ISSN:(O) 2320-5407, ISSN(P) 3107-4928 Int. J. Adv. Res. 14(03), March-2026, 593-602

Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/22976
DOI URL: http://dx.doi.org/10.21474/IJAR01/22976

ISSN (O): 2320-5407
ISSN (P): 3107-4928

RESEARCH ARTICLE

FIELD TRIAL ON THE EFFECTS OF SEEDLING AGE, YIELD AND ECONOMIC RETURNS OF SAHEL 134 UNDER LOWLAND IRRIGATED ECOLOGY

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Manuscript Info

Manuscript History
Received: 10 January 2026
Final Accepted: 12 February 2026
Published: March 2026

Key words:-
Seedling age,yield, economic returns, irrigated ecology.

Abstract

In the Sahel and West Africa, the yields of rice are marginally low and other parts of the world, mainly attributed to soil-related constraints such as poor soil fertility, salinity, water management, poor land development and inadequate adherence to best agronomic practices. The objective of the research was to evaluate the growth, yield and economic returns of Sahel 134 rice variety in low land irrigated rice ecology. The research was conducted using a randomized complete block design (RCBD) with four (4) treatments 2, 3, 4,5 and control treatment.The data collected were analyzed using Microsoft Excel and analysis of variance (ANOVA). The results showed that percentage of ripened grains in the 2and 5-weeks old seedling age is significantly higher of 80%than 2 weeks andcontrol of 69% at 3 weeks old. The Sahel 134 exhibited highest paddy yield from 3 weeks of 12.27 t/ha and obtained 13.02 t/ha at 5 weeks while lowest yield scored was 9.82t/ha at 2 weeks respectively. The result shows that, with the production cost of D75,550 per hectare and the selling price of D20/kg.Furthermore, the results indicate that, at 5 weeks seedling performed optimally with significant improvement on yield and economic returns.In conclusion, at 5 weeks of seedling age enhances productivity and profitability of Sahel 134 rice variety with optimal economic returns. The research finding reveals implication to policy makers, researchers and rice farmers in their quest to improve on rice production, productivity and economic returns.

Introduction:-

Rice (Oryza Sativa) is a semi-aquatic plant, and it is the only crop that can grow well on fields with different levels of flooding conditions. Rice requires specific growing conditions to be successfully cultivated. It must be grown in a flooded field in several inches of water.Rice is a staple food for over 3.5 billion people worldwide (50%), with the majority of consumption occurring in Asia and Africa.The global demand for rice will be about 584 million tons or less towards 2050. With positive technological developments in the rice research arena, the shape of rice agriculture

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will change towards 2050. Asia may lose about 5 million ha and Africa gain about 10 million ha of rice land by 2050 (Parshuram, S. et al; 2021).The demand for rice in the Sub-Saharan Africa is continuously increasing. The worldwide rice consumption has seen a steady increase, reaching 520,437 thousand metric tons in 2022-2023 (Kavi Kumar K.S. 2021). Rice production in sub-Saharan Africa has been significantly affected by recurring droughts, which is more susceptible to when compared to other crops. In sub-Saharan Africa, rice production is primarily under rain fed conditions that rely primarily on rainfall pattern, making the crops vulnerable to droughts, floods and rising temperatures. Climate change intensifies soil salinity, and this greatly affects crop yield and the technical efficiency of rice farming (Oelviani, et al; 2024).Farmers use a variety of climate-smart practices and technologies to respond to climate events. Such climate-smart practices include planting improved rice varieties, planting different crops, soil and water conservation techniques, adjusting planting and harvesting dates, irrigation, reliance on climate information and forecasts, planting on the nursery, appropriate application of fertilizer, and effective use of pesticides (Ul H, et al; 2023).

In many African countries, rice is considered a staple food and constitutes a major part of the diet. Globally, rice production is anticipated to increase a range of 58 to 567 metrics tons by 2030 (Mohidem, et al; 2022).Rice production in The Gambia is undertaken in different ecologies lowland rainfed, lowland irrigated (pump and tidal), hydromorphic conditions, upland rainfed, and swamps ecology (mangrove swamps). Food security can be maintained by enhancing crop yields through cultivating rice on limited land areas, particularly in The Gambia. As rice-based agro-ecosystems develop intensively, this adversely impacts environmental health. The intensively managed rice agro-ecosystem, known as a cropping system, has a number of unique properties due to which the application of agricultural technologies in rice farming is considered unusual in the global agronomy (Mohidem, et al; 2022). It is the staple food with a per capita consumption of 117 kg per annum, which is above the world average of 56.6 kg per annum.The annual requirement which is determined by the annual population increase stands at about 436,000 metric tons of paddy with a population of 2.2 million people in 2021 of which only 19% was locally produced and the deficit is met through importation (Luo et al; 2022). Rice is an important food crop and an emerging income crop for smallholder farmers.

The population of The Gambia is projected to increase to 3 million by people in 2030 with a projected increment in rice requirement to 552,000 metric ton of paddy(Parshuram et al; 2021).The mean yield at farmer level has increased significantly from 1-2 tons per hectare in the past decades to 2-3 tons/per hectare in the upland conditions and 4-8 ton per hectare in the lowland irrigated rice fields due to the activities of the agricultural projects and government initiatives in the rice value chain. However, several constraints hinder the production and productivity of the rice sector in both ecologies. The lowland irrigated fields are affected by poor land development, poor water management (irrigation and drainage facilities), knowledge gaps in the effective utilization of fertilizers (fertilizer application rate and timing), planting density, seedling age, weeding frequency seed quality(Dossou and Saito, 2022). Rice is commonly grown by transplanting seedlings in lowland ecologies.

Optimizing seedling age of Sahel 134 provides agronomic and economic benefits for rice producers in The Gambia valley. The present study is guided by four principal considerations. Firstly, there is no or limited research on the use of optimal seedling age for Sahel 134 that is commercially accepted by the producers in The Gambia and her regional member countries, leaving a gap in context-specific agronomic recommendations. Secondly, the land and water productivity coupled with climate resilience is significantly recognize as a vital to optimal grain yield and quality. Soil and water productivity is crucial in Gambian lowland irrigated rice fields where water management is needed. Thirdly, evaluating the economic robustness and sensitivity is important to empower smallholder farmers and the extension unit with a database for a profitable decision-making process. Finally, overcoming local challenges in determining the best age suitable for Sahel 134 and similar varieties to local soil and climatic conditions thereby, overcoming traditional farming practices. With the national focus on improving domestic production, addressing rice self-sufficiency and food security issues through better agricultural practices, by addressing these gaps. Furthermore, climate change is the main cause of biotic and abiotic stresses, which have adverse effects on the world's crop production and productivity (Began, T. 2022).

Several studies have shown that the ages of seedling at transplanting have a significant effect on the growth, yield, and economic return of rice. According to (Wang et al;2024) observed that seedling ages at transplanting had a significant effect on productive tillers per hill, post-transplant shock, and impact on yield components. Adoption of climate -smart agriculture practices such as improved rice varieties, soil and water conservation techniques, effective and efficient use of pesticides, and adjusting the planting and harvesting dates can increase yield by approximately

15.87% as well as incomes of farmers (Bijarniya, D.et al; 2020).Applying proper seedling age are among the good agricultural practices (GAPs) contributing to narrow down the existing yield gaps. Using older seedling ages affects rice growth, tillering pattern, vegetative and reproductive period while too young seedling ages creates seedling establishment problem mainly in waterlogged field conditions (Bijarniya, D. et al;2020). Therefore, the study aims to identify the optimal seedling age on the growth, yield and economic returns of Sahel 134 in the lowland irrigated rice fields of Central River Region.

Materials and Methods:-

Experiment Site Description:-

The experiment was conducted at the Sapu Agricultural Research Station, Central River Region (CRR), of the fromFebruary to August 2025.The soil characteristics is a loamy clay soil and varying dry pattern of high temperatures and high humidity period in which the experiment was conducted in an ideal condition. The field trial was conducted under lowland irrigated rice ecology system with favorable environmental condition.

Experimental Design and layout:-

The experiment consists of one factor (seedling age) of four (4) treatments. The treatments weredesigned in a randomized complete block design (RCBD) with three (3) replications, with each plot measuring 4m x 3m, giving a total of 12m^2 plots. Each plot size was separated by 1m between plots and 1m between blocks respectively.

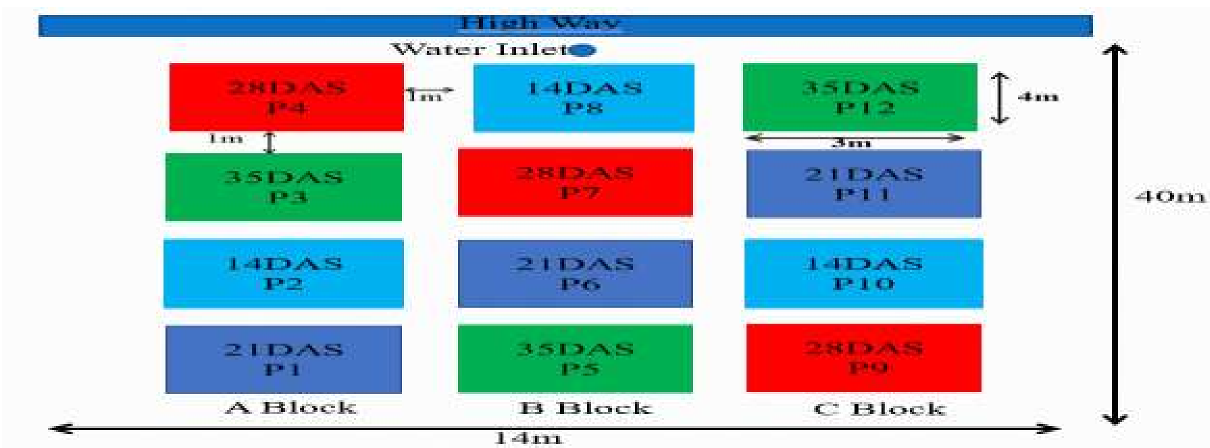

Figure 1. Experimental Design and Layout.

Sampling procedures (sampling methods), treatment justification, sample size justification, and control measures:-

Rice growth was monitored and recorded systematically. Agronomic parameters including plant height (cm), tiller number per hill, and leaf color were measured and recorded at approximately every 7-10 days. Five (5) representative hills per plot were tag and information on tiller (stem) number, plant height using a ruler, leaf color determined using a leaf color chart (Fujihira Industry Co. Ltd.) were measured across all treatments and replications for the growth data. A component-based measurement was implored to determine the grain yield. In this method, five (5) sample hills were randomly selected from the middle rows of each plot avoiding the border rows and plant hills. The harvested hills by sickle were dried in a screenhouse for fourteen days and panicles cut and counted, spikelets (grains) quantified. Matured grains were separated with water, air-dried and recounted to determine the exact ripening ratio. Matured and filled grains were weighed to calculate the 1,000-grain weight using an electronic weighing scale. A moisture grain tester adjusted to 14% standard was use to established the moisture content of each treatment. With the computation of these yield components, the grain yield ton/ha was estimated.

Seed Treatment:-

Rice seeds of Sahel 134 were pre cleaned and floated in water to remove empty grains. This was followed by hot water treatment at 60^{0}C for 10 minutes and soaked in warmwater for 5 minutes to simmer down. The seeds of SAHEL 134 varieties were pre germinated for 48 hours at 25-30^{0}C and seeds were sown onnursery boxes measuring 60cm x 30cm with a sowing rate of 140 grams of seeds respectively.

Field Preparation and Fertilizer Application.:-
The land was prepared for cultivation using a tractor mounted with an arrow for ploughing and rotovator for land levelling and evapotranspiration of the field. The fertilizers were applied according to the setup of the field conditions and guided by rice farmer's recommendationswith an equal distribution across all plots. This included an application of compound fertilize N, +P205, +. K20(15:15:15)50kg/bag and Urea 46% 50kg/bag. In each bag of compound fertilizer N+P205, K20. (15:15:15) 50kg/bag contained7.5kg of nitrogen (N), phosphorus (P), and potassium (K) respectively. In addition, in each bag of 50kg of urea contained 23kg of nitrogen (N). In the process of fertilizer application,the Ratio is N129kg/ha; P_2O_5 60kg/ha; K_2O 60kg/hawas applied at basal dressing (-3DBT) and 20% at top dressing (47DBT), while 60% of urea was applied at basal dressing (-3DBT) and 40% at top dressing (47DBT). Table 2. Shows fertilizer application rate and timing.

Table 1. Fertilizer application rate and timing.

Compound Fertilizer	Application Methods		Total number of fertilizer/kg
	Basal Dressing (-3daysbefore transplanting)	Top Dressing (47 days after transplanting)	
NPK	320 (80%)	80(20%)	400 (8bags)
Urea	90 (60%)	60 (40%)	150 (3bags)
Grand total			

Data collection and Statistical Analysis:
In any field trial data collection is very key and important as it directs you to take decisive decisions or make adequate projections to meaningful development initiatives. The data was collected on the growth stages and yield component of Sahel 134. The parameters in growth observed were plant length (cm), stem number, and leaf color. Data were almost collected at an interval of every 10 days from a total of five (5) identified and labeled sample plants from each plot.Data were analyzed using Microsoft Excel and analysis of variance (ANOVA) with Turkey's HSD Test (JMP ver.14.0).

Limitations and Future Scope:-
This evaluation relies on a single set of cost and price parameters. Variability in input prices, labor availability, and weather can alter economic outcomes. Multi-season and multi-site trials would strengthen generalizability and expansion of the trial to other rice ecologies remains futile as requires financial resources to conduct this kind of research trial.

Results and Discussion:-
In field experimentation data collection, analysis and interpretation of the results is important for projections for future development initiatives for appropriate decision making on policy matters. The results from the field trial shows that, all the treatments demonstrated a steady increase in plant length from active tillering stage to ripening stage as in Figure 2.The mean plant height for Sahel 134 rice varieties at 60 days after transplanting, the highest mean length of 110.1cm was recorded in the control treatment (3 weeks) seedling age, 104.5cm recorded with 4 weeks treatment, 98.7cm was recorded at 5 weeks treatment while the smallest of 94.6cm was recorded at 2 weeks old treatments. Seedling age 3 weeks old scored a higher mean plant length, likely attributed to more advanced growth stage, greater initial vigor, which helped to minimize post transplanting shock which could improve utilization of nutrients resources and solar radiation. Within SRI, seedling age and crop geometry are key determinants of yield and economic returns. Early transplanting of young seedlings maximizes tillering potential by transplanting before the fourth phyllochron begins (Kavi, 2021).Statically, significant treatment effect differences on plant length by seedling age were observed from 23DBT to 60DBT with a p-value 0.0009, at $P<0.05$.

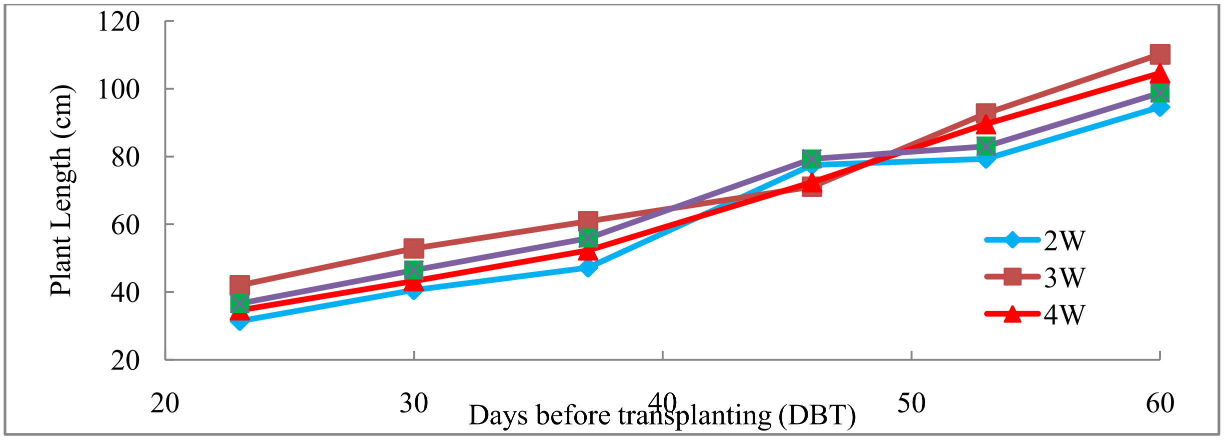

Figure 2. Changes in plant length on Sahel 134 under different seedling ages:

In rice agronomy stem number and tillering is an integral component of crop physiology as it determines the yield potential in terms of grain composition(Mebrate, T.and Abdisa, 2023).The results in figure 3 shows that, Sahel 134 had rapid increment rapid increment in tiller number/m^2 from 23DBT-45DBT in all treatments 2, 3, 4, and 5 respectively. At 46-47DBT (top dressing), 3 weeks old seedling age started declining in tiller number while the remaining treatments (2, 4, and 5) recorded a slide increment not significantly different. A steady decline of tiller number/m^2 was observed in all treatments except the 2 weeks old seedling after the maximum tillering stage until the heading stage. This is attributed to the die-off of unproductive tillers with the highest treatments of 3, 4, and 5 as plants redirected energy from tiller production (vegetative stage) to panicle development and grain filling (reproductive stage). Variation occurred among the treatments due to the rate of decline, with some maintaining higher tiller number/m^2 than others. Treatment of 2 weeks old seedling age had relatively the highest tiller number/m^2.

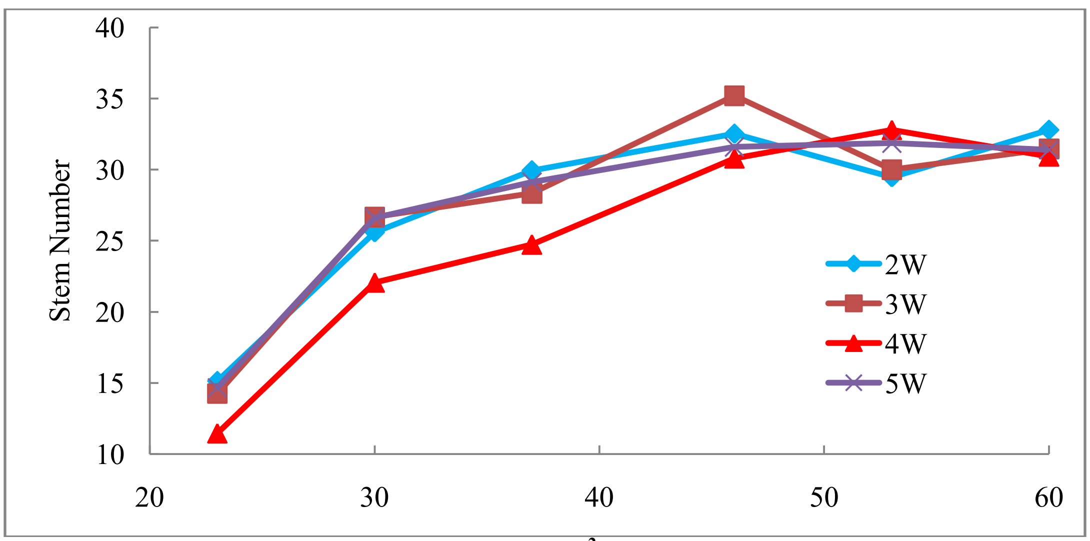

Figure 3. Changes in stem/tiller number/m^2 on Sahel 134 under different seedling ages.

In rice production and productivity, the leaf color is a morphological trait that reveals the photosynthetic activity and nutrient content of the rice plant (citation). The leaf color chart helps farmers decide when and how much nitrogen fertilizer to apply and is a visual cue for nitrogen content. As shown in figure 3 the leaf color increase steadily from transplanting up to maximum tillering stage. A week from top dressing fertilizer application, there was a consistent increase in leaf color across the treatments, with 3 weeks all seedlings showing a greater increase compared to others. According to (Mupeta et al; 2022) at 53DBT (heading), all treatments, showed a marked decrease in leaf color, indicating a reduction in nitrogen levels as the rice crop approached the harvesting period.This also indicates the leaf (source organ) had started supplying photosynthetic products to sink (panicles and grains). Moreover, the

ANOVA results indicated that the interaction had no statistically significant effect on Leaf Color. Moreover, the ANOVA results indicated that the interaction had no statistically significant effect on leaf color

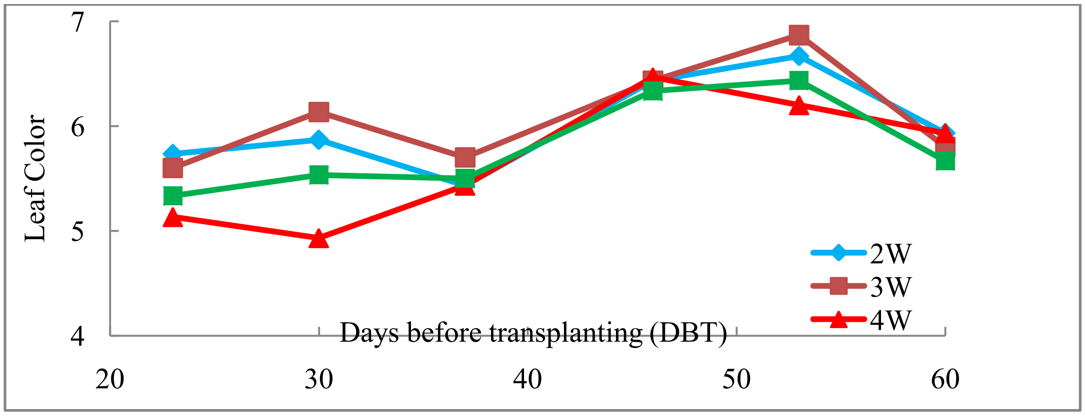

Figure 4. Changes on leaf color on Sahel 134 under different seedling ages.

In the process of rice production yield is primarily is determined by four key components of panicles per unit area, spikelet per panicle, percentage of filled spikelets and individual grain weight. These, along with other factors like tillers per hill and panicle length directly influence the final grain while optimal management of these components is crucial for achieving high, sustainable, and profitable rice production(Wang et al; 2024). The results from the research findings in Table 2showed that the interaction of the seedling age on yield components, difference in panicle number among seedling ages was not statistically significant (p>0.05). However, the difference in grain number per panicle and the difference in 1000-grain weight among seedling ages are statistically significant, whereas the difference in percentage of ripened grains among seedling ages was highly significant. The highest mean panicle number of 31.3 happened at a seedling age of 5 weeks with a grain number of 108.3ab influences a greater yield of gram per meter square of (1302), despite the difference was not statistically significant for panicle number. The lowest yield occurred at 2 weeks and 4 weeks old seedling ages asshowed in Table 2 and Figure 5.According to (Liang et al. 2025)if temperatures exceed 30 °C for more than five consecutive days during the grain-filling stage, aleurone layer development is suppressed and starch accumulation is impaired, resulting to poor grain formation.

Table 2. Effect of treatments on grain yield and yield components.

Seedling age (Week)	Panicle (#of hills)	Grain number (#/panicle)	Percentage (%) ripened grains	1000-grain (g/1000-grain)	Yield (g/m^2
2	23.3	94.0b	80.1a	25.3ab	982
3	27.4	112.7a	69.4bc	25.8ab	1227
4	25.1	109.2ab	65.2c	28.4a	1128
5	31.1	108.3ab	78.8ab	21.9b	1302
P-value	0.0708	0.0317	0.0003	0.0089	

Note 1: Figures followed by the same letter are not significantly different at P=0.05 by Turkey's HSD Test
ANOVA: Analysis of Variance

Further, discussion and interpretation of the results data, it is equally important to see the interaction between the yield (t/ha) and seedling age in weeks. The results in Figure 5 showed that, at the seedling age of 3 weeks 12.3 tons/ha was obtained while seedling age of 4 weeks slightly obtained 11ton/ha. The highest tons/ha scored was 13ton/ha at the seedling age of 5 weeks. In rice production and productivity high yields above 10ton/ha under control environment would determine the level of food and nutrition security in a given country (Sah et al; 2023).

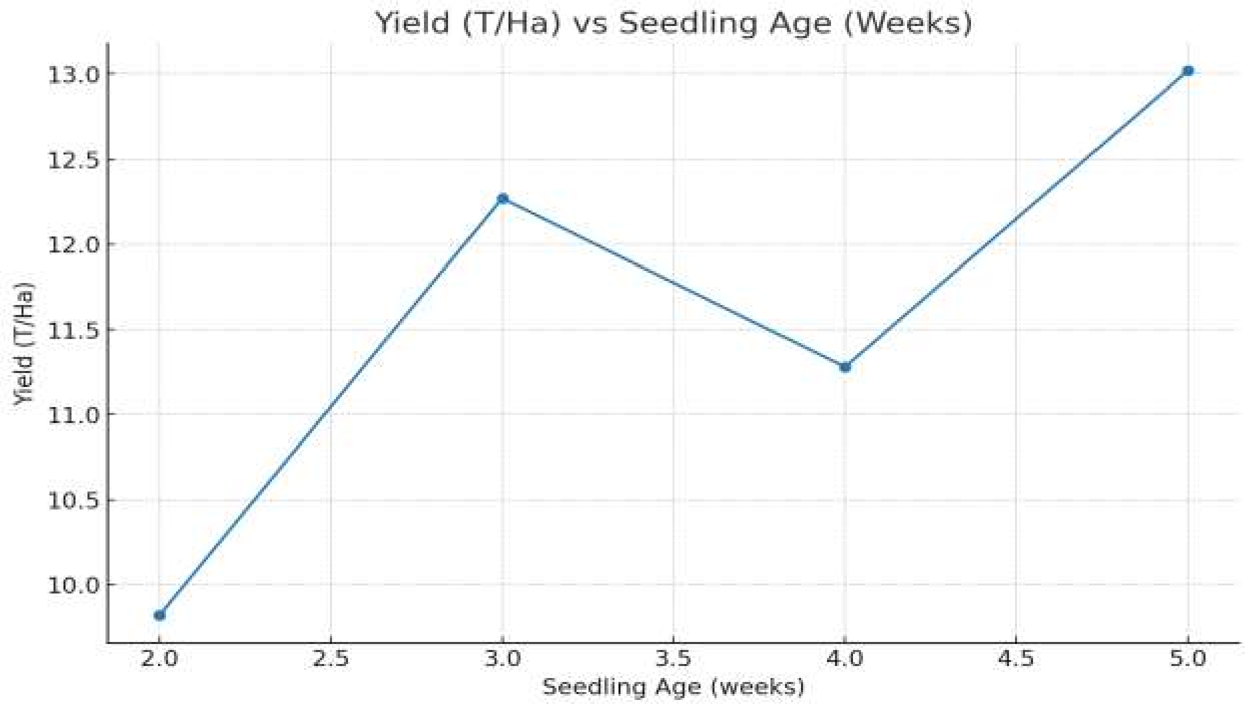

Figure 5. Relationship between paddy yield (t/ha) and seedling age (weeks)
Note 2: Grain yield (t/ha) is the paddy yield adjusted for a moisture content of 14 %

The production cost-benefit analysis which comprises of the fixed costs and variable costs is a crucial tool in the production of Sahel 134 rice.The application of climate-smart agricultural technologies by smallholder farmers is vital for sustaining rice production (Anugwa et al., 2022).It helps farmers and policymakers evaluate the profitability and efficiency of different production systems. By comparing the costs of various inputs, outputs, and practices, cost of production analysis can reveal the optimal allocation of resources and the best strategies for improving productivity and sustainability.From table 5 the results indicate superior profitability for transplanting 3 weeks and 5 weeks old is more profitable provided that management is adequate. Seedling age of five weeks delivers the highest net incomes and favorable BCRs, with adequate agronomic management for older transplants(Champness, et al; 2023).

Table 3. Results ofcost-benefits analysis of Sahel 134 rice variety.

Seedling age (weeks)	Yield (t/ha)	Revenue (GMD)	Net income (GMD)	BCR	ROI	Profit margin (%)
2	9.82	196,400	120,850	2.60	1.60	61.5
3	12.27	245,400	169,850	3.25	2.25	69.2
4	11.28	225,600	150,050	2.99	1.99	66.5
5	13.02	260,400	184,850	3.45	2.45	71.0

In the interpretation of the results in Figure 4 showed that, at the seedling age of 3weeks scored net income D170,000 while net income declined to D150,000 net income. Further, the most outstanding net income obtained was above D180,000 at the age of 5 weeks. The relationship between net income and seedling age in agriculture is typically inverse, with younger seedlings generally producing higher net income due to better establishment, higher tillering, and greater crop yield. Adoption of climate -smart agriculture practices such as improved rice varieties, soil and water conservation techniques, effective and efficient use of pesticides, and adjusting the planting and harvesting dates can increase yield by approximately 15.87% as well as incomes of farmers (Bijarniya D, et al; 2020).

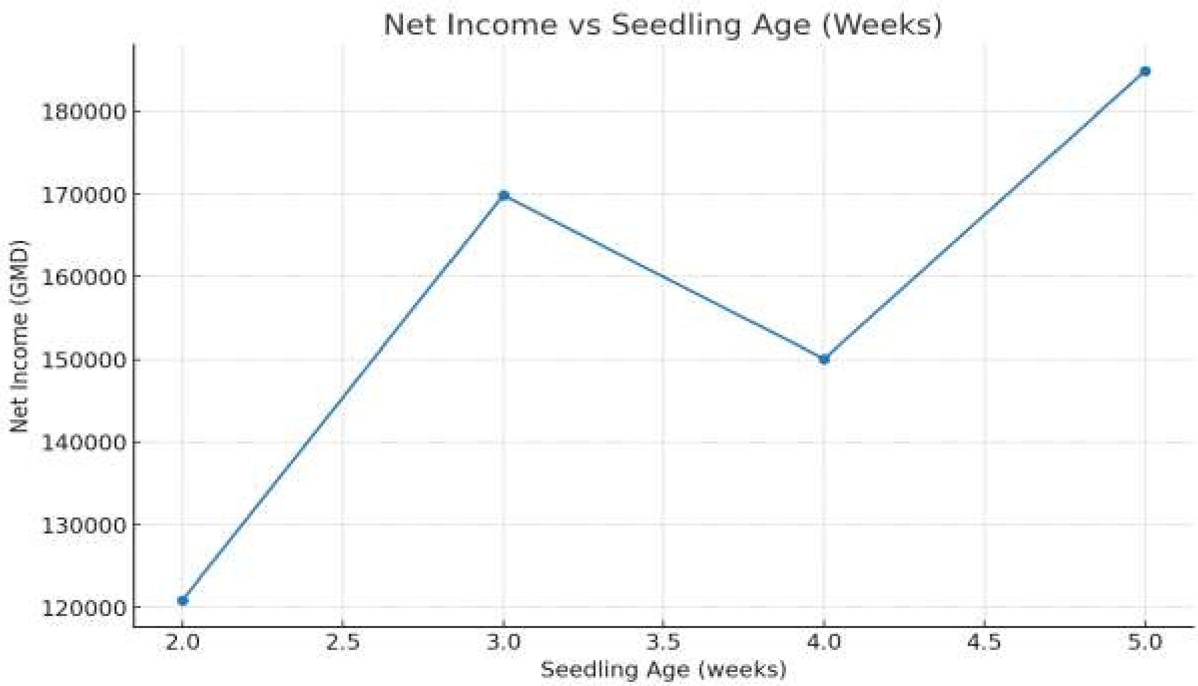

Figure 6: Relationship between seedling age and net income

Conclusion and Recommendation:-

In developed and developing countries rice as a crop is widely grown and consumed in the Sahel and West African countries in which is not exceptional. The government and the Ministry of Agriculture, Livestock and Food Security have set series of development priorities especially in the area of rice production. The policy direction is shifting from subsistence to commercialization towards the attainment of rice self-sufficiency in a medium term. The trial research trial was conducted in Sapu Research Agricultural Station with the ultimate objective was evaluate the growth, yield and economic returns of Sahel 134 rice variety in low land irrigated rice ecology. The research was conducted using a randomized complete block design (RCBD) with four (4) treatments 2, 3, 4,5 and control treatment. The data collected were analyzed using Microsoft Excel and analysis of variance (ANOVA x) JMB (ver.14.0). The results revealed that, at the age of 2 to 5 weeks suggestsunder normal trial conditions, older transplants experienced less transplanting shock and had greater initial biomass and root capacity to support rapid post-transplant establishment. These advantages likely increased tiller survival and panicle number per unit area, translating into higher yields and returns. The results from the research findings in Table 2 showed that the interaction of the seedling age on yield components, the difference in panicle number among seedling ages was not statistically significant ($p>0.05$).

Furthermore, at 5-weeks of seedling ageobtained the best results while under normalconditions very old seedlings can reduce tillering potential or increase lodging risk affecting the yield component. The economic robustness and sensitivity revealed that the benefit-cost ratios (BCRs) exceed 3.45 for the top treatments indicating wide profit margins under better selling price 20 GMD/kg) and cost structure. The results showed that percentage of ripened grains in the 2- and 5-weeks old seedling age is significantly higher of 80%than 2 weeks andcontrol of 69% at 3 weeks old. The Sahel 134 exhibited highest paddy yield from 3 weeks of 12.27 t/ha and obtained 13.02 t/ha at 5 weeks while lowest yield scored was 9.82t/ha at 2 weeks respectively. Importantly, operationalize 3-5 weeks transplanting window, farmers will require reliable nursery management uniform seedling trays or well managed seedbeds, that is timely land preparation, and assured water management and nutrients. Where labor is a constraint, labor-saving arrangements (group transplanting, mechanized transplanting where feasible) can support adoption without eroding profitability. The research implications to farmers will the window of opportunity to adopt and apply the best practice of 3and 5-weeks seedling age for better yields. This will help the small-holder farmers to attain food self-sufficiency and income security. Furthermore, for practice and policy implications will the governments to develop coherent policies, programs and strategies to revamp rice production and productivity in medium- and long-terms. The research implication to the private sector would strengthen the public-private partnership andknowledge generated shall be used by the private sector to enhance rice production for better yields. In conclusion, the research results revealed that, the practical window of 3-5 weeks is advisable for smallholder farmers to adopt and put into practice new technology generated with suitable temperature, adequate water regime and proper seedling management. The research recommends further trial on the application of different fertilizer rates on different rice varieties.

Acknowledgement:-
I would like to acknowledge the entire staff of the Ministry of Agriculture, Livestock, and Food Security (MoALFS) for their support at the time of field experimenttrial. I would also extend my gratitude to the Central Project Coordinating Unit (CPCU)for their immense support by funding the research trial. I would like to express my sincere gratitude to the Government of Japan, throughJapan International Cooperation Agency (JICA) for their generous support. I thanked Mr. Musa Humma, Director General, Department of Agriculture and Dr. Demba Jallow, Director General, National Agricultural Research Institute for their guidance and technical support. My heartfelt appreciation goes to Dr. Hisayoshi Hayashiand Dr. Saikou E. Sanyangfor their valuable mentorship throughout the research process. I am also grateful to Mr. Alieu Loum for sharing his knowledge, skills and wealth of experiences during the entire process. Finally, I acknowledged my field assistant Mr. Mustapha E. Ceesay and my family for their patient and understanding during the research work and write-up to the success of the scientific paper.

Declarations:-
Fund Statement:-
The work was funded by GIRAV (World Bank) and P2P2RS (African Development Bank)

Conflict of interest:-
The Author declared no conflict of interest in this research work.

References:-

1. Anugwa, I. Q., Onwubuya, E. A., Chah, J. M., Abonyi, C. C., Nduka, E. K., A., Chah, J. M., & Abonyi, C. C. (2022). Farmers' preferences and willingness to pay for climate- smart agricultural technologies on rice production in Nigeria. Climate Policy, 22(1), 112–131 https://www.researchgate.net/publication/382027238_
2. Begna, T. (2022). Effects of Drought Stress on Crop Production and Productivity. International Journal of Research Studies in Agricultural Sciences, 6(9), 34–43. https://doi.org/10.20431/2454-6224.0609005.
3. Bijarniya D, Parihar, C.M, Kalvania K, and Kakraliya, S.K. and Jat M.L. (2020). Doi: 10.3390/ agronomy 10101561.
4. Champness, M.Vial, L., Ballester, C. and Hornbuckle, J. (2023). Evaluating the performance and opportunity cost of a smart-sensed automated irrigation system for water-saving rice cultivation in temperate Australia. Agriculture. mdpi.com
5. Dossou, Y.E.R, and Saito, K.(2022). Impact of management practices on weed infestation, water productivity, rice yield and grain quality in irrigated systems in Cote ˆ d′ Ivoire. Field Crop. Res. 270, 108209 https://doi.org/10.1016/j.fcr.2021.108209.
6. Kavi Kumar K.S. (2021). Rice Production Systems and Drought Resilience in India. In: Dasgupta P., Saha A.R., and Singhal R. (eds.) Sustainable Development Insights from India. India Studies in Business andEconomics. Springer, Singapore. https://doi.org/10.1007/978-981-33-4830-115.
7. Liang H, Zhou J, and Chen, C. (2025) The aleurone layer of cereal grains: development, genetic regulation, and breeding applications. Plant Commun. https://doi.org/10.1016/j.xplc.2025.101283.
8. Luo, W., Chen, M., Kang, Y., Li, W., Li, D., Cui, Y., Khan, S., and Luo. Y.(2022). Analysis of crop water requirements and irrigation demands for rice: Implications for increasing effective rainfall. Agricultural Water Management.https://doi.org/10.1016/j.agwat.2021.107285.
9. Mebrate, T. and Abdisa (2023), "Suitable Spacing and Phosphorus Application Rate for Shero-Type Field Pea (Pisum sativum L.) Production on Acidic Nitisols in the Central Highlands of Ethiopia", Cross Current International Journal of Agriculture and Veterinary Sciences, 5(6): 108-117.DOI: 10.36344.
10. Mohidem, N.A, Hashim N, Shamsudin R, and Man, H.C. (2022). Rice for food security: Revisiting its production, diversity, rice milling process and nutrient content. http:/doaj.org/ article/a62338ec.
11. Mupeta, I. Susu W. C.and Nkumbe, N. C.(2022).The Effect of Seedling Age on Growth and Yield of NERICA4Rice. Asian Journal of Agriculture and Food Sciences https://doi.org/10.24203/ajafs.v10i1.6881

12. Oelviani R, Adiyoga W, Suhendrata T, Bakti I, Sutanto, H.A, and Fahmi, D. A (2024). Effects of soil salinity on rice production and technical efficiency: Evidence from northern coastal region of Central Java, Indonesia.
13. Parshuram, S. Suresh, C.B.Biswajit, M. and Sarba, N. M. (2021). The global rice agriculture towards 2050: An inter-continental perspective. https://doi.org/10.1177/00307270221088338.
14. Sah, M.K.Shrestha, A. Shah, P.and Mishra, A. (2023) Impact of Age of Seeding and Varieties on Yield and Yield Attributing Characters of Rice in Central Terai Region of Nepal. Agronomy Journal of Nepal.https://doi.org/10.3126/ajn.v7i1.62154.
15. Ul, H., Rezvi, A., Azim, A. A., Ahmed, T., Mohammad, T., Hasan, M., Farhana, T., Dawood, M. F. A., Skalicky, M., & Brestič, M. (2023). Rice and food security: Climate change implications and the futureprospects for nutritional security. Food and Energy Security, 12(430), 1–17.https://doi.org/10.1002/fes3.43 Wang, J., Han, M., Huang, Y., Zhao, J., Liu, C., and Ma, Y. (2024). Flooding Tolerance of Rice: Regulatory Pathways and Adaptive Mechanisms.https://doi.org/10.3390/plants13091178.
16. NB: I have improved on the references and proof read the text once again.