©Kashere J. Anim. Sci. Volume 1 Issue 1 56 - 63 ISSN: 3115-6479
Date received: 21st September 2025
Date accepted: 8th November 2025
Date published: 19th November 2025

OPTIMIZING NITROGEN FERTILIZATION FOR ENHANCED HYDROPONIC PRODUCTION OF WHEAT (*Triticum aestivum*) AND RICE (*Oryza sativa*) FODDER IN SUDAN SAVANNAH, NIGERIA

[1]Ghazali, A.A., [1]Garba, M.G., [1]Musa, I. and [1]Idowu, W.
[1]Department of Animal Science, Federal University Dutsin-Ma, Katsina State, Nigeria.
*Corresponding Author: abdulazeezghazali@gmail.com; +2348037980800

ABSTRACT
Year-round provision of high-quality green fodder is a major constraint to sustainable livestock production in tropical Nigeria. Hydroponic fodder production presents a viable solution, but its productivity depends on precise nutrient management, particularly nitrogen (N) supplementation. This study investigated the effects of varying nitrogen fertilizer regimes (0, 1, and 2 g per 2 liters of water) on the growth and yield of hydroponically cultivated wheat and rice in Nigeria's Sudan savannah. The experiment was arranged in a completely randomized design. Parameters assessed included germination percentage, plant height, root mat depth, and final fresh biomass yield. Nitrogen application significantly ($p<0.05$) improved germination rates and shoot development in both crops, with wheat exhibiting a more pronounced response than rice. Plant height showed a positive correlation with increasing N levels, indicating stimulated vegetative growth. Conversely, root mat depth remained consistent across treatments, suggesting root architecture is governed more by physical factors than nutrition. Fresh herbage yield increased progressively with higher N inputs. Wheat demonstrated superior nitrogen use efficiency, yielding a maximum of 2.1 kg per tray, compared to 1.6 kg for rice. The results conclusively highlight the critical role of nitrogen in optimizing hydroponic fodder production and identify wheat as the more suitable and responsive crop for these systems. These findings provide actionable insights for maximizing fodder output in arid, resource-limited environments.

Keywords: Hydroponics, Fodder, Nitrogen Fertilization, Wheat, Rice, Sudan Savannah.

1.0 INTRODUCTION
Feed and fodder are essential components in providing adequate nutrition to livestock. However, ensuring a consistent supply of high quality green fodder throughout the year remains a major challenge in tropical regions such as Nigeria. Inadequate availability of both the quantity and quality of feed has been identified as the most significant constraint to livestock productivity (Ulfina *et al*., 2005). With a steadily growing livestock population, the gap between feed demand and forage availability continues to widen, creating a major bottleneck for sustainable production. Green fodder is widely recognized as indispensable in livestock diets, as it directly influences both productive and reproductive performance (Ayele *et al.*, 2021). Without sufficient inclusion of green fodder, animal nutrition is incomplete, leading to reduced efficiency in growth, milk production, and reproduction. For sustainable livestock farming, therefore, quality fodder must form a regular part of the ration (Dung *et al*., 2010). This need has become even more pressing in Nigeria, where increasing interest in crossbred animals demands higher quality nutrition to optimize performance. Hydroponics, derived from the Greek words *hydro* (water) and *ponos* (work), meaning "water working" offers a modern and sustainable solution to this challenge. Hydroponic fodder production is a soilless cultivation technique in which plants are grown using nutrient enriched water under controlled environmental conditions (Dung *et al*., 2010). This technology is particularly valuable for farmers constrained by rocky, infertile soils or lack of access to arable land, providing a farmer friendly and resource efficient alternative. A variety of crops, including maize, wheat, rice, barley, oats, sorghum, rye, alfalfa, and triticale, have been successfully produced hydroponically, along with legumes such as cowpea, horse gram, and sun hemp (Jemimah *et al*., 2015). Among the essential nutrients, nitrogen is often the most limiting factor for biomass production, nutrient management plays a critical role in maximizing the productivity of hydroponic systems.

Urea fertilizer, for instance, is the most widely used nitrogen source globally, with an estimated 107 Mt/Ha applied in agriculture between 2018 and 2019 (Hassan *et al*., 2024). Its popularity stems from both its affordability and its high nitrogen content (46%), which surpasses most other nitrogen fertilizers (Guardia *et al*., 2018). Nitrogen is an essential macronutrient required for plant growth, being directly involved in the biosynthesis of amino acids, nucleic acids, and chlorophyll, and consequently enhancing biomass yield and crop quality. This study aimed to evaluate the effect of nitrogen fertilization on the growth performance and herbage yield of hydroponically grown wheat and rice fodder, with the goal of identifying the most efficient crop and management strategy for sustainable fodder production.

2.0 MATERIALS AND METHOD

2.1 Experimental Site

The experiment was carried out at the Small Ruminant Unit of the Prof. Lawal Abdu Saulawa Livestock Teaching and Research Farm, Department of Animal Science, Federal University Dutsin-Ma, Katsina State. The farm is located in the Sudan savannah ecological zone at latitude 12°27'18'N and longitude 7°29'29'E, with an altitude of 605 meters above sea level and an average annual rainfall of about 700 mm (Garba *et al*., 2024).

2.2 Hydroponic Housing Unit

The hydroponic housing unit was a custom built structure designed to provide a temperature controlled environment for optimal fodder production. The unit was constructed using hydroponic cloth and timber, with a concrete floor and an open outdoor extension. Inside the housing, multi-tier shelving was installed to accommodate the fodder trays. The trays were positioned at a slight incline to facilitate drainage of excess water and minimize the risk of mold development. A polythene roof and shade netting were incorporated to regulate humidity, reduce direct solar radiation, and provide protection against birds, insects, dust, and other external contaminants.

2.3 Seed Collection, Preparation & Pre-germination

The cereal grains (wheat and rice) used in this study were procured at a reasonable cost from the local market in Dutsin-Ma. The grains were carefully sorted to remove impurities and disinfected with sodium hypochlorite solution. They were then briefly dried to attain a moisture content of 12–14%, which is considered optimal for both storage stability and germination. The seeds were thoroughly washed with clean freshwater to remove dirt and dust particles, soaked in a sodium chloride solution for 40 minutes to minimize microbial contamination, rinsed twice with fresh water, and subsequently soaked in clean water for 12 hours. After soaking, the water was drained, and the seeds were air-exposed for 1 hour to enhance respiration and promote uniform germination. The pre-germinated seeds were packed in gunny bags and left for 48 hours to complete sprouting, during which they were sprinkled with water three times daily to maintain adequate moisture. Subsequently, 400 g of seeds were uniformly spread into trays measuring 16 × 10 × 3 inches (length × breadth × depth) and placed in the hydroponic chamber for growth.

2.4 Irrigation

Irrigation was carried out twice daily, with nitrogen fertilizer applied on days 1 and 5 of transfer to tray. The fodder was then allowed to grow for 10 days, after which it was harvested for subsequent evaluation.

2.5 Shifting of Trays

Trays were shifted daily to the next level to maintain uniform progression in the growth cycle. At each shift, the last tray in every row was moved to the front of the same row, ensuring that all trays advanced by one position each day. This practice allowed equal exposure to environmental conditions and minimized positional bias. Adequate watering was ensured for all trays throughout the cycle. In cases where uneven growth was observed across a tray (e.g., one side growing faster than the other), the tray was rotated to balance light and moisture distribution, thereby promoting uniform fodder growth.

2.6 Harvesting

After 10 days of transplanting, the fodder had developed green leaves and a whitish root mat. At this stage, samples of the fodder were collected for yield analysis.

2.7 Data Collection

Data on the following parameters ware collected as follows;

2.7.1 Plant Height

Plant height of the fodder was measured using a meter rule and measuring tape. Five representative samples per tray were tagged with color labels, and measurements were taken from the mat surface (tray level) to the tip of the tallest foliage. Data were collected on days 4, 6, and 8 after transplanting. The mean values were computed and recorded for further analysis.

2.7.2 Germination percentage (%)

Seed count before sowing: The total number of seeds was counted and recorded by measuring a 100 g sample to estimate seed quantity

Counting germinated seeds: The number of seeds that had germinated was counted.

Calculation: Germination percentage was calculated using the formula

$$\text{Germination (\%)} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100$$

2.7.3 Mat depth

Mat depth was measured using a meter rule by inserting it vertically from the tray base to the top of the root mat. Measurements were taken at three different points per tray, and the mean values were recorded.

2.7.4 Herbage Yield

Herbage yield was determined from three samples by harvesting the entire biomass from each tray at the end of the growth period. The harvested fodder was allowed to drain excess water and weighed immediately using a digital balance scale to obtain the fresh weight.

2.8 Experimental Design

The experiment was conducted using a Completely Randomized Design (CRD) with three treatments and five replications. The treatments consisted of three nitrogen concentrations in the irrigation solution: 0 g (T1, control), 1 g (T2), and 2 g (T3) of urea per 2 liters of water. Two cereal crops, wheat and rice, were tested. Each tray was supplied with 2 liters of the respective fertilizer solution during irrigation events on days 1 and 5 of the growth cycle. Irrigation with plain water was carried out twice daily on all other days.

2.9 Statistical Analysis

All the data generated from this study was subjected to the Analysis of Variance (ANOVA) using statistical software package GENSTAT 2015 V.17.1 and treatment mean was separated using Duncan Multiple range test (DMRT) at 5% level of significance of the same software package.

3.0 RESULT AND DISCUSSION

3.1 Effect of Nitrogen Fertilizer on Rice Hydroponic Fodder Germination Percentage, Plant Height and Mat Depth

The result of the effect of nitrogen fertilizer on rice hydroponic fodder germination percentage, plant height and mat depth were presented in table 1 below. The result clearly reveal that nitrogen fertilizer had a strong influence on the performance of rice grown under hydroponic fodder conditions. Germination percentage responded positively to nitrogen, with T3 achieving the highest germination (53.34%), followed by T2 (46.03%), while T1 recorded the lowest (27.82%). This suggests that nitrogen made more nutrients available to the seeds during the early stages, which supported faster and more uniform sprouting. It also suggest that, nitrogen gave the seedlings the kick-start nutrient they needed for proper establishment. Plant height followed the same trend. The tallest plants were observed in T3 (11.85 cm), with T2 coming next (9.00 cm), while T1 plants remained stunted (5.05 cm).

This makes sense because nitrogen is closely linked to chlorophyll formation and photosynthesis, which provide the energy for cell division and elongation. Essentially, the more nitrogen the plants received, the better they were able to grow upwards and sustain healthy vegetative development. The consistency between germination and plant height further confirms the central role of nitrogen in early growth under hydroponic conditions. In contrast nitrogen had little to no effect on mat depth, which remained fairly similar across treatments (1.950-2.10 cm). This shows that while nitrogen boosts what happens above the surface, root mat development in hydroponics is likely shaped more by the availability of water and the physical support system rather than just fertilizer at this early stage.

3.1.1 Interpretation

The results indicate that nitrogen fertilization substantially enhanced germination and plant height in rice hydroponic fodder, while having little influence on root mat depth. This highlights nitrogen as a key input for improving shoot growth and overall green biomass yield. However, the lack of improvement in root development suggests that other agronomic factors such as adequate aeration and provision of root support structures may be necessary to promote stronger and more balanced root systems (Rajasegar *et al*., 2023).

Table 1: Effect of Nitrogen Fertilizer on Rice Grown Hydroponic Fodder

Parameters	T1(0g)	T2(1g)	T3(2g)	SEM
Germination (%)	27.82^{a}	46.03^{b}	53.34^{c}	1.843
Average Plant height (cm)	5.050^{a}	9.000^{b}	11.850^{a}	1.215
Mat depth (cm)	1.950^{a}	2.050^{a}	2.100^{a}	0.0577

The means were separated using DMRT, ^{a,b,c} means in the same row with different superscripts are significantly different (P<0.05), SEM= Standard error of mean

3.2 Effect of Nitrogen Fertilizer on Wheat Hydroponic Fodder Germination Percentage, Plant Height and Mat Depth

The effect of nitrogen fertilizer on wheat grown under hydroponic fodder conditions is shown in Table 2. Germination percentage was significantly (P<0.05) influenced by nitrogen application. T3 recorded the highest germination (54.84%), followed closely by T2 (52.08%), while T1 had the lowest value (44.64%). This indicates that nitrogen fertilization promotes faster and more uniform germination in wheat seeds. The improved germination may be attributed to enhanced nitrogen availability, which supports the synthesis of proteins and enzymes required for seed metabolic activities. Similar findings have been reported in cereals where nitrogen application accelerated early seedling emergence and vigor (Jan et al., 2002). Average plant height also responded significantly (P<0.05) to nitrogen treatments. Plants in T3 attained the tallest height (14.95 cm), followed by T2 (13.30 cm), while Trt1 (11.20 cm) was shortest. The increase in plant height with nitrogen supplementation suggests that nitrogen plays a crucial role in vegetative growth by enhancing chlorophyll production, photosynthetic activity, and cell elongation. The trend observed aligns with the germination response, further emphasizing the importance of nitrogen in sustaining early seedling growth under hydroponic systems. On the other hand, mat depth did not differ significantly (P>0.05) among treatments, with values ranging from 1.95 to 2.00 cm. where values recoded in T3 (2.000) are numerically higher followed by T2 (1.950) and T1 (1.850). The uniformity across treatments indicates that root proliferation in wheat hydroponic fodder was not influenced by nitrogen fertilization during the study period. Rather, root mat development in hydroponic systems appears to be governed more by factors such as oxygen availability, water distribution, and physical support from the growth medium than by nutrient supplementation at this stage.

3.2.1 Interpretation

The results demonstrate that nitrogen application plays a critical role in improving germination and shoot development of hydroponically cultivated wheat fodder, although it does not significantly influence root mat depth. Enhanced germination rates and taller plants observed under higher nitrogen levels highlight the nutrient's importance in promoting rapid establishment and vigorous vegetative growth. In contrast, the uniformity of mat depth across treatments indicates that root proliferation may be more strongly influenced by environmental conditions such as aeration, water movement, or the physical characteristics of the rooting medium rather than nitrogen supply. Therefore, while nitrogen fertilization is indispensable for maximizing yield and above-ground biomass quality in hydroponic wheat fodder systems, complementary strategies are needed to enhance root mat formation (Grigas *et al*., 2020).

Table 2: Effect of Nitrogen Fertilizer on Wheat Grown Hydroponic Fodder

Parameters	T1(0g)	T2(1g)	T3(2g)	SEM
Germination (%)	44.64^{a}	52.08^{b}	54.84^{b}	3.08
Average Plant height (cm)	11.20^{a}	13.30^{ab}	14.95^{b}	0.713
Mat depth	1.850^{a}	1.950^{a}	2.000^{a}	0.0577

The means were separated using DMRT, , ^{a,b,c} means in the same row with different superscripts are significantly different (P<0.05), SEM= Standard error of mean

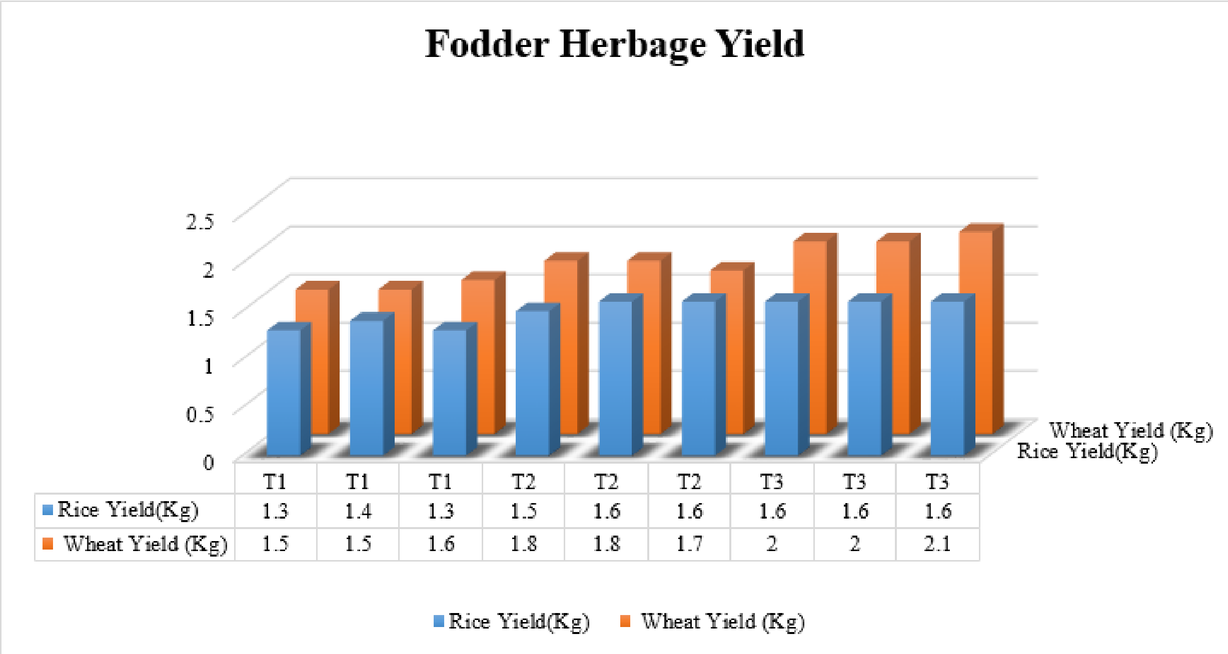
3.3 Effect of Nitrogen Fertilizer on Herbage Yield of Hydroponically grown wheat and rice fodder

The graph presents the effect of nitrogen fertilizer on the herbage yield of rice and wheat grown under hydroponic fodder conditions. Across all treatments, wheat consistently produced higher herbage yields than rice. At T1 (control), wheat yield was at range of 1.5-1.6 kg compared to 1.3-1.4 kg for rice, showing a higher baseline advantage of wheat in hydroponic production systems. As nitrogen levels increased (T2 and T3), both rice and wheat showed progressive increases in herbage yield. In rice, yields rose from approximately 1.3-1.4 kg at T1 to 1.5-1.6 kg at T2 and 1.6 kg at T3. Similarly, wheat yields improved from 1.5-1.6 kg at T1 to 1.8-1.9 kg at T2, and further to 2.0-2.1 kg at T3. These results indicate that nitrogen supplementation had a positive and dose dependent effect on fodder yield for both cereals. Importantly, wheat responded more strongly to nitrogen fertilization compared to rice. The yield advantage of wheat over rice widened with increasing nitrogen levels, at T1, the difference was ~0.2 kg, while at T3 it increased to ~0.5 kg. This suggests that wheat has a higher nitrogen use efficiency under hydroponic fodder conditions, likely due to its stronger capacity for rapid biomass accumulation and tillering compared to rice.

3.3.1 Interpretation

Naik *et al*. (2015) noted in their review that the fresh yield of hydroponic fodder is influenced by several factors, including crop species, harvesting time, drainage of excess water before weighing, seed type and quality, seed rate, seed treatment, water quality, irrigation frequency, nutrient solution, light intensity, growth duration, temperature, humidity, and the overall hygiene of the greenhouse environment. Findings further indicated that nitrogen fertilization significantly improved herbage yield in both rice and wheat, with wheat consistently producing higher yields than rice across all treatments. The stronger response of wheat suggests it is more suitable for hydroponic fodder production when the objective is to maximize green biomass output. For farmers and feed producers, this implies that although both crops benefit from nitrogen application, wheat offers greater efficiency in resource limited systems where maximizing yield per unit of input is critical Vijayakumar (2024). Rice, however, remains a viable option, particularly in regions where it is more accessible, though its lower responsiveness may require more careful optimization of inputs to achieve yields comparable to wheat. (Naik, *et al.,* 2015).

Graph1: Showing the Yield among Treatments



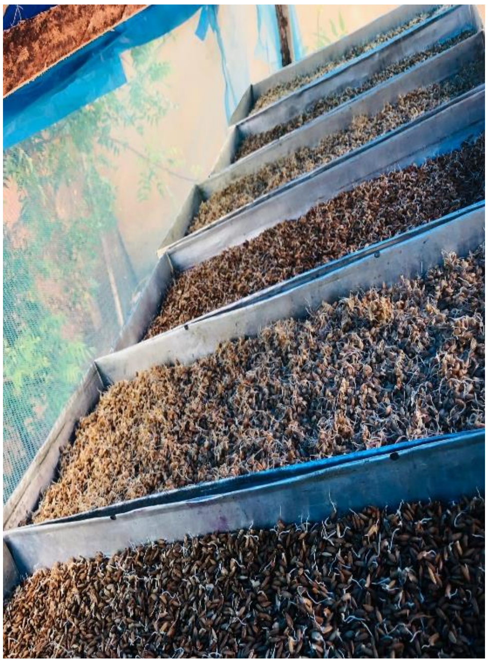


Fig:1 Seeds evenly spread on trays


Fig: 2 Germinated Fodder on trays


Fig: 3 Fodder ready for animals feed

4.0 Conclusion

Nitrogen fertilization significantly enhanced germination, plant height, and herbage yield of hydroponically grown fodder, with wheat outperforming rice across all treatments. Root mat depth, however, was not influenced by nitrogen, indicating that factors such as aeration and water management play a greater role in root development. These results highlight wheat as a more efficient and responsive crop for hydroponic fodder production under nitrogen supplementation. Overall, integrating nitrogen management into hydroponic systems offers a practical strategy for improving fodder yield and quality, thereby supporting sustainable livestock production in regions with limited feed resources.

Author Contributions

Conceptualization, A.A. Ghazali; methodology and investigation, A.A. Ghazali, M.G. Garba, I. Musa, and W. Idowu; data analysis and visualization, A.A. Ghazali and M.G. Garba; writing original draft preparation, A.A. Ghazali; writing review and editing, A.A. Ghazali, M.G. Garba, I. Musa, and W. Idowu; supervision, A.A. Ghazali. All authors have read and approved the final version of the manuscript.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

Reference

Ayele, J., Tolemariam, T., Beyene, A., Tadese, D. A., and Tamiru, M. (2021). Assessment of livestock feed supply and demand concerning livestock productivity in Lalo Kile district of Kellem Wollega Zone, Western Ethiopia. *Heliyon*, *7*(10), e08177. https://doi.org/10.1016/j.heliyon.2021.e08177

Dung, D.D., Godwin, I.R. and Nolan, J.V. (2010). Nutrient content and in sacco degradation of hydroponic barley sprouts grown using nutrient solution or tap water. *Journal of Animal and Veterinary Advances*, 9: 2432-2436

Garba, M. G., Gaddafi, S., Ahmed, A., and Nasir, M. (2024). Physicochemical Properties and Proximate Composition of *Panicum Maximum* Fermented with Fungi (Saccharomyces Cerevisiae) and Molasses. *Conference Nigerian Society for Animal Production*,1(4),1617–1619. https://njap.org.ng/index.php/njap/article/download/7219/5802/12294

Grigas, A., Kemzūraitė, A., Steponavičius, D., Steponavičienė, A., and Domeika, R. (2020). Impact of Slope of Growing Trays on Productivity of Wheat Green Fodder by a Nutrient Film Technique System. *Water*, *12*(11), 3009. https://doi.org/10.3390/w12113009

Guardia, G., Sanz-Cobena, A., Sanchez-Martín, L., Fuertes-Mendizábal, T., GonzálezMurua, C., and Álvarez, J. M., (2018). Urea-based fertilization strategies to reduce yield-scaled N oxides and enhance bread-making quality in a rainfed Mediterranean wheat crop. Agric. Ecosyst. and Environ. 265, 421–431. doi:10.1016/j.agee.2018.06.033

Hassan, M. U., Guoqin, H., Arif, M. S., Mubarik, M. S., Tang, H., and Xu, H., (2024). Can urea coated fertilizers be an effective means of reducing greenhouse gas emissions and improving crop productivity. Journal Environmental Management. 367, 121927. doi:10.1016/j. jenvman.2024.121927

Jan, M.T., Shah, M. and Khan, S. (2002). Type of nitrogen fertilizer rate and timing effect on wheat production. *Sarhad Journal of Agriculture*. 18(4): 405-410

Jemimah, R. E., Gnanaraj, P. T., Muthuramalingam, T., Devi, T., Babu, M., and Sundharesan, A. (2015). *Hydroponic green fodder production: TANUVAS experience*. Retrieved from http://rkvy.nic.in/(S(dj5ug3cfjygd1hmikvs3bm25))/2016023524_Hydrophonic_Final.pdf

Naik, P.K., Swain, B.K. and Singh, N.P. (2015). Review-Production and Utilisation of Hydroponics Fodder. *Indian Journal of Animal Nutrition*. 32 (1): 1-9

Rajaseger, G., Chan, K. L., Yee Tan, K., Ramasamy, S., Khin, M. C., Amaladoss, A., and Kadamb Haribhai, P. (2023). Hydroponics: current trends in sustainable crop production. Bioinformation, 19(9), 925–938. https://doi.org/10.6026/97320630019925

Ulfina, G., Zelalem, B., Jemal, D., Gemeda, D., Chala, M., Jiregna, D., Diriba, G., Lemma, G., Workneh, A., and Adam, D. (2005). Survey of Cattle Production and Marketing Practices in Danno District, Western Ethiopia, Using PRA Tools. PRA 7(2):5-11. http://www.ilri.org/html/Stakeholder%20Consultation%20Workshop%20report.pdf

Vijayakumar, S., Gobinath, R., Kannan, P., and Varunseelan, M. (2024). Optimizing potassium mining in rice-wheat system: Strategies for promoting sustainable soil health-A review, Farming System, 2(3), 100-099, ISSN 2949-9119, https://doi.org/10.1016/j.farsys.2024.100099.