Survey of Canopy Structure of Soybean (Glycine max) and Redroot Pigweed (amaranthus retroflexus) in Competition with Each Other

Marjan Samaee, Gholam Abbas Akbary, Eskandar Zand, Jahanfar Daneshian

ABSTRACT

In order to determine the effects of redroot pigweed on canopy structure of soybean, a factorial experiment in randomized complete block design was carried out with three replications in the research field of Seed and Plant Improvement Institute, Karaj, Iran. The treatments included the soybean cultivars (L11, Clark and Pershing) and the pigweed densities (0, 4, 8, 16 & 32 pigweeds in a meter of row) in the soybean plots and 4 densities of the pure pigweed involved (4, 8, 16, 32 pigweeds in a meter of row). Sampling of the soybean cultivars and the pigweed was carried out 57 days after appearance that L11 and Clark was in R3 and Pershing was in R1 (Fehr and Caviness Identification). The maximum leaf area in all of the soybean cultivars was compounded in 20-40 cm height. Overall, the behavior of Clark was similar to Pershing in presence of the weed, the portion of leaf area in the upper parts of the crop decreased in 4 plants of pigweed, and then it shifted to upper layer by addition of the pigweed. However, it increased with 4 plants of the weed in L11. On the whole, investigation of biomass profiles of soybean in competition with pigweed showed that soybean changed biomass distribution pattern in such a manner that higher amounts of biomass were allocated to the upper layers that corresponded with leaf area. Moreover, the maximum leaf area of pigweed was allocated in 20-40 cm height in the different pigweed densities, lonely. Generally, in the mixed culture, the leaf area and biomass distribution of the pigweed shifted to upper layers in low densities whereas transferred to downer layers in high numbers of the weed. Moreover, the most grain yield was observed in control treatment of L11, Clark and Pershing, respectively. Grain yield of the soybean cultivars decreased by the pigweeds as none linearly.

Key words: Soybean, Pigweed, Density, Canopy, Leaf Area & Biomass.

Introduction

A successful integrated weed management program for the control of weeds cannot be implemented without a clear understanding of interspecific competition between major field crops and weeds [11]. These days, instead of eradicating weeds in fields, the control of weed population is recommended, thus awareness of weed’s behaviors and its effects on crop are necessary for weed management.

Canopy structure is one of the most important factors in determining the competitive ability of crop and weed [5]. Leaf angle, leaf area index, and leaf area distribution are traits with major role in light interception and consequently canopy photosynthesis [28]. However, those traits that lead to maximum canopy photosynthesis are not necessarily seen in each single plant. For example, photosynthetic capacity of canopy with vertical leaves is higher than horizontal leaves because more light will pass among the vertical leaves, reach lower layers, and lead to uniform distribution of light with in the canopy. Moreover, a crop with horizontal leaves will receive more light and have more photosynthesis when weeds have vertical leaves [26,28].

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 [25,27]. Vertical
distribution of leaf area is leaf areas per horizontal layers, based on height [4]. 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, too [14]. In fact, the effect of leaf area distribution on light competition can be illustrated by dividing the canopy into horizontal layers [32]. 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 [31,18].

According to Daugovish et al [9], Soybean (Glycine max) is an important food crop for human consumption whose yield is up to 80% is lost due to weed competition in many parts of the world. In addition, Redroot pigweed (Amaranthus retroflexus) is highly competitive weed that causes large crop yield losses [16] and is widely distributed through cropping area of our country. Moreover, redroot pigweed can grow more than 1 m which makes it advantageous to capture more sunlight and other resources such as water and nutrients in a relatively short time [15] resulted in large amounts of dry matter accumulation. The ability of redroot pigweed to cause serious yield losses is documented for some crops such as cotton, soybean and snap beans [8]. Moreover, Heydarian & et al., illustrated interference the redroot pigweed on three cultivars of sunflower and they reported traits were affected by 8 and 16 plant of the redroot pigweed per meter of row, significantly.

Generally, Competition between oil crops and weeds vary with species involved [13]. Moreover, studying competition between weeds and crops can help many societies to reach their goals of increased food production [23]. The objective of this study was the survey of competitive effects of redroot pigweed on canopy structure of three soybean cultivars.

Materials and Methods

A factorial experiment in significant randomized complete block design was carried out with three replications in the research field of the Seed and Plant Improvement Institute, Karaj, Iran. The soil of the experimental plots was loamy. The treatments included soybean cultivars (L11, Clark and Pershing) and pigweed densities (0, 4, 8, 16 & 32 pigweeds in a meter of row) in soybean plots and 4 densities of pure pigweed involved (4, 8, 16, 32 pigweeds in a meter of row). In order to omission of seed dormancy from pigweed, the seeds were wetted 48 hours, then they were dried off by indoor temperature one week before planting that had recommended by Cowan & et al.,[7]. The density of soybean was 40 plants in a meter square. The seeds of the pigweed were hand planted when the seeds of soybean were planting except that the pure soybean cultivars and 3 weeks after pigweed emergency, weed seedlings thinned to achieve the densities, too. The field hand hoed to remove undesired weeds, continually. The seeds of soybean were vaccinated by Brady rhizobium japonicum (150 grams per 30 kilograms of soybean seeds) and irrigation was done after planting, immediately.

Sampling of the soybean and the pigweed was carried out 57 days after appearance that L11 and Clark was in R3 and Pershing was in R1 [12]; 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-3100. Afterwards, all samples were oven-dried at 75 ºC for 48 hours and weighted. Both leaf area and biomass were calculated as percentage (%) in relation to whole plant. In the end of growth season grain and biological yield were measured and all data were subjected to the statistical analysis (ANOVA) using SAS software, too.

Results and Discussion

Leaf Area:

The maximum leaf area of L11 in the pure treatment was 42.65% that was observed in 20-40 cm layer from down and it was 46.06% in presence of 4 plants of the pigweed (Figure1, a & b). However, an extra layer was observed in presence of 4 plants of the pigweed (Figure1, a & b), and then the leaf area shifted to the upper layer by addition of the pigweed (Figure1, c, d & e). It seemed that decrease or increase in height of the soybean can be affected by the intensity of competition; it could be increased by intensive competition and vice versa. Probably, in low densities of Amaranthus retroflexus , the soybean competed for light by addition of height, whereas in high densities of the weed, it captured light by shifting leaves to upper layers.

Moreover, the maximum leaf area of the pigweed was allocated in 20-40 cm layer (41.61%) in the different pigweed densities, lonely (Figure 1, f, g, h & i). In mixed culture of L11 and pigweed with the density of 4 plants, the maximum leaf area of the pigweed was 34.88% that was found in 20-40 cm (Figure1, b). However, it shifted to upper layer by addition of density up to 16 plants of pigweed (Figure1, b, c & d). In mono culture of the pigweed, it was transferred to upper layer by addition of the density up to 16 plants while it shifted to downer height in 32 pigweeds that was corresponded with the mixed culture, too (Figure1).

Aghaalikhani [1] demonstrated that leaf area allocated to the upper layer in presence of weeds in corn. 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 [19].

The maximum leaf area of Clark in weed free was 46.98% that was observed in 20-40 cm from down (Figure 2, j). Generally, leaf area of this cultivar was allocated in upper layer by addition of the density of the pigweed for example Clark had the extra layer in 32 plants of the weed (Figure 2, j & n). However, it happened in 4 plants of the pigweed for L11 (Figure 1, a & b). In spite of the fact that the maximum leaf area of pure pigweed was allocated in 20-40 cm layer in 4 plants, it was found in the third layer from ground (40-60 cm) when pigweed competed white Clark in the 4 plants of the pigweed ((Figure 1, f & Figure 2, k). Moreover, the portion of the leaf area of downer layers in the weed was added in mixed culture as a layer was omitted in the 32 plants (Figure 2, n).

Effects of weed height on light penetration through the crop canopy were reported in competition studies between velvetleaf (Abutilon theophrasti Medikus) and soybean [2]. Vazin et al., [28] in a research of mixed canopy of redroot pigweed (Amaranthus retroflexus) with corn demonstrated that the most leaf area of redroot pigweed had concentrated in 40-60 cm of canopy height.

![Fig. 1](image1.png)

**Fig. 1:** Leaf Area profiles of Soybean (L11) in Different density of Amarant (D0(a), D4(b), D8(c), D16(d) & D32(e)) and the pure densities of the pigweed (D4(f), D8(g), D16(h) & D32(i)).

![Fig. 2](image2.png)

**Fig. 2:** Leaf Area profiles of Soybean (Clark) in Different density of Amarant (D0(j), D4(k), D8(l), D16(m) & D32(n)).

Similar to the other cultivars of soybean, the maximum leaf area of Pershing in weed free was observed in 20-40 cm (43.97%) from down (Figure 3,o). Generally, the behavior of Pershing was like to Clark in presence of the weed (Figure 2 & 3) except that its leaf area shifted to lower layer in 8 plants of the weed (Figure 3, q). It seems that with increase in density, competition for light will be increased and both height and distribution pattern of the leaf canopy will be affected. Soybean cultivars developed a large proportion of their leaf area in the upper portion of the canopy, indicating their competition for available light in the canopy [19]. Height and leaf area index are regarded as two factors determining competitive advantage in crop-weed mixed canopy. It is believed that the species with more leaf area and height will be more successful [14]. Moreover, leaf area of the pigweed was transferred to upper height in 4 plants of the pigweed in comparison with the control while it shifted to downer layer by addition of
the pigweed (Figure 3, p & s). Probably, in low densities, the pigweed could be a more successful competitor than Pershing, but in high densities of the pigweed, Pershing could acted better than the Amaranthus retroflexus for light absorption.

**Fig. 3:** Leaf Area profiles of Soybean (Pershing) in Different density of Amarant (D0(o), D4(p), D8(q), D16(r) & D32(s)).

**Biomass:**

The maximum amount of soybean biomass of L11 (44.11 %) in weed free and in condition of the competition with pigweed were established in layer 20-40 cm (Figure 4, A) and it was according to leaf area distribution (Figure 1 & 4).

Generally, the trend of differences of biomass in the pure weed was similar to leaf area and it shifted to downer layers by addition of the densities (Figure 4, F & I). Moreover, profiles of the weed biomass distribution in the treatments showed that, when soybean (L11) competed with the pigweed, this weed also had translocated the most percentage of biomass to the higher layer up to 16 plants (Figure 4, B & E). In fact, this rate of biomass was for the reason of formation of the most part of leaf area in this layer and this distribution pattern of biomass seems to be for more radiation capturing.

The plant structure that is suitable for pure culture is not necessarily suitable for mixed culture, For example it is an advantage for a species in mixed culture, to have more leaf area index or more horizontal leaves above the canopy; but it is not necessarily an advantage in pure culture [22].

Interference between the cultivars of soybean and weeds caused shift the maximum layer of leaf area and dry matter to the upper layer of canopy. Distribution of leaf area and dry matter in weeds canopy was related to its species and the growth form [21].

**Fig. 4:** Biomass profiles of Soybean (L11) in Different density of Amarant (D0(A), D4(B), D8(C), D16(D) & D32(E)) and the pure densities of the pigweed (D4(F), D8(G), D16(H) & D32(I)).

The maximum amount of Clark biomass in all treatments was compounded in 20-40 cm layer and the biomass also was increased by addition of the pigweed density for example there was a more layer
in Clark biomass when competed with 32 plants of the pigweed like leaf area distribution, too (Figure 5, J & N). Soybean tried to have more leaves in upper layer of the canopy by increase in the pigweed densities, so dry matter accumulation was more in the upper layer (Figure 2, j & n - Figure 5J & N). Profiles of the pigweed biomass distribution in Clark indicated that the biomass was shifted to upper layer up to 8 plants of the pigweed (Figure 5, K & L).

However, it shifted to downer layers by addition of the pigweed that could be due to much more ability of Clark for capturing light in the more densities of the pigweed (Figure 5, L, M & N). The main characteristics that allowed the weed to compete against a strong competitor such as soybean was its height plasticity, canopy architecture, concentrated leaves in the upper part of the plant, and higher light extinction coefficient [1].

Fig. 5: Biomass profiles of Soybean (Clark) in Different density of Amarant (D0(J), D4(K), D8(L), D16(M) & D32(N)).

The maximum amount of soybean biomass in the pure treatment of Pershing was found in 20-40 cm layer (57.05%) (Figure 6, O). On the whole, investigation of biomass profiles of Pershing in competition with pigweed showed that soybean changed biomass distribution pattern in such a manner that higher amounts of biomass were allocated to the upper layers which probably was due to increased height and more branching in the upper layers (Figure 6, P & S). The trend of the pigweed biomass in Pershing was similar to the leaf area distribution, too (Figure 3 & 6).

It seems that weed compensated low irradiance by increasing the leaf area and partitioning more dry matter to stems and later on to leaves which would increase the amount of photosynthetic active area when competing with soybean [20].

Fig. 6: Biomass profiles of Soybean (Pershing) in Different density of Amarant (D0(O), D4(P), D8(Q), D16(R) & D32(S)).

Grain Yield:

The statistical analysis of data on the grain yield indicated the significant differences among the soybean cultivars and the pigweed densities. In addition, the most grain yield was observed in control treatment of L11, Clark and Pershing, respectively. Grain yield of the soybean cultivars were decreased by addition of the pigweed densities none linearly and almost from 8 pigweeds in meter of row, the percentage of decline in the grain yield was less than the percentage of the addition of the pigweed. Probably, it was because of increasing intra competition among the pigweeds. Moreover, the least and the most percentage of decline of the grain yield in comparison with the control occurred in L11 and Pershing, respectively. Redroot pigweed densities of 8, 10 and 12 plants per meter in soybean field decreased soybean yield 25, 31 and 38%, respectively, and therefore, it is a highly competitive weed, which causes economical losses even in low densities.

Conclusion:

Present study demonstrated that redroot pigweed is a highly competitive weed which competed with soybean in low densities. Therefore, in order to prevent yield losses, it is recommended that to control it even in low densities. Moreover, changing the leaf area and biomass profile in soybean canopy is an important trait in the result of competition between soybean and the weed. The results suggest that if a cultivar of soybean can shift the leaf area and
the biomass to upper layers in the low densities of the pigweed like L1, might conserve more economical yield in presence of the weed rather than the high densities of the pigweed. It can serve as the basis for making economic decision rules for managing redroot pigweed in soybean.

References


