Effect of planting and harvest dates on forage productivity and quality in pearl millet (*Pennisetum glaucum*)

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Abstract

The experiment was conducted at the May 1st Research Station during the 2024 agricultural season, to determine the optimal planting date and number of harvesting, estimating the productivity of green and dry fodder, assessing some quality traits, and examining the correlations among the studied traits in millet group-2. A split-plot design with three replicates was used, with three main plot dates (April 1, April 15, May 1) and six Harvests in the split plots. Productivity traits of wet and dry green fodder, including percentages of protein, carbohydrates, fats, and fiber, were studied. The results indicated that Date 2 yielded an average of 11.28 tons ha-1 of wet green fodder compared to Dates 1 and 3 (5.71- and 7.63-tons ha-1, respectively). Date 2 also yielded a dry green fodder yield of 2.79 tons ha-1 compared to Dates 1 and 3 (1.45- and 1.93-tons ha-1). The total green and dry fodder yields were 67.71 and 16.73-tons ha-1, respectively. Harvest 1 yielded a higher wet and dry green fodder yield (19.72- and 4.96-tons ha-1, respectively) compared to Harvest 2 and 3. Harvest 2 and Harvest 1 also yielded higher protein content (13.22- and 12.61-tons ha-1, respectively). t. ha-1, respectively), while Date 1 had the highest carbohydrate and fiber contents (29.57 a and 21.84 a t. ha-1, respectively). Wet green fodder yield was positively correlated with dry fodder yield traits and protein and fat content (r = 0.99*, r = 0.93, r = 0.96, respectively), and negatively correlated with carbohydrate and fiber content. Millet is recommended for maximum wet and dry fodder production on the April 15 planting date.

Keywords: Millet, green fodder, dry fodder, planting dates, Harvestings, quality traits, nutritional content.

Introduction

Millet (Pennisetum glaucum (L.) belongs to the Poaceae family and the Pennisetum genus. It is also known as pearl millet. Millet is classified according to the length of time required to mature into early-maturing and late-maturing millet. The millet plant is also divided into two categories: primary and secondary. The main and most common types of millet are pearl, foxtail, finger, proso (or white), and Italian. Foxtail millet originated in Asia, while pearl millet, which is currently widely cultivated, is native to tropical Africa. Some varieties are used as green fodder or grazed by livestock in the southern United States, or their grains are used as human food [1]. Millet is also known as pea, gour, and elan. Its grains are panicle-shaped and come in a variety of colors, including dark red, gray, white, and yellow. These plants typically range in height from approximately 0.5 to 4 meters, with fibrous roots. A few can reach 1.5 meters, while most remain at 40 cm from the soil surface. Millet is characterized by its high ability to produce abundant saplings and its great affinity for light and heat.

Millet is a summer forage Harvest suitable for hot, low-humidity climates. It also tolerates drought, high temperatures, and soil salinity, making it prevalent in tropical, subtropical, and temperate regions worldwide. It is characterized by a short growing season [2,3].

Ninety million people in more than 30 countries depend on millet for their food, and global production amounts to approximately 32 million tons. Africa produces 55% of global production, followed by Asia with 41%, Europe with 3%, and the Americas with only 1%. Sudan ranks first in the Arab world and third globally in millet production, accounting for 9% of global production [4]. In Syria, millet is grown on limited areas and is often used as green fodder or poultry feed.

The Arab Center for Agricultural Development (ACSAD), the Food and Agriculture Organization (FAO), and several international and national research centers are giving special attention to millet, designating 2023 as the International Year of Millet. Given its resilient nature, it provides an affordable and nutritious option. Increased efforts must be made to promote its cultivation as a source of nutrition for millions of people in some Arab countries, sub-Saharan Africa, and Asia.

Materials and Methods

The genetic material, namely, the millet 2 population, was selected from the gene bank of the Maize Research Department at the General Commission for Scientific Agricultural Research (GCSARR). It is a local population that was purified and selected until it reached a homogeneity and similarity rate of more than 95%. The research experiment was carried out at the May One Research Station during the 2024 agricultural season, located 620 m above sea level, with an annual rainfall of 156 mm, and characterized by a light-textured clay soil. The soil was analyzed at the Center for Scientific Agricultural Research in Damascus, and the agricultural soil was found to be highly homogeneous, well-drained, and free of harmful salinity and alkalinity (Table 1).

Table (1): Chemical and mechanical analysis of the experimental soil in 2024

Chemical analysis							Mechanical %analysis		
(EC) dS.m-1	(PH)	organic matter %	calcium carbonate %	N Kidney %	K Available mg/kg	P Available mg/kg	sand	Salt	clay
2.04	8.09	1.22	66.5	0.102	165.5	145.9	28	24	48

The research experiment was carried out according to a split-plot design with three replications, where the main plots were the planting dates (April 1, April 15, May 1), and the split plots were the harvests (6 harvests).

The land was plowed and organic fertilizer was added at a rate of 4 m3 per dunum. The soil was then smoothed and leveled, and irrigation lines were opened. Nitrogen fertilizer was added at a rate of 5 units of pure nitrogen, along with the entire phosphate fertilizer, for a total of 6 units of pure P2O5 per dunum at the time of planting. After each Harvest, 3 units of pure nitrogen were added per dunum.

Seeds were planted manually, with each Harvest planted in two 3-meter-long lines, 70 cm apart, and 25 cm apart in each planting hole in each experimental plot, measuring 4.2 m2.

Three to five seeds were placed in each hole. Seedlings were thinned when plants reached 15 cm in height, leaving two per hole. After thinning, the seedlings were used to patch areas without plants and were immediately irrigated to support plant growth and prevent drought.

Traits studied:

Wet green fodder yield (tons/ha): The weight of the experimental plot's plants (kg) was recorded immediately after Harvest. The first Harvest was conducted during the boot stage, Harvesting at a height of 15 cm above ground level, 50 days after the first irrigation. Harvests were then repeated approximately every 30 days, totaling six Harvests. Productivity was estimated by converting the measured plant weights to tons per hectare.

- Dry fodder yield (tons/ha): The dry weights were taken (six Harvests separately) after the plants were sun-dried for 10 days. Productivity was estimated by converting the measured plant weights to tons per hectare.
- Protein content (%): Estimated by laboratory analysis of the three Harvests.
- Carbohydrate content (%): Estimated by laboratory analysis of the three Harvests.
- Fat content (%): Estimated by laboratory analysis of the three Harvests.
- Fiber content (%): Estimated by laboratory analysis of the three Harvests.

Results and Discussion

Wet green fodder productivity (tons/ha)

The results of Table 2 showed that Planting date 2 outperformed planting dates 1 and 3 in terms of average wet green fodder productivity (11.28 tons ha-1) over planting date 1 and 3 (5.71 tons ha-1 and 7.63 tons ha-1, respectively). The second planting date also had the highest total wet green fodder production (67.71 tons ha-1),due to the increase in the number of plant leave , followed by planting date 3 (45.78 tons ha-1), while planting date 1 had the lowest production (34.23 tons ha-1). Harvest 1 (19.72 t. ha-1) was significantly superior to the other Harvests in terms of green fodder productivity. In the interaction between Harvest and planting dates, both Harvest 2 and Harvest 1 were superior in terms of green fodder productivity at planting date 2 (22.87 and 22.75 t. ha-1, respectively). These results are consistent with those of [5] and [6]. which indicate differences between the Harvest averages and the also-Harvest averages, and between the planting dates. It is noted that the productivity of harvest 6 was less than one ton, with an average productivity of (0.31f tons. ha-1), indicating that the overwintering capacity of millet is determined by three economic harvests [7,8].

Dry green fodder productivity (tons/ha)

The results for dry green fodder (Table 2) show that the productivity of planting date 2 (2.79a tons. ha-1) was superior to the productivity of both dates 1 and 3 (1.45c, 1.93b tons. ha-1). The total dry fodder production of planting date 2 was ranked first (16.73 tons. ha-1), followed by dates 3 and 1 (11.60b, 8.72c, respectively). Harvest 1 (4.96a tons. ha-1) outperformed the other harvests in dry green fodder productivity, and the least productive was harvest 6 (0.08 t/ha-1). Harvest 1 at planting date 3 and harvest 2 at planting date 2 were superior in dry green fodder productivity (5.68 and 5.60 t/ha-1, respectively). These results are consistent with what was reported by [9,10,5], that there was a significant variation in dry fodder productivity between planting dates and harvests as well.

Table (2): Wet and dry green fodder productivity of the millet Harvest

The crop	Harvests	Wet green fodder productivity t/hectare^{-1}				Dry green fodder productivity t/hectare^{-1}			
		Planting date 1	Planting date 2	Plantin g date 3	Averag e	Planting date 1	Plantin g date 2	Plantin g date 3	Averag e
millet	1	15.40	21.01	22.75	19.72^{a}	3.95	5.25	5.68	4.96^{a}
	2	11.44	22.87	14.43	16.24^{b}	2.85	5.60	3.61	4.02^{b}
	3	4.71	16.09	6.08	8.96^{c}	1.18	4.02	1.52	2.24^{c}
	4	1.56	6.45	1.30	3.10^{d}	0.44	1.61	0.36	0.80^{d}
	5	0.75	1.01	0.94	0.90^{e}	0.25	0.25	0.23	0.25^{e}
	6	0.37	0.27	0.29	0.31^{f}	0.05	0.01	0.20	0.08^{e}

Average	5.71c	11.28a	7.63b		1.45c	2.79a	1.93b	
the total	34.23	67.71	45.78		8.72c	16.73a	11.60b	
LSD 5%	Appointments	Harvests	Interaction		Appointments	Harvests	Interaction	
	0.040	0.140	0.220		0.067	0.267	0.467	
CV %	2.70				21.00			

Means with the same alphabetical letter are not significantly different at the 5% level.

Protein content (%)

Planting date 3 (11.42% a) significantly outperformed Planting date 2 (10.39% b) and Planting date 1 (9.01% c) in protein content. Harvest 1 (12.61% a) also significantly outperformed Harvests 2 and 3 (9.88% b, 8.33% c, respectively) (Table 3). In the interaction between Harvests and planting dates, Harvest 1 and Planting Date 2 (13.22%) outperformed the remaining treatments. These results can be attributed to the lower carbohydrate content in both Harvest 1 and Planting date 3 [11].

Carbohydrate percentage (%)

The carbohydrate results in Table 3 showed that planting date 1 (29.57a) was significantly higher than both dates 2 and 3 (28.27b, 27.93c, respectively), while Harvest 3 (29.82a) outperformed Harvest 2 (28.25b) and Harvest 1 (27.70c) in carbohydrate percentage. In the interaction, Harvest 3 with planting date 1 (31.73%) outperformed the remaining treatments. Research results confirm that carbohydrate content is usually inversely related to protein content in plants [9,11]

Table (3): Percentage of protein and carbohydrates (100% dry matter) for three millet harvests

The crop	Harvests	% Protein				% Carbohydrates			
		Planting date 1	Planting date 2	Planting 3date	Average	Planting date 1	Planting date 2	Planting date 3	Average
millet	1	11.80	13.22	12.80	12.61a	28.00	27.67	27.42	c 27.70
	2	8.07	10.11	11.47	9.88b	28.98	28.40	27.38	b 28.25
	3	7.17	7.85	9.98	8.33c	31.73	28.73	28.98	a

									29.82
Average		9.01 c	10.39 b	11.42 a		29.57 a	28.27 b	27.93 c	
LSD 5%		Appointments 0.20	Harvests 0.15	Interaction 0.27		Appointments 0.03	0.0Harvests 2	Interaction 0.05	
CV %	0.93					0.07			

Fat percentage (%)

The results in Table 4 show no significant differences between planting dates 1 and 2 in fat content. However, both harvest 1 (1.13% a) and harvest 2 (1.11% a) significantly outperformed harvest 3 (0.67% b) in fat content. In the interaction between planting dates and harvests, harvest 1 with planting date 1 and harvest 2 with planting date 3 had higher fat content (1.33% and 1.27%, respectively) than the other treatments. Fat percentage typically increases as carbohydrate and protein content decrease [11-12].

Fiber percentage (%)

It is noted that planting date 1 (21.84% a) was superior in fiber content to planting dates 2 and 3 (18.61% c, 18.88% b, respectively) (Table 4). Also, Harvest 3 (20.38% a) was superior to both Harvest 1 and 2 (19.50% b, 19.46% c, respectively). Harvest 1, with planting date 1, had the highest interaction value between Harvests and dates (24.29%). This can be attributed to planting date 1 having the highest forage productivity, whether wet or dry, and to fiber content usually increasing with the number of Harvests and the advancement of plant age. These results are similar to those reported by [12,13,14].

Table (4): Percentage of fat and fiber (100% dry matter) for three millet rations

The crop	Harvests	% Fat				% Fiber			
		Planting date 1	**Plantin 2g date**	**Planting date 3**	**Average**	**Planting date 1**	**Planting date 2**	**Planting date 3**	**Average**
millet	1	1.33	1.27	0.80	a 1.13	24.29	16.93	17.27	b 19.50
	2	1.07	1.00	1.27	a 1.11	20.80	18.58	19.00	c 19.46
	3	0.80	0.93	0.27	b 0.67	20.45	20.31	20.38	a 20.38
Average		a	a	a		a	c	b	

	1.07	1.07	0.78		21.84	18.61	18.88	
LSD 5%	Appointments 0.333	Harvests 0.133	Interaction 0.267		Appointments 0.040	Harvests 0.027	Interacti on0.047	
CV %	11.333				0.067			

Means with the same alphabetical letter are not significantly different at the 5% level.

Correlation between traits

Table 5 shows that the wet green fodder productivity trait was positively correlated with the dry fodder productivity traits and protein and fat percentage (r=0.99*, r=0.93, r=0.96, respectively), and negatively correlated with the carbohydrate and fiber traits (r=-0.99*, r=-0.93, respectively). Dry fodder productivity was positively correlated with the protein and fat percentage traits (r=0.94, r=0.95, respectively), and negatively correlated with the carbohydrate and fiber traits (r=-0.99*, r=-0.92, respectively). While protein content was positively correlated with fat content (r=0.80) and negatively with both carbohydrate and fiber content (r=-0.91, r=-0.75, respectively), carbohydrates were positively correlated with fiber content (r=0.95) and negatively with fat content (r=-0.97), and there was a negative and significant correlation between fiber and fat content (r=-0.99*). The existence of a negative correlation between protein content and both carbohydrate and fat content can be attributed to biological control mechanisms, as increased accumulation of one chemical compound in the plant can lead to a decrease in the percentages of other compounds [7,15,16,17].

Such near-perfect correlations ($r \approx 0.99$) result from the direct dependence of dry matter accumulation on fresh biomass production under uniform environmental conditions and synchronized harvest timing. Furthermore, the simultaneous impact of physiological age and maturity stages across treatments contributes to these strong linear relationships.

Table (5): Correlation between the quantitative and qualitative traits studied in 3 harvests of the millet group^{-1}

	Wet fodder yield	**dry**	**protein**	**carbohydrate**	**Fats**	**Fibers**
Wet fodder yield	1					
dry	0.99*	1				
protein	0.93	0.94	1.0000			
carbohydrate	-0.99*	-0.99	-0.91	1.0000		
Fats	0.96	0.95	0.80	-0.97	1.0000	
Fibers	-0.93	-0.92	-0.75	0.95	-0.99*	1.0000

Significant significance at the 1% level

Based on the above results, the following can be concluded:
Millet planting date of April 15 achieved the best wet and dry fodder yields (67.71 tons ha-1 and 16.73 tons ha-1, respectively). Cultivar 1 also yielded the highest wet and dry fodder yields (19.72 tons ha-1 and 4.96 tons ha-1, respectively).
Wet green fodder yield was positively correlated with dry fodder yields, protein and fat content, and negatively correlated with carbohydrate and fiber content.
Dry fodder yield was positively correlated with protein and fat content, and negatively correlated with carbohydrate and fiber content.
Plant millet group 2 in mid-April to achieve the best dry and wet fodder yields, Pay attention to the first Harvest, as it yielded the best yields, Relying on millet as a fodder to provide ample amounts of green and dry fodder, Emphasizing the use of millet as a fodder due to its richness in protein and fat, Enhancing the fodder provided by millet hulls with carbohydrates and fiber, as these are often poor in these nutrients.
To guide farmers and livestock breeders based on their specific production goals, this study recommends the following:
For maximum yield: Planting on April 15. For high protein fodder: Prioritizing the first harvest and planting in early May. For high fiber content: Planting on April 1

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