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Nutritional potential value of *Sesbania grandiflora* (L.) Pers., *Lablab purpureus* (L.) Sweet, and *Vigna radiata* (L.) Wilczek in two sowing methods

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ABSTRACT

Objective: To evaluate the agronomic performance and nutritional potential of *Sesbania grandiflora*, *Lablab purpureus*, and *Vigna radiata* in two sowing methods.

Design/methodology/approach: The morphological and bromatological parameters of leaves and stems of *S. grandiflora*, *L. purpureus*, and V. radiata sown flat and in beds were determined. The forages of leaves and stems of the three species were classified according to their quality parameters. Data for morphological and bromatological parameters were analyzed with a completely randomized design with a 3×2 factorial arrangement and least squares means were compared with Tukey ($p<0.05$).

Results: *Sesbania grandiflora* in flat and bed sowing presented greater height, higher percentage of leaf dry matter, and percentage of stem dry matter. While *V. radiata* in flat sowing presented greater plant weight, leaf weight and stem weight. *Sesbania grandiflora* leaf forages in flat and bed sowing obtained a higher percentage of crude protein, while *V. radiata* in flat and bed sowing obtained a lower percentage of neutral detergent fiber. For stem forage, the three species in flat and bed sowing presented high percentage values of neutral detergent fiber and acid detergent fiber. The leaf forages in bed sowing were classified as excellent quality, as were the leaf forages of *S. grandiflora* and *V. radiata* in flat sowing, which also had excellent quality.

Findings/conclusions: The forage of *S. grandiflora* leaves in flat and bed sowing was of excellent quality, related to its higher percentage of dry matter and crude protein and its lower percentage of neutral detergent fiber and acid detergent fiber.

Keywords: Fabaceae, crude protein, Sesbania, mung bean

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the forage species with the highest nutritional quality, considered among the main sources of protein (21% Crude Protein) in animal feed (Wayu & Atsbha, 2019). However, there are some drawbacks in its production process, as it is a crop with high water requirements and is marketed in dried conditions (Medina-García *et al.*, 2020). It consumes 1.5 times more water than its water footprint (181 $m^3 t^{-1}$), indicating low water use efficiency (IMTA, 2020).

Due to the challenges posed by the production of *M. sativa* in the Mexicali Valley and the growing demand for proteins for human and animal consumption in developing countries, exploring alternative protein sources for animal feed is justified. These alternatives must present high nutritional value to supplement livestock's nutritional requirements and allow animals to express their maximum genetic potential (Percy, 2015). This is the case with fabaceae (formerly known as legumes), which, due to their adaptability and protein content, could yield good results (Guerra-Guzmán *et al.*, 2021).

The Fabaceae family exhibits a great diversity of plant species, with approximately 727 genera and 19,325 species (Lewis *et al.*, 2005). Among these are plants with potential uses in food, forage, medicine, timber, and ornamentation (Al-Sghair & Mahklouf, 2020). The consumption of these species by ruminants improves fiber degradability, increases dry matter intake, and enhances the population of ruminal microorganisms (Chanthakhoun *et al.*, 2011).

Among this variety of Fabaceae with high nutritional value are *Sesbania grandiflora* (L.) Pers. (Sesbania), *Lablab purpureus* (L.) Sweet (Dolichos), and *Vigna radiata* (Mung bean) (L.) Wilczek, which exhibit crude protein content and dry matter production equivalent to 25%, 16%, and 25%, and 87%, 32%, and 90%, respectively (Gebreyowhans *et al.*, 2019; Mekkara & Bukkan, 2021; Aguerre *et al.*, 2023). These nutritional parameters demonstrate that these species possess desirable characteristics for evaluation as forages in animal nutrition. However, in the Mexicali Valley, there is a lack of scientific information regarding their agronomic performance and nutritional value. These plant species may exhibit different parameters, as the conditions in this region are arid. Additionally, to maintain productivity in the agricultural and livestock sectors, it is necessary to make adjustments in forage production by introducing species tolerant to water and salt stress (Medina-García *et al.*, 2020). For this reason, in the search for new forage alternatives, the agronomic performance and nutritional potential value of *Sesbania grandiflora*, *Lablab purpureus*, and *Vigna radiata* were evaluated under two sowing methods, with the aim of contributing alternative forage species with high nutritional quality for animal feed.

MATERIALS AND METHODS

Study Area Location

The experiment was conducted at the experimental agricultural station of the Institute of Agricultural Sciences, located on Delta Highway S/N Ejido Nuevo León, 50 km south of Mexicali, Baja California, Mexico (32° 24"44.16" N, 115° 11"56.87" W) at an altitude of 12 m above sea level. The average annual temperature is 22 °C, and the average annual precipitation is 75.9 mm. The climate is classified as desert, with January being the coldest month, having an average minimum temperature of −1.66 °C, and August being the hottest month, with a maximum temperature of 45 °C. Establishment took place during the first week of June 2022, and harvesting was conducted in the second week of September. The maximum temperature in June was 44 °C, while the minimum was 13 °C. In September, the maximum temperature reached 43 °C, with minimum temperatures dropping to −3 °C. Throughout the crop development period, maximum and minimum temperatures fluctuated between −3 °C and 49 °C.

Biological Material

The genetic material used was donated by the International Maize and Wheat Improvement Center (CIMMyT) - Northern Pacific Hub: Sesbania (*S. grandiflora*), Dolichos (*L. purpureus*), and Mungo (*V. radiata*).

Crop Establishment

The species *S. grandiflora*, *L. purpureus*, and *V. radiata* were established in six experimental plots (6.4 m wide×100 m long), with three plots designated for flat sowing and three for raised bed sowing (80 cm wide). This resulted in six treatments: Sesbania flat (SES-F), Sesbania raised bed (SES-B), Dolichos flat (DOL-F), Dolichos raised bed (DOL-B), Mungo flat (MUN-F), and Mungo raised bed (MUN-B).

Irrigation was applied at the time of sowing, and two supplemental irrigations at 50 and 80 days after sowing. No fertilizer was applied during the experiment. The agronomic management of the crops with Fabaceae was conducted in accordance with the Official Mexican Standard for Agricultural Activities —Use of Phytosanitary Inputs or Pesticides and Plant Nutrition Inputs or Fertilizers— Safety and Hygiene Conditions (NOM-003-STPS-1999).

Morphological variables

At the end of flowering for each genotype, 25 plants were randomly selected for each treatment, and their fresh weight and height per plant were recorded. Subsequently, the leaves and stems of each plant were separated, and the fresh weight of each morphological component was determined.

The percentage of dry matter for each component was determined by selecting four samples of 200 g of leaves and stems from each treatment, which were dried in an oven at 65 °C for 48 h. The dry weight of each component was then recorded. Finally, the percentage of dry matter was calculated by relating the fresh weight and the dry weight of the sample using Equation 1.

$$\%DM = \frac{Dry\ weight\ of\ the\ sample}{Fresh\ weight\ of\ the\ sample} \times 100 \qquad \text{Equation 1}$$

Bromatological variables

Bromatological characterization was performed for the leaves and stems of the three species. The samples were dried in an oven at 65 °C for 48 h. The dried samples were then ground in a Willey mill using a 1 mm sieve. Subsequently, the forage samples were dried for 24 h at 105 °C in a forced-air oven to determine dry matter (DM) content, and then incinerated for six h at 600 °C in a muffle furnace.

The determination of the percentage of crude protein was performed using the Kjeldahl method and calculated as %N×6.25. The quantification of ash percentage (%ASH) and crude protein percentage (%CP) was conducted according to AOAC (2000) procedures. The percentages of acid detergent fiber (%ADF) and neutral detergent fiber (%NDF) were determined using the procedure reported by Van Soest *et al.* (1991) employing the ANKOM-Fiber Analyzer (Ankom Technology, Fairport, NY).

Forage quality

The forage samples obtained in this study were classified according to their quality parameters based on the relative forage value (RFV) proposed by Rohweder *et al.* (1978), with the scale presented in Table 1.

Table 1. Quality standards for forages (legumes, grasses and their ixtures in the U.S.) assigned by the Hay Market Task Force of the American Forage and Grassland Council.

Quality	CP (%)	ADF (%)	NDF (%)	RFV
Excellent	>19	<31	<40	>151
1	17-19	31-40	40-46	151-125
2	14-16	36-40	47-53	124-103
3	11-13	41-42	54-60	102-87
4	8-10	43-45	61-65	86-75
5	<8	>45	>65	<75

Percentage of crude protein (%CP), percentage of acid detergent fiber (%ADF), percentage of neutral detergent fiber (%NDF), relative forage value (RFV).

The RFV Index relates %NDF and %ADF, which is determined using Equation 2:

$$RFV = \frac{\left[88.9 - (0.779 \times \%ADF)\right] \times \left[\frac{120}{\%NDF}\right]}{1.29} \qquad \text{Equation 2}$$

Statistical Analysis

The data for plant weight, plant height, leaf weight, and stem weight were analyzed using a completely randomized design with a 3×2 factorial arrangement and 25 replications. The least squares means were compared using Tukey's test ($p<0.05$) (SAS, 2001). The data for the percentage of dry matter in leaves and stems were analyzed using a completely randomized design with a 3×2 factorial arrangement and 4 replications, and the least squares means were compared using Tukey's test ($p<0.05$).

The data for dry matter, ash, crude protein, acid detergent fiber, neutral detergent fiber, lignin, and ether extract were analyzed using a completely randomized design with a 3×2 factorial arrangement and 2 replications. The least squares means were compared using Tukey's test ($p<0.05$) (SAS, 2001).

RESULTS AND DISCUSSION

Morphological variables

The effect of the interaction (genotype and planting method) was significant for plant height ($F=497.12$; $df=2$; $p=0.0001$), root length ($F=10.85$; $df=2$; $p=0.0001$), total plant weight (F=10.25; df=2; p=0.0001), leaf weight (F=25.71; df=2; p=0.0001), stem weight (F=33.31; df=2; p=0.0001), percentage of dry matter in leaves (F=3.75; df=2; p=0.0435), and percentage of dry matter in stems (F=4.00; df=2; p=0.0366).

SES-F and SES-B exhibited greater height compared to MUN-F, MUN-B, DOL-F, and DOL-B, with greater plant height observed in the flat planting method (F=85.27; df=1; p=0.001), regardless of the plant species (Table 2). The treatment MUN-F exhibited greater root length (F=5.89; df=2; p=0.0035), total plant weight (F=7.53; df=2; p=0.008), leaf weight (F=18.54; df=2; p=0.001), and stem weight (F=19.85; df=2; p=0.0001), indicating that MUN-F produced higher biomass, with 5.32, 4.10, 3.72, 3.57, and 1.57 times more fresh weight in the whole plant compared to MUN-B, SES-B, DOL-B, SES-F, and DOL-F, respectively (Table 2). A similar behavior was observed for leaf weight and stem weight, thus highlighting Mungo bean in flat planting as having high forage potential.

The greater height exhibited by Sesbania compared to Mungo and Dolichos is related to the growth habit of these species. Sesbania is considered a small perennial tree with a high growth rate, reaching heights of 4 to 6 meters within 6 months (Ella *et al.*, 1989; Prajapati *et al.*, 2003; Joshi, 2008). In contrast, Mungo is an annual shrub with a maximum height of 1.25 meters (Lambrides and Godwin, 2006), while Dolichos is a perennial shrub but is typically cultivated as an annual, with an average height of 1.27 meters (Chaudhari *et al.*, 2013).

Mogotsi (2006) reports that *V. radiata* is a species with good root development, which is consistent with the findings of this research, where Mungo bean in flat planting exhibited greater root development than Sesbania and Dolichos.

SES-B and SES-F exhibited a higher %DM compared to DOL-B, DOL-F, MUN-B, and MUN-F, regardless of the type of morphological component. Overall, a greater %DM production was observed in flat planting, and it was also noted that there was similar %DM production in both leaf and stem across all treatments. The higher %DM content of SES-B and SES-F (over 24% DM) compared to the other treatments indicates that

Table 2. Effect of the interaction between genotype and planting method on the morphological variables of *Sesbania grandiflora*, *Lablab purpureus*, and *Vigna radiata*.

Treaments	Morphological variables						
	ALT (cm)	LR (cm)	PTP (g)	PH (g)	PT (g)	%MSH	%MST
DOL-C	46.36±2.96e	22.04±0.85b	56.43±3.09c	25.63±2.12c	24.68±2.17c	19.96±3.08c	19.61±3.77c
DOL-P	73.12±1.88c	23.84±2.04b	133.49±8.47b	33.99±2.51b	53.71±3.01b	21.44±3.42bc	23.16±6.42b
MUN-C	29.72±1.56f	15.36±1.09c	39.44±2.72d	16.23±2.10c	13.35±1.79c	14.72±6.94d	19.78±5.79c
MUN-P	56.10±1.27d	28.28±2.52a	210.00±11.48a	90.75±7.22a	136.75±6.64a	22.19±1.61bc	17.91±2.24c
SES-C	151.84±13.10b	18.20±1.02bc	51.55±2.97c	19.50±3.40c	26.44±3.20c	24.11±3.46ab	24.59±1.16ab
SES-P	178.96±4.20a	17.92±1.12c	58.77±3.92c	21.60±2.57c	32.80±2.58c	26.36±3.18a	27.27±1.46a

DOL-F (Dolichos in flat), DOL-B (Dolichos in bed), SES-F (Sesbania in flat), SES-B (Sesbania in bed), MUN-F (Mungo in flat), MUN-B (Mungo in bed), THE (total height), SW (stem weight), LW (leaf weight), TPW (total plant weight), RL (root length), %DML (percentage of dry matter in leaves), %DMS (percentage of dry matter in stems). Means followed by the same letter in a column do not show significant differences (Tukey's test with $\alpha=0.05$).

Sesbania forages would have greater nutrient availability, as a plant species with a high %DM also has a higher protein content (Reyes-Purata *et al.*, 2009), resulting in greater nutritional contribution. Additionally, the high %DM for SES-B and SES-F indicates that this species was harvested at its optimal phenological stage to achieve maximum %DM yield (end of flowering).

In general, the flat planting method had a significant effect on all evaluated variables, regardless of the plant species. This result differs from reports indicating that raised bed planting increases yield in different crops (Majeed *et al.*, 2015).

In other studies, flat planting has been reported to outperform raised bed planting (Kendal, 2019), as occurred in this research. However, raised bed planting promotes water savings for irrigation, weed control, disease management, and reduces soil erosion (Fahong *et al.*, 2004; Govaerts *et al.*, 2005). The results obtained in this study may be related to soil type, water quality, and environmental conditions present in the Mexicali Valley (Escobosa-Garcia *et al.*, 2021).

Bromatological variables (Leaves)

The analysis of variance indicated that the effect of the interaction between genotype and planting method was significant for %CP ($F=28.43$; $df=2$; $p=0.0009$) and %NDF ($F=6.71$; $df=2$; $p=0.0295$). In contrast, no significant differences were observed for %ASH ($F=1.32$; $df=2$; $p=0.3358$), %ADF ($F=0.07$; $df=2$; $p=0.9352$), %LIG ($F=0.26$; $df=2$; $p=0.7810$), and %EE ($F=0.27$; $df=2$; $p=0.7714$).

SES-F and SES-B exhibited a higher percentage of protein in leaves compared to Dolichos and Mungo, regardless of the planting method, with 6.18, 2.53, 2.51, and 4.72 times more crude protein content in relation to DOL-B, DOL-F, MUN-B, and MUN-F, respectively. The treatments SES-F and SES-B showed similar protein content, at 34.46% and 34.86%, respectively, indicating that the planting method did not affect the protein production of this species (Table 3). The high protein content of SES-F and SES-B obtained in this study was higher than that reported by Usman *et al.* (2013), who found 20-25% crude protein for Sesbania; a similar result was obtained by Chanda *et al.* (2019), who reported 18.2%.

In the case of %NDF in leaves, DOL-F showed the highest percentage (55.64%), followed by SES-F, DOL-B, and SES-B. Finally, the MUN-F and MUN-B treatments had the lowest %NDF values at 25.49% and 24.77%, respectively (Table 3). NDF is a parameter that determines forage quality (Raffrenato *et al.*, 2019), as it affects consumption, food density, digestibility, digestibility rate, and the decrease in digestibility in relation to increased consumption (Mertens, 1997). Thus, the higher the NDF in the forage, the lower its quality and the lower the voluntary intake by ruminants (Van Soest *et al.*, 1991). Therefore, DOL-F can be considered a low-quality forage due to its high %FDN, while MUN-F and MUN-B can be regarded as high-quality forages based on their low NDF content.

Bromatological Variables (Stems)

The analysis of variance indicated that the effect of the interaction between genotype and planting method was significant for %ADF ($F=8.22$; $df=2$; $p=0.0191$) and %NDF

(F=17.77; df=2; p=0.0030). However, there were no significant differences for %ASH (F=2.49; df=2; p=0.1620), %SW (F=0.49; df=2; p=0.6358), %LIG (F=0.91; df=2; p=0.4508), and %EE (F=0.40; df=2; p=0.6897). The stems of SES-F and SES-B exhibited higher %NDF, with 74.29% and 79.35%, respectively.

In general, all treatments exhibited a high content of neutral detergent fiber (NDF) (Table 4), indicating that the forage obtained from the stems of the three Fabaceae was of low quality due to its high percentage of NDF. Similar results were observed for acid detergent fiber (ADF) in all treatments, confirming the low quality of the forage obtained from the stems. Overall, the forages obtained from the stems of the three species, regardless of the planting method, showed higher percentages of NDF and ADF compared to the forage from the leaves. In contrast, these forages exhibited a lower content of crude protein compared to the forages obtained from the leaves (Table 4). The difference between the leaves and stems of the three species evaluated for NDF and ADF could be explained by the fact that the stems of the plants have a higher content of cellulose and hemicellulose

Table 3. Effect of the interaction between genotype and planting method on the bromatological variables of leaves of *Sesbania grandiflora*, *Lablab purpureus*, and *Vigna radiate*.

Treaments	Bromatological variables					
	%CEN	%PH	%NDF	%ADF	%LIG	%EE
DOL-c	13.89±6.53a	5.64±5.548 c	43.89±10.42 b	17.93±21.50a	0.0268±0.015a	5.11±4.24a
DOL-P	16.67±4.86a	13.73±3.557b	55.64±12.88 a	19.61±4.48a	0.0314±0.015a	4.76±1.95a
MUN-C	13.72±4.20a	13.87±3.539b	24.77±9.72 d	12.93±2.08a	0.0187±0.017a	3.27±1.15a
MUN-P	14.32±1.99a	7.37±4.855 c	25.49±3.16 d	13.40±1.58a	0.0166±0.009a	3.28±1.89a
SES-C	9.62±0.09a	34.46±3.532a	30.66±9.73c	15.46±4.51a	0.0429±0.032a	3.83±0.38a
SES-P	9.59±0.19a	34.86±2.232a	45.76±4.55b	16.51±12.03a	0.0417±0.067a	4.04±2.66a

DOL-F (Dolichos in flat), DOL-B (Dolichos in bed), SES-F (Sesbania in flat), SES-B (Sesbania in bed), MUN-F (Mungo in flat), MUN-B (Mungo in bed), %ASH (Percentage of ash), %NDF (Percentage of neutral detergent fiber), %ADF (Percentage of acid detergent fiber), %LIG (Percentage of lignin), %EE (Percentage of ether extract), %PH (Percentage of protein). Means followed by the same letter in a column do not show significant differences (Tukey's test with α=0.05).

Table 4. Effect of the interaction between genotype and planting method on the bromatological variables of stems of *Sesbania grandiflora*, *Lablab purpureus* and *Vigna radiata*.

Treaments	Bromatological variables					
	%CEN	%PT	%NDF	%ADF	%LIG	%EE
DOL-c	12.81±4.55a	7.35± 0.428a	61.71±10.23c	40.98±5.43cd	0.0505±0.001a	1.61±0.347a
DOL-P	13.10±6.35a	6.51± 0.454a	62.62±9.57c	39.27±0.13cd	0.0459±0.002a	1.69±1.200a
MUN-C	12.25±3.32a	6.51± 0.454a	48.65±2.65e	37.87±2.49d	0.0413±0.001a	1.18±0.253a
MUN-P	11.97±2.49a	4.34± 0.527a	55.32±5.68d	41.82±4.29c	0.0486±0.045a	1.49±1.673a
SES-C	6.67±0.41a	6.43± 0.457a	79.35±4.10a	61.52±7.26a	0.0572±0.007a	1.23±0.537a
SES-P	6.75±1.89a	4.80± 0.529a	74.29±3.63b	56.88±13.07a	0.0590±0.051a	1.30±0.631a

DOL-F (Dolichos planted flat), DOL-B (Dolichos planted in bed), SES-F (Sesbania planted flat), SES-B (Sesbania planted in bed), MUN-F (Mungo planted flat), MUN-B (Mungo planted in bed), %ASH (Percentage of ash), %NDF (Percentage of neutral detergent fiber), %ADF (Percentage of acid detergent fiber), %LIG (Percentage of lignin), %EE (Percentage of ether extract), %PT (Percentage of protein). Means followed by the same letter in a column do not show significant differences (Tukey test with α=0.05).

than the leaves, as this plant organ requires greater cell rigidity to support the weight of the plant. Cellulose and hemicellulose are the main structural carbohydrates that constitute plant fiber; thus, the higher content of these compounds in the stems translates to higher percentages of detergent fibers (Casler *et al.*, 2002).

Forage quality

Considering the chemical composition of the leaves of *S. grandiflora*, *L. purpureus*, and *V. radiata* cultivated in two types of planting —flat and raised beds— we found that SES-F, SES-B, MUN-F, MUN-B, and DOL-B were classified as excellent quality forages according to their RFV (Table 5). Among these excellent quality forages, MUN-B, SES-F, and SES-B stood out, as they exhibited high CP content and low levels of NDF and ADF. These quality parameters indicate that MUN-B, SES-F, and SES-B would provide a high amount of nutrients, greater digestibility, and increased voluntary consumption of the forage.

Although the forages from DOL-B and MUN-F were classified as excellent quality, they are less suitable for animal feeding compared to MUN-B, SES-F, and SES-B, due to their low CP content, with 5.64% and 7.37% of CP, respectively (Table 5), indicating a low nutritional contribution. Overall, the planting method did not have a significant effect on forage quality.

None of the forages derived from the stems of *S. grandiflora*, *L. purpureus* and *V. radiata* were classified as excellent quality. SES-B and SES-F were rated quality 5, DOL-B, DOL-F, and MUN-F were rated quality 3, and MUN-B was rated quality 1. In general, better forage quality was observed in the leaves compared to the stems, as leaves are the most nutritious and digestible part of the plants. In some cases, leaves can contain around

Table 5. Forage quality of leaves and stems from *Sesbania grandiflora*, *Lablab purpureus* and *Vigna radiata* in flat and bed planting systems.

Forage	CP (%)	NDF (%)	ADF (%)	RFV	Classification
Leaves					
DOL-C	5.64	43.89	17.93	158.82	Excellent quality
DOL-P	13.73	55.64	19.61	123.09	Quality 2
MUN-C	13.87	24.77	12.93	296.04	Excellent quality
MUN-P	7.37	25.49	13.40	286.34	Excellent quality
SES-C	34.86	30.66	15.46	233.19	Excellent quality
SES-P	34.86	45.76	16.51	154.58	Excellent quality
Stems					
DOL-C	7.35	40.98	61.71	92.68	Quality 3
DOL-P	6.51	39.27	62.62	95.03	Quality 3
MUN-C	6.51	37.87	48.65	125.28	Quality 1
MUN-P	4.34	41.82	55.32	101.89	Quality 3
SES-C	6.43	61.52	79.35	40.96	Quality 5
SES-P	4.80	56.88	74.29	50.74	Quality 5

35% crude protein, while stems contain only about 16% (Rojas-García *et al.*, 2019), which aligns with the findings of this research.

CONCLUSIONES

The results of this research represent the first report on the agronomic behavior and nutritional value of *Sesbania grandiflora*, *Lablab purpureus*, and *Vigna radiata* in the Mexicali Valley. It is concluded that the forage from the leaves of *S. grandiflora*, grown in both flat and raised bed systems, was of excellent quality, attributed to its higher %DM and %CP and lower %NDF and %ADF. Although these results highlight *S. grandiflora* as having high nutritional value, it is important to confirm this through *in vitro* and *in vivo* studies of digestibility and voluntary dry matter intake of the forage.

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