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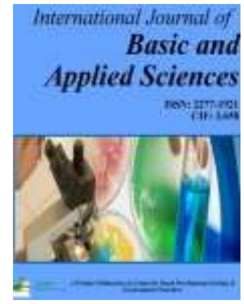

Full Length Research Paper

Effects of Integrating Deficit irrigation and Carbonate Foliar Fertilizers into the System of Rice Intensification on Growth and Yield: A Case study of Mkindo Irrigation Scheme, Tanzania

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ABSTRACT

Individually, the System of Rice Intensification (SRI), deficit irrigation and foliar fertilizer application have proved to be effective in enhancing rice growth and yield, however, the information on their combined effects is limitedly known. Therefore, a study was conducted to evaluate the effects of integrating deficit irrigation and carbonate foliar fertilizer (Lithovit) application into SRI on rice growth and yield. This study was conducted in Mkindo Irrigation scheme in Mvomero, Morogoro, Tanzania during the dry and wet season (October 2020 to June 2021). The experiment was laid out in a split plot design with three levels of irrigation for main plots which were 100% of the irrigation water requirement (40mm) imitating the SRI alternate wetting and drying pattern and induced deficit irrigation applied at 80% and 50% of the irrigation water requirement as IR_{100}, IR_{80} and IR_{50}, respectively. Irrigation was carried out at the appearance of soil cracks in IR_{100}. The sub-plot fertilizer treatments were five in number namely: (A) Diammonium Phosphate (DAP) and Urea (normal practice), (B) DAP, Urea and 100% of recommended foliar fertilizer (Lithovit Standard), (C) DAP and 50% (Lithovit and Urea), (D) Lithovit Standard only and (E) no fertilizer. The data was analyzed using IBM SPSS version 20 at 5% probability level in order to ascertain if any significant differences between the various treatment combinations existed. Water application IR_{80} had the best performance in terms of growth and yield. Among fertilizer applications, the highest yield was attained by treatment B with 11.09 t/ha and 6.74 t/ha in the dry and wet season respectively. Treatment E had the least yield of 7.26 t/ha and 4.10 t/ha in the dry and wet season respectively. Foliar treatments performed considerably well as Lithovit supplies higher concentrations of carbon dioxide thereby aiding photosynthesis hence increasing crop growth and yield.

Introduction

Globally, about 26% of the population (2 billion) lack regular access to safe, nutritious and sufficient food (FAO, 2019). According to United States Department of Agriculture (USDA) (2019), the global population of food insecure people is expected to fall from 19.3 to 9.2% between 2019 and 2029. On the contrary, Sub-Saharan Africa (SSA) is predicted to be the epicenter of global food insecurity by 2029 with 22.5% of its population being food insecure (USDA, 2019). This calls for more food production to meet this global target while curbing the aggravating situation of SSA. Rice, wheat and maize are the three most essential cereals critical for the survival of a vast population globally (FAO, 2016). According to FAO (2016), daily consumption of cereals is expected to increase by 390 million tonnes between 2014 and 2024. By 2050, an annual demand for rice, wheat and maize is predicted to reach 3.3 billion tonnes (FAO, 2016).

Rice (*Oryza sativa L*) is the primary staple food for over half of the world's population while sustaining livelihoods of more than 100 million people in Sub-Saharan Africa (SSA) (FAO, 2013). Globally, rice ranks third after wheat and maize in terms of production with a daily consumption of more than three billion people (GRiSP, 2013). Nearly 11% of the world's cultivated land is occupied by rice covering an area of about 158 million hectares with over 527 million tonnes as annual production (FAO, 2019). As the world population is projected to increase to 8.27 billion in 2030 (UN, 2015), correspondingly, there will be increase in rice demand. The global rice demand is projected to increase from 439 - 555 million tonnes (milled rice) between 2010 and 2035 (GRiSP, 2013). Other studies such as Shamshiri *et al.* (2018); Dinesh *et al.* (2019); Raut *et al.* (2019); are all promoting increase in rice production following the increase in rice demand.

In Tanzania, rice is the third most important food crop after maize and cassava consumed by about 30% of the households (FAO, 2015). About 20% of farmers are involved in rice production (Mtaki, 2018) with 80% of these being small scale farmers (Katambara *et al.*, 2016). Tanzania is also the lead rice producer in Eastern and Southern Africa while accounting for about 9% of the total 30.8 million tonnes of African rice production (FAO, 2014). However, the rice yield gap for Tanzania is over 87% (Senthilkumar *et al.*, 2018). This is attributed to the generally low rice yields ranging from 1.1 t/ha under rainfed lowland conditions to 3.5 t/ha under irrigated conditions (SRI-Rice, 2020) which is below the world's average yield of 4.31 t/ha (FAO, 2015). Despite its central role in food security and economic development, rice production in Tanzania is faced with a number of constraints such as low rice yielding varieties, weed infestation, prevalence of pests and diseases with water scarcity and poor/low fertilizer application being of major concern.

Various studies have been carried out to assess the capacity of the System of Rice Intensification (SRI) as a means to curb rice production constraints and improve the yields in Tanzania (Katambara et al., 2013; Reuben et al., 2016; Kangile et al., 2018; Materu et al., 2018; Gowele et al., 2020). SRI has been profound in boosting yields between 6-8 t/ha and water productivity by saving water of up to 25% as compared to conventional flood irrigation (Katambara et al., 2013). Despite SRI success, the potential rice yields have not been achieved in Tanzania. Another study by Nhamo et al. (2014) reported that the use of fertilizers could avail a relative yield gain of 52%, equivalent to 948 kg /ha of rice grain in Eastern and Southern Africa. This highlights the inadequacy of nutrients availability (fertilization) to the plants that limits more production per unit area to consequently close the yield gap (Khan and Iqbal, 2018; Hashem, 2019; Kumar et al., 2019). Evidently, rice requires sufficient nutrients to produce ample yields (Kumar et al., 2019). Senthilvalavan and Ravichandran (2019) reported that integration of organic and inorganic fertilizers is essential in enhancing the growth and physiological attributes of rice. Moreover, micronutrients are also very essential in the production of rice (Khan and Iqbal, 2018; Raut et al., 2019; Gowele et al., 2020). However, the use of low or excess amount of fertilizers compromises the soil quality and crop yield in addition to high production costs (Raut et al., 2019).

In addition, the methods of fertilizer application have a significant impact on the growth and yield attributes (Raut et al., 2019). Rice fields require slow release of fertilizers (Tarigan et al., 2019) yet large volumes of fertilizers are lost through leaching and fixation following basal fertilizer application (Raut et al., 2019). Foliar application, the technique of spraying liquid fertilizers (macro or micro nutrients) directly onto the leaves of crops is considered key in attaining maximum and quality yields (Khalil and Hussein, 2015; Buczek, 2017; Jakab-gábor and Komarek, 2017; Kaleri et al., 2019; Kumar and Nagesh, 2019; Aljutheri et al., 2020) while alleviating inhibition due to water stress (Badawi et al., 2013).

Foliar fertilizers are reported to have significant impact on the growth and yield of paddy rice (Badawi et al., 2013; Toromanova and Georgieva, 2017; Hashem, 2019; Raut et al., 2019). Hashem (2019) recommended the use of foliar fertilizer application together with the conventional fertilizers at the various growth stages in order to enhance rice productivity. Badawi et al. (2013) affirmed that the interaction between foliar fertilizer application and deficit irrigation had significant impact on the yield of rice. Toromanova and Georgieva (2017) reported that foliar fertilizer application played a positive effect on rice productivity with a 13.1% increase in productive tillering capacity following application of Lithovit fertilizer which was the highest among other foliar treatments used. Lithovit is a natural 100% organic calcite carbonate fertilizer extracted from natural limestone deposits suitable for organic farming (Nassef et al., 2013; Morsy et al., 2018; Zorovski et al., 2021). Lithovit consists of nano-particles that are directly absorbed through the stomata and can considerably increase the photosynthesis rate, reduce crop water requirement and increase crop yield (Farouk, 2015). Deficit irrigation, SRI and foliar fertilizer application have proved to be effective in enhancing rice growth and yield individually. However, the information on their combined effects is limitedly known.

Therefore, this study evaluates the effects of integrating deficit irrigation and carbonate foliar fertilizer application into SRI on rice growth and yield.

Materials and Methods

Description of the Study Area

The study was conducted at Mkindo farmer managed irrigation scheme in Morogoro, Tanzania given that the scheme is among the few farmer-based schemes which practice SRI. Small scale irrigation schemes are considered essential in improving the livelihoods of majority of small scale farmers in Tanzania (Fundi and Kinemo, 2018). Mkindo irrigation scheme is located in Mkindo village, Mvomero District, Morogoro Region in eastern Tanzania between latitude $6^0$16’ and $6^0$18’ South, and longitude $37^0$32’ and $37^0$36’ East as shown in Fig. 1. Its altitude ranges between 345 m and 365 m above mean sea level and is about 85 km from Morogoro Municipality (Kahimba *et al.*, 2014). The major crop grown in the area is rice under surface irrigation supplied by Mkindo Perennial River.

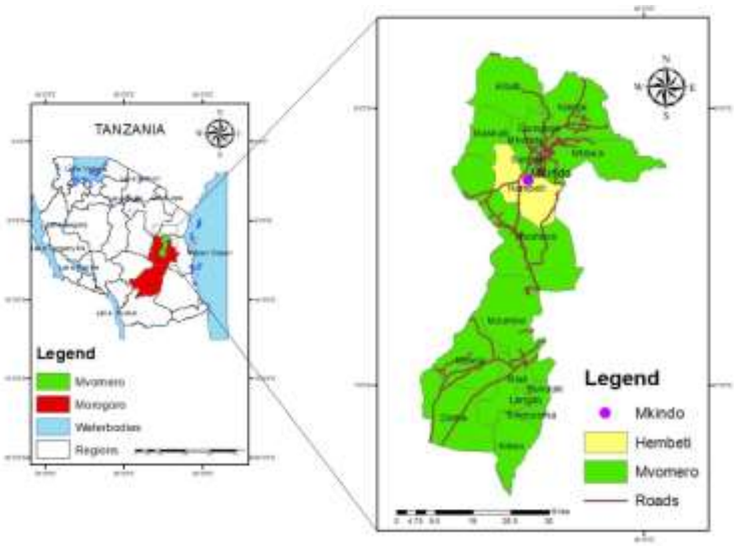

Fig 1: Location of the Study area

The study area is characterized by an average annual temperature of 24.95˚C, with a minimum temperature of 15.8˚C in July and a maximum temperature of 33.8˚C in February as shown in Fig. 2. The study area has a bimodal rainfall regime which determines the two rice growing seasons- dry season (*vuli*) with short rains starting in October to December and wet season (*masika*) with long rains starting from March to May. Rainfall in Mkindo usually starts in October with an increased trend until May with peak rainfall in April. The trend then decreases from May until July where the least rainfall is attained. The average annual total rainfall ranges between 700 and 1600 mm.

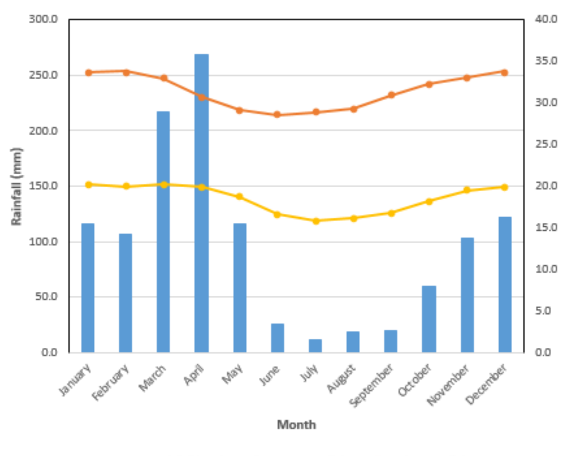

Fig 2: Average Monthly Rainfall, Maximum and Minimum temperature from 2000-2020 (Source: Mtibwa Sugar Estate Meteorological Station)

The soils of the study area are sandy clay loam (69.12%, 23.6% and 7.28%) with pH of 5.54 (medium acidic soils), electrical conductivity (EC) of 87.7 µS/cm (acceptable range), total nitrogen (N) and organic carbon of 0.09% (very low) and 1.26% (medium) respectively. Other properties include: available phosphorus (P) of 7.11 mg/kg (medium) with Cation Exchange Capacity (CEC) of 8.0 Cmol/kg (low) and exchangeable Ca, Mg, K, Na of 3.29 (medium), 1.44 (medium), 0.16 (medium) and 0.21 (low) Cmol/kg respectively. These soils are deemed suitable for rice cultivation according to Msanya (2012) and Shamshiri et al. (2018) as they facilitate root proliferation, aeration, water infiltration and water holding capacity, soil nutrients retention and drainage.

Experimental design

The experiment was laid out in a split plot design with three levels of irrigation for main plots which were 100% of the irrigation water requirement (40mm) imitating the SRI alternate wetting and drying pattern and induced deficit irrigation applied at 80% and 50% of the irrigation water requirement as IR_{100}, IR_{80} and IR_{50}, respectively. Irrigation was carried out at the appearance of soil cracks in IR_{100}. The sub-plot fertilizer treatments were five in number namely: (A) Diammonium Phosphate (DAP) and Urea (normal practice), (B) DAP, Urea and 100% of recommended foliar fertilizer (Lithovit Standard), (C) DAP, 50% (Lithovit and Urea), (D) Lithovit Standard only and (E) no fertilizer. The combined irrigation and fertilizer treatments tested were IR_{100}A, IR_{100}B, IR_{100}C, IR_{100}D, IR_{100}E, IR_{80}A, IR_{80}B, IR_{80}C, IR_{80}D, IR_{80}E, IR_{50}A, IR_{50}B, IR_{50}C, IR_{50}D and IR_{50}E.

All the treatments were randomly allocated and replicated three times. An individual plot size was 4 m × 2 m (8 m^2) each separated from the other by 0.5 m buffer zone to prevent lateral movement of water from one plot to another as shown in Fig. 3.

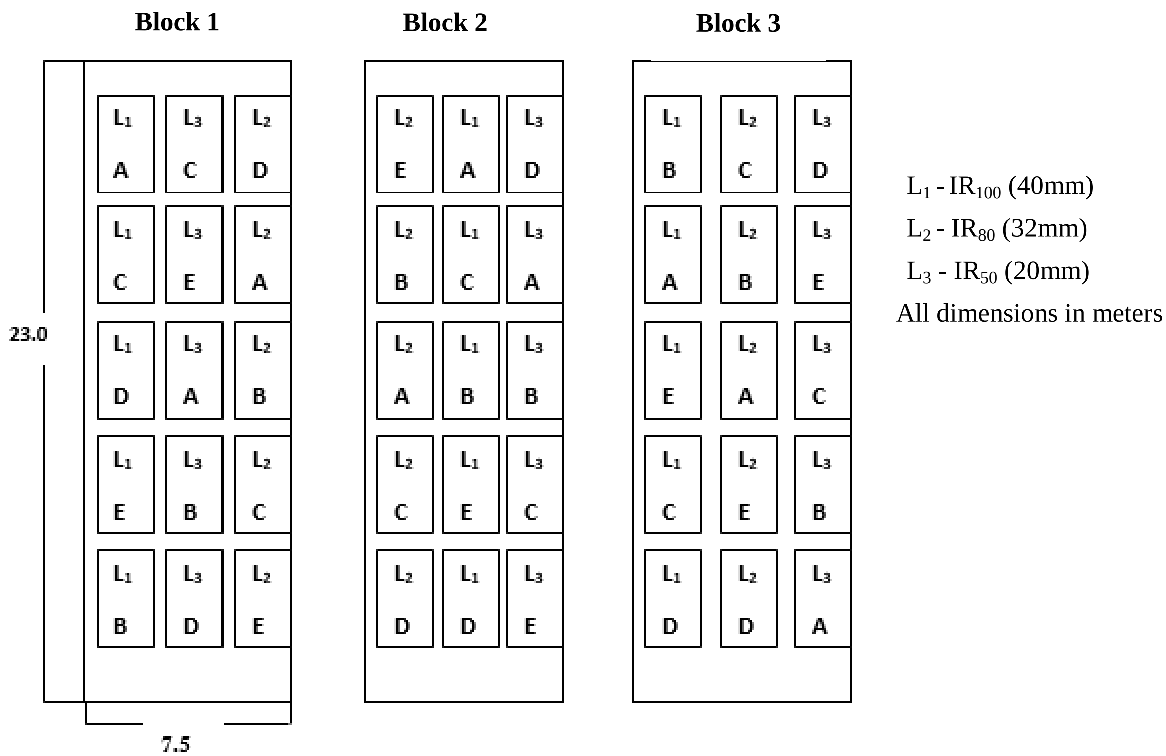

Fig 3: Set up of the experiment

Agronomic practices

The agronomic practices that were carried out include nursery and field preparation, transplanting, fertilizer application and weeding. During land preparation, the field was properly turned using a power tiller. Levelling was also carried out to aid uniform wetting of the soil. Proper drainage was maintained to facilitate water discharge especially during the rainy period. The SARO (TXD 306) rice variety was used as it is well suited to the conditions of Mkindo and was recommended by the Ministry of Agriculture, Tanzania (Kahimba et al., 2014).

During nursery preparation, only viable seeds were used and were identified by submerging all the seeds in a salty solution in which an egg would float. All the seeds that floated were considered inferior and were discarded. Seed priming was then done by soaking the seeds in clean water to enhance the rate of seedling emergence and germination.

One seedling per hill was transplanted at the age of 10 days using 25 cm × 25 cm spacing (Reuben et al., 2016). While considering particular sub-plots with their respective treatments, DAP was applied only once on the second day after transplanting (DAT), Urea was applied at two different times (30 and 60) DAT while all foliar fertilizers were applied at 30, 60 and 81 DAT. Urea and DAP were applied at a rate of 125kg/ha while all foliar treatments at 1kg/ha in 100 litres of water. The fertilizer compositions are as shown in Table 1.

Table 1: Fertilizer composition for the various treatments (Source: Lithovit)

S/N	Fertilizers	Composition
1.	DAP	Nitrogen, N (18%) Phosphate, PO_4 (46%)
2.	Urea	Nitrogen (46%)
3.	Lithovit Standard	Calcium carbonate, $CaCO_3$ (60%) Calcium oxide, CaO (35%) Silicon dioxide, SiO_2 (12%) Magnesia, Mg (2%) Iron, Fe (1%) Manganese, Mn (0.02%)
4.	Lithovit and Urea (50%)	Calcium Carbonate (33%) Nitrogen (21%) Calcium oxide (18.5%) Silicon dioxide (6.5%) Magnesia (1.2%) Iron (0.5%) Manganese (0.01%)

Weeding and spraying of pesticides against white fly infestation was carried out four and two times in the dry and wet season respectively. Before harvesting, a 14 days dry period was observed to allow for maximum transfer of nutrients to the grains. The rice was harvested manually with serrated edged sickles at 112 days when about 90% of the panicles had ripened spikelets and threshed using wooden sticks.

Measurement of plant attributes

Growth attributes

Areas (one square meter) with average uniformly growing representative plants were randomly selected and labelled from each field plot for measurements of five plants that were carried out after every two weeks. The variables that were measured after every two weeks include; plant height, number of leaves and total number of tillers. Plant height was measured using a tape measure while number of leaves and total number of tillers were measured manually by counting.

Yield attributes

At harvest, the number of productive tillers, length of panicles, biomass, yield and dry weight of 1000 grains were measured. Length of panicles was measured using a tape measure while the number of productive tillers was measured manually by counting. Dry weight of 1000 grains was measured by randomly picking two grain panicles from 10 plant samples within each sub plot excluding the boundary crops. The panicles were then air dried and 100 grains were manually counted off and weighed using a digital electronic balance. The weight was then projected to 1000 grains. Biomass and grain yield were measured by randomly harvesting one square meter of rice from each plot. Thereafter the grains were separated from the straw by manual threshing. The weight of the grains was determined after winnowing and one kilogram of straw was also measured off for further drying. Air drying was then carried out until constant weight was attained for both the straw and grains. A digital electronic balance was used to measure the grain and straw weights.

Data analysis

Analysis of Variance (ANOVA) was used ($p<0.05$) to determine the existence of any differences between both the main and sub plot treatments for the growth and yield attributes. Data was analyzed using IBM SPSS version 20 which is best recommended for split plot nature of experiments. Duncan's multiple range test was used to determine if any significant difference existed between the various treatment combinations.

Results and Discussion

Seasonal trend of growth

There was rapid increase in plant height and total number of leaves in the vegetative (28-56 DAT) and reproductive phases (84 DAT) which became constant during maturity stage (112 DAT). The trend of growth of plant height and total number of leaves throughout the entire dry and wet season under IR_{100}, IR_{80} and IR_{50} for fertilizer treatments A, B, C, D and E at 28, 56, 84 and 112 DAT is as shown in Fig. 4. There was also slight variation in plant height and total number of leaves at the different growth stages among the different water and fertilizer treatments. At every growth stage, either treatment A or B had the highest plant height or number of leaves followed by C, D while the no fertilizer treatment E had the least performance. Growth and panicle initiation occurs during the vegetative and reproductive phases. In addition, all fertilizer applications were carried out before the reproductive phase hence the rapid increase in growth is due to ample supply of nutrients during these phases. A similar trend was also observed by Thakur et al. (2014); Hidayati et al. (2016); Materu *et al.* (2018) and Yoga et al. (2020). The variations in plant height and total number of leaves among the different water applications is attributed to the variation in water depth as also observed by Materu et al. (2018). The variations between the conventional and foliar fertilizer treatments is due to the impact of Lithovit foliar fertilizers. Lithovit is a nano-fertilizer which contains Calcium carbonate ($CaCO_3$) and Magnesium carbonate ($MgCO_3$) that rapidly penetrates into plant tissues and aids in biological and physiological processes. In addition, other macronutrients are availed which increase enzymatic activity and growth. This is in agreement with Nassef et al. (2013); Morsy et al. (2018) and Zorovski et al. (2021).

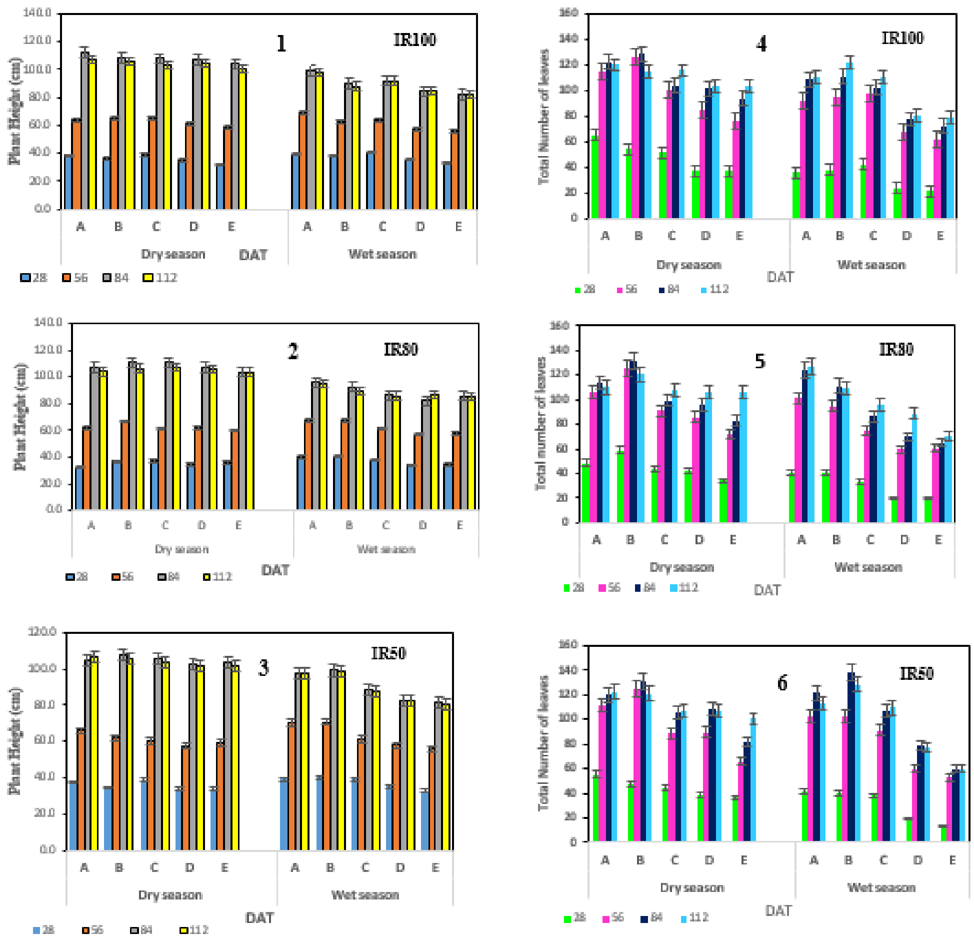

Fig 4: Plant height at 28, 56, 84 and 112 days after transplanting (DAT) for (1) IR_{100}, (2) IR_{80} and (3) IR_{50} respectively. Total number of leaves at 28, 56, 84 and 112 DAT for (4) IR_{100}, (5) IR_{80} and (6) IR_{50} respectively

Effect of water application levels

There was no significant difference ($p>0.05$) among the different water applications for plant height, leaves, total and effective tillers, panicle length and straw for both the dry and wet season in addition to dry season 1000 grain weight and yield. However, there was significant difference among the different water applications ($p<0.05$) for 1000 grain weight (dry season) and yield (wet season). The effect of the different water levels, IR_{100}, IR_{80} and IR_{50} on plant height, number of leaves, total and effective tillers, panicle length, dry weight of 1000 grains, straw and yield for both the dry and wet seasons is as shown in Table 2.

Table 2: Water regimes dry and wet season analysis for growth and yield attributes

Season	Water level	Plant Height (cm)	Leaves	Total tillers	Effective tillers	Panicle length (mm)	1000 grain weight (g)	Straw (g)	Yield (t/ha)
Dry season	IR_{100}	109.1a	112a	15a	14a	261.5a	31.01a	0.51a	9.02a
	IR_{80}	109.2a	110a	14a	14a	262.6a	31.16a	0.53a	8.75a

	IR_{50}	107.2a	112a	15a	14a	268.0a	32.21b	0.52a	8.22a
Wet season	IR_{100}	89.3b	101b	14b	13b	228.9b	30.08c	0.51b	5.76b
	IR_{80}	89.4b	98b	15b	14b	230.7b	30.26c	0.50b	5.41bc
	IR_{50}	89.1b	98b	14b	13b	228.9b	30.63c	0.49b	5.13c

(Mean values followed by different letters within similar columns differ significantly at p< 0.05 according to Duncan's Multiple-range test)

The highest 1000 grain weight for the dry season was recorded under IR_{50} followed by IR_{80} and IR_{100} with 32.21, 31.16 and 31.01g respectively but with no significant difference between IR_{80} and IR_{100}. While considering yield for the wet season, there was a significant difference between IR_{100} and IR_{50} with a 12% difference in yield while IR_{100} had 6.5% more yield than IR_{80}.

Dry season 1000 grain weight is contrary to Zoundou et al. (2019) who recorded the highest 1000 grain weight with IR_{100} and the least with IR_{50} but with no significant difference (p>0.05). The plant heights recorded are higher than in Materu et al. (2018) who observed mean values of 44.0, 40.0 and 30.0 cm for IR_{100}, IR_{80} and IR_{50} respectively. The total and productive tillers for the dry and wet seasons fall within the range of Kissou and Wang (2017) whose range was between 16 and 18 tillers. The panicle lengths are in agreement with Ndiiri et al. (2017) and Kissou and Wang (2017) who observed panicle length between 213 - 252 mm and 194.2 - 271.5 mm respectively. The panicle lengths for both the dry and wet seasons were higher than those observed by Zoundou et al. (2019) who recorded 197.5, 195.0 and 177.5 mm as the highest panicle length under IR_{50}, IR_{80} and IR_{100} respectively.

The yield falls within the range of Materu et al. (2018) who recorded yield of (11.5-7.5 t/ha) and (6.0-5.0 t/ha) for the dry and wet seasons respectively. However, less yield than attained in this study of 6.3 t/ha and 8.5 t/ha was reported for the same area location by Kombe (2012) and Reuben et al. (2016) respectively indicating the impact of foliar fertilizers in enhancing yield performance. The no significant difference in growth and yield attributes among the water regimes was due to heavy rainfall during the second month (November 2020) and first month (March 2021) of the vegetative phase for both the dry and wet seasons respectively which disrupted water regimes. This was also reported by Materu et al. (2018).

Effect of fertilizer applications

There was significant difference (p<0.05) among the different fertilizer applications for all growth and yield attributes except for dry season panicle length and straw weight. The effect of the various fertilizer treatments A, B, C, D and E on plant height, leaves, total and effective tillers, panicle length, 1000 grains weight, straw and yield for both the dry and wet seasons is as shown in Table 3.

Table 3: Subplot (fertilizer treatment) analysis

Season	TRT	Plant Height (cm)	Leaves	Total tillers	Effective tillers	Panicle length (mm)	1000 grain weight (g)	Straw (g)	Yield (t/ha)
Dry Season	A	110.0a	118a	16a	15a	263.8a	32.08a	0.52a	9.41a
	B	109.4ab	119a	17b	17b	268.1a	32.07a	0.51a	11.09b
	C	108.2ab	110b	14c	13c	262.4a	31.04ab	0.50a	8.19c
	D	108.1ab	106bc	14c	13c	264.9a	31.37ab	0.54a	8.16c
	E	106.7b	104c	12d	12d	260.9a	30.75b	0.52a	7.26c
Wet season	A	97.0c	117d	17e	15e	242.7b	30.78cd	0.57b	6.05de
	B	91.9d	120d	19e	17e	234.4bc	31.71c	0.53bc	6.74d
	C	88.6de	105d	15f	13f	223.9ce	30.33d	0.53bc	5.70e
	D	84.7ef	82e	12g	11g	230.6c	29.98d	0.46cd	4.38f
	E	82.5f	70e	10g	9h	215.8e	28.81e	0.40d	4.10f

(Mean values followed by different letters within similar columns differ significantly at p< 0.05 according to Duncan's Multiple-range test)

Plant height and leaves

For the dry season, the highest plant height was attained by A (110.0 cm) followed by B (109.4 cm), C (108.2 cm) and D (108.1 cm) while E had the least plant height of 106.7 cm. A similar trend was observed under the wet season with plant heights of 97.0, 91.9, 88.6, 84.7 and 82.5 cm for treatments A, B, C, D and E respectively. For the dry season, B had 1%, 8%, 12% and 14% more leaves than treatments A, C, D, and E respectively. However, there was no significant difference between treatment B and A while a high significant difference ($p<0.01$) existed between treatment pairs (B, C), (B, D) and (B, E). For the wet season, B had the highest number of leaves (120) while E had the least (70). There was no significant difference among treatments A, B and C with B having only 3% and 14% more leaves than A and C respectively. Treatment D had 17% more leaves than E but with no significant difference ($p>0.05$).

Total and effective tillers

Treatment B had the highest number of total and effective tillers followed by A, C, D and E in both seasons. For the dry season, B had 13% more effective tillers than A, 31% than (C and D) and 42% than E. The post-hoc results indicate no significant difference between treatments C and D while the rest of the fertilizer applications were significantly different ($p<0.05$). For the wet season, treatments B, A, C and D had 90%, 70%, 50% and 20% more total tillers than E. While considering effective tillers, there was no significant difference between treatments A and B while the rest of the treatments were significantly different.

Panicle length and straw weight

For the dry season, panicle length ranged between 268.1 and 260.9 mm with B and E having the highest and least panicle length respectively. For the wet season, A had the highest panicle length of 242.7 mm while E had the least panicle length of 215.8 mm. There was a significant difference between treatments (A, B), (B, C), (C, D) and (C, E). Dry season straw weight ranged between 0.50 and 0.54 g with the highest and least weight being attained by D and C respectively with no significant difference ($p>0.05$) between the various fertilizer applications. For the wet season, treatments A and E had the highest (0.57g) and least (0.40g) straw weight respectively. Treatment A had 8%, 24% and 43% more straw than (B and C), D and E respectively.

Dry weight of 1000 grains and yield

For the dry season, A had the highest 1000 grain weight of 32.08g while E had the least of 30.8g. However, there was no significant difference between treatment pairs (A, B), (C, D) and (D, E). For the wet season, treatment B had the highest average 1000 grain weight (31.7g) while E had the least (28.8g). There was no significant difference between treatment pairs (A, B), (A, C) and (C, D). For the dry season, Treatment B had the highest yield (11.09 t/ha) followed by A, C, D and E with 9.41, 8.19, 8.16 and 7.26 t/ha respectively. Treatment B had 18% more yield than the conventional treatment A while treatment C had 13% less yield than A hence justifying the no significant difference between treatment A and C. Treatment B had 53% more yield than E and there was no significant difference between E and D. A similar trend was followed by the wet season with B having the highest average yield of 6.74 t/ha followed by A, C, D and E with 6.05, 5.70, 4.38 and 4.10 t/ha respectively. Treatment B had the best yield performance attributed to the combination of both basal and foliar fertilizers. This is in agreement with Hashem (2019) who recommended combining basal and foliar fertilizers as a form of rice yield enhancement. Treatment E had the least performance as no fertilizers were applied throughout the entire growing period. However, its overall performance was still better than the conventional continuous flooding with average yield of 3.83 t/ha (Kombe, 2012) due to the impact of SRI. The practice of alternate wetting and drying (AWD) facilitates about 80% of free living bacteria and other microbes in and around rice roots (Berkelaar, 2007) which have nitrogen fixing ability thereby supplying nutrients such as nitrogen, phosphorus and potassium in addition to micronutrients such as calcium, sulphur, iron, copper, manganese and zinc to the soil hence the better performance. Further, AWD creates a moist but unsaturated soil condition that facilitates deeper root growth in the search for water hence aiding crop growth and yield. This is in agreement with Materu et al. (2018) and Dinesh et al. (2019). In addition, the large plant spacing under SRI (25 x 25 cm) creates ample aeration therefore less competition for nutrients hence more growth. This is in agreement with Kahimba et al. (2014) and Reuben et al. (2016).

The dry season had more yield than the wet season due to the differences in the cropping seasons. This was also observed by Materu et al. (2018). Further, actual yield of rice depends on the amount of starch that fills the spikelets especially during the ripening stage. Low temperatures affect crop development at the various growth stages and can lead to spikelet sterility where no grain is produced (Ndiiri et al., 2017). Ndiiri et al. (2017) reported that minimum temperatures below 16 °C yielded 100% sterility. The average minimum temperatures in this study for the wet season were 14.8 °C and 13.5 °C for the months of May and June, the reproductive and ripening stages respectively which are most prone to sterility. This therefore justifies the cause of the lower yields in the wet season than the dry season. However, the maximum yield attained in both the dry and wet seasons was greater than the yield obtained by Kombe (2012) and Reuben et al. (2016) who reported a maximum yield of 6.3 t/ha and 8.5 t/ha respectively under SRI with 25 x 25 cm spacing for Mkindo area. The increase in yield is attributed to the effect of foliar fertilizers. Lithovit fertilizers contain calcium carbonate ($CaCO_3$) (80%) which decomposes to calcium oxide (CaO) and carbon dioxide (CO_2) in the stomata of the leaves which accelerates photosynthesis hence leading to increased carbon intake and assimilation.

Interaction effect between water and fertilizer applications

The interaction between water applications and fertilizer treatments for both seasons across all growth and yield attributes was not significant ($p > 0.05$). These findings are similar to Zhang et al. (2012) who found no significant interaction among rice varieties, water management and fertilizer application under AWD of rice.

Conclusion

Generally, integrating deficit irrigation and carbonate foliar fertilizers into SRI had a positive impact on growth and yield attributes. The IR_{80} had the best performance in terms of growth and yield attributes. Among fertilizer applications, treatment B had the best overall performance in terms of growth and yield. Therefore, combining foliar treatments with conventional fertilizers played a key role in the performance enhancement of treatment B. Foliar treatments C and D performed considerably as good as the conventional fertilizer treatment A. This is attributed to the influence of Lithovit foliar fertilizer which accelerates physiological and biological processes, avails micronutrients and reduces on impact of water stress. Treatment E had the least performance in terms of all growth and yield attributes as no fertilizers were applied throughout the entire growing period. However, its overall performance was still better than the conventional continuous flooding due to the impact of AWD practice under SRI. The interaction between water and fertilizer applications was not significant due to disruption of water regimes by heavy rainfall. Further, the dry season performed better than the wet season for all growth and yield attributes due to low temperatures during the reproductive and ripening stages that affected crop growth and development.

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