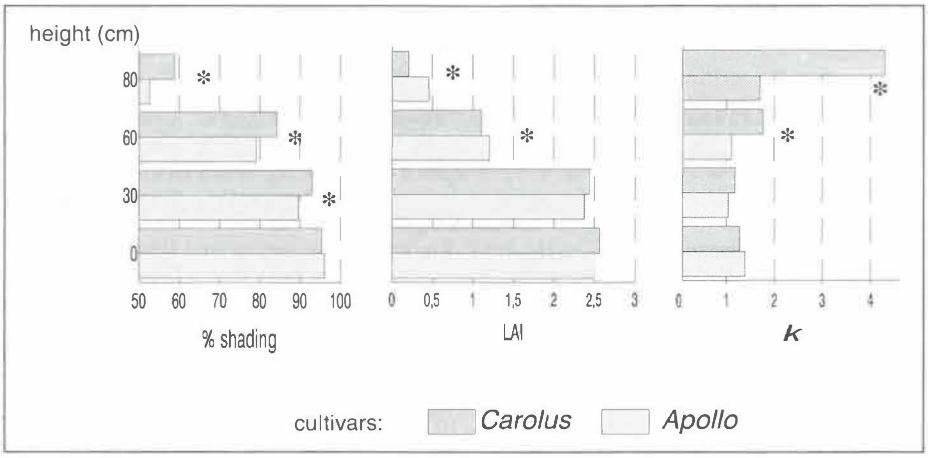

Fig. 4: Shading, leaf area index and extinction coefficient *k* in four different canopy layers under the cultivars Carolus with planophile and Apollo with erectophile leaves (EC 70, experimental site Wiesengut 1990). *: significant differences with $\alpha = 0.05$.

*Beschattung, Blattflächenindex und Extinktionskoeffizient k in vier Bestandeshöhen unter den Sorten Carolus mit planophiler und Apollo mit erectophiler Blatthaltung (EC 70, Versuchsgut Wiesengut 1990). *: Signifikante Unterschiede mit $\alpha = 0.05$.*

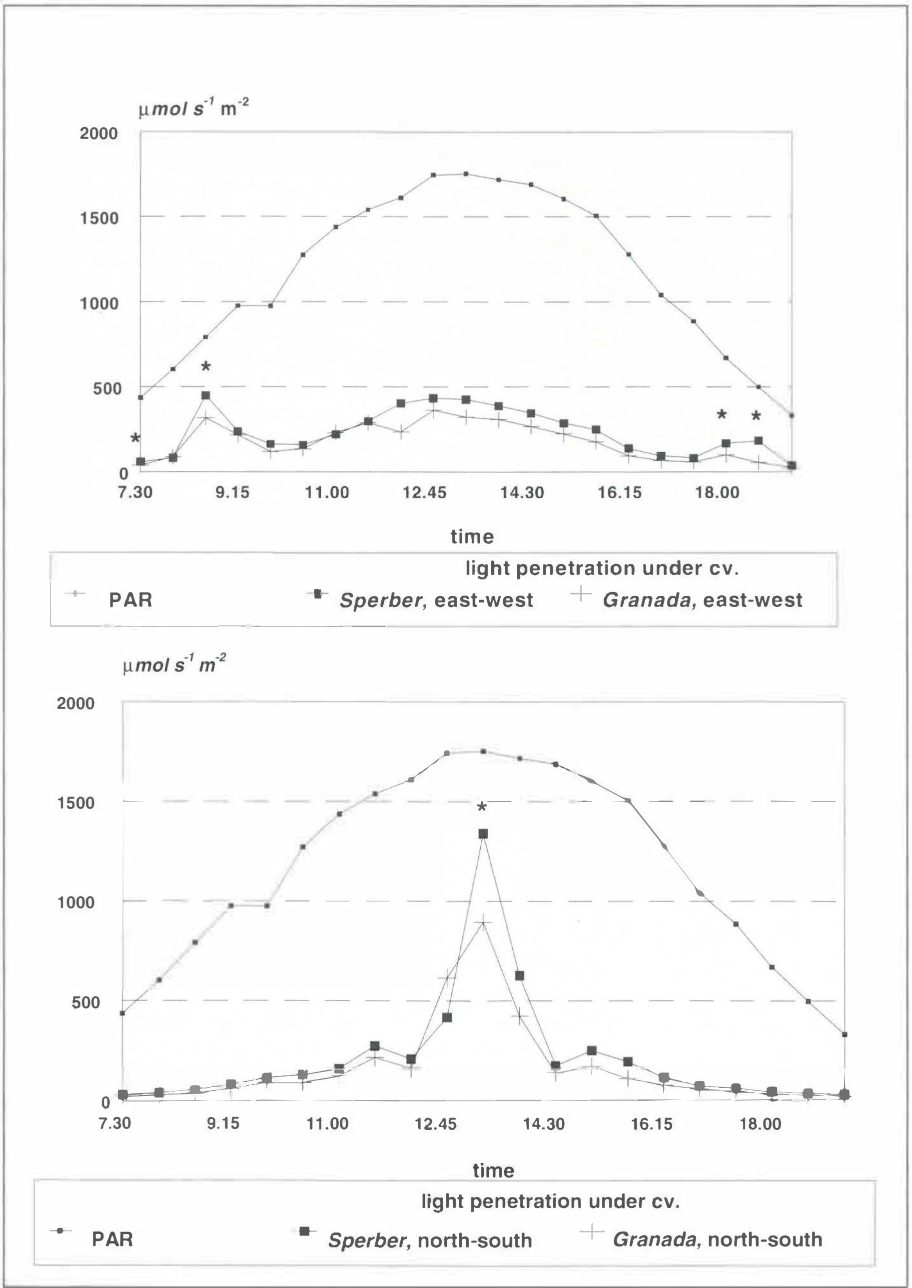

Fig. 5: Daily course of solar radiation (PAR) above the stand and light penetration measured on soil surface under the cultivars *Sperber* (erectophile) and *Granada* (planophile) in two different row directions (experimental site Wiesengut 1989). *: significant differences with $\alpha = 0.05$.

*Tagesverlauf der Sonneneinstrahlung (PAR) über dem Bestand und Einstrahlung am Boden unter den Sorten Sperber (erectophil) und Granada (planophil) in zwei unterschiedlichen Drillrichtungen (Versuchsgut Wiesengut 1989). *: Signifikante Unterschiede mit $\alpha = 0.05$.*

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