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Response of leaf area and dry matter of crop, weeds and cover crops to competition and fertilizer resources

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ABSTRACT

Plasticity of plants to allocate leaf area and dry matter to upper layer of canopy play important role in canopy architecture and competition. In order to study the vertical distribution of leaf area and dry matter of corn (*Zea mays* L.), cover crops and weeds canopy in different fertilizer condition and competition, a randomized complete block design experiment with 8 treatments and 3 replicates was conducted at Sari Agricultural Sciences and Natural Resources University in 2012. Treatments were included corn with soybean (*Glycine max* (L.) Merr.) as cover crop without fertilizer application, corn with soybean as cover crop with chemical fertilizer application, corn with soybean as cover crop with compost fertilizer application, corn with wheat (*Triticum aesitivum* L.) as cover crop without fertilizer application, corn with wheat as cover crop with chemical fertilizer application, corn with wheat as cover crop with compost fertilizer application and corn monoculture both in weedy and weed free conditions. The results showed that weed infestation reduced total leaf area and dry matter of corn. Corn distributed more leaf area and dry mater of canopy to the upper layer in weedy conditions. Between cover crops, soybeans allocated corn leaf area and dry mater to the higher layers of canopy than wheat. Also, soybean reduced leaf area and dry mater production of weeds more than wheat. Soybean as cover crop with the use of compost treatment was more efficient in reducing of weed biomass and corn yield production.

Key words: corn, compost, dry matter allocation, soybean**,** weed biomass, wheat

IZVLEČEK

ODZIV LISTNE POVRŠINE IN SUHE SNOVI POLJŠČIN, VMESNIH POSEVKOV IN PLEVELOV NA KOMPETICIJO IN IZRABO GNOJIL

Sposobnost rastlin za premeščanje listne površine in suhe snovi v zgornje plasti krošnje ima pomebno vlogo v njihovi zgradbi in tekmovalnosti. Za preučevanje vertikalne razporeditve listne površine in suhe snovi v krošnji koruze (*Zea mays* L.), njenega vmesnega posevka in plevelov v različnih razmerah gnojenja in tekmovalnosti je bil v letu 2012 izveden naključni bločni poskus z osmimi obravnavanji in tremi ponovitvami na Sari Agricultural Sciences and Natural Resources University. Obravnavanja so obsegala koruzo in njen vmesni posevek sojo (*Glycine max* (L.) Merr.) brez uporabe mineralnih gnojil, koruzo s sojo kot vmesnim posevkom gnojeno s kompostom, koruzo s pšenico (*Triticum aesitivum* L.) kot vmesnim posevkom brez gnojenja, koruzo s pšenico kot vmesnim posevkom, gnojeno z mineralnimi gnojili, koruzo s pšenico kot vmesnim posevkom gnojeno s kompostom in monokulturo koruze v razmerah z in brez plevelov. Rezultati so pokazali, da so pleveli zmanjšali listno površino in vsebnost suhe snovi pri koruzi. Koruza je premestila več listne površine in suhe snovi v zgornje plasti krošnje v razmerah zapleveljenosti. V razmerah z vmesnimi posevki je koruza premestila več listne površine in suhe snovi v zgornje plasti z vmesnim posevkom sojo kot pa s pšenico. Podobno je soja bolj zmanjšala listno površino in suho snov plevelov kot pšenica. Soja je kot vmesni posevek ob uporabi komposta bolj učinkovito zmanjšala biomaso plevelov kot tudi pridelek koruze.

Ključne besede: koruza, kompost, alokacija suhe snovi, soja**,** biomasa plevelov, pšenica, vmesni posevek

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1 INTRODUCTION

Weeds are one of the major threats to crop production in cropping systems. The risk of weeds not only reducing crop yields but also decreasing the commercial quality and the feeding palatability of main crops and enhance the soil seed bank of weeds, which may cause continuous weed infestation of field crops (Uchino *et al*., 2012).

The primary goal of weed management approaches is reducing the negative effects of weeds on crop. Herbicides have developed to be a reliable and highly effective method for weed control. However, demand for safe food products and food that have been produced with a minimum application of chemical inputs increased. Therefore, farmers interested in weed management have to rely on other control approaches (Hollander *et al*., 2007). An alternative weed control method is the use of cover crops (Uchino *et al*., 2009), which can suppress the growth of weeds by competition for light, soil moisture and nutrients, and also by producing allelopathic compounds (Compigla *et al*., 2010). Cover crops have been successfully integrated into conservational agriculture systems in many parts of the world. Jedrszczyk and Poniedziałek (2007) reported cover crops increased the content of corn dry matter in comparison to monoculture of corn in weedy condition. Uchino *et al.,* (2009) resulted in increased coverage of corn, soybean and cover crop, declined weed dry matter. Weeds were suppressed effectively and stably without yield reductions of main crops by inter-seeded cover crops with sufficient fertilization in organic farming systems (Uchino *et al*., 2012).

In competition, height and leaf area index are two important, so that species with greater leaf area and height are more successful (Vazin *et al*., 2010; Rezvani *et al*., 2013). Plant ability to allocate green shoot to upper layer is one of the main traits in competition (Agha-Alikhani *et al*., 2009). Because, the canopy structure impact on the absorption of radiation, evaporation and transpiration, canopy and dry matter accumulation and yield (Rezvani *et al*., 2010). Agha-Alikhani *et al*. (2009) indicated that in weed free corn pure stand, 30.36 % of the maximum leaf area was distributed in 90-120 cm layer of canopy, but when corn was grown with weed, the maximum leaf area were established in the upper.

The objective of the research was investigating leaf area and biomass profile in corn, cover crops and weeds under different treatments of cover crops and fertilizer resources. Also, yield of corn and performances of applied weed managements were evaluated.

2 MATERIALS AND METHODS

The experiment was carried out at Sari Agricultural Sciences and Natural Resources University, Sari. The soil was a silt-clay soil with 7.34 pH, 2.53 % organic matter, 0.23 % total N, 38.74 ppm P and 400 ppm K. Field preparation was consisted of a deep tillage in previous fall and a vertical disk in spring.

The experiment was established in a randomized complete block design with four replicates. Corn was considered as main crop and soybean and wheat were the cover crops. Treatments were included corn with soybean as cover crop without fertilizer application, corn with soybean as cover crop with chemical fertilizer application, corn with soybean as cover crop with compost fertilizer application, corn with wheat as cover crop without fertilizer application, corn with wheat as cover crop with chemical fertilizer application, corn with wheat as cover crop with compost fertilizer application, corn monoculture both in weedy and corn monoculture in weed free conditions. Natural weed population of all plots except corn monoculture in weed free treatment maintained in all growth stages. Weed free corn monoculture treatment was weeded in all growth stage. Varieties of corn, wheat and soybean were NS-640, Milan and Sari, respectively.

Corn planted in 75 cm row spacing with 20 cm between plants in the same row. Each plot was included 5 rows corn. Crops were planted on 26 May 2012.

Cover crop inter-seeded simultaneously in the main crop. Chemical fertilizer treatment was used according to the soil analysis. 400 kg ha^{-1} N-fertilizer as Urea, 200 kg ha^{-1} K-fertilizer as Potassium sulfate and 150 kg ha^{-1} P-fertilizer as Triple superphosphate were applied. A total of 20 ton ha^{-1} mushroom compost was used as an organic fertilizer resource. The chemicals properties of compost were as 6.9 pH, 1.8 % N, 1.8 % P and 1.6 % K. At planting, 200 kg ha^{-1} N-fertilizer and total P and K-fertilizer and compost was incorporated into the soil. Other 200 kg ha^{-1} N-fertilizer top dressed in early flowering stage of corn.

At the corn canopy closure stage, a vertical card board frame marked in 30-cm increments was used in the field as a guide to cut standing plants including corn, cover crops and weeds. In each vertical layer of canopy, leaves and stem samples were separated. The leaf area both crops and weeds were measured with a leaf area meter LICOR-3000A (LI-COR, Lincoln, NE, USA). Stem and leaf samples oven dried.

Weed biomass production of treatments evaluated at the corn harvest time. Also, Corn yield was measured by mechanically harvesting both middle rows and adjusting to 13% moisture.

2.1 Statistical analysis

Corn yield and weed biomass data subjected to analysis of variance (ANOVA) using the SAS (ver. 9.2). Means were compared with LSD test at $P=0.05$. The vertical distribution of leaf area and dry matter were plotted by Grapher (ver. 9) software.

3 RESULTS AND DISCUSSION

3.1 Vertical changes of corn and cover crops leaf area

The maximum leaf area of corn cultivated with soybean as cover crop both in compost and chemical fertilizer treatments were placed at 90-120 cm layer (Figs. 1a). In all treatments that wheat used as cover crop, corn allocated the leaf area in lower layers of canopy that those of treatments that corn growth with soybean as cover crop (Figs. 1a).

Figure 1b indicates vertical distribution of corn monoculture both in weedy and weed free conditions. Results showed that in weedy condition the most leaf area (24.01 %) placed in layer of 150-180 cm corn canopy. But, in weed free condition the maximum leaf area of corn (22.33 %) established in the layer of 90-120 cm (Fig. 1b).

Between cover crops, soybeans compared to wheat expanded corn leaf area to the upper layers of the canopy.

Large proportion of the soybean leaf area was established at both layers of 60-90 cm and 90-120 cm (Fig. 2), while the major part of the wheat leaf area was allocated to the layer of 0-30 cm of the canopy in all corn with wheat as cover crop treatments. Soybean leaf area was expanded to the upper layers of the canopy than wheat, which can cause superiority of soybean plants in competition with weeds (Fig. 2).

Corn allocated more leaf area to the upper layer in presence of weeds. In response to competition, plants transfer their leaf area to upper layers of canopy; through preventing light penetration to the bottom layers, to increase their competitive abilities (Safahani-Langerodi *et al.,* 2008). Saadatian *et al.* (2011) also reported increasing the ration of the upper layer of wheat canopy in interference conditions with wild mustard.

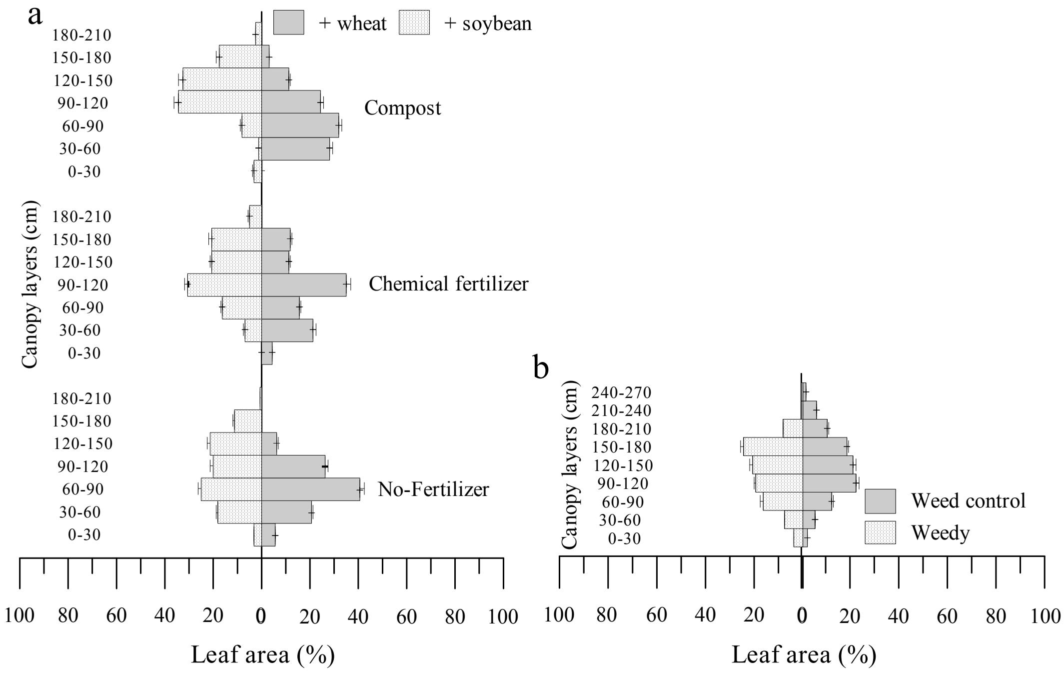

Figure 1: Vertical distribution of corn leaf area under presence of cover crops (a) and corn monocropping (b). Vertical bars represent *Se* of the means.

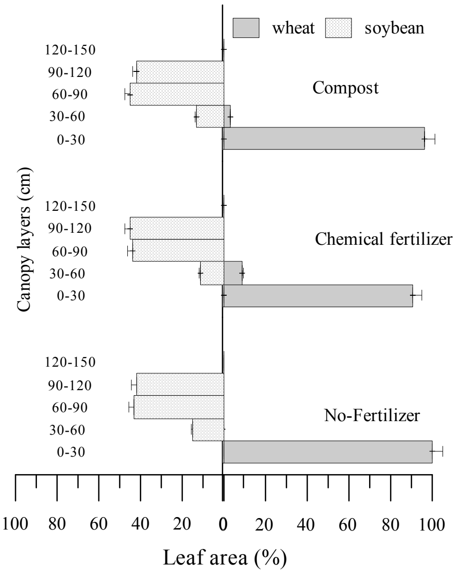

Figure 2: Vertical distribution of cover crops leaf area. Vertical bars represent *Se* of the means.

3.2 Vertical changes of weed population leaf area

The dominant weed species were velvetleaf (*Abutilon theophrasti* Medic.), Johnson grass (*Sorghum halepense* (L.) Pers.), wild melon (*Cucumis melo* var. agrestis) and giant foxtail (*Setaria glauca*) in the experimental field.

Velvetleaf leaf area was expanded to the upper layers of the canopy in wheat used as cover crop compared with soybean used as cover crop treatment. But, in soybean was as cover crop with compost treatment, velvetleaf expanded all its leaf area to 30-60 cm layer (Fig. 3a).

Velvetleaf in weedy monoculture of corn expanded its leaf area to 90-120 cm layer and the maximum proportion of the leaf area allocated to 60-90 cm layer (Fig. 3f). Generally, in presence of cover crops conditions weeds allocated leaf area to the lower layers. But, in no fertilizer treatment due to competition for nutrients, weeds allocated the major part of leaf area at 90-120 cm layer (Fig. 3a).

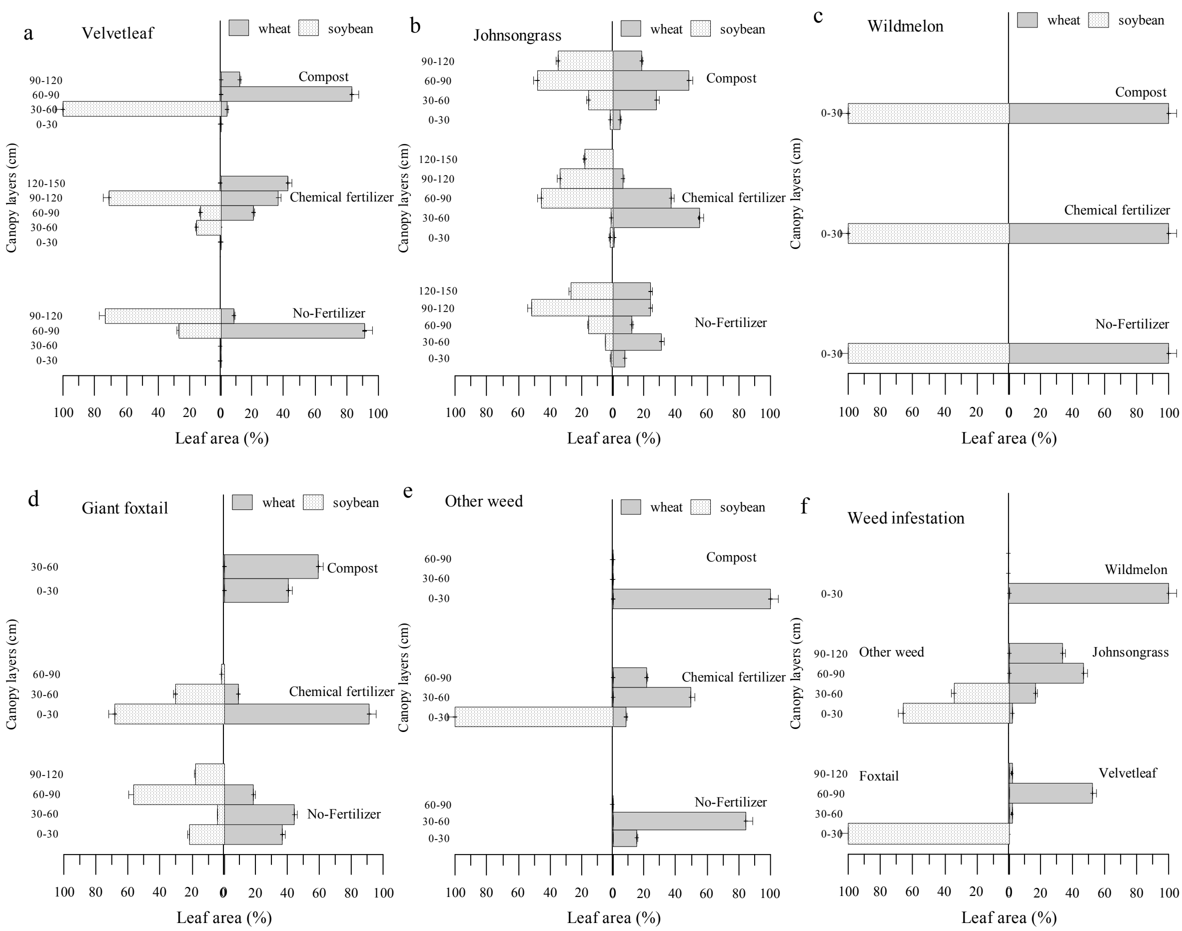

Figure 3: Vertical distribution of leaf area of velvetleaf (a), johnson grass (b), wild melon(c), giant foxtail (d) and other (e) under presence of cover crops and vertical distribution of weeds leaf area in monocropping of corn under weed infestation. Vertical bars represent *Se* of the means.

Johnson grass in soybean with cover crop was more successful in competition than wheat with cover crop treatments, because of the ability to expand the most leaf area to the upper layers of canopy height. The maximum leaf area Johnson grass in soybean cover crop with compost, chemical fertilizer and no fertilizer treatments were placed at 60-90 cm, 60-90 cm and 90-120 cm layers of canopy, respectively (Fig. 3b). Johnson grass leaf area in no fertilizer allocated to higher layer of canopy than other fertilizer treatments. The maximum leaf area of Johnson grass in monoculture of corn was observed at 60-90 cm layer (Fig. 3f).

Leaf area of Wild melon in all treatments expanded only at 0-30 cm canopy layer. Giant foxtail completely suppressed and controlled with treatments of compost and soybean used as cover crop (Fig. 3d). Soybean as cover crop was more successful than wheat in giant foxtail control. Other weeds of fields in treatments of soybean cover crop were observed only in chemical fertilizer treatments at 0-30 cm layer (Fig. 3e) and two other fertilizer treatments were free of other weeds. In wheat used as cover crop treatments other weeds were presented in all three fertilizer treatments and in chemical fertilizer treatment compared to other treatments, expanded their leaf area to the upper layers of the canopy. In corn monoculture weedy condition treatments, other weeds allocated the maximum leaf area Layer to 0-30 cm (Fig. 3f).

Uchino *et al.* (2012) with study of the possibility of suppressing weeds in corn by cover crops reported that the maximum total leaf area of weeds was observed in no cover crops treatments.

3.3 Vertical changes of corn and cover crops dry matter

Corn in soybean cover crop treatments compared to wheat cover crop allocated dry matter to the upper layer of canopy. The layer of the maximum corn dry matter in soybean cover crop treatments with compost and chemical fertilizer were observed at 90-120 cm. But, in no fertilizer treatments the layer was formed at 60-90cm layer of canopy. In wheat cover crop treatments the maximum layer of corn dry matter accumulated at 30-60 cm, 90-120 cm and 60-90 cm layers in plots with compost, chemical fertilizer and no fertilizer, respectively (Fig. 4a). Ahmadvand *et al.* (2006) who worked on wheat and wild oat (*Avena fatua* L.) canopy structure, reported allocation of total dry matter and leaf area of wild oat to the upper layers increased by enhancement of density.

In the monoculture of corn with weed infestation due to competition between corn and weed, observed a reduction in dry matter of corn than in weed free (Data did not shown). The maximum amount of corn dry matter in weed free treatment was established in layer of 120-150 cm (Fig. 4b). Corn in competition with weeds, translocated the most percentage of dry matter to the upper layers of canopy. The changes in distribution of dry matter pattern may be due to more light achievement. Study of rice (*Oryza sativa* L.) canopy structure showed that rice allocated more leaf area and dry matter to the upper layers in competition with barnyard grass (*Echinochloa cruss-galli*) because of competition over nutrient and light sources (Aminpanah *et al.*, 2009).

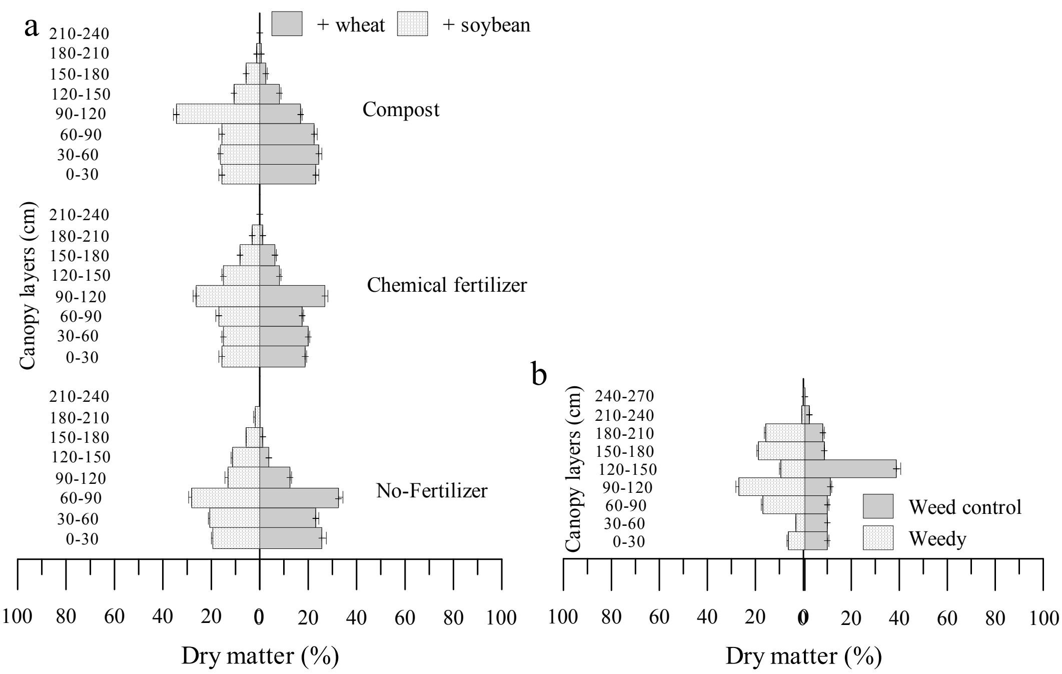

Figure 4: Vertical distribution of corn dry matter under presence of cover crops (a) and monocropping of corn (b). Vertical bars represent *Se* of the means.

Both compost and chemical fertilizer with soybean used as cover crop treatments dry matter of corn allocated to the upper layers of the canopy than no fertilizer ones. In treatment of compost with soybean as cover crop allocated more dry matter to higher layer (90-120 cm) than chemical fertilizer (Fig. 4a). All dry matter of wheat cover crop accumulated at 0-30 cm layer in no fertilizer treatment while in compost and chemical fertilizer treatments 9.12 % and 6.59 % of dry matter transferred to the 30-60 cm layer, respectively (Fig. 5). Also wheat dry matter transferred to the upper layer in compost application treatment was more than chemical fertilizer ones (Fig. 5). The maximum dry matter of soybean in compost and chemical fertilizer treatments were allocated to the upper layer of canopy than no fertilizer ones (Fig. 5).

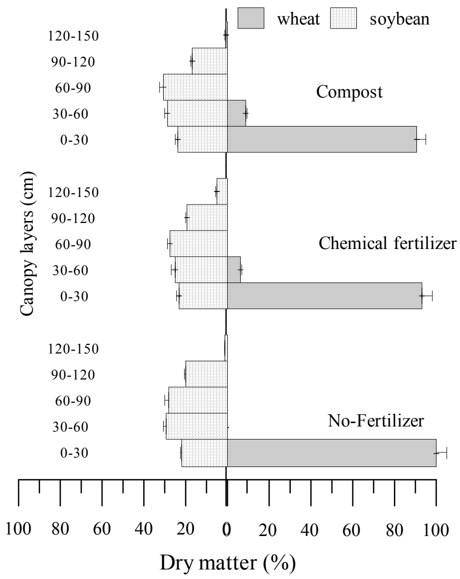

Figure 5: Vertical distribution of cover crops dry matter. Vertical bars represent *Se* of the means.

3.4 Vertical changes of weed population dry matter

In soybean used as cover crop with compost velvetleaf allocated whole dry matter to the 0-30 cm and 30-60 cm layers (Fig. 6a). In monoculture of corn velvetleaf transferred its dry matter to the upper layers (120-150 cm) (Fig. 6f). Haj-Seydhady *et al.* (2007) reported allocation of redroot pigweed (*Amaranthus retroflexus*) and lambsquarters (*Chenopodium album* L.) biomass to the upper layers of the canopy in order to compete with potato (*Solanum tubersum* L.) to absorb more light. Soybean in control of Johnson grass was not as successful as wheat and transferred the dry matter to the upper layers of canopy in compared to soybean. Study of profiles of weeds dry matter distribution in the treatments showed that, when corn and soybean competed with Johnson grass, accumulated the most percentage of dry matter to the upper layers. The main characteristics that allowed this weed to compete against a strong competitor such as corn and soybean were its height plasticity, canopy architecture, concentrated leaves in the upper part of the plant and higher light extinction coefficient (Agha-Alikhani *et al.*, 2009).

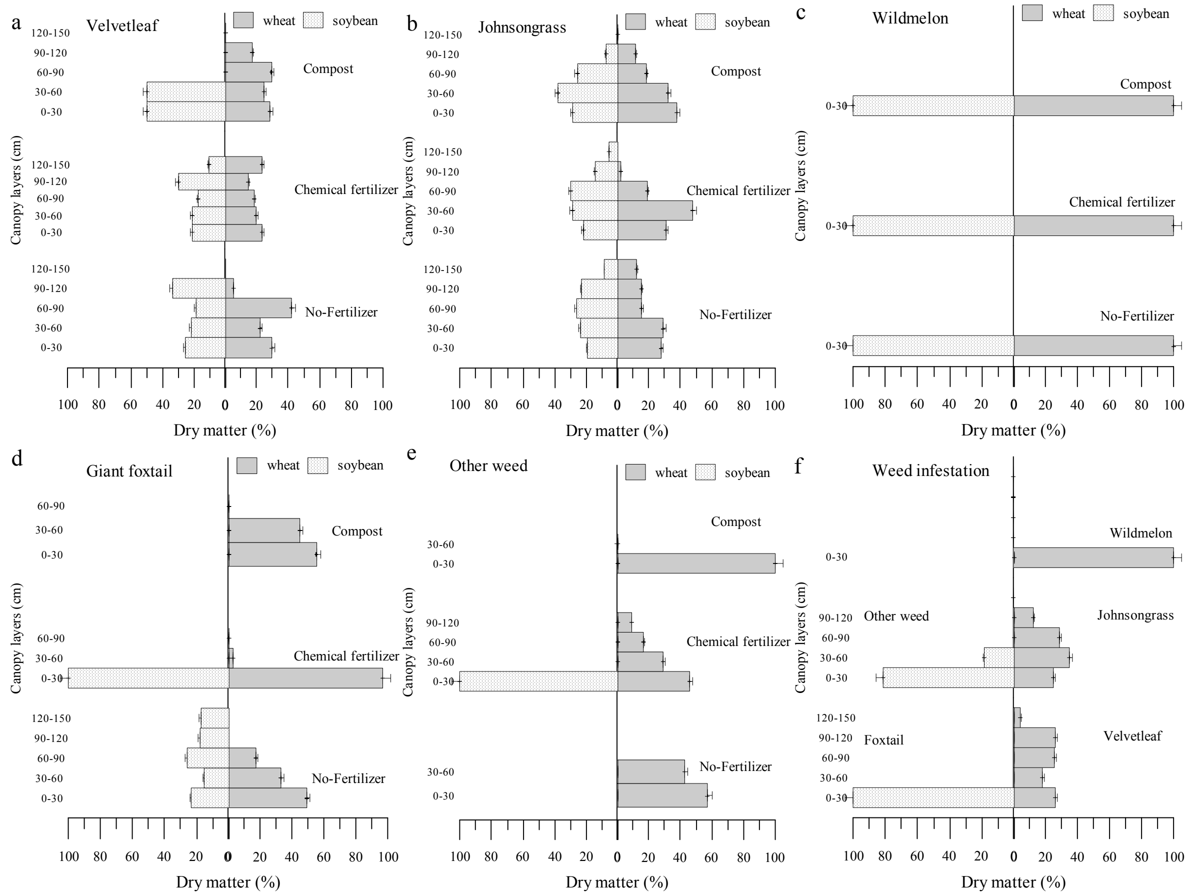

Figure 6: Vertical distribution of dry matter of velvetleaf (a), johnson grass (b), wild melon (c), giant foxtail (d) and other (e) under presence of cover crops and vertical distribution of weeds dry matter in moonocropping of corn under weed infestation. Vertical bars represent *Se* of the means.

Wild melon because of vegetative growth form allocated dry matter to the 0-30 cm layer (Fig. 6c). Giant foxtail growth completely suppressed by the soybean cover crop both in compost and chemical fertilizer application treatment (Fig. 6d). Other weed in the soybean cover crop were observed only in chemical fertilizer application treatments and in wheat cover crop with compost was observed only at 0-30 cm layer, but in other treatments were placed at the upper layers (Fig. 6e and 6f). Previous studies showed that use of hairy vetch (*Vicia villosa*) (Czaper *et al.,* 2002), Italian ryegrass (*Lolium multiflorum*) (Faget *et al.,* 2012), red clover (*Trifulium pratense*) and rye (*Secale montanum*) (Altentorbert *et al.,* 1996) as cover crops reduced biomass, density and diversity of weeds.

3.5 Weed biomass and Corn yield

Use of cover crops decreased weed biomass. In treatments of soybean with compost and also wheat with compost produced the minimum weed biomass. Generally, soybean as cover crop was more successful than wheat to inhibit weed growth (Table 1). There is a wide agreement in the researches conclusion that living cover crops will suppress weeds successfully. Barnes and Putnam (1983) also reported a living mulch of spring-planted rye reduced early season biomass of common lambsquarters, large crabgrass [*Digitaria sanguinalis* (L.) Scop.], and common ragweed (*Ambrosia artemisi-ifolia* L.) compared to controls. Effect of cover crops in reducing weed biomass previously reported by Ngoguajio *et al.* (2003) Samarajeewa *et al.* (2006). The suppressive effect of cover crop could be due to inhibition of weed seed germination through effect on the radiation and chemicals environment of seeds. Also continuous suppressive effect of cover crop could reduce seed production by weeds (Brennan and Smith, 2005).

Results of analysis of variance indicated treatments had significant effect on corn economic yield (Data not shown). Corn monoculture in weed free condition produced the maximal yield (Table 1). In the cover crop treatments including soybean with compost and soybean with chemical fertilizer had the highest economic yield (Table 1). All wheat used as cover crop treatment was not as successful as soybean in grain yield production (Table 1). There are reports that cover crops can suppress cash crops growth through the competition for resources. But, simulative effect of legume cover crops on cash crops through enhancement of nitrogen availability was reported by Sarrantonio and Gallandt (2003) and Calegari *et al.* (2005) and promotion of genes that delay senescence and enhance disease resistance (Kumar *et al.,* 2004).

Table 1: Mean comparison of corn yield and weed biomass.

Treatments		Economic yield (kg/ha)	Weed biomass (g/m^2)
Corn monoculture	Weed free	12124.00a	-
	Weedy	2733.30d	33.92a
Corn+soybean	No-fertilizer	3884.70cd	21.4c
	Chemical fertilizer	7769.70b	19.52c
	Compost	8351.30b	5.45d
Corn+wheat	No-fertilizer	3795.00cd	27.53b
	Chemical fertilizer	4903.00bcd	25.55b
	Compost	4089.70c	12.58cd

In each column, numbers with the same letter are not significantly different at 5 % level.

4 CONCLUSIONS

According to our research corn allocated more leaf and dry matter to upper layers in response to competition to cover crops and weeds to light absorption. Compost application and use of soybean as a cover crop was a successful management in weed growth suppression. Results showed use of legume as cover crop especially with organic fertilizers can be an alternative approach for herbicides and are more effective than others. However, further studies are required on cover crops species, seeding rate and growth pattern and their nutrition management such as amount and type of fertilizer.

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