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THE RELATIONSHIP BETWEEN MATURITY STAGE AND FORAGE YIELD AND QUALITY OF FIELD PEA (*PISUM SATIVUM* SSP. *ARVENSE*)

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Abstract

The aim of the study was to determine the appropriate growth stage for the harvest of peas (*Pisum sativum* L., cv. Özkaynak) to obtain a better yield and quality. The study was conducted in Kızıltepe district, Mardin province in the Southern Anatolian Region of Turkey during the 2018-2019 and 2019-2020 growing seasons. Forage peas were harvested at 3 different stages: 50% flowering stage, visible first pod stage, and full pod stage. Green matter (GM) and dry matter (DM) yields, crude protein (CP) ratio, CP yield, acid detergent fiber (ADF), neutral detergent fiber (NDF), digestible dry matter (DDM), dry matter intake (DMI), and relative feed value (RFV) were determined. The harvest at the visible first pod stage showed the highest values for GM, DM, CP yield, ADF, DMI, and RFV. Harvesting before or after this stage resulted in a significant decrease in these parameters. However, the highest CP rate and DDM value were recorded for the harvest at the 50% flowering stage, and the highest NDF was noted when the harvest was done at the full pod stage. Therefore, it is concluded that the most appropriate maturity stage for forage pea harvest in the Mardin province of Turkey and regions with similar ecological conditions is the first visible pod stage.

Key words: Pea, *Pisum sativum*, Forage, Fodder, Harvest stage

Introduction

Forage production is becoming increasingly important in the agricultural sector worldwide to meet dairy requirements. The production of forage crops has become an intensive farming system, and as a result, high-input forage crops have been included in the system. However, the sustainability of the system requires various low-input broadleaf crops. Forage pea (*Pisum sativum* L.) could potentially be the ideal crop in this regard because it requires low inputs and produces high-quality forage yield (Begna *et al*., 2021; Sayed *et al*., 2024).

Forage pea is a cool-season legume that is palatable and nutritious both as grain and forage (Mihailovic *et al*., 2013; Iqbal *et al*., 2022). Thus, many countries in Europe, West Asia, and North Africa use it as fresh fodder, dry fodder, silage, haylage, or straw for ruminants (Mihailovic & Mikic, 2014). Moreover, it is known to produce high-yield and quality forage even under harsh drought conditions. Therefore, forage pea is an important legume crop, particularly for the temperate regions of the world. Recently, winter peas have also become a considerable crop for haylage production in Turkey as well as in different parts of the world. Forage pea contributes to the evaluation of fallow fields as an intermediate product during the winter months. In addition, it contributes to sustainable agriculture due to its contribution to soil quality, like other legumes (Karadeniz & Bengisu, 2022).

Different local fodder pea (*P. sativum* ssp. *arvense* L.) ecotypes have been selected. These ecotypes have been widely tested for their forage yield and quality for several years, especially in the Eastern Anatolia of Turkey (Tan *et al*., 2012; Tan *et al*., 2013). Besides, some cultivars have also been tested in Eastern Anatolia, the Mediterranean region, and various locations with Mediterranean-type climates (Bilgili, 2010; Türk & Albayrak, 2012; Çaçan *et al*., 2018).

Previous studies revealed that, in addition to the characteristics of the species or varieties, climatic conditions of the production area, soil type, fertility status, planting time, etc. significantly alter the yield and quality of legume crops (Türk & Albayrak, 2012; Iqbal *et al*., 2020). The development (maturity) stage of the legume crops and accordingly the harvest period is also effective on the forage yield and quality (nutrient composition). Generally, late harvest reduces the forage quality (nutritional composition) of legumes (Tan & Serin, 1996; Tan *et al*., 1997, 2003). Similarly, a decrease in the forage quality of different pea varieties has been observed due to harvest at late maturity/development stages (Türk & Albayrak, 2012; Yuksel & Turk, 2019; Kamran *et al*., 2023). However, the CP ratio, TDN (total digestible nutrients) and RFV values of forage crops decreased due to the advancing growth, while total DM and CP yields, ADF, and NDF increased (Türk & Albayrak, 2012).

Although the total DM and CP ratio increases as the maturation process of forage peas is delayed, generally CP and TDN rates and RFV values decrease due to the leaves falling from the lower nodes of the cultivated plants. Therefore, harvesting in late growth stages causes a significant decrease in forage quality. Thus, the nutrient composition of the forage crops alone is not considered a criterion to determine the harvest period, but also the total DM and CP yields, ADF, NDF, etc. should be considered (Tan *et al*., 2003; Rebole *et al*., 2004; Türk & Albayrak, 2012).

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Studies on the cultivation of forage pea in Turkey have primarily been conducted in the Eastern Anatolia region. However, studies in the Southeastern Anatolia region are scarce, resulting in a significant knowledge gap for the cultivation of forage peas in the area. Southeastern Anatolia is located in the Fertile Crescent and has a very high agricultural production potential. In the current study, hay yield and quality were compared depending on the development stages of forage peas under the ecological conditions of Kiziltepe district, Mardin province, Turkey. Determining the appropriate harvest period for forage pea cultivation in the Southeastern Anatolia region was the major objective of the study.

Material and Methods

The field experiments were conducted in Köprübaşı village, Kızıltepe district, Mardin province in the Southeast Anatolia Region of Turkey during the winter growth seasons of 2018-2019 and 2019-2020 (Fig. 1).

The total precipitation in the area during the first year (2018) was 396 mm, while it was 488 mm during the second year (2019). In both years, the total amount of rainfall was higher than the long-term average of 272 mm. Despite a minor difference in rainfall between the two years, the average temperature and relative humidity remained alike, as stated in (Table 1).

Based on the soil analysis, it was revealed that the soil in the area was clay-loam and slightly saline. It was also found to be deficient in organic matter and lime, high in potassium, and low in phosphorus. Additionally, the pH of the soil was neutral. For further details on the soil properties within the 0-30 cm range, please refer to (Table 2).

The Özkaynak pea (*P. sativum* ssp. arvense) variety was used in the experiments, and it was registered in 2008 by the Selcuk University Faculty of Agriculture in Konya, Turkey. Before sowing, the field was deeply plowed, and the seedbed was prepared using a cultivator and press. The experimental units (parcels) were 2.4×5m and had an area of 14 m2, with a 20 cm row spacing. Manual seed sowing was done with 100 seeds per m2, on 05 November and 3 November in 2018 and 2019, respectively. A total of 30 kg ha-1 pure N was applied during sowing, and weeds were manually controlled in both years. Harvesting was done at three different growth/maturity stages, which were the 50% flowering stage, the first visible pod formation stage, and the full pod stage of the plants. The experiment was laid out according to a Randomized Complete Block Design (RCBD) with three replications.

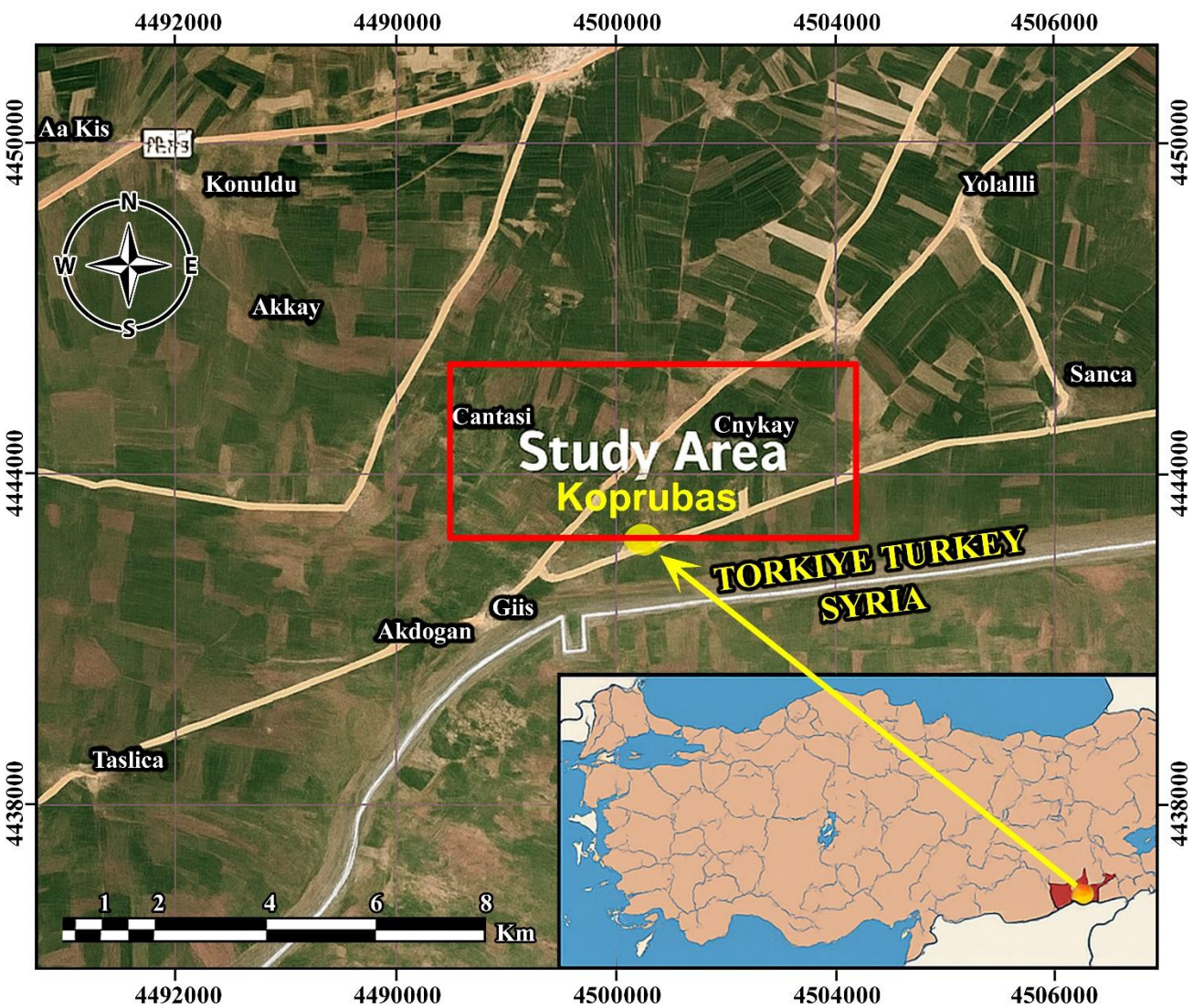


Fig. 1. Research area location map.

Table 1. Climatic (precipitation, temperature, and humidity) data during the experimental period and long-term averages data of Kızıltepe/Mardin*

	Years	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature (°C)	2018	8.5	10.2	14.3	17.7	21.8	28.1	30.9	30.2	27.0	21.6	13.2	9.1
	2019	6.6	8.8	10.7	13.9	22.7	29.5	30.8	31.7	26.3	22.3	13.5	9.9
	2020	3.6	3.8	10.7	14.1	19.9	26.2	31.5	29.9	29.3	22.8	12.0	
Precipitation (mm)	LTA	6.9	9.0	12.2	16.0	21.7	28.5	32.1	30.9	26.2	20.5	13.3	8.1
	2018	48.3	35.7	5.2	12.1	103.8	0.8	0.9	0.2	0.1	48.6	32.2	51.5
	2019	44.1	27.4	95.8	79.7	49.2	16.3	1.7	0.1	0.3	32.7	11.8	54.5
	2020	75.9	102.8	157.3	51.6	30.5	31.5	4	0	0	0	35.7	
Humidity (%)	LTA	36.03	33.15	59.18	37.62	38.77	3.53	0.73	0.20	1.47	24.51	33.29	33.53
	2018	67.4	70.9	64.1	53.0	60.8	33.9	31.3	38.3	35.3	47.4	77.8	88.1
	2019	86.5	87.5	86.7	94.3	9.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	2020	71.9	71.4	65	59.7	43.4	26	20.6	22.1	20.6	22.5	55.8	
	LTA	71.6	66.1	69.0	63.0	47.0	25.1	21.0	27.6	30.5	38.3	50.7	65.5

* Data was obtained from the Mardin Meteorology Provincial Directorate. LTA: Long Term Average.

Table 2. The major soil properties of the research site prior to forage pea planting.

Soil properties	2018	2019
Texture	Clay-Silt	Clay-Silt
Ph	7.35	7.28
Salt	0.3	0.28
Organic matter	1.45	1.51
$CaCO_3$ (%)	4.63	4.41
N	0.84	0.95
Phosphorus (P_2O_5) (kg ha^{-1})	27.2	26.4
Potassium (K_2O) (kg ha^{-1})	2580	2620

The yield of green forage was determined by weighing the plant materials at different harvest stages. A 500-gram fresh plant sample was oven-dried at 70°C until a constant weight was obtained to determine the dry matter yield. The Acid detergent fiber (ADF) and Neutral detergent fiber (NDF) were determined using the ENISO 13906 (2008) method. The nitrogen content was determined by using the Kjeldahl method, and the crude protein (CP) ratios (%) were obtained by multiplying these values by a coefficient of 6.25 (Anon., 1990). The method proposed by Moore & Undersander (2002) was used to calculate the dry matter intake (DMI), digestible dry matter (DDM), and relative nutritional value (RVF). The equations used in the calculations are given below.

$$DMI\ (\%) = 120/NDF \quad (1)$$
$$DDM\ (\%) = 88.9-(0.779 * ADF) \quad (2)$$
$$RFV\ (\%) = (DMI * DDM)/1.29 \quad (3)$$

Statistical analysis was conducted according to RCBD, and the JMP statistical program was used for variance analysis (Kalayci, 2005).

Results and Discussions

According to a recent study conducted in the Eastern Anatolia region of Turkey (Erzurum), the yield of green forage varied between 1587.8 and 2764.5 kg da-1 for different genotypes (Kadıoğlu *et al*., 2020). Another study conducted in the same region showed a green forage yield of 874-1552 kg da-1 and a dry forage yield range of 129-232 kg da-1. The findings of previous studies in the area are consistent with the results reported here (Sayar & Anlarsal, 2008; Sayar *et al*., 2009; Sayar & Han, 2016). The slight variations observed in the present study and other studies in the region can be attributed to differences in cultivars and regional climatic conditions. The study concludes that the southeast Anatolian region of Turkey is suitable for forage pea cultivation based on the green and dry forage yield in current and previous studies.

In this study, it was found that the highest yield of green and dry matter for forage pea was obtained during the first visible pod stage of harvest, followed by the whole pod and 50% flowering stages (Fig. 2). Similarly, Vasiljevic *et al*., (2016) reported that hay yield for forage peas was lower during the mid-flowering period (385-390 kg/da) than during the first visible pod period (725-727 kg/da) (Fig. 3). Pursley *et al*., (2020) also discovered significant differences in pea yields based on maturation stages. They found that the dry matter yield was significantly higher during the mid and late maturity stages (435 kg/da and 442 kg/da, respectively) compared to the early stage (187 kg/da). Previous studies are in agreement with these results. Therefore, it can be concluded that the first visible pod stage is the most suitable maturity/growth stage for forage pea harvest in the region.

It seems like the first visible pod stage is the most suitable maturity/growth stage for forage pea harvest in the region, according to the results of the current study and previous studies conducted by Vasiljevic *et al*. (2016) and Pursley *et al*. (2020). Green and dry matter yield of forage pea was found to be highest during this stage, followed by harvest at the whole pod and 50% flowering stages. Pursley *et al*. (2020) also reported significant differences in pea yields according to the maturation stages, with the dry matter yield being significantly higher in the Mid and Late maturity stages compared to the Early stage. These findings suggest that the timing of forage pea harvest can significantly impact yield, and careful consideration should be given to the maturity/growth stage for optimal results. The analysis of variance showed that the impact of the harvesting stage on all other measured factors was statistically significant. However, the interaction of years and years x harvesting stage was not significant for other parameters. Therefore, the outcomes are presented as the average of two years, as illustrated in (Figs. 4-10).

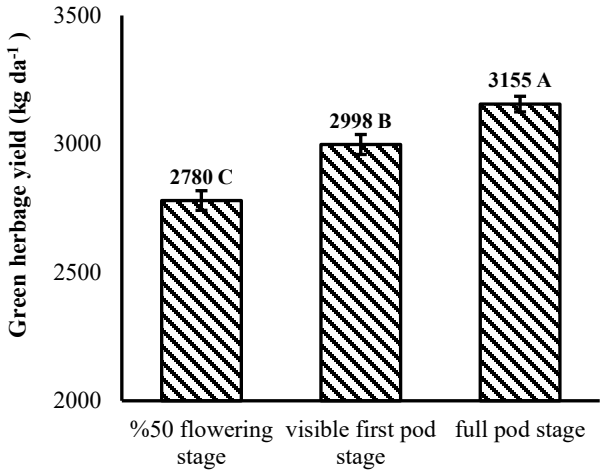


Fig. 2. The determined green forage yields of forage peas depending on the harvesting stages.

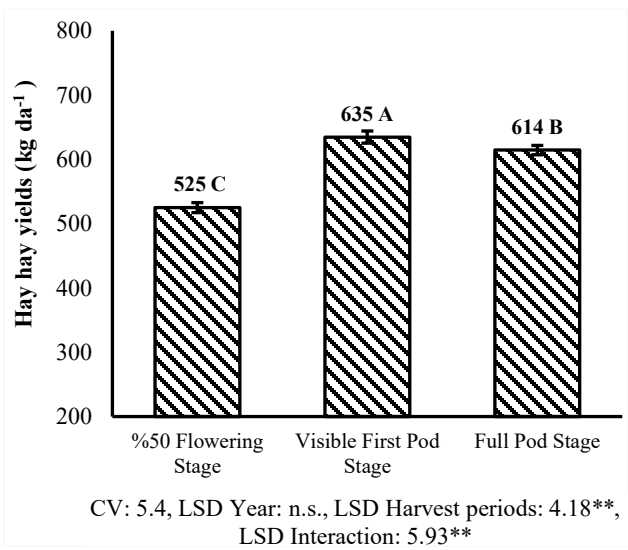


Fig. 3. The determined dry hay yields of forage peas depending on the harvesting stages.

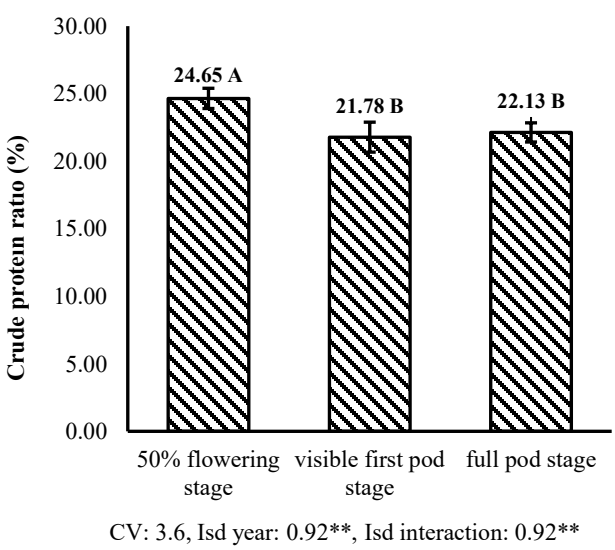


Fig. 4. The determined CP ratios of forage peas depending on the harvesting stages.

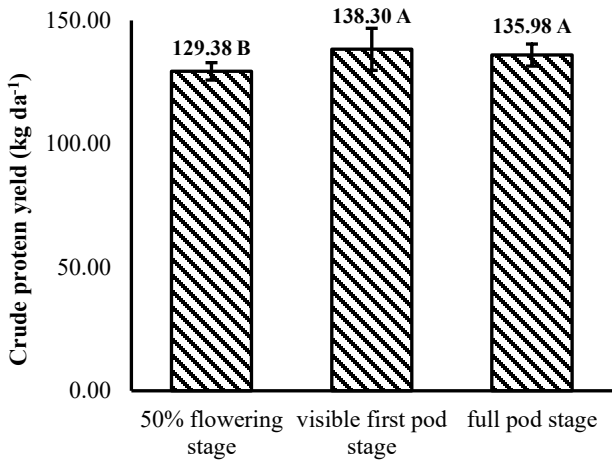


Fig. 5. The determined CP yields of forage peas depending on the harvesting stages.

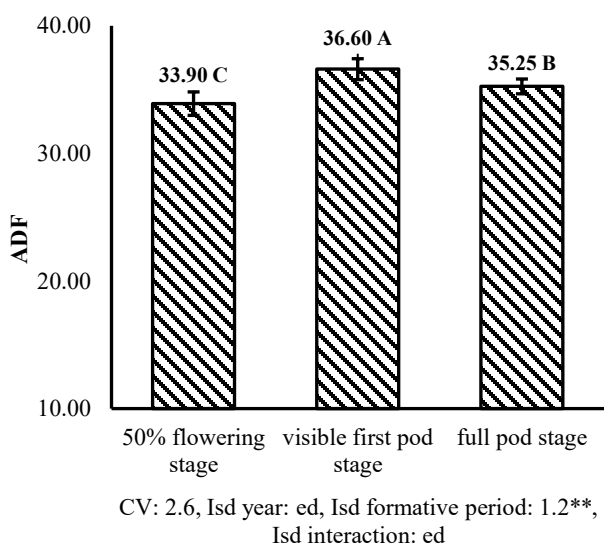


Fig. 6. The determined average ADF values of forage peas depending on the harvesting stages.

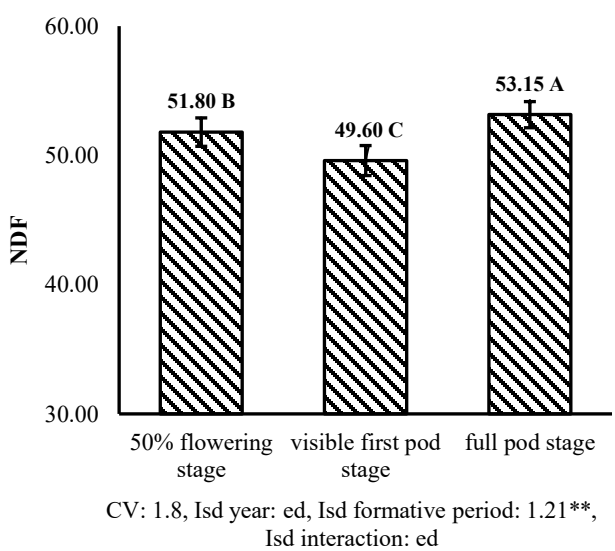
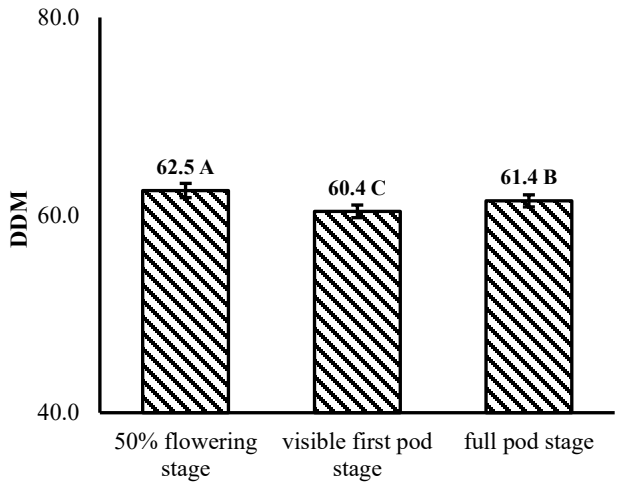
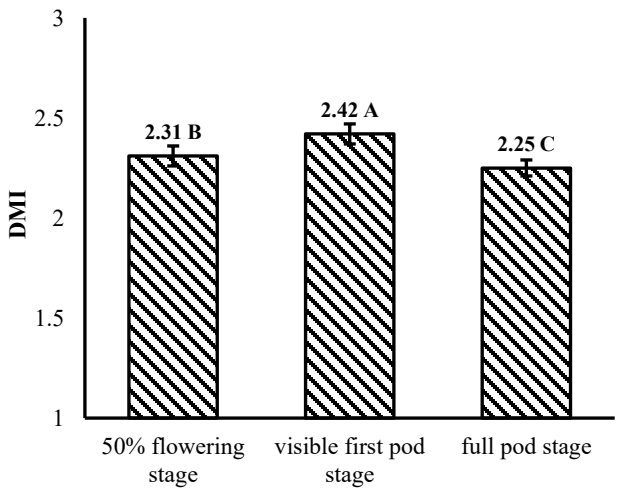


Fig. 7. The determined average NDF values of forage peas depending on the harvesting stages.



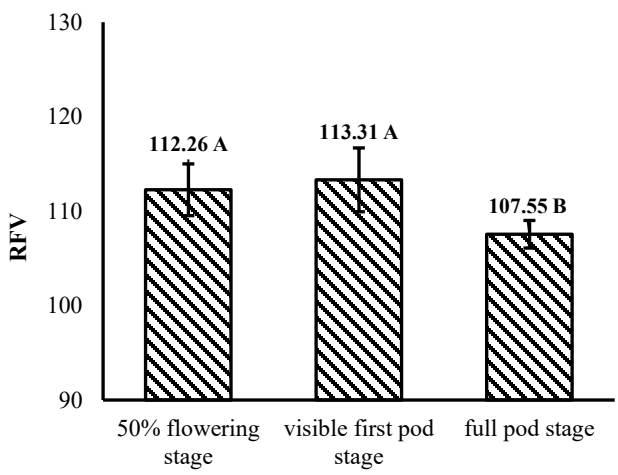
CV: 1.17, Isd year: 0.67**, Isd interaction: 0.67**

Fig. 8. The determined average DDM values of forage pea depending on the harvesting stages.



CV: 1.17, Isd year: 0.67**, Isd interaction: 0.67**

Fig. 9. The determined average DMI values of forage peas depending on the harvesting stages.



CV: 1.75, Isd year: ed, Isd form period: 2.57**, Isd interaction: ed

Fig.10. The determined average RFV values of forage peas depending on the harvesting stages.

The highest ratio of crude protein (CP) was observed at the 50% flowering stage (24.65%), while the lowest ratio was recorded at the first visible pod stage (21.78%). The difference between the first visible pod and full pod stages was not statistically significant (Fig. 4). In contrast to the CP ratio, the highest yield of CP (averaged over two years) was found at the first visible pod stage (138.3 kg da-1), while the lowest yield was recorded at the 50% flowering stage (129.4 kg da-1) (Fig. 5). These findings are in agreement with Kocer & Albayrak (2012) who also reported a decrease in CP ratio, but an increase in total CP yield with the delay in development/maturity of forage pea. Türk & Albayrak (2012) also found that the CP ratio decreased, while the total CP yield increased due to the delay in development/maturity period of forage pea. The high leaf rate of the crop during the 50% flowering stage possibly caused an increase in the CP content of the plant material. However, CP yields increased in later growth stages due to the overall increase in yield.

According to Figure 6, the highest ADF value of 36.6% was recorded for the harvest at the first visible pod stage, while the lowest value of 33.9% was recorded for the harvest at the 50% flowering stage. On the other hand, Figure 7 shows that the highest NDF value of 53.2% was observed when the crop was harvested at the full pod stage, and the lowest value of 49.6% was noted for the harvest at the first visible pod stage.

The ADF (25.8 - 34.9%) and NDF (35.8 - 44.1%) values were found to be relatively lower in various studies conducted across different regions of Turkey (Kocer & Albayrak, 2012; Cacan *et al*., 2019; Yuksel & Turk, 2019). These differences could be attributed to the variations in ecological conditions of the experimental areas and the cultivars used in the studies. Yuksel & Turk (2019) reported that the ADF and PDF ratios of forage peas increased from 27.00% to 29.20% and from 35.80% to 39.98%, respectively, as the maturity progressed. Similarly, Türk & Albayrak (2012) stated that allowing peas to advance in maturity stages generally increased the ADF and NDF values. Therefore, the findings of the current study align with the results of these previous studies.

It was observed that there were significant differences in DDM and DMI values depending on the harvest stages. The crop harvested at the 50% flowering stage showed the highest DDM value (62.5%), while the lowest value (60.4%) was observed when the crop was harvested at the first visible pod stage (Figure 8). On the other hand, the crop harvested at the full pod stage exhibited the highest DMI value (2.42%), while the lowest value (2.25%) was noted when the crop was harvested at the first visible pod stage (Fig. 9).

Cacan *et al*. (2019) conducted a study on fourteen different pea lines and cultivars in which they found that DDM (dry matter digestibility) and DMI (dry matter intake) values varied between 61.7% and 67.4%, and 2.62% and 3.26%, respectively. In contrast, Naydenova & Kosev (2015) reported that DDM and DMI values in 8 varieties of forage peas varied between 63.6% and 67.9%, and 3.2% and 3.6%, respectively. Kocer & Albayrak (2012) reported the DDM rate of feed peas as 68.03%.

These results suggest that the DDM and DMI values in the current study are relatively lower. In addition, Naydenova & Kosev (2015) found a higher DDM value (70.0%) from the full pod stage among three different forage pea harvest stages (budding, beginning of flowering, and full pod formation), which is opposite to the current study's findings. Meanwhile, Pursley *et al*. (2020) stated that the maturity stage of pea at harvest (used for hay) does not affect DMI for beef cattle. These varying results from different studies may be due to differences in ecological conditions and varieties used.

According to Figure 10, the crop harvested at the first visible pod stage had the highest RVF value (113.3), and there was no significant difference between the RVF values of the crop harvested at the first visible pod stage (113.3) and the 50% flowering stage (112.3). However, there was a statistically significant difference in RVF values between the crop harvested at the full pod stage (107.6) and the other two stages. The RVF value increased until the first visible pod stage and then decreased as the crop matured.

Although the RFV value is not a direct measure of nutritional content, it is an essential indicator for estimating the forage intake and energy values of forage crops (Van Soest, 1996; Lithourgidis *et al*., 2006). The RFV is derived from DMI and DDM values, and forages are classified into six groups based on the RVF index: prime (>151), premium (150-125), good (124-103), medium (102-87), poor (86-75), and rejected (<75) (Lithourgidis *et al*., 2006). In the current study, the RVF values at all maturity stages were between "124-103," which falls under the "good" category. Therefore, there is no difference in forage values (the forage intake and energy) based on the RVF values.

In a study conducted by Yuksel & Turk (2019), a decrease in RFV values was observed due to the advancing growth stages of forage peas, with the values dropping from 176.3 to 153.9. However, Kocer & Albayrak (2012) reported a higher RFV value of 167.3, similar to that of Yuksel & Turk (2019), unlike the current study's findings. Cacan *et al*., (2019) also reported varying RFV values (between 130.9 and 166.4) based on the varieties and lines of peas. Therefore, differences in RVF values among studies, as well as other measured parameters, are likely due to variations in cultivars, agricultural practices, soil characteristics/fertility, ecological conditions, and other factors.

Conclusions

Based on the study conducted in Mardin province of Turkey, it was found that the harvest of forage peas at the first visible pod stage provided the highest values for green forage, hay and CP yield, ADF, DMI, and RFV. However, harvesting forage peas before (50% flowering period) or after (full pod period) this stage caused a significant decrease in these parameters. The highest CP ratio and DDM value were noted for the harvest at 50% flowering stage, but the highest NDF values were recorded for the crop harvest at the full pod stage. Therefore, it can be concluded that the most suitable maturity stage for pea harvest in the Mardin province of Turkey, and regions with similar ecological conditions, is the first visible pot stage to obtain higher yield and quality.

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