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FORAGE AND GRAIN YIELD PERFORMANCES OF SOYBEAN LINES

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ABSTRACT

Field experiments were conducted to evaluate the yield and yield components of twelve soybean genotypes as a forage and a grain crop in Marmara Region of Turkey in 2003-2004 growing seasons. Forage and dry matter yield and yield components at one vegetative stage (V5) and two reproductive stages (R2, and R4) and seed yield was determined in all soybean genotypes. The experiments showed that the harvest stages had significant effects on forage and dry matter yield, and R4 reproductive stage had the highest forage and dry matter yield. Dry matter partitioning of soybean plant parts was greatly affected by harvest stages, while the genotypes had little effect on dry matter partitioning of soybean plant parts. There were statistically significant differences between soybean genotypes in seed yield, but the differences were small. The correlations between forage and dry matter yield and seed yield were not statistically significant.

KEY WORDS: Glycine max, dry matter yield, protein yield, harvest stages, forage quality

INTRODUCTION

Soybean [Glycine max (L.) Merr.] is a productive, high-quality annual forage legume [5]. Prior to 1941, the acreage harvested for hay exceeded that harvested for grain. However, forage soybean production has been of minor importance (only 2-3 % of the total acreage) and is practiced mostly when crop damage limits grain harvest [7],[14]. Recently, interest in growing soybean specifically as a forage crop has increased with breeding of soybean cultivars for forage [2].

Limited research is available on the potential benefits of soybean as a forage crop [14]. Forage yields from grain-type soybeans in Wisconsin, USA ranged from 2.4 to 7.4 t ha^{-1}, depending on the stage of maturity at harvest. Grain soybean cultivars harvested at the R7 stage (one seed pod at mature color; 50% of leaves yellow) produced forage that was similar in quality to alfalfa harvested at early bloom [5]. As soybean matured from stage R1 (beginning bloom) to R7, the leaf proportion declined. Changes in the stem proportion with soybean maturation were less consistent [3]. Hintz and Albrecht (1994) [6] reported that the leaf percentage of grain type soybean decreased from 70.8 % at R1 to 16.8 % at R7. Meanwhile, the stem fraction increased from 29.2 % at R1 to 38.3 % at R5 (beginning seed development) and then declined to 28.3 % at R7 as the pod and seed components increased. The harvest of soybean for forage at R6 to R7 maximized both the dry matter yield and forage quality [5], [10]. However, the dry matter yield of soybean forage typically increased with advancing maturity, and with variability in forage quality [4].

In our previous studies, fall seeded pea (Pisum sativum L.) and common vetch (Vicia sativa L.) produced satisfactory forage yield for hay or silage production in rainfed conditions of Mediterranean-type environment. In contrast, forage yield was dramatically reduced in spring seeded crops because of high temperatures and water deficits [1], [19]. Livestock producers in the region are interested in growing forage soybean in summer and ensiling alone or in mixtures with corn (Zea mays L.) or sorghum (Sorghum bicolor L.) which are widely grown for silage production in this Region [17], [18]. Soybean can be a high quality alternative forage in summer, but little is known about the yield and composition of soybean plant components, and whole-plant forage quality. This study was conducted to evaluated twelve soybean lines for forage yield at different harvesting stage and their seed yield performances in Marmara Region of Turkey.

MATERIAL AND METHOD

The research was conducted at the coastal zone of northwest Turkey (40° 11′ North, 29° 04′ East) at Uludag University, Bursa, 70m above the sea level. The soil was clay loam, classified as vertisol typic habloxrert, slightly alkaline (pH is 7.2), medium in P (73 kg ha^{-1}) and rich in K (1130 kg ha^{-1}), containing 1.4 % organic matter. Soybean lines; 1535, 1609, 1309, 602, 517, 436, 1530, 1304, 626, 613, 435 and a cultivar A-3127 were planted in a randomized complete block design with three replications. The soybean lines have been developed at Cukurova Agricultural Research Institute, Adana, Turkey. Seeds were planted by hand with 100 kg ha^{-1} seeding rate on 18 May 2003, and 23 May 2004. The plot size was 10 m x 5 m = 50 m^{-2}, consisting of eight rows spaced 60 cm. The soybean crop was not inoculated. A 100 kg ha^{-1} N fertilizer was applied after seeding in both growing seasons. Weed control was achieved manually. Irrigation was applied three times (V5, R2 and R5 stages) with a rotary sprinkler to maintain the soil near field capacity. The timing of irrigation was estimated visually as the soil surface dried.

Forage yield data were collected three times in 2003, corresponded to vegetative growth stage V5 (the fifth node above the cotyledonary leaf is fully opened) and reproductive growth stages R2 (an open flower at one of the two uppermost nodes on the main stem with a fully developed leaf) and R4 (the pod reaches 2 cm at one of the four uppermost nodes of the main stem with a fully developed leaf). At each sampling date, a sample of 2 m^2 was randomly harvested in each plot for forage production and then dried at 70 °C for 48 h. Randomly selected ten plants from each plot were measured for plant height, leaf width and leaf length and then separated for its constituent plant components, leaflet, pedicel, stem and flower + pods. The components were dried and weighed.

At seed ripening stage (R8), five plants were randomly sampled from each plot to determine plant height, pods/plant and seeds/pod characteristics every year. Seed yield was determined after cleaning the seeds. Four replicated 100-seed lots were weighed.

During every harvest stage, nitrogen was determined by the micro kjeldahl technique on duplicate dry matter for each line. Crude protein content (N x 6.25) and crude protein yields were calculated.

Analysis of variance was performed on morphological measurements and yield data using MINITAB (University of Texas, Austin) and MSTAT-C (Version 2.1 Michigan State University, 1991) programs. The significance of main effects was determined by the F-test.

Table 1. Yield and some characteristics of soybean lines in different stages.

Soybean Lines	Plant height (cm)	Leaf width (cm)	Leaf length (cm)	Forage yield (t ha^{-1})	Dry matter yield (t ha^{-1})	Protein yield (t ha^{-1})
			V5 Stage			
1535	25.4 d	5.4 b	7.9 bcd	5.9 gh	1.5 bcd	0.22
1609	35.0 ab	6.0 ab	9.2 a	6.4 ef	1.3 de	0.25
1309	30.8 bc	5.7 ab	7.7 cd	7.0 cd	1.2 e	0.23
602	27.6 cd	5.3 b	8.4 abc	5.6 h	0.9 f	0.15
517	31.6 bc	5.8 ab	8.3 abc	6.2 fg	1.7 a	0.27
436	30.5 bc	6.3 a	7.9 bcd	6.6 e	1.4 cde	0.29
A3127	27.3 cd	5.5 b	7.2 d	6.7 de	1.3 de	0.23
1530	31.8 bc	5.7 ab	8.3 abc	7.8 b	1.6 abc	0.26
1304	33.5 ab	6.0 ab	8.8 ab	8.3 a	1.6 ab	0.28
626	34.3 ab	5.5 b	7.8 bcd	7.0 d	1.4 de	0.23
613	33.0 ab	3.2 c	8.7 abc	7.9 b	1.6 a	0.28
435	37.0 a	5.8 ab	8.8 ab	7.4 c	1.4 de	0.24
Means	31.5	5.5	8.3	6.9	1.4	0.24
			R2 Stage			
1535	77.2 de	6.5 cd	12.0	12.5 h	3.1 e	0.48
1609	88.3 bc	6.9 cd	10.7	13.8 gh	3.6 cde	0.60
1309	83.1 bcde	6.9 cd	9.8	15.3 f	3.3 de	0.50
602	75.7 e	6.0 d	10.3	15.2 f	3.2 e	0.54
517	90.7 ab	8.4 a	11.5	14.9 fg	3.2 e	0.43
436	85.5 bcde	8.1 ab	10.8	17.2 de	3.8 bcd	0.57
A3127	80.9 bcde	7.1 bc	10.4	16.9 de	3.9 bcd	0.48
1530	87.6 bc	7.0 cd	10.3	20.1 ab	4.3 ab	0.70
1304	98.5 a	7.5 abc	11.3	20.3 a	4.7 a	0.66
626	86.1 bcd	6.5 cd	9.5	18.9 bc	4.4 ab	0.48
613	90.3 ab	4.8 e	11.2	17.8 cd	4.1 bc	0.53
435	80.2 cde	7.1 bc	10.2	16.0 ef	3.6 cde	0.57
Means	85.3	6.9	10.7	16.6	3.4	0.59
			R4 Stage			
1535	82.2 bc	8.0 abc	13.2	40.7 b	12.5 de	1.05
1609	109.0 a	9.2 ab	13.1	45.7 a	14.8 a	1.26
1309	72.3 bcd	7.8 abcd	11.5	33.0 de	10.6 fg	1.02
602	70.4 cd	8.2 abc	12.4	29.9 e	10.1 g	1.17
517	91.4 ab	9.8 a	13.1	41.7 b	14.1 ab	1.60
436	71.8 cd	8.6 ab	11.1	35.6 cd	12.7 cd	1.56
A3127	62.8 d	7.2 bcd	10.5	23.7 f	8.3 h	0.95
1530	75.6 bcd	7.0 bcd	11.3	40.9 b	13.8 abc	1.09
1304	91.2 ab	7.7 abcd	11.8	39.0 bc	13.3 bcd	0.91
626	76.5 bcd	6.1 cd	11.1	32.6 de	11.3 ef	0.71
613	76.2 bcd	5.6 d	13.0	32.6 de	11.3 efg	0.95
435	88.8 bc	9.8 a	13.1	33.8 d	11.2 efg	0.83
Means	80.7	7.9	12.1	35.8	12.0	1.10

RESULT AND DISCUSSION

The statistical analysis of the data revealed that performance of the lines for all agronomic parameters was significantly different over the years. Statistically significant differences ($P< 0.05$) were present for the main effects of lines and harvest maturities on forage and dry matter yield (Table 1). Both forage and dry matter yield significantly increased with advancing the maturity stages. Forage yield averaged 6.9 t ha^{-1} at V5 stage, 16.6 t ha^{-1} at R2 stage, and 35.8 t ha^{-1} at R4 stage. The yield reached 8.3 t ha^{-1}, 20.3 t ha^{-1}, 45.7 t ha^{-1} at V5, R2 and R4 stage in some lines, respectively. Dry matter yield also showed a similar pattern to forage yield. The dry matter yield produced by lines ranged from 0.9 to 1.7 t

Table 2. Constituent plant components of dry matter (DM) of soybean lines used at three different stages.

Soybean Lines	Plant Components (%)			
	Stem	Pedicel	Leaflet	Flower + pod
		V5		
1535	28.5 c	22.6 cd	46.2 b	-
1609	30.3 bc	21.9 d	46.1 b	-
1309	32.8 ab	22.6 cd	44.8 bc	-
602	32.1 abc	22.7 cd	45.3 bc	-
517	29.2 bc	25.6 abc	43.1 bc	-
436	29.2 bc	25.3 bc	44.2 bc	-
A3127	31.9 abc	25.9 ab	43.5 bc	-
1530	31.7 abc	21.9 d	46.0 b	-
1304	35.0 a	28.6 a	37.6 d	-
626	34.4 a	26.6 ab	42.6 bc	-
613	32.4 ab	21.6 d	41.8 c	-
435	29.5 bc	20.6 d	50.7 a	-
Mean	31.4	23.8	44.3	-
		R2		
1535	40.2 bc	11.9 bc	41.5 abc	6.4 c
1609	40.9 bc	13.1 ab	41.5 abc	4.7 e
1309	39.4 bc	11.3 cde	42.7 ab	6.6 c
602	44.2 a	9.8 f	38.9 cd	7.0 bc
517	39.5 bc	13.5 a	41.8 abc	5.2 de
436	40.2 bc	11.6 cd	41.9 abc	6.3 cd
A3127	42.1 ab	9.8 f	39.9 bcd	8.1 ab
1530	39.1 bc	12.0 bc	42.3 abc	6.6 c
1304	40.4 bc	9.9 ef	43.8 a	5.9 cd
626	44.5 a	10.6 cdef	37.5d	7.8 ab
613	38.7 c	10.3 def	42.3 abc	8.7 a
435	39.4 bc	11.6 cd	42.5 ab	6.6 c
Mean	40.7	11.3	41.4	6.7
		R4		
1535	25.0 ab	13.6 abcd	23.2 bc	39.0 de
1609	26.7 a	14.4 ab	32.8 a	26.2 f
1309	23.9 abc	12.6 bcde	25.5 bc	38.0 de
602	21.3 bcd	11.0 ef	20.2 bcde	47.4 abc
517	24.1 abc	14.7 a	24.2 bc	37.0 e
436	19.8 cd	13.8 abc	20.8 bcde	45.5 bcd
A3127	17.9 d	10.4 f	17.4 de	54.2 a
1530	21.8 bcd	12.9 abcde	24.2 bc	41.2 cde
1304	22.1 abcd	11.7 def	21.9 bcd	43.6 bcde
626	21.0 bcd	12.0 cdef	15.5 e	51.4 ab
613	19.8 cd	11.4 ef	20.1 cde	48.7 abc
435	23.9 abc	13.0 abcde	25.9 b	37.1 e
Mean	22.3	12.6	22.6	42.4

ha^{-1} at V5 stage, from 3.1 to 4.7 tha^{-1} at R2 stage, from 8.3 to 14.8 tha^{-1} at R4. Yield values observed in the current experiment are comparable to previously published studies, which reported dry matter yield between 2.6 and 14.3 tha^{-1}, depending on the environmental conditions and management [11], [14].

The dry matter yield of soybean averaged 12.0 t ha^{-1} with 9.7 % crude protein content at R4 stage. It was reported that dry matter yield of spring seeded field pea for 3 years averaged 3.6 t ha^{-1} [19], or common vetch 2.9 t ha^{-1} [1]. Our study indicated that, the soybean dry matter yield is clearly higher than those of spring sown annual

Table 3. Grain yield and some morphological characteristics of soybean lines

Soybean Lines	Plant height (cm)	Pods/plant	Seed/pod	1000-seed weight (g)	Grain yield (t ha^{-1})
1535	76.9 b	61.6 a	2.9	166.5 b	2.3 c
1609	101.9 a	61.0 a	2.7	146.7 cde	2.3 c
1309	70.9 bc	54.6 bc	2.8	154.4 c	2.4 c
602	69.6 bc	57.6 ab	2.9	139.4 e	2.4 c
517	95.8 a	54.8 bc	2.8	150.8 cd	2.5 bc
436	75.4 b	55.1 bc	2.8	154.0 c	2.7 ab
A3127	63.8 c	54.7 bc	2.9	144.2 de	2.3 c
1530	74.1 bc	52.2 cd	2.9	169.4 ab	2.8 a
1304	78.4 b	52.2 cd	2.9	139.3 e	2.3 c
626	73.1 bc	47.9 d	2.8	143.5 de	2.4 c
613	78.4 b	51.5 cd	2.9	177.3 a	2.4 c
435	92.0 a	60.2 a	2.6	143.4de	2.3 c
Mean	79.2	55.3	2.8	152.4	2.4

forage legumes, irrigated soybean can be a suitable summer forage for hay production in Mediterranean-type conditions. However, the soybean dry matter yield is not comparable with 25.1 t ha^{-1} dry matter yield of silage corn [17] or 28.6 t ha^{-1} of sweet sorghum [18]. Since silage crop harvesting timing is similar, soybean forage may be used for ensiling in mixtures with corn or sorghum in the region.

Hay protein content of the lines was significantly affected by harvest stages. Crude protein content averaged 17.7, 13.7 and 9.2 % at he V5, R2 and R4 stages, respectively. However crude protein yields increased linearly from 0.24 t ha^{-1} at V5 to 1.10 t ha^{-1} at R4, since great dry matter yield increases with advancing maturity (Table 1).

The plant height, leaf width and leaf length in vegetative (V5) and reproductive growing stages (R2, R4) was statistically influenced by the genotypes and harvest stages. However, the effect of harvest stages was greater than genotypes (Table 2). Harvest maturity had also the greatest effect on dry matter partitioning of soybean plant parts. The average stem fraction of total plant mass increased from 31.4 % at V5 to 40.7 % at R2, and then decreased significantly. The pedicel fraction decreased from 23.8 % at V5 to 12.6 % at R4. The leaf dry matter fraction decreased continually as plants were harvested at later reproductive growth stages, declining from 44.3 % at V5 to 22.6 % at R4. Contrarily, the flower + pod fraction increased from R2 to R4, as expected. Very little information is presently available on the effect of harvesting stages on protein content and dry matter partitioning in soybean genotypes. It is well known that crop maturation has the most pronounced effect on forage yield and quality of leguminous forage crops. In general, as the forage develop from early bud stage to full maturity, forage dry matter yield increased and the protein content decreased [16].

At maturity, plant height, pods per plant and 1000 seed weight were significantly influenced by the genotypes. Plant height varied from 63.8 cm to 101.9 cm, pods per plant varied from 47.9 to 61.6 and 1000 seed weight varied from 139.3 g to 177.3 g among soybean genotypes. Seeds per pod were not varied significantly, averaging 2.8 seeds per pod (Table 3). Although significant differences in mean seed yield were found among soybean lines within years, the seed yield variation was limited in both experimental years. Mean seed yield of the soybean lines varied from 2.3 t ha^{-1} to 2.8 t ha^{-1} in experimental years. The highest seed yield was obtained in line 1530 at combined years (Table 3). Our seed yield values generally concur with those of several early reports [8], [9], [13]. According to 2004 FAO statistics, soybean seed yield averaged 2253 kg ha^{-1} in the world and 2863 kg ha^{-1} in USA. Our grain yields were broadly similar to those grain yields.

It is generally stated that high forage and high seed yield are not usually parallel traits [12].. Also, Somaroo (1988) [15] indicated that the correlation between dry matter and seed yield is low in several forage legumes. In close agreement with those reports, in this study the correlations between seed and forage yields determined at three stages were small (r= 0.08 - 0.27) and statistically not significant. Although the correlations were obtained from only 12 soybean genotypes, these low correlations suggested that there were no clear associations between forage and seed yield in soybean.

CONCLUSIONS

Irrigated soybeans can be a suitable annual summer forage in Mediterranean-type environments like that of the Marmara Region of Turkey. This study indicates soybean forage yield exceeds that of broadleaf crops like field pea and vetch. Although forage yields do not compare with those of corn or sweet sorghum silage, soybean forage can be harvested at the same time as those grassy forage crops improving overall forage quality through increased protein. The forage and dry matter yield of soybean significantly increased with advancing the harvest stages. Hay protein content of the lines was significantly affected by harvest stages. The protein content decreased with advancing the maturity stages. Harvest maturity had also the greatest effect on dry matter partitioning of soybean plant parts. Significant differences in mean seed yield were found among soybean lines within years, the seed yield variation was limited in both experimental years.

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