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EFFECTS OF IRRIGATION SCHEDULING AND ORGANIC FERTILIZER ON RICE CROP GROWTH AND YIELD USING BASIN IRRIGATION SYSTEMS

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ABSTRACT

The need for additional food supplies to reduce poverty among smallholder farmers resulted to rapid expansion of irrigation by developing small-scale irrigation schemes and techniques required for tackling household food insecurity. However, high cost of energy for water application and availability, quality and cost of inorganic fertilizer are among the major constraints militating against the productivity of small holder rice irrigation farmers in Nigeria. Thus, this study investigated the effects of varying irrigation schedules and chicken manure application on the growth and yield of irrigated rice (Oriza Sativa L.) using basing irrigation technique at Namtari to establish a decision-making tool for smallholder farmers to increase the grain yield potential at low cost of production. The experiment employed a Randomized Complete Block Design (RCBD) with sixteen treatments, combining four irrigation intervals (6, 8, 10 days and Irregular intervals) and four chicken manure application rates (0, 8, 10 and 12 tons/ha). The rice variety used was Gawal R1 (CHAOTAN), lowland variety resistant to various stresses. Results showed that the 6-day irrigation schedule with a 10 ton chicken manure application rate (I_6C_{10}) resulted in highest growth height value and crop grain yield of 115.15 cm and 7.50 tons/ha, respectively, compared to other treatments in the study area. The 6-day irrigation schedule also demonstrated superior water use efficiency (WUE) and water productivity (WP), highlighting the effectiveness of optimized irrigation combined with organic fertilizers. The incorporation of chicken manure improved the water-holding capacity, ensuring consistent moisture availability during critical growth stages. Thus a 6-day irrigation interval combined with moderate amount of chicken manure at the rate of 10 tons/ha is recommended as a sustainable approach to rice production in semi-arid regions that will promote both crop productivity and resources conservation.

Keywords: Irrigation scheduling, organic fertilizer, rice yield, water use efficiency, basin irrigation, Namtari

1 INTRODUCTION

Rice (*Oryza sativa L.*) is a vital crop for food security in Nigeria, yet its production is constrained by several factors, including water scarcity and the high cost of inorganic fertilizers [1]. The increasing volatility in fertilizer prices, driven by global energy costs and supply chain disruptions, has further exacerbated the challenges faced by smallholder farmers [2]. In response, there has been a growing interest in the use of organic fertilizers, such as chicken manure, as a sustainable alternative to inorganic fertilizers. Chicken manure not only provides essential nutrients for crop growth but also improves soil structure and water-holding capacity, making it beneficial in water-scarce environments [3]. In addition to fertilizer management, irrigation scheduling plays a crucial role in determining rice productivity. Efficient irrigation practices, such as the alternate wetting and drying (AWD) method, have been shown to reduce water use while maintaining or even increasing rice yields [4]. However, the interaction between irrigation scheduling and organic fertilizer application has not been extensively studied using basin irrigation methods. Basin irrigation, which involves the division of fields into level basins for controlled flooding, is widely used in rice production due to its simplicity and low cost [5]. However, the effectiveness of this technique depends on the synchronization of water and nutrient management practices. The integration of optimized irrigation scheduling with organic fertilizer application has the potential to enhance rice growth and yield while reducing production costs and environmental impacts. Studies have shown that the combined use of organic fertilizers and efficient irrigation practices can improve soil health, increase water use efficiency (WUE), and boost crop yields [6]. According to [7], the application of chicken manure has been found to increase soil organic matter, improve nutrient availability, and enhance rice yields. Similarly, optimized irrigation schedules can ensure that water is applied at critical growth stages, thereby maximizing crop productivity [8]. This study aims to investigate the effects of irrigation scheduling and organic fertilizer application on rice growth and yield in a basin irrigation system. By evaluating the combined impact of these practices, the study seeks to provide a sustainable approach to rice production that enhances productivity while minimizing resource use and environmental degradation. The findings will contribute to the development of best practices for smallholder farmers in Nigeria and other semi-arid regions, where water and nutrient management are critical for food security.

2 LETERATURE REVIEW

2.1 Basin Irrigation

Basin irrigation is a traditional and widely used method for rice cultivation, particularly in regions with small fields and moderate to slow intake soils [5] and [9]. The technique involves the division of fields into basins, which are enclosed by levees to prevent runoff and allow for uniform water distribution [10]. Basin irrigation is particularly suitable for rice cultivation due to its ability to maintain ponded water, which is essential for the crop's growth and development [11]. However, the efficiency of basin irrigation depends on proper land leveling and the maintenance of perimeter dikes to prevent water loss [12]. The integration of organic fertilizers with basin irrigation can further enhance soil fertility and water retention, leading to improved rice growth and yield.

2.2 Irrigation Scheduling

Irrigation scheduling is a critical component of water management in rice cultivation, particularly in basin irrigation systems. It involves determining the optimal timing and quantity of water application to maximize crop yield and water use efficiency [13]. The use of alternate wetting and drying (AWD) techniques has been shown to improve water use efficiency while maintaining or even increasing rice yields [14]. In basin irrigation systems, irrigation scheduling should be tailored to ensure that water is applied uniformly and efficiently to the rootzone, particularly when organic fertilizers are used, as they can influence soil moisture retention and nutrient availability [15].

2.3 Chicken Manure

Organic fertilizers, such as chicken manure, play a vital role in improving soil fertility and crop yield. Chicken manure is rich in essential nutrients such as nitrogen, phosphorus, and potassium, which are released slowly into the soil as the manure decomposes [6]. The application of chicken manure has been shown to increase soil organic matter, improve soil structure, and enhance water retention, making it particularly beneficial for rice cultivation in basin irrigation systems [16]. Additionally, the use of chicken manure can reduce the need for chemical fertilizers, thereby lowering production costs and minimizing environmental impacts [17].

2.4 Cost of Production

The integration of irrigation scheduling and organic fertilizers can have a significant impact on the cost of rice production. Organic fertilizers, such as chicken manure, can reduce the need for chemical fertilizers, thereby lowering input costs [6]. Additionally, optimized irrigation scheduling can improve water use efficiency, reducing the amount of water needed for rice cultivation and further lowering production costs [13]. The use of basin irrigation, combined with organic fertilizers and efficient irrigation scheduling, can lead to higher yields and improved profitability for rice farmers [18].

2.5 Crop Water Use Efficiency

Water use efficiency (WUE) is a critical factor in rice cultivation, particularly in basin irrigation systems. WUE can be improved through the adoption of water-saving irrigation techniques such as Alternate Wet and Dry (AWD), which has been shown to reduce water use by up to 30% while maintaining or even increasing yields [19]. The use of organic fertilizers, such as chicken manure, can further enhance WUE by improving soil structure and water retention, leading to more efficient water use and higher crop yields [16]. The effects of irrigation scheduling and organic fertilizers can therefore lead to significant improvements in rice growth and yield, particularly in basin irrigation systems.

3 METHODOLOGY

3.1 Experimental Site

The study was conducted during the dry season at Namtari in Yola South Local Government Area, Adamawa State, Nigeria. Namtari is located between Latitude 9°10'N to 9°25'N and Longitude 12°5' to 12°35'E, approximately 25 km from Yola metropolis. The area lies within the savannah ecological zone of Nigeria, with an elevation ranging from 119 to 160 meters above sea level. The region experiences two major seasons: the rainy season (May to October) and the dry season (November to April). The driest months are December to April, while the wettest months are July to September. The average temperature ranges from 16°C to 42°C, with a minimum relative humidity of 14%, mean annual rainfall of 1150 mm, and an average monthly daylight of 186 hours. Agriculture is the primary livelihood for about 80% of the inhabitants, with rice, maize, soybean, cowpea, sorghum, sesame, and groundnut being the major crops grown in the area. The study site has an irrigable land area of about 2500 hectares, with approximately 1500 hectares under cultivation [20].

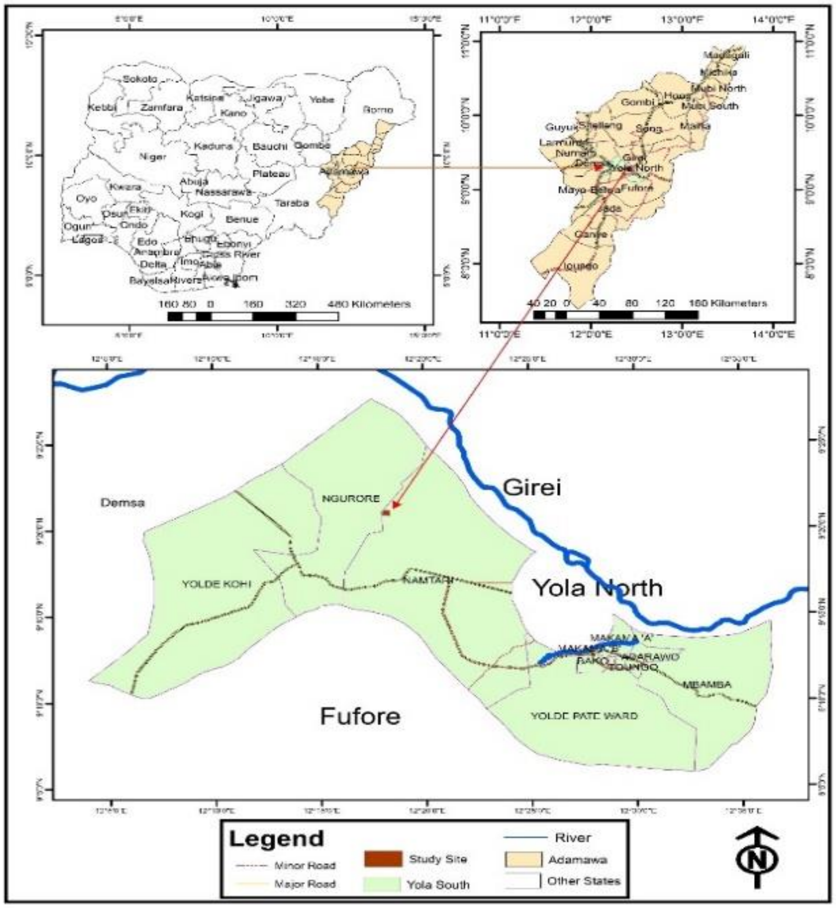

Figure 1. Map of the study area, Namtari dry season irrigation farming site, Yola South LGA (source: Department of Geography, MAU Yola)

3.2 Determination of Soil Textural Classification and Bulk Density

Soil samples were collected randomly from the experimental field at incremental depths of 150 mm down to 600 mm using a soil auger. The hydrometer method was used to determine the particle size distribution, and the soil texture was classified using the USDA soil textural triangle. The bulk density was determined using the core sampler method, where soil cores were collected, dried, and weighed to calculate the bulk density [22].

3.3 Experimental Design and Field Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with sixteen treatments. Four irrigation intervals (6 days, 8 days, 10 days, and irregular intervals) were tested at four levels of chicken manure application rates (0, 8, 10, and 12 tons/ha). Each treatment was replicated four times, with plot sizes of 0.0025 ha. A total plot size of 0.0384ha was used for the treatment's layout. The rice variety used was Gawal R1 (CHAOTAN), a lowland variety with a maturity period of 90 to 105 days, resistant to shattering, lodging, iron toxicity, blast, stem borers, and termites [23].

3.4 Field Operations

Field operations included land preparation, levelling, puddling, transplanting, weeding, chicken manure application, irrigation, insecticide spraying, bird scaring, and harvesting. Land preparation involved manual tillage to create fine, pulverized, and levelled beds. Rice seedlings were transplanted at a spacing of 15 cm x 15 cm, 21 days after nursery establishment. Weeding was done manually at 14-21 days and 45-52 days after transplanting. Cypermethrin insecticide was applied at the rate of 1 liter in 150 liters of water per hectare during the initial flowering stage to prevent pest damage.

3.5 Chicken Manure Application

Chicken manure was applied at rates of 0, 8, 10, and 12 tons/ha before transplanting. The manure was weighed using a weighing scale and incorporated into the soil in line with [7].

3.6 Determination of Crop Growth

Crop growth parameters, including plant height and number of tillers, were recorded weekly from 21 days after transplanting until 90 days after transplanting. Five plants were selected from each plot for measurement using meter rule.

3.7 Determination of Crop Yield

Harvesting was done when the rice was fully mature. The harvested heads were threshed manually, and the grain yield was weighed and converted to tons per hectare.

3.8 Statistical Analysis

Data collected were subjected to statistical analysis using GenStat version 15.1 and means separated using Fischer's Protected LSD test at a 5% level of significance to determine the effects of irrigation scheduling on rice growth and yield. Excel application was also used for regression analysis and developing graphs.

4 RESULTS AND DISCUSSION

4.1 Crop Growth

This study investigated the effects of irrigation scheduling and organic fertilizer application on rice growth and yield under basin irrigation systems. Table 1 present the Mean weekly crop growth (heights) of rice in the study area. The results indicated that the combination of irrigation scheduling and chicken manure application significantly influenced crop growth. The 6-day irrigation schedule with a 10-ton chicken manure application rate (I_6C_{10}) resulted in the higher crop growth, reaching 115.15 cm at week 14. This was closely followed by the 6-day irrigation schedule with an 8-ton chicken manure rate (I_6C_8). These findings are consistent with previous studies by [25], which emphasized the positive impact of organic fertilizers on crop growth when combined with optimal irrigation schedules. The variations in crop growth can be attributed to the synergistic effects of irrigation scheduling and organic fertilizer application. The incorporation of chicken manure into the soil improved its water-holding capacity, which is crucial for enhanced crop growth [26]. The 6-day and 8-day irrigation schedules (I_6) and (I_8), combined with organic fertilizer, resulted in higher growth values compared to the irregular irrigation schedule (I_0) and the 10-day irrigation schedule(I_{10}). The highest crop growth height value of 115.15 cm recorded for I_6C_{10}, is closer to the crop growth height of 120 cm for rice at maturity in line with earlier report of [23]. This difference in value may be attributed to climate and soil condition as at the time of conducting the experiment. Statistically, there was no significant difference in crop growth height among the treatments at week 3 after transplanting. However, significant differences were observed from weeks 4 to 14 at a 5% level of significance. This indicates that the combined effects of irrigation scheduling and organic fertilizer application become more pronounced as the crop matures, emphasizing the importance of maintaining optimal irrigation intervals and nutrient availability throughout the crop growing period.

Table 1. Mean Weekly Rice Crop Growth (Height) cm in the study area

Treat-ments	gw3	gw4	gw5	gw6	gw7	gw8	gw9	gw10	gw14
I_0C_0	7.45^{c}	12.73^{c}	13.29^{e}	14.35^{f}	15.25^{g}	21.29^{h}	42.52^{f}	51.53^{d}	79.51^{f}
I_0C_8	7.51^{c}	10.00^{b}	13.27^{e}	15.14^{e}	16.45^{f}	24.31^{f}	29.53^{j}	39.15^{f}	78.55^{f}
I_0C_{10}	7.44^{c}	9.67^{b}	13.06^{e}	14.03^{f}	16.42^{f}	23.94^{fg}	32.74^{i}	49.61^{d}	82.47^{e}
I_0C_{12}	7.37^{c}	9.45^{b}	13.16^{e}	14.17^{f}	16.31^{f}	23.17	34.79^{h}	46.25^{e}	80.23^{e}
I_6C_0	7.03^{cd}	13.31^{bc}	15.41^{c}	16.09^{de}	19.45^{c}	29.12^{c}	46.03^{d}	57.34^{c}	89.25^{d}
I_6 C_8	9.20^{ab}	14.64^{a}	15.22^{c}	16.23^{d}	18.61^{d}	27.08^{e}	48.45^{c}	67.65^{b}	104.24^{b}
I_6 C_{10}	7.54^{c}	14.51^{a}	15.71^{c}	17.22^{c}	20.52^{b}	33.05^{a}	54.64^{a}	82.51^{a}	115.15^{a}
I_6C_{12}	7.61^{c}	13.76^{b}	15.32^{c}	16.16^{de}	19.32^{c}	31.28^{b}	48.91^{c}	68.94^{b}	103.20^{bc}
I_8C_0	8.70^{b}	13.83^{b}	17.23^{a}	18.28^{ab}	20.27^{b}	28.52^{d}	34.15^{h}	50.11^{d}	86.51^{de}
I_8C_8	9.10^{ab}	13.25^{bc}	17.05^{ab}	19.49^{a}	20.68^{b}	30.74^{bc}	43.25^{ef}	60.52^{c}	95.25^{cd}
I_8 C_{10}	7.50^{c}	14.73^{a}	17.85^{a}	18.18^{b}	21.45^{a}	29.01^{c}	50.64^{b}	66.37^{bc}	105.35^{b}
I_8C_{12}	8.37^{ab}	13.13^{bc}	16.91^{b}	19.21^{a}	20.39^{b}	29.45^{c}	42.97^{f}	60.14^{c}	95.71^{cd}
$I_{10}C_0$	9.70^{a}	13.65^{b}	16.44^{bc}	18.42^{ab}	20.18^{b}	28.69^{d}	44.02^{e}	57.45^{c}	108.30^{b}
I_{10} C_8	8.02^{bc}	11.51^{d}	13.37^{e}	14.27^{f}	15.26^{g}	21.24^{h}	26.41^{k}	37.14^{f}	77.17^{f}
$I_{10}C_{10}$	6.90^{d}	13.64^{b}	14.64^{d}	16.45^{d}	17.19^{e}	23.27^{g}	37.51^{g}	57.11^{c}	99.04^{c}
$I_{10}C_{12}$	8.11^{bc}	12.25^{c}	15.33^{c}	16.25^{d}	18.18^{d}	24.73^{f}	35.41^{h}	51.31^{d}	95.62^{cd}

a,b,c,d,e,f,g,h,i,j,k Means with same letter along each column are not significantly ($p<0.05$) different (gw = Weekly growth)

4.2 Crop Yield

Table 2 present the values of the mean crop yield, water productivity and water use efficiency of the rice crop in the study area. The result revealed that crop yield, water productivity and water use efficiency varied in all the treatments and the plots in the study area. The 6-day irrigation schedule with a 10-ton chicken manure application rate (I_6C_{10}) produced the highest crop yield of 7.50 tons/ha, followed closely by the 6-day irrigation schedule with a 12-ton chicken manure rate (I_6C_{12}) at 7.22 tons/ha. These results suggested that the combination of shorter irrigation intervals and moderate rates of organic fertilizer is more effective in maximizing rice yield. The irregular irrigation schedule (I_0) resulted in the lowest yield of 4.69 tons/ha, further underscoring the importance of regular irrigation and organic fertilizer application in achieving optimal crop productivity. The water productivity (WP) and water use efficiency (WUE) also varied significantly among the treatments. The 6-day irrigation schedule (I_6) exhibited higher WP and WUE compared to the irregular irrigation schedule (I_0). This is consistent with findings by [5], who noted that optimized irrigation scheduling, combined with organic fertilizers, enhances water retention and nutrient availability, leading to more efficient water utilization by the crop. The mean WUE for the study area was 0.625 tons/ha/mm, which falls in the range of 0.4 to 0.9 tons/ha/mm reported by [27]. The combination of a 6-day irrigation schedule with moderate rates of organic fertilizer proved to be the most effective in maximizing crop productivity and water use efficiency.

Table 2. Mean Crop Yield, Water Productivity and Water Use Efficiency

Treatments	Yield (Tons/ha)	Water Productivity (Tons/m^3)	Water Use efficiency (tons/ha/mm)
I_0C_0	4.65^d	0.51^d	0.41^f
I_0C_8	5.11^c	0.42^e	0.46^f
I_0C_{10}	4.78^d	0.39^f	0.35^g
I_0C_{12}	4.31^d	0.37^f	0.28^h
I_6C_0	6.19^b	0.62^c	0.32^{gh}
I_6C_8	6.20^b	0.51^d	0.37^g
I_6C_{10}	7.50^a	0.58^d	0.43^f
I_6C_{12}	7.22^a	0.62^c	0.45^f
I_8C_0	5.43^c	0.71^b	0.81^c
I_8C_8	6.72^b	0.72^b	0.90^{bc}
I_8C_{10}	6.51^b	0.70^b	0.85^c
I_8C_{12}	6.24^b	0.71^b	0.64^e
$I_{10}C_0$	5.32^c	0.80^a	0.89^c
$I_{10}C_8$	4.21^d	0.57^d	0.73^d
$I_{10}C_{10}$	4.19^d	0.61^c	0.94^b
$I_{10}C_{12}$	5.05^c	0.70^b	1.16^a

^{a,b,c,d,e,f,g,h} Means with same letters along each column do not significantly ($p<0.05$) differ

5 CONCLUSIONS

In conclusion, the combination of a 6-day irrigation schedule and moderate rates of chicken manure application of 10 tons/ha ($I_6\ C_{10}$) is highly effective in maximizing rice growth and yield in basin irrigation systems. This approach not only improves crop productivity but also promotes sustainable farming practices by enhancing soil health and water use efficiency. Also, combining a 6-day irrigation schedule with chicken manure application rates of 10 tons/ha ($I_6\ C_{10}$) produced the highest crop yield of 7.50 tons/ha. This highlights the importance of integrating organic fertilizers into rice production systems to improve soil fertility and crop performance.

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