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Research Article

Effects of Different Harvest Stages on Forage Yield and Quality of Soybean Cultivars Grown as Second Crops

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Abstract: In this study, the effect of three different harvesting stages [full bloom stage (R2), full pod stage (R4), and full seed stage (R6)] on forage yield and quality of three soybean (*Glycine max* (L.) Merr.) cultivars (Adasoy, Derry and Yeşilsoy) were evaluated under Mediterranean climate conditions in Adana, Türkiye in second crop seasons. Plant height, green herbage yield, dry matter yield, crude protein (CP), crude protein yield (CPY), leaf and stem ratio, dry matter intake (DMI), acid detergent fiber (ADF), neutral detergent fiber (NDF), digestible dry matter (DDM) and relative feed value (RFV) were determined. The results showed that the average plant height of three soybean cultivars was 106.5-203.5 cm and green herbage yield was 190 42-603 50 kg ha^{-1}. The highest values were obtained from cv. Derry at R4 and R6 harvest stages. In both years, the highest CPY values were determined from the R6 harvest stages. Obtained ADF, NDF, DMI, DDM, and RFV values were found to be between 32.8-47.1%, 41.1-59.3%, 2.0-3.6%, 52.1-63.3%, 83.0-180.2%, respectively, and the best results were obtained from the R6 harvest stage of cv. Yeşilsoy. According to these results, in second crop conditions, while cv. Derry came to the fore of soybean yield, cv. Yeşilsoy stands out in terms of quality. As a result, it is thought that it is appropriate to harvest soybean in the R6 harvest period, the use of soybean as a green herbage should be expanded and its addition to feed rations can provide positive contributions.

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1. Introduction

High-quality feed production plays an important role in the development of the livestock industry. Feed costs, which constitute approximately 70 percent of the production cost in livestock enterprises, are an important factor determining profitability. Considering that the profitability of the enterprise is affected by the yield and quality of the feed used, it is a great necessity to feed the animals with quality roughage. There is no problem in producing quality feed in the countries where animal husbandry is developed. However the problem of quality feed production in our country increases year by year (Ozkan and Demirbag, 2016). Grass and straw cereals grown for grain are very poor in protein. The amount of stem straw obtained from cereals in Türkiye is 40 million tons with a 40% harvest index, and about 10 million tons of these are used for animal feeding (Sancak, 2011). However, it is known that these feeds are not quality roughage. Legumes are of increasing importance as a source of plant protein for both human and animal consumption (Voisin et al., 2014; Henchion et al., 2017). Legumes as forage crops are quality roughages rich in protein.

With the increase in soybean varieties developed for feed purposes in recent years, the production of soybean for roughage has also increased (Anderson et al., 2019). Roughage made from soybean attracts attention as a valuable protein source that can be used as an alternative to expensive protein sources in ruminant nutrition (McCandlish et al., 2017). Soybean is preferred in animal production for meat and dairy purposes because of its high digestibility, low fiber, high protein, and energy content (McPeake et al., 2010). In the south of the US, forage yields of soybean ranged between 1.1 and 5.4 mg ha^{-1} with 150 to 190 g kg^{-1} CP and 740 to 790 g kg^{-1} in vitro digestible dry matter and therefore adopted as a high-quality forage (Northup and Rao, 2015; Baath et al., 2018). Additionally, soybean is a highly productive plant. Studies conducted at different locations with Mediterranean climates demonstrated that it is possible to produce an average of 9 300 and 11 300 kg ha^{-1} at R4 and R6 stages, respectively, with soybean forage averaging 13.3% CP, 8.2% DP, and 60.6% IVDMD (Acikgoz et al. 2007). In addition, soybean, as a legume plant, provides additional nitrogen to cereal crops used in rotation due to its nitrogen fixation ability. For these reasons, studies are needed to include soybean in the production system. In this study, it was aimed to determine the yield and quality of three soybean cultivars (Adasoy, Derry, and Yeşilsoy) according to the harvesting stages in order to improve forage soybean production and diversity.

2. Materials and Methods

2.1. Study site and experiment treatments

This study was conducted in the experimental fields of Eastern Mediterranean Agricultural Research Institute (EMARI) (Türkiye, South East, and 36 ° 85' north latitude, 35 ° 34' east longitude and altitude of 12 m) second crop season in the years of 2014 and 2015. The organic matter level of the soil in texperimental area has been observed to be low with a percentage of (1.07%) but the phosphorus (P_2O_5) content was intermediate (36.0 kg ha^{-1}) and potassium (K_2O) level was sufficient. The soil structure was slightly alkaline and limy with pH=7.8, and clayed-loam. This region has a Mediterranean climate. Table 1 shows the average temperatures, rainfall, and humidity for both the 2014 and 2015 growing seasons as well as long-term (1950-2015) averages for the region.

Table 1. Temperature, precipitation, and relative humidity during the 2014-2015 growing period and their long-term average (1950-2015)*

	Average temperature (°C)			Precipitation (mm)			Relative Humidity (%)		
Months	LT	2014	2015	LT	2014	2015	LT	2014	2015
June	25	23	24	17	3	0	67	72	69
July	28	28	28	10	0.25	0	71	72	69
August	28	29	30	8	0.25	9	71	70	62
September	26	26	28	16	80.5	41	65	64	66
Total	109	106	110	51	84	50	273	276	266
Mean	27	27	28	13	21	13	68	70	67

*LT: Long term, The data of Adana Meteorological Station Province between 1950-2015 (Anonymous, 2016b).

The experiment was carried out using four replications in a split plot design with cultivars as main plots and harvest stages as subplots. The main plots had three soybean cultivars (Adasoy, Yeşilsoy, and Derry) and three harvesting stages [full bloom stage (R2), full pod stage (R4) and full seed stage (R6)] as subplots applied. Adasoy, Derry, and Yeşilsoy cultivars are registered as grain, forage, and silage, respectively and they are in the maturation groups of fourth, sixth, and fifth, respectively (Anonymous, 2016a). In the experiment, each plot was planted in 15 rows, 70 cm row spacing, and 5 m in length. Intervals between plots were 1.5 m and intervals between blocks were 2 m. The seeds were sown on 16 Jun 2014 in the first year and on 20 Jun 2015 in the second year. In the sowing 30 kg ha^{-1} N, 70 kg ha^{-1} P_2O_5, and 100 kg ha^{-1} K_2O were given to the plots fertilizer. Sowing was done with a plot seeder in the amount of 60-80 kg ha^{-1} according to seed size of cultivars. Before planting, soybean seeds were inoculated with *Bradyrhizobium japonicum* bacteria. The plants were irrigated three times at the beginning of the pre-flowering and during the full flowering and pod formation periods.

2.2. Measurements, chemical and statistical analysis

Harvest was performed in the three maturity stages: full flowering (R2), full pod (R4), and full seed stages (R6) (Cirak and Esendal, 2005). Plant height and leaf/stem ratio (fresh weight) were determined with 20 plants measuring. In the harvest stage, for each plot, the materials in three rows, except for the edge effect, were harvested and the dry and green herbage yield and crude protein value were determined. Dry matter yield was obtained by drying at 70 ^{0}C in oven. The total N of soybean in different harvesting stages was determined, using Kjeldahl's method, and crude protein was calculated by multiplying the N content by 6.25 (AOAC, 1990). ADF, NDF % Van Soest et al., (1991) and DDM %, DMI%, and RFV were calculated by the method indicated by Mayouf and Arbounche (2014) as followed:

$$DDM = 88.9 - (0.779xADF) \tag{1}$$

$$DMI = 120/NDF \tag{2}$$

$$RFV = (DDMxDMI)/1.29. \tag{3}$$

In a study with 4 replications (R) using a split plot experimental design (with main plots as cultivars and sub-plots as harvest periods), the average effects of harvest periods (HS) and cultivars (V) on the investigated traits were determined. All statistical tests were analyzed in the SAS Statistical, Version 9.1 program. Mean comparisons were performed using Duncan's Multiple Range Test. All significant differences were evaluated by $p<0.05$ level tests.

3. Results and Discussions

In both years, the effect of cultivars, harvest stages, and interaction on plant height, green herbage yield, and dry matter ratio was significantly, except for the effect of the variety x harvest stage interaction for dry matter in the second year. The difference between years is also significant (Table 2).

The highest increase in plant height was recorded by the Derry soybean variety in both years (153.7 cm, 188.6 cm, respectively). Adasoy and Yeşilsoy varieties gave shorter plant heights in the same statistical group in the first year. In the second year, Adasoy gave the shortest plant height (119.3 cm). Plant height increased as the maturation stage progressed. However, no significant difference was found at the R4 and R6 harvest stages. In the study, the lowest plant height in both years was measured as 110.5 cm and 127.6 cm, respectively, in the R2 period. It was observed that a higher green herbage yield was obtained from R6 stage of the Derry variety in both years (Figure 1,2). Plant height varies significantly according to ecology and plant growth stages. Acikgoz et al. (2007) reported that the plant heights of forage soybean were 73.6, 100.9, and 105.2 cm at the R2, R4, and R6 harvest stages in Bursa conditions, respectively. Relating to the effect of variety averages, the highest green herbage yields were obtained from the Derry variety as 36513 and 54458 kg ha^{-1} for the first and second years, respectively. On the other hand, Adasoy gave the lowest yields as 278 02 kg ha^{-1} and 390 78 kg ha^{-1} for the first and second years, respectively. As soybean has unlimited growth characteristics, there may be significant increases in plant height and green herbage yields in different harvest stages as the plant growth stage prolongs. Nazlican (2010) who worked on Yeşilsoy and Yemsoy soybean varieties for silage purpose took 400 00-560 00 kg ha^{-1} of green herbage yield. In terms of harvest stage, the highest green herbage yields were obtained as 388 35 and 525 65 kg ha^{-1} at R6 stage in both years, respectively. The lowest green herbage yield was measured at R2 stage in both years. The R6 stage, also known as the green seed stage, is when the pods reach maximum weight . For this reason, the R6 phase is the period when green herbage yield is highest. It was observed that higher green herbage yield was obtained from R6 stage of Derry variety in both years (Figure 1,2). Nevertheless, the dry matter rate ranged between 19.3% and 30.9% in 2014 and between 23.2% and 28.8% in 2015. Similar results were reported by Garcia (2006) who worked on soybean plants and obtained 22-30% dry matter content in soybean. The highest dry matter rates were obtained from Adasoy and Derry varieties as 26.8-26.4% in 2014 respectively, but the highest dry matter in 2015 (28.0%) was obtained from Derry. Moreover, during both years the highest dry matter rate was obtained at R6 harvest stage (Table 2). Dry matter rate was low in early harvested stages and it increased with the progress of the harvest stage. Hintz et al. (1992) and Munoz et al. (1983) reported that the increase of soybean yield continued until the R7 harvest stage. Sheaffer et al. (2001) mentioned that the increase in the yield at R4 and R6 harvest stage for all varieties was 20%. The same authors stated that the most significant increase in yields was between R3 and R4 for feed type of soybean varieties and at R6 and R7 for grain soybean varieties. Acikgoz (2001) reported that the good quality of green herbage product was obtained from plants during full flowering and full seed stages, and green herbage yield in soybean varied between 20 and 40 tons ha^{-1}.

Table 2. Means and the standard errors of investigated parameters and probabilities of factors

	Year (Y)	**PH (cm)**	**GHY (kg ha^{-1})**	**DMR (%)**	**HY (kg ha^{-1})**	**CP (%)**	**CPY (kg ha^{-1})**	**LR (%)**	**SR (%)**
Years	2014	132.1 ±17.4^{b}	320 93 ±545.6^{b}	25.0 ±3.9^{b}	854 2 ±250.6^{b}	13.5 ±2.9	106 9 ±28.7^{b}	50.5 ±13.8	49.4 ±6.9
	2015	146.9 ±23.6^{a}	453 57 ±790.6^{a}	26.1 ±2.6^{a}	120 84 ±310.9^{a}	13.6 ±2.7	160 3 ±39.7^{a}	49.1 ±8.6	49.9 ±7.5
2014	**Harvest Stage (HS)**								
	R2	110.5 ±12.9^{b}	228 08 ±388^{c}	19.3 ±3.2^{c}	442 9 ±122.3^{c}	16.6 ±4.8^{a}	697.5 ±12.6^{c}	52.2 ±14.1^{a}	47.3 ±8.8^{b}
	R4	141.9 ±19.8^{a}	346 35 ±397^{b}	24.8 ±3.1^{b}	886 9 ±129.3^{b}	11.2 ±3.1^{c}	977.6 ±22.1^{b}	48.5 ±11.0^{b}	49.9 ±10.6^{b}
	R6	143.8 ±18.7^{a}	388 35 ±508^{a}	30.9 ±2.4^{a}	123 28 ±197.7^{a}	12.5 ±1.7^{b}	153 1 ±24.7^{a}	46.6 ±11.4^{b}	53.5 ±7.8^{a}
	Varieties (V)								
	Adasoy	121.5 ±11.7^{b}	278 02 ±702^{c}	26.8 ±6.1^{a}	800 3 ±359.1^{b}	14.4 ±1.3^{a}	1150 ±51.1	53.8 ±12.6^{a}	46.5 ±9.8^{b}
	Derry	153.7 ±22.1^{a}	365 13 ±765^{a}	26.4 ±3.9^{a}	102 35 ±372.8^{a}	10.4 ±2.2^{b}	1045 ±43.1	49.0 ±14.1^{b}	51.2 ±10.4^{a}
	Yeşilsoy	120.9 ±16.9 ^{b}	319 64 ±763^{b}	21.8 ±5.4^{b}	738 8 ±309.7^{b}	15.5 ±5.5^{a}	1010 ±24.7	52.0 ±11.2^{a}	47.6 ±12.6^{b}
	P Value								
	R	0.007**	0.704	0.136	0.864	0.323	0.519	0.580	0.718
	HS	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.015*	0.018*
	V	0.000**	0.000**	0.000**	0.000**	0.000**	0.091	0.002**	0.000**
	RxV	0.138	0.342	0.616	0.415	0.331	0.329	0.164	0.170
	VxHS	0.003**	0.000**	0.039*	0.108	0.000**	0.002**	0.100	0.154
2015	**Harvest Stage (HS)**								
	R2	127.6 ±25.1^{b}	336 08 ±902.1^{c}	23.2 ±2.3^{c}	7946 ±291.6^{c}	13.7 ±3.6^{a}	999.4 ±13.8^{c}	58.1 ±7.6^{a}	41.3 ±7.1^{c}
	R4	155.0 ±36.4^{a}	499 01 ±658.6^{b}	26.0 ±2.2^{b}	130 54 ±214.5^{b}	12.3 ±2.4^{b}	158 0 ±25.8^{b}	50.8 ±7.3^{b}	47.8 ±7.6^{b}
	R6	158.0 ±34.8^{a}	525 65 ±677.3^{a}	28.8 ±3.4^{a}	152 33 ±334.4^{a}	14.7 ±2.5^{a}	222 0 ±44.1^{a}	38.2 ±5.7^{c}	60.4 ±5.3^{a}
	Varieties (V)								
	Adasoy	119.3 ±10.9^{c}	390 78 ±932,4^{c}	26.1 ±3.1^{b}	105 09 ±407.6^{b}	13.5 ±3.2^{b}	132 0 ±37.3^{b}	55.5 ±10.1^{a}	43.5 ±9.5^{c}
	Derry	188.6 ±21.8^{a}	544 58 ±766.1^{a}	28.0 ±3.6^{a}	154 36 ±361.2^{a}	11.5 ±2.3^{c}	183 7 ±71.4^{a}	41.9 ±7.5^{c}	57.0 ±7.7^{a}
	Yeşilsoy	132.8 ±15.5^{b}	422 58 ±817,6^{b}	23.9 ±2.3^{c}	103 08 ±263.1^{b}	15.7 ±2.1^{a}	164 2 ±54.6^{a}	49.7 ±10.1^{b}	48.8 ±9.6^{b}
	P Value								
	R	0.342	0.173	0.299	0.083	0.046*	0.477	0.227	0.217
	HS	0.000**	0.000**	0.000**	0.000**	0.001**	0.000**	0.000**	0.000**
	V	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.056	0.000**
	RxV	0.057	0.386	0.513	0.951	0.417	0.288	0.388	0.782
	VxHS	0.001**	0.002**	0.097	0.010**	0.000**	0.009**	0.000**	0.546

*p<0.05, **p<0.01; full blooming stage (R2), full pod stage (R4), full seed stage (R6). Plant height (PH), green herbage yield (GHY), dry matter rate (DMR), hay yield (HY), crude protein (CP), leaf ratio (LR), stem ratio (SR); Different superscript letters denote significant differences (p < 0.05).

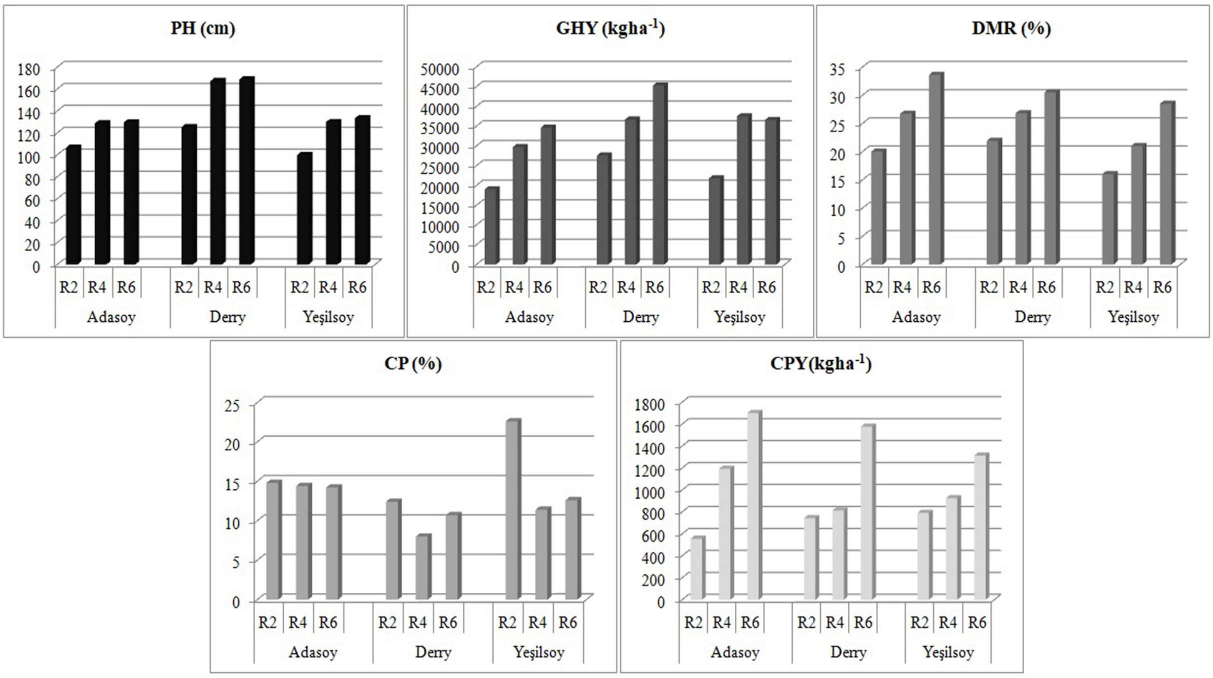

Figure 1. Significant interactions of 2014.

The all harvest stages had a significant impact on hay yield, CP and CPY during both seasons. In the both years, the effect of varieties on hay, CP, and CPY was significant, except for the CPY in the first year. Also, the interaction was effective on the criteria examined except for hay yield in the first year (Table 2; Figure 1,2). In terms of variety average, the highest hay yield was obtained from the Derry variety with 102 35 and 154 36 kg ha^{-1}, respectively during both years, while the lowest value was taken from Yeşilsoy (738 8 and 103 08 kg ha^{-1}, respectively). Sheafer et al. (2001) reported that there were significant differences between varieties of feed and grain types in different maturity stages. These results are in agreement with the results of our study. Derry and Yeşilsoy are forage varieties while Adasoy is a grain type and they have different maturity stages. Derry variety recorded higher yields in all harvest stages than the other two varieties. Derry variety recorded higher yields in all harvest stages than the other two varieties. For CPY, there was no significant difference between the varieties in 2014. In 2015, the highest CPY was obtained from Derry and Yeşilsoy varieties (183 7 and 164 2 kg ha^{-1}, respectively). Adasoy had the lowest yield (132 0 kg ha^{-1}) (Table 2). Different harvesting stages caused significant changes in hay yield. According to the harvest stage averages, the highest hay yield was obtained at the R6 stage and the lowest was obtained at the R2 harvest stage. The highest CP was detected at The R2 stage with 16.6% in the first year whereas in the second year, it was detected at R2 and R6 stages (13.7% and 14.7% respectively). Hintz et al. (1992) pointed out that the crude protein content of soybeans decreased during the transition from the R1 to R3 harvesting stage, while remained constant at R3 and R5, and then increased during the R5 and R7 harvest stages. The ratio of crude protein increases with the progress of the maturity of the soybean (Ocumpaugh et al. 1981.). The nutrient content and forage quality of whole-plant soybeans do not change drastically with advancing maturity because the seed is much higher in protein (Munoz et al. 1983). The highest CPY in both two years was obtained from the R6 harvest stage as 153 1 kg ha^{-1} and 222 0 kg ha^{-1}, while the lowest yield was taken from the R2 harvest stage as 697 kg ha^{-1} and 999 kg ha^{-1}, respectively. The best protein yield was obtained from the R6 harvest period of the Deryy variety in the interaction of the cultivar harvest period (Figure 1, 2). This is related to the high protein content of the R6 harvest period.

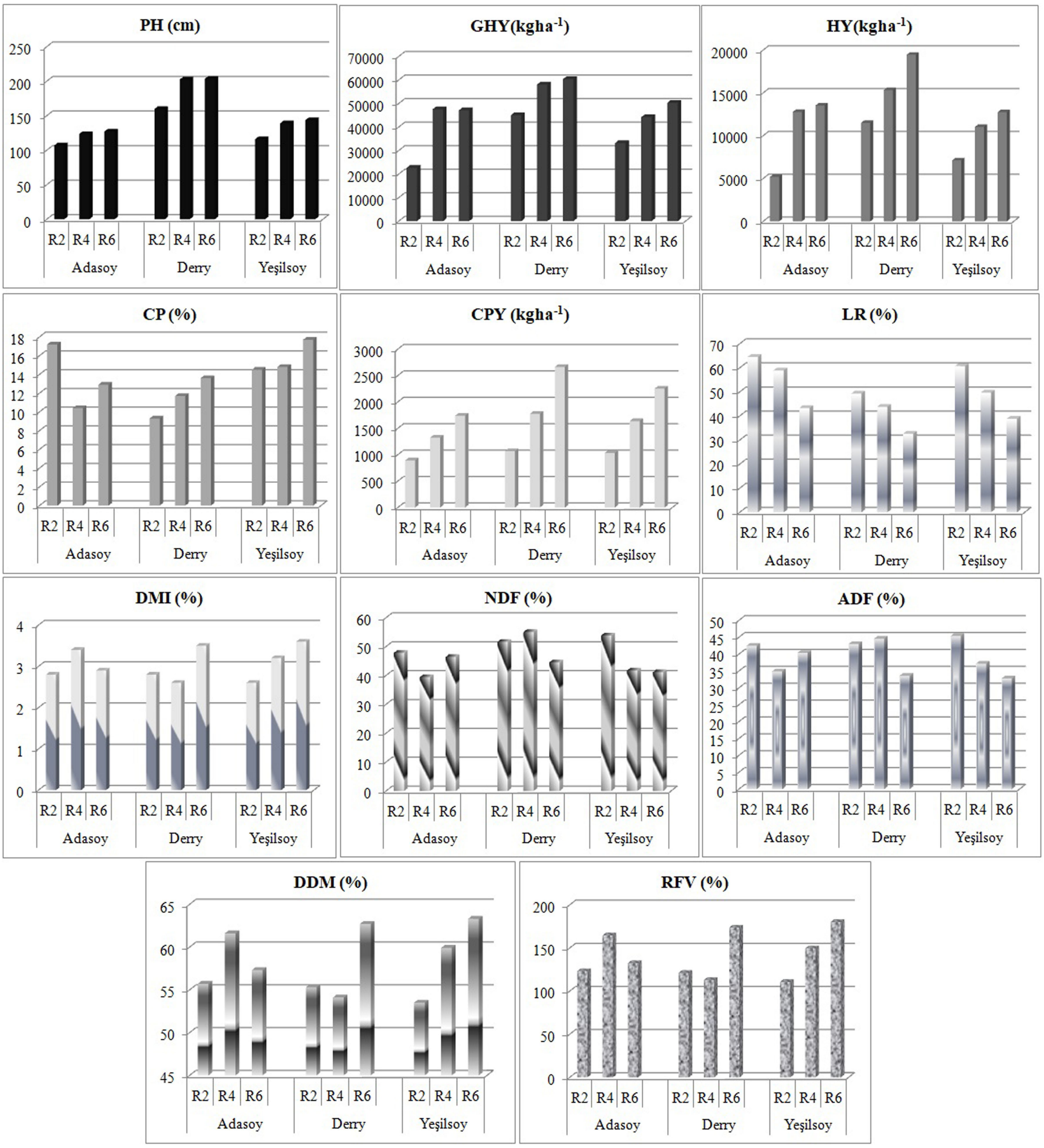

Figure 2. Significant interactions of 2015.

The effect of varieties and harvest stage on the leaf and stem ratio was significant in both the 2014 and 2015 years. Variety x harvest stage interaction was not significant (Table 2). On the other hand, the averages of the varieties of the first year reveal that the highest value of this character was obtained by the Adasoy and Yeşilsoy varieties while the Derry variety was the lowest average. Adasoy variety recorded the highest leaf rate in the second year while Derry variety recorded the lowest rate. In terms of harvest stage averages, in the 2014 year, the highest leaf ratio was 52.2% at the R2 stage and the lowest was 46.6% and 48.5% at the R6 and R4 stages, respectively. According to the harvest stage averages for 2015, the highest leaf rate was obtained from the R2 harvest stage (58.1%), and the lowest leaf ratio was obtained from the R6 harvest stage (38.2%). It was observed that the Derry variety had the highest stem ratio in the first season (51.2%). The lowest stem ratio was obtained from Adasoy and Yeşilsoy varieties with 46.5% and 47.6%. In the second year, the highest stem ratio was obtained from the Derry variety with 57.0%, and the lowest stem ratio was taken from Adasoy (43.5%). The results in Table 2 for the average harvest period of 2014 show that the highest stem rate was determined as 53.5% in the R6 stage and the lowest stem rate was obtained from the R2 and R4 stages as 47.3% and 49.9%.

In 2015, the highest stem ratio was obtained as 60.4% from the R6 stage. The lowest stem ratio was determined at the R2 stage. It is known that the higher leaf rate is better for the quality and taste of the forage. Almost all animals prefer plants. When green herbage or hay is given in a lot amount, it is observed that animals consume the leaves at first, because the leaves are tastier than the stems. Therefore, the quality of forage decreases with decreasing the leaf/stem ratio while in parallel, the rate of crude cellulose increases with increasing the stem ratio. The harvest period is one of the important features affecting quality. In many forage crops, if the harvest delays, dry matter yield, and stem ratio increase but the leaf rate decreases (Acikgoz, 2001). Hintz et al. (1992) reported that, in all soybean types studied, the stems had lower feed quality, because the stem includes lesser crude protein than leaves and pods. Therefore, they emphasized that a high leaf rate is an important feed quality criteria.

In the first year dry matter intake was affected from varieties and harvest stages, while in the second year, it was affected from harvest stage and variety x harvest stage interaction. The highest DMI (2.6 %) was obtained from Yeşilsoy in the first year, whereas DMI rates ranked between 3.0-3.1 % in the second year. According to harvest averages, the highest DMI rate in 2014 was determined at the R2 and R6 stages (2.4%, and 2.3% respectively), while the lowest DMI was obtained from the R4 stage (2.1%). The highest DMI ratio was 3.4% in 2015 at the R6 stage and the lowest was 2.7% at the R2 stage (Table 3). NDF rate was affected from variety and harvest time in 2014, whereas it was affected from variety, harvest time, and variety x harvest stage interaction in 2015. When ADF, DDM, and RFV were examined, it was seen that variety and harvest times affected these three characteristics in the first year, while they were affected by harvest time and cultivar x harvest time interaction in the second year (Table 3). Concerning the variety averages, the highest NDF content in 2014 was detected in the Derry and Adasoy varieties with 56.6% and 53.4%, respectively and the Yeşilsoy variety had the lowest NDF content (46.7%). In the 2015 season, the Derry variety recorded the highest NDF content with 50.4%, while the Adasoy and Yeşilsoy varieties resulted in the lowest NDF contents with 44.5% and 45.5%, respectively. In 2014, ADF rates were 33.6% and 47.6%, in 2015 they varied between 32.8% and 45.4%. In terms of variety averages, the highest ADF ratio in 2014 was obtained from Derry and Adasoy varieties with 43.3% and 41.6%, respectively, and the lowest ADF ratio was obtained from Yeşilsoy with 37.7%. The highest ratio of DDM was found in the Yeşilsoy and Adasoy varieties in the first year (59.5%, and 56.4% respectively) while the lowest ratio was found in the Derry variety with 55.3%. In the second year, the varieties had no effect on DDM. Data presented in Table 3 indicated that for variety averages, the highest RFV value was obtained from the Yeşilsoy variety with 122.6% in 2014. The lowest ones were obtained from Derry and Adasoy varieties as 92.3% and 98.9%, respectively.

The means of harvest stages indicated that R4 and R6 produced the highest NDF values in 2014 (% 55.7, % 51.6 respectively) while the lowest one was taken from R2 (% 49.4). In 2015 the highest NDF content with 51.1% was obtained from the R2 stage while the lowest NDF content was recorded from R6 and R4 with 44.0%, the 45.3%, respectively. In 2014, the highest ADF ratios were determined in the R4 and R6 stages with 43.9% and 40.2%, respectively while the lowest ADF content was determined in the R2 stage as 38.1%. In the second year, the highest ADF rates were achieved at R2 and R6 stages as 43.6, while the lowest ADF content was obtained at R4 with 38.9%. According to the averages of harvest stages for the first year, the highest DDM rate was found in stages R2 and R6 with 59.1% and 57.5%, respectively. The lowest DDM rate was in stage R4 with 54.6 %. In the second season, the highest DDM rate with 61.6% was obtained from the R6 harvest stage while the least value of the DDM rate was 54.8% at the R2 harvest stage. In the first year, the highest RFV value was obtained from the R2 and R6 stages with 113.0% and 108.6%, respectively, while the highest RFV value in the second year was taken in R6 with 162.1% (Table 3).

The forage having low digestibility takes a long time for it to pass through the rumen and it passes slowly through the digestive system, which limits the intake of dry matter. Under these circumstances, the amount of dry matter intake is affected adversely because the rumen, reticulum, and abomasum expand while the feed stimulates receptors on the outer walls of these organs. It should be taken into consideration that when used the low digestibility forage, the most important factor of the digestive system is the neutral detergent fiber ratio (NDF) (Mertens, 1994; Allen, 1996). Generally, dry matter intake is reduced when the percentage of NDF increases (Joachim and Jung, 1997). NDF in general, is closely associated with the feed consumption of an animal while ADF is closely related to the degree of digestion, because the digestion of NDF and ADF by micro-organisms are difficult. NDF contains cellulose, hemicellulose, and lignin. Also, ADF contains cellulose and lignin. When the harvest is delayed, the amount of lignin in the feed will increase and then the lignin will form a bridge between cellulose and hemicellulose, that will reduce the digestion of feed. In the same connection, Acikgoz et al. (2013) reported that the effect of varieties on ADF and NDF were insignificant whereas the harvest stages had a significantly impact on ADF and NDF. Researchers obtained that ADF rates were 27% and 32.7% for R1 and R5 respectively, and NDF rates were 34.2% and 39.6% for R1 and R5 respectively. In our study, in the both two years, NDF was affected from varieties whereas ADF was only affected from variety in the second year. In the first year, the lowest NDF and ADF were obtained from R2 whereas the lowest NDF in the second year was recorded at R4 and R6 stages, and the lowest ADF at R4 harvest stage. Depending on the feed quality, the feeding behavior of animals, feed consumption, feed digestibility, and its conversion into animal products varies (Van Soest, 1994). Digestible dry matter is calculated from the ADF value. A high level of ADF will cause to decrease digestible of dry matter. In the first season of our study, in terms of DDM value Yeşilsoy had higher values compared to other varieties. The DMI value depends on the NDF value and if the NDF is high, DMI decreases. The quality of forage is usually determined by measuring the chemical, physical, and biological values of forage. Relative feed value (RFV), which was developed for alfalfa plants in the USA and then used in other forage crops, is used to measure the nutritive value of forage (Ball et al., 1996). DMI and DDM values are used to calculate the relative feed value, so ADF and NDF are important in relative feed values (Moore and Undersander, 2002). Alfalfa in the full flowering stage having 41% ADF and 53% NDF is considered to have a feed value of 100%. The feed quality decreases as the relative feed value falls below 100 and increases when it rises (Redfearn et al., 2006). If RFV is less than 75, it is named 5th quality, 4th quality between 75-86, 3rd quality between 87-102, 2nd quality between 103-124, and first quality between 125-150. If the RFV is greater than 150, it is called the highest-quality feed (Rohweder et al., 1978). In our study, Yeşilsoy produced better results than the others in terms of RFV. The effect of harvest stages on RFV varied between years.

Table 3. Means and the standard errors of investigated parameters and probabilities of factors

	Year (Y)	DMI (%)	NDF (%)	ADF(%)	DDM(%)	RFV
Years	2014	2.3 ±0.3^{b}	52.3 ±5.9^{a}	40.8±6.2	57.1±4.8	104.6 ±21.7^{b}
	2015	3.1 ±0.4^{a}	46.9 ±5.6^{a}	39.4±4.9	58.1±3.8	141.0 ±29.6^{a}
2014	**Harvest Stage (HS)**					
	R2	2.4 ±0.3^{a}	49.4 ±5.4^{b}	38.1 ±4.9^{b}	59.1 ±3.8^{a}	113.0 ±17.9^{a}
	R4	2.1 ±0.2^{b}	55.7 ±5.2^{a}	43.9 ±5.6^{a}	54.6 ±4.4^{b}	92.2 ±16.0^{b}
	R6	2.3 ±0.4^{a}	51.6 ±9.1^{a}	40.2 ±7.4^{ab}	57.5 ±5.8^{ab}	108.6 ±32.8^{a}
	Varieties (V)					
	Adasoy	2.2±0.2^{b}	53.4 ±3.8^{a}	41.6 ±4.5^{ab}	56.4 ±3.6^{ab}	98.9 ±13.2^{b}
	Derry	2.1 ±0.2^{b}	56.6 ±5.7^{a}	43.3 ±6.1^{a}	55.3 ±4.8^{b}	92.3 ±17.0^{b}
	Yeşilsoy	2.6 ±0.4^{a}	46.7 ±7.6^{b}	37.7 ±7.4^{b}	59.5 ±5.7^{a}	122.6 ±29.9^{a}
	P Value					
	R	0.753	0.717	0.050*	0.049*	0.288
	HS	0.035*	0.009**	0.003**	0.032*	0.024*
	V	0.000**	0.000**	0.04**	0.043*	0.001**
	RxV	0.185	0.172	0.616	0.626	0.322
	VxHS	0.152	0.153	0.071	0.072	0.106
2015	**Harvest Stage (HS)**					
	R2	2.7 ±0.3^{c}	51.1 ±3.7^{a}	43.6 ±4.1^{a}	54.8 ±3.2^{c}	118.4 ±18.8^{c}
	R4	3.1 ±0.4^{b}	45.3 ±7.5^{b}	38.9 ±4.5^{b}	58.5 ±3.5^{b}	142.5 ±54.3^{b}
	R6	3.4 ±0.4^{a}	44.0 ±4.3^{b}	35.7 ±4.2^{a}	61.1 ±3.3^{a}	162.1 ±19.3^{a}
	Varieties (V)					
	Adasoy	3.0 ±0.3	44.5 ±4.5^{b}	39.3 ±4.3	58.2 ±3.4	140.1 ±23.8
	Derry	3.0 ±0.4	50.4 ±5.4^{a}	40.4 ±5.7	57.3 ±4.5	136.0 ±31.3
	Yeşilsoy	3.1 ±0.5	45.5 ±6.9^{b}	38.5 ±6.1	58.9 ±4.7	146.9 ±32.7
	P Value					
	R	0.356	0.242	0.106	0.226	0.302
	HS	0.000**	0.000**	0.000**	0.000**	0.000**
	V	0.278	0.001**	0.153	0.272	0.236
	RxV	0.176	0.877	0.053	0.326	0.387
	VxHS	0.001**	0.000**	0.000**	0.000**	0.236

*p<0.05, **p<0.01; full blooming stage (R2), full pod stage (R4), full seed stage (R6). Dry matter intake (DMI), neutral detergent fiber (NDF), acid detergent fiber (ADF), digestible dry matter (DDM) and relative feed value (RFV); Different superscript letters denote significant differences (p < 0.05).

4. Conclusion

According to the results of this study, the highest plant height and green herbage yield were obtained from the Derry variety, and the lowest was obtained from the Adasoy variety. These results show that forage type soybean varieties have higher yields than grain types which was supported in other studies. In the harvesting stage, the R4 and R6 stages had the highest plant height and green herbage yield values. In the study, the best results were obtained from the Yeşilsoy variety according to the values used in determining feed quality such as DMI, NDF, ADF, and DDM. Although some differences are incurred between the seasons in terms of harvest stages, especially on the basis of the RFV value, the R6 harvesting stage can be considered as the period that produces better quality feed. According to these results, the Derry variety gave the best results in terms of soybean yield as a second crop and the Yeşilsoy variety was prominent in terms of quality as a second crop under Mediterranean conditions where the study was carried out. Generally, from the experimental results, it can be suggested that harvesting soybean at the R6 harvest stage is appropriate. As a result, it can be said that the use of soybeans as feed should be generalized, and adding to the feed rations will contribute positively.

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