Study of Growth and Yield Traits in Pearl Millet Genotypes under Nitrogen Fertilization (Pennisetum glaucum L.)

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ABSTRACT:

A field experiment was conducted during the summer season of 2025 at the Research Station of the College of Agriculture in Al-Buaitha area to investigate the response of three pearl millet genotypes (Syrian, Egyptian, and Saudi) to different nitrogen fertilization rates. The experiment was arranged as a split-plot design within a randomized complete block design (RCBD) with three replications. Four nitrogen levels (0, 60, 120, and 180 kg N ha^{-1}) were allocated to the main plots, while the three genotypes were assigned to the subplots.The results demonstrated significant differences among the genotypes for most of the evaluated traits. The Saudi genotype exhibited the best overall performance, achieving the highest mean values for plant height (197.49 cm), flag leaf area (118.02 cm^2), leaf chlorophyll content (42.66 SPAD), 1000-grain weight (6.30 g), and total grain yield (1.435 t ha^{-1}). Nitrogen fertilization also significantly influenced the studied traits. The highest values of plant height (170.09 cm) and flag leaf area (86.78 cm^2) were obtained with 180 kg N ha^{-1}, whereas the application of 120 kg N ha^{-1} resulted in the highest leaf chlorophyll content (43.21 SPAD), 1000-grain weight (5.96 g), and total grain yield (1.205 t ha^{-1}) .Furthermore, the genotype × nitrogen fertilization interaction had a significant effect on several traits. The maximum interaction values reached 221.30 cm for plant height, 120.18 cm^2 for flag leaf area, 44.38 SPAD for leaf chlorophyll content, 6.96 g for 1000-grain weight, and 1.527 t ha^{-1} for total grain yield. Overall, the results indicate that both genotype and nitrogen supply, as well as their interaction, play an important role in improving the growth characteristics and grain productivity of pearl millet under the conditions of the study.

Keywords: Nitrogen fertilization; Growth and yield characteristics; Genotypes; Pearl millet.

1. Introduction:

Pearl millet [*Pennisetum glaucum* (L.)] is considered one of the oldest cereal crops cultivated since ancient times. Its widespread importance is largely attributed to its high adaptability to diverse environmental conditions, particularly harsh environments [1]. Consequently, pearl millet is extensively cultivated in arid and semi-arid regions of the world, where it represents an important food crop in desert and semi-desert ecosystems. Its nutritional significance is mainly associated with its content of essential nutrients and minerals, particularly protein, iron, and zinc, which enhances its role in alleviating malnutrition and contributing to food security [2]. Pearl millet is predominantly cultivated in tropical dry and semi-dry regions, particularly in Asia and Africa, with a global cultivated area estimated at approximately 30 million hectares [3]. The crop also accounts for a substantial proportion of global millet production and constitutes a staple food for nearly 90 million people, particularly in the African Sahel and northwestern India [4]. Pearl millet grains are characterized by high nutritional value owing to their

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richness in energy, carbohydrates, and dietary fiber. In addition, the grains contain considerable amounts of protein, ranging from 8–19%, and fat, ranging from 3–8%, together with minerals, antioxidant compounds, and resistant starch, which collectively contribute to their nutritional and health-promoting value [5]. Pearl millet grains also provide several important vitamins, including thiamine, riboflavin, and niacin, as well as essential minerals such as magnesium, iron, potassium, phosphorus, zinc, copper, and manganese [2]. Another important nutritional characteristic of pearl millet is that it is naturally gluten-free and has a low glycemic index, making it a suitable dietary option for individuals with gluten intolerance as well as those with diabetes [7]. The importance of pearl millet is particularly evident in marginal agricultural areas because of its ability to grow and produce under low-fertility soil conditions and to withstand harsh environmental and climatic conditions that limit the successful cultivation of many other cereal crops [8]. Among the major nutritional factors affecting plant growth and productivity, nitrogen plays a fundamental role in the synthesis of essential biological compounds, particularly proteins, nucleic acids, and chlorophyll. Accordingly, an adequate supply of nitrogen contributes to enhanced vegetative growth and improved photosynthetic efficiency, which in turn can directly or indirectly increase crop productivity [9]. Although nitrogen constitutes approximately 78% of the atmosphere, it occurs predominantly as molecular nitrogen gas (N_2), a form that cannot be directly utilized by plants. Therefore, atmospheric nitrogen must be converted into chemically available forms through a series of biological and chemical processes occurring in the soil. These processes result in the formation of nitrogen compounds that can be absorbed and utilized by plants, including ammonia (NH_3) and nitrates [10].

The study aimed to evaluate the effects of different nitrogen fertilization levels on the growth and yield traits of several pearl millet (Pennisetum glaucum L.) genotypes, determine their responses to nitrogen fertilization, and identify the genotype and nitrogen fertilization level for improving growth and increasing yield under the prevailing environmental conditions.

2. Materials and Methods:

This field experiment was conducted during the summer growing season of 2025 at the Research Station of the College of Agriculture in the Al-Buaitha area, along the Euphrates River, to evaluate the performance of three pearl millet genotypes under different levels of nitrogen fertilization. The experiment was laid out according to a split-plot arrangement within a randomized complete block design (RCBD), with three replications. The main plots were assigned to four nitrogen fertilization levels: 0, 60, 120, and 180 kg N ha^{-1}, whereas the subplots comprised three pearl millet genotypes, namely Syrian, Egyptian, and Saudi.

Prior to sowing, the experimental field was prepared by ploughing, levelling, and smoothing, and subsequently divided into 36 experimental plots, each measuring 2 × 2 m, with a total plot area of 4 m^2. Each plot consisted of four rows spaced 60 cm apart, with a spacing of 25 cm between hills within each row. Sowing was carried out manually on April 7, 2025, using 2–3 seeds per hill. The seeds were lightly covered with sandy soil to facilitate germination and seedling emergence. Immediately after sowing, the plots were lightly irrigated, followed by subsequent irrigation according to crop requirements and soil moisture sensor readings.

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Hills in which seeds failed to germinate were subsequently replanted to ensure uniform plant establishment. Thinning was performed one to two weeks after germination by removing excess seedlings and retaining one healthy plant per hill. Nitrogen fertilizer was applied in two equal or scheduled applications, with the first application at seedling emergence and the second at the elongation stage [10].

Table 1 shows the physical and chemical properties of soil

characteristics	**values**	**Units measurement**
Soil reaction	**7.6**	**DC Siemens^{-1}**
EC	**4**	**microgram gm^{-1}**
Available Nitrogen	**15.7**	**microgram gm^{-1}**
Phosphor Available	**16.37**	**microgram gm^{-1}**
Potassium Available	**210.19**	**microgram gm^{-1}**
Organic matter	**1.3**	**%**
CEC	**6.5**	**Milli- equivalent/100 g/L**

Traits studied

1. Plant height (cm): Plant height was recorded for ten representative plants randomly selected from the central rows of each experimental plot. Measurements were taken from the soil surface up to the node bearing the panicle, and the average value of the selected plants was used for statistical analysis.

2. Flag leaf area (cm²): The flag leaf area was estimated using ten randomly selected plants from the central rows of each experimental plot. Measurements were obtained according to the procedure proposed by [11] using leaf length and maximum leaf width in the following equation:

$$A = K \times L \times W$$

Where:
A = flag leaf area (cm²)
L = flag leaf length (cm)
W = maximum flag leaf width (cm)
K = constant factor (0.75).

3. Leaf chlorophyll content (SPAD): Chlorophyll content was assessed at the flowering stage using a SPAD chlorophyll meter. Readings were obtained from three leaves of each of ten randomly selected plants per experimental plot. The mean of the recorded readings was calculated and used to represent the chlorophyll content of the respective experimental plot.

4. Thousand-grain weight (g): Following grain harvesting, 1,000 grains were randomly selected from each experimental plot and weighed using a precision electronic balance. The recorded weight was expressed in grams and considered the thousand-grain weight.

5. Grain yield (t ha^{-1}): At maturity, ten representative plants were randomly selected from the central rows of each experimental plot. The grains obtained from these plants were weighed, and the resulting grain weight was converted to grain yield and expressed as tonnes per hectare (t ha^{-1}).

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3. Results and discussion:

3.1 Plant height (cm):

The results presented in Table (2) demonstrated significant differences in plant height among the pearl millet genotypes and nitrogen fertilization. The genotype × nitrogen fertilization interaction also exerted a significant effect on this trait in the season. The Saudi genotype recorded the highest mean plant height, reaching 197.49 cm, respectively, whereas the Syrian genotype exhibited the lowest mean, recording 80.64 cm, respectively. The superiority of the Saudi genotype in plant height may be attributed to its genetic characteristics and greater adaptation to the prevailing environmental conditions, which could have promoted cell division and elongation, consequently enhancing vegetative growth [12]. Similar findings were reported by [13] [14] [15].

Nitrogen fertilization also significantly affected plant height, as an increase in nitrogen application resulted in a corresponding increase in this trait. The highest mean plant height was recorded at 180 kg N ha^{-1}, reaching 170.09 cm, whereas the control treatment (0 kg N ha^{-1}) recorded the lowest mean of 143.50 cm. The positive response of plant height to increasing nitrogen levels may be explained by the role of nitrogen in promoting vegetative growth through stimulating cell division and elongation, as well as enhancing overall plant development [16]. These results are consistent with the findings [17] [18].

The genotype × nitrogen fertilization interaction was significant for plant height in both seasons. The Saudi genotype fertilized with 180 kg N ha^{-1} achieved the highest mean plant height, reaching 221.30 cm, while the Syrian genotype under the control treatment recorded the lowest mean, at 72.08 cm. This significant interaction indicates that the response of plant height to nitrogen fertilization varied among the genotypes, reflecting differences in their genetic potential and ability to utilize the supplied nitrogen under the prevailing environmental conditions.

Table (2): shows the effect of genotypes, nitrogen fertilization levels, and their interaction Plant height (cm) of pearl millet.

Nitrogen fertilization	**Plants genotype**			**Average of nitrogen fertilization**
	Syrian	**Egyptian**	**Saudi**	
0	72.08	173.51	184.92	143.50
60	80.97	190.04	190.11	153.71
120	82.97	196.80	193.62	157.80
180	86.53	202.46	221.30	170.09
Average genotypic plant	80.64	190.70	197.49	

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L.S.D 0.05	**Nitrogen fertilization**	**Plant genotype**	**Interaction**	
	4.349	2.359	5.344	

3.2 Flag leaf area (cm²):

The data presented in Table (3) indicated that genotype, nitrogen fertilization level, and their interaction significantly affected flag leaf area. Among the genotypes evaluated, the Saudi genotype exhibited the greatest flag leaf area, with a mean value of 118.02 cm² plant⁻ ¹. The Egyptian genotype ranked second, recording 114.70 cm² plant⁻ ¹, and its value was statistically comparable with that of the Saudi genotype. In contrast, the Syrian genotype showed a markedly lower mean flag leaf area of 21.99 cm² plant⁻ ¹. The observed genotypic differences could be attributed to variations in genetic constitution and the ability of each genotype to adapt to and exploit the prevailing environmental conditions. The larger flag leaf area of the Saudi genotype may also be associated with its superior plant height and branching characteristics, which may have contributed to enhanced leaf development. In addition, genetic differences in growth habit, leaf dimensions, position of the flag leaf on the stem, and leaf orientation may have contributed to the variation observed in this trait. Similar genotypic variation in flag leaf area has been reported by [19] [20].

Nitrogen fertilization significantly influenced flag leaf area. The highest mean value, 86.78 cm² plant⁻ ¹, was obtained with the application of 180 kg N ha⁻ ¹, whereas the control treatment without nitrogen recorded the lowest mean value of 83.98 cm² plant⁻ ¹. The increase in flag leaf area with increasing nitrogen availability may be explained by the essential role of nitrogen in promoting vegetative growth, cell division, and cell expansion, as well as in enhancing nutrient uptake and assimilation. These processes contribute to greater leaf development and expansion. Since the flag leaf is an important source of assimilates during the reproductive stage and contributes substantially to grain filling, its greater surface area may enhance photosynthetic capacity and assimilate production during grain development [21]. The present findings are in accordance with those of [22].

The interaction between genotype and nitrogen fertilization level also had a significant effect on flag leaf area. The highest value was recorded by the Saudi genotype supplied with 180 kg N ha⁻ ¹, reaching 120.18 cm² plant⁻ ¹. In contrast, the lowest value of 20.95 cm² plant⁻ ¹ was obtained from the Syrian genotype under the same nitrogen level. The contrasting responses among genotypes indicate differences in their capacity to utilize and respond to the supplied nitrogen. The pronounced response of the Saudi genotype may reflect its superior genetic potential for nutrient utilization and leaf development, allowing it to benefit more effectively from the applied nitrogen and consequently produce a larger flag leaf area.

Table (3): The effect of genotypes, nitrogen fertilization levels, and interaction **Flag leaf area (cm²)** of pearl millet.

Nitrogen fertilization	**Plants genotype**			**Average of nitrogen fertilization**
	Syrian	**Egyptian**	**Saudi**	
0	21.77	112.78	117.39	83.98
60	22.42	114.20	118.65	85.09
120	20.95	114.52	115.88	83.78
180	22.84	117.31	120.18	86.78
Average genotypic plant	21.99	114.70	118.02	
L.S.D 0.05	**Nitrogen fertilization**	**Plant genotype**	**Interaction**	
	0.827	0.787	1.440	

3.3 Leaf chlorophyll content (SPAD)

The findings of Table (4) demonstrated that pearl millet genotypes, nitrogen fertilization levels, and their interaction significantly influenced total leaf chlorophyll content during the growing season. Among the genotypes, the Saudi genotype attained the highest chlorophyll content, with a mean of 42.66 SPAD, whereas the Syrian genotype recorded the lowest mean value of 41.14 SPAD. The observed differences among genotypes may be associated with their inherent genetic variability and differences in their physiological responses to the prevailing environmental conditions. The relatively higher chlorophyll content of the Saudi genotype may also be related to its better performance in other vegetative growth traits, which could have contributed to greater chlorophyll accumulation in the leaves [24]. Similar genotypic differences were reported by [25].

Nitrogen application also exerted a significant effect on leaf chlorophyll content. The treatment receiving 120 kg N ha^{-1} resulted in the highest mean chlorophyll value of 43.21 SPAD, whereas the unfertilized control treatment produced the lowest value of 40.29 SPAD. The increase in chlorophyll content in response to nitrogen application can be attributed to the fundamental role of nitrogen in chlorophyll biosynthesis and the formation of photosynthetic pigments. Adequate nitrogen availability promotes the

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development of metabolically active leaves and supports the synthesis of chlorophyll, thereby increasing leaf chlorophyll concentration. Under the conditions of the present experiment, the application of 120 kg N ha^{-1} appeared to provide a suitable nitrogen supply for maintaining higher chlorophyll content [26]. This result agrees with the findings of [27].

The interaction between genotype and nitrogen fertilization level was also significant for leaf chlorophyll content. The highest interaction value was obtained from the Saudi genotype supplied with 120 kg N ha^{-1}, which recorded 44.38 SPAD. In contrast, the lowest value, 40.03 SPAD, was observed in the Syrian genotype under the control treatment. The significant interaction indicates that chlorophyll accumulation was influenced by the combined effects of genotype and nitrogen availability. The contrasting responses among genotypes may reflect differences in their genetic capacity to absorb and utilize nitrogen, as well as differences in their physiological efficiency in converting the available nitrogen into chlorophyll and other components associated with photosynthetic activity.

Table (4): shows the effect of nitrogen fertilization levels, genotypes, and their interaction **Leaf chlorophyll content (SPAD)** of pearl millet.

Nitrogen fertilization	**Plants genotype**			**Average of nitrogen fertilization**
	Syrian	**Egyptian**	**Saudi**	
0	40.03	40.65	40.20	40.29
60	40.85	41.46	42.66	41.65
120	42.15	43.09	44.38	43.21
180	41.55	42.79	43.42	42.59
Average genotypic plant	41.14	42.00	42.66	
L.S.D 0.05	**Nitrogen fertilization**	**Plant genotype**	**Interaction**	
	0.6387	0.4467	0.8979	

3.4 Thousand-grain weight (g):

According to the results shown in Table (5), genotype, nitrogen fertilization level, and the interaction between these factors had significant effects on thousand-grain weight. The Saudi genotype produced the highest mean value, reaching 6.30 g, and

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was significantly superior to the other genotypes. Conversely, the Syrian genotype recorded the lowest mean thousand-grain weight, at 3.40 g. Variation in thousand-grain weight can arise from both genetic and environmental influences, as environmental conditions determine the extent to which the genetic potential of a genotype can be expressed. The differences among the tested genotypes may also be related to their ability to produce and accumulate assimilates within the developing grains, leading to variation in the degree of grain filling and, consequently, grain weight. Comparable results were reported by[28].

Nitrogen fertilization significantly affected thousand-grain weight, with the response increasing as nitrogen availability increased up to 120 kg N ha^{-1}. The highest mean value was obtained at this level, reaching 5.96 g, while the control treatment (0 kg N ha^{-1}) gave the lowest value of 4.61 g. The improvement in grain weight under adequate nitrogen supply may be explained by the role of nitrogen in stimulating vegetative development and maintaining photosynthetic activity, which increases the production of assimilates and dry matter. A greater supply of photosynthetic products during the grain-filling period can enhance their translocation and deposition in the developing grains. Furthermore, sufficient nitrogen may prolong the functional period of the leaves, thereby sustaining assimilate production for a longer duration and supporting more effective grain filling. These physiological effects may ultimately result in heavier grains[29]. This explanation is supported by while similar responses have been documented by[27] [28] [30].

The genotype × nitrogen fertilization interaction was significant for thousand-grain weight. The combination of the Saudi genotype with 120 kg N ha^{-1} produced the highest value, recording 6.96 g, whereas the Syrian genotype grown without nitrogen fertilizer recorded the lowest value of 3.12 g. This differential response suggests that the genotypes varied in their ability to utilize the available nitrogen and translate it into grain development. The superior response of the Saudi genotype may be associated with greater efficiency in photosynthesis and assimilate production under adequate nitrogen availability. These assimilates can subsequently be transported from source tissues to the developing grains, where their accumulation promotes grain filling and increases final grain weight.

Table (5): The influence of genotypes, nitrogen fertilization levels and their interaction **Thousand-grain weight (g):** of pearl millet.الف

Nitrogen fertilization	**Plants genotype**			**Average of nitrogen fertilization**
	Syrian	**Egyptian**	**Saudi**	
0	3.30	6.53	6.58	4.61
60	3.31	6.53	6.58	5.47
120	4.17	6.76	6.96	5.96

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180	3.12	5.18	5.79	4.69
Average genotypic plant	3.40	5.85	6.30	
L.S.D 0.05	**Nitrogen fertilization**	**Plant genotype**	**Interaction**	
	0.3239	0.1972	0.4210	

3.5 Grain yield (t ha^{-1}):

The data presented in Table (6) showed that both genotype and nitrogen fertilization, as well as their interaction, had a significant influence on the overall grain yield across growing seasons. The Saudi genotype achieved the highest mean grain yield, reaching 1.435 t ha^{-1}, and was significantly superior to the Syrian genotype. However, its yield was statistically comparable with that of the Egyptian genotype, which recorded a mean of 1.433 t ha^{-1}. The Syrian genotype produced the lowest grain yield, with an overall mean of 0.438 t ha^{-1}. The superior productivity of the Saudi genotype may be related to its genetic constitution and its greater adaptation to the environmental conditions prevailing during the experiment. In addition, its better performance in important yield components, particularly grain number and thousand-grain weight, likely contributed to its higher final grain yield. Since these components directly influence yield formation, their improvement can result in a substantial increase in total grain production[29]. Similar genotype-related differences in grain yield have been reported by [13] [12] [31] [15].

Nitrogen fertilization also produced a significant response in grain yield. Grain production increased progressively with nitrogen application and reached its maximum at 120 kg N ha^{-1}, where the mean yield was 1.205 t ha^{-1}. In comparison, the unfertilized treatment produced the lowest mean yield of 1.035 t ha^{-1}. The positive response to nitrogen may be attributed to its essential function in regulating plant growth and several physiological and metabolic processes. Adequate nitrogen nutrition enhances vegetative development, photosynthetic performance, and the formation of protein and carbohydrate compounds, thereby increasing the production of assimilates available for reproductive growth. Improved nitrogen status may also facilitate the movement of these assimilates toward the developing reproductive structures and grains, ultimately promoting yield formation[16]. The present results are in agreement with those reported by [27] [30] [32].

Table(6): The influence of genotypes, nitrogen fertilization levels and their interaction **Grain yield (t ha^{-1})** of pearl millet.

Nitrogen fertilization	**Plants genotype**			**Average of nitrogen fertilization**
	Syrian	**Egyptian**	**Saudi**	
0	0.425	1.338	1.396	1.053
60	0.459	1.501	1.527	1.162
120	0.496	1.594	1.524	1.205
180	0.372	1.301	1.295	0.989
Average genotypic plant	0.438	1.433	1.435	

L.S.D 0.05	**Nitrogen fertilization**	**Plant genotype**	**Interaction**
	0.05166	0.04772	N.S

4. Conclusions

The findings of this study confirmed that genotype and nitrogen fertilization significantly influenced the growth and yield characteristics of pearl millet. Significant genetic differences were observed among the evaluated genotypes for several traits, including plant height, flag leaf area, leaf chlorophyll content, 1000-grain weight, and grain yield. Among the tested genotypes, the Saudi genotype exhibited superior performance compared with the Egyptian and Syrian genotypes for most of these traits, with significant differences detected at $P<0.05$. Nitrogen fertilization generally promoted gradual improvements in growth and yield characteristics, with the 180 kg N ha^{-1} treatment producing the highest response for several traits. However, increasing nitrogen supply beyond the optimum level was associated with a slight decline in 1000-grain weight and total grain yield, suggesting that excessive nitrogen application may not necessarily enhance productivity. Furthermore, the significant genotype × nitrogen fertilization interaction demonstrated that genotypes differed in their responses to nitrogen availability. Therefore, selecting well-adapted genotypes and optimizing nitrogen fertilization rates are essential for achieving improved growth performance and grain productivity of pearl millet under the conditions of the study.

5. Recommendations

•Genotype selection: The Saudi genotype is recommended for cultivation

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and future breeding programs due to its superior performance in several grain quality traits.

•Nitrogen management: Application of 120 kg N ha^{-1} is recommended as an appropriate rate for improving grain quality, particularly protein and ash content, while maintaining carbohydrate accumulation.

•Integrated management: Nitrogen fertilization should be adjusted according to genotype response to achieve better productivity and grain quality.

•Extension: The recommended genotype and nitrogen level should be promoted through agricultural extension programs to support sustainable pearl millet production.

6. References

[1] Rai, K. N., Govindaraj, M., & Rathore, A. (2024). Pearl millet: A climate-resilient nutritious cereal crop for drylands. Crop Science, 64(1), 1–19. https://doi.org/10.1002/csc2.21045

[2] Ghatak, A., Chaturvedi, P., Bachmann, G., Valledor, L., Ramšak, Ž., Bazargani, M. M., ... & Weckwerth, W. (2021). Physiological and proteomic signatures reveal mechanisms of superior drought resilience in pearl millet compared to wheat. Frontiers in Plant Science, 11, 600278.

[3] Baby, J., Ganesan, N. M., Ganesan, K. N., Sivakumar, S. D., Chandrasekhar, C. N., & Sobhakumari, V. P. (2023). Stomatal studies on colchicine treated bajra napier hybrids (Pennisetum glaucum× P. purpureum). Agricultural Science Digest, 43(5), 610-615.

[4] Shivali Sharma, Rajan Sharma, Mahalingam Govindaraj, Rajendra Singh Mahala, Tara Satyavathi C., Rakesh Srivastava K., et al. (2020). Harnessing wild relatives of pearl millet for germplasm enhancement: Challenges and opportunities.

[5] Uppal, R. K., Wani, S. P., Garg, K. K., & Alagarswamy, G. (2015). Balanced nutrition increases yield of pearl millet under drought. Field Crops Research, 177, 86–97.

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

[7] Al-Naimi, M. I. A., Ali, S. B., & Muhammad, A. M. (2011). The effect of using local millet seeds on the chemical composition of Awassi lamb carcasses. Kirkuk University Journal of Agricultural Sciences, 2(2).

[8] Stavropoulos, P., Papastylianou, P., & Markellou, E. (2025). Effects of plant density and type of fertilizer on nutritional composition of seeds. Agronomy, 15(12), 2738.

[9] Triki, H., et al. (2023). Characterization and trait association analysis of 27 pearl millet accessions for agronomic traits. Agronomy, 13(8), 2128

[10] Yang, S., et al. (2022). Optimizing nitrogen fertilization and variety for millet grain yield and biomass formation. Agronomy, 12(9), 2116. https://doi.org/10.3390/agronomy12092116

[11] Joshi, N. L., & Yadav, M. S. (1982). Leaf area determination in pearlmillet (Pennisetum americanum L. Leeke). Indian Botanical Reporter, 1(1), 73–74.

ISSN 2072-3857

[12]Sawsan, H. K., Bakhit, O. A., & Ahmed, T. E. 2020. Effect of sowing techniques on yield and rainfall productivity of pearl millet in gardud soil of north Kordofan state. Journal of Agricultural Sciences (Belgrade), 65(1), 37-46.

[13] Sabbar Sayel, N. M., & Al-Rifai, S. I. M. (2023). Study of some yield characteristics of genotypes of Sudanese millet under different planting dates. Al-Muthanna Journal for Agricultural Sciences, 10(Supplement 1). https://doi.org/10.52113/mjas04/10.s1/

[14] Babiker, S. A., Khair, M. A., Ali, A. A., Abdallah, M. A., Hagelhassan, A. M., Mohamed, E. I& Tahir, I. S. (2024). Multi-Locational Evaluation of Forage-Suited Selected Sudan Pearl Millet [Pennisetum glaucum (L.) R. Br.] Accessions Identified High-Yielding and Stable Genotypes in Irrigated, Arid Environments. Crops, 4(2), 195-210.

[15] Shubham Shukla, Rajesh Singh, Kumar Raj, and Akankhya Pradhan. (2026). Effect of nitrogen management on growth and yield of pearl millet (Pennisetum glaucum L.) hybrids. International Journal of Advanced Biochemistry Research 2026; SP-10(6): 200-204. https://www.doi.org/10.33545/26174693.2026.v10.i6Sc.8583

[16] Maqtari., & Basbaa (2019) Influence of Nitrogen and Phosphorus on growth and yield of two pearly millet (Pennisetumglaucum (L.) R.Br.) cultivars In DultaTuban. University of Aden Journal of Natural and Applied Sciences, 23(2), 317–330. https://doi.org/10.47372/uajnas.2019.n2.a05

[17] Saikishore, A., Rekha, K. B., Hussain, S. A., & Madhavi, A. (2021). Grain yield, nutrient uptake and post-harvest soil properties of browntop millet under varying sowing windows and nitrogen levels. International Journal of Bio-resource and Stress Management, 12(5), 541-551.

[18]Dharmendra, K., & Umesha, C. (2022). Influence of nitrogen and phosphorus on growth and yield of finger millet Eleusine coracana L.economics of finger millet (Eleusine coracana L.) The Pharma Innovation Journal 2021; 10(11): 723-725

[19]Wankhede, S. Y., Jadhav, J. D., & Kharbade, S. B. 2018. RESPONSE OF KHARIF PEARL MILLET CULTIVARS TO GROWTH ATTRIBUTE UNDER DIFFERENT SOWING WINDOWS.

[20]Khorshid, N. S., & Kalee, H. A. (2025, December). Effect of planting row spacing and nitrogen fertilizer sources on the growth, yield, and quality of pearl millet Pennesitum glaucum. In IOP Conference Series: Earth and Environmental Science (Vol. 1549, No. 1, p. 012138). IOP Publishing.

[21]Tsado, E. K., Jatau, D. B., & Daniya, E. (2016). Performance of finger millet (Eleusine coracana L. Gaertn) as influence by nutrient source in the Sourthern and Northern Guinea Savannah, Nigeria. Direct Research Journal of Agriculture and Food Science, 4(7), 182-192.

[22] Patel, H., & Desai, K. (2020). Effect of nutrient management and spacing on ash content in pearl millet. International Journal of Agricultural Sciences, 16(2), 201–208.

[23] Siddiqui, D. A., Sharma, G. K., Chandrakar, T., Thakur, A. K., & Pradhan, A. (2020). Differential levels of fertilizer and row spacing affects growth and yield of brown top millet)Brachiaria ramosa L.)

ISSN 2072-3857

in Entisols of Bastar Plateau zone of Chhattisgarh. International Journal of Current Microbiology and Applied Sciences, 9(8), 3459–3472.

[24] Korra, V. (2024). The role of nitrogen fixation in combating global food challenges. International Research Journal of Plant Science, 15(6), 01–02. https://doi.org/10.14303/irjps.2024.54

[25]Wang, Y. H., Fan, Y. Q., Han, Y. L., Miao, Z. F., Bie, H., Liu, J. Z., ... & Zhang, X. S. (2023). Effects of planting density and nitrogen application level on the yield and agronomic traits of millet.

[26] Kumar, S., Sharma, P., & Verma, R. (2023). Yield and yield components of pearl millet under different fertilizer regimes. Agricultural Research Journal, 58(2), 150-158

[27]Al-Zuraijawi, Dhu Al-Fiqar Mohammed Wali. (2023). Effect of row spacing and nitrogen fertilization on the growth and yield of millet (Panicum miliaceum L.). College of Agriculture, Al-Muthanna University.

[28]Raza, M. N., Nazeer, S., Ali, M., Sadia, A., & Mubashra, S. (2021). Modeling the Growth and Yield of Pearl Millet (Pennisetum glaucum) Crop. Journal of Agriculture, Food, Environment and Animal Sciences, 2(1), 61-76.

[29]Bharathi, C., Singh, K., & Dawson, J. (2024). Effect of Nitrogen and Zinc on Yield and Economics of Pearl Millet. Journal of Experimental Agriculture International, 46(8), 174-178.

[30]Lakew, S. (2026). Effects of Nitrogen Fertilizer Application Rates and Mung Bean Intercropping on Growth and Yield of Pearl Millet in the Dryland Areas of Waghemra Zone, Amhara Region, Ethiopia. Advances in Agriculture, 2026(1), 2498388.

[31] Yang, S., Wang, L., Akhtar, K., Ahmad, I., & Khan, A. (2022). Optimizing nitrogen fertilization and variety for millet grain yield and biomass accumulation in dry regions. Agronomy, 12(9), 2116.

[32] Palchetti, E., Moretta, M., Calamai, A., Mancini, M., Dell'Acqua, M., Brilli, L., ... & Masoni, A. (2023). Effects of nitrogen fertilization and plant density on proso millet (Panicum miliaceum L.) growth and yield under mediterranean pedoclimatic conditions. Agriculture, 13(9), 1657.

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