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THE PERFORMANCE AND ECONOMIC EFFICIENCY OF NEW GENOTYPES OF ALFALFA (*MEDICAGO SATIVA*)

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Abstract

Alfalfa is the most widely grown perennial forage legumes that are planted frequently for hay, pasture, and silage worldwide, due to its extremely nutritious forage and wide range of adaptability. High yield and economic efficiency of alfalfa (Medicago sativa L.) are important in determining the effective distribution of new cultivars to farmers. The present study was conducted to explain alfalfa yield variation induced by environmental conditions and genotype. Forage yield, aboveground phytomass, stems elongation, internodes number, growing rhythm, economic performance was assessed for a set of 10 Romanian alfalfa genotypes experienced at ARDS Caracal, Romania, in each of three years (2019-2022). Stem elongation values ranged between 131.4 cm for alfalfa line F2909-2 and 138,8 cm for alfalfa line F2910, while the average internode number ranged between 24.6 for F 2908 and 27 for F2906. Variation in stem elongation was associated with variation in the number of internodes and was positively correlated (r = 0.4448). Also, the fastest growing rhythm was observed to the genotype F2905 and the lowest to F2910. The most economic efficient and profitable was the genotypes F 2907, F2908 and F 2910. Alfalfa production offers a compelling case for both economic efficiency and sustainable agriculture.

Key words: *Medicago sativa, genotype, input costs, economic efficiency, yield*

INTRODUCTION

Alfalfa (*Medicago sativa* L. subsp. *sativa*, 2n =4x=32) known as “Queen of forages” is one of the most important forage crops worldwide having multiple benefits for both agriculture and environmental protection [9][22][24]. Alfalfa is one of the few crops that can withstand challenging growth circumstances. From the deserts 250 feet below sea level to approximately 10,000 feet above, in sandy or clay soils, it can grow in practically any elevation [15]. Despite of this, to adapt to and maybe benefit from the future climate, gradual modifications in management of perennial crops (planting dates, harvest dates, number of harvests, crop genetics, and pest control) will be necessary [7][23] [26] [30].

In the USA is the third crop in value behind corn and soybean being used also in the form of milk, cheese pizza, ice cream, honey, leather, or wool sweaters having high nutritional value (proteins 50–65%), available carbohydrate (5–20%), crude fibres (0.5–1.5%), fat (7–25%), ash (0.5–1.5%) and its average total energy is 439 kcal per 100 g [11][25].

Alfalfa is an excellent ground cover reducing soil erosion and phosphorus and pesticides into streams and lakes [27]. Also, alfalfa is capable of fixing atmospheric nitrogen which meets its requirements for high yields [8][29][34]. In addition to nitrogen, crops that follow alfalfa in a crop rotation generally yield up to 10-15% greater and require less pesticides [33].

Besides its role in soil fertility, alfalfa adds aesthetic value to the landscape and serves as a significant home for a variety of species, including many helpful insects [13][10][28].

Alfalfa is actually used by 28% of California's wildlife for either feeding, cover, or nutrition [22]. It is highly valued by organic and conventional farmers alike for its soil health-building characteristics. Also, compared to many other crops, alfalfa actually has a higher water use efficiency when measured as harvestable biomass/applied water [23].

Moreover, regards the irrigation management, alfalfa is incredibly adaptable because it is a perennial crop that naturally tolerates drought [20].

Alfalfa yield improvement has not been as successful as improvements in other qualities, and it has been slower than improvements in cereal production [3].

A number of issues that also apply to other perennial forages, such as low breeding investment, lengthy selection cycles, inability to choose true hybrids or pure lines, and high genotype environment interaction (GEI), limit genetic advancement for alfalfa producing ability [2].

Other reason for the limited yield in alfalfa is placed on yield per se than in the other grains, which contributes to the restricted increase in production [1][3][12].

Instead of measuring yield on plots grown at stand densities used in commercial production, as is done in the case of the major grain crops, alfalfa output is frequently determined indirectly based on evaluation of vigour on spaced plants or on short family rows [19]. However, for the last decades, alfalfa yields, forage quality and persistence have increased thanks to improved genetics, disease and insect control and more intensive nutrient and harvest management [17][18][19].

The global alfalfa market size was $21.63 billion in 2021 and is projected to grow to $35.20 billion in 2028 at a CAGR of 7.2% in forecast period, 2021-2028 [21]. Moreover, the risk of growing alfalfa is much lower than many other crops, making year-to-year profits steadier. Thus, improved varieties and better management tools continue to increase yields of alfalfa leading to profitability when compared to other forage crops over a number of years. Alfalfa and other forage crops can have a fruitful and sustainable future by breeding plans for the future and taking action to adapt to the climate change.

Considering the aspects above mentioned, the paper provides a comprehensive discussion on alfalfa Romanian germplasm diversity and explain the economic importance of growing new genotypes with better traits, climate change mitigation and improved performance.

MATERIALS AND METHODS

Selection for yielding capacity of ten Romanian alfalfa genotypes was carried out by a field experiment performed during 2019-2022 in the Breeding Field of the Agricultural Research Station Caracal of the University of Craiova, Romania (44°11'N and 24°37'E). The trial was conducted in a split–plot design with the main plots (10 m^2) arranged in a randomized complete block with three replicates.

All recommended cultural practices (pests' control with Decis 0,15l/ha and Mospilan 5 g/10 l water and fertilizing with Aminofed 20 g/10 l water, etc.) and other management were applied.

The local long term average rainfall amount was 541.7 mm, while long term average temperature was +11.6^{o}C. Severe summer drought was avoided by providing three irrigations of 55 mm each before harvests in all experimental years.

Total biomass and total dry matter yield on a plot basis was recorded over the three harvests for each experimental year.

Harvest took place when plants approached 10% blooming for every genotype. In addition, there were assessed: (a) stems elongation (cm), b) number of internodes and c) growth rhythm, each recorded on a subsample of ten plants per plot.

Economic efficiency was calculated using Total Costs (Ct), Net Profit (Vn) and Profitability Rate (R) [5]. For Total Costs was used the formula:

Ct = Cf + Cv, where:
Cf – fix costs (lei/ha) (Table 1)
Cv – the sum of variable costs) (lei/ha)

Net profit (Vn), using the formula:
Vn (lei) = (Pv × Qt) - Ct, where:
Pv – selling price (lei/kg)
Qt – Total Yield (kg)
Ct – Total Costs (lei/kg)

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Profitability Rate (R), using the formula:
R (%) = (Vn/Ct) ×100

Table 1. Alfalfa Fix Costs (Cf) for experimental years (2019-2022)

No	Technology operation	1st year (lei/ha)	2nd year (lei/ha)	3th year (lei/ha)
1	Tillage	600		
2	Tilling 1	200		
3	Tilling 2	200		
4	Fertilizing	400	200	200
5	Sowing	200		
6	Seed	600		
7	Irrigation	1,600	1,600	800
8	Fertilizers	300	300	300
9	Mowing	450	450	450
10	Raking together	300	300	300
11	Balling	700	800	900
12	Transport	200	300	300
Total		5,750	3,950	3,250
TOTAL (lei/ha/3 years)		**12,950**		

Source: own calculations.

Worldwide increasing yield, improving nutritional value, growing economic performance and improving resistance to abiotic and biotic stressors are significant breeding objectives for alfalfa, as for other crops. Known as a perennial crop, alfalfa produces its maximum yields in the second year of growth. Alfalfa is grown for three to four years continuously in mild winter climates, whereas it is grown for six to nine years with a winter dormant period in continental areas with cold winters. The number of cuttings per growing season varies with climate and ranges from 2 to 12. Annually, the forage yield per cut varies with climatic conditions and genotype. Despite of this aspect, the markets for alfalfa have stayed much more stable than those for several other crops because it is resistant to weather changes and improved yielding capacity.

The experiment was based on the comparison of ten alfalfa genotypes performance as expressed by total biomass yield over three cropping years. Also, some morphological characters were considered.

The elongation of stems is influenced by a combination of external environmental and internal factors. Among external factors the most important is the light that influence positively the accumulation of dry matter and improving the yield of the crop [4]. Also, plant hormones play a major role in controlling plant height, and the majority of these genes are involved in the metabolism or signal transduction of hormones including GA3, IAA, CTK, and brassinolide (BR) [16]. Previous studies showed that among all hormones involved in regulating plant height, the most important is gibberellin (GA) and it can promote internode elongation in, rapeseed (*Brassica campestris*), sugarcane (*Saccharum officinarum*) and other crops [6][31][32].

Stem elongation values ranged between 131.4 cm for alfalfa line F2909-2 and 138.8 cm for alfalfa line F2910 (Table 2). Only the lines F 2906 and F2910 recorded slightly higher values of stem elongation that the control genotype Catinca, while all the others assessed alfalfa genotypes exhibited lower values. Stem length values that ranged between 80.58 cm and 86.77 cm for high alfalfa genotypes and between 54.46 cm and 55.65 cm were exhibited by [14] in China.

Table 2. Alfalfa stem elongation values (average 2019-2022)

No.	Genotype	Stems length (10 stems / variant) (cm)				Relative length %
		mower				
		I	II	III	Total cm	
1	Catinca - Control	38.6	47.7	52.0	138.3	100
2	F Ileana	35.7	47.7	49.4	132.8	96.0
3	F 2020	33.7	49.4	50.0	133.1	96.2
4	F 2905	37.8	45.8	50.1	133.7	96.6
5	F 2906	34.6	51.2	52.8	138.6	100.2
6	F 2907	31.7	49.4	54.3	135.4	97.9
7	F 2908	37.0	46.9	47.1	138.2	99.9
8	F 2909-1	34.7	47.8	49.5	132.0	95.4
9	F 2909-2	35.3	47.2	48.9	131.4	95.0
10	F 2910	37.2	50.4	51.2	138.8	100.3

Source: own data.

More and more genes related to internode lengthening and plant height have been cloned and functionally discovered as molecular biology research into these topics has progressed. However, as a typical example of forage, alfalfa has received minimal attention in terms of the process underlying stem elongation, with the majority of studies concentrating on the nutritional value of the stem.

To examine the patterns of internode elongation in alfalfa from a variety of perspectives, including phenotype, cytology, and molecular biology, and to clarify the mechanism of alfalfa plant height development, there is necessary to use tall- and short-stem alfalfa varieties with notable differences in internode length and constant internode numbers as experimental materials. Further study is still needed on the genetic control mechanism as well as the underlying causes of the variations in plant height in alfalfa.

The average internode number ranged between 24.6 for F 2908 and 27 for F2906 (Table 3). The genotypes F2905 and F2910 have the same internodes number (26) as the control genotype (Catinca). The only alfalfa genotype that recorded higher number of internodes was F 2906 with 3.8% more than the control.

[14] showed there is no significant difference in the number of internodes between tall- and short-stem alfalfa materials.

Table 3. Alfalfa number of internodes (average 2019-2022)

No	Genotype	Internodes number (10 stems / variant)				Relative number %
		mower				
		I	II	III	Total cm	
1	Catinca - Control	9.0	8.9	8.1	26.0	100
2	F Ileana	8.1	9.4	7.6	25.1	96.5
3	F 2020	9.0	9.0	7.4	25.4	97.6
4	F 2905	8.8	9.5	7.7	26.0	100
5	F 2906	8.8	9.7	8.5	27.0	103.8
6	F 2907	8.3	9.6	7.8	25.7	98.8
7	F 2908	8.3	8.9	7.4	24.6	94.6
8	F 2909-1	8.3	9.2	8.0	25.5	98
9	F 2909-2	8.2	9.0	7.8	25.0	96.1
10	F 2910	8.7	9.5	7.8	26.0	100

Source: own data.

There was a significant and positive correlation between stem elongation and internode number (r = 0.4448). The growing rhythm seems to be particular for each alfalfa genotype depending on climatic conditions and genetic background [14]. Thus, the fastest growing rhythm was observed to the genotype F2905 and the lowest to F2910 (Table 4).

Table 4. Alfalfa growing rhythm (cm) (average 2019-2022)

No.	Genotype	Growth rhythm (cm)		
		*RI	RII	RIII
1	Catinca - Control	1.5	1.5	3.5
2	F Ileana	1.5	1.5	1.5
3	F 2020	2.5	1.5	1.0
4	F 2905	3.0	2.0	3.5
5	F 2906	1.0	2.0	3.5
6	F 2907	1.0	1.5	1.5
7	F 2908	1.5	3.0	2.0
8	F 2909-1	1.0	2.0	1.0
9	F 2909-2	1.0	3.0	1.0
10	F 2910	1.0	1.0	1.0

Source: own data *R= replication

Previous findings emphasized that alfalfa economic sustainability is threatened by lower rates of genetic yield gain in comparison with cereals, such as maize or wheat, which have gained importance as forage crops in the last decades [2].

The present study revealed that alfalfa yield can vary significantly based on factors like climate, genotype and management practices. However, under optimal conditions, alfalfa has shown remarkable yield potential, often surpassing other forage crops.

Analysis of input costs demonstrated that tillage, seed irrigation and balling were major cost components in alfalfa production (Table 5). This suggests that sustainable practices, such as no-till farming and efficient irrigation systems, can reduce these costs and enhance economic efficiency. The research found that alfalfa prices have remained relatively stable,

making it an attractive option for consistent revenue generation.
The results of this study suggest that alfalfa production can be economically efficient under various conditions.
The most economic efficient and profitable was the genotypes F 2907, F2908 and F 2910.

Table 5. Alfalfa economic efficiency (2019-2022)

No	Genotype	Yield	Price	Gain	Costs	Vn	R	
		Kg/ha/ 3 years	Lei/kg	lei/ha/ 3 years	lei/ha/ 3 years	lei/ha/ 3 years	%	Diff. %
1	Catinca Control	37,100	0.585	21,704	12,950	8,754	67.59	100
2	F Ileana	37,210	0.585	21,768	12,950	8,818	68.09	100.7
3	F 2020	37,930	0.585	22,189	12,950	9,239	71.34	105.5
4	F 2905	36,660	0.585	21,446	12,950	8,496	65.61	97.1
5	F 2906	36,530	0.585	21,370	12,950	8,420	65.02	96.2
6	F 2907	39,710	0.585	23,230	12,950	10,280	79.38	117.4
7	F 2908	39,630	0.585	23,184	12,950	10,234	79.02	116.9
8	F 2909-1	37,760	0.585	22,090	12,950	9,140	70.58	104.4
9	F 2909-2	36,010	0.585	21,066	12,950	8,116	62.67	92.7
10	F 2910	38,830	0.585	22,716	12,950	9,766	75.41	111.6

*Vn = net proft; R = Profitability Rate
Source: Own data.

Factors such as high yield potential, stable market prices, and the potential for reduced input costs make alfalfa a viable choice for farmers seeking to maximize their profitability. Managing input costs is critical to maximizing profitability. Moreover, the environmental benefits associated with alfalfa cultivation further enhance its appeal. Farmers can enhance their economic outcomes by adopting new alfalfa genotypes, improving resource use efficiency, and exploring sustainable production methods. Sustainable practices not only benefit the environment but also contribute to profitability.
Water-efficient irrigation, reduced tillage, and using new performant genotypes not only lower costs but can also open up premium markets for sustainably produced alfalfa.

CONCLUSIONS

For increasing alfalfa productivity and advancing the grass and animal industries, it is of great significance to cultivate new alfalfa (*Medicago sativa* L.) types with high yield and quality.
Forage yield and phenotypic traits varied between cultivars in each year of the experiment, as shown by the interactions between year x cultivar x forage yield. The most economic efficient and profitable was the genotypes F 2907, F2908 and F 2910.
Alfalfa production exhibits considerable economic efficiency potential, particularly when managed optimally and in regions with favourable conditions. Farmers, policymakers, and agricultural stakeholders should consider alfalfa as a sustainable and profitable crop choice. Future research should focus on refining management practices and assessing the long-term economic and environmental impacts of alfalfa cultivation.

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