Egyptian J. Desert Res., 75, No. 2, 343-369 (2025)

EFFECT OF IRRIGATION RATES AND PLANTING METHODS ON FORAGE YIELD AND WATER USE EFFICIENCY OF PEARL MILLET UNDER SEASONAL VARIATIONS IN MATROUH GOVERNORATE, EGYPT

Essam F. El-Hashash[1], Mohamed A. Attia[2], Karima M. El-Absy[3], Ahmed M.A. Youssef[4*], Hassan M. Al-Shaer[5] and Sobhy M.A. Sallam[6]
[1]Department of Agronomy, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt
[2]Department of Plant Production, Desert Research Centre, Cairo, Egypt
[3]Eco-physiology Unit, Department of Plant Ecology and Ranges, Desert Research Center, Cairo, Egypt
[4]Department of Geophysical Exploration, Desert Research Center, Cairo, Egypt
[5]Department of Animal and Poultry Nutrition, Desert Research Centre, Cairo, Egypt
[6]Department of Animal and Fish Production, Faculty of Agriculture, Alexandria University, Egypt
[*]E-mail: amayoussef.drc@gmail.com

Effective planting methods and irrigation rates are essential for optimizing fodder production and resource use of pearl millet. Two field experiments were conducted in the 2023 and 2024 growing years in the west Matrouh region conditions, Matrouh Governorate, Egypt, to examine the effects of three planting techniques (hole farming, drill in row and broadcasting) and two irrigation rates (4760 and 5236 m^3 per hectare) on the forage yield and water use efficiency traits at the three cuts, as well as the mean and total of the three cuts of the local pearl millet cultivar Shandaweel-1. Seasonal variations, irrigation rates, planting methods and their interactions had significant effects (p<0.05 or 0.01) on plant height (cm), number of (tillers/m^2), fresh forage yield (ton/hectare), dry forage yield (ton/hectare), fresh forage water use efficiency (kg/m^3) and dry forage water use efficiency (kg/m^3) at most the three cuts, as well as the mean and total of the three cuts. The year and climate have a significant impact on the forage output and water use efficiency at the different cuts. The Shandaweel-1 pearl millet under the hole farming method produced greater fodder yield and water use efficiency than the drill in row and broadcasting planting methods at various cuts in both irrigation rates and growing seasons. The cultivar achieved a higher forage yield and dry forage water use efficiency under a 5236 m^3 irrigation rate than a 4760 m^3 irrigation rate, while dry forage water use efficiency increased with a 4760 m^3 irrigation rate at the various cuts. There are positive and significant associations among most studied traits at all cuts. PCA based on the phenotypic correlation demonstrated the importance of studied factors as the main contributing traits for forage yield and water use efficiency of pearl millet. Generally, the pearl millet performed well under the hole farming method with a 5236 m^3 irrigation rate at the three cuts, as well as the mean and total of the three cuts in the west Matrouh region conditions, Matrouh Governorate, Egypt.

Keywords: Pearl millet, irrigation rates, planting methods, folder yield, water use efficiency, correlation, PCA analysis

INTRODUCTION

Although agriculture has advanced significantly over the past ten years, it is still facing challenges such as global climate change, famine and malnutrition. Millet is made from flowering plants in the Poaceae or Gramineae (herb) families of cereal crops (El-Hashash et al., 2023). According to El-Hashash et al. (2023), millets are climate-smart crops that create sustainable market opportunities for producers and consumers while also achieving climate resilience, nutritional security, developing sustainable diets, offering numerous health benefits and promoting sustainable production agriculture and meeting the needs of the world's expanding population. In light of climate change and rising global temperatures, these robust qualities make them more significant than rice and wheat (Sharma et al., 2024). In light of these salient characteristics, the United Nations Food and Agriculture Organization designated (2023) as the International Year of Millets (IYM2023) in an effort to raise awareness of the significance of millets (Ceasar and Baker, 2025). There are two types of millets: major and minor. Major millets are another name for pearl millet (Maharajan et al., 2024). After rice, wheat, maize, barley and sorghum, pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the sixth most significant cereal crop. Nearly half of the world's millet production comes from this crop, which is produced extensively on 30 million hectares in dry and semi-arid tropical parts of Asia and Africa (Satyavathi et al., 2021).

The main causes of low forage production are inadequate land availability, incorrect sowing timing and methods, a lack of high-quality forage seeds, inadequate irrigation and nutrition management, weed infestation, inadequate plant protection, etc. (Arslan et al., 2018). Plant yields are significantly impacted by agronomic practices, including planting and irrigation. Pearl millet is a warm-season C4 grass that thrives in semiarid regions, where worries about finite and diminishing water supplies always drive efforts to find crop management strategies that maximize water usage efficiency (Crookston et al., 2020). The success of a crop under water stress conditions is determined by its capacity to detect ecological differences and modify physiology accordingly (Farooq et al., 2019). Weather and irrigation treatment had a noticeable impact on the amount of biomass produced. The pearl millet crop yielded more when irrigation levels were greater and less when irrigation levels were lower (Bhattarai et al., 2020). In the dry and semi-arid parts of Africa, pearl millet yield can be severely restricted by water scarcity. Irrigation alone, however, could not be sufficient to explain all of the observed variations between the rainfed and irrigated sites because of geographical differences (Halilou et al., 2020). Under well-irrigated conditions, the duration to maturity rose along with the yields of pearl millet grain and total dry matter. On the other hand, because of prolonged dry spells, rainfed pearl millet produced the lowest yields of grain and total dry matter, plant height and tiller number (Ausiku et al., 2025). One crucial characteristic that characterizes how well crop plants use the water available for carbon fixation is water-use efficiency (Farooq et al., 2019).

Crop population and individual development are also significantly influenced by the planting technique; plant agronomic features are crucial markers for assessing plant growth (Qiao et al., 2025). Because sowing techniques impact germination, stand establishment and plant population (Chattha et al., 2017), they play a significant role in determining the production potential of fodder crops (Verma et al., 2024). Broadcasting, drilling, or line sowing, dibbling and other techniques are the most common sowing techniques for fodder crops (Verma et al., 2024). Various planting strategies can have a direct impact on the crop's microenvironment, which in turn can have an impact on the crops growth traits and yield components (Qiao et al., 2025). Effectively optimizing planting techniques increases the soil's capacity to hold roots, fosters the formation of subterranean root systems and improves the environmental conditions for root growth (Zhang et al., 2022). Ridge culture promotes root development and the more robust the fixation capacity, the more resilient the plant is to lodging (Du et al., 2024). Changing climatic conditions, density and row spacing can impact the grain filling process and consequently, crop population quality (Ge et al., 2022). The accumulation of dry matter per plant can be impacted by varying planting densities, according to research (Gonzalez et al., 2019). The space between rows or the spatial arrangement of plants has an impact on plant competition for environmental resources (Verma et al., 2024).

Understanding the intricate relationships between planting and irrigation practices under seasonal variations is crucial to optimizing the forage productivity of pearl millets in Egypt, as these practices are necessary to boost forage productivity. Thus, the current field experiments were carried out to investigate the impacts of two irrigation rates (4760 and 5236 m^3 per ha) and three planting techniques (hole farming, drill in row and broadcasting) under seasonal variations (2023 and 2024 growing seasons) on the forage yield characteristics of pearl millets at the Matrouh Governorate, Egypt.

MATERIALS AND METHODS

1. Experimental Design and Treatment Details

The seeds of local cultivar Shandaweel-1 were brought from the Field Crop Institute, Agriculture Research Center, Ministry of Agriculture, Giza, Egypt. Two field experiments were carried out on a private farm in Wadi El-Raml at West of Marsa Matrouh City (Latitude 27°09´13.1" N and Longitude 31°16´17.8" E), Matrouh Governorate, Egypt, during the 2023 and 2024 summer growing seasons. These trials were performed to study the effect of two irrigation rates (4760 and 5236 m^3 per ha) and three sowing methods (hole farming, drill in row and broadcasting) on the forage yield and water use efficiency traits of pearl millet. Each year, pearl millet seed was sown in a split-plot in a randomized complete blocks design with three replicates. The main plots were the two irrigation rates, and the sub-plots were the three planting methods. Each experimental unit area was 15 x 40 (400 m^2) and the distance between the row was (20 cm), while the distance between one the hole and another was (10 cm). To reduce environmental variability as much as possible, recommended fertilization for this type of soil and other agricultural practices were applied according to the Desert Research Center as recommended for the ordinary pearl millet in the experimental location. Fig. (1) shows the results of soil analysis at Wadi El-Raml location for (0-30 and 30-60 cm) depths before planting in 2023 and (2024) growing seasons using standard methods by Page et al. (1982).

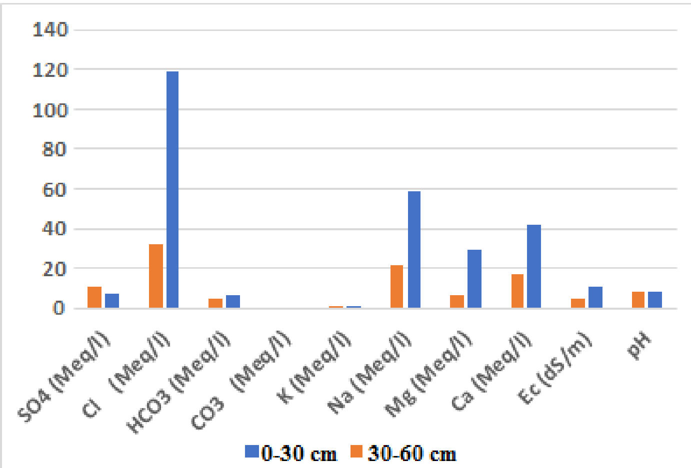

Fig. (1). Some chemical properties of soil samples for 0-30 and 30-60 cm depths at the Wadi El-Raml location.

Organic manure and calcium super phosphate fertilizers (15.5% P_2O_5) were added during soil preparation for two locations at rates of (20 m^3/fed and 200 kg/fed, respectively). Nitrogen fertilizer rates were applied in the farm of ammonium nitrate (33.5% N) at a rate of (200 kg/fed) in the three equal doses. The 1st dose was applied 20 days from the sowing date; the 2nd dose was added after the first cut and the 3rd dose after the 2nd cut just with irrigation. Soil additives treatments will be carried out as 1-Potassium humate was used in a rate of (1 kg/fed), the commercial name "Humic Total" consists of humic acid (80%), 12% K_2O – water solubility (98%), pH (8-9), and bulk density (83 g/100 ml). Planting was carried out on (15 May 2023 and 20 may 2024). The seed rate was (48 kg per ha) and pearl millet was sown under a drip irrigation system. Pearl millet seeds were sown, at the above-mentioned sowing dates, in hills (about 5 seeds/hill-10 cm apart) on the two ridges of furrows and covered with the sand and irrigation was applied directly after sowing. The 1st cut was taken, after (50 days), the two cut was taken after (80 days) from sowing date and the three cut was taken after (105 days) sowing date.

2. Measurements of Studied Traits

At the cuts, one square meter from each plot was chosen at random, and the two cuts were taken after the first to estimate the plant height (cm), number of tillers/m^2), fresh weight (ton/hectare) and dry weight (ton/hectare). Each cut was harvested by hand. Two kilograms were taken as a subsample and separated into leaf and stem after the fresh weight of the entire sample was recorded in the field. After two days of oven drying at 80°C, the dry weight of the plant parts was determined. Fresh and dry forage water use efficiencies (kg/m^3) were calculated by dividing the fresh and dry forage yield (t/hectare) by the amount of water received in both growing seasons (m^3/hectare), respectively.

3. Statistical Approaches

According to Steel and Torrie (1980) methodology, the measured data were subjected to a three-way ANOVA test and the coefficient of variation (CV%) to identify any significant variations in the impact of experimental factors and their interactions. The least significant difference (LSD) test was used to compare means at $p<0.05$. The column means were compared using small letters. According to Gomes (2009), the (CV%) estimations were divided into four categories: extremely high (CV≥21%), high (15.0%≤CV≤21.0%), moderate (10%<CV≤20%) and low (CV<10%). Correlation coefficient and principal component analysis (PCA) were used to better comprehend the association between the traits and the experimental treatments under study. The computer applications SPSS version 20 and Origin Pro 2021 version b 9.5.0.193 were used to do the ANOVA and PCA, respectively.

RESULTS

1. Seasonal Weather

The climate data during the (2023 and 2024) growing seasons at the studied location were provided by the Applied Agricultural Meteorological Laboratory of the Desert Research Center, Egypt. Climate statistics for the April–September growing seasons of (2023 and 2024) are shown in Table (1). Higher temperatures were observed in August for both growing seasons. Still, they increased in the (2024) growing season than in the (2023) growing season, with values 1.24 and 0.78% at minimum and maximum air temperatures, respectively. While lower temperatures were found in April during both growing seasons. Generally, the (2024) growing season recorded the highest minimum and maximum temperatures compared with the (2023) growing season. All months in the (2023) growing season were higher for average relative humidity (%) than in the (2024) growing season, except April and September. The highest average relative humidity (%) was noticed in June and July during the (2023 and 2024 growing seasons, respectively). While lower average relative humidity (%) was found in August and May during the (2023 and 2024 growing seasons, respectively). The highest values of total precipitation (mm) were recorded during April in both growing seasons. Generally, total precipitation in the (2023) growing season was higher than in the (2024) growing season. Average Wind Speed (m/s) and Total Solar Radiation ($MJ/m^2/day$) reached their highest values in April in both growing seasons.

2. Analysis of Variance (ANOVA)

In Table (2), the ANOVA test showed that the plant height (cm), number of ($tillers/m^2$), fresh forage yield (t/hectare), dry forage yield (t/hectare) and dry forage water use efficiency (kg/m^3) were significantly affected by irrigation rates and planting methods (p<0.05 or 0.01) at three cuts, as well as means and total of the three cuts. As for fresh forage water use efficiency (kg/m^3), significant effects (p<0.05 or 0.01) were observed by planting methods at the three cuts, as well as at the mean and total of the three cuts and by irrigation rates at the second and third cuts. While seasonal changes significantly affected (p<0.05 or 0.01) plant height, fresh forage yield, and fresh forage water use efficiency traits at the second and third cuts, and the number of tillers, dry forage yield and dry forage water use efficiency traits at all cuts. Seasons vs. irrigation rates showed significant effects on fresh forage yield and fresh forage water use efficiency traits at the second cut and on dry forage yield and dry forage water use efficiency traits at all cuts except the second cut (p<0.05 or 0.01). Also, all cuts were significantly affected (p<0.05 or 0.01) by seasons vs. planting methods for the number of tillers, dry forage yield and dry forage water use efficiency traits, except at the first cut; for fresh forage yield and fresh forage water use efficiency, except at the third

Table (1). Climatic data at study region, west Matrouh region, Matrouh Governorate, Egypt during the 2023 and 2024 growing seasons.

Seasons	Months	Minimum air temperature (°C)	Maximum air temperature (°C)	Average relative humidity (%)	Total precipitation (mm)	Average wind speed (m/s)	Total solar radiation (MJ/m²/day)
2023 Season	April	**15.23**	**21.29**	69.02	21.40	4.53	23.29
	May	17.84	23.64	74.43	0.40	4.54	25.10
	June	21.07	26.32	76.20	0.20	4.36	25.97
	July	24.67	30.30	72.09	0.00	4.66	27.55
	August	25.68	30.96	**66.75**	0.00	3.90	25.11
	September	25.11	29.98	65.03	4.30	4.07	20.94
2024 Season	April	**16.47**	**22.42**	72.34	2.30	4.23	23.85
	May	19.15	25.58	**63.25**	0.00	3.97	25.84
	June	23.20	29.57	68.41	0.20	3.77	27.30
	July	25.57	30.71	68.66	0.00	4.48	27.95
	August	26.33	31.45	66.05	0.00	3.74	25.60
	September	25.44	29.74	66.94	0.00	3.88	21.37

Table (2). ANOVA test (p-values) for the effect of the seasons (S), irrigation rates (I) and planting methods (P) on the studied traits of pearl millet at the three cuts as well as the mean and total of the three cuts.

S.O.V	Plant height (cm)					No. of tillers/m^2				
	1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
Seasons	0.99^{ns}	0.00**	0.00**	0.21^{ns}	---	0.00**	0.00**	0.00**	0.00**	---
Irrigation	0.00**	0.00**	0.00**	0.00**	---	0.08*	0.02*	0.04*	0.02*	---
S x I	0.89^{ns}	0.36^{ns}	0.58^{ns}	0.47^{ns}	---	0.27^{ns}	0.67^{ns}	0.95^{ns}	0.46^{ns}	---
P	0.00**	0.00**	0.00**	0.00**	---	0.00**	0.00**	0.00**	0.00**	---
S x P	0.38^{ns}	0.48^{ns}	0.01*	0.09*	---	0.12^{ns}	0.00**	0.01*	0.00**	---
I x P	0.01*	0.06*	0.82^{ns}	0.01*	---	1.00^{ns}	0.96^{ns}	0.72^{ns}	0.94^{ns}	---
S x I x P	0.58^{ns}	0.28^{ns}	0.02*	0.42^{ns}	---	0.99^{ns}	0.67^{ns}	0.78^{ns}	1.00^{ns}	---
C.V.%	4.79	6.06	3.81	3.66	---	11.14	8.09^{ns}	14.58	8.85	---
S.O.V	**Fresh forage yield (t/hectare)**					**Dry forage yield (t/hectare)**				
	1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
Seasons	0.35^{ns}	0.00**	0.00**	0.79^{ns}	0.79	0.03*	0.06*	0.00**	0.00**	0.00**
Irrigation	0.00**	0.00**	0.01*	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
S x I	0.97^{ns}	0.06*	0.25^{ns}	0.46^{ns}	0.46	0.03*	0.22^{ns}	0.00**	0.03*	0.03*
P	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
S x P	0.02*	0.00**	0.23^{ns}	0.00**	0.00**	0.62^{ns}	0.03*	0.00**	0.01*	0.01*
I x P	0.09*	0.29^{ns}	0.47^{ns}	0.09*	0.09*	0.00**	0.87^{ns}	0.00**	0.00**	0.00**
S x I x P	0.03*	0.78^{ns}	0.00**	0.03*	0.03*	0.32^{ns}	0.51^{ns}	0.10^{ns}	0.75^{ns}	0.75^{ns}
C.V.%	8.04	3.27	6.09	4.47	0.79	5.53	4.77	8.79	2.97	2.97
S.O.V	**Fresh forage water use efficiency (kg/m^3)**					**Dry forage water use efficiency (kg/m^3)**				
	1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
Seasons	0.37	0.00**	0.00**	0.83	0.83	0.04*	0.07*	0.00**	0.00**	0.00**
Irrigation	0.99	0.00**	0.09*	0.29	0.29	0.00**	0.00**	0.06*	0.00**	0.00**
S x I	0.99	0.03*	0.35	0.48	0.48	0.05*	0.26	0.00**	0.05*	0.05*
P	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**	0.00**
S x P	0.02*	0.00**	0.25	0.00**	0.00**	0.67	0.03*	0.00**	0.01*	0.01*
I x P	0.10	0.06*	0.26	0.06*	0.06*	0.00**	0.74	0.02*	0.00**	0.00**
S x I x P	0.03*	0.78	0.01*	0.03*	0.03*	0.35	0.45	0.07*	0.80	0.80
C.V.%	8.42	3.15	6.26	4.65	4.65	5.67	4.85	8.78	2.99	2.99

Statistically significant differences at $*p \leq 0.05$ and $**p \leq 0.01$; ns: indicate the non-significant difference.

cut; and for plant height, except at the first and second cuts. Concerning irrigation rates vs. planting methods, plant height, fresh forage yield, dry forage yield and dry water as well as fresh forage water use efficiency were significant at all cuts (p<0.05 or 0.01), except at the third cut, at the second and third cuts, at the second cut and at the first and third cuts, respectively In terms of second-order interaction, significant effects (p<0.05 or 0.01) were observed on plant height and dry forage water use efficiency at the third cut and fresh forage yield and fresh forage water use efficiency at the first and third cuts, as well as at the mean and total of the three cuts. Low (CV%) were noticed for all studied traits at all cuts, which were less than 10%, except for the number of tillers at the first and third cuts with values of (11.14 and 14.58%, respectively) (Table 2). The fresh forage yield at the total of the three cuts had the lowest (CV%) values, at 0.79%.

3. The Main Effects of Experimental Factors

Results in Table (3) exhibited that the experimental factors significantly affected the evaluated traits at most cuts under study. In both seasons, all the studied traits at the first cut outperformed the second and third cuts under all planting methods and irrigation rates. The maximum values of plant height, number of tillers, fresh forage yield, dry forage yield, water use efficiency for fresh and dry forage were observed in (2024) growing season compared with (2023) growing season at the most cuts, as well as the mean and total of the three cuts. Plant height, number of tillers, fresh forage yield, dry forage yield and water use efficiency for dry forage traits were significantly higher in 5236 m^3 irrigation rate than in the 4760 m^3 irrigation rate at the three cuts as well as the mean and total of the three cuts. While a 4760 m^3 irrigation rate increased fresh forage water use efficiency at the second and third cuts as well as the mean and total of the three cuts. As for the planting methods, the hole farming method displayed significantly higher plant height, number of tillers, fresh forage yield, dry forage yield, fresh and dry forage water use efficiency traits than the other planting methods at the three cuts as well as the mean and total of the three cuts. The best forage yield and water use efficiency of pearl millet were obtained with the hole farming method, followed by the drill in row method and then the broadcasting method under 5236 m^3 irrigation rate at the three cuts as well as the mean and total of the three cuts.

4. The First and Second-Order Interactions Effects

The maximum values of plant height, number of tillers, fresh forage yield, dry forage yield and dry forage water use efficiency traits at the three cuts as well as the mean and total of the three cuts were recorded with (5236 m^3) irrigation rate in both growing seasons compared with (4760 m^3) irrigation rate (Table 4). While, opposite for fresh forage water use efficiency at the second and third cuts as well as the mean and total of the three cuts. When compared to their values in other seasons x irrigation rates interactions, the

Table (3). The main effect of seasonal changes, irrigation rates, and planting methods on studied traits of pearl millet at the three cuts as well as the mean and total of the three cuts.

Factors	Plant height (cm)					No. of tillers/m²				
	1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	105.75	79.77b	84.52a	90.01	---	57.11b	48.67b	38.04b	47.94b	---
2024	105.77	93.41a	75.17b	91.45	---	181.11a	124.78a	71.89a	125.93a	---
LSD 5%	NS	3.62	2.10	NS	---	9.17	4.85	5.54	5.32	---
5236 m³	110.86a	91.21a	82.17a	94.75a	---	123.17a	89.67a	57.82a	90.22a	---
4760 m³	100.66b	81.97b	77.52b	86.72b	---	115.06b	83.78b	52.11b	83.65b	---
LSD 5%	3.50	3.62	2.10	2.29	---	9.17	4.85	5.54	5.32	---
Row	103.43b	84.16b	78.50b	88.70b	---	115.58b	84.25b	50.58b	83.47b	---
Hole farming	119.50a	97.73a	87.51a	101.58a	---	134.25a	99.67a	68.17a	100.69a	---
Broad	94.36c	77.87c	73.53c	81.92c	---	107.50b	76.25c	46.15b	76.63c	---
LSD 5%	4.29	5.13	2.58	2.81	---	11.23	5.94	6.79	6.51	---
Factors	**Fresh forage yield (t/hectare)**					**Dry forage yield (t/hectare)**				
	1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	64.34	50.82a	12.19b	42.45	127.35	14.74b	11.06b	1.35b	9.05b	27.15b
2024	66.00	48.56b	13.28a	42.62	127.85	15.39a	11.41a	1.81a	9.54a	28.61a
LSD 5%	NS	1.12	0.54	NS	NS	0.58	0.35	0.10	0.19	0.57
5236 m³	68.29a	51.22a	13.11a	44.20a	132.61a	16.94a	12.53a	1.70a	10.39a	31.17a
4760 m³	62.05b	48.17b	12.36b	40.86b	122.59b	13.19b	9.94b	1.46b	8.20b	24.59b
LSD 5%	3.62	1.12	0.54	1.31	3.94	0.58	0.35	0.10	0.19	0.57
Row	65.66b	50.18b	12.67b	42.84b	128.52b	13.59b	9.97b	1.59b	8.38b	25.14b
Hole farming	71.73a	55.12a	14.53a	47.13a	141.39a	19.14a	14.60a	2.03a	11.92a	35.77a
Broad	58.11c	43.78c	11.00c	37.63c	112.89c	12.47c	9.14c	1.12c	7.58c	22.73c
LSD 5%	4.44	1.38	0.66	1.61	4.83	0.71	0.45	0.12	0.23	0.70
Factors	**Fresh forage water use efficiency (kg/m³)**					**Dry forage water use efficiency (kg/m³)**				
	1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	12.87	10.18a	2.44b	8.50	25.50	2.94b	2.21b	0.27b	1.81b	5.42b
2024	13.21	9.72b	2.66a	8.53	25.58	3.07a	2.28a	0.36a	1.90a	5.70a
LSD 5%	NS	0.22	0.11	NS	NS	0.12	0.07	0.02	0.04	0.11
5236 m³	13.04	9.78b	2.50b	8.44	25.33	3.24a	2.39a	0.32a	1.98a	5.95a
4760 m³	13.04	10.12a	2.60a	8.58	25.75	2.77b	2.09b	0.31b	1.72b	5.17b
LSD 5%	NS	0.22	0.11	NS	NS	0.12	0.07	0.02	0.04	0.11
Row	13.17b	10.05b	2.54b	8.58b	25.75b	2.71b	1.99b	0.32b	1.67b	5.02b
Hole farming	14.34a	11.04a	2.91a	9.43a	28.30a	3.81a	2.91a	0.41a	2.38a	7.13a
Broad	11.61c	8.76c	2.20c	7.52c	22.57c	2.49c	1.82c	0.22c	1.51c	4.53c
LSD 5%	0.93	0.27	0.14	0.34	1.01	0.14	0.09	0.02	0.05	0.14

Means sharing different letters in the same column indicate statistically significant ($p \leq 0.05$) differences according to the LSD test.

best values for plant height, number of tillers, fresh forage yield, dry forage yield traits and dry forage water use efficiency were observed by (5236 m³) irrigation rate in the (2024) growing season at the three cuts as well as the mean and total of the three cuts, except for plant height and dry forage water use efficiency and fresh forage yield traits at the third and the second cuts, respectively. Irrigation rate (4760 m³) significantly increased fresh forage water use efficiency at the second cut in the (2023) growing season. Generally, our results indicated that the (5236 m³) irrigation rate in both growing seasons increased the forage yield and water use efficiency of pearl millet in the region under study.

Table (4). Seasonal changes vs. irrigation rates for studied traits of pearl millet at the three cuts as well as the mean and total of the three cuts.

Seasons	Irrigations (m³)	Plant height (cm)					No. of tillers\m^2				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	5236	110.73	83.57	86.56	93.62	---	58.67	51.11	40.98	50.25	---
	4760	100.77	75.97	82.49	86.41	---	55.56	46.22	35.11	45.63	---
2024	5236	110.99	98.86	77.78	95.88	---	187.67	128.22	74.67	130.19	---
	4760	100.56	87.97	72.56	87.03	---	174.56	121.33	69.11	121.67	---
LSD 5%		NS	NS	NS	NS	---	NS	NS	NS	NS	---
Seasons	**Irrigations (m³)**	**Fresh forage yield (t/hectare)**					**Dry forage yield (t/hectare)**				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	5236	67.42	51.81aa	12.41	43.88	131.64	16.31b	12.24	1.58b	10.04b	30.12b
	4760	61.25	49.84b	11.97	41.02	123.06	13.18c	9.87	1.12c	8.06d	24.17d
2024	5236	69.15	50.62a	13.81	44.53	133.58	17.58a	12.82	1.82a	10.74a	32.22a
	4760	62.85	46.50c	12.76	40.70	122.11	13.20c	10.00	1.80a	8.34c	25.01c
LSD 5%		NS	1.59	NS	NS	NS	0.81	NS	0.14	0.27	0.81
Seasons	**Irrigations (m³)**	**Fresh forage water use efficiency (kg/m^3)**					**Dry forage water use efficiency (kg/m^3)**				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	5236	12.88	9.89b	2.37	8.38	25.14	3.11b	2.34	0.30c	1.92b	5.7bb
	4760	12.87	10.47a	2.51	8.62	25.85	2.77c	2.07	0.24d	1.69d	5.08d
2024	5236	13.21	9.67b	2.64	8.50	25.51	3.36a	2.45	0.35b	2.05a	6.15a
	4760	13.20	9.77b	2.68	8.55	25.65	2.77c	2.10	0.38a	1.75c	5.25c
LSD 5%		NS	0.31	NS	NS	NS	0.17	NS	0.03	0.05	0.16

Means sharing different letters in the same column indicate statistically significant ($p \leq 0.05$) differences according to the LSD test.

As for seasons x planting methods interaction (Table 5), the highest values for plant height, number of tillers, fresh forage yield, dry forage yield and fresh and dry forage water use efficiency traits were under the hole farming method, followed by the drill in row method and then the broadcasting method in both growing seasons at the three cuts as well as the mean and total of the three cuts. The maximum plant height, number of tillers, dry forage yield and dry forage water use efficiency traits throughout the (2024) growing period were recorded with the hole farming method at the three cuts as well as the mean and total of the three cuts, except for plant height

Table (5). Seasonal changes vs. planting methods for studied traits of pearl millet at the three cuts as well as the mean and total of the three cuts.

Seasons	Planting methods	Plant height (cm)					No. of tillers\m^2				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	Row	102.25	77.00	83.17b	87.47b	---	57.00	47.67d	37.00c	47.22c	---
	Hole farming	119.00	89.80	90.02a	99.61a	---	65.50	55.00d	44.33c	54.94c	---
	Broad	96.00	72.50	80.38b	82.96c	---	48.83	43.33d	32.80c	41.66c	---
2024	Row	104.60	91.33	73.83c	89.92b	---	174.17	120.83b	64.17b	119.72b	---
	Hole farming	120.00	105.67	85.00b	103.56a	---	203.00	144.33a	92.00a	146.44a	---
	Broad	92.72	83.25	66.67d	80.88c	---	166.17	109.17c	59.50b	111.61b	---
	LSD 5%	NS	NS	3.64	3.97	---	NS	8.40	9.60	9.21	---
Seasons	**Planting methods**	**Fresh forage yield (t/hectare)**					**Dry forage yield (t/hectare)**				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	Row	61.10b	49.79c	11.86	40.92c	122.75c	13.29	9.77c	1.27c	8.11d	24.34d
	Hole farming	73.49a	56.40a	14.28	48.06a	144.17a	18.64	14.11b	1.74b	11.50b	34.49b
	Broad	58.43b	46.28d	10.42	38.38d	115.13d	12.30	9.28cd	1.03d	7.54e	22.61e
2024	Row	70.23a	50.57c	13.48	44.76b	134.28b	13.89	10.16c	1.90b	8.65c	25.95c
	Hole farming	69.98a	53.84b	14.79	46.20ab	138.61ab	19.64	15.08a	2.33a	12.35a	37.05a
	Broad	57.80b	41.27e	11.58	36.89d	110.66d	12.64	9.00d	1.20c	7.61e	22.84e
	LSD 5%	6.27	1.95	NS	2.28	6.83	NS	0.64	0.17	0.33	0.99
Seasons	**Planting methods**	**Fresh forage water use efficiency (kg/m^3)**					**Dry forage water use efficiency (kg/m^3)**				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	Row	12.22b	9.98c	2.37	8.19b	24.57b	2.66	1.95c	0.25d	1.62d	4.86d
	Hole farming	14.71a	11.30a	2.86	9.62a	28.87a	3.72	2.82b	0.35c	2.29b	6.88b
	Broad	11.69b	9.27c	2.09	7.68d	23.05d	2.45	1.85cd	0.21e	1.50e	4.51e
2024	Row	14.11a	10.12b	2.70	8.98c	26.94c	2.77	2.02c	0.38b	1.72c	5.17c
	Hole farming	13.98a	10.78b	2.96	9.24ac	27.73ac	3.91	3.01a	0.47a	2.46a	7.38a
	Broad	11.53b	8.25d	2.31	7.36d	22.09d	2.52	1.79d	0.24d	1.52e	4.55e
	LSD 5%	1.32	0.38	NS	0.47	1.42	NS	0.13	0.03	0.07	0.20

Means sharing different letters in the same column indicate statistically significant ($p \leq 0.05$) differences according to the LSD test at the third cut. On the other hand, the hole farming method produced the best fresh forage yield and fresh forage water use efficiency traits at all three cuts, as well as the mean and total of the three cuts, during the (2023) growing season. Generally, our results indicated that the hole farming method in both growing seasons increased the forage yield and water use efficiency of pearl millet in the region under study.

Concerning the interaction of irrigation rates and planting methods, the best results for all studied traits under three planting methods were recorded with (5236 m^3) irrigation rate at the three cuts as well as the mean and total of the three cuts, except fresh forage water use efficiency (Table 6). Also, the highest values for all studied traits under the hole farming method, followed by the drill in row method and then the broadcasting method in both irrigation rates at the three cuts as well as the mean and total of the three cuts. Compared with other interactions of irrigation rates and planting methods, the maximum values for all studied traits were found by the hole farming method with (5236 m^3) irrigation rate at the three cuts as well as the mean and total of the three cuts, except for fresh forage water use efficiency, which increased under a (4760 m^3) irrigation rate. On the other hand, the minimum values were found for all studied traits under the broadcasting method with (4760 m^3) irrigation rate at the three cuts as well as the mean and total of the three cuts. All first-order interactions exhibited a variety of trends. Nevertheless, statistical analysis showed that the hole farming method with a (5236 m^3) irrigation rate in the (2024) growing season produced the highest values for most of the traits under study at the cut treatments.

Table (7) shows the effects of the experimental factors' second-order interactions on the traits under investigation. The three planting methods under (5236 m^3) irrigation rate in both growing seasons recorded the best values for most studied traits at the three cuts as well as the mean and total of the three cuts. The better values were observed for plant height, number of tillers, dry forage yield and dry forage water use efficiency traits at the three cuts as well as the mean and total of the three cuts and for fresh forage yield at the three cuts under the hole farming method under (5236 m^3) irrigation rate in the (2024) growing season, compared with those of other second-order interactions. While, the hole farming method in the (2023) growing season had the highest values for fresh forage yield and fresh forage water use efficiency traits (5236 and 4760 m^3 irrigation rates, respectively) at the mean and total of the three cuts. The hole farming method with a (5236 m^3) irrigation rate in both growing seasons generally boosted the forage production and water use efficiency of pearl millet, according to the results of the effect of experimental factors as well as the first and second-order interactions.

5. Pearson's Correlation Coefficient

The relationships between the traits of forage yield and water use efficiency of pearl millet that were investigated under the two irrigation rates

Table (6). Irrigation rates vs. planting methods for studied traits of pearl millet at the three cuts as well as the mean and total of the three cuts.

Irrigation (m^3)	Planting methods	Plant height (cm)					No. of tillers\m^2				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
5236	Row	106.82b	86.41b	80.56	91.26b	---	119.33	86.83	52.33	86.17	---
	Hole farming	128.73a	105.32a	90.29	108.11a	---	138.50	102.50	72.50	104.50	---
	Broad	97.03c	81.91bc	75.65	84.87c	---	111.67	79.67	48.63	79.99	---
4760	Row	100.03c	81.92bc	76.44	86.13c	---	111.83	81.67	48.83	80.78	---
	Hole farming	110.27b	90.15b	84.73	95.05b	---	130.00	96.83	63.83	96.89	---
	Broad	53.35c	41.71	10.40	35.16d	105.47c	11.14f	7.90	1.08d	6.71f	20.12f
LSD 5%		6.06	6.28	NS	3.97	---	NS	NS	NS	NS	---
Irrigation (m^3)	**Planting methods**	**Fresh forage yield (t/hectare)**					**Dry forage yield (t/hectare)**				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
5236	Row	65.93b	51.70	12.94	43.52b	130.57b	15.02c	11.26	1.67b	9.32c	27.96c
	Hole farming	76.06a	56.11	14.78	48.98a	146.95a	22.00a	15.96	2.27a	13.41a	40.23a
	Broad	62.88b	45.84	11.60	40.11c	120.32c	13.80d	10.38	1.15d	8.44d	25.33d
4760	Row	65.40b	48.67	12.40	42.16bc	126.47bc	12.16e	8.67	1.50c	7.44e	22.33e
	Hole farming	67.40b	54.13	14.29	45.27b	135.82b	16.28b	13.24	1.80b	10.44b	31.32b
	Broad	53.35c	41.71	10.40	35.16d	105.47c	11.14f	7.90	1.08d	6.71f	20.12f
LSD 5%		6.27	NS	NS	2.28	6.83	1.00	NS	0.17	0.33	0.99
Irrigation (m^3)	**Planting methods**	**Fresh forage water use efficiency (kg/m^3)**					**Dry forage water use efficiency (kg/m^3)**				
		1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
5236	Row	12.59	9.87c	2.47	8.31c	24.94c	2.87c	2.15	0.32c	1.78c	5.34c
	Hole farming	14.53	10.72b	2.82	9.36a	28.07a	4.20a	3.05	0.43a	2.56a	7.68a
	Broad	12.01	8.75d	2.22	7.66d	22.98d	2.63d	1.98	0.22d	1.61d	4.84d
4760	Row	13.74	10.22c	2.60	8.86b	26.57b	2.56d	1.82	0.31c	1.56d	4.69d
	Hole farming	14.16	11.37a	3.00	9.51a	28.53a	3.42b	2.78	0.38b	2.19b	6.58b
	Broad	11.21	8.76d	2.19	7.39d	22.16d	2.34e	1.66	0.23d	1.41e	4.23e
LSD 5%		NS	0.38	NS	0.47	1.42	0.20	NS	0.03	0.07	0.20

Means sharing different letters in the same column indicate statistically significant ($p \leq 0.05$) differences according to the LSD test.

Table (7). The second-order interaction of the three factors for studied traits of pearl millet at the three cuts as well as the mean and total of the three cuts.

Seasons	Irrigation (m³)	Planting methods	Plant height (cm)					No. of tillers\m²				
			1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	5236	Row	106.10	79.70	86.12a	90.64	---	58.67	49.67	38.67	49.00	---
		Hole	128.80	97.30	90.25a	105.45	---	67.33	58.67	47.67	57.89	---
		Broad	97.30	73.70	83.30ab	84.77	---	50.00	45.00	36.60	43.87	---
	4760	Row	98.40	74.30	80.21bc	84.30	---	55.33	45.67	35.33	45.44	---
		Hole	109.20	82.30	89.79a	93.76	---	63.67	51.33	41.00	52.00	---
		Broad	94.70	71.30	77.46c	81.15	---	47.67	41.67	29.00	39.44	---
2024	5236	Row	107.53	93.12	75.00c	91.89	---	180.00	124.00	66.00	123.33	---
		Hole	128.67	113.33	90.33a	110.78	---	209.67	146.33	97.33	151.11	---
		Broad	96.77	90.12	68.00d	84.96	---	173.33	114.33	60.67	116.11	---
	4760	Row	101.67	89.53	72.67c	87.96	---	168.33	117.67	62.33	116.11	---
		Hole	111.33	98.00	79.67bc	96.33	---	196.33	142.33	86.67	141.78	---
		Broad	88.67	76.37	65.33d	76.79	---	159.00	104.00	58.33	107.11	---
	LSD 5%		NS	NS	5.15	NS	---	NS	NS	NS	NS	---

Seasons	Irrigation (m³)	Planting methods	Fresh forage yield (t/hectare)					Dry forage yield (t/hectare)				
			1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	5236	Row	64.80b	50.60	12.35c	42.58c	127.75c	14.33	10.89	1.49	8.90	26.71
		Hole	76.13a	57.12	14.68ab	49.31a	147.93a	20.98	15.51	2.14	12.87	38.62
		Broad	61.34b	47.71	10.18d	39.74cd	119.23cd	13.61	10.32	1.10	8.34	25.03
	4760	Row	57.39bc	48.99	11.37c	39.25d	117.74d	12.26	8.65	1.06	7.32	21.97
		Hole	70.85ab	55.68	13.88ab	46.80ab	140.41ab	16.30	12.72	1.34	10.12	30.37
		Broad	55.51c	44.85	10.66d	37.01d	111.02d	10.99	8.24	0.96	6.73	20.19
2024	5236	Row	67.05b	52.79	13.53abc	44.46bc	133.38bc	15.72	11.63	1.86	9.73	29.20
		Hole	76.00a	55.10	14.87ab	48.66ab	145.97ab	23.03	16.41	2.41	13.95	41.84
		Broad	64.41bc	43.97	13.02c	40.47c	121.40c	13.98	10.44	1.20	8.54	25.62
	4760	Row	63.96bc	48.35	13.43ac	45.06bc	135.19bc	12.07	8.69	1.94	7.57	22.70
		Hole	73.41ab	52.58	14.70a	43.75bc	131.24bc	16.25	13.76	2.25	10.75	32.26
		Broad	51.20c	38.57	10.15d	33.30e	99.91e	11.29	7.56	1.20	6.68	20.05
	LSD 5%		8.87	NS	1.31	3.22	9.66	NS	NS	NS	NS	NS

Seasons	Irrigation (m³)	Planting methods	Fresh forage water use efficiency (kg/m³)					Dry forage water use efficiency (kg/m³)				
			1st cut	2nd cut	3rd cut	Mean	Sum	1st cut	2nd cut	3rd cut	Mean	Sum
2023	5236	Row	12.38bcd	9.66	2.36de	8.13bc	24.40bc	2.74	2.08	0.28d	1.70	5.10
		Hole	14.54ab	10.91	2.80bc	9.42a	28.25a	4.01	2.96	0.41b	2.46	7.38
		Broad	11.72cd	9.11	1.94e	7.59cd	22.77cd	2.60	1.97	0.21e	1.59	4.78
	4760	Row	12.06cd	10.29	2.39de	8.25bc	24.74bc	2.57	1.82	0.22e	1.54	4.61
		Hole	14.88a	11.70	2.92ab	9.83a	29.50a	3.42	2.67	0.28d	2.13	6.38
		Broad	11.66cd	9.42	2.24de	7.77c	23.32c	2.31	1.73	0.20e	1.41	4.24
2024	5236	Row	12.81cb	10.08	2.58cd	8.49b	25.47b	3.00	2.22	0.36c	1.86	5.58
		Hole	14.51a	10.52	2.84a	9.29ab	27.88ab	4.40	3.13	0.46a	2.66	7.99
		Broad	12.30cd	8.40	2.49d	7.73c	23.19c	2.67	1.99	0.23e	1.63	4.89
	4760	Row	15.42a	10.16	2.82abc	9.47ab	28.40ab	2.54	1.83	0.41b	1.59	4.77
		Hole	13.44bc	11.05	3.09a	9.19ab	27.57ab	3.41	2.89	0.47a	2.26	6.78
		Broad	10.76d	8.10	2.13e	7.00d	20.99d	2.37	1.59	0.25d	1.40	4.21
	LSD 5%		1.86	NS	0.27	0.67	2.01	NS	NS	0.11	NS	NS

Means sharing different letters in the same column indicate statistically significant ($p \leq 0.05$) differences according to the LSD test.

and three planting techniques during the two growing seasons at the three cuts, as well as the mean and total of the three cuts, are understood using Pearson's correlation coefficient, as shown in Fig. (2). A perfect positive correlation (r=1) was observed between plant height at the first cut and the mean of the three cuts, among the number of tillers at the first cut, the second cut and the mean of the three cuts, as between fresh forage yield and fresh forage water use efficiency traits at the mean and the total of the three cuts, and among dry forage yield and dry forage water use efficiency traits at all the three cuts as well as the mean and total of the three cuts except the third cut. All pairs possible among plant height, among number of tillers, among fresh forage yield, among dry forage yield, among fresh forage water use efficiency and among dry forage water use efficiency at the three cuts, as well as the mean and total of the three cuts, showed a positive and significant correlation (p<0.05 or 0.01), except plant height at the second and third cuts. A significant positive correlation (p<0.05 or 0.01) were noticed among plant height, fresh forage yield, dry forage yield, fresh and dry forage water use efficiency traits at the three cuts, as well as the mean and total of the three cuts. Plant height at the second cut is significantly positively correlated with the number of tillers at the three cuts and the mean of the three cuts (p<0.05 or 0.01). The number of tillers at the second cut with dry forage yield and dry forage water use efficiency traits at the third cut as well as the number of tillers at the third cut with fresh and dry forage yields traits as well as fresh and dry forage water use efficiency traits at the third cut exhibited a positive and significant association (p<0.05).

6. Principal Component Analysis (PCA)

The four PCs for all pearl millet traits at the three cuts, as well as the mean and total of the three cuts based on the seasonal changes, irrigation rates and planting methods, are shown in Table (8). The extracted values for PC1, PC2, and PC3 were 22.35, 4.13 and 1.21, respectively, indicating eigenvalues greater than one (eigenvalue >1). PC4 also had eigenvalues that were less than one (eigenvalue <1). Of the overall variation among the variables under study, PC1, PC2 and PC3 account for 98.88%. PC1 only described roughly 79.81% of the measured data total variability, its contributions to the total variance were greater than those of PC2 (14.75%) and PC3 (4.32%). The PC1 and PC2 results can be used to explain the overall variance and the PC collection, as well as to summarize the original variables in any additional data analysis. In the (2024) growing season, PC1 exhibited a positive correlation with the hole farming method under (5236 m^3) irrigation rate, as well as with all the traits that were examined at the three cuts, the mean, and the sum of the three cuts. These findings suggested that PC1 was influenced by the favorable factors of pearl millet forage yield. The number of tillers at the three cuts and the mean of the three cuts, as well as the broadcasting method under a (4760 m³) irrigation rate in the (2023) growing season, have been identified by PC2 as having positive loading factors and contributing to the variables.

Based on PCA, Fig. (3) shows (PC1 and PC2 for the experimental factors and all traits at the three cuts, the mean, and the sum of the three cuts. The biplot diagram demonstrated how planting methods under irrigation rates changed throughout the growing years, causing variability in every trait that was looked at. According to PCA, the data regarding the contribution of experimental factors revealed a steep angle between them and a positive correlation with most of the traits under investigation. Nonetheless, there were variations in the quantity and level of uniformity. The results of PCA were similar to the results of the Pearson's correlation coefficient. In PC1, the hole farming method under (5236 m³) irrigation rate in the (2024) growing season, which fell in the first and fourth quarters, were highly and positively connected with all evaluated traits at the three cuts, as well as the mean and total of the three cuts. Generally, hole farming method under (5236 m³) irrigation rate in the (2024) growing season was located near the forage yields and water efficiency of pearl millet.

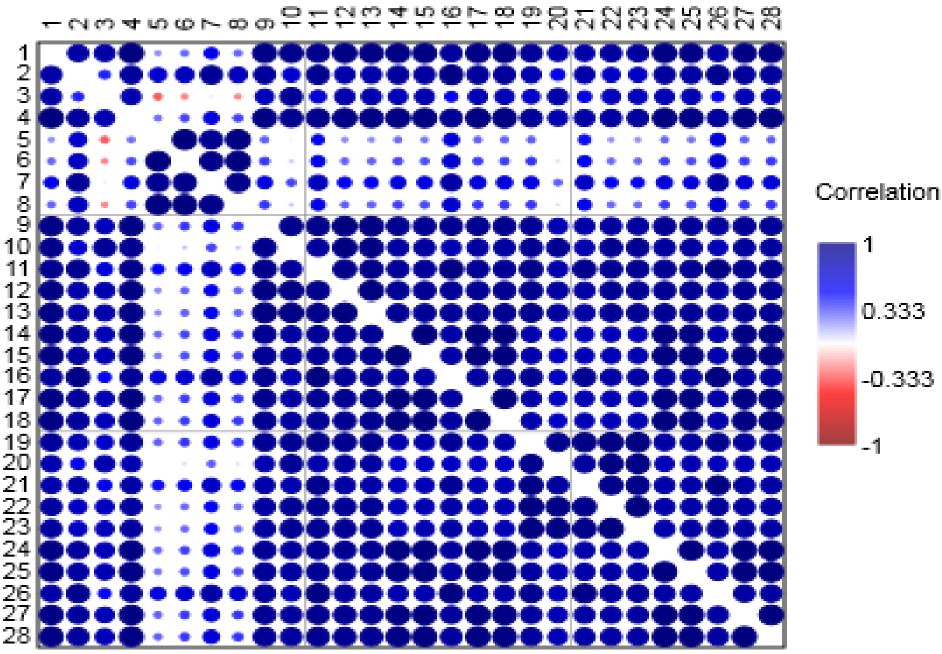

Fig. (2). Plot Pearson's correlation coefficient among studied traits at the three cuts, as well as the mean and total of the three cuts across the three experimental factors. The treatment's key names can be found in Table (8).

Table (8). Results of PCA in the first four PCs for the studied traits of pearl millet at the three cuts, as well as the mean and total of the three cuts as affected by the three experimental factors.

No.	Traits	Cuts	PC1	PC2	PC3	PC4
1	Plant height	1st cut	0.21	-0.09	-0.11	-0.11
2		2nd cut	0.19	0.18	-0.12	-0.12
3		3rd cut	0.16	-0.33	-0.07	0.01
4		Mean	0.21	-0.05	-0.11	-0.09
5	Number of tillers	1st cut	0.08	0.45	0.02	-0.03
6		2nd cut	0.10	0.43	0.03	-0.03
7		3rd cut	0.15	0.35	-0.04	0.12
8		Mean	0.10	0.43	0.01	-0.01
9	Fresh forage yield	1st cut	0.20	-0.03	-0.02	-0.44
10		2nd cut	0.19	-0.18	0.10	-0.26
11		3rd cut	0.21	0.05	0.09	-0.08
12		Mean	0.20	-0.08	0.04	-0.33
13		Sum	0.20	-0.08	0.04	-0.33
14	Dry forage yield	1st cut	0.20	-0.04	-0.28	0.00
15		2nd cut	0.20	-0.05	-0.25	0.11
16		3rd cut	0.20	0.13	0.09	-0.20
17		Mean	0.20	-0.03	-0.25	0.04
18		Sum	0.20	-0.03	-0.25	0.03
19	Fresh forage water use efficiency	1st cut	0.20	-0.03	0.29	0.01
20		2nd cut	0.18	-0.18	0.37	0.20
21		3rd cut	0.19	0.06	0.31	0.28
22		Mean	0.19	-0.08	0.33	0.12
23		Sum	0.19	-0.08	0.33	0.12
24	Dry forage water use efficiency	1st cut	0.21	-0.04	-0.18	0.21
25		2nd cut	0.20	-0.05	-0.15	0.31
26		3rd cut	0.20	0.14	0.18	0.00
27		Mean	0.21	-0.03	-0.14	0.25
28		Sum	0.21	-0.03	-0.14	0.24
2023 growing season			-1.46	-3.46	-0.07	0.03
2024 growing season			1.46	3.46	0.08	-0.03
5236 m³ (IR1)			2.03	-0.13	-1.38	-0.62
4760 m³ (IR2)			-2.04	0.13	1.38	0.62
Row			-1.21	-0.10	1.39	-0.86
Hole farming			8.33	-0.58	-0.18	0.50
Broadcasting			-7.12	0.68	-1.21	0.36
Eigenvalues			22.35	4.13	1.21	0.31
Variance (%)			79.81	14.75	4.32	1.12
Cumulative (%)			79.81	94.55	98.88	100.00

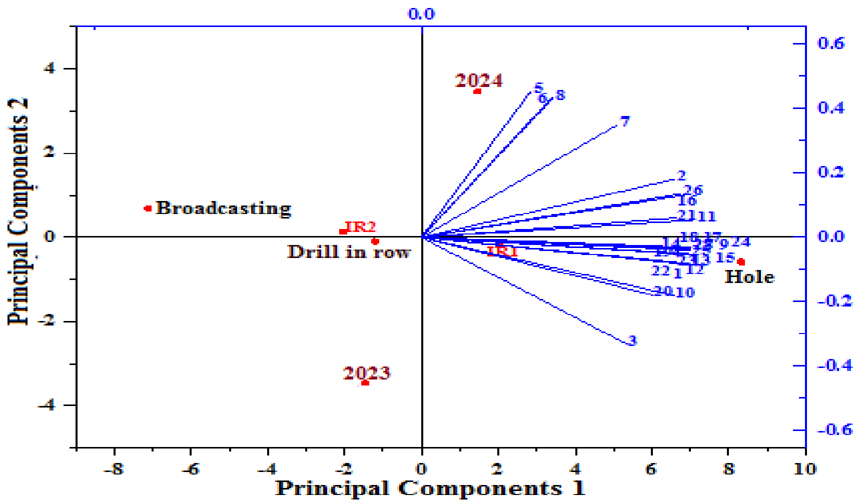

Fig. (3). Biplot diagram between PC1 and PC2 shows relationships between the studied traits at the three cuts, as well as the mean and total of the three cuts across the growing seasons, irrigation rates and planting methods. The treatment's key names can be found in Table (8).

DISCUSSION

The present study evaluated the plant height, number of tillers, fresh and dry forage yields as well as fresh and dry forage water use efficiency of the local cultivar Shandaweel-1 for pearl millet in the west Matrouh region conditions, Matrouh Governorate, Egypt, using three planting techniques under two irrigation rate dates in each of the growing years (2023 and 2024). Plant height (cm), number of tillers/m², fresh forage yield (t/hectare), dry forage yield (t/hectare), fresh forage water use efficiency (kg/m^3) and dry forage water use efficiency (kg/m^3) at all cuts were affected significantly by seasonal changes, irrigation rates and planting methods, according to the ANOVA test. These findings imply that there is variation among the experimental factors under investigation, which implies that the fodder productivity and water use efficiency of pearl millet in the research area can be enhanced. In all seasons, irrigation levels had a significant impact on water usage efficiency, pearl millet yields and their characteristics (Salem and Shoman, 2021). Crookston et al. (2020) mentioned that pearl millet forage dry matter and forage water use efficiency were affected by seasons and irrigation treatments. The plant height, number of tillers, straw production and water use efficiency of pearl millet (Jan et al., 2015 and Hassan et al., 2020) and finger millet (Thakur et al. 2016) are all significantly impacted by the methods used for sowing. In our results, the first- and second-order interactions showed some significant effects on the studied traits at the three cuts as well as the mean and total of the three cuts. Because dry sowing caught more rain, it performed better during the season with heavy rainfall, according to the significant interaction of seasons and sowing techniques (Hassan et al., 2020). The various planting techniques had an impact on plant height and the overall dry fodder yield at the first, second and total of the two pearl millet cuts (Verma et al., 2024). The experiment's high degree of precision was demonstrated by the (CV%) data, which showed that the environmental influence was minimal (<10%) for the majority of examined traits at the three cuts, as well as the mean and total of the three cuts. That would suggest that there are substantial differences between the experimental factors being studied.

Generally, all the studied traits at the first cut outperformed the second and third cuts under all planting methods and irrigation rates in both seasons. The best forage yield and water use efficiency of pearl millet was produced in the (2024) growing season. This season increased plant height and number of tillers at the mean of the three cuts, as well as fresh forage yield, dry forage yield, fresh and dry forage water use efficiency at the total of the three cuts by (0.79, 44.86, 0.20, 2.62, 0.16 and 2.52%) as compared to the (2023) growing season, respectively. The findings are consistent with those of Taha and Ghandour (2021), who reported that under all irrigation regimes, plant height, number of tillers and fresh and dry yields of pearl millet rose somewhat in one season relative to the other.

The best values of studied traits were obtained with (5236 m^3) irrigation rate compared with (4760 m^3) irrigation rate, which increased plant height and number of tillers at the mean of the three cuts, as well as fresh forage yield, dry forage yield and dry forage water use efficiency at the total of the three cuts by (4.42, 3.78, 3.93, 11.80 and 7.01%, respectively). While (4760 m^3) irrigation rate increased fresh forage water use efficiency at the total of the three cats by (0.82%). According to De Almeida et al. (2022), pearl millet's water productivity ranged from (4.5 to 9.0 kg) of dry biomass yield/m^3 of water applied. These outcomes were consistent with those of Hiekal and Khafaga (2021), Taha and Ghandour (2021) and Ausiku et al. (2025), who discovered that as irrigation water increased green forage yield and water use efficiency as well as other traits rose linearly for pearl millet. Under well-irrigated conditions, pearl millet's total dry matter yield rose as the crop took longer to mature (Ausiku et al., 2025). By lowering the green leaf area index and, hence, transpiration, fewer tillers assist the crop to tolerate water stress; however, productivity is reduced (Sowjanya et al., 2021). A moderate amount of insufficient irrigation may be advantageous for irrigated fodder as a water management strategy, especially in areas with scarce water supplies, claim Hussein et al. (2024). Therefore, using the water saved from deficit irrigation to irrigate a larger area can result in a more efficient and sustainable approach to water use.

Effective planting methods are essential for optimizing production and resource use (Bamboriya et al., 2017). Regarding planting methods, the hole farming method outperformed drill in row and broadcasting methods. The hole farming method raised plant height and number of tillers at the mean of the three cuts, as well as fresh forage yield, dry forage yield, fresh and dry forage water use efficiency traits at the total of the three cuts by (6.77, 9.35, 4.77, 17.45, 4.72 and 17.37%) than drill in row method and by (10.715, 13.57, 11.21, 22.29, 11.26 and 22.30%) than broadcasting method, respectively. The pearl millet production and water use efficiency were highest under the ridge-planting approach, which was followed by the bed-planting method, while the broadcasting method had the lowest water use efficiency (Babloo et al., 2015). Bamboriya et al. (2017) found that improved planting methods increased pearl millet growth rates. Abdella and Bairum (2021) state that growing pearl millet on flat beds with (40 cm) between rows is the best method to boost production for forage yield components under irrigation in Sudan. When pearl millet was sown in lines instead of broadcasts, the plants grew more vigorously in terms of height because of improved sunshine, aeration and other micro environmental conditions (Verma et al., 2024). It may be inferred that the seedbed prepared with a chisel plough and sown on dry soil generated the largest grain yield, as the dry sowing technique considerably created the tallest plant (Hassan et al., 2020). Importantly, under broadcast seeding, the minimum heights of pearl millet plants were noted (Verma et al., 2024). According to Ramniwas et al. (2023), planting methods have a significant impact on plant height. They attribute the higher growth with pit approaches to reduced plant density, enhanced light penetration and effective soil moisture and nutrient use.

The hole farming method with a (5236 m^3) irrigation rate in the (2024) growing season boosted the forage production and water use efficiency of pearl millet in the region under study, according to the results of the effect of experimental factors as well as the first and second-order interactions. In both seasons, water consumption efficiencies were impacted by both water regimes (Ausiku et al., 2025). Under full irrigation, a good yield and water use efficiency were observed, indicating the pearl millet crop's potential. In pearl millet, all cultivars' water consumption efficiency rose with moisture stress during the three growth seasons (Ausiku et al., 2025).

Finding important factors affecting folder yield and ware use efficiency is made possible by combining the methods of PCA and correlation coefficient. The reciprocal correlations among most of the variables under research were positive and either significant or insignificant ($p<0.05$ or 0.01) during the seasonal changes, irrigation rates and planting methods at the three cuttings, as well as the mean and total of the three cuts. Plant height, fresh forage yield, dry forage yield, fresh and dry forage water use efficiency traits at the three cuts, as well as the mean and total of the three cuts, showed strong positive relationships ($p<0.05$ or 0.01). Patil et al. (2021) and Goswami et al.

(2023) found similar results and concluded that selecting for these traits will assist in increasing pearl millet's potential production. A similar result was also observed by Sharma et al. (2018), Kumawat et al. (2019) and Patil et al. (2021). Positive and significant correlation of dry fodder yield with plant height, and productive tillers was also reported by Kaushik and Vart (2022). Hence, selection for these characters would help improve the yield potential of this crop (Patil et al., 2021).

PCA has been used to ascertain the relationships between the studied traits across the experimental factors being examined. PC1, PC2, and PC3 account for almost (99%) of the variance in all the variables analyzed under the seasonal changes, irrigation rates and planting methods at the three cuttings as well as the mean and total of the three cuts. PC1 accounted for almost (80%) of the total variability in the measured data for the original variables. High variability for a certain character of a PC is indicated by a high score for the variables in that PC (Shashibhushan et al., 2022). PC1 was influenced by the favorable factors of forage yield and water use efficiency, where the hole farming method under (5236 m^3) irrigation rate in the (2024) growing season were highly and positively connected with all evaluated traits at the three cuts, as well as the mean and total of the three cuts. However, PC2 seems to exhibit the characteristics of the other treatments that are being investigated. Consequently, PC1 and PC2 can be interpreted as reactions to the experimental conditions that impact forage pearl millet production in both positive and negative ways. Based on results by Sayed et al. (2022), the PC1 of total variability for plant height, total fresh yield and total dry yield, along with other variables under study, was (43%). The largest contribution to PC1 was made by total fresh yield. PC1 had a positive correlation with every attribute under study (Triki et al., 2023). According to Sayed et al. (2022), the PC2 of the variance contribution rate was (18%). Plant height and total fresh and dry yields produced negative findings, while other traits produced good results for the PC2 variation. PCA based on the phenotypic correlation demonstrated the importance of studied factors as the main contributing traits for forage yield and water use efficiency of pearl millet. Generally, the statistical analysis of the relationship between the variables studied revealed that local cultivar Shandaweel-1 under the hole farming method with (5236 m^3) irrigation rate in both seasons gave the highest forage yield and water use efficiency of pearl millet in the west Matrouh region conditions, Matrouh Governorate, Egypt.

CONCLUSIONS

Statistically significant differences between the seasonal changes, irrigation rates and planting methods and their interactions for the majority of the traits assessed at the three cuts, as well as the mean and total of the three cuts. The seasonal changes and climate have a significant impact on the production of fodder pearl millet. Positive and significant associations were observed among plant height, fresh forage yield and dry forage yield traits at the three cuts, as well as the mean and total of the three cuts. Based on our statistical analysis, the results showed that the hole farming method under a (5236 m^3) irrigation rate boosted the forage yield of pearl millet for the local cultivar Shandaweel-1 in the west Matrouh region conditions, Matrouh Governorate, Egypt.

ACKNOWLEDGEMENT

The authors extend their sincere thanks and appreciation to the Science and Technology Development Fund (STDF) for funding this work and providing the opportunity to publish this scientific paper. The authors also extend their sincere thanks and appreciation to the Desert Research Center for providing technical and logistical support during the implementation of this work.

REFERENCES

Abdella, A.N.A. and R.S.E. Bairum (2021). Effect of sowing methods and seed rates on growth and forage yield of *Pennisetum glaucum* L. under irrigation in River Nile State, Sudan. Journal of Environmental and Natural Studies, 6 (1): 27-34.

Arslan, N., U. Zulfiqar, M. Ishfaq, M. Ahmad, M. Anwar et al. (2018). Weed control practices and varying sowing dates effects on seed production of Pearl millet (*Pennisetum americanum* L.) under semi-arid environment. American Journal of Plant Sciences, 9 (9): 1974-1986.

Ausiku, P.A., J.G. Annandale, M.J. Steyn and A. Sanewe (2025). Growth analysis of pearl millet genotypes grown under different management practices. Agronomy, 15 (4): 767.

Babloo, S., R. Kumar, P. Kumari, S. Meena and R.M. Singh (2015). Effect of planting pattern on productivity and water use efficiency of pearl millet in the Indian semi-arid region. Journal of the Indian Society of Soil Science, 63 (3): 259-265.

Bamboriya, S.D., R.S. Bana, V. Pooniya and Y.V. Singh (2017). Planting density and nitrogen management effects on productivity, quality and water use efficiency of rainfed pearl millet under conservation agriculture. Indian Journal of Agronomy, 62 (3): 363.

Bhattarai, B., S. Singh, C.P. West, G.L. Ritchie and C.L. Trostle (2020). Effect of deficit irrigation on physiology and forage yield of forage sorghum, pearl millet, and corn. Crop Science, 60 (4): 2167-2179.

Ceasar, S.A. and A. Baker (2025). Millets for food security and agricultural sustainability. Planta, 261: 39.

Chattha, M.U., A. Iqbal, M.U. Hassan, M.B. Chattha, W. Ishaque et al. (2017). Forage yield and quality of sweet sorghum as influenced by sowing methods and harvesting times. Journal of Basic and Applied Sciences, 13: 301-306.

Crookston, B., B. Blaser, M. Darapuneni and M. Rhoades (2020). Pearl millet forage water use efficiency. Agronomy, 10 (11): 1672.

De Almeida, A.M., R.D. Coelho, T.H. Da Silva Barros, J. De Oliveira Costa, C.A. Quiloango-Chimarro et al. (2022). Water productivity and canopy thermal response of pearl millet subjected to different irrigation levels. Agricultural Water Management, 272: 107829.

Du, X., W. Jin, X. Chen, L. Kong, W. Wu and M. Xi (2024). Raised bed planting pattern improves root growth and nitrogen use efficiency of post-rice wheat. Journal of Soil Science and Plant Nutrition, 24: 4086-4098.

El-Hashash, E.F., A.M. Al-Habeeb, H. Bakri and A.Y. Majjami (2023). A comprehensive review of pearl and small millets: taxonomy, production, breeding and future prospects in Saudi Arabia. Asian Journal of Research in Crop Science, 8 (4): 151-166.

Farooq, M., M. Hussain, S. Ul-Allah and K.H. Siddique (2019). Physiological and agronomic approaches for improving water-use efficiency in crop plants. Agricultural Water Management, 219: 95-108.

Ge, J., Y. Xu, M. Zhao, M. Zhan, C. Cao, C. Chen and B. Zhou (2022). Effect of climatic conditions caused by seasons on Maize yield, kernel filling and weight in central China. Agronomy, 12 (8): 1816.

Gomes, F.P. (2009). In 'Curso de estatística experimental'. 15ed. Piracicaba: Esalq. p477.

Gonzalez, V.H., E.A. Lee, L.N. Lukens and C.J. Swanton (2019). The relationship between floret number and plant dry matter accumulation varies with early season stress in Maize (*Zea mays* L.). Field Crops Research, 238: 129-138.

Goswami, P.A., P.R. Patel, H.S. Patel and H.R. Chavda (2023). Correlation and path coefficient analysis for grain yield and its attributes in pearl millet (*Pennisetum glaucum* (L.) R. Br.). The Pharma Innovation Journal, 12 (12): 2151-2154.

Halilou, O., Y. Assefa, H. Falalou, H. Abdou, B.F. Achirou, S.M.A. Karami, S.V.K. Jagadish (2020). Agronomic performance of pearl millet genotypes under variable phosphorus, water, and environmental regimes. Agrosystems, Geosciences and Environment, 3: e20131.

Hassan, S.K., O.A. Bakhit and T.E. Ahmed (2020). Effect of sowing techniques on yield and rainfall productivity of pearl millet in gardud soil of North Kordofan State. Journal of Agricultural Sciences, 65 (1): 37-46

Hiekal, H.A.M. and H.S. Khafaga (2021). Integrated management package to maximize productivity of forage pearl millet under marginal soil and water resources of North Sinai, Egypt. Journal of Soil Sciences and Agricultural Engineering, 12 (7): 481-490

Hussein, M.A., A. Haileslassie, M.B. Derseh, T.T. Assefa, F.T. Riga et al. (2024). Enhancing irrigated forage crop production through water and nutrient management in the Ethiopian sub-humid highlands. Frontiers in Sustainable Food Systems, 8: 1373698.

Jan, A., I. Khan, S. Ali, Amanullah and A. Sohail (2015). Sowing dates and sowing methods influenced on growth, yield and yield components of pearl millet under rainfed conditions. Journal of Environment and Earth Science, 5 (1): 105-109.

Kaushik, J. and D. Vart (2022). Correlation between yield and yield-related traits in pearl millet germplasm lines. Forage Research, 47 (4): 432-435.

Kumawat, K.R., N.K. Sharma and N. Sharma (2019). Genetic variability and character association analysis in pearl millet single cross hybrids under dry conditions of Rajasthan. Electronic Journal of Plant Breeding, 10 (3): 1067-1070.

Maharajan, T, T.P.A. Krishna, N.M. Krishnakumar, M. Vetriventhan, H. Kudapa and S.A. Ceasar (2024). Role of genome sequences of major and minor millets in strengthening food and nutritional security for future generations. Agriculture, 14 (5): 670.

Page, A.I., R.H. Miller and D.R. Keeney (1982). Methods of Soil Analysis. Part II. In ‘Chemical and Microbiological Methods’. 2nded. American Society of Agronomy, Madison, WI, USA, pp. 225-246.

Patil, S.H., P.B. Wadikar, D.N. Dhutraj and P.R. Sargar (2021). Correlation analysis for grain yield and its components in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Madras Agricultural Journal, 108 (4–6): 169-171.

Qiao, J., G. Li, M. Liu, T. Zhang, Y. Wen et al. (2025). Effects of different planting patterns on growth and yield components of foxtail millet. Agronomy, 15 (4): 840.

Ramniwas, S.M. Kumawat, G. Ola, P. Gautam, S.R. Bhunia et al. (2023). Effect of planting methods, mycorrhiza and zinc fertilization on growth and grain yield of pearl millet (*Pennisetum glaucum*). Indian Journal of Agricultural Sciences, 93 (11): 1225-1230.

Salem, E.M.M. and H.S. Shoman (2021). Impact of irrigation water quantities and soil mulching on pearl millet performance under heat stress conditions. Egyptian Journal of Agronomy, 43 (3): 333-345.

Satyavathi, C.T., S. Ambawat, V. Khandelwal and R.K. Srivastava (2021). Pearl millet: a climate-resilient nutricereal for mitigating hidden hunger and provide nutritional security. Frontiers in Plant Science, 12: 659938.

Sayed, M., M. Rajab and A. Helmy (2022). Phenotypic characterization and genetic divergence of some pearl millet genotypes based on cluster and principal component analysis. Journal of Plant Production, 13 (12): 875-881.

Sharma, A., S.A. Ceasar, H. Pandey, V. Devadas, A.K. Kesavan et al. (2024). Millets: Nutrient-rich and climate-resilient crops for sustainable agriculture and diverse culinary applications. Journal of Food Composition and Analysis, 137: 106984.

Sharma, B., L.K. Chugh, R.K. Sheoran, V.K. Singh and M. Sood (2018). Study on genetic variability, heritability and correlation in pearl millets germplasm. Journal of Pharmacognosy and Phytochemistry, 7 (6): 1983-1987.

Shashibhushan, D., C.V.S. Kumar and R.K.R. Kondi (2022). Principal component analysis for yield and yield-related traits in pearl millet cultivars. Ecology, Environment and Conservation, 28 (Suppl. 6): S104–S107.

Sowjanya, A., C.H. Rao and C.H. Rao (2021). Response of phosphorus on growth and yield of pearl millet, microbial population and system productivity in pearl millet-based cropping systems. Journal of Experimental Agriculture International, 43 (3): 113-124.

Steel, R.G.D. and J.H. Torrie (1980). In 'Principles and procedures of statistics'. 2nd edition. McGraw Hill Book Company Inc., New York.

Taha, A.M. and M. Ghandour (2021). Pearl millet forage productivity under sprinkler irrigation system in sandy soil. Moroccan Journal of Agricultural Sciences, 2 (4): 194-203.

Thakur, A.K., P. Kumar, P. Salam, R.K. Patel and C.R. Netam (2016). Effect of different sowing methods, nutrient management and seed priming on growth, yield attributing characters, yield and economics of finger millet (*Eleusine coracana* L.) at Bastar Plateau. Journal of Pure and Applied Microbiology, 10 (1): 407-415.

Triki, T., L. Bennani, F. Boussora, S. Tlahig, S. Ben Ali et al. (2023). Characterization and trait association analysis of 27 pearl millet landraces in southern Tunisia. Agronomy, 13 (8): 2128.

Verma, A., P. Kumari and Ravinder (2024). Effect of sowing methods and row spacing on growth, yield and economics of multicut sorghum and pearl millet hybrids. Indian Journal of Pure and Applied Biosciences, 12 (3): 58-65.

Zhang, G., Y. Hou, H. Zhang, H. Fan, X. Wen, J. Han and Y. Liao (2022). Optimizing planting pattern and nitrogen application rate improves grain yield and water use efficiency for rain-fed spring maize by promoting root growth and reducing redundant root growth. Soil and Tillage Research, 220: 105385.

تأثير معدلات الري وطرق الزراعة على إنتاجية العلف وكفاءة استخدام المياه للدخن تحت التغيرات الموسمية في محافظة مطروح، مصر

عصام فتحى الحشاش[١]، محمد عبد الحميد عطية[٢]، كريمة محمد العبسى[٣]، أحمد محمد على يوسف[٤]*، حسن محمد الشاعر[٥] وصبحى محمد سلام[٦]

[١]قسم المحاصيل، كلية الزراعة، جامعة الأزهر، القاهرة، مصر
[٢] قسم الانتاج النباتى، مركز بحوث الصحراء، القاهرة، مصر
[٣]وحدة فسيولوجيا البيئة، قسم البيئة النباتية والمراعى، مركز بحوث الصحراء، القاهرة، مصر
[٤]قسم الاستكشاف الجيوفيزيائى، مركز بحوث الصحراء، القاهرة، مصر
[٥]قسم تغذية الحيوان والدواجن، مركز بحوث الصحراء، القاهرة، مصر
[٦]قسم الانتاج الحيوانى والأسماك، كلية الزراعة، جامعة الاسكندرية

تُعدّ طرق الزراعة ومعدلات الري الفعّالة أساسيةً لتحسين إنتاج العلف واستغلال موارد الدخن. أُجريت تجربتان حقليتان خلال عامي (٢٠٢٣ و٢٠٢٤) تحت ظروف منطقة غرب مطروح، محافظة مطروح، مصر، لدراسة تأثير ثلاث طرق من الزراعة (الزراعة فى الجورة، الزراعة على الصفوف، البدار) ومعدلي ري (٤٧٦٠ و٥٢٣٦ م^{٣} للهكتارفى حالتى ١٠٠٪، ١١٠٪ من الاحتياجات الاروائية للدخن) على إنتاجية العلف وخصائص كفاءة استخدام المياه عند ثلاث حشات، بالإضافة إلى متوسط وإجمالي الحشات الثلاث للدخن المحلي شندويل-١. كان للتغيرات الموسمية ومعدلات الري وطرق الزراعة تأثيرات معنوية (p<٠.٠٥ أو ٠.٠١) على ارتفاع النبات (سم)، عدد السيقان/م^{٢}، إنتاج العلف الأخضر (طن/هكتار)، إنتاج العلف الجاف (طن/هكتار)، كفاءة استخدام المياه فى حالة العلف الأخضر (كجم/م^{٣})، وكفاءة استخدام المياه فى حالة العلف الجاف (كجم/م^{٣}) في الثلاث حشات. السنة والمناخ كان لهما تأثير كبير على إنتاج العلف وكفاءة استخدام المياه في الحشات الثلاث. أنتج الدخن شنداويل-١ تحت طريقة الزراعة فى الجور محصولًا أعلى من العلف وكفاءة استخدام المياه من طريقتي الزراعة على الصفوف والبدار في كل من معدلات الري ومواسم النمو. حقق الصنف محصولًا أعلى من العلف وكفاءة استخدام مياه العلف الجاف تحت معدل ري ٥٢٣٦ م^{٣} (١١٠٪ من الاحتياجات الاروائية) مقارنة بمعدل ري ٤٧٦٠ م^{٣} (١٠٠٪ من الاحتياجات الآروائية)، بينما زادت كفاءة استخدام المياه فى حالة العلف الجاف بمعدل ري (٤٧٦٠ م^{٣}) في الحشات الثلاث. هناك ارتباطات إيجابية وهامة بين معظم الصفات المدروسة في جميع الحشات. أظهر تحليل المكونات الرئيسية (PCA) لقائم على الارتباط الظاهري أهمية العوامل المدروسة كصفات رئيسية تساهم في إنتاج العلف وكفاءة استخدام المياه للدخن. بشكل عام، أظهر الدخن أداءً جيدًا تحت طريقة الزراعة بالجور بمعدل ري ٥٢٣٦ م^{٣} فى الحشات الثلاث.