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Silage Quality and Nutritional Evaluation of Narbon Vetch (*Vicia narbonensis* L.) Genotypes Harvested at Two Growth Stages

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I. Abstract

This study evaluated the influence of Narbon Vetch (*Vicia narbonensis*) genotypes, harvesting stages and their interaction on silage fermentation characteristics, nutritional composition, Fleig points and silage quality under controlled conditions of sulaimani governorate. Narbon vetch were planted according to Randomized Complete Block Design (RCBD) with factorial experiment (4 x 2), first factor was four genotypes (G1:ICARDA2384), (G2:ICARDA2383), (G3:ICARDA2380), and (G4:ICARDA2816)] of Narbon Vetch, and second factor was harvesting at two different growing stages (FS: flowering stage and RS: reproductive stage) to making silage, the crop harvested and chopped, then put in polyethylene bags and stored for 50 days. The results showed that the differences among genotypes are significant; G3 and G4 had higher dry matter percent, lower pH, higher lactic acid concentration, and superior Fleig scores, resulting in good to very good quality of silage in compare to G1 and G2 which was produced silage with poor fermentation and lower quality. Harvesting at flowering stage enhanced fermentation and Fleig points in comparison with the reproductive stage. The interaction between genotypes and harvesting stage significantly influenced most quality traits. The highest silage quality was obtained by interaction (G4xFS) and (G3xRS), on the other hand (G2xRS) interaction resulted in very poor silage quality.

Key Words: Keywords: Vicia narbonensis, silage quality, cutting stage, fermentation product, fleig points, nutritional composition.

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II. Introduction

The lack of availability of forage continues to be a significant barrier to livestock production in several semi-arid areas around the globe, including the Kurdistan region of Iraq. Seasonal variability in rains, limited pasture availability and fluctuated forage often result in inconsistent feed systems which reduce livestock productivity. Forages can be conserved to feed livestock during periods of shortage caused by limited pasture growth or inadequate conditions conserved forages can take the form of silage (Galata, & Haramaya, 2023). Silage is the most common methods of preservation of forages (Katoch, R. 2022). Silage production success is influenced by forage species; harvest stage; chemical composition and fermentation conduct (Long *et al*., 2022).

The plant that is most commonly used to make silage is corn (maize), it is the popular silage crop in the world because it has high energy and grows well. Other plants also used for silage: Grass (ryegrass, orchard grass), Alfalfa (lucerne), Sorghum, Barley, Wheat, Oats.

Narbon vetch (*vicia narbonensis* L.) is a leguminous crop with considerable potential for use as a grain and straw feed source in dry temperate environments, the species exhibits strong tolerance to drought and low temperatures and is easily established because its large seeds permit deeper sowing near soil moisture compared with other vetches (Muhammed, & Karim2021). As a result of these characteristics, it has the potential to be used for silage production in areas such as Sangaw location in Sulaimani region, due to climate-related restrictions on the performance of other forage crops. The most common methods of forage crop preservation are hay making and ensiling, ensiling or silage is a method of moist forage preservation whereby lactic acids bacteria convert water-soluble carbohydrates to organic acids by fermentation, mainly lactic acid under anaerobic conditions (without oxygen), as a result the pH decreases, inhibiting detrimental anaerobic bacteria, and so the moist forage is preserved, this is actually lactic acid solid-state fermentation of forage crops (Weinberg, 2008). Maturity stage is the most important factor determining forage quality, when forage harvesting at earlier stage of growth usually more digestible and has higher protein content compare to later harvesting stage, which have a higher biomass yield, greater percentage of fiber, and decrease forage quality, which could negatively affect fermentation efficiency and the amount of soluble sugars (Atis, *etal*., 2012). In our region there are no studies about silage making from narbon vetch, thus the objective of this study is to determine the influence of harvesting stages on ensiling characteristics and feeding value of silage made from four Narbon vetch varieties in Sangaw location of sulaimani region.

III. MATERIALS AND METHODS

This study was conducted to evaluate the effect of narbon vetch (Vicia narbonensis) genotypes, harvesting stages, and their interaction on ensiling characteristics, nutritional composition, fleig points, and overall silage quality in sangaw location of Sulaimani region which was located (Lat 35˚ 17′ 8″; N, Long 45˚ 10′ 42″; E, 833 masl) 40 Km South West of Sulaimani City during the winter season of 2022-2023 by using Randomized Complete Block

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Design (RCBD) with two factor, first factor are four genotypes of narbon vetch [(G1:ICARDA2384), (G2:ICARDA2383), (G3:ICARDA2380)and (G4:ICARDA2816)] which obtains from Agricultural Research Center-Sulaimania, and the second factor were two different harvesting stages (at flowering stage and reproductive stage) . Narbon vetch was harvested at these stages to making silage, cut forage (leaves and stems) were wilted to a dry matter of 70%, after that, they were chopped mechanically to about a length of 3-4 cm. All chopped materials were mixed, put, and packed in polyethylene bags by three replications, each replication consist of 8 polyethylene bags and 24 treatment combinations in the study. Silage additive (molases) was added by 1.5 kg for each 50 kg of narbon vetch in each polyethylene bags, were tightly closed. Finally, all polyethylene bags were placed in plastic barrels and left for fermentation at 25 °C for 55 days. At the end of fermentation period, three sample replicates of each plastic barrel were taken in order to determine chemical composition of silage.

Ensiling Characteristics were studied:

For pH analysis, 25g of each silage samples were placed in baker. Then, 100 ml of distilled water was added and mixture was thoroughly stirred for 5 minutes. After filtration through Whatman filter paper, the PH was measured using a digital pH meter. Dry matter percentage (DM %) was determined by drying 100g sub-samples in an oven at 65C$^{\circ}$ for 72 hours. Organic matter (OM %) was determined by subtracting ash percentage from the total dry matter (100%). All silage samples of narbon vetch were taken from flowering stage and reproductive stage to analyze silage quality (Protein, Ash, Lactic Acid, Acetic Acid, Butyric Acid) percent at the Laboratory of RAZGA COMPANY for Trading, General Contracting &Quality Control/LTD, Calibration and accuracy were conducted by using EDXRF (BRUKER), Model: S2PUMA A35X1-4A2D1E6BA1, razga.co.lab@gmail.com, Iraq, Penjwen, International Border Compound of Bashmakh. Fleig Point were calculated by the equation: 220 + (2 x DM% - 15) - 40 x pH, as stated by Denek and Can (2006), it was indicated that the Fleig point values are between 85 and 100. They are to be considered a very good quality if they are between 60 and 85, good quality between 55 and 60, moderate quality between 25 and 55, poor quality and less than 25, very poor quality. (Muhammed. *etal.*,2018). Statistical analysis: The data were statistically analyzed according to the methods of analysis of variance as a general test; and combined analysis of variance across locations also was conducted. Mean comparisons was conducted by using list significant differences (LSD) test at 0.05 probability (Steel *et al.*, 1997).

IV. RESULTS AND DISCUSSIONS

Table 1shows that the influence of varieties on dry matter percent and nutritional values of narbon vetch was significant for all traits, maximum values of dry matter and Ash recorded by G4 were (21.594%, and 2.774%) respectively, also for protein and organic matter were 5.445% and 98.721% exhibited by G1 and G2 Consistently. While, the minimum dry matter and protein percent (9.110% and 0.229%) recorded by G2 and G4, on the other hand, G3 produced minimum ash and organic matter percent (1.320% and97.175%) respectively. G1 and G3 appear

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more suitable for producing high-protein forage, while the G4 may be preferable when higher dry matter and mineral content are desired. These differences likely reveal genetic variability affecting nutrient accumulation, plant structural composition. This finding is in agreement with previous result indicating that the variation in forage quality traits among narbon vetch varieties due to genetic variation (Larbi, *etal*., 2010).

Table 1: Effect of Genotypes on dry matter percent and nutritional values of narbon vetch silage.

Genotypes	DM%	Protein%	Ash%	OM%
G1	9.706	5.445	1.508	98.338
G2	9.110	2.880	1.585	98.721
G3	19.681	0.816	1.320	97.175
G4	21.594	0.229	2.774	97.188
LSD(P≤0.05)	1.083	0.313	0.541	0.551

Table 2 explains the effect of genotypes on pH and silage quality parameters of Narbon vetch was significant for all characters. The highest pH was observed in G2 (4.817), while the lowest pH value was recorded in G4 indicating better fermentation quality,

Among the genotypes, G4 produced the maximum values of acetic acid (1.622%), lactic acid (2.371%), butyric acid (2.373%), fleig point (86.080) and minimum pH (4.050) which indicate better fermentation quality. But the lowest values of acetic acid (0.971%) and butyric acid (1.552%) exhibited by G3, and for lactic acid and fleig point were (1.595% and 32.727) recorded by G2. As shown G4 had the lowest pH level and achieved the highest fleig point then produced very good silage quality, a low pH is a critical indicator to success fermentation of lactic acid, as it reflects quick acidification and efficient preservation of the ensiled material, but the higher fleig point confirmed the excellent fermentation quality of G4 silage. Since the fleig point is calculated based on pH and dry matter, higher value indicates well preservation of silage and minimal losses of nutrient. This achieved result support the previous result showed by Kung Jr, L. (2010) that confirmed decreasing in pH cause inhibit the growth of undesirable anaerobic microorganisms such as enter bacteria and clostridia.

Table 2: Effect of Genotypes on pH and silage quality of narbon vetch silag*e*.

Genotypes	PH	Acetic acid%	Lactic acid %	Butyric acid%	Fleig Points	Silage quality
G1	4.800	1.594	2.318	2.252	36.387	Poor
G2	4.817	1.013	1.595	1.715	32.727	Poor
G3	4.083	0.971	1.777	1.552	82.320	Good
G4	4.050	1.622	2.371	2.373	86.080	Very Good
LSD (P≤0.05)	0.339	0.207	0.386	0.413	13.419	

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*Fleig points: values between 85 and 100, very good quality: 60 and 85, good quality: 55 and 60, moderate quality: 25 and 55, poor quality, and <25, very poor quality.

Table 3 illustrates that the influence of harvesting stages on dry matter percent and nutritional values of Narbon vetch was significant for dry matter and protein contents, but for ash and organic matter were not significant. The maximum dry matter percentage (15.293%) was obtained at the reproductive stage, in compare to the flowering stages which recorded minimum percent of dry matter (14.753%). Regarding protein percent, the silage produced at flowering stage was higher protein content (2.467%) in compare to reproductive stage that showed lower protein percent (2.218%). Dry matter accumulation in forage crops increases as the plant moves through growth stages but protein concentration declines as the plant mature, similar results were obtained previously by (Uyanik & Carpici 2025) whom confirmed that the dry matter accumulation increased depending on the progress of the plant development periods.

Table 3: Effect of harvesting stages on dry matter percent and nutritional values of narbon vetch silage.

Harvesting Stages	DM%	Protein%	Ash%	OM%
Flowering Stage	14.753	2.467	1.745	98.05
Reproductive Stage	15.293	2.218	1.848	97.661
LSD (P≤0.05)	0.516	0.222	N.S	N.S

Table 4 demonstrates the effect of harvesting stages on pH and silage quality parameters of Narbon vetch silage was significant for all traits. The maximum pH value was observed at reproductive stage (4.617), while the minimum pH value was recorded at flowering stage (4.050) indicating better fermentation quality. Acetic acid, lactic acid, butyric acid recorded the highest values were 1.656%, 2.432%, 2.232% respectively when silage made at flowering stage, while lowest values of acetic acid were 0.944%, lactic acid 1.598%and butyric acid 1.714% produced when narbon vetch harvested at reproductive stage. When narbon vetch harvested at flowering stage decrease pH value and produced higher lactic acid in compare to other acid which indicate higher quality of silage. These results correspond with the results of previous studies on effects of maturity stage on the yield, nutritive composition, and silage fermentation quality of whole-crop wheat. (Xu, *etal*., 2024). Concerning Fleig point, the biggest value recorded by harvesting at flowering stage (65.77) that is reflecting a good silage quality, while harvesting at reproductive stage gave lower Fleig points (52.987), corresponding to medium silage quality. At flowering stage, typically plants contain higher concentration of soluble carbohydrates and lower content of fiber, which supports the activity of lactic acid bacteria and enhance desirable fermentation. These findings highlight the strong influence of harvesting stage on fermentation and quality traits of silage. The fleig point is calculated based on pH and dry matter, and it serves as indicator of fermentation success and effective preservation.

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Table 4: Effect of harvesting stages on PH and silage quality of Narbon Vetch silage.

Harvesting Stages	PH	Acetic acid%	Lactic acid %	Butyric acid%	Fleig Points	Silage quality
Flowering Stage	4.258	1.656	2.432	2.232	65.77	Good
Reproductive Stage	4.617	0.944	1.598	1.714	52.987	Medium
LSD (P≤0.05)	0.240	0.147	0.273	0.292	9.489	

*Fleig points: values between 85 and 100, very good quality: 60 and 85, good quality: 55 and 60, moderate quality: 25 and 55, poor quality, and <25, very poor quality.

Table 5 confirms the interaction effect between genotypes and harvesting stages which was found to be significant on dry matter and protein percent only, but on ash and organic matter was not significant. the highest value of dry matter percent was (22.199%) recorded by the interaction between G4 and reproductive stage or when G4 harvested at reproductive stage to make silage, whereas the lowest value was (8.528%) produced when G2 harvested at flowering stage. Concerning protein content, maximum percent was 5.513% recorded when G1 harvested at reproductive stage, while the minimum protein content was 0.170% was exhibited by interaction between G4 and flowering stage. This indicates that G1 may possess superior genetic characteristics for maintaining nutritive value at later growth stages and could be suitable where delayed harvest is unavoidable, and this genotype has the ability to maintain nitrogen accumulation in plant tissues even at advanced maturity. This result is in agreement with the previous results of Barriere., *etal*., (2009) which was noticed that genetic variation and harvesting stage significantly affect silage nutritional quality, also Karnatam, *etal.*, (2023) confirmed that gene families impacting silage yield and quality.

Table 5: Interaction Effect of varieties and harvesting stages on dry matter percent and nutritional values of narbon vetch silage.

Genotypes / Harvesting Stages		DM%	Protein%	Ash%	OM%
G1	Flowering stage	10.339	5.377	1.253	98.517
	Reproductive stage	9.074	5.513	1.763	98.159
G2	Flowering stage	8.528	3.442	1.972	98.867
	Reproductive stage	9.692	2.318	1.199	98.574
G3	Flowering stage	19.156	0.878	1.256	97.415
	Reproductive stage	20.207	0.754	1.384	96.934
G4	Flowering stage	20.988	0.170	2.501	97.399
	Reproductive stage	22.199	0.287	3.047	96.976
LSD (P≤0.05)		1.033	0.443	N.S	N.S

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Table 6 illustrates that the interaction effect of varieties and harvesting stages on pH and all silage quality traits of Narbon vetch silage was significant. The highest pH was 5.233 recorded by G2 at the reproductive stage, while the lowest pH 3.767 and the highest percent of Acetic acid, Lactic acid, and Butyric acid were (2.267, 3.152, and 2.742) % respectively recorded when G4 harvested at the flowering stage. Also G4 at flowering stage had the biggest value of Fleig point (95.106) indicating very good silage quality. On the other hand, the lowest values of Acetic acid, Lactic acid, Butyric acid, and Fleig point were (0.460%, 0.727%, 0.988%, and 16.380) respectively showed by G2 harvesting at reproductive stage which produce very poor quality of silage. On the whole very good or excellent silage quality was consistently detected in G4 at flowering stage, while G2 at reproductive stage created very poor quality of silage. This finding emphasize that silage quality depends more on the correct combination of genotype × harvest stage than on either factor alone. Early harvesting at flowering can compensate for yield reduction by improving feeding value, while delayed harvest severely deteriorates silage quality even if biomass yield is higher. The results of this study are similar to those that reflected by David *et al*. (2010).

Table 6: Interaction Effect of varieties and harvesting stages on pH and silage quality of narbon vetch silage.

Genotypes	Harvesting Stages	PH	Acetic acid%	Lactic acid %	Butyric acid%	Fleig Points	Silage Quality
G1	Flowering stage	4.700	1.696	2.273	2.186	41.810	Medium
	Reproductive stage	4.900	1.492	2.363	2.319	30.967	Poor
G2	Flowering stage	4.400	1.567	2.463	2.441	49.090	Medium
	Reproductive stage	5.233	0.460	0.727	0.988	16.367	Very Poor
G3	Flowering stage	4.167	1.093	1.841	1.559	77.070	Good
	Reproductive stage	4.000	0.848	1.713	1.545	87.573	Very Good
G4	Flowering stage	3.767	2.267	3.152	2.742	95.120	Very Good
	Reproductive stage	4.333	0.977	1.589	2.004	77.040	Good
LSD (P≤0.05)		0.480	0.293	0.545	0.583	18.978	

*Fleig points: values between 85 and 100, very good quality: 60 and 85, good quality: 55 and 60, moderate quality: 25 and 55, poor quality, and <25, very poor quality.

Conclusion:

The present study concluded significant variation in silage quality among Narbon vetch genotypes and at different harvesting stages. Genotypes G3 (ICARDA 2380) and G4 (ICARDA 2816) regularity exhibited superior fermentation traits and higher fleig points, illustrating their potential for excellent silage production. In contrast, G2 performed less favorable, with a notable decline in fermentation quality during the reproductive stage. Harvesting

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stage at flowering stage generally enhanced silage fermentation parameter, resulting in improved pH values and higher fleig scores compared with harvesting at the reproductive stage. However, the interaction between genotypes and harvesting stage was notable. The highest silage quality was achieved by G4 when harvested at flowering and by G3 at the reproductive stage, suggesting that optimal performance depends on both genetic background and crop maturity. Overall, optimizing silage quality in narbon vetch requires both the selecting of appropriate genotypes and careful timing of harvesting. Coordinated genotype selection and harvest management can greatly improve fermentation performance and preserve forage effectively.

Appendix: Mean squares of variance for pH, nutritional quality and fleig point of narbon vetch silage

S.O.V	d.f	pH	DM%	Protein %	Ash%	OM%	Acetic acid%	Lactic acid %	Butyric acid%	Fleig Points
R	2	0.049	0.486	0.174	0.022	0.4935	0.014	0.1605	1.136	36.376
A	3	1.102**	256.201**	33.423**	1.747**	3.777**	0.761**	0.904**	0.964**	4956.456**
B	1	0.77**	1.751*	0.371*	$0.042^{n.s}$	$0.859^{n.s}$	3.036**	4.174**	1.609**	980.488*
A*B	3	0.285*	2.179**	0.531**	$0.377^{n.s}$	$0.024^{n.s}$	0.483**	1.349**	0.800**	485.861*
Error	14	0.075	0.348	0.064	0.191	0.198	0.028	0.097	0.111	117.438

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