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

Hassan Karimmojeni[1*], Hamid Rahimian Mashhadi[2] , Saeed Shahbazi[2], Alireza Taab[3], Hassan Mohammad Alizadeh[2]

[1]Department of Agronomy and Plant Breeding, College of Agriculture, Isfahan University of Technology, Iran
[2]Department of Agronomy and Plant Breeding, Agricultural and Natural Resources Campus, University of Tehran
[3]Department of Agronomy, Faculty of Agriculture, Ilam University, Ilam, Iran

***Corresponding author: kmojeni@cc.iut.ac.ir**

Abstract

Field experiments were conducted in 2006 and 2007 to evaluate *Xanthium strumarium* and *Datura stramonium* single and multi-species 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. s*tramonium. 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			
IWM	Integrated weed management	PAR	Photosynthetic active radiation
LAI	Leaf area index	A	Amount of light receiving above the canopy
WAP	Week after planting	B	Amount of light passing the mixed canopy
H_t,	Plant height (cm) at time T	Y	The light percentage passing of the mixed canopy
H_{max}	The maximum plant height (cm)	X	Days after planting of maize
H_{50}	Number of days to reach 50% of final plant height (day) (H_{max})	a, b	Coefficients of the equation
b	The slope around H_{50}	R^2	Coefficient of determination

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 (Buhler, 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. stramoium* 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) and 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. stramoium* 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[a] fitted to maize height data in monoculture and in competition with *Xanthium strumarium* or *Datura stramonium*. Values in the parentheses are standard errors.

Weed density	2006				2007			
(plant m^{-2})	H_{max}[b] (cm)	H_{50} (day)	*b*	R^2	H_{max} (cm)	H_{50} (day)	*b*	R^2
	X. strumarium							
0 (monoculture)	213.02 (4.7)	53.70 (1.09)	0.10 (0.01)	0.99	232.00 (1.95)	45.11 (0.41)	0.15 (0.01)	0.99
4	214.29 (6.54)	55.27 (1.5)	0.09 (0.01)	0.99	226.32 (1.89)	45.13 (0.41)	0.14 (0.07)	0.98
8	202.99 (5.7)	54.88 (1.4)	0.09 (0.01)	0.98	228.01 (6.29)	45.87 (1.41)	0.12 (0.01)	0.99
12	200.11 (4.9)	54.83 (1.24)	0.09 (0.01)	0.99	226.53 (6.4)	46.63 (1.46)	0.11 (0.01)	0.98
16	198.88 (5.24)	55.42 (1.29)	0.10 (0.01)	0.98	223.09 (5.23)	46.60 (1.19)	0.11 (0.01)	0.99
	D. stramonium							
4	206.04 (6.8)	56.12 (1.6)	0.09 (0.01)	0.99	229.30 (3.4)	46.34 (0.75)	0.12 (0.01)	0.98
8	189.66 (6.5)	54.74 (1.72)	0.09 (0.01)	0.99	225.51 (5.6)	47.33 (1.26)	0.11 (0.01)	0.99
12	179.34 (9.77)	56.83 (2.7)	0.07 (0.01)	0.98	228.21 (6.61)	48.54 (1.5)	0.10 (0.01)	0.98
16	180.17 (6.79)	56.08 (1.9)	0.08 (0.01)	0.99	220.54 (5.52)	49.78 (1.29)	0.09 (0.01)	0.99

[a]$H_t=H_{max}/(1+ (T/H_{50})^b)$ [a]Abbreviations: H_{max}, maximum plant height; H_{50}, time to reach 50% H_{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 Bazzaz, 1994). Leaf senescence in white clover (*Trifolium repens* L.) (Woledge, 1986) and maize (Cavero 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 in 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 250 and 150 kg ha^1, respectively, each year in spring before planting. Moreover, 200 kg ha^{-1} N (as urea) was added at the 6-8 leaf growing stage of maize along with irrigation. To protect both the crop and weed against *Agrotis*sp. Chlorpyrifos (1.5 L/ha 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 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 hoeing.For both maize and weeds, height and LAI were measured five weeks 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 (Cavero et al., 1999) was fitted to the height data measured in each treatment separately by year: Eq. (1)

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

where H_t, is plant height (cm) at time T; H_{max}, is the maximum plant height; H_{50}, describes number of days to reach 50% of final plant height (H_{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

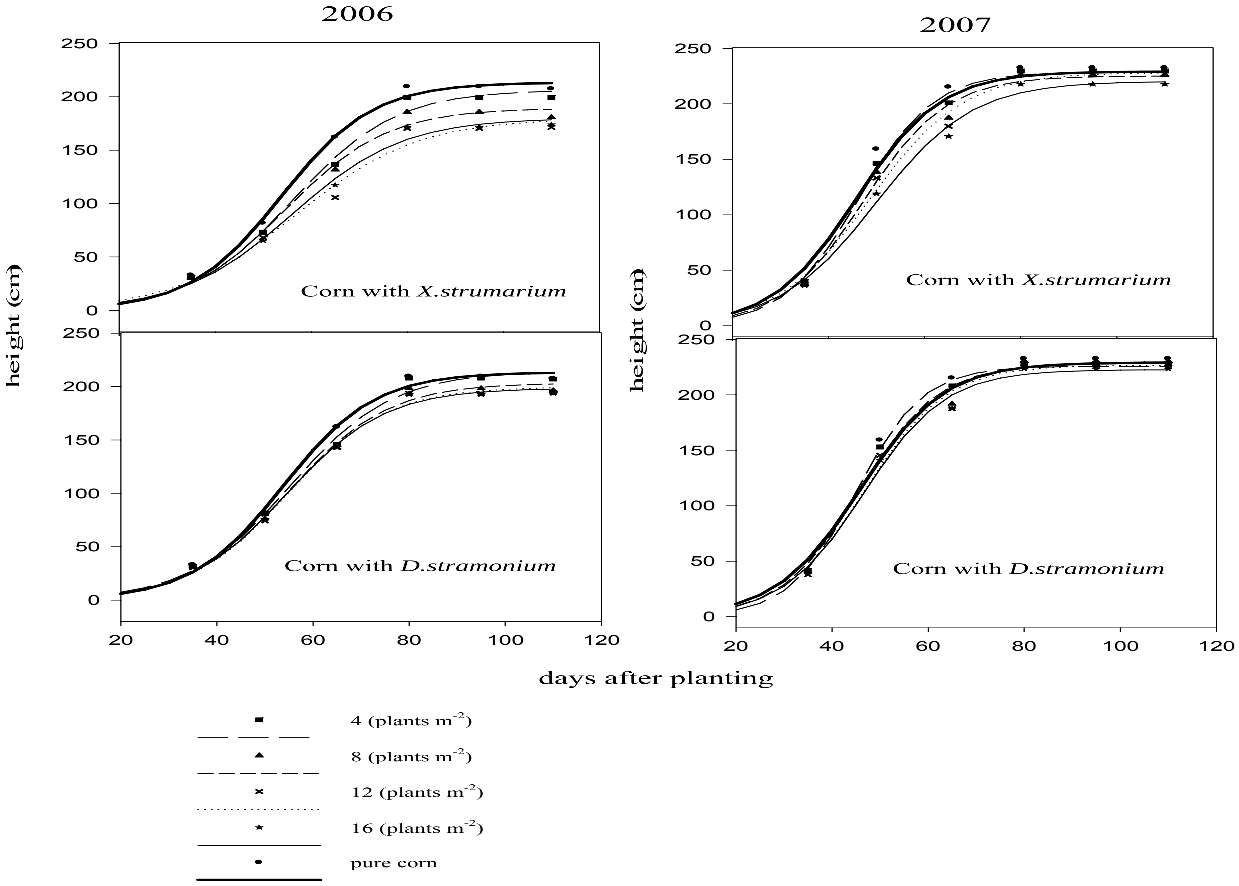

Fig 1. Changes in maize height over time as affected by *Xanthium strumarium* or *Datura stramonium* densities in 2006 and 2007. Lines represents the functional logistic model [$H_t = H_{max}/[1 + (T/H_{50})^b]$] fitted to the data. See Table 1 for the regression coefficients.

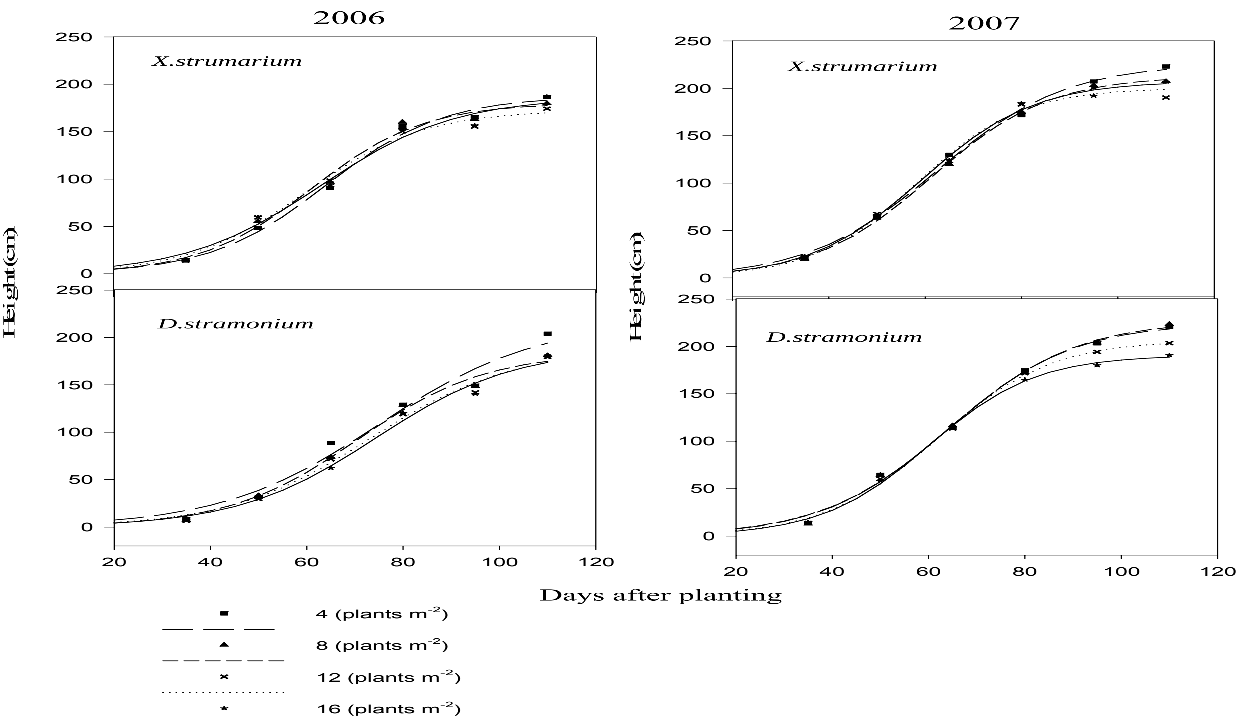

Fig 2. Effect of different densities of *Datura stramonium* or *Xanthium strumarium* on theirs height in single species competition with maize in 2006 and 2007.

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 light passing the mixed canopy was measured (B). The percentage of light passing the canopy in each stage was obtained from Eq. (2): Y= 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 days after planting of maize 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* in 2006. *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 crops 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 time 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. stramoium* 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 higher in 2007 like maize. The weed heights were decreased by increasing their density. In both years, under single species competition, height of *X. strumarium* and *D. stramonium* were lowest at 12 plants m^{-2} and 16 plants m^{-2}, respectively (Fig. 2). In multi-species 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 degreases 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 between maize

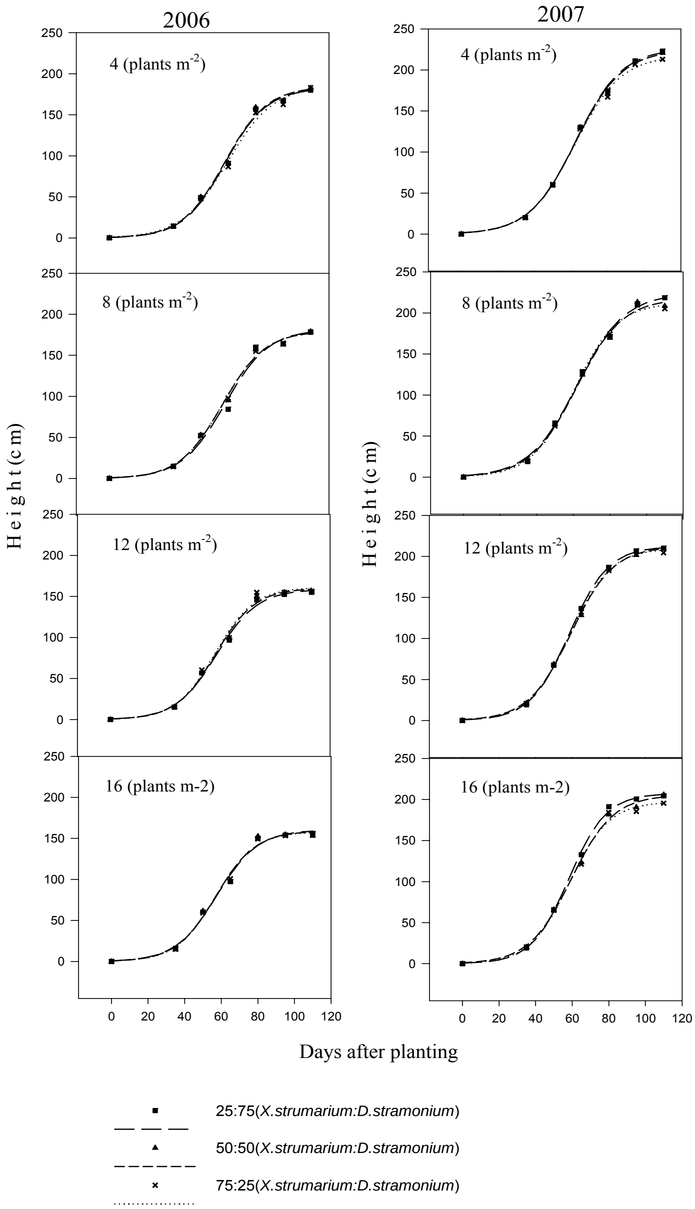

Fig 3. Effect of *Datura stramonium* or *Xanthium strumarium*, at different densities and proportions, on their height in multispecies competition with maize in 2006 and 2007.

and *D. stramonium*, whereas *X. strumarium* reached the height almost equivalent to maize. We concluded that *X. strumarium* could be more successful in light absorption in the mixture than *D. stramonium*. The differences in height of crop and weed can partly be considered as an interaction during competition for light (Rao, 2000). An interesting point is that increased density and proportion of *X. strumarium* in the mixture maximized the difference in height between maize and *D. stramonium* (Fig. 5). Therefore, maize and *X. strumarium* limited the light received by *D. stramonium*. Kropff et al (1992) stated that little difference in height of two plants in time of competition can cause a lot differences in competition.Change in height difference between crop and weeds has been considered as one of the most important effects of weed competition that can be favorable for crop or weeds based on species and purposed conditions (Knezevic et al., 1994).

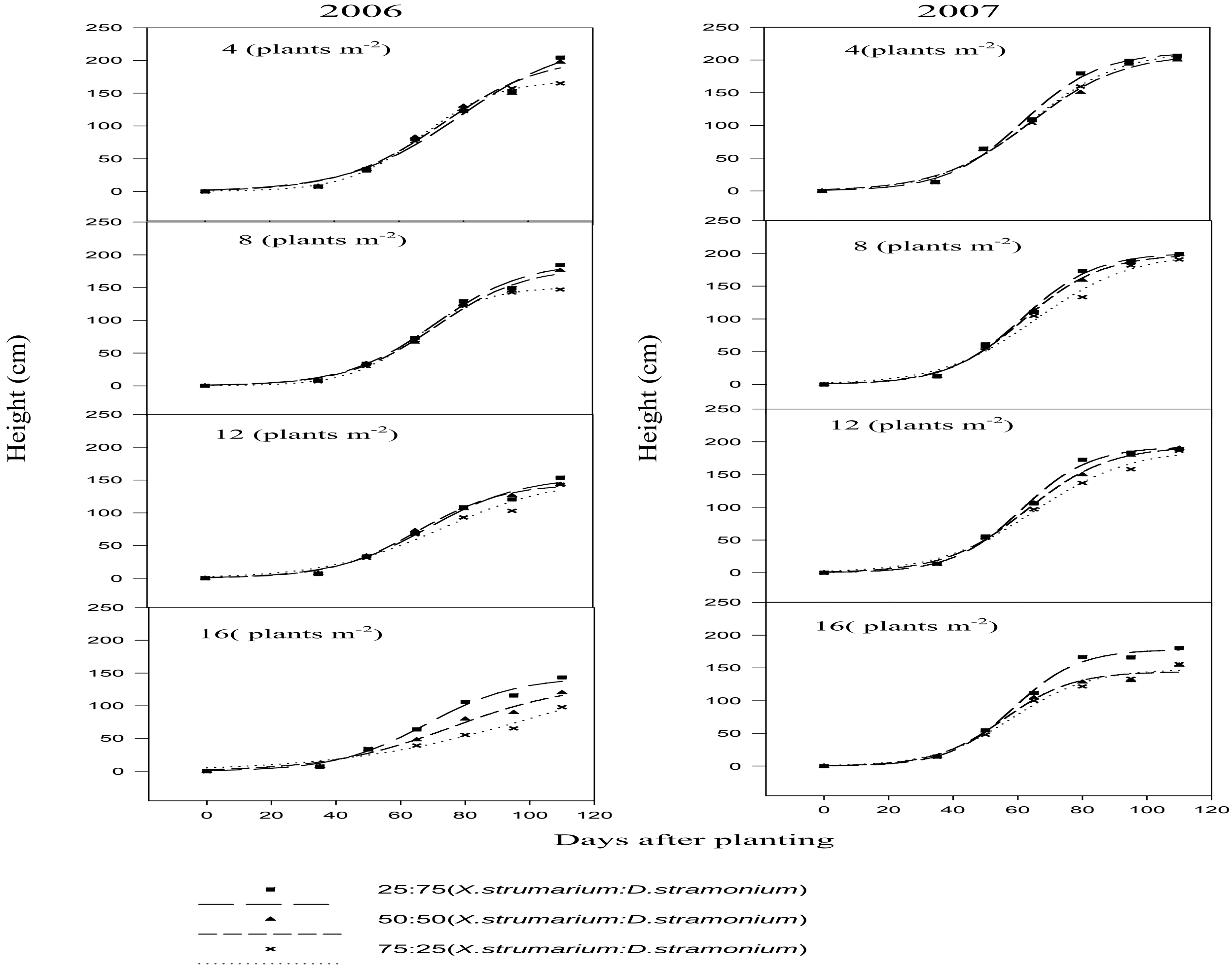

Fig 4. Effect of *Datura stramonium* or *Xanthium Strumarium* at different densities and proportions on *D. stramonium* height in multispecies competition with maize in 2006 and 2007.

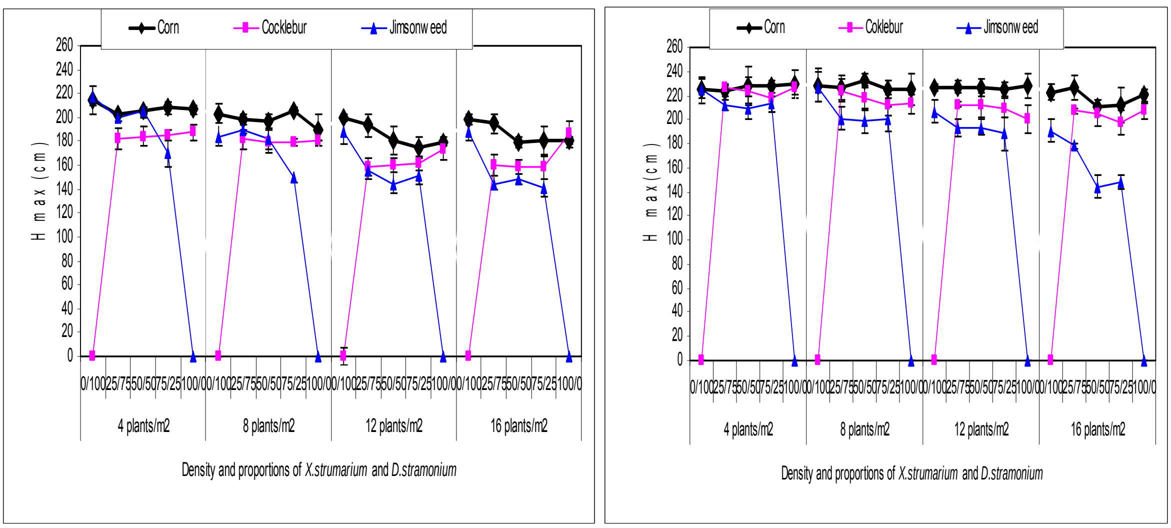

Fig 5. Maximum changes in maize and weeds (*Datura stramonium* or *Xanthium strumarium*) height at different densities and proportions of these two weeds in 2006 (left) and 2007 (right).

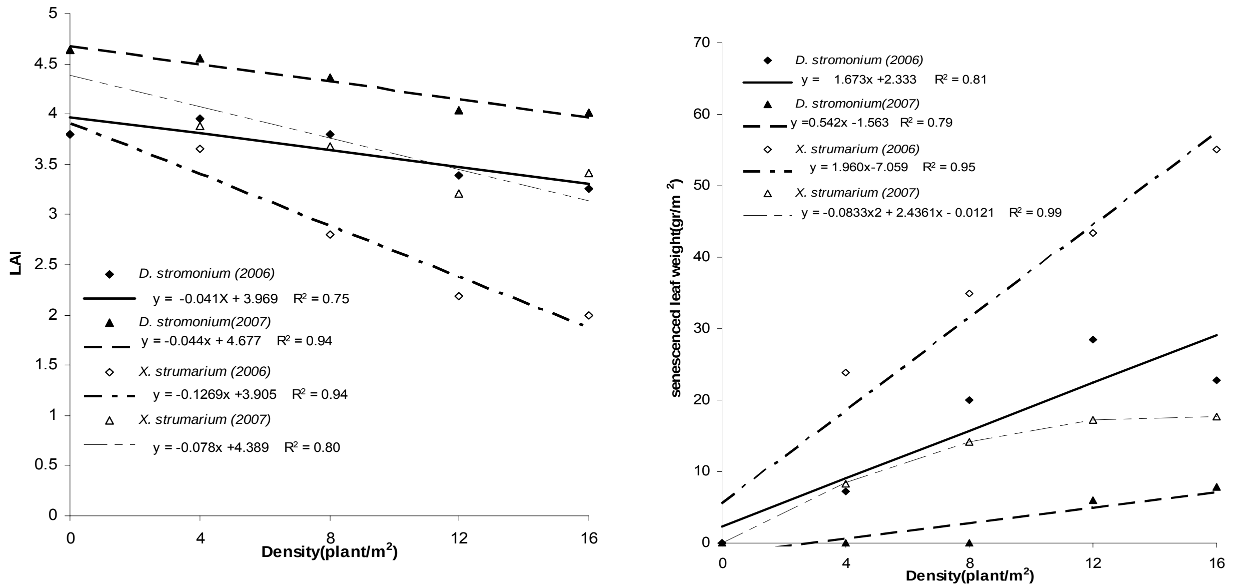

Fig 6. Effect of *Datura stramonium* or *Xanthium strumarium* densities on maize LAI and leaf senescence at maize silking growth stage in 2006 and 2007.

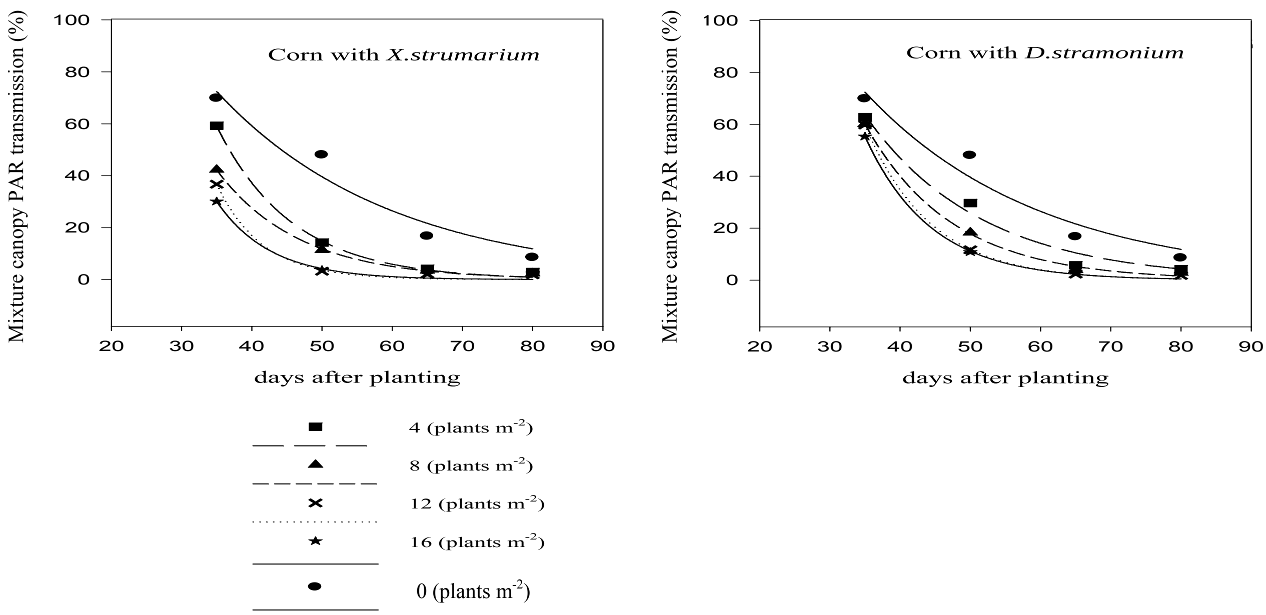

Fig 7. Effect of *Datura stramonium* or *Xanthium. strumarium* densities on light transition percentage of mixed canopy of maize:*X. strumarium* or maize: *D. stramonium*.

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. stramoium* (Fig. 6). However, *X. strumarium* caused more reductions in maize LAI than *D. stramoium*. It reduced maize LAI by 47% in 2006 and 26% in 2007 at the density of 16 plant m^{-2}. At the same density, *D. stramoium* 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. stramoium* (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 photosysnthesis

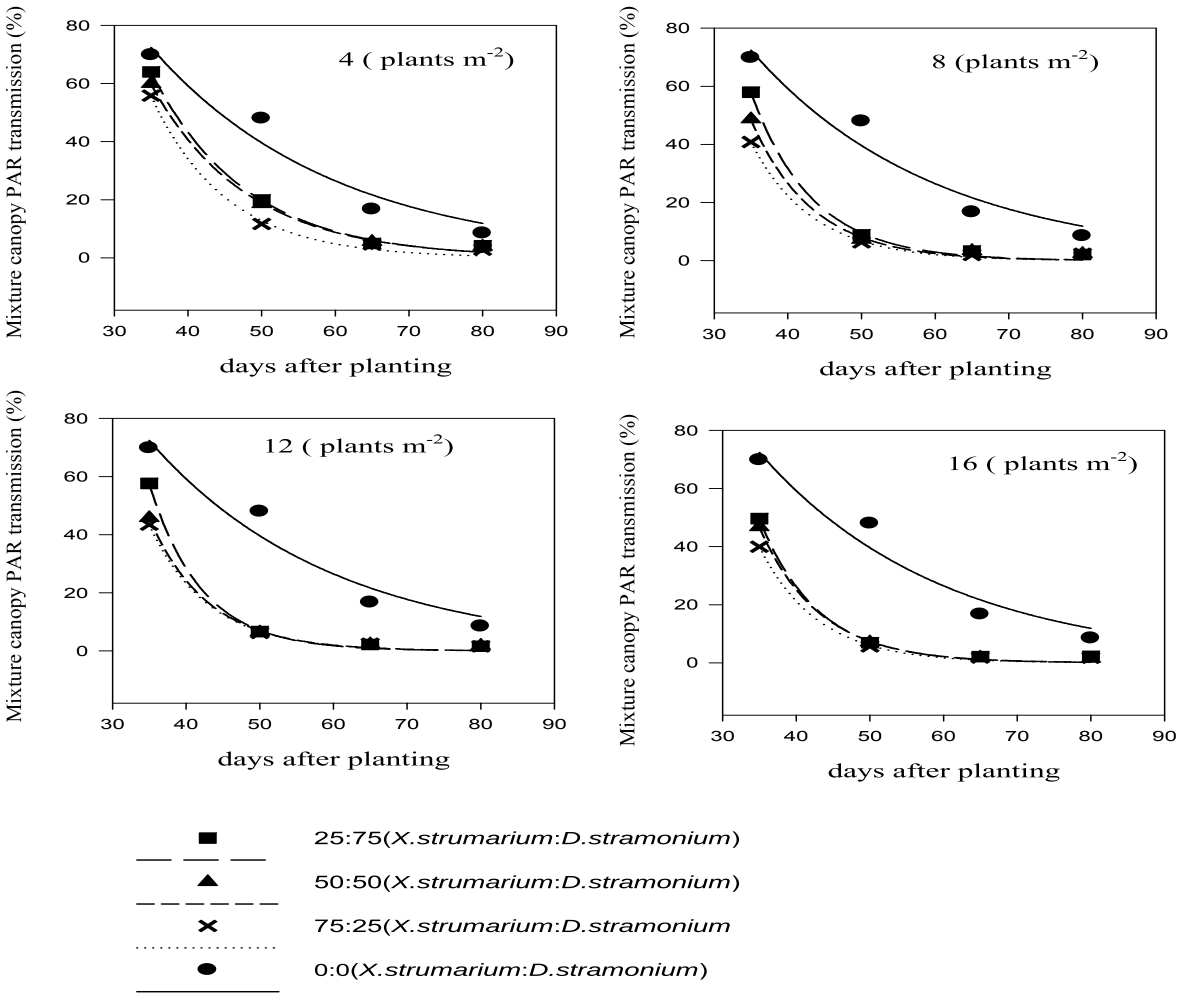

Fig 8. Effect of *Datura stramonium* or *Xanthium strumarium* at different densities and proportions on light transition percentage from mixed canopy in maize

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 leaves 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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