academicJournals

Vol. 9(2), pp. 222-229, 9 January, 2014
DOI: 10.5897/AJAR11.1646
ISSN 1991-637X ©2014 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Evaluation of light extinction coefficient, radiation use efficiency and grain yield of soybean genotypes

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Accepted 13 May, 2013

This experiment was performed at the Research Center of Agriculture and Natural Resources, Ardabil, province (Moghan), Iran, in 2009 and 2010. Light extinction coefficient, radiation use efficiency, yield and yield components of 17 soybean genotypes were evaluated. Number of seed per plant was significantly affected by years. In both years, all traits among genotypes were significantly different. In both years, the highest number of seed per plant was obtained from Apollo genotype. Omaha and NE-3399 genotypes had the highest seed weight in the first and second years respectively, whereas L.83-570 genotype produced the lowest value for this trait in both years. The highest yield in the first year (351.3 and 349.8 g m^{-2}) were obtained from Apollo and Ks-4895 genotypes, respectively, while in the second year, Zane genotype produced the highest yield. In both years the lowest yield were derived from Rend and L.83-570 genotypes. The maximum (0.62 ± 0.084) and minimum (0.44 ± 0.034) value for coefficients of light extinction were obtained from Hsus-H116 and Apollo genotypes respectively. The highest radiation use efficiency (1.14 ± 0.134) was obtained from Darby, and the lowest (0.91 ± 0.152) from L.17 genotype. In general the Apollo genotype with respect to its low light extinction coefficient and high radiation use efficiency produced the highest grain yield.

Key words: Light extinction coefficient, radiation use efficiency, genotype, soybean.

INTRODUCTION

Grain yield in soybean is influenced by environmental factors in growing conditions during the grain filling period (Mathew et al., 2000). Dynamics of grain growth process are affected by reproductive stage duration and environmental factors, such as solar radiation and temperatures govern during this growth stage (Bastidas et al., 2008). Radiation use efficiency (RUE) as g MJ^{-1}, is defined as amount of dry matter produced per solar energy received (Sinclair and Muchow, 1999; Purcel et al., 2002; Soltani et al., 2006) and frequently, calculated by linear regression slope of biomass vs. cumulative radiation absorbed or absorbed photosynthetic active radiation (Akmal and Janssens, 2004). RUE levels varies according to plant species, climatic conditions, crop management, plant developmental stage, measuring method and plant components, so, the models must be changed and developed for the species and the environmental conditions (O'Connell et al., 2004). Pengelly et al. (1999) reported that the light extinction coefficient (LEC) and RUE in bean, faba bean, sesbania and soybean is very different. However, the larger amount of radiation is received by the early growth of soybean on account of higher leaf area index; the highest RUE was obtained by sesbania, bean, soybean, and faba

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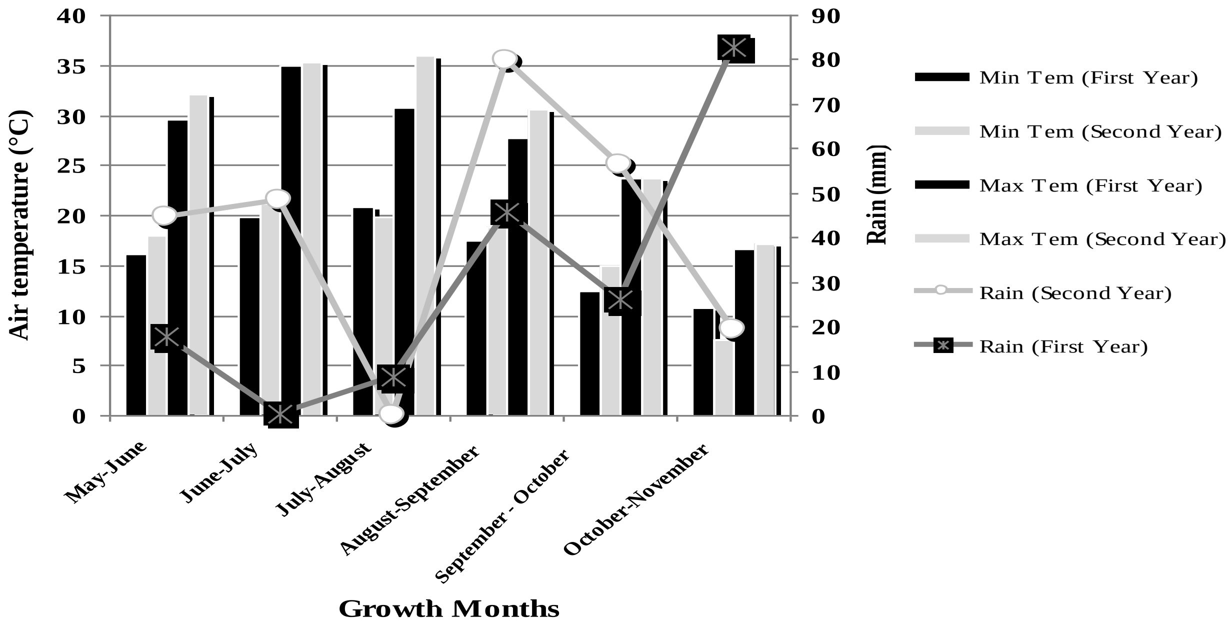

Figure 1. Local temperature and rainfall variance over the two years of experiment.

bean of 1.08, 0.94, 0.89 and 0.77 g MJ^{-1}, respectively. Also, LEC value for soybean, bean, sesbania,and faba bean was achieved 0.5, 0.59, 0.58 and 0.60, respectively. Alimadadi et al. (2006) found statistically significant difference for LEC and RUE among various cultivars of red beans and stated that with increasing leaf area index (LAI) and reduced LEC, RUE was increased in bean cultivars. Bell et al. (1993) showed that with increase in LEC from 0.3 to 1, RUE was decreased from 2.75 to 1.5 g MJ^{-1} in peanut. Also such results have been reported in C_4 plants (Kiniry et al., 1989). Ellis et al. (2000) calculated the amount of RUE for soybean isolines from 1.3 to 2.8 g MJ^{-1} and suggested that this can be attributed to higher RUE resulting from a more suitable arrangement of the leaves within the canopy and assigning the fewer photosynthetic matters to the reproductive parts. The lowest and highest amount of LEC in this work varied from 0.29 to 0.51 and the faster development of the leaf area coincided with the faster LEC. De Costa and Shanmugathasan (2002) reported the maximum RUE in soybean var. PB1 in about 0.92 to 0.98 g MJ^{-1} in full irrigation based on the absorbed photosynthetic active radiation (PAR), while in 0.45 PAR of the total radiation, maximum RUE of about 2.04 to 2.18 g MJ^{-1} was obtained. De Oliveira et al. (2009), obtained the RUE values in soybean of 1.46 to 1.99 g MJ^{-1} under the natural field conditions located in Brazilian Amazon region, based on the PAR in 2007 to 2008, respectively. In their opinion, the difference between the years was likely due to the water limitation in 2007 associated with the higher air temperature and pressure deficit. Liu et al. (2005) reported that the grain yield significantly varied in different soybean genotypes and found that the number of seeds and pods was higher in the high yielding ones. Liu et al. (2006) stated that the existing of the enough light in the flowering period increased yield of 144 to 252%, while, this increment varied from 32 to 115% in the pod stage. Soybean cropping, as second cultivation, is done in the Moghan region, which is associated with the reduced day length hours and incident radiation in the late season, so, it is necessary to evaluate different soybean genotypes and to introduce those having the higher yield and RUE.

MATERIALS AND METHODS

A field experiment was performed at the Research Center for Agriculture and Natural Resources, Ardabil province (Moghan), Iran, in 2009 and 2010. Moghan plain has warm and semi-dry Mediterranean climate. Average annual, maximal and minimal temperatures are 20.7, 14.7 and 8.6°C, respectively. Changes in temperature and precipitation of the region in the two years of the trial are shown in Figure 1. Soil type is calcareous thiosol, light brown to gray brown, with a depth of several meters in some areas. Soil pH is varied from 7.5 to 8.1 and the amount of electrical conductivity (EC) in the depth of a meter, reaches 1 m mho/cm. Experiment was conducted using 17 soybean genotypes (Table 1) in a randomized complete block design with three replications. Planting date was assigned on July first and third in the first and second tests, respectively. Each plot contained five rows, each four meters 45 cm apart and a total density of 20 plants per square meter was applied. After the seedbed preparation, seeds were inoculated with bacteria and immediately planted at a depth of 3 to 5 cm. Amount of the applied fertilizer was set according to the soil test results. Agricultural operations, including the amount and frequency of irrigation, were arranged based on the regional current standards.

Light extinction coefficient and radiation use efficiency

To determine the LEC, amount of the incident light above and under

Table 1. Soybean genotypes names used in this experiment.

No	Genotype
1	L.83-570
2	L.93-3312
3	NE3399
4	Darby
5	L.75-6141
6	Omaha
7	L.77-2061
8	Rend
9	Stress land
10	Ks4895
11	Spry
12	Hsus-H116
13	INA
14	Williams
15	L.17
16	Zane
17	Apollo

the canopy, and leaf area index (LAI), sun scanning device (Delta T, Cambridge England) was applied. Measurements were done in the three points of each plot in the mid-day through 11 am to 1 pm. Based on the measured values of LAI and radiation levels above and under the canopy, amount of the LEC (k) for all genotypes was determined using the Beer-Lambert equation (Sarmadnia, 1994):

$$\text{Ln } I_t/I_o = -k \times LAI$$

Where; I_t = amount of the light in the lower part of the canopy (MJ m^{-2} s^{-1}), I_0 = amount of the light in the upper part of the canopy (MJ $m^{-2}s^{-1}$), k = light extinction coefficient, LAI = leaf area index.

Slope of the linear relationship between LAI and the natural logarithm of the cumulative received radiation is considered as LEC. Recording the incident radiation and absorption by the canopy was performed five times to flowering stage and then, absorption amount of the radiation (F) was calculated according to Soltani et al. (2006):

$$F = 1- (I_1 / I_0)$$

Daylight hours, during the emergence to flowering stage of soybean genotypes (Prepared by the Meteorological Organization of the Ardabil province), were changed to the solar absorbed radiation (Doorenbos and Pruitt, 1977). Daily solar radiation values were calculated and collected as daily cumulative data by multiplying solar received radiation by the ratio of the received radiation per day. RUE (g MJ^{-1}) was calculated from the fitted linear relationship between the cumulative received radiation and the cumulative dry matter, the slope of this line represents the RUE (Sinclair and Muchow, 1999). Plant height of three plants per plot was selected at the time of maturity and the average was calculated for a single plant. Number of seeds per plant, 100-seed weight and the grain yield per plant, were measured by harvesting from a square meter area of each plot.

Statistical analysis

The normality (uniformity) of data, were assigned by SPSS software. Data were subject to analysis of variance by SAS and graphs were drawn using Excel software.

RESULTS

Light extinction coefficient

In this experiment, the slope of the linear fit between LAI and cumulative radiation received by the natural logarithm to be served as LEC. The highest LEC (0.62) was observed in Hsus-H116 genotype (Figure 2) followed by genotypes Omaha, L.17 and L.83-3312 (Table 2). Also, the lowest K (0.44) belonged to the Apollo genotype (Figure 2).

Radiation use efficiency

Slope of the linear relationship between received cumulative radiation and the cumulative dry matter was considered as RUE. The highest RUE (1.14) was observed in genotype Darby (Figure 3) followed by the Omaha, Apollo and Ks-4895 genotypes, respectively (Table 2). Also, the lowest RUE (0.91) was obtained from L.17 genotype (Figure 3) and genotypes Rend, INA and L.83-570 with minor differences were placed before this genotype (Table 2).

Mean comparison of traits

Seed number per plant

Genotypes Apollo and Darby (with 99.9 and 96.4 seed per plant, respectively) were obtained as the maximum value of this trait in the first year, while the lowest number of seeds per plant (62.9) belonged to genotype Rend (Table 3). In the second year, the highest number of seeds per plant (108.5 and 107) belonged to the Apollo and Zane genotypes, and the lowest one, to the Rend, L.17 and INA at a rate of 76.9, 75.2, and 73.4, respectively (Table 3).

100-Seed weight

In the first year, the highest and lowest 100-seed weights were observed in Omaha (19.3 g) and L.83-570 (15.2 g) (Table 3). In the second year, the highest value for this trait (18.4 g) resulted from NE-3399 genotype, followed by genotype L.93-3312. In the second year, genotype L.83-570 possessed the lowest 100-seed weight (14.0 g) similar trend with first year (Table 3).

Seed yield

The highest seed yield (351.3 and 349.8 g m^{-2}) was obtained from Apollo and Ks-4895 genotypes in first year,

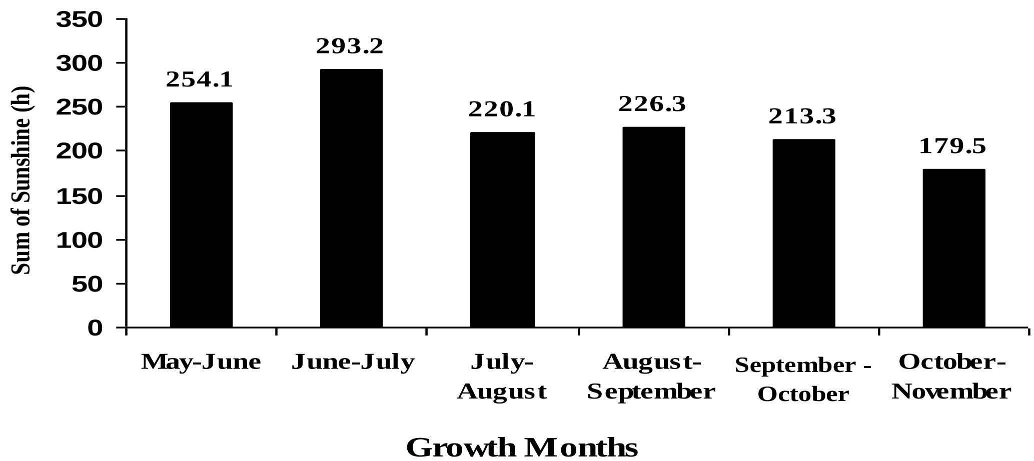

Figure 2. Sum of sunshine at growth season in first year of experiment.

Table 2. Radiation use efficiency (RUE g MJ^{-1}) (RUE ±SE) and extinction coefficients (k ±SE) with their corresponding R^2 and CV for soybean genotypes as a second crop.

Genotypes	Extinction coefficients (k)	R^2	CV (%)	RUE (g $DM.MJ^{-1}$)	R^2	CV (%)
L.83-570	0.51±0.075	0.961	8.7	0.97±166	0.919	19.7
L.93-3312	0.59±0.017	0.997	2.3	1.01±0.139	0.946	16.1
NE3399	0.50±0.050	0.971	7.8	0.99±0.148	0.936	17.7
Darby	0.50±0.023	0.993	3.4	1.14±0.134	0.961	13.4
L.75-6141	0.49±0.027	0.991	4.3	1.01±0.139	0.947	16.0
Omaha	0.60±0.039	0.987	5.1	1.13±0.166	0.940	16.7
L.77-2061	0.51±0.123	0.849	17.6	0.99±0.132	0.949	15.2
Rend	0.54±0.134	0.843	18.5	0.94±0.148	0.931	18.4
Stress land	0.47±0.090	0.900	14.4	1.02±0.164	0.928	18.5
Ks4895	0.50±0.051	0.969	7.9	1.10±0.141	0.953	13.5
Spry	0.54±0.041	0.982	6.0	1.07±0.145	0.948	14.3
Hsus-H116	0.62±0.084	0.946	10.6	1.08±0.156	0.942	15.4
INA	0.56±0.087	0.931	11.9	0.96±0.167	0.917	20.4
Williams	0.45±0.034	0.982	5.9	1.04±0.173	0.923	19.7
L.17	0.59±0.044	0.983	5.9	0.91±0.152	0.923	19.3
Zane	0.53±0.034	0.988	4.9	1.03±0.191	0.907	20.8
Apollo	0.44±0.031	0.985	5.4	1.11±0.200	0.912	19.6

respectively. Also, genotypes L.83-570 (212.6 g m^{-2}) and Rend (207.0 g m^{-2}) showed the lowest rates (Table 3). In the second year, Zane genotype produced the highest grain yield (377.4 g m^{-2}), and Rend and L.83-570 genotypes showed the lowest yields (231.6 and 224.2 g m^{-2}), respectively (Table 3).

DISCUSSION

Light extinction coefficient

The highest and lowest LEC were obtained from Hsus-H116 (0.62) and Apollo (0.44) genotypes. Findings of Ellis et al. (2000) in soybean isolines illustrated that the lowest and highest LEC (0.29 and 0.51) was affected by faster leaf area development. Pengelly et al. (1999) reported the soybeans LEC about 0.50. Alimadadi et al. (2006) reported that there is significant difference among the varieties of red beans and vetch for the LEC and they showed reduction in LEC with increases of leaf area index. Ellis et al. (2000) believed that the differences for LEC between the various lines of soybean in the long term is a function of differences in canopy structure and in case of the vertical leaves in the upper parts and horizontal ones in the lower parts of the canopy, which provide

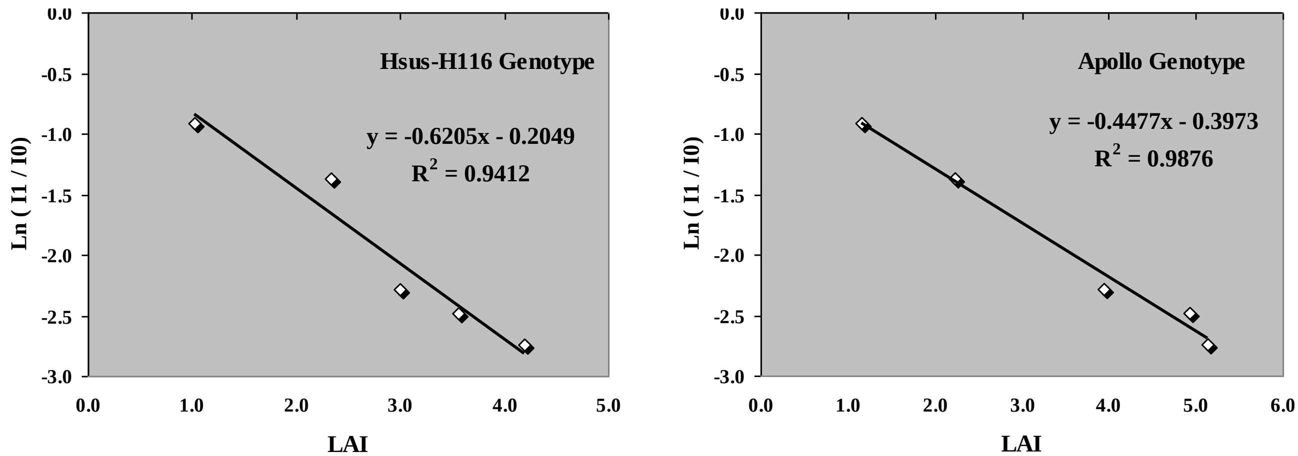

Figure 3. Relationship between natural logarithm (Ln I1/I0) and leaf area index (LAI) for anthesis of soybean genotypes with highest and lowest extinction coefficient (k) (Linear regression slope as light extinction coefficient (k)).

greater amount of light penetration into the canopy and the possibility of photosynthesis in the mid sections and lower parts (Keating and Carberry, 1993). Squire (1990) believes that the plants with the rapid canopy closure, has less LEC than those are slowly expanding. In this experiment, although Williams's genotype, having the highest leaf area index (5.4) and LEC, was almost equal to Apollo genotype, but had lower yield that it would be due to the low harvest index and assignment of photo assimilates into the parts more than grain.

Radiation use efficiency

The highest RUE was observed in Darby genotype, followed by the Omaha, Apollo and Ks-4895 genotypes, respectively (Figure 4). Also, the lowest RUE was seen in the L.17 genotypes. It was found that the plants such as corn and soybean, can only capture 50 to 60% of the photosynthetically active radiation (PAR) during the cropping season, that is merely up to 20 to 36% annually PAR (Della-Maggiora et al., 2000). It would be of great importance in lower RUE. On the other hand, Wheeler et al. (1993) believe that longer flowering period and indeterminate growth of some genotypes in long run, has impact on RUE changes which is due to differences in leaf area development and canopy structure (Ellis et al., 2000). Also, Akmal and Janssens (2004) expressed that the amount of RUE varies according to the plant species, weather conditions, crop management, plant developmental stage, measurement and herbal ingredients, and so, developed models must be applied for the same species and environmental conditions. RUE rate in soybean has been reported by Pengelly et al. (1999) up to 0.89 g MJ^{-1}. Alimadadi et al. (2006) reported significant difference in RUE between different cultivars of red bean and vetch and found that with increasing leaf area index and decreasing LEC, RUE was increased between varieties of beans. Bell et al. (1993) showed that with increasing LEC in peanuts from 0.3 to 1, the RUE was decreased from 2.75 to 1.5 g MJ^{-1}. Ellis et al. (2000) calculated RUE rates in soybean isolines from 1.3 to 2.8 g MJ^{-1} total radiation and expressed that the higher RUE is due to the higher and relatively long lasting LAI; the better distribution and arrangement of more leaves within the canopy, and less allocation of photo assimilates to the reproductive structures. De Costa and Shanmugathasan (2002) observed the maximum RUE soybean, PB1 var. in about 0.92 to 0.98 g MJ^{-1} based on the PAR under full irrigation circumstances and concluded assuming the ratio of PAR to total global radiation to be 0.45, the maximum RUE will be of about 2.04 to 2.18 g MJ^{-1} (APAR). De Oliveira et al. (2009) obtained the RUE values under the field conditions in Brazil's Amazon region, from 1.46 to 1.99 g MJ^{-1} PAR, in 2007 and 2008, respectively. They announced the possible reason for the differences as the water restrictions in 2007 along with the higher air temperature, vapor pressure deficit, and also increase in the global radiation into the earth during 2008. In our trial, genotypes with high yields were of high RUE, low LEC and high LAI. Despite its high RUE, the Omaha genotype lost grain yield, due to the high LEC and low LAI, but high rate of harvest index largely compensated for this loss.

Seed number per plant

In combined analysis, the impact of year) on the number of seed per plant was significant (*P*<0.05). Average of this trait in the first and second year was 82.5 and 93.2, respectively (Table 3). Number of seed per plant in genotypes showed significant increase in the second year than first year. Apollo genotype possessed the highest value in both years which showed a difference with the Rend genotype in the first year of 37.0 and with the INA genotype in the second year of 32.3%. Considering the

Table 3. Mean values of some traits in soybean genotypes over two years.

Traits / Genotypes	Mean values													
	Plant height (cm)		Pod plant^{-1}		Seed plant^{-1}		100-seed weight (g)		Seed yield		Harvest index (%)		LAI	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
L.83-570	66.2^{e}	74.8^{de}	31.9^{f}	38.9^{fg}	69.8^{gh}	79.9^{de}	15.2^{e}	14.0^{g}	212.5^{f}	224.2^{f}	28.9^{c}	29.0^{d}	4.5^{a-f}	4.8^{a}
L.93-3312	63.7^{e}	71.4^{e}	37.9^{f}	45.0^{e}	75.5^{d-g}	88.6^{cd}	18.7^{abc}	18.3^{ab}	282.6^{de}	323.2^{abc}	38.2^{ab}	39.2^{bc}	3.7^{f}	4.0^{a-f}
NE3399	77.8^{d}	88.2^{bc}	42.8^{e}	51.2^{c}	74.7^{efg}	92.5^{bc}	18.5^{abc}	18.4^{a}	276.8^{de}	340.4^{abc}	38.3^{ab}	39.4^{bc}	4.7^{a-e}	5.0^{f}
Darby	68.2^{e}	73.5^{de}	41.6^{cd}	50.5^{cd}	96.4^{a}	103.9^{ab}	17.6^{bcd}	16.4^{c-f}	338.9^{ab}	341.4^{abc}	41.7^{a}	45.6^{ab}	4.6^{a-f}	4.9^{a-e}
L.75-6141	66.7^{e}	71.2^{e}	49.7^{b}	58.4^{b}	91.1^{ab}	104.0^{ab}	16.5^{de}	16.0^{def}	301.1^{bcd}	334.4^{abc}	41.6^{a}	39.5^{bc}	4.9^{a-d}	5.2^{a-e}
Omaha	82.1^{bcd}	81.3^{cd}	45.3^{bc}	52.4^{c}	84.8^{bc}	98.6^{abc}	19.3^{a}	17.2^{a-e}	326.6^{abc}	339.1^{abc}	40.6^{a}	41.5^{b}	4.0^{def}	4.3^{a-d}
L.77-2061	101.3^{a}	101.3^{a}	56.2^{a}	58.7^{b}	86.7^{bc}	103.4^{ab}	16.6^{de}	15.7^{ef}	286.5^{cd}	325.9^{abc}	38.8^{ab}	40.5^{b}	4.7^{a-e}	4.9^{def}
Rend	88.0^{b}	88.2^{bc}	39.6^{de}	46.7^{de}	62.9^{h}	76.9^{e}	16.4^{de}	15.1^{fg}	207.0^{f}	231.6^{f}	28.4^{c}	28.1^{d}	4.1^{def}	4.4^{a-e}
Stress land	88.1^{b}	88.3^{bc}	38.6^{de}	45.2^{e}	79.8^{c-f}	89.2^{cd}	18.8^{abc}	17.2^{a-e}	300.9^{bcd}	306.5^{bcd}	39.4^{a}	39.3^{bc}	4.8^{a-e}	5.1^{a-e}
Ks4895	83.1^{bcd}	86.2^{bc}	32.1^{f}	39.8^{fg}	91.1^{ab}	98.8^{abc}	19.1^{ab}	16.7^{b-f}	349.7^{a}	331.8^{abc}	42.4^{a}	41.3^{b}	5.0^{abc}	5.3^{abc}
Spry	80.9^{cd}	84.2^{bc}	39.6^{de}	40.2^{f}	92.3^{ab}	97.5^{abc}	17.6^{cde}	16.7^{b-f}	325.1^{abc}	328.5^{abc}	40.9^{a}	40.7^{b}	4.8^{a-e}	5.1^{a-e}
Hsus-H116	87.3^{bc}	88.6^{bc}	31.9^{f}	36.2^{gh}	$83.3^{b-}e$	88.8^{cd}	18.2^{abc}	17.0^{a-e}	303.5^{bcd}	301.4^{cde}	37.4^{ab}	39.1^{bc}	4.2^{c-f}	4.5^{c-f}
INA	85.1^{bc}	90.7^{b}	26.3^{g}	32.3^{h}	68.7^{gh}	73.4^{e}	17.6^{bcd}	17.1^{a-e}	241.9^{ef}	250.8^{ef}	32.8^{bc}	31.2^{cd}	4.4^{b-f}	4.7^{b-f}
Williams	102.3^{a}	105.1^{a}	42.5^{cd}	50.6^{cd}	84.5^{bcd}	97.5^{abc}	17.5^{cd}	17.8^{abc}	295.6^{cd}	347.7^{abc}	38.1^{ab}	42.5^{b}	5.4^{a}	5.7^{a}
L.17	82.3^{bcd}	90.6^{b}	33.2^{f}	33.5^{h}	73.6^{fg}	75.2^{e}	18.8^{abc}	17.7^{a-d}	277.6^{de}	$265.5d^{ef}$	38.5^{ab}	38.3^{bc}	3.9^{ef}	4.2^{ef}
Zane	80.4^{cd}	91.9^{b}	54.4^{a}	64.9^{a}	87.1^{bc}	107.0^{a}	17.7^{a-d}	17.5^{a-d}	308.6^{bcd}	377.4^{a}	40.5^{a}	46.4^{ab}	4.2^{c-f}	4.5^{c-f}
Apollo	88.3^{b}	86.0^{bc}	48.6^{b}	59.6^{b}	99.9^{a}	108.5^{a}	17.6^{bcd}	16.5^{a-d}	351.2^{a}	358.9^{ab}	42.7^{a}	52.0^{a}	5.1^{ab}	5.4^{ab}
Mean	81.9	86.0	40.8	47.3	82.5	93.2	17.8	16.8	293.3	313.5	38.2	39.6	4.5	4.8

Data with the same letter have no significant difference to each other at ($P<0.05$) probability level.

existence of significant positive correlation (0.871 and 0.861) between this trait and grain yield in the first and second years (Table 4), increased grain yield can be achieved by its improvement and genotypes with a greater number of seeds are expected to have a higher grain yield. Liu et al. (2005) indicated the role of seed number per plant in the final grain yield.

100-seed weight

100-seed weight was not influenced by year, but differences between genotypes within two years were significant (Table 3). With increasing seed number per plant in the second year, 100-seed weight partially was declined. As we know, in the process of seed filling, not only the environmental conditions such as sufficient moisture is involved in the transfer process, but also current enough photosynthesis, reserved substances and balance in the source and sink relations have great importance. Increase in the sink values without providing sufficient sources, may result in their inadequate and undesirable evolution and development. Omaha and NE-3399 genotypes obtained the highest seed weight in the first and second year, respectively. Higher amounts of this trait led to the favorable yields in these genotypes. In contrast, L.83-570 genotype that had lowest 100-seed weight during both years was found to be very low yielding within both years (Table 3). Positive and significant correlations (0.540 and 0.606) between the 100-seed weight and grain yield in first and second year (Table 4) show that with providing suitable conditions for enhancing 100-seed weight, final grain yield can be improved. Bangar et al. (2003) found that there is significant and positive correlation between 100-seed weight and grain yield in soybean genotypes, which is in accordance with our findings. Similar results was confirmed by Arashad

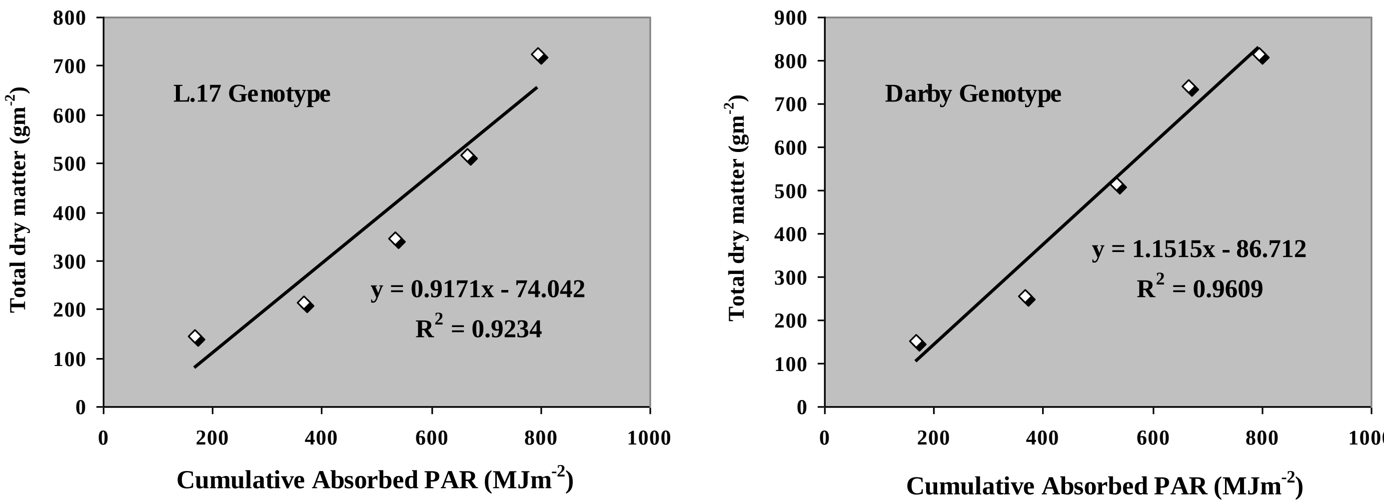

Figure 4. Relationship between dry matter accumulation and cumulative absorbed PAR for soybean genotypes with highest and lowest radiation use efficiency (RUE) (Linear regression slope as radiation use efficiency (MJm^{-2}).

Table 4. Correlation coefficients among measured traits in soybean genotypes over the two years.

Traits	Year	Plant height	Pod plant^{-1}	Seed plant	100-seed weights	Seed yield	Harvest index	LAI
Plant height	2009	1						
	2010	1						
Pod plant^{-1}	2009	0.184^{ns}	1					
	2010	0.055^{ns}	1					
Seed plant^{-1}	2009	0.040^{ns}	0.454**	1				
	2010	-0.040^{ns}	0.742**	1				
100-seed weights	2009	0.037^{ns}	-0.152^{ns}	0.063^{ns}	1			
	2010	0.081^{ns}	0.026^{ns}	0.123^{ns}	1			
Seed yield	2009	0.052^{ns}	0.291*	0.871**	0.540**	1		
	2010	0.010^{ns}	0.607**	0.861**	0.606**	1		
Harvest index	2009	0.010^{ns}	0.360*	0.806**	0.475**	0.909**	1	
	2010	0.033^{ns}	0.467**	0.739**	0.523**	0.859**	1	
Leaf area index	2009	0.199^{ns}	0.106^{ns}	0.410**	-0.094^{ns}	0.305*	0.307*	1
	2010	0.127^{ns}	0.196^{ns}	0.378*	-0.026^{ns}	0.288*	0.187^{ns}	1

ns, *,** non-significant and significant at $P<0.05$ and $P<0.01$, probability levels, respectively.

et al. (2006).

Seed yield

Seed yield was not affected by year, although in the second year its average increased compared with the first year at a rate of 6.4%, which was mainly related to the increases in number of seed per plant, because 100-seed weight was reduced this year (Table 3). Mathew et al. (2000) showed that growth conditions have profound effect on yield during grain filling period. In the environmental conditions without biotic and abiotic stresses, climatic factors such as light and temperature have the most impact on the yield, which was confirmed by Jeyaraman et al. (1990) finding, whom concluded that the production potential of the soybean plant can be improved when the maximal and minimal temperatures ranges from 31.2 to 31.6 and 20.4 to 20.9°C, respectively. Statistically significant differences in yield among the genotypes within two years of our experiment, indicated variability and genetic diversity among the populations and these genotypes are suitable for selection. Liu et al. (2008) stated that the continuous increases in soybean yield in North China during the last half century, especially in recent years, mainly resulted from increase in unit area and different factors including favorable tillage, plant density, LAI and its durability, increases in plant photosynthesis, sink-source relations, seed development regulators, stress physiology, cultivar selection, and also, plant protection. Traits related to the seed yield have major role in determining the final grain production. In this experiment, the highest seed yields in the first and second years were achieved from the Apollo and Zane genotypes, respectively. In general these genotypes had the greatest number of pods and seeds per plant (over the two years) among all of the investigated genotypes, and L.83-570 and Rend genotypes produced the lowest yield within two years. Also L.83-570 genotype had the lowest seed weight (at two years) and Rend genotype produced the lowest number of seed per plant (two years) among genotypes (Table 3).

Conclusion

It was found that there is high genetic diversity among the genotypes used in this trial. Among the traits related to yield, harvest index and the number of seed per plant showed the highest correlation with the grain yield. It was cleared that in the genotypes with high LAI, LEC was decreased and the amount of RUE was increased and this led to the seed yield increment.

ACKNOWLEDGEMENTS

Authors gratefully thank staff of the Research Center for Agriculture and Natural Resources of Ardabil province (Moghan). Efforts of the experts of the Ardebil Meteorological Organization for providing the necessary weather information are also greatly appreciated.

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