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Influence of pod and leaflet removal treatments on dry matter accumulation in soybean

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Abstract

A field study was conducted at the experimental site of the Islamic Azad University of Kermanshah province, Iran during 2010 to find out the effects of pod and leaflet removal treatments during reproductive growth stages on leaf area index (LAI) and dry matter accumulation in different part of soybean plant. The experimental design was a split plot in randomized complete block with three replications. Main plot treatments consisted cultivars V_1=Williams and V_2=Clark, and Subplot included six treatments of defoliation and pod removal: removing none (T_1), one lateral leaflet at R_1-R_3 (T_2), two lateral leaflets at R_1-R_3 (T_3), one lateral leaflet at R_5-R_6 (T_4), two lateral leaflets at R_5-R_6 (T_5) and pods removal 50% at R_5 +10 days (T_6). The results indicated that there are a compensatory responses by soybean to pod and leaf removals treatments, especially, when that leaflet removal occurred at the R_1-R_3 stages and sufficiently severe (T_3). Removal of two lateral leaflets at R_1-R_3 was caused that LDW/TDW ratio from 26 % at the 82 DAE increased up to 29 % at the 97 DAE. We did not compensatory responses at the other treatments (T_1, T_2, T_5 and T_6). In addition, maximum value of plant dry weight was obtained about at 82 and 95 days after emergence for Williams and Clark cultivars, respectively. Also, the highest LAI at the end of growth stage belonged to T_2 treatment and Clark cultivar.

Keywords: Compensatory responses, defoliation, leaf area index, reproductive stages, soybean

Abbreviation: DAE: day after emergence, LAI: leaf area index, TDW, SDW, LDW, PDW and GDW: total, stem, leaf, pod and grain dry weight per plant, respectively.

Introduction

Plant leaves act as photosynthesizing organs, temporal storage tissue and regulator plants growth processes by hormones that exists in leaves. In this study, we focused on the effects of defoliation at the reproductive growth stages and changes of dry matter accumulation and compensatory responses by soybean to pod and leaf removals. Leaf area of plants per unit area of soil (LAI) is an important role in yield formation (Liu *et al*., 2008) and there is a positive correlation between leaf area and Dry matter accumulation and yield of soybean (Dong *et al*., 1979) and with decreases in leaf area of plants, biomass decreased. With an increase in leaf area index, percentage of sunlight absorption increases up to optimal leaf area index. In addition, high leaf area duration (LAD) is very important (Chu, 1988). Jin *et al*. (2004 b) Emphasized that high leaf area during reproductive stages, as well as slower leaf senescence after R_5 stage, were associated with high yield and biomass in soybean. Zhang *et al*. (2000) stated that shading or defoliation at reproductive stages mostly reduced biomass and yield in soybean. Altering growth pattern to favour development of leaf area is the compensatory response by plant to leaf removal (Eissenstat & Duncan, 1992; Mediene *et al*., 2002). Leaf area compensation for defoliation may be expressed through changes in new leaf area expansion or in normal plant senescence. Gazzoni (1974) reported that high recovery in leaf area occurred when treatments of defoliation applied on vegetative stage, while defoliation at reproductive stages, induced a light recovery of leaf area. Contrarily, Boote (1981) and Higgins *et al*. (1983) stated that in their study did not detect any compensatory growth in leaf area. By definition, reproductive partitioning is the proportion of total growth or biomass allocated to reproductive tissues (Gifford *et al*., 1984; Hay, 1995; Sinclair, 1998; vega *et al*., 2001). Liu *et al*. (2005 a) found that the most dry matter and photoassimilates produced in plants happened during pod filling. With reducing rate of photosynthesis due to defoliation, carbohydrate levels in leaves and other part of plant decreased (jin *et al*., 2004 a). Leaf removal in plant reduce plant growth (assimilates supply, dry matter accumulation) if leaf removal is sufficiently severe (Armour *et al*., 2003; Neilsen & Pinkard, 2003; Pinkard, 2003; Salleo *et al*., 2003). Thus, the objective of this study was to evaluate effects of defoliation treatments during reproductive growth stages on Leaf area index (LAI) and dry matter accumulation in different part of soybean plant.

Materials and methods

Two commercial indeterminate soybean cultivars, Williams (maturity group III) and Clark (maturity group IV), were grown under field conditions at the Experimental site of the Islamic Azad University of Kermanshah province, Iran ($34^0 23'$ N, $47^0 8'$ E; 1351 m elevation) during the 2010 growing season. The experimental design was a split plot in randomized complete block with three replications. Main plot treatments consisted cultivars V_1=Williams and V_2=Clark, both of which had an indeterminate growth habit and Subplot included six treatments of defoliation and pod removal: removing none (T_1), one lateral leaflet at R_1-R_3 (T_2), two lateral leaflets at R_1-R_3 (T_3), one lateral leaflet at R_5-R_6 (T_4), two lateral leaflets at R_5-R_6 (T_5) and pods removal 50% at R_5 +10 days (T_6). Individual plots were 5 m long and 4.8 m wide (eight rows with 0.60 m between rows). The plots were irrigated when necessary to avoid water deficits. Before sowing, 27 kg of ammonium phosphate (200 kg h^{-1}) and 7 kg of urea (50 kg h^{-1}) were applied and mixed with soil. Inoculation of seeds with appropriate strain of *Bradyrhizobium japonicum* was carried out. Soybean cultivars were sown at May 14. Phonological stages were defined according to Fehr & Caviness (1977). Soybean cultivars were sown at May 14 and the emergence date was May 26. Beginning bloom (R_1), beginning pod set (R_3), seed enlargement (R_5), and full maturity (R_8) occurred at 47, 56, 79 and 128 day after emergence (DAE), respectively, for Williams and at 51, 63, 87 and 134 DEA, respectively, for Clark. Pods and seeds sampled from the beginning pod set (R_3) up to full maturity (R_8) for each cultivar, separately. In order to study trend of growth, sampling was performed every 15 days, from the seven days after emergence until physiological maturity.

Leaf Area Index (LAI) was calculated was using the formula (Khan *et al*., 2008):

$$\mathrm{LAI} = \frac{\textbf{Surface area of sampled leaf}}{\textbf{Ground area occupied by the sampled plants}}$$

During any sampling times, plants were cut from soil surface with shears, and then, leaves area was measured and different parts were separated, put in paper bags, and placed in oven at 70^{0c} for 48 hr. For determination of dry weight, different parts of plant (stem, leaf, pod, and grain) were separately weighed. For drawing of chart were used from the Excel software version 2007.

Results and discussion

Evaluation of leaf area index among cultivars was shown that Clark had the highest value of LAI, and superiority to Williams with a highly minor difference. In addition, Clark had the more leaf area duration than the Williams. Otherwise, Williams had the highest stem and leaf dry weight per plant than the Clark cultivar (Fig. 1 and 2). At the onset of growth stage of plant, the amount of whole plant dry weight increases slowly due to small green area of crop on the field and to waste of large amount of sunlight, after some time, fast growth of plant begins. In this stage whole plant dry weight increases more in comparison with previous stages because of sufficient enlargement of leaves on canopy. Sean Malone *et al*. (2002) recognized LAI equal to 3.5-4 essential for absorbing 95% of sunlight and argued that soybean yield was dependent on amount of sunlight absorbed at of reproductive growth stages. With an increase in leaf area index, percentage of sunlight absorption increases up to optimal leaf area index. According to Liu *et al*. (2008) the issue about the optimal leaf area is a complex one, because cultivars have different leaf size, leaf angel, leaf shape and leaf pattern in canopy. At a high leaf area index, mutual shading of lower leaves usually becomes the main limiting factors. Therefore, increasing leaf area to a certain threshold would benefit yield (Zhang & Song, 1979). Comparison of total dry weight among cultivars showed that the increase in total dry weight was nearly the same for Williams and Clark cultivars, but for Clark, total dry weight value reached its maximum in longer interval to emergence date.

The results of this study indicated that maximum value of plant dry weight was obtained about at 82 and 95 days after emergence (R_6 growth stage, approximately) for Williams and Clark cultivars, respectively, and then declined until maturity stage (R_8). The results also agree with Pedersen & Lauer (2004). The results were shown that leaf area expansion is slow at onset of growth season, then faster expansive. Maximum LAI was obtained in R_5 stage, approximately then reduced sharply at the end of growth season due to leaves falling, but there more LAI can be observed in Clark cultivar at the maturity stage (Fig 2). Egli (1990) reported that reduction

Fig.1. Leaf area index (LAI), total dry weight (TDW), and stem dry weight (SDW) in Williams and Clark cultivars. Beginning bloom (R_1), beginning pod set (R_3), seed enlargement (R_5), and full maturity (R_8) occurred at 47, 56, 79 and 128 day after emergence (DAE), respectively, for Williams and at 51, 63, 87 and 134 DAE, respectively, for Clark.

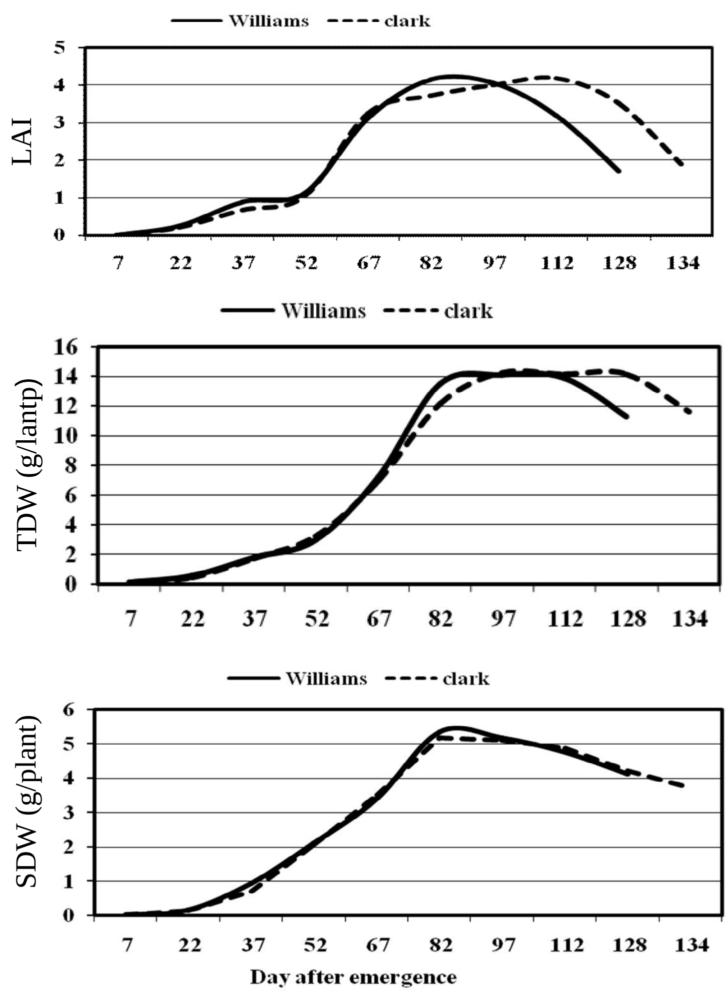
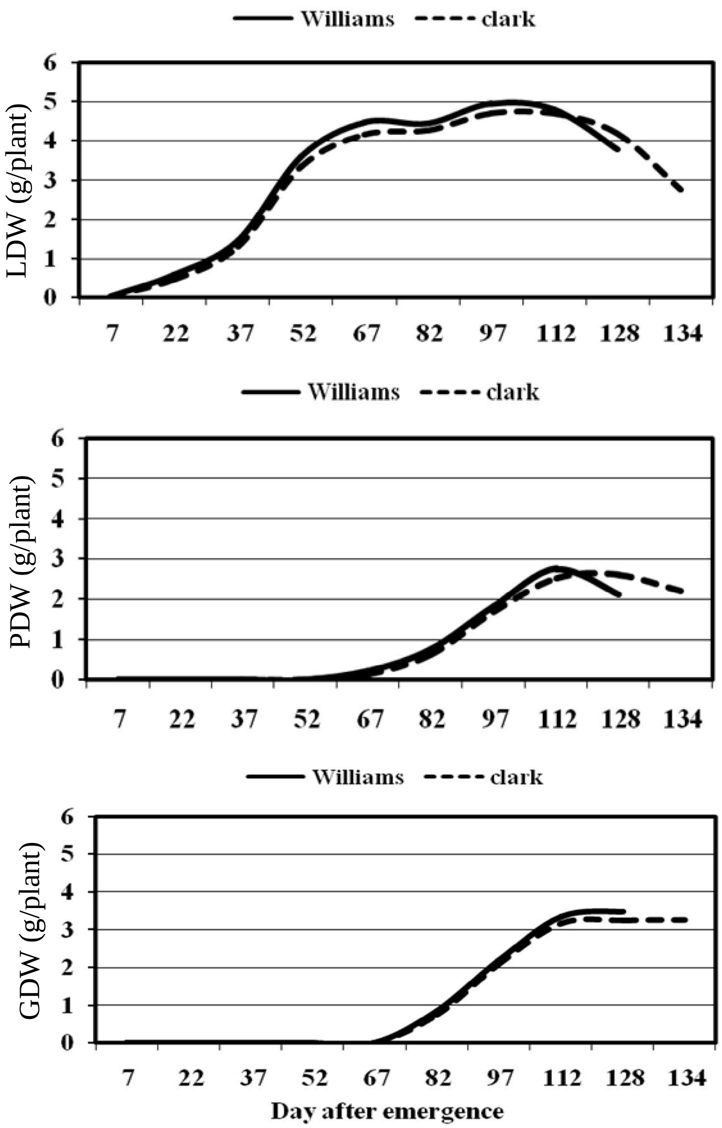


Fig.2. Leaf dry weight (LDW), pod dry weight (PDW), and grain dry weight (GDW) in Williams and Clark cultivars. -Beginning bloom (R_1), beginning pod set (R_3), seed enlargement (R_5), and full maturity (R_8) occurred at 47, 56, 79 and 128 day after emergence (DAE), respectively, for Williams and at 51, 63, 87 and 134 DAE, respectively, for Clark.



of leaf area at the end of growth stage might be due to senescence of leaves associated with remobilization of the stored metabolites from the leaf to developing seeds. Trend of leaf area index and total dry weight of plant was observed in (Table 1). The highest dry weight per plant was observed in T_1, T_2 and T_6 treatments at 97 DAE and T_3, T_4 and T_5 treatments at 112 DAE. Also, changes in trend of LAI was showed that one lateral leaflet removal at R_5-R_6 (T_4) and pod removal 50% at R_5 +10 days (T_6) had the highest and lowest LAI at the maturity stage, respectively. These results indicated that leaves falling or aging affected by pod removal, on the other hand sink limitation conduced source limitation. Therefore, in the present experiment, we did observe simple relation

Table 1. The effects of pod and leaflet removal treatments on leaf area index and total dry weight in soybean

	LAI					
Sampling date (day after emergence)	T_1	T_2	T_3	T_4	T_5	T_6
7	0.02	0.02	0.02	0.01	0.02	0.02
22	0.25	0.25	0.23	0.19	0.21	0.27
37	0.71	0.83	0.87	0.92	1.07	0.86
52	1.12	1.29	1.14	1.21	1.34	1.17
67	3.38	2.71	2.25	3.38	3.52	3.11
82	3.92	3.08	2.79	3.79	3.11	3.88
97	4.16	3.17	2.88	3.05	2.73	4.15
112	4.13	2.54	2.83	3.12	2.87	3.11
128	3.34	2.13	2.54	2.56	2.65	2.76
134	1.92	2.03	2.15	2.38	2.12	1.39
TDW (g/plant)						
7	0.13	0.12	0.10	0.10	0.12	0.11
22	0.64	0.66	0.68	0.67	0.67	0.68
37	1.65	1.71	1.65	1.83	1.71	1.73
52	3.74	3.12	2.51	4.27	4.75	4.12
67	7.52	6.46	7.55	8.11	8.85	7.23
82	12.57	11.16	12.07	10.83	10.21	9.42
97	14.52	13.69	12.10	11.97	11.51	10.74
112	14.12	12.19	12.39	12.32	11.61	9.25
128	13.11	12.52	11.83	12.07	11.13	9.15
134	10.28	10.16	9.89	8.72	9.32	7.12

- T_1, T_2, T_3, T_4, T_5, and T_6: removing none, one lateral leaflet removal at R_1-R_3, two lateral leaflet removal at R_1-R_3, one lateral leaflet removal at R_5-R_6, two lateral leaflet removal at R_5-R_6, and pod removal 50% at R_5+10 days, respectively.

between leaf senescence and pod removal (Table 1, 2 and 4). In previous studies leaf senescence shown by rapid decline in leaf area index (Sionit & Kramer, 1977; de Souza *et al*., 1997). Table 4 indicated that there are a compensatory responses by soybean to pod and leaf removals treatments especially when leaflet removal occurred at the R_1-R_3 stages and T_3. Similar trend was also observed with T_4 treatment. This result agrees with earlier reports (Eissenstat & Duncan, 1992; Mediene *et al*., 2002). But, we did not observe compensatory responses with the other treatments (T_1, T_2, T_5 and T_6) that agree with Higgins *et al*. (1983).

Results of this experiment indicated that pod and leaf removal treatment can strongly influence grain dry matter accumulation in soybean, which ultimately affected grain weight per plant. The pattern of grain growth is typically characterized by a sigmoid curve. Therefore, at first the dry matter accumulation increases lightly, and then, trend of dry weight accumulation in grain was accelerated. In all treatments from T_1 to T_6 this occurred at 82 days after emergence, approximately. From 112 day after emergence, the trend of dry matter accumulation in grain was declining till the end (Table 3). The highest of stem dry weight was observed in T_3 treatment at 82 DAE. Also,

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Table 2. The effects of pod and leaflet removal treatments on stem and leaf dry weight in soybean

Sampling date (day after emergence)	SDW (g/plant)					
	T_1	T_2	T_3	T_4	T_5	T_6
7	0.03	0.03	0.04	0.03	0.02	0.04
22	0.19	0.17	0.16	0.17	0.18	0.16
37	0.81	0.91	0.79	0.85	0.91	0.85
52	2.15	2.19	2.25	2.18	2.24	2.35
67	3.48	3.53	3.71	3.65	3.49	3.53
82	5.49	5.72	5.91	5.36	5.41	5.52
97	5.19	5.16	4.25	5.16	5.11	5.19
112	4.77	4.49	3.13	3.11	3.21	4.83
128	4.18	3.17	2.86	2.97	2.52	4.49
134	3.83	2.39	2.12	2.26	2.08	3.91
LDW (g/plant)						
7	0.03	0.03	0.02	0.02	0.03	0.03
22	0.55	0.56	0.57	0.56	0.56	0.54
37	1.29	1.41	1.36	1.35	1.47	1.35
52	3.08	2.31	1.71	3.18	3.13	3.27
67	4.45	2.99	2.73	3.35	3.38	4.52
82	4.97	3.35	3.18	2.71	2.26	4.55
97	4.86	3.72	3.45	3.37	2.75	4.53
112	4.46	3.38	3.25	3.11	2.84	4.39
128	4.25	2.52	2.81	2.13	2.07	4.31
134	2.61	1.35	1.45	1.11	1.01	2.51

- T_1, T_2, T_3, T_4, T_5, and T_6: removing none, one lateral leaflet removal at R_1-R_3, two lateral leaflet removal at R_1-R_3, one lateral leaflet removal at R_5-R_6, two lateral leaflet removal at R_5-R_6, and pod removal 50% at R_5 +10 days, respectively.

Table 4. The effects of pod and leaflet removal treatments on leaf and total dry weight ratio in soybean

Sampling date (day after emergence)	LDW/TDW × 100					
	T_1	T_2	T_3	T_4	T_5	T_6
7	23	25	20	20	25	27
22	85	84	84	83	84	79
37	78	82	82	73	85	78
52	82	74	65	74	64	79
67	59	46	36	40	37	61
82	40	30	26	25	22	48
97	33	27	29	28	23	48
112	32	26	24	25	23	47
128	32	20	24	18	18	43
134	25	17	15	13	10	35

- T_1, T_2, T_3, T_4, T_5, and T_6: removing none, one lateral leaflet removal at R_1-R_3, two lateral leaflet removal at R_1-R_3, one lateral leaflet removal at R_5-R_6, two lateral leaflet removal at R_5-R_6, and pod removal 50% at R_5 +10 days, respectively.

Table 3. The effects of pod and leaflet removal treatments on pod and grain dry weight in soybean

Sampling date (say after emergence)	PDW (g/plant)					
	T_1	T_2	T_3	T_4	T_5	T_6
7	0	0	0	0	0	0
22	0	0	0	0	0	0
37	0	0	0	0	0	0
52	0	0	0	0	0	0
67	0.20	0.21	0.25	0.22	0.17	0.22
82	0.72	0.51	0.46	0.52	0.57	0.59
97	1.89	1.35	1.41	1.47	1.11	0.86
112	2.83	1.61	1.48	1.93	1.72	1.13
128	2.69	1.23	1.13	1.48	1.27	1.18
134	2.51	1.21	1.01	1.34	1.13	0.98
GDW (g/plant)						
7	0	0	0	0	0	0
22	0	0	0	0	0	0
37	0	0	0	0	0	0
52	0	0	0	0	0	0
67	0.010	0.009	0.008	0.009	0.009	0.009
82	0.86	0.59	0.51	0.83	0.79	0.43
97	2.21	1.71	1.53	1.61	1.32	1.14
112	3.37	2.65	2.31	2.49	2.34	1.97
128	3.51	2.59	2.35	2.54	2.46	2.12
134	3.52	2.46	2.35	2.52	2.40	2.14

- T_1, T_2, T_3, T_4, T_5, and T_6: removing none, one lateral leaflet removal at R_1-R_3, two lateral leaflet removal at R_1-R_3, one lateral leaflet removal at R_5-R_6, two lateral leaflet removal at R_5-R_6, and pod removal 50% at R_5 +10 days, respectively.

the rapid declining of SDW in T_2, T_3, T_4, and T_5 treatments revealed that stems have an important compensatory role in remobilization of the stored carbohydrates to grain at the different conditions (Table 2).

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