Journal of Plant Sciences
2025, Vol. 13, No. 2, pp. 66-72
https://doi.org/10.11648/j.jps.20251302.15

Review Article

Agronomic Management Practices for Rice Production and Productivity in Ethiopia: A Review

Eshetu Yadete Urge*

Agronomy Department, Jimma Agricultural Research Center, Jimma, Ethiopia

Abstract

Rice (Oryza sativa L.) has emerged as a strategic and priority commodity for food security in Ethiopia. Nonetheless, Ethiopia's average rice production is only about 2.8 t ha-1, which is less than the global average of 4 t ha-1, statistics indicate that has been flat for a long time. The main reasons for Ethiopia's low rice yield and productivity are poor agronomic management practices (improper land preparation, untimely planting, inadequate fertilizer applied, inappropriate seed rate, weeds and insect pest). Enhancing agronomic management practices would increase rice yield and productivity. Yet, poor land preparation, suboptimum seed rate and date of planting techniques are reported to be the most important rice production constraint. Another key factor in rice production is the availability of plant nutrients, especially nitrogen, at different phases of plant growth. The most effective fertilizers management that is right fertilizers rate, right source, right place and right time of fertilizer applications are enhanced rice productivity. NPS and urea (supplying nitrogen and phosphorus) were the major fertilizers used by farmers in Ethiopia. In order to get the highest possible yields of rice, effective agronomic management techniques are required to increase productivity. Improving rice production and productivity as well as facilitating its processing and marketing access is therefore one of a key part of the economic growth strategies in the Ethiopia government's food self-sufficiency initiatives. Therefore, this review advances our understanding of recommended agronomic practices for rice production in Ethiopia's and will encourage more use of recommended agronomic practices.

Keywords

Agronomic Practices, Seed Rate, Fertilizer Rate, Sowing Date, Management

1. Introduction

Rice is globally the most important food crop and there is a dire need to feed the ever-increasing population by improving its productivity [21]. It has been realized that poor agronomic management practices are the major impediment towards enhancing the productivity of this crop. Rice is the third most cultivated cereal crop in the world, after wheat and maize having 745 million tons of volume production [14]. Recognizing the comparative advantages of rice over other food crops, it is considered as the millennium crops that is expected to contribute to ensuring food security in the country [8]. At present rice is gaining the same importance as some of the most common cereal crops for both domestic consumption as well as market use in Ethiopia. The rice is currently considered as a strategic food security crop in Ethiopia.

Rice is the most crucial blending crop for enjera preparation in different parts of Ethiopia. The national production

*Corresponding author: eshetuyadete24@gmail.com (Eshetu Yadete Urge)

Received: 10 March 2025; **Accepted:** 31 March 2025; **Published:** 28 April 2025

Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

area in 2019 was approximately 57 thousand hectares with 170 thousand tones of paddy rice with an average yield of 2.96 t ha^{-1}. The production area of rice in Ethiopia increases from 29 to 90 thousand hectares from 2010 to 2019 [15]. It indicates the rapid distribution of rice production to different parts of Ethiopia as a staple food crop. In Ethiopia, few research findings revealed that the maximum grain yield (5.4 t ha^{-1}) was recorded on research field [40]. This result might not be represented for whole rice ecosystem of Ethiopia.

Because of its versatility, rice is grown in a variety of settings, including rainfed uplands, irrigated lowlands, and irrigated uplands [10, 22, 50]. Despite the fact that different growing conditions have varying levels of productivity, there are significant obstacles that reduce rice output. The main ones that lower rice production include improper agronomic techniques (seed rate, fertilizer rate, and sowing date).

Nitrogen (N) fertilization management are factors that are highly associated with yields and are easy for farmers to adjust and manipulate. Nitrogen is the most important nutrient for plant growth and development as well as grain quality. Determining the ideal amount of nitrogen application for each rice cultivar is essential due to the importance of nitrogen as a primary nutrient for rice crops to achieve high grain production [19]. Hence, significantly influencing crop productivity. Nitrogen deficiency in rice plants causes yellowing of leaves, reduces leaf size, and leads to low productivity, whereas excessive N fertilization results in agronomic and economic losses. Therefore, it becomes imperative that a sufficient and optimum N dose should be applied to obtain stable grain production. To reduce the nitrogen loss from rice fields, surface runoff, denitrification, ammonium volatilization, and leaching should be managed. Sustainable and environmentally friendly fertilizer management practices enhance the sustainable soil fertility status and, thereby, crop yields. According to the findings of the current study conducted in northwest Ethiopia, applying a nitrogen level of 184 kg ha^{-1} with a seed rate of 100 kg ha^{-1} produced the highest grain yield and economic profitability of rice, with the Selam variety achieving the highest grain yield of 6.641 t ha^{-1} [45].

Numerous studies' findings have shown that using N and P fertilizers increases rice grain yield by boosting the size of its yield characteristics [32, 47]. Higher yield attributable characteristics are linked to improved nutrition and nutrient uptake, which contribute to healthier plant growth and development [23, 47]. This, in turn causes more dry matter to be produced and transferred to the sink [11]. According to Panda et al. [32] reported increased dry matter production including grain yield of rice due to increased N and P uptake in response to external supply of both N and P fertilizers. The research findings indicate that farmers at the Fogera plain need to apply a combination of 60 kg N and 13.2 P kg ha^{-1} in order to improve the grain yield and yield components of flooded lowland rice grown on black clay soils (Vertisols) under rain fed conditions [18].

Furthermore, as essential components of initiatives to enhance rice production and soil fertility, fertilizer application under flooded rice cultivation should take into account soil water environment associated parameters that affect the availability and evaluation of nutrient in soils. Given that rice responds significantly to both fertilizers, it would be beneficial to do additional research to support integrated soil fertility management and develop fertilizer recommendations based on soil test results across different sites. Other inappropriate agronomic practices (planting windows, seed rate, and land preparation) are limiting factors that have an impact on rice productivity and production. Enhancing agronomic practices including seed rate, seedbed preparation, weed control, pest management and sowing date would increase rice yield and productivity. Since high seed rate increase competition for growth resource like air, water, space, nutrient and extra seed cost while lower seed rate unutilized growth resource.

Hence, the optimum seeding rate is an important factor in achieving high yields and quality. In order to improve yield, it is often advised to plough the land three or four times before planting rice. This helps to loosen the soil, provide organic matter, eliminate weeds, and produce a proper seedbed for the best root development. Timely sowing is the most economical and efficient way to guarantee enough rice yields, and it costs the farmer little to nothing. The proper sowing window for rice depends on the region, climate, and other factors. In general, the optimal planting date for rice is between mid May and mid June in Ethiopia. Therefore, this review advances our understanding of recommended agronomic practices for rice production and productivity in Ethiopia's and will encourage more use of recommended agronomic practices.

2. Literature Review

2.1. Land Preparation

Proper land preparation is crucial in rice cultivation. Leveling and bunding are one of activity of land preparation that is done to achieve good crop establishment and high-yield production. There are several methods for achieving this. Implementing the major leveling method or the cut and fill method produces the best land leveling results, especially during the dry season. A high degree of soil homogeneity can be achieved by ideal soil preparation practices, which boosts water consumption, rice plant development, input material and equipment usage, and rice production output [31].

Low and deep wet areas will result in fewer rice plants because uneven rice fields cause non-uniform germination of rice plants [30]. Rice output will also be impacted by uneven water depth levels [35]. After the harvest or hay collection season, rice field land preparation activities can start right away. In order to restore the levelness of the ground surface damaged during harvesting by heavy equipment weighing more than five tons, like a combine harvester, this step is essential [4]. The process of preparing land is usually divided into numerous phases that rely on a number of variables. There is no better time to prepare the soil than when the rice fields are dry. But before planting in rainy weather, farmers need to do at least one rotor tillering and one leveling operation [31].

Rotary tiller equipment will be used for land preparation in order to chop, compress, and enhance the structure of the soil. The soil in wet rice fields can also be leveled with a box leveler. This instrument is used to transfer soil from higher elevations to lower elevations. Meanwhile, the land is being ploughed and leveled concurrently by the power harrow tools. Generally, Proper land preparation can also help suppress weed growth by creating a more uniform environment for rice seedlings and optimizing rice growth and yield by preventing water logging and ensuring even water distribution across the field. Plowing three to four times rice field indicated that the best option for production and productivity of rice in southwestern Ethiopia [29].

2.2. Sowing Date

Sowing date is one of the most important factors influencing grain yield of crops where growth duration is important. The easiest and least costly adaptation for farmers is to determine the ideal sowing date to optimize production. Therefore, it would be imperative to alter the climatic factor patterns to align with rice development. According to several researchers, modifying the rice sowing date may enhance grain yield and dry matter accumulation. Most rice cultivation in Ethiopia takes place during the "meher" season, which is the main growing season with significant rainfall. The rice maturity group also responded to different time of planting. Early sowing led to an extended crop duration and significantly lower yields of the short-duration varieties. Early sowing resulted in low yields of the short-duration varieties, probably due to low solar radiation during the cloudy rainy season, which coincided with the vegetative stage [2].

Late sowing compromised yield of the medium- and long-duration varieties because of low temperatures during booting stage, which led to high spikelet sterility. Hence, lower yields may come from early sowing because of the rainy season's low solar radiation, whereas lower yields may result from late sowing because of the booting stage's cooler temperatures. The optimum period of time for sowing and transplanting of rice is critical in achieving high grain yield. However, optimum rice planting dates vary with regional, location and genotypes [3]. Seedlings that are sown later than is ideal produce fewer tillers since the vegetative stage is shortened, which leads to a low yield. When it comes to crop production tools, the best time and technique to sow are crucial agronomic tools that enable the crop to grow successfully and on schedule inside a particular agro-ecology zone [48]. Based on the start of the rainy season, the main rice-planting dates in Ethiopia are usually mid-May to mid-June. The majority of rice is grown during the "meher" season, which runs from May to September. The surveys conducted in southwestern Ethiopia to evaluating the major factors influencing in rice farming indicated that the best time to plant rice is from late May to mid-June [13, 29].

2.3. Planting Method

Rice crops can be either direct seeded or transplanted. In direct seeding, seeds are sown directly in the field. While in transplanting, seedlings are first raised in seedbeds before they are planted in the field. According to Tilahun-Tadesse et al. [42], when seedlings are transplanted at the appropriate time, their growth and tillering progress regularly, resulting in a uniform stand establishment. A seedling will generate fewer tillers and have a lower yield if it is more than optimum (36). Mobasser et al. [26] reported that under aged seedlings will be tender and may die due to high temperature. The seedling older than 35 days led to more prolonged recovery from transplanting shock than younger seedlings [26].

Seedlings age and transplanting time determined rice yield. Transplanting at the optimum age of seedlings and time is important for ensuring less risk of crop failures in rainfed lowland environments. Even though transplanting is a good way to reduce weeds, preserving seeds is not a widespread practice in Ethiopia. Increase in labor costs in some countries created the switch from transplanting to direct seeding. Since there is no water layer to inhibit weed growth and weeds germinate concurrently with rice when rice is dry-seeded, direct-seeded rice is more vulnerable to severe weed infestations than transplanted rice [16]. Yield losses of 10-100% have been reported from weeds in direct seeded rice. Moreover, cost for weed control is usually higher than transplanting. Although direct seeding saves time and labor to planting, farmers may end up using the labor saved for weed controlling [33]. In the northwest Ethiopian Fogera lowlands, broadcast direct seeding is typically used by farmers to establish rainfed lowland rice. The direct seeding (broadcasting) is still dominant in many rice producing part of Ethiopia. However, in southwestern Ethiopia, lowland rice rain fed confirmed that transplanting higher productivity than broadcasting [13]. The transplanting in seedling age at 20-25 days for the best performance of rice yield attributes were recommended.

2.4. Fertilizer Application

In Ethiopia, one of the main reasons restricting rice production is poor soil fertility. In order to increase soil fertility and rice production, it is crucial to apply fertilizer appropriately [6]. An inadequate fertilizer applied through improper application technique is one of the factors responsible for low yield of rice [25]. Appropriate fertilizer application is an important management practice to improve soil fertility and the production of rice. The availability of plant nutrients, particularly nitrogen at various plant growth stages is of crucial importance in rice production [12, 37].

Fertilizers are food for plants main nutrient that rice plants needs are nitrogenous, phosphate, and potassium fertilizers. A key factor in rice production is the availability of plant nutrients, especially nitrogen, at different phases of plant growth. For a variety of agricultural systems, recommendations for the time frame for applying nitrogen fertilizer were provided. The number of splits is affected by the total amount of nitrogen fertilizer to be applied based on the desired yield level [1]. The most efficient method of treating broadcast seeded rice, according to recent research from the rice research and training center, is to apply fertilizer nitrogen in three equal doses; one third at planting, one third at mid tillering and one third at panicle initiation. Nitrogen management is considered as one of the most challenging parts of the direct seeded rice to achieve higher grain yield and nitrogen use efficiency [7].

Shukla et al. [38] stated that due to lack of synchronization between the nitrogen demand and nitrogen supply more than 60% of applied nitrogen was lost. Nitrogen fertilizer is typically applied by farmers in set time split doses without taking into account the plant's current nitrogen requirements [24]. Since recommendations are mostly based on empirical testing of nitrogen response to a few fixed doses, this does not take into account the dynamic crop nitrogen requirement and soil nitrogen supply [9, 38]. Therefore, for rice to be produced sustainably, N must be managed well using 4R nutrient stewardship. The optimum use of nitrogen can be achieved by matching its supply with the crop demand. However, nitrogen recommendations differ depending on the soil type, crop variety, rainfall and location.

Different research findings conducted in different location indicated vary recommendation. For instance, an experiment conducted in Tigray, the combination of 138 kg N ha^{-1} and 46 kg P_2O_5ha^{-1} resulted in grain yield of 5723 kg ha^{-1} and the control (i.e. no N with no P) resulted in the lowest grain yield (1601 kg ha^{-1}) [41]. A experiment conducted on rainfed lowland rice in southwestern Ethiopia, application of fertilizers at the rate of 46 kg P_2O_5 and 46 kgN ha^{-1} is the best recommended fertilizer rate for rice production [27]. Another field experiment carried out on lowland and upland rice rainfed indicated that combined application of 184-46 N-P_2O_5 kg ha^{-1} and 138-46 N-P_2O_5 kg ha^{-1} are the best for higher productivity and economic profitability in Fogera plain and Libokemkem respectively [43]. In addiction the experiment conducted at melko and Shebe southwestern Ethiopia during rain fed condition on rice varieties with nitrogen fertilizer rate indicated that the variety Nerica-4 with application of 92 N kg ha^{-1} and Edget rice variety with 69 N kg ha^{-1} gave maximum yield [29]. This could be due to the nutrient available in soil, crop variety and amount of rain fall could be varied NP fertilizer rate and time of N application. Therefore, farmers should apply fertilizers according to recommendations based on soil test analysis for different agro ecology of rice.

2.5. Seed Rate

The most crucial production variables for increased grain yield are the ideal seeding rate and appropriate row spacing adjustment. Number of plants per unit area depends on spacing [49]. Yield is directly affected by the plant density per unit area, which is determined by space between plants and rows. Plants become weaker and thinner as result of increased competition for nutrients, air, and light with closer spacing, which hinders intercultural operation and lower yield [5]. Increased competition between weeds and crop plants is another benefit of wider spacing. Therefore, the growth of plants slows down and their grain yield falls. Conversely, closer spacing encourages competition between plants for light, air and nutrients, making them weaker; mutual shadowing hence favors more straw yield over grain yield [39]. Plant densities that are lower or higher have a favorable impact on rice yield [20]. A seeding rate causes lodging susceptibility, more severe disease pressure and unproductive tillers [17]. By utilizing more solar radiations and nutrients, plants with optimal spacing are able to grow both aerially and subterranean [28].

Since high seeding rate increases competition for growth resource like space, light, air and nutrient while lower seeding rate unutilized growth resource. Therefore, optimum seeding rate and proper adjustment of row spacing is important for rice productivity and production. The Fogera Plain experiment on the effects of row spacing and seed rate on rice yield and yield components revealed that the most lucrative combination was a seed rate of 100kg kg ha-1 and a row spacing of 20 cm [44]. The Fogera Plain experiment on the effects of row spacing and seed rate on rice yield and yield components revealed that the most lucrative combination was a seed rate of 100 kg ha-1 and a row spacing of 20 cm [44]. Some research findings showed that different sowing method (transplanting, dibbling and drilling) save seed rate than broadcasting. For transplanting and drilling require seed rate 25-40 kg ha^{-1} and 40-60 kg ha^{-1} respectively.

Another study on farm evaluation agronomic management approaches in southwest Ethiopia found that the most profitable row spacing is 25 cm and the seed rate is 80 kg ha-1 [27]. Most surveys that assessed the key elements impacting rice cultivation in southwestern Ethiopia found that farmers used a seed rate of 100–200 kg ha^{-1} [13]. As result obtained from survey, most of farmers used high seed rate to reduced weed infestation accordingly. However, a seed rate of 120 kg ha^{-1} and row spacing of 20 cm is recommended for upland rice production while rain-fed lowland rice production requires a seed rate of 100 kg ha^{-1} and row spacing of 20 cm [44]. From every angle, the best row spacing of 20 to 25 cm and a seed rate of 100 to 150 kg ha^{-1} are utilized by farmers to maximize the production and productivity of various rice ecosystems.

2.6. Weed Management

Weed management has become the most important and inevitable aspect of crop management for achieving a higher rice yield [34]. Timely weed control is important in the early stages growth. Three weeding may be required before crop reaches maturity. Due to labor availability and financial constraints, Ethiopian rice fields are primarily managed for weeds using a combination of hand-weeding, hoeing, flooding, and limited herbicide use. The most popular method is hand-weeding, which is often done several times during the growing season. Flooding the fields is also used to suppress certain weed species that cannot withstand conditions of water logging. To successfully implement IWM, a weed-monitoring program is necessary. Various weed-management strategies, such as cultural weed management using stale seedbed and crop residue mulch, and crop-competitiveness using appropriate cultivars and adjusting seed rate, row spacing, nutrient, and water management, can improve the crop's competitiveness. Generally, three weeding at an interval of 15 days are sufficient [29]. Weeding may be done with hand hoe or wheel hoe in line sown crop.

2.7. Pest and Disease Management

Insect, pest and disease management is vital in attaining sustainable rice production. Rice is a strategic food security commodity in Ethiopia, and its production has effected significant change in the livelihoods of farmers, and has created job opportunities for a large number of people across different areas of the country. However, disease outbreaks, pests, and insects have a significant impact on its productivity. Numerous pests and diseases have impacted rice, which has led to decreased yielding performance of rice varieties in Ethiopia [46]. Management practices are needed to control the loss carried out by different diseases and insects and pests. Most common practices include agronomic practices, biological and chemical control through integrated pest management (IPM) strategies is vital to protect yields. By creating a favorable environment for improved crop survival, the best use of diverse agro-techniques can be utilized to effectively prevent a variety of destructive diseases, including bakanae, sheath blight, and rice blast, among many others [21]. In addition, a number of diseases can be effectively controlled by using good varieties, high-quality seed, establishment techniques, planting schedules, and weed, fertilizer, and water management techniques.

3. Summary and Conclusion

In Ethiopia, key agronomic management practices for rice cultivation include: using improved rice varieties, proper land preparation with bunding and leveling, broadcasting as the primary planting method, optimum seed rate, weed management, fertilizer application based on soil analysis, pest and disease control, and water management strategies adapted to different rice ecosystems (rainfed lowland, irrigated, and upland), with a focus on research and extension services to promote these practices among farmers, which contributes significantly to Ethiopia's rice production. In order to maximize nutrient availability for rice development, fertilizer application must be based on soil analysis. Although the ideal nitrogen level varies depending on the particular rice variety and soil conditions, applying nitrogen fertilizer to rice varieties generally results in increased plant growth and yield. Excessive nitrogen can have detrimental effects, such as excessive vegetative growth at the expense of grain production, which could affect the overall yield and raise environmental concerns. Proper land preparation is crucial, involving bunding and leveling to ensure efficient water management in rice fields.

Planting time (cropping calendar) is decided by analyzing meteorological data such as rainfall and maximum and minimum temperature. While broadcasting is still common practiced in abundant areas, transplanting is considered the most efficient planting method for higher yields. Monitoring and controlling pests and diseases through integrated pest management strategies is vital to protect yields. Weed management is a significant challenge, often requiring a combination of hand weeding and selective herbicides. Implementation of the recommended agronomic management practices improves the productivity of crops with quality. Crop management practice is the set of agricultural practices applied to improve the growth, development, and yield of crops. Use of proper agronomic practices for exploiting the potential of crop environment interaction through reduced cost chemical fertilizer, herbicide, reduced seed rate and to bridge the yield gap closure for ensuring sustained food security. However, the main obstacles to Ethiopia's rice production include inadequate post-harvest management, restricted access to high-quality seeds, and poor mechanization.

Abbreviations

NPS	Nitrogen Phosphorus Sulfur
IWM	Integrated Weed Management
IPM	Integrated Pest Management
Kg/ha	Kilogram Per Hectare

Author Contributions

Eshetu Yadete Urge is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abdulkadir, B., Kassa, S., Desalegn, T., Tadesse, K., Haile selassie, M., Fana, G., Abera, T., Amede, T. and Tibebe, D., 2017. Crop response to fertilizer application in Ethiopia: a review. EJNR, 16(1), pp. 21-48.

[2] Abera, B. B., Stuerz, S., Senthilkumar, K., Cotter, M., Rajaona, A. and Asch, F., 2020. Season - specific varietal management as an option to increase rainfed lowland rice production in East African high altitude cropping systems. Journal of Agronomy and Crop Science, 206(4), pp. 433-443.

[3] Abera, W., Tamene, L., Tibebe, D., Adimassu, Z., Kassa, H., Hailu, H., Mekonnen, K., Desta, G., Sommer, R. and Verchot, L., 2020. Characterizing and evaluating the impacts of national land restoration initiatives on ecosystem services in Ethiopia. Land Degradation & Development, 31(1), pp. 37-52.

[4] Ahmad, M. T., Khadzir, M. K. and Omar, M. F. Z., 2020. Performance of a triangular rubber tracked tractor in paddy fields. Advances in Agricultural and Food Research Journal, *1*(2), pp. 1–7.

[5] Alam, M. S., Baki, M. A., Sultana, M. S., Ali, K. J. and Islam, M. S., 2012. Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant aman rice. International Journal of Agronomy and Agricultural Research, 2(12), pp. 10-15.

[6] Alem, R., Hailegebriel, K., Yirgalem, T., Redae, W. and Welegerima, G., 2018. Effects of N and P Fertilizer application rates on yield and economic performance of upland rice in Tselemti District of NW Tigray, Ethiopia. Journal Rice Research, *6*(191), p. 2.

[7] Ali, M. A., Ladha, J. K., Rickman, J., Lales, J. S. and Alam, M. M., 2012. Evaluation of drill seeding patterns and nitrogen management strategies for wet and dry land rice. Bangladesh Journal of Agricultural Research, 37(4), pp. 559-571.

[8] Assefa, A., Tadese, T. and Liben, M., 2013. Influence of time of nitrogen application on productivity and nitrogen use efficiency of rain-fed lowland rice (Oryza sativa L.) in the vertisols of Fogera Plain, northwestern Ethiopia. Ethiopian Journal of Science and Technology, 6(1), pp. 25-31.

[9] Cassman, K. G., Peng, S., Olk, D. C., Ladha, J. K., Reichardt, W., Dobermann, A. and Singh, U., 1998. Opportunities for increased nitrogen-use efficiency from improved resource management in irrigated rice systems. Field crops research, *56*(1-2), pp. 7-39.

[10] Choudhary, A. K. and Suri, V. K., 2014. Integrated nutrient-management technology for direct-seeded upland rice (Oryza sativa) in Northwestern Himalayas. Communications in Soil Science and Plant Analysis, 45(6), pp. 777-784.

[11] Dalai, P. K. and Dixit, L., 1987. Response of medium duration rice varieties (dwarf indica) to levels of nitrogen. India Journal of Agronomy 32(3): 38687.

[12] Daquiado, N. P., 2019. Growth and yield performance of some lowland rice varieties applied with different rates of organic and inorganic fertilizers. Asian Journal Soil Science and Plant Nutrition, 4(2), pp. 1-11.

[13] Eshetu Y, Muhidin B. and Sisay G., 2023). Progress report. Survey assessment.

[14] FAO. 2020. The State of Food and Agriculture 2020. Moving forward on food loss and waste reduction. Rome.

[15] FAOSTAT (Food and Agriculture Organization Statistics), 2019. Statistics Division, available at: http://www.fao.org/faostat/en/#data/ QC. 2019: (Accessed on April 20, 2021).

[16] Farooq, M. K. H. M., Siddique, K. H., Rehman, H., Aziz, T., Lee, D. J. and Wahid, A., 2011. Rice direct seeding: experiences, challenges and opportunities. Soil and Tillage Research, 111(2), pp. 87-98.

[17] Garba, A. A., Mahmoud, B. A., Adamu, Y. and Ibrahim, U., 2013. Effect of variety, seed rate and row spacing on the growth and yield of rice in Bauchi, Nigeria. African Journal of Food, Agriculture, Nutrition and Development, 13(4), pp. 8155-8166.

[18] Gebrekidan, H. and Seyoum, M., 2006. Effects of mineral N and P fertilizers on yield and yield components of flooded lowland rice on vertisols of Fogera Plain, Ethiopia. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 107(2), pp. 161-176.

[19] Hameed, F., Xu, J., Rahim, S. F., Wei, Q., Rehman Khalil, A. U. and Liao, Q., 2019. Optimizing nitrogen options for improving nitrogen use efficiency of rice under different water regimes. Agronomy, 9(1), p. 39.

[20] Harris, K. D. and Vijayaragavan, R., 2015. Optimum seed rate for maximum yield in rice (Oryza sativa L.). Research Journal of Agriculture and Forestry Sciences, *3*(11), pp. 1-5.

[21] Jehangir, I. A., Ahangar, M. A., Hassan, T., Hussain, A., Mohiddin, F. A., Majid, A., Waza, S. A. and Raja, W., 2022. Agronomic practices for sustainable diseases management in rice: A review. Environment Conservation Journal, 23(3), pp. 122-134.

[22] Kaur, S., Singh, S. and Mohan, C., 2015. Impact of crop establishment and weed control on disease infestation and rice productivity. Ecology Environ Conservation, 21, pp. 163-166.

[23] Kumar, K. and Rao, K. V. P., 1992. N and P requirement of upland rice in Manipur. Oryza, 29, pp. 306-306.

[24] Ladha, J. K., Fischer, K. S., Hossain, M., Hobbs, P. R. and Hardy, B., 2000. Improving the. Productivity and Sustainability of Rice-Wheat Systems of the lndo-Gangetic Plains: A Synthesis of NARS-IRRI Partnership Research. Discussion Paper, 40.

[25] Ministry of Agriculture and Rural Development (MoARD). 2010. National rice research and development strategies of Ethiopia.

[26] Mobasser, H. R., Tari, D. B., Vojdani, M., Abadi, R. S. and Eftekhari, A., 2007. Effect of seedling age and planting space on yield and yield components of rice (Neda variety). Asian journal of plant sciences, 6(2), pp. 438-440.

[27] Mogiso, M., 2022. On-farm Evaluation of Agronomic Management Practices on Yield of Upland Rice in Kaffa Zone. Journal of Agriculture and Aquaculture, 4(3).

[28] Mohaddesi, A., Abbasian, A., Bakhshipour, S. and Aminpanah, H., 2011. Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological indices in high-yield rice (number 843).

[29] Muhidin et al., 2022, Research Achievements, Challenges and Future Prospects of Field Crops Agronomy and Physiology in Southwest Ethiopia. Proceedings of the 50 Anniversary Golden Jubilee of Jimma Agricultural Research Center (JARC), Ethiopian Institute of Agricultural Research (EIAR): Fifty Years of Coffee Based Agricultural Technology Service: 6-7 November 202, Jimma Agricultural Research Center, Jimma, Ethiopia. Pp. 1-394.

[30] Nawale S. A., Kadu V. M., Rane S. V., Lende A. B. and Gharte L. V., 2008. Evaluation of Tractor Mounted Laser Guided Land Laveler. International Journal of Agriculture, Environment & Biotechnology. Vol 1, issue 3 pp. 154-157.

[31] Omar, M. F. Z., Bookeri, M. M., Ahmad, M. T., Bakar, B. A., Abdullah, M. Z. K. and Harun, W. W., 2023. The Impact of Land Preparation Operations on the Land Leveling Index Status in a Rice Field. Advanced and Sustainable Technologies (ASET), 2(2).

[32] Panda, S. C., Panda, P. C. and Nanda, S. S., 1995. Effect of levels of nitrogen and phosphorus on yield and nutrient uptake of rice. Oryza, 32, pp. 18-20.

[33] Pandey, S. and Velasco, L., 2002. Economics of direct seeding in Asia: patterns of adoption and research priorities. Direct seeding: Research strategies and opportunities, pp. 3-14.

[34] Pattanayak, S., Jena, S., Das, P., Maitra, S., Shankar, T., Praharaj, S., Mishra, P., Mohanty, S., Pradhan, M., Swain, D. K. and Pramanick, B., 2022. Weed management and crop establishment methods in rice (Oryza sativa L.) influence the soil microbial and enzymatic activity in sub-tropical environment. Plants, 11(8), p. 1071.

[35] Prakash, M., Sunilkumar, B., Narayanan, G. S., Gokulakrishnan, J. and Anandan, R., 2016. Seed germination and seedling growth of rice varieties as affected by flooding stress. Indian Journal of Agricultural Research, 50(3), pp. 268-272.

[36] SanjeewanieGinigaddara, G. A. and Ranamukhaarachchi, S. L., 2011. Study of age of seedlings at transplanting on growth dynamics and yield of rice under alternate flooding and suspension of irrigation of water management. Recent Research in Science and Technology, *3*, pp. 76-88.

[37] Sharada, P. and Sujathamma, P., 2018. Effect of organic and inorganic fertilizers on the quantitative and qualitative parameters of rice (Oriza sativa L.). Current Agriculture Research Journal, *6*(2), p. 166.

[38] Shukla, A. K., Ladha, J. K., Singh, V. K., Dwivedi, B. S., Balasubramanian, V., Gupta, R. K., Sharma, S. K., Singh, Y., Pathak, H., Pandey, P. S. and Padre, A. T., 2004. Calibrating the leaf color chart for nitrogen management in different genotypes of rice and wheat in a systems perspective. Agronomy Journal, 96(6), pp. 1606-1621.

[39] Sultana, M. R., Rahman, M. M. and Rahman, M. H., 2012. Effect of row and hill spacing on the yield performance of boro rice (cv. BRRI dhan45) under aerobic system of cultivation. Journal of the Bangladesh Agricultural University, 10(1), pp. 39-42.

[40] Taddesse, L., 2015. Estimation of Genetic Variability and Trait Association in Nitrogen Use Efficiency of Upland Rice Varieties in North-Western Ethiopia. International Journal of Research and Review, 2(9), pp. 527-535.

[41] Tadesse, T. and Tadesse, Z., 2019. Review of rice response to fertilizer rates and time of nitrogen application in Ethiopia. International Journal of Applied Agricultural Sciences, 5(6), pp. 129-137.

[42] Tadesse, T., Liben, M., Assefa, A. and Tadesse, Z., 2013. Effect of transplanting on rice in Northwestern Ethiopia. Ethiopian Journal of Science and Technology, 6(1), pp. 47-54.

[43] Tadesse, T., Tadesse, Z., Assega, H. and Abaychew, D., 2020. Biological and economic response of rice to nitrogen and phosphorous fertilizer applications under rain-fed lowland production ecology. Academic Research Journal of Agricultural Science and Research, 8(2), pp. 60-9.

[44] Tadesse, Z., Tadesse, T. and Habtamu, A., 2019. Effect of seed rate and row spacing on yield and yield components of rain fed lowland rice (Oryza sativa L.) variety. International Journal of Research Studies Agricultural Science 5, pp. 18-26.

[45] Taye, Y., Ayalew, D. and Abera, B., 2024. Optimum Seeding and Nitrogen Fertilizer Rates for Maximizing Yield and Sustaining Rain-Fed Lowland Rice (Oryza Sativa L.) in Fogera Plain North-western Ethiopia. Journal of Chemical, Environmental and Biological Engineering. Vol. 8, No. 2, pp. 52-65.

[46] Tegegne, M. A., 2020. Assessment on Constraints and Opportunities of Rice Production Trends in Fogera-Ethiopia. The Case of Lowland Rice Production System. International Journal of Research, 6(4), pp. 1-7.

[47] Thakur, R. B., 1993. Effect of split application of nitrogen on growth yield and N uptake in wetland rice (Oryza sativa). Indian Journal of Agronomy, 38(2), pp. 38_2-38_2.

[48] Vange, T. and Obi, I. U., 2006. Effect of planting date on some agronomic traits and grain yield of upland rice varieties at Makurdi, Benue state, Nigeria. Journal of sustainable development in agriculture and environment, 2(1), pp. 0794-8867.

[49] Yoshida, S., Satake, T. and Mackill, D. S., 1981. High-temperature stress in rice [study conducted at IRRI, Philippines]. IRRI Research Paper Series (Philippines), (67).

[50] Younas, A., Yousaf, Z., Riaz, N., Rashid, M., Razzaq, Z., Tanveer, M. and Huang, S., 2020. Role of nanotechnology for enhanced rice production. Nutrient dynamics for sustainable crop production, pp. 315-350.