Plant Archives Vol. 25, Supplement 1, 2025 pp. 2659-2663 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.366

THE IMPACT OF PLANT DENSITY AND NITROGEN FERTILIZATION ON YIELD ATTRIBUTES AND YIELD IN DUAL-PURPOSE YELLOW SORGHUM (PYPS-2)

Amulya Vemu[1*], G. S. Madhu Bindu[2], B. Padmaja[3] and G. Kiran Reddy[4]
[1]Department of Agronomy, College of Agriculture, Professor Jayashankar Telangana Agricultural University, Rajendranagar -500030, Hyderabad, India.
[2]Examinations Center, Professor Jayashankar Telangana Agricultural University, Rajendranagar -500030, Hyderabad, India.
[3]Department of Agronomy, Water Technology Center, Professor Jayashankar Telangana Agricultural University, Rajendranagar -500030, Hyderabad, India.
[4]Department of Soil science, AICRP on Integrated Farming Systems, Professor Jayashankar Telangana Agricultural University, Rajendranagar -500030, Hyderabad, India.
*Corresponding author e-mail: amulyaennam@gmail.com
(Date of Receiving : 08-11-2024; Date of Acceptance : 10-01-2025)

ABSTRACT

A study was conducted at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *kharif* 2023 to evaluate the effect of plant density and nitrogen levels on the yield attributes and yield of yellow sorghum. The experiment was laid in split-plot design with three plant densities (D_1: 222222 plants ha^{-1} (30cm x 15cm), D_2: 148148 plants ha^{-1} (45cm x 15cm) and D_3: 111111 plants ha^{-1} (60cm x 15cm)) in the main plots and nitrogen levels (N_0: 0 kg N ha^{-1}, N_1: 30 kg N ha^{-1}, N_2: 60 kg N ha^{-1} and N_3: 90 kg N ha^{-1}) in the sub plots and replicated thrice. Moderate plant density (D_2) resulted in highest grain (1439 kg ha^{-1}) and stover yields (fresh: 14,897; dry: 4960 kg ha^{-1}), whereas the highest nitrogen application (N_3) gave the best yields. Plant density had a minor influence on ear head count, ranging from 9-10 per m^2. However, nitrogen application considerably raised ear head counts, with 11-12 at higher nitrogen rates (60-90 kg ha^{-1}) compared to fewer heads at 0 kg ha^{-1}. Wider spacing (D_2 and D_3) and more nitrogen (N_3) increased grain counts per earhead (896 (D_2), 811 (D_3), and 939 (N_3)), resulting in heavier grains weighing 22.6, 19.4, and 23.7 g, respectively. Test weight was negligible across treatments, ranging from 23.2-23.9 g.
***Keywords* :** Nitrogen levels, plant density, yellow sorghum, yield, yield attributes.

Introduction

Sorghum (*Sorghum bicolor*), also known as great millet or jowar is the world's fifth most important cereal crop. It is a climate-resilient cereal and dietary staple food crop for more than 200 million people of the world. In India, "jowar" is used as one of the important food (55%) and fodder (33%) cereal crops, especially in the traditional and small-holder farming sector as stated by Visarada and Aruna (2019), and is cultivated under 4.24 million hectares with a production of 4.78 million tonnes and productivity of 1128 kg ha^{-1} (Anonymous (2021)). It is a reliable crop to resource poor farmers for nutritional and livelihood security as mentioned by Shivprasad and Singh (2017). Sorghum has a high biomass in terms of green and dry fodder yield and plays an important role in meeting the enormous demand for fodder, as opined by Meena *et al*. (2023). In Telangana, it is cultivated in one lakh hectare with production of 1,90,000 tonnes and productivity of 1855 kg ha^{-1} (Anonymous, (2021), out of which 79,100 ha accounting to 70 % is cultivated under rainfed conditions.

More recently sorghum grains with yellow pericarp are gaining more demand in the market due to their high nutritional, good *roti* making and keeping qualities. They are mostly preferred by diabetic patients for their bitterness in the grains. This created a need to increase area and production. The yellow sorghums cultivated in tribal patches of Telangana are low yielding as local land races unable to supply to the demand in the market. So, the Regional Agricultural Research Station (RARS), PJTAU, Palem has developed a high yielding dual purpose yellow sorghum variety - PYPS-2 (Palem Yellow Pericarp Sorghum-2). Utilization of this crop as a livestock feed is increasingly popular in regions characterized by environmental stresses, making it a suitable replacement for corn in animal feeding, as reported by Arroyo *et al*. (2016). Yellow sorghums are tall statured reaching a height of 2.5-3.0 m unlike white sorghums with a height of around 2.0 m. The PYPS-2, a high yielding yellow sorghum variety has high resource use efficiency evident from its tillering capability under high resource availability. The stay green trait of this variety also endorses it to have the capability to efficiently use the resources till the fag end stage of the crop, thus the possibility of achieving higher fodder yield in addition to grain yield at harvest.

Presently, the variety PYPS-2 is recommended to the farmers with the same package of practices as recommended for white sorghum. However, considering its tillering ability, response to fertilisers and moisture and dual-purpose nature, it can be explored for its performance at varying plant densities and nutrient levels. Hence, it is hypothesised that the dual-purpose nature of yellow sorghum may vary at different plant densities and both seed and fodder yield and quality may be enhanced with varied N nutrition. The present field study was carried out with the objective to evaluate the impact of different plant densities and enhanced nitrogen levels on the yield attributes and yield of yellow sorghum.

Materials and Methods

The experiment was conducted at College Farm, College of Agriculture, Professor Jayashankar Telangana Agricultural University (PJTAU), located at Rajendranagar, Hyderabad, during *kharif* 2023 on sandy clay and normal soils, with pH 6.8 and E.C<0.4 dSm^{-1}. The soil was low (235 kg ha^{-1}) in available nitrogen, medium (21 kg ha^{-1}) in available phosphorus and medium (225 kg ha^{-1}) in available potassium. The experiment was laid out in split-plot design with three plant densities D_1: 222,222 plants ha^{-1} (30cm x 15cm), D_2: 148,148 plants ha^{-1} (45cm x 15cm) and D_3: 111,111 plants ha^{-1} (60cm x 15cm) in main plots and four nitrogen levels in sub plots, N_0: 0 kg N ha^{-1}, N_1: 30 kg N ha^{-1}, N_2: 60 kg N ha^{-1} and N_3: 90 kg N ha^{-1} and replicated thrice. The PYPS-2, a high yielding yellow sorghum variety was used in the study. Phosphorus (40 kg ha^{-1}) and potash (30 kg ha^{-1}) in the form of single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively were applied uniformly as basal application at the time of sowing in all the plots, while nitrogen was applied as per the treatments. The observations on number of earheads per m^2, grains per earhead, grain weight per earhead, test weight, grain yield and stover yield were recorded at harvest.

Results and Discussion

Yield attributes

Earheads per m^2

The number of earheads per m^2 in yellow sorghum varied significantly with both plant density and nitrogen levels, though their interaction was not significant (Table 1). The number of earheads per m^2 ranged from 6 to 12 as influenced by the above mentioned factors.

Plant density had a less prominent effect on the development of earheads. Earhead numbers across different densities ranged from 9 to 10 per m^2, with closely spaced plants (30 cm × 15 cm) producing 10 earheads per m^2, and more widely spaced plants (45 cm × 15 cm and 60 cm × 15 cm) yielding 9 earheads per m^2. In denser plant stands, plants compete more intensely for resources like light, water, and nutrients, which can stimulate growth responses that increase the number of reproductive structures, including earheads. This competition encourages plants to maximize their reproductive output for survival and propagation.

Nitrogen application showed a prominent impact on number of earheads per m^2 in yellow sorghum. Earheads per m^2 ranged from 6 to 12 due in response to varying levels of nitrogen application. In comparison to lower N application rates, higher nitrogen levels (60 and 90 kg N ha^{-1}) showed higher earhead counts of 11 and 12 respectively. In contrast, there was a plummet in earhead number in the crop unfertilized with nitrogen (N_0). The above results are in agreement with Dembele *et al.* (2020), who reported that nitrogen has a profound impact on the number of earheads. This can be attributed to the high nitrogen levels enhancing cellular processes and energy production, which support the development of more reproductive structures, including earheads. This effect is especially evident when plants are not nutrient-limited, enabling them to reach their maximum potential for earhead formation.

Grains per earhead

The grain count per earhead in yellow sorghum differed significantly with changes in plant density and nitrogen levels, though their interaction was insignificant. Across these factors, grain counts per earhead ranged from 597 to 939 (Table 1).

The grain number per earhead increased with wider plant spacing. The crop in D_2 (45 cm × 15 cm), and D_3 (60 cm × 15 cm) densities registered comparably higher grain counts of 896 and 811, respectively. In contrast, the lowest grain count was observed in D_1 (639). With fewer plants per unit area in lower densities (D_2 and D_3), light can reach more of the plant canopy, especially the lower leaves. This increase in light interception boosts photosynthesis, providing more energy for the development and filling of grains.

Grain count also varied notably with nitrogen application. Increasing nitrogen rates led to a higher grain count in yellow sorghum. The highest grain count per earhead (939) was achieved with the highest nitrogen rate (N_3-90 kg ha^{-1}), while the lowest count (597) was found in the crop without nitrogen (N_0-0 kg ha^{-1}). These results are similar to those obtained by Mahama *et al*. (2014), who reported that the increase in sorghum grain yield with the increase in nitrogen was attributed to an increase in grain number. Higher nitrogen application provides ample nutrients crucial for cell division and growth, particularly in reproductive structures like grains. Sufficient nitrogen promotes grain filling, resulting in larger and more fully developed grains per earhead.

Grain weight per earhead

Grain weight per earhead in yellow sorghum was significantly affected by both plant density and nitrogen levels, though their interaction was not significant (Table 1).

Higher grain counts at D_2 and D_3 plant densities resulted in the highest grain weights per earhead, measuring 22.4 and 19.6 g, respectively. Conversely, the lowest grain count at the D_1 density led to a lower grain weight of 15.2 g. At moderate plant densities like D_2 (148148 plants ha^{-1}) and D_3 (111111 plants ha^{-1}), plants experience less crowding compared to very high density, allowing them to access adequate sunlight, water, and nutrients. This balanced resource distribution supports grain filling, resulting in higher grain weights per earhead. Conversely, at the denser spacing D_1, plants experience increased competition for these resources, leading to lower grain number and grain weight.

Similarly, the increase in grain count with higher nitrogen application rates also contributed to greater grain weights per earhead. The highest grain weight (23.7 g) was observed at the highest nitrogen rate of 90 kg ha^{-1} (N_3). In contrast, the lowest grain weight of 14.3 g was recorded in N_0 (0 kg N ha^{-1}), due to the lower grain count per earhead. At higher nitrogen rates, there is a significant increase in photosynthesis and nutrient transport to the developing grains, which allows for the development of fuller and heavier grains. The highest grain weight recorded at 90 kg ha^{-1} nitrogen can be attributed to the optimal supply of nitrogen, enhancing the grain filling.

Test weight

The test weight of yellow sorghum showed no significant variation due to differences in plant density, nitrogen levels, or their interaction (Table 1). Across treatments, test weight ranged from 23.2 to 23.9 g, regardless of plant density or nitrogen application. This limited variation could be attributed to uniform growing and soil conditions, such as consistent soil moisture, sunlight, temperature, fertility, texture, and moisture-holding capacity, which likely reduced the impact of these treatments. Additionally, the yellow sorghum variety PYPS 2, known for its resilience to varying conditions, may have maintained consistent test weight across treatments. Furthermore, plants might have employed compensatory growth mechanisms to adapt. For instance, at higher densities, plants might produce fewer but larger kernels to compensate yield, balancing the test weight. Likewise, under low nitrogen, the plants might allocate available resources more efficiently, minimizing the impact on test weight.

Yield

Grain yield

Grain yield is an essential parameter for enhancing productivity, improving resource efficiency, and promoting sustainable farming practices. To maximize grain yield, optimizing plant density and nitrogen levels is crucial. Proper plant density ensures efficient resource use, while adequate nitrogen supports plant growth and grain formation. Balancing these factors prevents issues like overcrowding and nutrient runoff, leading to healthier plants and higher yields. In this study, yellow sorghum's grain yield varied significantly with plant density and nitrogen levels, though their interaction was not significant (Table 1).

Grain yield ranged from 874 to 1439 kg ha^{-1} depending on plant density, with the highest yield

(1439 kg ha^{-1}) at moderate plant density (D_2-45 cm×15 cm), and the lowest (874 kg ha^{-1}) at the highest density (D_1-30 cm×15 cm,). The higher yield in D_2 was likely due to more earheads and heavier grains. Moderate plant density optimizes grain yield by balancing resource use and minimizing competition, allowing plants to access sufficient light, water, and nutrients without overcrowding, as noticed during their study by Fromme *et al.* (2012). This balance is disrupted at low densities (leading to underutilized resources by nutrient leaching as mentioned by Amede and Dialo (2022) and high densities (resulting in excessive competition), both of which reduce yields.

Buah and Mwinkaara (2009) observed that the nitrogen application had a notable impact on grain yield, similar to the observations noted in the present study with the values ranging from 527 to 1776 kg ha^{-1}. Grain yield increased with each added nitrogen level, reaching a peak of 1776 kg ha^{-1} at 90 kg ha^{-1} of nitrogen (N_3), followed by 1330 kg ha^{-1} at 60 kg ha^{-1} (N_2). The lowest yield of 527 kg ha^{-1} was recorded in the absence of nitrogen (N_0), where the crop depended on native soil nitrogen. Desta *et. al.* (2023) noticed similar observations, where grain yield was increased with the increase in nitrogen application. Compared to N_0, grain yield increased by approximately 85, 153, and 237 percent at the N_1 (30 kg ha^{-1}), N_2 (60 kg ha^{-1}) and N_3 (90 kg ha^{-1}) rates, respectively. Similar to the obtained results, improved grain yield in response to the enhanced levels of nitrogen was also observed by Kumar *et al.* (2022). The increased nitrogen enhanced photosynthesis, biomass production, grain filling, and extended growth duration, all contributing to heavier, fuller grains and higher yields which was in line with the opinion of Zhao *et al*. (2005).

Stover yield

Estimating stover yield (fresh and dry) at varying plant densities and nitrogen levels helps optimize livestock feed, resource use, soil health, and bioenergy production, enhancing overall farm productivity. In similar lines with the grain yield, the stover yield (fresh and dry) of yellow sorghum had shown significant differences due to different plant densities and nitrogen levels. Whereas, their interaction was not significant (Table 1).

The stover yield of yellow sorghum followed a similar trend to the grain yield results. The highest stover yield (fresh: 14897; dry: 4960 kg ha^{-1}) was observed in density level D_2, followed closely by D_1 at (fresh: 14206; dry: 4390 kg ha^{-1}), though the difference was statistically significant. The lowest stover yield (fresh: 10104, dry: 3605 kg ha^{-1}) occurred at the D_3 plant density. The higher stover yield at moderate plant density is likely due to an optimal balance between competition for resources and the ability to capture sunlight effectively. In moderate plant density (D_2), plants have enough space for root and canopy development, allowing them to utilize available nutrients and water efficiently, leading to robust growth and biomass accumulation. At higher plant density (D_1), although there are more plants per unit area, intense competition for light, nutrients, and water can limit individual plant growth, reducing the overall stover yield per plant. However, the increased plant population still allows for a substantial total yield, though slightly lower than at moderate density. In low plant density (D_3), plants have ample access to resources but may not fully utilize the available space, leading to a reduced total stover yield per unit area. The lower number of plants limits the overall biomass production despite less competition.

As nitrogen levels increased, fresh stover yields increased ranging from 6737 to 17509 kg ha^{-1} and dry stover yields increased from 2202 to 5807 kg ha^{-1} depending on varying plant densities and nitrogen application rates. The highest stover yield (fresh: 17509, dry: 5807 kg ha^{-1}) was achieved at N_3 (90 kg N ha^{-1}), followed by N_2 (60 kg N ha^{-1}) (fresh: 15469, dry: 5172 kg ha^{-1}), while the lowest yield (fresh: 6737, dry: 2202 kg ha^{-1}) was recorded with no nitrogen application N_0 (0 kg N ha^{-1}). A similar trend of stover yield with nitrogen application was documented by Meh *et al.* (2015). The higher stover yield at increased nitrogen rates compared to no nitrogen application is primarily due to nitrogen's critical role in plant growth and biomass production. Nitrogen is a key component of chlorophyll, the molecule essential for photosynthesis, and it supports the production of amino acids and proteins, all of which are necessary for robust plant development. Kumar and Chaplot (2015) opined that with higher nitrogen rates, plants have an enhanced capacity for photosynthesis, leading to greater energy production and increased biomass accumulation. This contributes to more vigorous vegetative growth, larger leaves, and thicker stems, resulting in a higher stover yield. In contrast, with no nitrogen application, plants must rely solely on the limited nitrogen available in the soil as mentioned by Teshome *et al.* (2023). This deficiency restricts photosynthesis and protein synthesis, leading to stunted growth and reduced biomass, and thus a lower stover yield.

Table 1 : Yield attributes and yield of yellow sorghum in response to plant densities and nitrogen levels

Treatments	No. of earheads per m^2	No. of Grains per earhead	Grain weight per earhead (g)	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	
						Fresh	Dry
Plant densities							
D_1 - 222222 plants ha^{-1} (30cm x 15cm)	10	639	15.2	23.4	874	14206	4390
D_2 - 148148 plants ha^{-1} (45cm x 15cm)	10	896	22.4	23.7	1439	14897	4960
D_3 - 111111 plants ha^{-1} (60cm x 15cm)	9	811	19.6	23.7	1141	10104	3605
SEm(±)	**0.05**	**32**	**0.89**	**0.09**	**17**	**128**	**53**
CD (P=0.05%)	**0.19**	**126**	**3.51**	**NS**	**67**	**504**	**207**
Nitrogen levels							
N_0 - 0 kg N ha^{-1}	6	597	14.3	23.2	527	6737	2202
N_1 - 30 kg N ha^{-1}	8	721	17.2	23.5	973	12561	4094
N_2 - 60 kg N ha^{-1}	12	871	21.1	23.8	1330	15469	5172
N_3 - 90 kg N ha^{-1}	12	939	23.7	23.9	1776	17509	5807
SEm(±)	**0.44**	**37**	**0.75**	**0.18**	**26**	**211**	**65**
CD (P=0.05%)	**1.32**	**111**	**2.24**	**NS**	**76**	**628**	**192**
Interaction effect							
D within N							
SEm(±)	**0.77**	**75**	**1.66**	**0.32**	**49**	**395**	**127**
CD (P=0.05%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
N within D							
SEm(±)	**0.77**	**65**	**1.31**	**0.30**	**44**	**366**	**112**
CD (P=0.05%)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Conclusion

From the above results it can be concluded that the plant densities around 148148 plants ha^{-1} (45 cm × 15 cm) can be recommended for maximizing grain and fodder yields up to 1439 and 14897 kg ha^{-1}, respectively. Both grain (1776 kg ha^{-1}) and fodder (17509 kg ha^{-1}) yields increased with the increasing nitrogen levels, with 90 kg N ha^{-1} being the most effective rate for maximizing productivity of yellow sorghum.

References

Amede, T. and Dialo, A. (2022). Enhancing Agronomic efficiency of fertilizers in Sub-Saharan Africa : Evidence from the field, Growin Africa, **1**(1): 18-22.

Anonymous. (2021). Agricultural statistics at a glance 2021. Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Directorate of Economics and Statistics.

Arroyo, J. Dubois, J.P. Lavigne, F. Brachet, M. and Fortun-Lamothe, M. (2016). Effects of replacing corn with sorghum on the performance of overfed mule ducks. *Poultry Science*, **95**(6): 1304-1311.

Buah, S.S.J. and Mwinkaara, S. (2009). Response of sorghum to nitrogen fertilizer and Plant density in the Guinea Savanna Zone. Journal of Agronomy, 1812-5379.

Desta, K.T. Choi, Y. Shin, M. Yoon, H. Wang, X. Lee, Y. Yi, J. Jeon, Y. and Lee, S. (2023). Comprehensive evaluation of nutritional components, bioactive metabolites and antioxidant activities in diverse sorghum (*Sorghum bicolor* (L.) Moench) landraces. *Food Research International,* **173**: 113390.

Fromme, D.D. Fernandez, C.J. Grichar, W.J. and Jahn, R.L. (2012). Grain sorghum response to hybrid, row spacing and plant populations along the Upper Texas Gulf Coast. *International Journal of Agronomy,* 2012: 930630.

Kumar, R. Makarana, G. Mishra, J.S. and Bhatt, B.P. (2022). Response of sorghum (*Sorghum bicolor*) cultivars to nitrogen in non-traditional areas of Bihar. *Indian Journal of Agricultural Sciences* **92**(9): 1076-1079.

Kumar, D. and Chaplot, P.C. (2015). Performance of multi-cut sorghum genotypes to fertility levels. *Forage Research*, **41**(3): 199-201.

Meena, G.L. Sharma, L. Singh, H. Bairwa, K.C. and Kumar, K. (2023). Cost and return analysis of *kharif* sorghum (*Sorghum bicolor*) in Bhilwara district, Rajasthan. *Agricultural Science digest*, **43**(2): 196-200.

Mahama, G.Y. Prasad, V.P.V. Mengel, D.B. and Tesso, T.T. (2014). Influence of nitrogen fertilizer on growth and yield of grain sorghum hybrids and inbred lines. *Agronomy Journal,* **106**(5): 1623-1630.

Meh, H. Bilkis, T. Khandaker, Z.H. Akbar, M.A. and Khaleduzzaman, A.B.M. (2015). Effect of nitrogen and phosphorus fertilizer on yield and nutritional quality of Jumbo grass (Sorghum Grass × Sudan Grass). *Advances in Animal and veterinary Sciences,* **3**(8): 444-450.

Shivprasad, M. and Singh, R. (2017). Effect of planting geometry and different levels of nitrogen on growth, yield and quality of multicut fodder sorghum (*Sorghum bicolor* (L.) Moench. *Journal of pharmacognosy and Phytochemistry,* **6**(4): 689-899.

Teshome, H. Molla, E. and Feyisa (2023). Identification of yield-limiting Nutrients for sorghum (*Sorghum bicolor* (L.) Moench) yield, Nutrient uptake and use efficiency on vertisols of Raya Kobo district, Northeastern Ethiopia. *International Journal of Agronomy,* 5394806.

Visarada, K.B.R.S. and Aruna, C. (2019). Sorghum: A bundle of opportunities in the 21st century. In C. Aruna, K.B.R.S. Visarada, B.V. Bhat and V.A. Tonapi, (eds) - Breeding sorghum for diverse end uses, 1st ed., Sawston, UK: Woodhead Publishers, 1–14.

Zhao, D. Reddy, K.R. Kakani, V.G. and Reddy, V.R. (2005). Nitrogen deficiency effects on plant growth, leaf photosynthesis, and hyperspectral reflectance properties of sorghum. *European Journal of Agronomy*, **22**: 391-403.