Crop row orientation induced photo-sensory effect on the competitive interactions of crops and weeds

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Summary  Four trials were conducted in the Western Australian wheat belt during the 2002 to 2005 growing seasons to examine the effect of crop row orientation induced photo-sensory processes on weeds and crops. Grain yields of wheat were 25 to 42% greater and those of barley were 8 to 43% greater when sown in an east-west orientation than in a north-south orientation. Plant growth and grain protein contents of wheat and barley were also greater in the east-west orientation than in the north-south orientation. Weed dry matter in the east-west orientation was 23 to 81% lower in wheat and 21 to 87% lower in barley than in north-south orientation probably due to 45 to 58% greater light interception by the crop canopy in the east-west than in the north-south orientation. No definite pattern of the impact of row orientation on yields of lupin, canola and field pea was observed. The results from this study may have vital implications in guiding growers as to whether they should sow crops in an east-west or north-south orientation. Sowing cereal crops in an east-west orientation, especially in tramline systems, could be more productive than in a north-south orientation under the agro-ecological conditions similar to Avondale and Merredin in Western Australia.

Keywords  Competition, dry matter, grain yields, grain protein content, light interception.

INTRODUCTION

Crop row orientation is a non-chemical and environmentally friendly weed management tactic that has not been explored in Western Australia (WA). It is an important factor in regulating crop/weed competitive relationships, growth and development of the neighbouring plants (Holt 1995, Ballaré and Casal 2000, Martínéz-Ghersa et al. 2001, Shrestha and Fidelibus 2005). Crops and weed species generally respond differently in changing soil and light environments. For example, the weed Italian ryegrass (Lolium multiflorum Lam.) has a longer seed dormancy period than wheat, and growth is more responsive to changing soil and light environments than is wheat (Martínéz-Ghersa et al. 2001). Manipulation of the light environment near the soil surface could be an additional weed management strategy in cropping systems (Ballaré et al. 1989, Ghersa et al. 1994), and light could be used to favour crops and disfavour weed growth (Holt 1995). However, only a few studies have demonstrated how changing light environments (Holt 1995) and the physiological ecology of weed could be used to improve weed management (Holt 1991). Many studies have quantified the effects of competition for light between weeds and crops (Cudney et al. 1991, Blackshaw et al. 2002, Zimdahl 2004). To date, little attention has been paid to the causes of those effects (Holt 1991, Hashem et al. 1998) and its future weed management implications.

Crop rows orientated at a near right angle to the direction of sunlight may suppress weed growth by creating partial shade on weeds (Holt 1995). However, such effects have rarely been observed. In some parts of the WA wheat belt, the sun angle goes as low as 35° during wintertime. Therefore, row orientations may affect weed growth and crop yield significantly in this area. If this were so, growers could capitalise on the concept of row orientation, particularly when establishing tramline farming.

The aim of this study was to examine the effect of crop row orientation and row spacing, induced photosensory processes on the growth and development of weeds and crops.

MATERIALS AND METHODS

Trials at Merredin  Two trials were conducted in 2004 and 2005 on a loamy sand at the Merredin Research Station (31°27’S, 118°12’E), WA. In 2004, annual ryegrass (Lolium rigidum Gaudin) seeds (200 m²) and wild radish (Raphanus raphanistrum L.) pod segments (300 m²) were introduced into the site at sowing time. Five crops (wheat, barley, lupins, canola and field pea) were sown at standard seeding rates with two row spacings (18 and 36 cm) and two row orientations (east-west and north-south). The crops were sown in the first week of June on a unit plot size of 2 m × 10 m following standard agronomic practices.
No pre- or post-emergence herbicides were sprayed for weed control.

In 2005, annual ryegrass seeds (200 m⁻²) were introduced into the site at seeding time and natural populations of wild radish were used. The same five crops were sown at standard seeding rates with two row spacings (23 and 60 cm) and two row orientations (east-west and north-south).

**Trials at Avondale** Two trials were conducted on a shallow sandy duplex soil at the Avondale Research Station (32°40’S, 117°72’E), WA in 2002 and 2004 using natural populations of ryegrass and wild radish. Five crops (wheat, barley, lupin, canola and field pea) were sown at standard seeding rate with two row spacing (18 and 36 cm) and two row orientations (east-west and north-south). The crops were sown in the first week of June on a unit plot size of 2 m × 10 m following standard agronomic practices. No pre- or post-emergence herbicides were sprayed for weed control.

**Measurements** The density of crops and weeds was recorded three weeks after emergence and at flowering stage of crop from two 100 cm × 50 cm fixed quadrats per plot. Aboveground dry matter of crops and weeds was recorded from the same quadrats at flowering stage of crops. Photosynthetically active radiation (PAR) was measured above the crop and weeds canopies, at the centre of inter-row spaces at mid-day on a sunny day, with a Sunfleck Ceptometer (Pearcy 1991). Light interception by crop canopy was expressed as percent of global light (i.e. light above the crop canopy). At harvest, crop yields, grain size and grain protein content were recorded.

**Design and analysis** All trials were arranged in a factorial randomised complete block design with three replications at each site. Data were subjected to ANOVA and means were compared by least significant difference (LSD).

**RESULTS**

**Plant emergence and growth** The major dominant weed species were annual ryegrass and wild radish at both locations each year. Other weeds such as cape-weed (*Arctotheca calendula* L.) and double-gee (*Emex australis* Steinh.) were also present at low densities. The initial weed densities did not significantly differ due to row orientations or row spacings (data not presented). Weed dry matter was significantly less in crops sown in the east-west orientation than in the north-south orientation at Merredin in 2005, averaged over row spacings (Table 1).

The initial plant densities of crops did not significantly differ due to row orientations (data not presented). Plant densities of wheat and barley were 84 to 93 plants m⁻² across all seasons, averaged over two row spacings. Dry matter of wheat and barley was significantly greater in crops sown in the east-west orientation than in the north-south orientation across all seasons at both locations, measured at the late flowering stage of crops (Table 2). For example, dry matter was 23% greater in wheat and 9% greater in barley crops sown in the east-west orientation than in the north-south orientation at Avondale in 2002, averaged over row spacings (Table 2).

**Table 1.** Weed dry matter (g m⁻²) measured at the flowering stage of crops from two row orientations of wheat and barley at two locations, averaged over row spacings from 2002 to 2005.

<table>
<thead>
<tr>
<th>Location and (year)</th>
<th>Weed DM in wheat (g m⁻²)</th>
<th>Weed DM in barley (g m⁻²)</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-W</td>
<td>N-S</td>
<td>E-W</td>
<td>N-S</td>
</tr>
<tr>
<td>Merredin (2005)</td>
<td>8.1</td>
<td>28.1</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>18.6</td>
<td>45.5</td>
<td>55.4</td>
</tr>
<tr>
<td>Merredin (2004)</td>
<td>10.3</td>
<td>18.6</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>69.9</td>
<td>55.4</td>
<td>4.8</td>
</tr>
<tr>
<td>Avondale (2004)</td>
<td>na^</td>
<td>na</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>149</td>
<td>na</td>
<td>24.5</td>
</tr>
<tr>
<td>Avondale (2002)</td>
<td>8.1</td>
<td>64.0</td>
<td>16.4</td>
</tr>
<tr>
<td></td>
<td>62.2</td>
<td>24.5</td>
<td>31.8</td>
</tr>
<tr>
<td>^na = not available, E-W = east-west, N-S = north-south, DM = dry matter.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.** Crop dry matter (g m⁻²) measured on opposing row orientations of wheat and barley in four trials at two locations, averaged over row spacings from 2002 to 2005.

<table>
<thead>
<tr>
<th>Location and (year)</th>
<th>DM of wheat (g m⁻²)</th>
<th>DM of barley (g m⁻²)</th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-W</td>
<td>N-S</td>
<td>E-W</td>
<td>N-S</td>
</tr>
<tr>
<td>Merredin (2005)</td>
<td>604</td>
<td>526</td>
<td>485</td>
</tr>
<tr>
<td></td>
<td>526</td>
<td>485</td>
<td>49.9</td>
</tr>
<tr>
<td></td>
<td>362</td>
<td>318</td>
<td>93.5</td>
</tr>
<tr>
<td>Avondale (2004)</td>
<td>na^</td>
<td>na</td>
<td>609</td>
</tr>
<tr>
<td></td>
<td>482</td>
<td>64.0</td>
<td>164</td>
</tr>
<tr>
<td>Avondale (2002)</td>
<td>678</td>
<td>525</td>
<td>678</td>
</tr>
<tr>
<td></td>
<td>616</td>
<td>616</td>
<td>75.7</td>
</tr>
<tr>
<td>^na = not available, E-W = east-west, N-S = north-south, DM = dry matter.</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Grain yield of wheat and barley increased significantly when the crops were sown in an east-west orientation compared to a north-south orientation at both locations in all seasons (Table 3). Grain yields were 25 to 42% greater in wheat and 8 to 43% greater in barley sown in east-west orientation than in the north-south orientation (Table 3). Yield data of canola, lupin and field pea differed between locations. At one location yields of these crops were greater in the east-west orientation than the north-south orientation, and vice versa at the other location (data not presented).

Grain protein content of wheat and barley measured at Merredin was greater in the east-west orientation than in the north-south orientation. The average grain protein content of wheat and barley were 12.13 and 12.81% in crops sown in the east-west orientation, compared to 11.45 and 11.41% in the north-south orientation, respectively.

Grain size was not influenced by row orientations or row spacing. On average, wheat grain size was 34.6 to 36.3 g 1000 seed\(^{-1}\) and barley grain size was 35.4 to 39.6 g 1000 seed\(^{-1}\), irrespective of crop row orientations and row spacings.

Soil water and light interception

Light interception by the crop canopy of wheat and barley was 45 to 58% greater in the east-west orientation than in the north-south orientation when measured at mid-day at the centre of inter-row space at late flowering stage, averaged over row spacing and locations (Figure 1). The water content in the top 0–15 cm soil depths was 11 to 18% greater in the east-west than in north-south orientation when measured at the centre of inter-row space at the late flowering stage of wheat and barley.

**DISCUSSION**

Grain yields of wheat or barley were consistently greater when sown in an east-west orientation than in a north-south orientation. The increase in the yield of these crops could be attributed to improved plant growth (Table 2) and reduced weed growth (Table 1) in the east-west orientation compared to the north-south orientation. The lower weed dry matter in the east-west orientation than in the north-south orientation was presumably due to a suppression of weed growth and development induced by shading from crop plants leading to a reduction in PAR available to the weed canopy. Martínez-Ghersa et al. (2001) reported that under barnyard grass (Echinochloa crus-galli (L.) P. Beauv.) shading treatments wheat yield increased up to 67% and Italian ryegrass production was reduced by more than 20%. It is therefore possible to design or manipulate light environments to suppress weed growth and development (Holt 1995). Results for grain yield of canola, lupin and field pea were inconsistent between orientations presumably due to their inherent canopy architectures, which probably caused more mutual shading, irrespective of row orientation.

The water content was greater in the east-west than in north-south orientation. It may be possible that shade created by crop plants in the east-west orientation resulted in lower light intensities and reduced soil temperature, and thus reduced soil water loss.

Light interception by the canopy of wheat and barley was always greater in the east-west orientation than in the north-south orientation when measured

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**Grain yield and quality**

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Light interception by the canopy of wheat and barley was always greater in the east-west orientation than in the north-south orientation when measured
at midday at the centre of inter-row space at each location (Figure 1). This means the crop plants in the east-west orientation created more shade on the weed plants growing in close proximity of crop rows than did the crop plants in the north-south orientation. This resulted in weed dry matter being reduced more in the east-west orientation than the north-south orientation (Table 1).

The effect of changing light environments on weed and crop productivity has been described for cropping systems (Holt 1995, Hashem 1998). The total quantity of light could be exploited to promote crop productivity and suppress weed growth through manipulation of current agronomic practices such as crop row orientations.

The results from this study may have vital implications in guiding growers as to whether they should sow wheat and barley crops in an east-west or north-south orientation. It appears that sowing cereal crops in an east-west orientation, especially in tramline systems, could be more productive than in a north-south orientation under the agro-ecological conditions similar to Avondale and Merredin in Western Australia. More research is needed to understand the influence of row orientations on the yield of lupin, canola and field pea.

ACKNOWLEDGMENTS
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REFERENCES