Competitive interaction between maize, *Xanthium strumarium* and *Datura stramonium* affecting some canopy characteristics

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**Abstract**

Field experiments were conducted in 2006 and 2007 to evaluate *Xanthium strumarium* and *Datura stramonium* single and multispecies interferences with maize. At different weed densities (4, 8, 12 and 16 plants m⁻²), *X. strumarium* and *D. stramonium* were planted in five proportions of 0:100, 25:75, 50:50, 75:25 and 0:100. Monoculture of maize at 6 plant m⁻² and pure stands of *X. strumarium* and *D. stramonium* at two densities of 4 and 16 plants m⁻² were also included. The results showed that *X. strumarium* is the most competitive weed in mixed plant community of maize, *X. strumarium* and *D. stramonium*. Maize, mainly due to its greater height at high density of weeds and because of its greater height and LAI at low density of weeds, was more successful in competition for light than the two weed species. At mixture of *X. strumarium* and *D. stramonium* under competition with maize, *X. strumarium* due to its greater LAI and height, showed greater ability in light interception than the other weed species. Therefore, stronger competitive ability of a weed in competition for light may be attributed to its canopy characteristics e.g. greater height and LAI expansion. In the mixed plant community, these characteristics enable the species to soon occupy the space and capture the common resources i.e. light. To control these weeds in maize, appropriate control measures have to be taken in early growth stages.

**Keywords:** interference, LAI, height, light competition

**Abbreviations**

<table>
<thead>
<tr>
<th>IWM</th>
<th>Integrated weed management</th>
<th>PAR</th>
<th>Photosynthetic active radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAI</td>
<td>Leaf area index</td>
<td>A</td>
<td>Amount of light receiving above the canopy</td>
</tr>
<tr>
<td>WAP</td>
<td>Week after planting</td>
<td>B</td>
<td>Amount of PAR passing the mixed canopy</td>
</tr>
<tr>
<td>Hₜ</td>
<td>Is plant height (cm) at time T</td>
<td>Y</td>
<td>is the light percentage passing of the mixed canopy</td>
</tr>
<tr>
<td>Hₘₐₓ</td>
<td>Is the maximum plant height (cm)</td>
<td>X</td>
<td>Maize day after planting</td>
</tr>
<tr>
<td>Hₛₒ</td>
<td>Number of days to reach 50% of final plant height (day) (Hₘₐₓ)</td>
<td>a, b</td>
<td>Are coefficients of the equation</td>
</tr>
<tr>
<td>b</td>
<td>Is the slope around Hₛₒ</td>
<td>R²</td>
<td>Coefficient of determination</td>
</tr>
</tbody>
</table>

**Introduction**

Weeds are a main threat in maize production. Maize is very sensitive to weed competition especially in the first four weeks after planting (Olorunmaiye and Olorunmaiye, 2009). To obtain higher yields weed control is very important because weed compete with crops for water and nutrients (Bijanzadeh et al., 2010). Integrated weed management (IWM) systems require a comprehensive knowledge of weed biology and ecology (Buhrer, 1999). Information on competitive interaction between weeds and crops are useful for developing and implementing effective weed management programs (Fu and Ashley, 2006). Jimsonweed (*D. stramonium* L.) and common cocklebur (*X. strumarium* L.) are found as the most competitive weeds in maize and other crops in the world’s (Byrd and Coble, 1991; Royal et al. 1997; Cavero et al., 1999; Karimmojeni et al., 2010). These weeds highly compete for light. Canopy architecture characteristics, plant height (Scott et al., 2000), leaf area index (LAI) and position of maximum leaf area in the canopy (Holt, 1995) are crucial factors for light competition. Leaf area distribution in the canopy appeared to have distinct effects on light interception in crop mixtures such as sorghum/cowpea (Gilbert et al., 2003), potato/maize (Mushagalusa et al., 2008). Competition for light between tomato (*Lycopersicum esculentum* L.) and eastern black nightshade (*Solanum ptycanthum* Duh.) (McGiffen et al., 1992) were well explained by crop and weed height. In a study of competition between *D. stramonium* and soybean, the major competitive impact was associated with the greater height of the weed (Stoller and Woolley, 1985). Graham et al. (1989) observed that smooth pigweed (*Amaranthus hybridus* L.) and palmer amaranth (*Amaranthus palmeri* S.) reduced light penetration into the sorghum canopy by absorbing light in the upper canopy. Competition from the weed may reduce the LAI of crops (Cavero et al., 1999;
Table 1. Parameter estimates for the logistic model fitted to maize height data in monoculture and in competition with Xanthium strumarium or Datura stramonium. Values in the parentheses are standard errors.

<table>
<thead>
<tr>
<th>Weed density (plant m$^{-2}$)</th>
<th>2006</th>
<th></th>
<th></th>
<th>2007</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$H_{\text{max}}$ (cm)</td>
<td>$H_{50}$ (day)</td>
<td>$b$</td>
<td>$R^{2}$</td>
<td>$H_{\text{max}}$ (cm)</td>
</tr>
<tr>
<td>0 (monoculture)</td>
<td>213.02 (4.7)</td>
<td>53.70 (1.09)</td>
<td>0.10 (0.01)</td>
<td>0.99</td>
<td>232.00 (1.95)</td>
</tr>
<tr>
<td>4</td>
<td>214.29 (6.54)</td>
<td>55.27 (1.5)</td>
<td>0.09 (0.01)</td>
<td>0.99</td>
<td>226.32 (1.89)</td>
</tr>
<tr>
<td>8</td>
<td>202.99 (5.7)</td>
<td>54.88 (1.4)</td>
<td>0.09 (0.01)</td>
<td>0.98</td>
<td>228.01 (6.29)</td>
</tr>
<tr>
<td>12</td>
<td>200.11 (4.9)</td>
<td>54.83 (1.24)</td>
<td>0.09 (0.01)</td>
<td>0.99</td>
<td>226.53 (6.4)</td>
</tr>
<tr>
<td>16</td>
<td>198.88 (5.24)</td>
<td>55.42 (1.29)</td>
<td>0.10 (0.01)</td>
<td>0.98</td>
<td>223.09 (5.23)</td>
</tr>
<tr>
<td>X. strumarium</td>
<td>228.01 (6.29)</td>
<td>45.87 (1.4)</td>
<td>0.12 (0.01)</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>D. stramonium</td>
<td>226.53 (6.4)</td>
<td>46.63 (1.46)</td>
<td>0.11 (0.01)</td>
<td>0.98</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: $H_{\text{max}}$, maximum plant height; $H_{50}$, time to reach 50% $H_{\text{max}}$; $b$, slope around $H_{50}$.

Steinmause and Norris, 2002). Lower leaves of some plants fall in response to the shade of maize, soybean, or adjacent weeds (Sattin et al., 1992; Tremmel and Barzaz, 1994). Leaf senescence in white clover (Trifolium repens L.) (Woledge, 1986) and maize (Caverlo et al., 1999) has shown to increase in the presence of weeds. Maize under single species competition with X. strumarium or D. stramonium has been previously studied (Karimmojeni et al., 2010). However, information on canopy architecture and light absorption by maize under multispecies competition with these weeds, to our knowledge, has not been reported yet. Since there is usually multispecies competition the field, these data can be used to develop IWM for maize and to improve the competitive ability of this crop with weeds. The objective of this research was to study the competitive interaction between X. strumarium, D. stramonium and maize affecting canopy architecture characteristics including LAI, height, light absorption and transition in plant community consist of these two weed species and maize.

### Material and methods

Field experiments were conducted at the Research Farm, University of Tehran, Karadj, Iran in 2006 and 2007. The soil type was a loam with pH 5.7 and 0.61% and 1.67% organic matter in 2006 and 2007, respectively. The field at the test site had lain fallow in preceding year of study. To prepare the seedbed deep plowing (20-25 cm) was carried out with a moldboard plough each year in autumn followed by disking in the spring. The soil fertility was improved by applying diammonium phosphate (18-46-0 N-P-K) and urea at the rate of 350 and 150 kg ha$^{-1}$, respectively, each year in 2006 and 2007. The maize hybrid “Singles Cross 704” was sown at the rate of 250 and 150 kg ha$^{-1}$ as Dursban EC®, 40.8% active ingredient, Ghazal chemistry, Babol, Iran, http://www.ghazalshimi.com) was applied two times during the growing season (at early growing stage and 15 days after that). The maize hybrid “Singles Cross 704” was sown at the desired density (6 plant m$^{-2}$), seeds spaced 22 cm apart in rows spaced 75 cm apart on 4 May 2006 and 2007. Seeds from both weed species were concurrently sown on each side of the maize rows at a distance of 15 cm. Each experimental plot consisted of four rows 10 m long. Weeds and maize were over seeded to cover uniform germination. However, the extra plants were removed after seedling establishment. Plots were furrow irrigated soon after planting to ensure rapid establishment of the crop and weeds. Irrigation was done weekly until physiological maturity of the maize. X. strumarium and D. stramonium were placed at four densities (4, 8, 12 and 16 plant m$^{-2}$) and at five ratios of X. strumarium to D. stramonium (100:0, 75:25, 50:50, 25:75 and 0:100). In other words, 20 different competition situations were arranged. In addition, pure stands of X. strumarium and D. stramonium at two densities of 4 and 16 plants m$^{-2}$ and maize monoculture at the density of 6 plant m$^{-2}$ were included. The 25 treatments were arranged in a randomized complete blocks design with 3 replicates in the field. Throughout the growing season, all emerged weeds other than X. strumarium and D. stramonium were thoroughly removed by hand hoing.For both maize and weeds, height and LAI were measured five week after planting (WAP) and biweekly thereafter in 2006 and 2007. For a given species plant height was measured by randomly selecting four plants from each plot and measuring the distance from the ground to the stem tip. Moreover, for each plant species leaf area of green leaves was measured using a Delta England leaf area meter (Delta-T Devices, Cambridge, England).

### Statistical analysis

Data from different treatments were subjected to ANOVA for each year using PROC GLM procedure of SAS, version 9.1 (SAS Institute, 2002). Data were not combined over years because of different plant heights and thus canopy divisions. Data were not transformed since the assumptions for the ANOVA (homogeneity and normal distribution of residuals) were adequately met. A logistic equation (Caverlo et al., 1999) was fitted to the height data measured in each treatment separately by year: Eq. (1)

$$H_{1} = \frac{H_{\text{max}}}{1 + \left(\frac{T}{H_{50}}\right)^{b}}$$

where $H_{1}$ is plant height (cm) at time $T$; $H_{\text{max}}$ is the maximum plant height; $H_{50}$ describes number of days to reach 50% of final plant height ($H_{\text{max}}$) and $b$ is the slope around $H_{50}$. All regression analyses were conducted using SigmaPlot ver. 10.0 (SigmaPlot, 2004). To determine the trend of light passing from the mixed canopy during the growing season in 2007 PAR was measured during the fourth stage of sampling (from 35 days after planting to closure canopy in 80 days after planting) by a 1m long sensor of Sunscan device between 10 am to 2 pm when sky was sunny. This was done in each sampling by first putting sensor completely horizontal at above of canopy in two states (both vertical and parallel on planting lines) and the amount of light receiving above the canopy was estimated (A). Then, this
Fig 1. Changes in maize height over time as affected by *Xanthium strumarium* and *Datura stramonium* densities in 2006 and 2007. Lines represent the functional logistic model \[ H_t = H_{\text{max}} / \left[ 1 + (T / H_{50})^b \right] \] fitted to the data. See Table 1 for the regression coefficients.

Fig 2. Effect of different density of *Datura stramonium* and *Xanthium strumarium* on theirs height in single species competition with maize in 2006 and 2007.
operation was replicated at three points in the bottom of mixed canopy (along with maize rows, weed rows and between planting lines), and the amount of PAR passing the mixed canopy was measured (B). The percentage of light passing the canopy in each stage was obtained from Eq. (2): $Y=\frac{B/A}{100}$ (2). Then, to estimate the light passing the mixed canopy during the growing season, the following exponential relationship between the light passing the canopy and days after planting of maize was fitted. $Y=ae^{bx}$ eq. (3). In the recent relationship, (Y) is the light percentage passing the mixed canopy, (x) describes maize day after planting and (a) and (b) are coefficients of the equation 3. Regression analysis and graph plotting were done using statistical software (Excel 2003 and Sigmaplot 10).

Results and discussion

Maize height

Pattern of changes in maize height, during the growing season, under weed free condition and different weed densities were explained well by the logistic equation in both years of the study (Fig. 1 and Table 1). Maximum theoretical plant height (i.e. Hmax) decreased with the density of both weed species with more noticeable reductions by X. strumarium at the highest density. Reduced Hmax by 33 cm as compared to maize pure stand. Maize plants were taller in 2007 and were affected less by the weed densities than in 2006. Density-dependent effect of weeds on crop height and variation by year has been reported (Scott et al., 2000). Time to reach 50% final height (i.e. H50) was affected neither by weed species nor by the density. In 2006, H50 values were considerably greater than that of 2007, regardless of competition environment. For example, monoculture maize grew faster in 2007 and required 8.6 day less to reach H50 (Table 1). Maize was considerably taller than both weeds throughout the growing season in both years. However, the differences were negligible in late season especially for D. stramonium height (data not shown). The greater height of maize could be the main reason for its competitiveness against the weeds (Cavero et al., 1999).

Weeds height

Maize affected the height of X. strumarium and D. stramonium under competition (Fig. 2). Height of X. strumarium and D. stramonium were lowest at 12 plant m$^{-2}$ and 16 plant m$^{-2}$, respectively (Fig. 2). In multispecies competition, D. stramonium had lowest height and this was more pronounced at higher densities and proportions in the mixture (Fig. 3 and Fig. 4). As height is one of the determined factors for light competition (Holt, 1995). Thus, X. strumarium appeared to be a stronger competitor for light than D. stramonium. Toller et al (1996) reported that the higher height of Amaranthus retroflexus was a major factor in competition for light with soybean. Plant height elongation induced by light competition (Kurashige and Agrawal, 2005) may explain the growth reactions between maize and weeds. In terms of decreases in plant height in the mixture, there was less differences between maize and X. strumarium in most of the combinations, particularly in 2007. In contrast, the differences were greater in D. stramonium that showed considerable decrease especially at the higher densities (Fig. 5). Therefore, competition for light might become sever

![Fig 3. Effect of Datura stramonium or Xanthium strumarium, at different densities and proportions, on their height in multispecies competition with maize in 2006 and 2007.](image-url)
Fig 4. Effect of *Datura stramonium* or *Xanthium strumarium* at different densities and proportions on *D. stramonium* height in multispecies competition with maize in 2006 and 2007.

Fig 5. Maximum changes in maize and weeds (*Datura stramonium* or *Xanthium strumarium*) height at different densities and proportions of these two weeds in 2006 (up figure) and 2007 (down figure).
Maize LAI and leaf senescence

In both years of the study, maximum maize LAIs, 3.8 in 2006 and 4.63 in 2007, obtained from the weed free treatments. Under single species weed competition, maize LAI measured at silking, (coincides to the maximum LAI of maize) decreased linearly with increased density of X. strumarium or D. stramonium. It reduced maize LAI by 47% in 2006 and 26% in 2007 at the density of 16 plants m$^{-2}$. At the same density, D. stramonium caused 14% reduction in maize LAI in both years of the study. Massinga et al., (2001) reported reduction in maize LAI by increasing Amaranthus palmeri density from 0.5 to 8 plants m$^{-1}$ row. Mosier and Oliver (1995) also showed that more reduction in total LAI of soybean by X. strumarium than Ipomoea hederacea. Maize leaf senescence, determined as the dry weight of old leaves at silking, was accelerated by competition from weeds (Fig. 6). The maize leaf senescence rate followed a linear response to increasing of weed density in single species weed competition, with exception of X. strumarium that exhibited a quadratic response in 2007. However, no old leaf was observed in weed-free maize plots in both years. X. strumarium at 16 plants m$^{-2}$ caused the highest maize leaf senescence rate in 2006 (55 gm$^{-2}$ senesced leaf). In both years, maize leaf senescence rate was lower in competition with D. stramonium (Fig. 6). It is concluded that X. strumarium exhibit a stronger competitive effect on maize. Leaves senescence occurs faster as weed competition with the crop to capture resource become more severe i.e. at a higher weed density. Plant leaf senescence is induced by shading (Vos and van der Putten, 2001) and photosynthesis.
rate also decreases by shading (Myers et al., 2005). Shaded leaves suffer from higher respiratory losses and lower water use efficiency (Fischer et al., 2000). Under severe weed competition, the crop is likely face to scarcity of the needed resources. In this condition, the crop mobilizes the stored resource in organs like stems and leaves to allocate for grain production. Consequently, the nutrition resources in the lower leases might primarily transferred to the plant reproduction organs. Therefore, this might be the reason that senescence could occur soon in the lower leaves in the canopy. In addition, lower leaves over-shaded by the mixed canopy are photosynthetically less active and costly for the plant to keep.

**Light transition from mixed canopy**

The light transition rate from canopy decreased during the growing season as crop canopy was under development (Fig. 7 and Fig. 8). In single species weed competition (Fig. 7) the light transition rate from mixed canopy reduced by increasing weed density. Light transition percentage from X. strumarium and maize canopy was less than D. stramonium and maize canopy particularly early in the growing season (Fig. 7). Zhang et al., (2008) also reported that PAR rate in mixed wheat and cotton was somewhat higher than in the wheat monoculture. The canopy closure occurred sooner by increasing density of X.strumarium and D.stramonium (light transition at rate of 5%) than weed-free maize canopy. Crop leaf growth and canopy development decreased during the growing season due to weed competition in the mixture, caused reduced PAR absorbed by the crop canopy (Fig. 7). PAR transmission from canopy considerably decreased in the multi-species competition scenario than maize monoculture. The rate of decrease in PAR transmission also increased with density (Fig. 8). In the first sampling, higher X. strumarium proportion in the mixture caused more reduction in PAR transmission from the canopy. However, the reduction was similar at all of the mixture proportions late in the season. Cavero et al (1999) reported that the PAR absorbed percentage of mixed canopy of maize and D. stramonium was more than maize canopy under weed free conditions. Thus, PAR transmission from the canopy decrease by plant density and canopy closure in the mixture and consequently PAR transmission reduction occur earlier in the growing season.

**Conclusion**

X. strumarium was a stronger competitor than D. stramonium with maize. It had more effects on maize LAI, height, leaves senescence and reduction in light transmission from the mixed canopy. In general, maize LAI and height substantially affected by weed density and prolonged period of weed competition. Maize leaves senescence also increased with weed density indicating severity of competition. Therefore, for efficient control of these weeds species in maize, weed
control measures has to be take into consideration early in the growing season

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