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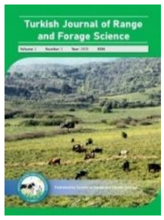

Forage Yield Performance of Soybean Genotypes for Spring Seeding and Double Cropping

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A B S T R A C T

Soybean, an annual broadleaf legume, may be grown as hay and pasture crop or ensiled with corn and sorghum for livestock. Field experiments in a Mediterranean-type climate were conducted in the 2013, 2014 and 2015 growing seasons to evaluate DM yield and some yield components of soybean genotypes [*Glycine max* (L.) Merr.] in Bursa, Turkey. In the study's first step, seventy soybean genotypes and five check cultivars were evaluated in augmented design in 2013 and then selected genotypes were grown in a completely randomized block design with three replications in 2014 and 2015 experimental years. All field studies were established in main (spring planting) and double cropping conditions, simultaneously. There were statistically significant differences between soybean genotypes in dry matter (DM) yield, yield components and partitioning of soybean plant parts in both main and double cropping. In main cropping conditions, DM yield of fifteen selected soybean genotypes averaged 15931 kg ha^{-1} in first and 9645 kg ha^{-1} in the second year of the study. Indicating planting date and year-to-year genotype differences, the DM genotypes ranged from 5683 to 26028 kg ha^{-1} in the main cropping system. Nine genotypes were also evaluated over two years for plant height, branching, leaflet size, and DM yield in a double cropping system with significant differences in evaluated traits and DM yield. Even in the double cropping system, soybean genotypes averaged well over seven tonne per hectare DM with a range of 4568 to 13293 kg ha^{-1}. As an indication of soybean forage quality, leaflet percentage increased and stem percentage decreased in the double cropping system. In a Mediterranean climate, soybeans for forage can provide a high-yield annual broadleaf alternative to annual grass or perennial forages by critically evaluating cultivar selection.

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1. Introduction

Soybean [*Glycine max* (L.) Merr.] is a productive, high-quality warm season forage legume that can be used for hay, silage, grazing, cover crop, wildlife cover, or green manure. Historically, soybeans in the USA were used as a nutritious annual hay, pasture, and silage crop. Early research extensively investigated forage yield, but demand for high protein feed grain in the early 1940s shifted soybean production and research from primarily forage to seed yield. As a result, forage quality deteriorated with seed-focused genotype selection. In recent decades, soybean forage research has shifted from planting soybeans for forage to harvesting soybean grain varieties for emergency forage due to hail, drought, or early frost (Barnhart, 2007; Heinrichs et al., 1997; Undersander, 2001). Consequently, farmers have limited research available for determining proper selection of soybean as an intended forage or pasture crop.

Although recently several soybean cultivars and experimental lines have been bred for forage production (Asekova et al., 2014; Devine and Hatley, 1998; Devine et al., 1998; Hintz et al., 1992), farmers have been forced to use a century-old cultivar with public and private research strikingly inadequate. International forage research is found wanting when one of the top performing forage soybean genotypes in our study is a variety that was introduced in the USA in 1914, as PI40658, first planted there in 1915 and named, Laredo, by 1919 (Morse, 1919; Piper et al., 1923; Taylor, 1920). Laredo, that annually sold and farmer-tested acclaimed forage soybean (Bennett, 2001; Handcock, 2016; WMS, 2016), originated from Yangpingguan (Yangping), China where it was an established high performer untold years in order to justify that century-old international transfer (Bernard et al., 1987; Shurtleff and Aoyagi, 2013).

As would be expected, soybean forage yield and nutritive value varied depending on genotype, location and maturity stage at harvest (Hintz et al., 1992; Altinok et al., 2004; Bilgili et al., 2005). Munoz et al. (1981) indicated when soybean pods were filled and leaves began to turn yellow, the percentages of leaves, stems, and pods were 28, 36, and 36, respectively, with a total DM yield of 12.4 t ha^{-1}. When grown for forage, Sheaffer et al. (2001) found no dry matter (DM) yield differences between forage-type and grain-type soybeans cultivars, which averaged 8.8 t ha^{-1}. In the southern Great Plains Region, USA, DM yields of forage soybeans ranged from slightly less than 1 to 5.4 t ha^{-1}, depending on climatic conditions (Rao et al., 2005). In USA, forage soybean cultivars Derry, Donegal, and Tyrone produced DM yields varying from 5216 to 13900 kg ha^{-1}, depending on location and year (Nayigihugu et al., 2000). Dry matter yields of Derry and Donegal reached 7.95 t ha^{-1} in UK conditions (Koivisto et al., 2003). Soybeans grown for forage averaged 9.3 and 11.3 t ha^{-1} DM yield at R4 and R6 stages, respectively, containing 13.3% crude protein, 8.2% degradable protein, and 60.6% in vitro dry matter digestibility at three different locations with Mediterranean climates in Turkey (Acikgoz et al., 2007).

A cereal/soybean double cropping system has been used successfully in the southern USA (Touchton and Johnson, 1981; Hume et al., 1985) and in the southern Pampas, Argentina (Calvino et al., 2003). In this system, soybean is seeded immediately after cereal crop harvest. Double-cropping soybeans behind wheat can lead to increased farm income if satisfactory soybean grain yields can be obtained with suitable weather and normal frost dates. In shorter growing season areas, double cropping forage soybean after cereals was practical in the north central USA environment. Forage yields of double cropping soybean following barley, winter wheat, and winter rye ranged from 60 to 105% of the main cropping soybean, and after oat (the latest planted crop) double cropping soybean yielded 38 to 57% of the main cropping soybean (LeMahieu and Brinkman, 1990). In the USA southern Great Plains dryland double-cropping soybean after winter wheat (*Triticum aestivum* L.) provided high quality summer forage, but soybean forage yield ranged only from 1.35 to 1.90 t ha^{-1} when soybean was grazed or harvested at beginning seed fill (Mackown et al., 2007). Double cropping soybean based on maturity and branching characteristics to maximize forage or grazing potential has not been established.

In Mediterranean regions of Turkey, soybean can be grown as a main cropping system (spring seeding) or double cropped after cereal harvest where soybean growers generally prefer to plant soybean for grain immediately following winter cereal harvest (mostly barley or wheat). Fall seeded annual forage legumes such as pea (*Pisum sativum* L.) and common vetch (*Vicia sativa* L.) have produced satisfactory forage yield under rain-fed conditions in a Mediterranean environment. However, forage yield of these species was dramatically reduced as spring-seeded crops due to high temperatures and water deficits (Aydogdu and Acikgoz, 1995; Uzun et al., 2005). There are currently very limited alternative high yield summer forage legume crops for grazing, hay or silage production in the region. Soybean offers a high quality forage legume for summer production as pasture and hay in Mediterranean climate environment or other areas of the world where soybean forage is adapted. However, little is known about variation of morphological traits, DM yields, and plant components of different soybean genotypes under spring seeded, or double cropping conditions. The objectives of these studies were to evaluate soybean genotypes from diverse origins for some morphological traits, DM yield, and plant components in the Mediterranean-type climate of Bursa, Turkey.

2. Materials and Method

Field studies were conducted on irrigated experimental plots at Uludag University, Bursa, Turkey during the 2013, 2014 and 2015 growing seasons. At a level 70 m altitude located in the coastal zone of northwest Turkey (40° 11′ North, 29° 04′ East), it is characterized as a Mediterranean type climate.

The specific site soil type is clay loam and classified as vertisol typic habloxrert with 7.2 pH value. Soil is medium in P (73 kg ha^{-1}), and rich in K (1130 kg ha^{-1}) with 1.4 % organic matter. Long-term annual rainfall averages 579 mm with only 20% falling in the soybean growing period (April-September). Mean temperature during the growing period is 21.0 °C with relative humidity of 75%.

Experimental fields were fall moldboard plowed and cultivated level in early spring. Soybeans were not inoculated. 50 kg ha^{-1} N-P-K fertilizer was applied uniformly after hand seeding in all 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. Irrigation timing was estimated visually as the soil surface dried. Sunflower was the previous crop in all experimental years.

Soybean genotypes used in this study were mainly provided by IPK (Leibniz-Institute of Plant Genetics and Crop Plant Research, Germany) and collected from different countries, mostly China, Japan, USA and Russia. Some experimental lines and local genotypes from Turkey were also included. Five standard checks (Derry, Greencastle, and Laredo from USA and Yemsoy and Yesilsoy from Turkey) were added for this study. Derry, Greencastle, and Laredo are typical forage type soybean cultivars (Group VI) registered in USA, and Yemsoy and Yesilsoy (Group IV) are soybean cultivars registered for forage production in Turkey.

Two experiments were performed using two sets of soybean genotypes. In the first set, all genotypes collected were evaluated in augmented design in 2013; then the selected genotypes were seeded in a completely randomized block design in 2014 and 2015. All simultaneous experiments were spring-seeded (referred to as “main” cropping) and double cropped.

A total of 70 soybean genotypes were grown in the 2013 augmented design with five standard checks replicated in five blocks, 3 m long rows spaced 70 cm. Seeding rate was 60 seeds per row. Seeding was made on 30 April 2013 for main cropping and 16 July 2013 for double cropping.

In the 2013 augmented study, ten soybean genotypes and five cultivars were selected for main cropping and the five soybean genotypes and four cultivars were selected for double cropping production system based on their DM yield performances. In the main cropping system, 15 different soybean genotypes were seeded in a completely randomized block design with three replications in experimental years 2014 and 2015. Each genotype was sown in 14.0 m^2 (2.4 by 5.0 m) plots consisting of 4 rows with 70 cm row spacing. Main crop seedings were done on 10 April 2014 and 14 May 2015 at seeding rates of 100 seeds per row. In the double cropping experimental design, plot size and seeding rate were similar to those used in the main cropping system. Double crop seedings were done on 14 July 2014 and 9 July 2015.

All plots were monitored regularly and days to 50% flowering of genotypes were recorded. Forage yield data was collected at R4 stage in all experiments. Plants were hand-cut at soil surface. In the 2013 augmented trials, 0.7 m^2 area was cut for forage yield, and 2.8 m^2 area of the center rows was harvested in randomized block trials in the 2014 and 2015. Before cutting, 5 randomly selected plants from each plot were measured for plant height and branch number per plant; then each of those plants were dissected into leaflet, petiole, stem, and flower plus pods components before weighing. Components were dried and weighted again. All samples were dried at 70 °C for 48 h for DM yield determination.

Different experimental groups (augmented and completely randomized block design) were subjected to analysis of variance for each character using MINITAB (University of Texas, Austin), MSTAT-C (Version 2.1 Michigan State University, 1991) and JMP (version 7.0, SAS Institute Inc.) software. The significance of treatment, main effects and interactions were determined at the 0.05 and 0.01 probability levels, by the F-test. The F-protected least significant difference (LSD) was calculated at the 0.05 probability level.

3. Results

Variance analysis of the 2013 augmented study showed significant effect ($P<0.01$ and $P<0.05$) of check cultivars and genotypes on DM yield, plant constituents, and all characteristics measured in both main and double cropping conditions; wherein both plantings, blocks affects were not statistically significant.

Days to flower, plant height, branches per plant, and plant constituent data are presented in Table 1. To simplify interpretation of results, only average and variation limits of measured characteristics of soybean genotypes and check cultivars are summarized in that Table. There was considerable variation in flowering time among soybean genotypes. Some early soybean genotypes flowered 55 and 35 days after seeding in main and double cropping conditions, respectively, compared to later flowering genotypes (119 and 76 days).

Table 1. Average and variation limits of measured traits of 70 soybean genotypes and check cultivars in main and double cropping conditions tested at maturity stage R4 (2013)

	Soybean genotypes			Check cultivars*		
	Average	Min.	Max.	Average	Min.	Max.
				Main Cropping		
Days to flower (days)	72.5	55.0	119.0	94.0	77.0	110.0
Plant height (cm)	76.1	14.1	243.1	127.9	105.4	162.6
Branches/plant	3.4	0.1	7.6	3.7	2.4	4.9
Dry Matter Yield (g/row)	756.0	8.4	3227.0	1481.9	961.1	2811.4
Stem (%)	34.4	20.6	64.7	38.2	33.1	41.8
Leaflet (%)	38.1	16.3	50.6	36.5	32.3	43.8
Petioles (%)	16.7	9.1	29.8	12.2	11.4	16.3
Flower + pods (%)	10.8	3.3	30.6	13.1	11.3	25.3
				Double Cropping		
Days to flower (days)	49.6	35.0	76.0	55.0	49.0	68.0
Plant height (cm)	43.9	13.6	92.0	89.6	67.6	111.4
Branches/plant	2.5	0.0	5.8	2.9	2.1	5.2
Dry Matter Yield (g/row)	279.9	14.2	751.1	615.1	443.4	806.0
Stem (%)	25.4	15.4	39.6	30.3	27.1	32.2
Leaflet (%)	42.4	27.4	57.2	45.1	38.8	52.5
Petioles (%)	13.7	6.2	20.0	14.0	11.9	17.7
Flower + pods (%)	18.5	2.7	51.0	10.6	4.7	15.1

*Average of 5 block

Plant height differences between the soybean genotypes varied from 14.1 to 243.1 cm in main cropping and from 13.6 to 92.0 cm in double cropping conditions. In general, average plant height of soybean genotypes was much lower than typical forage type soybeans cultivars. However, some soybean genotypes reached heights of 243.1 cm. As may be expected, all soybean genotypes tested in double crop conditions were clearly shorter on average than main crop conditions (76.1 vs. 43.9 cm). Maximum plant heights of soybean genotypes and check cultivars were 92.0 and 111.4 cm, respectively, in double crop conditions. Very little branching was seen in some genotypes, whereas some soybean genotypes branched profusely in both main and double cropping conditions. Check cultivars had more consistent branching and were generally comparable between main and double crop plantings.

Unexpectedly wide variation occurred among soybean genotypes in DM yield per 1 m row ranging from 8.4 to 3227 g in main cropping and 14.2 to 751.1 g in the double crop system. Average DM yield of soybean genotypes was much lower than the check cultivars in main cropping (756.0 vs. 1481.9 g) and in double cropping conditions (279.9 vs. 615.1 g). However, some soybean genotypes produced higher DM yield than check cultivars in main cropping conditions supported by increased days to flower, plant height, and branches per plant. Dry matter yield of soybean genotypes sown in main cropping produced a maximum of 3227.0 g while the double cropping maximum was DM yield of 751.1 g. Some soybean genotypes exceeded check cultivars in DM yield in main cropping conditions.

The DM yield of soybean genotypes and check cultivars at R4 maturity averaged approximately equal proportions of leaflet and stem material with far less yield from petioles and flower + pods especially for the check cultivars. Since the purpose of our study was to evaluate forage performance and quality characteristics, it is important to note leaflet percentage of double cropping was consistently higher than the main crop for both soybean genotypes and check cultivars, very likely due to shorter plant height and smaller stem percentage in the double cropping system. Furthermore, for forage quality characteristics, double cropped soybean genotypes had nearly three fourths (74.6%) of their aerial dry matter from leaflet, petioles, and flower + pods and it was 69.7% for check cultivars. Comparatively, the main crop system had approximately two thirds (65.6%) and 61.8% of those components respectively for main soybean genotypes and check cultivars.

In 2014 and 2015 field studies established in a completely randomized block design, the analysis of variance for the main cropping showed statistical differences among soybean genotypes and significant year x genotype interactions detected for measured morphological traits and DM yield (Table 2).

Large differences were observed between the two years for the morphological traits measured and DM yield (Table 3). Plant height of the 15 soybean genotypes averaged 123.8 cm in combined years. However, in the first year of the study (2014), plants were taller on average than in 2015 the second year (137.1 vs. 110.3 cm), which likely was caused by rain-delayed planting difference of a month (10 April 2014 vs. 14 May 2015). Average height of plants in forage type soybean cultivars Greencastle, Laredo and Derry (reaching heights of 172.8 – 175.7 cm in 2014 and 133.7 – 171.9 cm in 2015) was significantly greater than those in other soybean genotypes and check cultivars.

Table 2. Variance analysis of measured quality characteristics in main cropping conditions (combined years 2014 and 2015)

	DF*	Plant height	Branch/ plant	Leaflet width	Leaflet length	Dry matter yield
Genotypes (G)	14	**	**	**	**	**
Years (Y)	1	**	ns	**	*	**
G x Y	14	**	**	**	**	**
Blocks	4	ns	ns	ns	ns	ns
Error	56					

*: degree of freedom, *, **: F-test significant at $P < 0.05$, and $P < 0.01$ levels, respectively; ns, not significant.

Table 3. Plant characteristics of soybeans genotypes and cultivars in main cropping conditions (combined years 2014 and 2015)

Genotypes	Plant height (cm)	Branch/ plant	Leaflet width (cm)	Leaflet length (cm)
A-38	93.7	4.5	7.2	12.4
A-1523	109.4	4.7	5.3	9.4
A-1725	90.8	3.7	7.7	12.6
A-4232	115.6	3.1	8.1	11.8
A-4548	147.7	2.7	7.3	12.8
M-1	111.1	3.7	6.7	11.6
M-14	96.6	4.8	6.5	11.4
MDY-7	132.9	2.3	6.6	11.9
MDY-8	122.7	2.3	6.9	12.6
MDY-9	138.1	1.2	6.4	11.5
Derry	153.3	2.8	7.1	12.4
Greencastle	173.4	1.9	7.9	12.6
Laredo	162.8	3.5	6.9	10.2
Yemsoy	96.9	2.7	7.5	13.5
Yesilsoy	110.3	2.6	8.3	12.9
Average	123.8	3.1	7.1	12.0
LSD (0.05)	6.1	0.5	0.6	0.8

A significant interaction existed between soybean genotypes between years in morphological traits and DM yield in experimental years (Table 4). Dry matter yield of 9645 kg ha^{-1} in the second year of the study was only about 60% the average yield of the first year 15931kg ha^{-1}. The tall, later-maturing, forage-type soybean cultivar Greencastle had about the average DM drop, but consistently out-yielded the other soybean genotypes and forage type cultivars in both years

Dry matter yield of Greencastle was 26028 kg ha^{-1}, compared to other high-yielding A-4548 (24631 kg ha^{-1}) and Derry (23883 kg ha^{-1}) in 2014. Greencastle produced 16185 kg ha^{-1} DM yield followed by A-4548 (12749 kg ha^{-1}) and MDY-7 (12007 kg ha^{-1}) in 2015 while Derry (10097 kg ha^{-1}) dropped to fifth place in total DM the second year.

Table 4. Dry matter yield of soybeans genotypes in main cropping conditions (kg ha^{-1})

Genotypes	Years	
	2014	2015
A-38	13308	5683
A-1523	10007	8779
A-1725	11530	10141
A-4232	9878	9611
A-4548	24631	12749
M-1	15723	8528
M-14	10402	7819
MDY-7	19674	12007
MDY-8	22924	9911
MDY-9	15297	10449
Derry	23883	10097
Greencastle	26028	16185
Laredo	13641	8982
Yemsoy	9670	7340
Yesilsoy	12371	6399
Average	15931	9645
LSD (0.05)	1662	288

Although weather conditions vary by year, the later spring planting date in 2015 appears to have made a significant difference in individual genotype DM performance. Some genotypes decreased DM over 50% (e.g. Derry down 57.5%, A-38 down 57.3%, and MDY-8 down 56.8%) while other genotypes declined less than 15% (e.g. A-4232 down 2.7%, A-1725 down 12.0%, and A-1523 down 12.3%). Optimum planting dates for soybean forage yield in this location have not been established.

The analyses of variance indicated significant effects for genotypes and years for each of the traits evaluated and DM yield in the double cropping soybean trial. Significant genotype x year interactions also occurred for all measured traits and DM yield (Table 5).

Table 5. Variance analysis of measured quality characteristics in double cropping conditions (combined years 2014 and 2015)

	DF*	Plant height	Branch/Plant	Leaflet width	Leaflet length	Dry matter yield
Genotypes (G)	8	**	**	**	**	**
Years (Y)	1	**	**	**	*	**
G x Y	8	**	**	**	**	**
Blocks	4	ns	ns	ns	ns	ns
Error	32					

*degree of freedom, *, **: F-test significant at P < 0.05, and P < 0.01, respectively; ns, not significant.

Average across years, plant height, branch/plant, and leaflet dimensions in double crop soybeans were summarized in Table 6. Soybean genotypes differed significantly in those traits. Plant height, branching and leaflet dimensions were significantly influenced by the genotypes. Plant height of soybean genotypes averaged 89.7 cm, while plant height of forage-type cultivars Laredo and Derry were well over 100 cm. Branches per plant varied from 1.6 to 3.4; leaflet width varied from 7.2 cm to 8.9 cm, and leaflet length varied from 10.4 cm to 12.7 cm among soybean genotypes in 2014 and 2015 (Table 6).

Table 6. Plant characteristics of soybeans genotypes double cropping conditions (combined years 2014 and 2015)

Genotypes	Plant height (cm)	Branch/ Plant	Leaflet width (cm)	Leaflet length (cm)
A-4232	81.6	2.3	8.7	12.4
M-14	71.6	3.3	7.6	11.3
M-42	68.1	2.8	7.7	12.0
MDY-2	66.4	3.4	7.9	11.8
MDY-4	75.8	3.1	7.2	11.5
Derry	115.7	2.0	7.9	10.4
Laredo	137.4	1.6	8.5	11.7
Yemsoy	93.8	2.4	8.9	12.7
Yesilsoy	96.6	1.9	8.8	12.7
Average	89.7	2.5	8.1	11.8
LSD(0.05)	5.9	0.3	0.6	0.7

When double cropped, soybean genotypes differed significantly in DM yield in both experimental years. In 2014, DM yields of double crop ranged from a low of 5499 kg ha $^{-1}$ to 13293 kg ha^{-1}, while two forage-type cultivars Laredo and Yesilsoy produced more than 12500 kg ha^{-1} DM yield, which was up over 150% of the average. In the second season (2015), Laredo and Yesilsoy were also the highest DM yielding cultivars 130% above the average (Table 7). Just as genotype DM average was down about 40% in 2015 vs. 2014 in the main planting season, likewise 2015 double crop DM yields averaged 23.6% less than 2014 even though 2015 double crop was planted 9 July 2015 five days earlier than in 2014 indicating year-to-year weather differences.

Table 7. Dry matter yield of soybeans genotypes in double cropping conditions (kg ha^{-1})

Genotypes	Years	
	2014	2015
A-4232	5499	5814
M-14	7396	5519
M-42	7276	6394
MDY-2	5999	5533
MDY-4	6835	4568
Derry	9264	6524
Laredo	12509	8513
Yemsoy	6557	5859
Yesilsoy	13293	8332
Average	8292	6339
LSD (0.05)	1102	329

4. Discussion

In this study, soybean genotypes flowered approximately two and half months after seeding in main cropping conditions compared to over three months to flowering for check cultivars. Whereas, soybean genotypes flowered under two months after seeding (averaging 49.6 days) compared to 55 days to average flowering for check cultivars in double cropping conditions. Soybean genotypes and cultivars flowered about 23 and 39 days, respectively, earlier in double cropping than main cropping conditions. This supports Calvino et al. (2003) who reported that double crop soybean cultivars flowered earlier in cooler environments in the southern Pampas, Argentina. It is well known that soybean flowering may begin within 25 to 50 days after seeding, depending on cultivars and environmental conditions (Hume et al., 1985) which was the case in our double cropping trials, but flowering averaged 72.5 days for soybean genotypes and 94 days after planting for our check cultivars.

Earlier reports indicated that delayed seedings shortened season length, leading to overall growth reductions in soybean (Calvino et al., 2003; Lawn and Hume, 1985; Purcell et al., 1987;). Our studies clearly showed that both soybean genotypes and check cultivars in double crop conditions were shorter than main crop conditions. In close agreement with our results, several researchers indicated that late seedings were shorter than plants in early seedings (Anderson and Vasilas, 1985; Pedersen and Lauer, 2004a, 2004b; De Bruin et al., 2010; Gulluoglu et al., 2016). Similarly, the genotypes had more branched plants in main cropping conditions. However, there was extensive branch development on some soybean genotypes, and was little branch production on other genotypes in both main and double cropping conditions.

It is well known that as soybeans mature, the leaf proportion rapidly declined, stem and petiole proportions were stable or declined slowly, and pod proportion rapidly increased (Hintz and Albrecht, 1994; Acikgoz et al., 2007, 2013). In this study, stem, leaflet, petioles and flower + pod proportions of soybean genotypes tested were 34.4, 38.1, 16.7 and 10.8%, respectively and forage type cultivars had slightly higher stem and lower leaflet percentages in main cropping conditions. Similarly, Hintz and Albrecht (1994) reported that average leaf (including petioles), stem and pod proportions were 51.2, 38.3 and 10.5%, respectively at R5 stage of early soybean (Corsoy 79) and late (Pella and Willams 82) soybean cultivars. The proportions in this study were in the range of our previous reports (Bilgili et al., 2005; Acikgoz et al., 2007, 2013). Double cropping soybeans genotypes had more leaflet and less stem proportions. Soybeans in double cropping initiated flowering earlier than main cropping soybeans, resulting in shorter plant height and lower stem yield.

Based on the one year augmented study, it clearly showed that there was significant DM yield and morphological traits differences between the seventy soybean genotypes. This indicated variability among soybean genotypes enabling selection for DM traits to develop new forage soybean genotypes for main and double cropping conditions.

The forage yield potential of soybeans was tested in detailed studies in 2014 and 2015. A genotypes x years' interaction occurred for DM yield in both seeding times, particularly in main cropping conditions. Dry matter yield averaged 15931 kg ha^{-1} in first year and 9645 kg ha^{-1} in the second year of the study. Lower DM yield in the second year of study was attributed to 34 days late seeding, because of heavy rains, although the second year also had lower DM yields when double cropped but planting occurred five days earlier in 2015. Consequently, year-to-year differences should be expected with some cultivars showing more differences than others providing trait selection criteria for subsequent forage soybean development.

Late maturing forage type varieties tend to grow taller and produce more DM yield. DM yield potential of some soybeans can exceed 20-25 tonnes per hectare in main crop conditions with the average of 15 genotypes yielding nearly 16 tonnes per hectare. Even late seeding in our second year, DM yield potential exceeded 16 tonnes per hectare on one genotype with an average of 9.6 tonnes. Our average and maximum DM yields for main cropping soybeans exceeded those of previous studies conducted in different regions of USA. Hintz et al. (1992) reported DM yield ranges from 2400 to 7400 kg ha^{-1}, Seiter et al. (2004) obtained DM yields ranged from 4500 to 13,900 kg ha^{-1}, and Sheaffer et al. (2001) had 8800 kg ha^{-1}. Dry matter yields of Derry and Donegal reached 7.95 t ha^{-1} in UK conditions (Koivisto et al., 2003). Mostly oil type soybeans produced 7343 kg ha^{-1} DM yield in Ankara, Turkey (Altinok et al., 2004). Reports of DM yield of soybeans in regions with a typical Mediterranean-type climate were limited. In our previous studies, DM yield of some soybean genotypes was comparable or slightly less than this study, ranging 12 to 13 ton per hectare in regions with Mediterranean-type climate (Bilgili et al., 2005; Acikgoz et al., 2007, 2013).

Even planting the 9th and 14th of July, dry matter yield of double crop soybeans averaged 8292 and 6339 kg ha^{-1} in first and second experimental years of this study, respectively. Forage-type cultivars Laredo and Yesilsoy produced more than 10 tonnes ha^{-1} combining two-year average DM yield. Since Laredo is the oldest continually produced soybean variety in the USA (introduced from China in 1914), surely improvements can be made on soybean DM performance compared to a variety that has been continuously used by soybean forage growers for over a century.

Proper seeding rates by branching affect to maximize soybean forage yield and quality have not been established. Effect of disease, nematodes, nutrient efficiency, solar radiation, proper maturity by latitude, proper planting dates by maturity, and feed quality characteristics based on livestock category in main 13 double cropping systems are considerations for selecting forage soybean genotypes, but were not covered in this study. All those factors have potential to influence soybean forage yield and quality when seed selection of cultivars is made by growers with planned forage use intensions.

As expected, DM yield of double cropping soybeans was lower than those of main cropping caused by later planting. Average across years and genotypes, DM yield of main cropping was 12788 kg ha^{-1} while only 7316 kg ha^{-1} when double cropping. In the absence of pests, soybean yield and yield components can be affected by growth habit, planting date, and climatic conditions.

Soybean forage quality varies by genotype, harvest timing, and environmental factors. When anticipating grazing or timing forage harvest, realize easily digestible grass and broadleaf soluble sugars vary by forage type; are impacted by environmental stress, and influence plant growth by regulating genes affecting metabolism (Brown, 1999; Mariana et al., 2009; Wietgrefe, 2014). Plants progress to maturity accumulating indigestible lignin (not uniformly) and decrease crude protein in plant DM (Altinok, 2004; Bellaloui, 2012; Hintz et al., 1992; Hintz et al., 1994). Therefore, soybean genotypes that maximize seed yield may not be suitable for forage use regardless of plant height, which does not correlate with DM yield (compare Tables 3 and 4).

Studies conducted in different regions showed that maximum seed yield was achieved with early seedings, then yields declined with soybean seeding date delayed (Beatty et al., 1982; Keim et al., 1999; Calvino et al., 2003; Pedersen and Lauer, 2004a, 2004b; De Bruin et al., 2010; Zhi-gang et al., 2011). Our studies tentatively indicate the same is true for forage soybeans although maximizing forage quality by quantity is a necessary consideration.

Following the delayed planting trend, the average seed yield of double-crop soybean was clearly less than monoculture soybeans (Sanford, 1981; Gesch et al., 2014). Despite several published studies on the effect of seeding time on seed yield and seed yield performances of double cropping of soybean, the effect of seeding time on DM yield, DM yield genotype performance of double cropping, and main cropping vs. double cropping soybeans DM differences is not presently available. In close agreement with our results LeMahieu and Brinkman (1990) and Mackown et al., (2007) indicated that double cropping forage soybeans yielded clearly less than main cropping, particularly under dryland conditions.

As indicated by Darmosarkoro et al., (2001) and Rao et al., (2005), late-maturing forage type soybean cultivars tend to grow taller and produced greater DM yield. Our results suggested that soybeans cultivars, particularly forage type, would produce higher DM yield in double cropping conditions if harvested at R4 stage and likely feed quality would increase as stem percentage drops. In Bursa, tall forage soybean in maturity groups V, VI, and VII reached this stage at harvest in late September before a killing frost or heavy rains.

In this study, plants were cut at R4 stage for DM yield in order to obtain high quality hay production. It is well known that DM yield of soybeans increased from early to late harvest stage. Several researchers indicated DM increases in soybean up to R7 stage, and soybean grown for forage may be harvested near the R7 stage for maximum yield (Munoz et al., 1983; Hintz et al., 1992; Sheffer et al., 2001; Acikgoz et al., 2007; 2013) but forage quality is expected to decline with decreased leaflet compared to stem and flower+pod percentage. Whereas due to leaflet loss, R7 harvest increases feed protein characteristics supplied by mature seed, assuming seed shattering can be minimized during the wilting process. R7 bypass protein and higher oil content may limit palatability and milk production for dairy and negatively affect the ensilage fermentation process (Heinrichs et al., 1997).

In main crop conditions, cutting may be delayed until R7 stage to increase DM yield, which may not be allowable in double crop situations. Late maturing cultivars and genotypes may not reach the desired R7 stage of development because of fall temperature conditions. Also, hay production and condition may be effected negatively by low temperatures, heavy rains and wind causing lodging that could delay harvest, and lower DM yield when mechanically harvested. Therefore, earlier maturing forage genotypes may be advisable in double cropping system if later stage harvesting is sought.

5. Conclusion

In many countries, there is renewed interest in developing new soybean grazing and feed cultivars with improved DM yield and forage value for farmers seeking high-yielding annual legumes, annual plantings to allow more intense crop rotations, and planting date flexibility to maximize labor and equipment availability. The number of soybean genotypes tested in this study is limited when compared with soybean germplasm in different gene banks. However, our study clearly showed that a considerable range of variation is available in maturity, morphological traits, and DM yields for breeders to develop new forage soybean genotypes for main and double cropping conditions.

Our results from testing 70 diverse soybean genotypes showed DM yield varied by over two orders of magnitude. Regarding soybean forage quality, some of those genotypes had more than three times more s 14 weight and significantly less leaflet area than others. Therefore, growers would be ill advised to plant untested grain-type genotypes for grazing or forage expecting high and consistent yields.

Soybean forage is greatly affected by planting date, fall harvest conditions, temperature, amount and distribution pattern of precipitation, soil type, nutrient availability, and pest pressure. Plant heights were clearly shorter and flowering occurred three to five weeks earlier when our broad genotype selections were double cropped. When planting is delayed and quality soybean forage is sought for R4 harvest, clearly we confirmed leaflet percentage of double cropping was consistently higher than the spring planted main crop system. Main and double cropping showed yield components, plant part partitioning, and DM had statistically significant differences. Our study also clearly showed that properly selected forage soybean cultivars and genotypes could provide significant DM yields in both main and double cropping conditions in regions with a Mediterranean-type climate.

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