Iranian Journal of Weed Science 5 (2009) 39-53

مجله دانش
علف‌های هرز

Corn and Soybean Intercropping Canopy Structure as Affected by Competition from Redroot Pigweed (*Amaranthus retrofelxus* L.) and Jimson Weed (*Datura srtramonium* L.)

M. Aghaalikhani[1*], F. Zaefarian[2] , E. Zand[3] , H. Rahimian Mashhadi[4] and M. Rezvani[5]

[1]Department of Agronomy, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran, Department of Agronomy and Plant Breeding, Sari Agricultural Sciences and Natural Resources University, Mazandaran, Iran. [3]Department of Weed Research, Iranian Plant Protection Research Institute, Iran.[4]Department of Agronomy, Faculty of Agriculture, University of Tehran, Tehran, Iran.[5] Department of Agronomy and Plant Breeding, Qaemshahr Branch, Islamic Azad University, Qaemshahr, Iran

(Received 17 January 2010; returned 16 June 2010; accepted 25 May 2011)

ABSTRACT

In order to determine the role of plant leaf area in radiation distribution within the canopy and a better understanding of how crops and weeds intercept light a study of the complexity of plants is necessary. The effect of intercropping on leaf area distribution and dry matter accumulation in corn, soybean and weeds canopy was studied in a field experiment at a research field of Tehran University (Karaj campus), during 2007 growing season. Treatments were arranged in a factorial experiment based on randomized complete blocks with three replications. The treatments were five different mixing ratios of corn (*Zea mays* L.) and soybean (*Glycine max* L.) including 100/0, 75/25, 50/50, 25/75 and 0/100 (corn/soybean). Crops were planted at four levels of weed infestations, including weed free, infested to redroot pigweed (*Amaranthus retroflexus* L., AMRET), infested to jimsonweed (*Datura stramonium* L., DASTR) and mixed stands of both weeds species (DASTR+AMRET). Results showed that in weed free corn pure stand, 30.36% of the maximum leaf area was distributed in 90-120 cm layer, but when corn was grown with jimsonweed or infested with both weed species (DASTR+AMRET), the maximum leaf area were established in the upper layer. Soybean weed free monoculture produced 34.66% of its total biomass in the layer of 30-60 cm, but contaminated soybean with DASTR+AMRET, allocated 32.97% of its biomass in the 60-90 cm layer. In this treatment *DASTR* had also its maximum biomass (49.54%) in the 120-150 cm layer. Soybean canopy in monoculture couldn't compete with weeds and was suppressed, but intercropped soybean with the corn especially in 50%: 50% mixing ratio, suppressed the weeds successfully. Therefore we can concluded that complementarily effect of corn/soybean intercropping created better condition for optimum utilization of solar radiation to successfully suppress weeds and maintain crop production.

Key words: canopy structure, leaf area distribution, legume/cereal intercropping

INTRODUCTION

Amount and vertical distribution of leaf area are essential for estimating interception and utilization of solar radiation of crop canopies and, consequently dry matter accumulation (Sivakumar & Virmani, 1984; Valentinuz & Tollenaar, 2006). Vertical distribution of leaf area is leaf areas per horizontal layers, based on height (Boedhram *et al.*, 2001). The presence of weeds intensifies competition for light, with the effect being determined by plant height, position of the branches, and location of the maximum leaf area (Holt, 1995).

The effect of leaf area distribution on light competition can be illustrated by dividing the canopy into horizontal layers (Wiles & Willkerson, 1991). Evaluating the interference of common cocklebur (*Xanthium strumarium*) and entire leaf of morning glory (*Ipomoea hederacea*) on soybean indicated that the crop LAI within a given canopy stratum was smaller in multi-species plots than those of soybeans grown alone or with single weed species and soybean plants also developed a large proportion of their leaf area in the upper portion of the canopy (Mosier & Oliver, 1995). Growth assessment of corn (*Zea mays* L.) in monoculture and in competition with *Datura stramonium* L. showed faster growth of corn leaf area and height reduced the photosynthetically active radiation (PAR) received by the weed. Corn had 70% and *Datura stramonium* had 95% of its leaf area in the upper half portion of the plant while weed competition did not affect the canopy architecture of corn (Cavero *et al.*, 1999). In the study of (Massinga *et al.*, 2003), palmer amaranth (*Amaranthus palmeri*) LAI increased with increasing its density from 0.5 to 8 plants.m^{-1}. While at low plant densities, 60% of palmer amaranth's leaf area occurred between 0.5 and 1.5 m. As plant density increased, 80% of the leaf area was concentrated above 1 m.

Above-ground biomass is one of the central traits in functional plant ecology and growth analysis. It is a key parameter in many allometric relationships (West *et al.*, 1999; Niklas & Enquist, 2002). The vertical biomass distribution is considered to be a main determinant determine of competitive strength in plant species (Schwinning & Weiner, 1998; Tackenberg, 2007). Many vegetation and yield variables are potentially influenced by the competition of the plant with a second crop in an intercrop system and by competition with other plants of the same species in monocrop systems, all being affected by changes of plant population density (PPD) (Fortin *et al.*, 1994). In monocrop systems, soybean plants are more sparsely branched at greater densities than at lower densities. Soybean height, LAI and light interception increased with increasing PPD (Boquet, 1990, Parvez *et al.*, 1989; Foroutan-pour *et al.*, 1999).

Although yield variability in corn and soybean intercrop systems has been the focus of much research work (e.g. Hayder *et al.*, 2003; Egbo *et al.*, 2004), there is little information on vertical distribution of leaf area and biomass in weed-crop components of an intercropping system (e.g. in corn-soybean mixed cropping).

Therefore, in this research we concentrate on leaf area and biomass changes in the mentioned crops and weeds.

MATERIALS AND METHODS

The experiment was conducted at research field of Tehran University (Karaj campus), during the growing season of 2007. Soil characteristics were clay-loam with 1.67% organic matter, 0.093% total N, 46.67 ppm P and 393.33 ppm K. Seedbed preparations were a deep tillage in previous autumn and two vertical diska and leveller in spring. Fertilization was done separately for each crop, in such a manner 400 $kg.ha^{-1}$ urea and 250 $kg.ha^{-1}$ ammonium phosphate for the corn row, applied in two stages, first split (200 kg) of urea and whole phosphorus fertilizer, and the second split of urea was applied at 6-8 leave stages. For soybean 150 $kg.ha^{-1}$ ammonium phosphates with 50 $kg.ha^{-1}$ urea were applied at early growing season. No diseases and insect were observed.

Treatments were established in factorial arrangement based on randomized complete blocks design with three replications. The treatments were five different mixing ratios of corn (*Zea mays* L.) and soybean (*Glycine max* L.) including(corn/soybean): 100/0 (P_1), 75/25 (P_2), 50/50 (P_3), 25/75 (P_4) and 0/100 (P_5) Which were planted at four levels of weed infestations: weed free (W_1), infested to redroot pigweed (*Amaranthus retroflexus* L. AMRET) at 25 plant m^{-2} (W_2), infested to jimsonweed (*Datura stramonium* L., DASTR) at 25 plant m^{-2} (W_3) and mixed stands of redroot pigweed and jimsonweed at total density of 25 plant m^{-2} (W_4).

Each plot had 6 rows with 60 cm inter row space and 6.5 m length. Corn (cv. K.SC. 500) and soybean (cv. Williams) were planted on June 5th with arrangement of 20 * 60 cm and 25*60 cm for corn and soybean respectively. The weed seeds which were collected last year from the research farm were kept at 4º C before sowing, then simultaneously sown 15 cm apart from crop rows at either two sides.. Weed seedlings were thinned to 15 plants per row meter at two-leaf stage. All weed species except of our target species were thinned in two stages until 8 leaves of corn. Field was irrigated with a seven days interval.

At corn canopy closure (50% silking), a vertical card board frame marked in 30-cm increments was used in the field as a guide to cut standing plants (both crops and weeds) into 30-cm strata increments with hedge shears (Mosier & Oliver, 1995). All samples were transferred to the laboratory, leaves and stem were separated and for every sample the area of green leaves was measured with a leaf area meter LICOR-3000 A (LI-COR, Lincoln, NE, USA). Afterwards all samples were oven-dried at 80 °C for 72 hours and weighted. Both leaf area and biomass were calculated as percentage (%) in relation to whole plant.

At the end of growing season, all plants in 2 meters of 4 rows were harvested in each plot, to evaluate the crop yield. The land equivalent ratio (LER) gives an accurate assessment of the greater biological efficiency of the intercropping situation and was calculated as equation (1):

Equation

(1): LER=(Yab/Yaa)+(Yba/Ybb)

LER = RYc +RYs

Where Yaa and Ybb are yields of sole crops and Yab and Yba are yields of intercrops. We considered RY_c and RY_s as relative yield of corn and soybean respectively. LER values greater than 1 were considered advantageous.

RESULTS AND DISCUSSION

Corn Monoculture

In monoculture of corn the maximum leaf area was 30.36% in weed free, while when grown in presence of one or two weed species, this index was higher (Figure 1 a, b, c & d). Similar to other studies corn allocated more leaf area to the upper layer in presence of weeds. (Rajcan & Swanton, 2001 & Cavero *et al.*, 1999). In sever competitiveness (intra & inter specific competition) there was no leaf area in layer 0-30 cm since plant ability to allocate green shoot in upper layer is one of the main traits therefore changing canopy architecture is very important in competition (Aerts, 1999). In corn infested to *DASTR*, and *DASTR* + *AMRET* the maximum leaf area of weeds was in layer 120-150 cm (Figure 1 f & g), while in corn infested to *AMRET*, the maximum leaf area (67.79%) was in layer 90-120 cm (Figure 1 e).

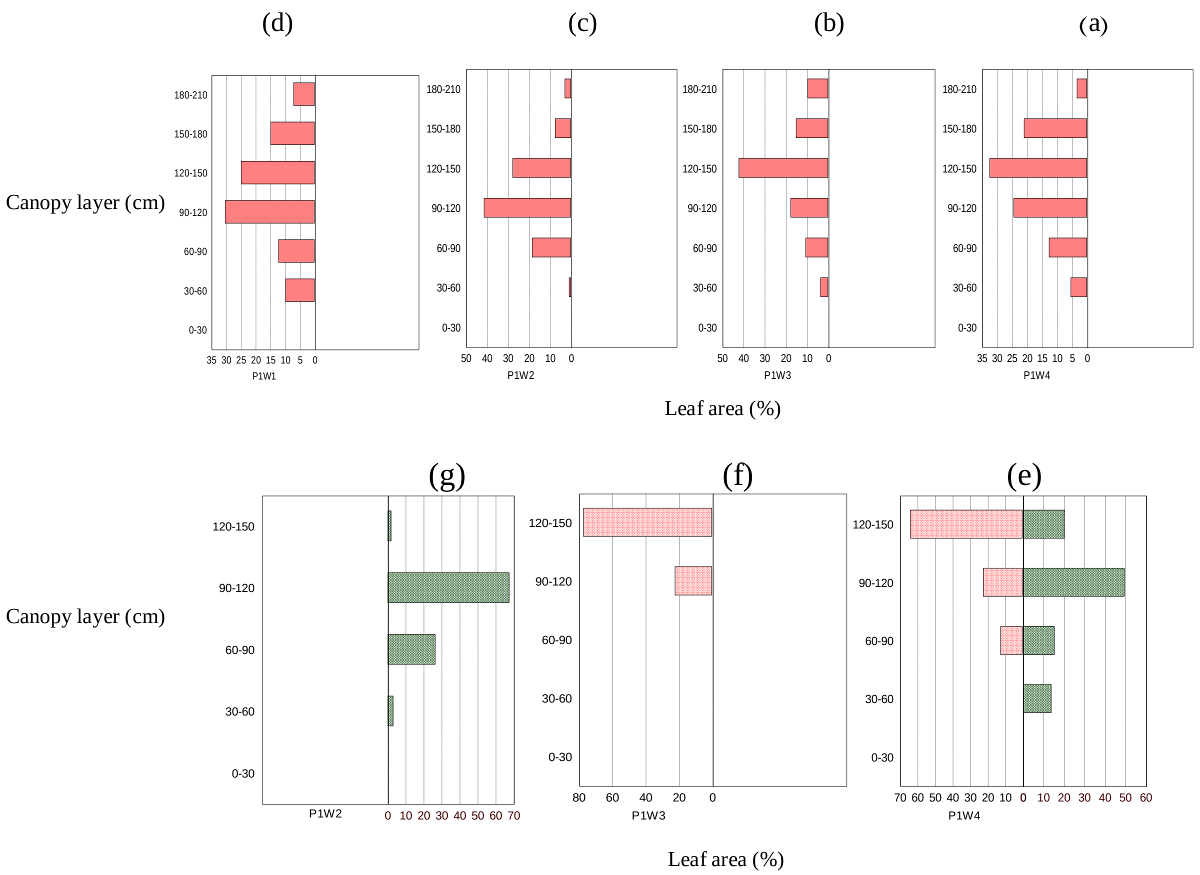

Figure 1. LAI profiles of corn , *A. retroflexus* and *D. stramonium* in 100% corn: 0% soybean.

The maximum amount of corn biomass (42.7 & 42.96 %) in weed free and in competition condition with *AMRET* were established in layer 90-120 cm, but in corn infested with *DASTR* and *DASTR* + *AMRET* the maximum amount of corn biomass (45.19 & 46.63%) was in layer 120-150 cm (Figure 2 a, b, c & d), which could be for the reason of ear formation in this layer.

Profiles of weeds biomass distribution in these treatments showed that, when corn competed with *DASTR* this weed also had translocated the most percentage of biomass to the highest layer (Figure 2 e). This rate of biomass was for the reason of formation of the most part of leaf area in this layer. The main characteristics that allowed this weed to compete against a strong competitor such as corn was its height plasticity, canopy architecture, concentrated leaves in the upper part of the plant, and higher light extinction coefficient. An important feature is its indeterminate growth habit, which allows continuous increase in height (Stoller & Wolley, 1985). This condition also, was in both weed contamination (Figure 2 g). This distribution pattern of biomass seems to be for more radiation capturing.

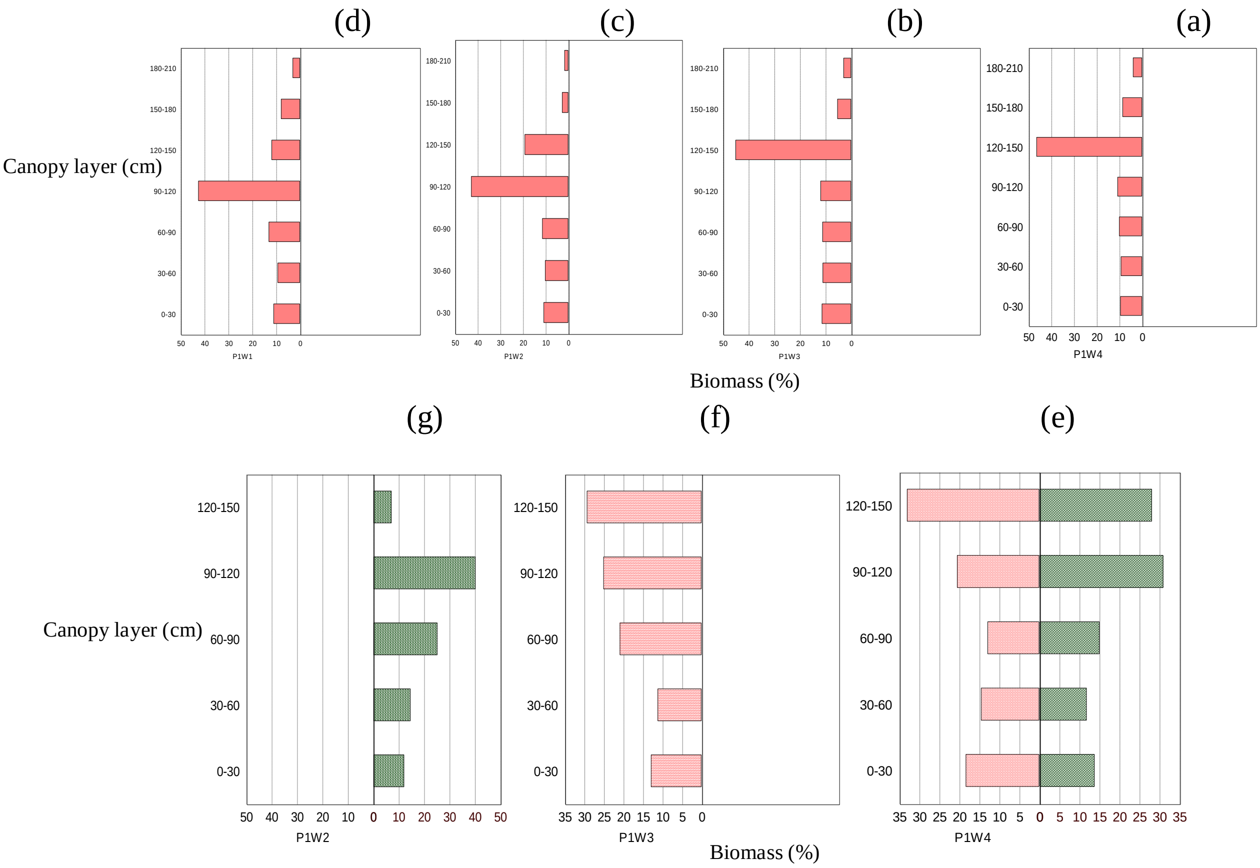

Figure 2. Biomass profiles of corn , soybean , *A. retroflexus* and *D. stramonium* in 100% corn: 0% soybean.

50% Corn: 50% Soybean Ratio

In weed free canopy of corn the greatest leaf area (28.56%) was found in layer 90-120 cm followed by layer 60-90 cm which had less leaf area (27.75%) than the above layer (Figure 3 a). which could be concluded that in the absence of weed, corn contributes its leaf area in lower layers. When corn was grown with *AMRET*, *DASTR* and both weed species, more leaf area was established between 120-150 cm. In such conditions weeds can not compete for light with crops.

Soybean in weed free unit had maximum leaf area (43.68%) in layer 30-60 cm. When grown with weed the maximum leaf area were formed in layers 60-90, 90-120, 90-120 cm in plots which were infested to *AMRET*, *DASTR* and *AMRET+DASTR* (50.96, 37.57 and 37.30%) respectively. Soybean plants developed a large proportion of their leaf area in the upper portion of the canopy, indicating their competition for available light in the canopy (Mosier & Oliver, 1995). In this ratio, crops in weed infested treatments expanded their leaf area and suppressed weeds for radiation capture. Therefore it is concluded that intercropping can be used as a tool to improve competitive ability of a canopy with good suppressive characteristics. Planting patterns would also provide better light distribution to obtain higher biomass accumulation rates and higher yields.

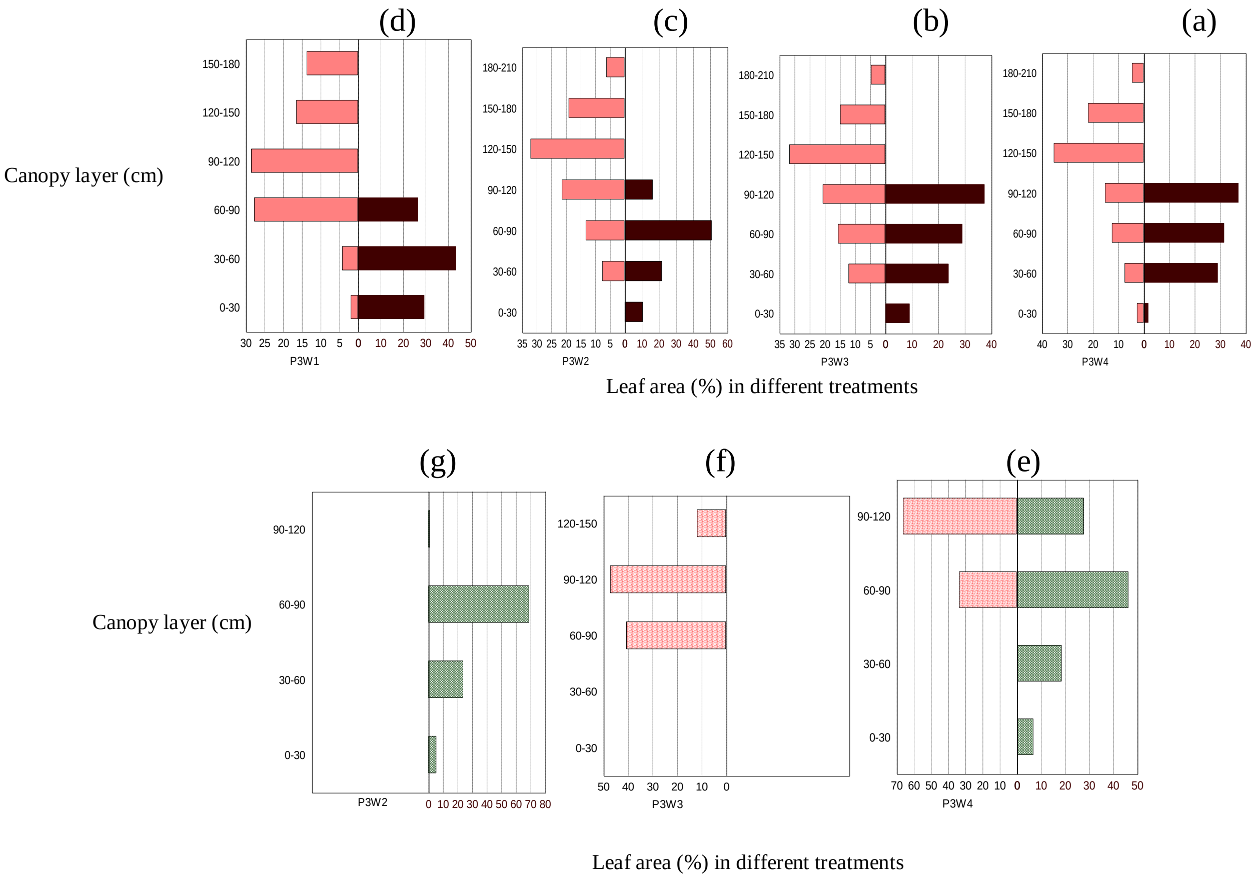

Figure 3. LAI profiles of corn , soybean , *A. retroflexus* and *D. stramonium* in 50% corn: 50% soybean.

In 50% corn: 50% soybean ratio, both crops reach to a higher height to compete with weeds (Figure 4 a, b, c & d) while weeds could not compete well with crops, because maximum biomass of *DASTR* and *AMRET* in this treatment was formed in layer 90-120 cm (Figure 4 e, f & g). A faster growth of leaf area and height in crops reduced the photosynthetically active radiation (PAR) received by the weed and consequently reduced weeds growth rate (Cavero *et al.*, 1999). Intercropped systems are reported to use resources higher and more efficiency than monocrop systems, thus decrease the availability of resources for weed production (Caruuthers *et al.*, 1998). In this ratio, crops can conquer weeds and have good growth, with or without weeds.

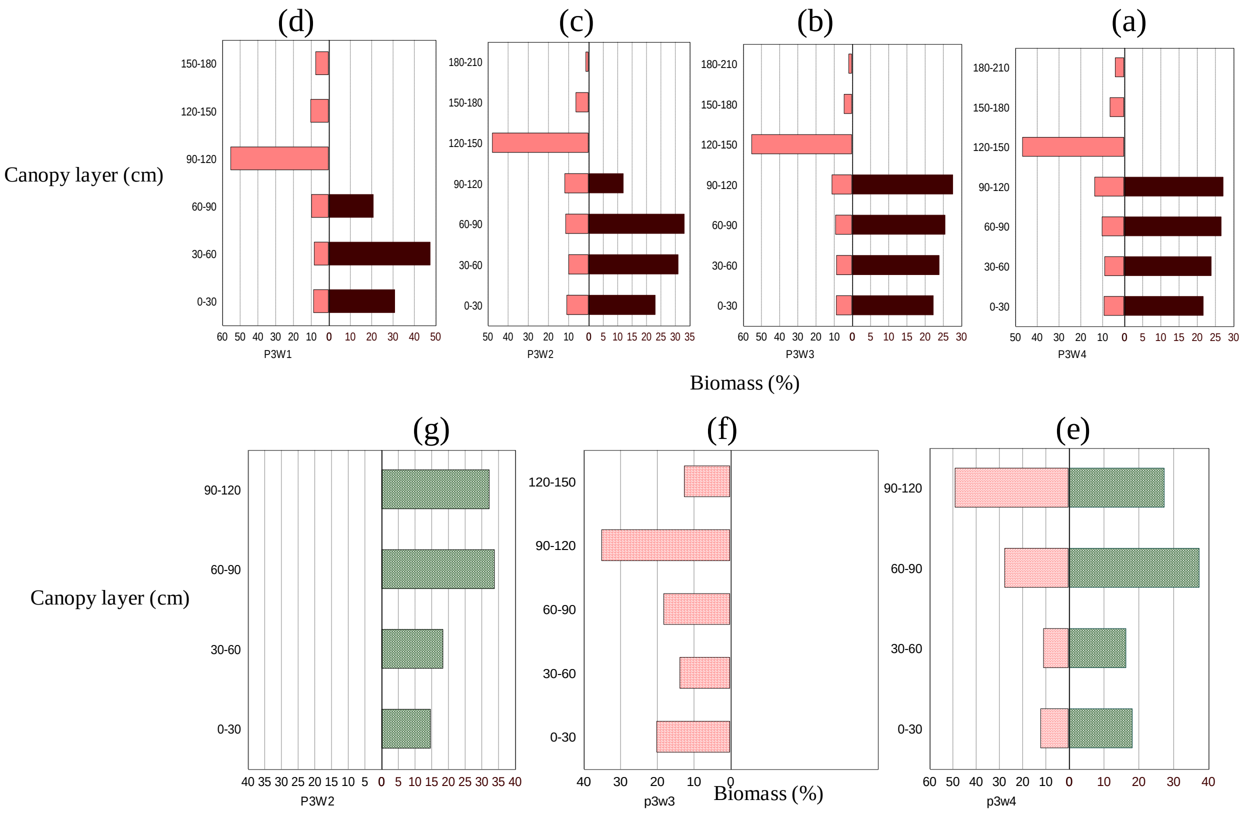

Figure 4. Biomass profiles of corn, soybean, *A. retroflexus* and *D. stramonium* in 50% corn: 50% soybean.

Soybean Monoculture:

Soybean in the weed free treatment, expanded leaf area throughout the whole canopy, but in weed infested plots it allocated its leaf area to upper layers due to inter specific competition (Figure 5 a, b, c, & d). Soybean plants infested to DASTR allocated its leaf area to layer 60-90 cm (47.05 %) (Figure 4 c), which was lower than the weed which shows that the weed is a better competitor than soybean specially when soybean grows by both weeds species (Figure 5 c & d).

Soybean infested to *AMRET* had higher leaf area in a lower layer than the weed (*A. retroflexus)* meaning that when the soybean grows in monoculture, it could not suppress the weed and thus fewer yields, but when it grown with corn, it could suppress weeds due to the similar ability in corn. Therefore in intercropping systems crop partners use resource and grow probably better than in monosulture condition. For this reason they can suppress weeds. The advantage that weeds have over crops for light interception is their height which is one of the best predictions of competitive success in light competition (Holt & Orcutt, 1991). Graham *et al.*, (1988) also observed that by absorbing light in the upper canopy, Palmer amaranth (*Amaranthus palmeri*) and smooth pigweed (*A. hybridus* L.) reduced light penetration into the sorghum canopy. Effects of weed height on light penetration through the crop canopy were reported in competition studies between velvetleaf (*Abutilun theophrasti* Medikus) and soybean (Akey *et al.*, 1990). although Mosier & Oliver, (1995) reported that soybeans grown alone/ monoculture of soybean or with *Ipomoea hederacea*, developed similar canopies and had similar strata LAI values because *Ipomoea hederacea* never acquired enough leaf area or size to affect the soybean canopy with irrigation.

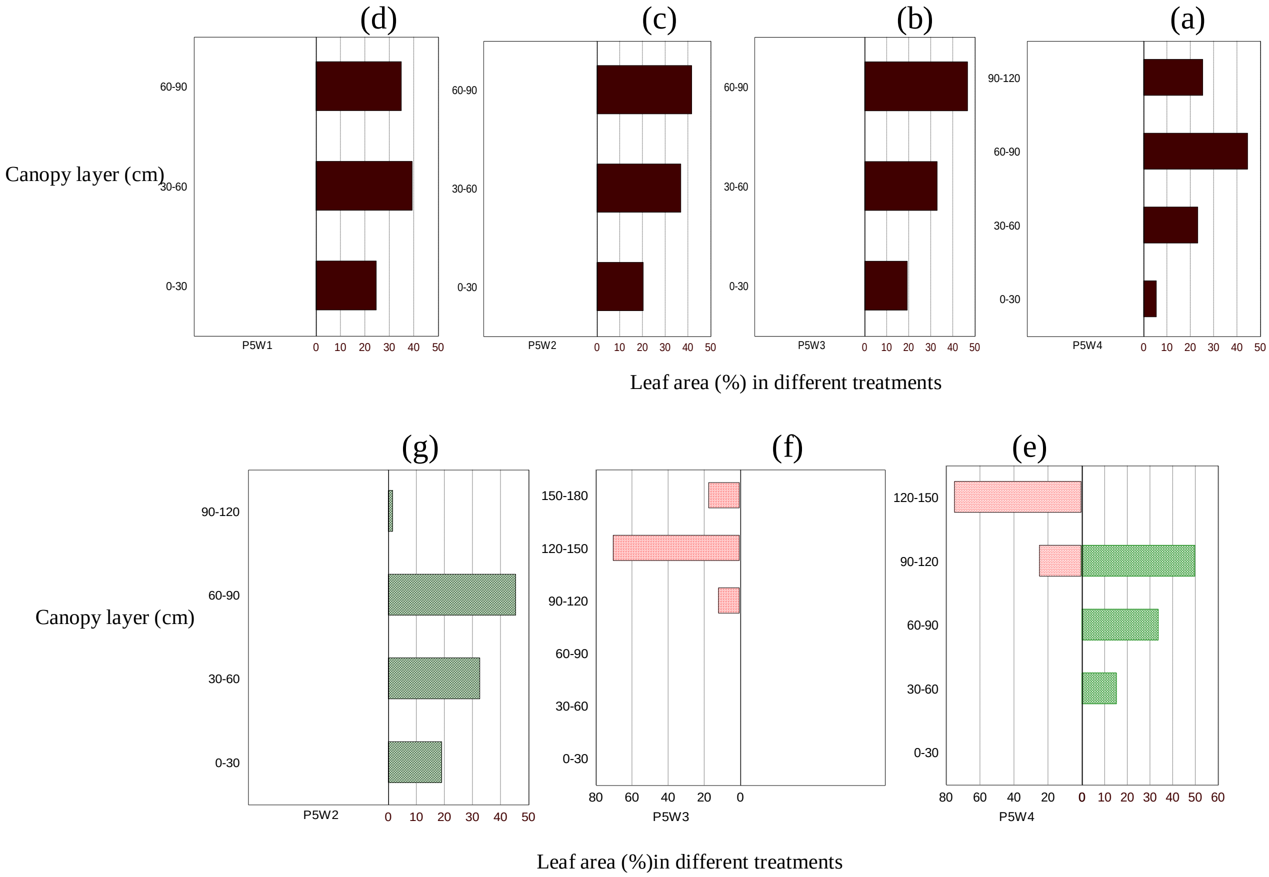

Figure 5. LAI profiles of soybean , *A. retroflexus* and *D. stramonium* in 0% corn: 100% soybean.

In weed free soybean biomass amounts of upper layers of canopy were decreased due to increasing height. This decrement in 30% upper layer was obvious. In non competition condition, soybean tried to have more branching which was caused in lower layers of canopy therefore dry matter accumulation was less in the upper layer. Lack of weed interference for light interception can be considered as an acceptable reason for this event (Figure 10 a). Investigation of biomass profiles of soybean in competition with DASTR, AMRET and DASTR+AMRET showed that soybean changed biomass distribution pattern (Figure 6 b, c & d) in such a manner that higher amounts of biomass were allocated to the upper layers (Figure 6 a, b, c & d). McLachlan *et al.*, (1993) suggested that lack of branching in high density may lead to decreasing light spectral quality as R/FR ratio. High plant density decreased light penetration into the canopy which can restrict stem branching and lateral growth.

Changing the biomass profile in a crop canopy is an important trait in the result of competition and final crop yield. In three way competition between soybean, DASTR and AMRET, jimsonweed had maximum biomass (38.29%) in 120-150 cm which was due to increased height and more branching in the upper layers, while redroot pigweed founded its maximum biomass(45.17%) in layer 90-120 cm (Figure 10 g).

The intensity of aboveground competition experienced by soybean was expected to increase from monoculture to intercropping. The architecture of plant affected the asymmetry of light competition. Corn effectively suppresses its neighbours with creating a deep shade on them. But weeds interference may be reduced by a combination of crop species occupying two or more niches in the field. Intercrops are more effective than sole crops in conquering resources from weeds, resulting to greater crop yield and less weed growth.

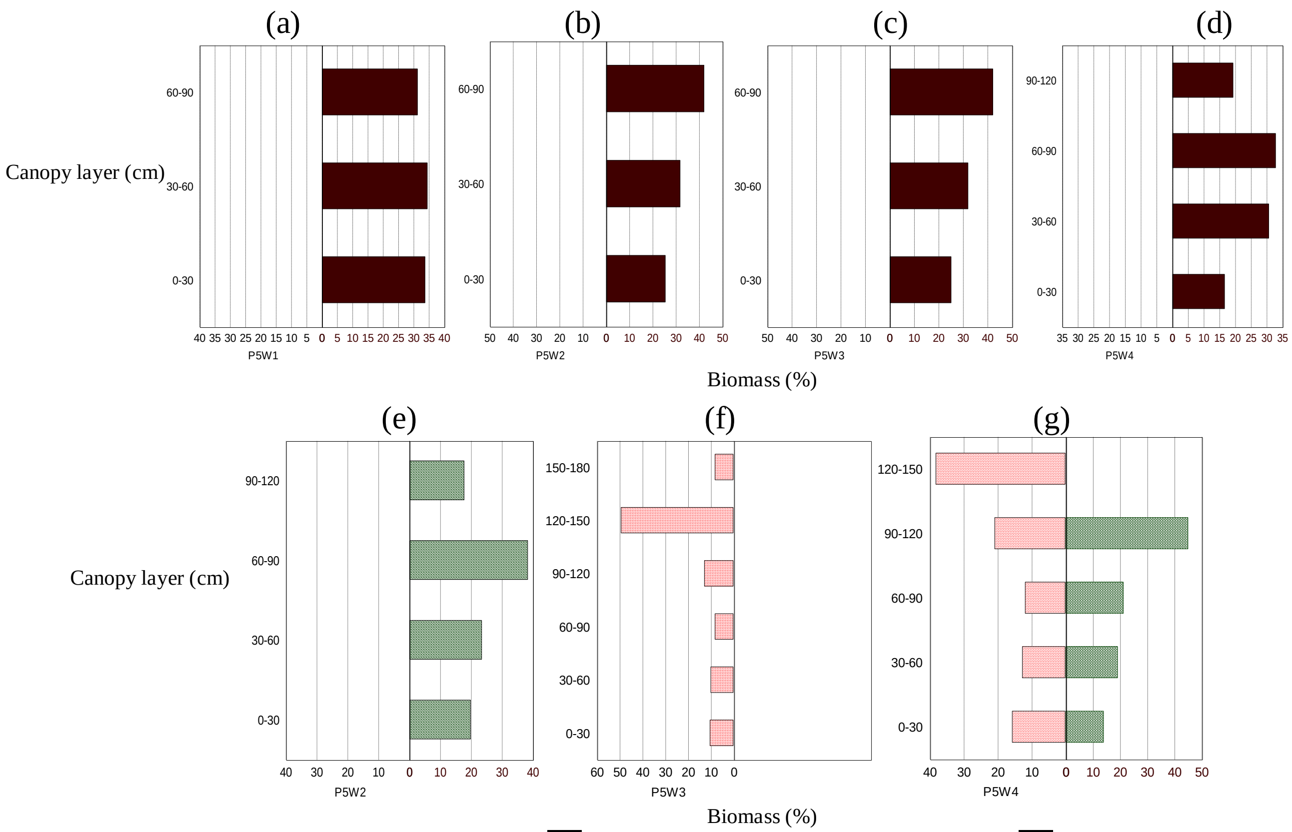

Figure 6. Biomass profiles of soybean ■, *A. retroflexus* ▩ and *D. stramonium* ▩ in 0% corn: 100% soybean.

Corn Yield

Corn/soybean mixing ratio and weed infestation significantly affected corn grain yield ($P<0.001$).The interaction effects was also significant ($P<0.01$). The highest amount of corn grain yield (9627.8 Kg ha^{-1}) was obtained in P_2W_1 treatment and lowest amount (3916.5 kg ha^{-1}) in P_4W_4 (Table 1 & Figure 1). Presence of both weed species had the highest effect on corn yield loss. Yield reduction in treatments of low density corn (P_4) has been contributed to low number of plants and increased weed competition ability for radiation reception and probably higher efficiency of weed roots for water and nutrient uptake.

In many intercropping experiments, consisting legume and grass, intercropping had higher yield compare to monocropping (Morris & Garrity, 1993). In a legume/cereal intercropping, the nitrogen of the associated crop may be improved by direct nitrogen transfer from the legume to cereal (Banik *et al.*, 2006). Legumes, with their adaptability to different cropping patterns and their ability to fix nitrogen, may offer opportunities to sustain increased productivity (Jeyabal & Kuppuswamy, 2001). Normally, productivity is potentially enhanced by the inclusion of a legume in a cropping system (Maingi *et al.*, 2001). Legume intercrops are also potential sources of plant nutrients that complement inorganic fertilizers (Banik & Bagchi, 1994; Banik *et al.*, 2006). Li *et al.*, (2001) showed that yield and nutrient uptake by intercropped wheat, maize and soybean were all significantly greater than monocultures of wheat, maize and soybean with the exception of potassium uptake by maize. Intercropping advantages in yield were 40-70% for wheat intercropped with maize and 28-30% for wheat intercropped with soybean.

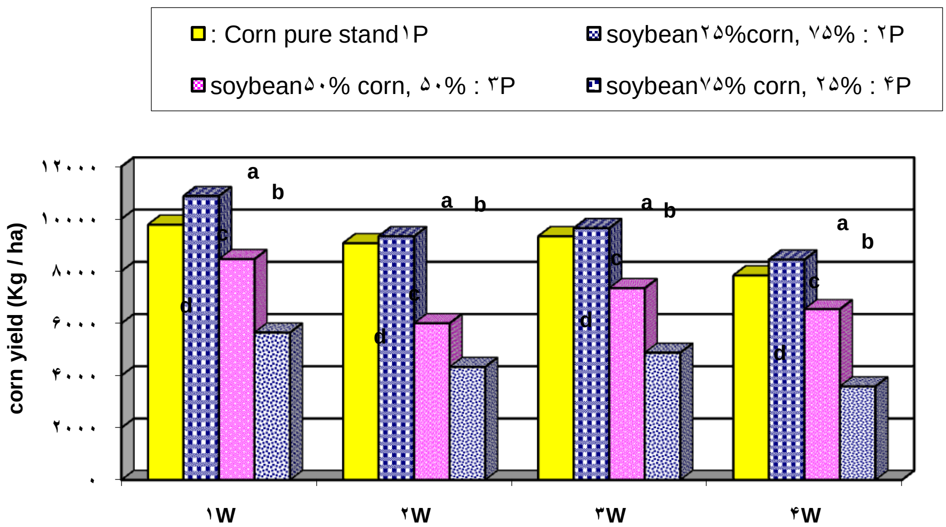

Figure 1. Interaction effect of mixing ratios and weed infestation on corn yield (W1): weed free, (W2): infested to redroot pigweed, (W3): infested to jimson weed and (W4): infested to both weed species.

Many researchers revealed that Leaf area and vertical leaf area profile influence the interception and utilization of solar radiation of corn canopy and consequently, corn dry matter accumulation and grain yield (Valentinuz & Tollenaar, 2006).

Soybean Yield

Both simple and interaction effects of mixing ratios of corn/soybean and weed infestation on soybean grain yield were statistically significant (P<0.001). Results indicated that in all weed infested treatments, soybean monoculture had higher yield than intercropped one (Table 2) mainly due to higher plant density. Similarly in intercropped treatments yield loss could be attributed to inter specific competition. Indeed decrement of soybean ratio in intercropping decreased soybean grain yield because of intensified competition.

Results showed that soybean has less competitive ability than corn in intercropping systems. According to soybean growth nature, it used to allocate part of its resources to symbiosis. Redroot pigweed and jimsonweed infestations caused greatest soybean yield loss in different ratios of intercropping. Simultaneous infestation of AMRET and DASTR have more competitive ability with soybean than one species infestation and caused restricted number of pod per plant, grain number per pod, 1000 grain weigh, and finally caused yield reduction. Banik *et al.*, (2006) confirm that higher grain yield of monocropped wheat and chickpea relative to intercropping treatments may be due to the fewer disturbances in the habitat in homogeneous environment of monocropping systems. The Highest amount of soybean grain yield (5050.0 kg ha^{-1}) was produced in P_5W_1 treatment while the lowest amount (365.67 kg ha^{-1}) was observed in P_2W_4 (Table 2 & Figurer 2).

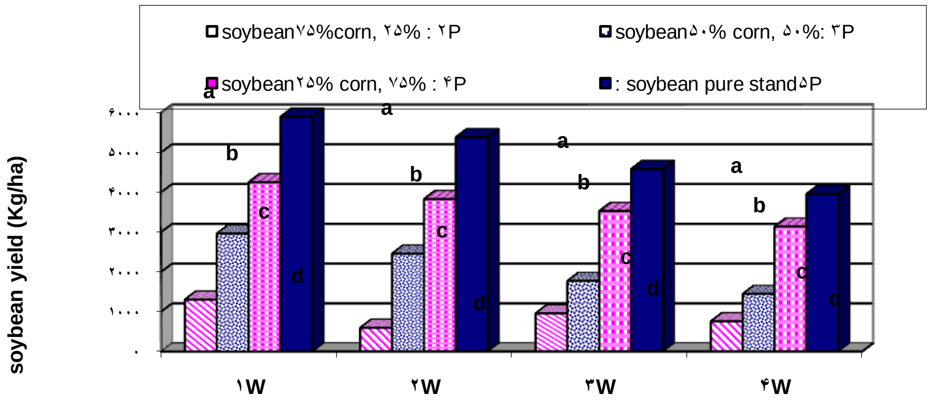

Figure 2. Interaction effect of mixing ratios to weed infestation on soybean yield. (W1): weed free, (W2):infested to redroot pigweed, (W3): infested to jimson weed and (W4): infested to both weed species.

It seems the weed compensated low irradiance by increasing the specific leaf area and partitioning more dry matter initially to stems and later on to leaves which increased the amount of photosynthetically active area in proportion to above – ground biomass, as found when competing with soybean (Regnier *et al.*, 1988).

Conclusion

According to our investigations from corn and soybean grain yield at their monocultures and intercrop, the highest amount of Land Equivalent Ratio (LER) (1.37) was observed in P_3W_1, which had the lowest weed leaf area and biomass, consequently suppressing weeds successfully. Occupied different niches in uptake of resources and reduced competition mechanism resulted in advantage for corn and soybean yield. Neighboring of C_4 (corn) and C_3 (soybean) species in all parts of growth stages not only decreased competition, but also increased facilitative mechanism (Table 1).

It is concluded that intercropping can be used as a tool to improve competitive ability of a canopy with good weed suppressive characteristics. Studies using species with growth forms similar to soybean are therefore needed because since this study suggests that the outcome of intercropping is influenced by the architectural and therefore size response of intercropped species.

Table 1- Land Equivalent Ratio of corn and soybean intercropping.

Treatment	RYc	RYs	LER
P_2W_1	1.12	0.221	1.33
P_2W_2	1.029	0.203	1.23
P_2W_3	1.033	0.208	1.24
P_2W_4	0.928	0.192	1.12
P_3W_1	0.865	0.501	1.37
P_3W_2	0.662	0.458	1.12
P_3W_3	0.787	0.387	1.17
P_3W_4	0.775	0.365	1.14
P_4W_1	0.577	0.721	1.30
P_4W_2	0.477	0.712	1.19
P_4W_3	0.522	0.770	1.29
P_4W_4	0.425	0.762	1.19

REFERENCES

Aerts, R. 1999. Interspesific competition in natural plant communities: Mechanisms, trade-offs and plant-soil feedbacks. *Journal of Experimental Botany* **50:**29-37.

Akey, W. C., Jurrik, T. W. and Dekker. 1990. Competition for light between a velvetleaf (*Abutillon theopharesti*) and soybean (*Glycine max*). *Weed Research* **30:**403-411.

Banik, P. and Bagchi, D. K. 1994. Evaluation of rice (Oryza sativa) and legume intercropping in upland situation of Bihar plateau. *Indian Journal of Agriculture Science*. **64:** 364–368.

Banik, P., Midya, A., Sarkar, B. K. and Ghose, S. S. 2006. Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering. *European Journal of Agronomy* **24:** 325–332.

Boedhram, N., Arkebauer, T. J. and Batchelor, W. D. 2001. Season-Long Characterization of Vertical Distribution of Leaf Area in Corn. *Agronomy Journal* **93:**1235–1242.

Boquet, D. J. 1990. Plant population density and row spacing effects on soybean at post-optimal planting dates. *Agronomy Journal* **82:**59–64.

Carruthers, K., Cloutier, Fe. and Smith, D. L. 1998. Intercropping corn with soybean, lupin and forages: weed control by intercrops combined with interrow cultivation. *European journal of Agronomy* **8:**225-238.

Cavero, J. Zaragoza, C., Suso, M. L. and Pardo, A. 1999. Competition between maize and *Datura sramonium* in an irrigated field under semi-arid conditions. *Weed Research* **39:**225-240.

Egbo, C. U., Adagba, M. A. and Adedzwa, D. K. 2004. Responses of soybean genotypes to intercropping with maize in the Southern Gulinea Savanna, Nigeria. Acta *Agronomica Hungarica* **52:**157-163.

Foroutan-pour, K., Dutilleul, P. and Smith, D. 1999. Soybean canopy development as Affected by population density and intercropping with corn: Fractal Analysis in Comparison with Other Quantitative Approaches. *Crop Science* **39:**1784–1791.

Fortin, M. C., Culley, J. and Edwards, M. 1994. Soil water, plant growth, and yield of strip-intercropping corn. *Journal of Production Agriculture* **7:**63–69.

Fortin, M. C. and Pierce, F. J. 1996. Leaf azimuth in strip – intercropped corn. *Agronomy Journal* **88:**6-9.

Graham, P. L., Steiner, J. L. and Weiese, A. F. 1988. Light absorption and competition in mixed sorghum-pigweed communities. *Agronomy Journal.* **80:**415-418.

Hayder, G., Mumtaz, S. S., Khan, A. and Khan, S. 2003. Maize and soybean intercropping under various levels of soybean seed rates. *Asian Journal of Plant Science*. **2**: 339-341.

Holt, J. S. 1995. Plant responses to light: a potential tool for weed management. *Weed Science* **43:**474–482.

Holt, J. S., Orcutt, D.R. 1991. Functional relationships of growth and competitiveness in perennial weeds and cotton (*Gossypium hirsutum*). Weed Sci. Vol. 39: p.575-584.

Jeyabal, A. and Kuppuswamy, G. 2001. Recycling of organic wastes for the production of vermicompost and its response in rice–legume cropping system and soil fertility. *European Journal of Agronomy* **15:** 153–170.

Li, L., Sun, J., Zhang, F., Li, X., Yang, S. and Rengel, Z. (2001). Wheat/maize or wheat/soybean strip intercropping, I. Yield advantage and inter specific interactions on nutrients. *Field Crops Research*. **71:** 123-137.

Maingi, M. J., Shisanya, A.C., Gitonga, M. N. and Hornetz, B. 2001. Nitrogen fixation by common bean (Phaseolus vulgaris L.) in pure and mixed stands in semi arid South east Kenya. *European of Journal of Agronomy* **14:** 1–12.

Massinga, R. A., Currie, R. S. and Trooien, T. P. 2003. Water use and light interception under Palmer amaranth (*Amaranthus palmeri*) and corn competition. *Weed Science* **51:**523–531.

McLachlan, S. M., Tollenaar, M., Swanton, C. J. and Weise, S. F. 1993. Effect of corn induced shading on dry matter accumulation, distribution, and architecture of redroot pigweed (*Amaranthus retroflexus*). *Weed Science* **41:**568–573.

Morris, R. A. and Garrity, D. P. (1993). Resource capture and utilization in intercropping: non-nitrogen nutrients. *Field Crops Research*.**34:** 303-317.

Mosier, D. G. and Oliver, L. 1995. Common Cocklebur (*Xanthium strumonium*) and Entireleaf Morningglory (*Ipomea hederacea* var. integriuscula) interference on soybean (*Glycine max*). *Weed Science* **43:**239-246.

Niklas, K. J. and Enquist, B. J. 2002. On the vegetative biomass partitioning of seed plant leaves, stems, and roots. *American Naturalist* **159:**482–497.

Parvez, A. Q., Gardner, F. P. and Boote, K. J. 1989. Determinate- and indeterminate-type soybean cultivar responses to pattern, density, and planting date. *Crop Science.* **29:**150–157.

Rajcan, I. and Swanton, C. I. 2001. Understanding maize-weed competition: resource competition, light quality and whole plant. *Field crop Research.* **71:**139-150.

Regnier, E. E., Salvucci, M. E. and Stoller, E. W. 1988. Photosynthesis and growth responses to irradiance in soybean (*Glycine max*) and three broadleaf weeds. *Weed Science* **36:**487-496.

Schwinning, S, Weiner, J. 1998. Mechanisms determining the degree of size asymmetry in competition among plants. *Oecologia* **113:**447–455.

Sivakumar, M. V. K. and Virmani, S. M. 1984. Crop productivity in relation to interception of photosynthetically active radiation. *Agricultural and Forest Meteorology* **31:**131–241.

Stoller, E. W. and Wooley, J. T. 1985. Competition for light by broadleaf weeds in soybeans (*Glycine max*). *Weed Science* **33:**199-202.

Tackenberg, O. 2007. A New Method for non-destructive measurement of biomass, growth rates, vertical biomass distribution and dry matter content based on digital image analysis. *Annals of Botany* **99:** 777–783.

Valentinuz, O. R. and Tollenaar, M. 2006. Effect of genotype, nitrogen, plant density, and row spacing on the area-per-leaf profile in maize. *Agronomy Journal* **98:**94–99.

West, G. B., Brown, J. H. and Enquist, B. J. 1999. A general model for the structure and allometry of plant vascular systems. *Nature* **400:** 664–667.

Wiles, L. J. and Wilkerson, G. G. 1991. Modeling competition for light between soybean and broad leaf weeds. *Agriculture System* **35:**37–51.

چکیده

با توجه به نقش تعیین کننده میزان سطح برگ در توزیع نور در داخل کانوپی، شناخت بهتر چگونگی جذب نور بوسیلهٔ گیاهان زراعی و علف های هرز، مستلزم مطالعهٔ ساختار کانوپی می باشد. به منظور بررسی اثر کشت مخلوط بر توزیع سطح برگ و ماده خشک گیاهی در پروفیل کانوپی ذرت، سویا و علف های هرز، آزمایشی در سال ۱۳۸۶ در مزرعهٔ پژوهشی دانشگاه تهران واقع در کرج به صورت فاکتوریل در قالب طرح بلوک‌های کامل تصادفی با ۳ تکرار انجام شد. تیمار های آزمایشی شامل پنج سطح نسبت اختلاط دو گونه گیاه زراعی ذرت (*Zea mays* L.) و سویا (*Glycine max* L.) به صورت تک‌کشتی ذرت، ۷۵ ٪ ذرت: ۲۵ ٪ سویا،۵۰ ٪ ذرت: ۵۰ ٪ سویا، ۲۵ ٪ ذرت: ۷۵ ٪ سویا و تک‌کشتی سویا بود که در چهار سطح آلودگی علف‌هرز تاج خروس (*Amaranthus retroflexus* L. AMRET) و تاتوره (*Datura stramonium* L., DASTR) شامل: عاری از علف هرز، آلوده به تاج‌خروس در تمام فصل، آلوده به تاتوره در تمام فصل و آلودگی توام به تاج خروس و تاتوره در طول فصل کشت شدند . نتایج نشان داد در تک کشتی ذرت و بدون حضور علف هرز، ۳۰/۳۶٪ از حداکثر سطح برگ گیاه در لایه ۱۲۰-۹۰ سانتی‌متری تشکیل شده بود. اما هنگامی‌که ذرت همراه با تاتوره یا هر دو گونه علف هرز رشد کرد، حداکثر سطح برگ در لایه‌های بالاتر تشکیل شد. در تک‌کشتی سویا بیشترین میزان زیست توده (۳۴/۶۶٪ از کل) در لایه ۳۰-۰ سانتی‌متری تولید شد، اما در زمان آلودگی با دو علف هرز (*DASTR+AMRET*) بالاترین میزان (۳۲/۹۷٪) در لایه ۹۰-۶۰ تشکیل گردید، در این تیمار تاتوره بیشترین میزان زیست توده خود (۴۹/۵۴٪) را در لایه ۱۵۰-۱۲۰ سانتی‌متری تشکیل داد. تک کشتی سویا نتوانست با علف‌های هرز رقابت کند و مغلوب علف های هرز شد. این در حالی است که کشت مخلوط سویا / ذرت بویژه در نسبت اختلاط ۵۰:۵۰، توانست با موفقیت باعث فرونشانی علف‌های هرز شود. به این ترتیب می‌توان نتیجه گرفت اثر مکملی ذرت و سویا در کشت مخلوط، زمینه استفاده بهینه از نور خورشید برای غلبه بر علف‌های هرز و حفظ عملکرد را فراهم نموده است.

کلمات کلیدی: ساختارکانوپی، توزیع سطح برگ، کشت مخلوط غله/ لگوم