J. Basic. Appl. Sci. Res., 2(9)9049-9055, 2012
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

An Evaluation of Effects of Source – Sink Limitation on Yield and Yield Components in Two Soybean Varieties

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ABSTRACT

To evaluate effects of source – sink limitation on yield and yield components in Soybean varieties, a field experiment was conducted at Research Farm of Islamic Azad University of Karaj, Iran during 2010-2011. The experimental design was a factorial in randomized complete block with 4 replications. The treatments included seven treatments of source – sink limitation: 20% pod removal (L1), 40% pod removal (L2), 60% pod removal (L3), 80% pod removal (L4), control (L5), 50% leaf removal (elimination upper half of plants (L6) and 50% leaf removal (elimination lower half of plants) (L7). The other treatments were included two varieties (M7 and M9). The results showed main effects of different varieties had significant effect on plant height, the number of nod, grain yield and harvest index. Furthermore, main effects of different levels of source-sink limitation had significant effect on plant height, the number of nod, the number of pod in plant, the number of pod in sub stem, the number of seed per plant, seed yield in single plant, seed yield, harvest index, biomass and 1000 seed weight. Moreover, interaction effects of different varieties and different levels of source-sink limitation had significant effect on the number of nod, sub stem and biomass. Variety of M7 had more yield than M9 (with 535.77 Kg per hectare). On the other hands, removal of 20% and 40% of the pods were placed in one statistical group with the control but removal of 60% and 80% of pods showed significant difference with control and reduced the seed yield.
Keywords: Soybean, source limitation, sink limitation, yield and yield components.

INTRODUCTION

Efficient use of solar energy by plant requires maximum absorption of radiations by its green tissues. Leaves efficiency for use of solar energy and its save duration are important factors for the accumulation of plant dry matter [8-]. The mobilization of photosynthetic materials from source to sink is related to production capacity of photosynthetic matter on the one hand and consumption capacity of photosynthetic matter on the other hand. The inequality between these two factors leads to decrease in yield. In other words, a suitable balance between sink and source is an important factor to have a good yield [7-]. Focusing on sources and sinks provides what appears to be a simple two-component system; unfortunately, analysis of this system does not always clearly identify the yield-limiting processes [6-]. The effect of source-sink manipulations on soybean yield depends on the stage of development of the crop. During flowering and pod set, pod and seed number respond to changes in photosynthesis [1-] indicating a source limitation. Some researchers reported different effects of leaf elimination on grain yield depending on time, intensity and method of implementation of leaf elimination [21-]. These strains probably are result of change in pattern of gas exchange [21-], allocation of photosynthetic materials [4-] or change in seed weight due to change in pattern of seed development [11-]. Yasari et al. (2009) reported that the sink-source elimination showed minimum number of seed per pod obtained at leaves elimination from the upper part of the canopy [18-], similar to what was observed for number of pods per plant, showing the vital role played by flag leaves in provision assimilates for seeds and pods at higher surfaces of the plant canopy. Egli and Bruening, 2001 suggested that the soybean plants are source limited if photosynthesis is reduced [4-].

Board (2004) in a study about leaf elimination on soybean observed that the decrease of LAI in 1/3 leaf removal in middle stage of grain filling was 41% and in 2/3 leaf removal was 56% [2-]. The results of 41% decrease in LAI were 92.1% decrease in light absorption and 7.6% decrease in yield loss. In soybean, the number of seeds per unit area is important yield component that variation in yield is explained mostly by changes in this component.

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There is a highly positive correlation between soybean yield and seed number (seed/m2) [9-], [12-; Moreover, seed number and seed size are primary components of soybean yield [15-]. Canviness & Thomas (1980) in soybean indicated that the increase of leaf elimination extent reduce the yield [3-]. Yelshetty et al., (1996) reported in sunflower upon increasing leaf elimination level and closing the leaf elimination to the flowering stage, the seed yield will be increased due to the reduction of plant's photosynthetic level [19-].

As soybean has a low grain yield in Karaj region, one of the main aims of this study was recognition of soybean limitation factor in this area. On the other hand, estimation of the most logical increase in leaves or increase in seed and pod numbers is useful for breeders to resolve limitations in soybean varieties in Karaj region. The objective of the present study was evaluation of sink-source relationship of soybean cultivars at different levels of source-sink limitation.

MATERIALS AND METHODS

To evaluate effects of source-sink limitation on yield and yield components in Soybean cultivars, a field experiment was conducted at Research Farm of Islamic Azad University of Karaj, Iran (35o 45' N, 50o 56' E, 1160 M) during 2010-2011. Soil texture was loam-sandy and PH and salinity through depth of 30 cm was 7.6 and 5.2 (ds m-1), respectively (Table 1). The experimental design was a factorial in randomized complete block with 4 replications. The treatments included seven treatments of source-sink limitation: 20% pod removal (elimination of all pods until 5th nod) (L1), 40% pod removal (elimination of all pods until 5th nod and elimination of other pods decussate (L2), 60% pod removal (elimination of all pods until 5th nod and elimination two of the tree of other pods) (L3), 80% pod removal (elimination of all pods until 5th nod and elimination of other pods three of the four) (L4), control (L5), 50% leaf removal (elimination upper half of plants) (L6), and 50% leaf removal (elimination lower half of plants) (L7). The other treatments included two varieties (M7 and M9). Each variety planted at 4 lines (as furrow) in 4 meters length and the distance between two rows was 50 cm and between two plants on each row was 5 cm. Measurement for yield were done on the two middle rows of each plot and 15 normal plants randomly selected from that rows were Measured for yield components.

Table 1 soil properties of the experimental plots

Soil texture	K(solvable) (ppm)	P(solvable) (ppm)	N total (ppm)	EC (ds/m)	PH	Organic carbon percentage (% O.C)
Loam-sandy	314	9.6	0.55	5.2	7.6	**0.6**

The SAS software package was used to analyze all the data (SAS 9.2) and means were compared by the least significant differences (LSD) test at 0.05 probability level.

RESULTS

Plant height

The plant height had a significant difference in levels of variations of sink and source and variety in probability range of 1% (Table 2). Considering means comparison of the levels of variations of sink and source, it was concluded that pod removal treatments had a significant difference with the control and had more height (Table 3). In other words, photosynthetic materials which have been used for seed filling will be used for reproductive growth and increasing the plant height after pods removing. Removal of 50% of upper leaves had no significant differences with control while removal of 50% of lower leaves did (Table 3).

Number of sub stem and node

According to the results, this trait had not a significant difference in sink and source and variety, just the interaction effect of variety × sink and source variations was significant in probability range of 5% (Table 2). In variety of M7, upon cutting the pods, the sub stem has been increased by comparison to the control, in other words, the extra photosynthetic materials have been used for increasing the stems but after cutting the leaves, as the plants had no extra photosynthetic materials, the sub stem did not increased and has been placed in one statistical group with the control. In variety of M9, whereas leaf and pod cutting has not changed the sub stem numbers, it may be concluded that the source limitation was more in this variety (Figure 1, Table 3).

In trait of number of node there was a significant difference between levels of sink and source variations and interaction effect of variety × sink and source variations (in probability range of 1%) and a significant difference between levels of variety (in probability range of 5%) (Table 2). In both varieties (M9 and M7), after cutting the pods, a significant difference in number of node with the control was observed and in fact upon cutting the pods the extra photosynthetic materials have been used for productive growth and have been increasing of the node numbers but upon cutting the leaves as the plants had no extra photosynthetic materials, the node number has not been increasing and has been placed with the control in one statistical group (Figure 2).

Pod number in plant, pod in sub stem and seed number in plant

Considering the variance analysis, among these traits, there was a significant difference only between the levels of sink and source in probability range of 1%, (Table 2). In the traits of pod number in plant and pod in sub stem in pod cutting treatments, a significant difference has been observed between the control and this result was predictable because it is one of the test treatments and has been applied manually, it means that source removal will not produce more pods (Table 3). But cutting leaves had no effect on pod number and was placed in one statistical group with the control; it probably indicates that the pod number is affected by genetics. In the trait of seed number per plant in the treatments of pod cutting, a significant difference has been observed with the control (Table 3). It means that the reduction of source gives the opportunity of seeds filling but finally this increase could not compensate the seed number and yield reduction resulted from seed number. In other words, the reduction of pod number could not lead to the increase of seed number in other pods and it indicates that probably the seed number per plant is referred to genetic factors, so probably plant breeders can improve the source limitation and produce the varieties which have more seed number in pod. Proulx and Nave, (2007) decelerated under sink-limited conditions, yield is correlated with seed number but not with seed size, although seed size is generally larger than the control [14].

Seed yield in a single plant

Seed yield in a single plant, there was a significant difference only between the levels of sink and source in probability range of 1% (Table 2). Means comparison of sink and source levels indicated that after cutting the pods, the seed weight in a plant was reduced (Table 3), it means that reduce of seed number in plant will reduce their weight, however the single seed weight is increased but finally will not compensate the reduction of total seed weight. Leaf elimination treatments have showed significant difference, in other words, the leaf elimination will reduce the seeds weight thus, it can be concluded that the plant has no extra leaves because after eliminating leaves, seed's weight is reduced and the materials transmission and seed filling is avoided but upper and lower leaves elimination have equal effect on seed's weight and the upper leaves of the plant have the same role that the lower leaves do, in seed filling.

1000 seed weight:

The 1000 seed weight was significant only in sink and source treatment in probability range of 1% (Table 2). In pod removal treatment, an increase in 1000 seed weight upon elimination of pods, and also a significant difference between pod removal treatment and control was observed. The highest amount of 1000 seed weight (139.95 g) was recorded in 80% pod removal [L4]. In the leaf removal treatments, removal of 50% of upper leaves had a significant difference with the control and reduced the 1000 seed weight (86.28 g) but removal of 50% of lower leaves had no significant differences with the control (Figure 3). Yasari et al (2009) reported that the comparison of different levels of leaf and flower elimination at flowering stage of the plant also showed that 33 % of flower elimination resulted in maximum 1000 seed weight [17]. The minimum 1000 seed weight (86.28g) was obtained in half of leaves elimination from the upper part of the canopy.

Seed yield

In the trait of seed yield a significant difference was observed between varieties and levels of sink and source variations in probability range of 1% (Table 2). In treatment of variety, M7 (535.77 kg/hectare) had more yield than M9 (489/78 kg/hectare). In pod removal treatments, it was observed that removal of 20% and 40% of the pods, were placed in one statistical group with the control but removal of 60% of pods (315.62 kg/hectare) and 80% of pods (312.50 kg/hectare) showed a significant difference with the control and reduced the seed yield. Yasari et al, (2009) reported that sink and source limitation showed that at control (without leaf or flower elimination) maximum seed yield (75.82g.m-2) was obtained, after which leaves elimination from the lower part of the canopy had the second highest seed yield (66.18 g.m-2) [17].

In leaf removal treatments no significant difference has been observed with control (Figure 4). Muro et al, (2001) reported that the 33% of leaf elimination in sunflower regardless of growth stage will reduce the yield significantly [13]. Proulx and Nave, (2007) showed that pod removal treatments increased seed size when compared to the control, indicating that seed growth was sink-limited within this treatment group [14].

Biomass and Harvest index

The results of biomass variance analysis showed that a significant difference exists between levels of variety and levels of sink and source variations (in probability range of 1%) whilst the interaction of variety × sink and source variations had a significant difference (in probability range of 5%), (Table 2).Totally variety of M7 with 36.72% had more harvest index than M9 (31.33 %). In two varieties of M9 and M7 upon pod removal, the biomass was not reduced comparing to the control means, no source limitation exists and the source can make the materials easily for the other parts of plant. Leaf removal treatments did not show any significant differences with the control and biomass did not vary consequently so the sink is limited (Figure 5).

In harvest index, a significant difference exists between levels of sink and source variations and variety in probability range of 1%) (Table 2). Between varieties, M7 had more harvest index comparing to M9. In the levels of sink and source variations upon increasing the number of removed pod, due to reducing the seed number and seed weight and, due to the increase of plant's productive growth, the harvest index will be reduced comparing to the leaf elimination. In this trait after removing leaves no significant difference has been observed with the control (Table 3). As mentioned, in seed and biomass yield no difference was shown between leaf removal and the control consequently so the sink is limited.

Table2: Analysis of variation for seed yield and attributing traits for different varieties and levels of sink-source limitation

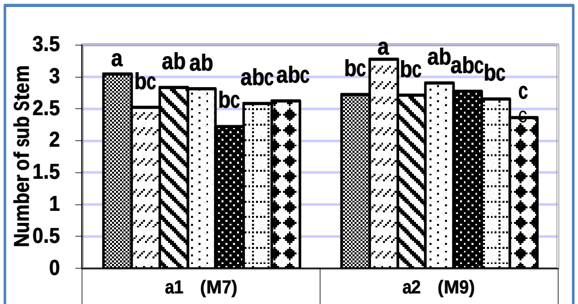
Source of variation	df	Plant height (cm)	Number of sub stem	Number of nod	Number of pod per plant	Number of pod in sun stem	Numbe r of seed per plant	Seed yield in single plant (g)	1000 grain weight (g)	Grain yield (kg/ha)	Biomass (kg/ha)	Harvest index
Replication	3	0.46^{ns}	0.001^{ns}	0.08^{ns}	32.53^{ns}	0.18^{ns}	142.43^{ns}	0.45^{ns}	116.27^{ns}	4762.23^{ns}	12334.14^{ns}	**141.5****
Variety (A)	1	35.29**	0.16^{ns}	0.82*	15.26^{ns}	0.67^{ns}	0.12^{ns}	2.39^{ns}	33.26^{ns}	188329.48**	1331739.05**	**407.53****
source – sink limitation (L)	6	45.51**	0.25^{ns}	6.08**	204.84**	19.25**	1177.5**	18.7**	3616.87**	109624.45**	260978.97**	**413.56****
A*L	6	7.57^{ns}	0.32*	1.02**	2.46^{ns}	0.27^{ns}	185.25^{ns}	1.06^{ns}	151.33^{ns}	23254.81^{ns}	145991.88*	**5.31^{ns}**
Error	39	3.64	0.12	0.17	13.33	0.16	90.87	0.71	81.23	12095.92	52329.2	**18.73**
C.V	-	4.93	12.87	3.25	22.33	15.2	25.62	18.87	7.87	23.01	15.34	**12.71**

**, Significant at 0.01 level *, Significant at 0.05 level n.s, non significant

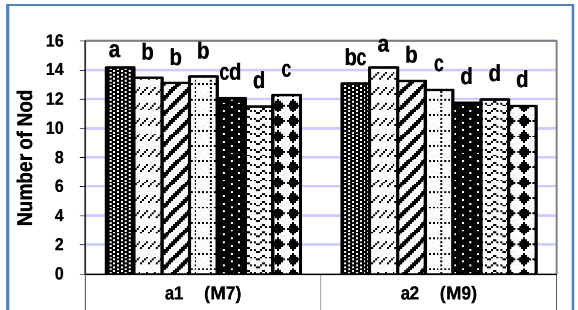
Table 3: Mean comparison different soybean varieties at levels of sink-source limitation.

Treatment	Plant height (cm)	Number of sub stem	Number of nod	Number of pod per plant	Number of pod in sun stem	Number of seed per plant	Seed yield in single plant (g)	1000 grain weight (g)	Grain yield (kg/ha	Biomass (kg/ha)	Harvest index
Variety											
M7(a1)	39.46a	2.66a	12.90a	16.87a	2.55a	37.16a	4.27a	115.27a	535.77a	1645.28a	36.72a
M9(a2)	37.87b	2.77a	12.66b	15.82a	2.77a	37.25a	4.69a	113.73a	419.78b	1336.85b	31.33b
LSD	1.03	0.18	0.22	1.97	0.21	5.15	0.45	4.87	59.45	123.66	2.33
source – sink limitation											
L1	40.43a	2.88a	13.65a	17.79b	2.45b	36.71bc	4.64bc	122.63c	512.66a	1801.7a	37.11b
L2	40.93a	2.90a	13.83a	16.08b	1.49c	34.51c	4.03c	126.53bc	510.42a	1535.4bc	31.71c
L3	40.40a	2.78ab	13.20b	10.10c	1.27c	23.04d	3.07d	133.78ab	315.63b	1241.7d	.06d
L4	39.81ab	2.86a	13.12b	9.00c	0.73d	20.72d	2.30d	139.94a	312.50b	1322.9cd	23.11d
L5	34.92c	2.50b	11.95c	22.65a	4.25a	50.76a	6.93a	98.91d	591.67a	1481.3bc	41.54a
L6	35.95c	2.62ab	11.77c	19.09ab	4.20a	44.70ab	5.30b	86.28e	514.06a	1572.4ab	39.28ab
L7	38.21b	2.49b	11.95c	19.70ab	4.22a	49.98a	5.09b	93.44de	587.50a	1482.1bc	39.37ab
LSD	1.93	0.35	0.42	3.69	0.41	9.64	0.85	9.11	111.23	231.35	4.37

Similar letters in each column shows non-significant difference

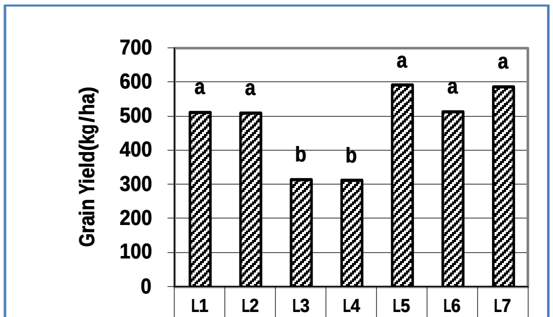


	a1 (M7)	a2 (M9)
L1	3.05	2.73
L2	2.53	3.28
L3	2.84	2.72
L4	2.82	2.91
L5	2.23	2.78
L6	2.59	2.66
L7	2.63	2.37

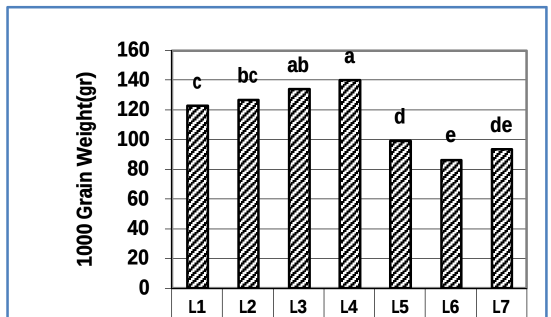


	a1 (M7)	a2 (M9)
L1	14.21	13.11
L2	13.48	14.2
L3	13.13	13.28
L4	13.57	12.67
L5	12.11	11.8
L6	11.53	12.02
L7	12.33	11.58

Fig 1 interaction between variety × sink-source limitation on number of sub stem Fig 2 interaction between variety ×sink-source limitation on number of nod

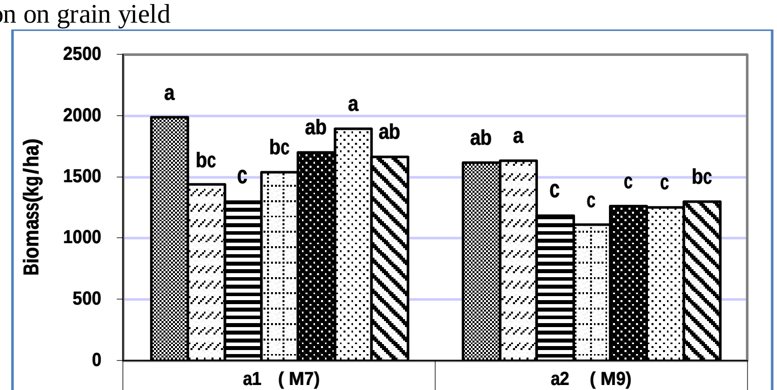


	L1	L2	L3	L4	L5	L6	L7
sink-source limitation	512.	510.	315.	312.	591.	514.	587.



	L1	L2	L3	L4	L5	L6	L7
sink-source limitation	122.	126.	133.	140	98.9	86.2	93.4

Fig 3 interaction between variety × sink-source limitation on 1000 grain weight Fig 4 interaction between variety ×sink-source limitation on grain yield



	a1 (M7)	a2 (M9)
L1	1984.69	1618.75
L2	1437.5	1633.33
L3	1300	1183.33
L4	1537.5	1108.33
L5	1700	1262.5
L6	1891.62	1253.12
L7	1665.62	1298.61

Fig 5 interaction between variety × sink-source limitation on biomass

DISCUSSION

Totally pod removal will maximize the vegetative growth of soybean (which are indeterminate varieties) and may conclude that probably M9 and M7 varieties had no limitations in source. Sink removal will increase the productive growth and mobilization photosynthetic materials to the plant's components such as making further leaf and vegetative stem then through applying effective crop production methods may use the produced energy which is spent for other components, for upraising more yield and seed number. The role of upper leaves in productive growth was more than lower leaves. Removal of upper leaves may cause to the extensive loss to photosynthesis but lower leaves have fewer role for increasing the productive growth of plant. According to study of Yasari et al 2009 Sink-source elimination,treatments showed that maximum plant height (47.46 cm) obtained at which the leaves of one-third height of lower part of the plant were eliminated. This record was not statistically different from those obtained at control (46.79 cm) and elimination of the leaves at the middle part of the plant height (47.16 cm). The minimum plant height (41.35 cm), observed at which the leaves of upper part of the plant were cut [17]. In levels of sink and source variations, upon pod removal, the yield was reduced because the extra photosynthetic materials could not be used for increasing the seeds, in other words, increasing the seeds weight in such condition could not compensate the seed yield reduction so may declare that the seeds have obtained their maximum weight thus the plant must be breed to have more seed number and may state that variety of M7 and M9 have sink-limitation. Although 1000 seed weight has been increased comparing to the control, this increase was not enough to compensate the yield reduction due to fewer seeds, thus the varieties which are available in the test, have limitation in seed number per plant so more seed number in plant must be used to obtain the maximum yield. Some researchers reported that an increase in seed yield was mostly due to proliferation of pod number per plant comparing to the seed number per pod and 1000 seed weight. The results are supported by those reported by *(*Yasari *et al*.,2008) suggesting that increase in seed yield was mainly because of more pod number per plant [18]. Similar observations were also reported by (Santonoceto *et al*., 2002) and (Hocking *et al*., 2003) for canola and (Zhaohui and Shengxiu ., 2004) for mustard [16], [10], [20].

One of the ways for increasing photosynthesis is sink demand. The sink demand will be increased when there are more seeds, thus the leaves will have more photosynthesis and considering that radiation rate for photosynthesis is more in climate condition of Karaj, so further seed number may increase the sink demand and yield. According to figure 4, the yield reduction in the pod removal treatment, are more than leaf removal treatment and the yield has not been reduced, it means that the plant confronts surplus of photosynthetic materials in leaf removal condition.

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