Original Research Article

Influence of SRI fertilizer practice on yield components and grain yield of hybrid rice varieties in Kenya

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ABSTRACT

Rice is one of the staple food crops in Kenya and its demand is generally increasing annually especially when maize production has declined due to various factors. The national rice consumption is estimated at 300,000 metric tonnes compared to annual production of 45,000-80,000 where the deficit is met through importation. The low production can be increased through adoption of system of rice intensification methods that can lead to higher yields and sustainable production. Several studies have been conducted on SRI water requirements, plant systems and soil but very little has been done on fertilizer regime on hybrid rice in Kenya. To address this challenge, yield performance of two rice hybrid varieties; Arize Tej Gold and Arize 6444 Gold against a locally inbred variety (BW 196) under SRI fertilizer regime were evaluated at two sites; Mwea irrigation scheme in Kirinyaga County and Ahero irrigation scheme in Kisumu County. The experiment was laid out in a split-plot design where the SRI fertilizer practices were the main plots (2.5 t ha^{-1} Evergrow, 200 Kg ha^{-1} SA, 2.5 t/ha Evergrow + 100 Kg ha^{-1} SA, 2.5 t ha^{-1} Evergrow +200 Kg ha^{-1} SA, and a control-without fertilizer) and the rice varieties were the sub-plots and replicated three times. Data was collected on number of grains per panicle, filled grains per panicle and grain yield then subjected to analysis of variance (ANOVA) using SAS 9.2 and means separated using Fischer's Protected LSD. Significant differences were observed on the number of grains per plant with the Evergrow+100 Kg ha^{-1} SA and Evergrow+200 Kg ha^{-1} SA SRI fertilizer treatments showing the highest at 293 and 275 grains per plant respectively under variety Arize Tej Gold at Mwea and 256 grains per plant at Ahero. The high number of grains per plant consequently led to the highest grain yield under the SRI treatments where the Evergrow+100 Kg ha^{-1} SA treatment had the highest grain yield per plot in Ahero (1202 g) and Mwea (4002 g). The application of 100 Kg ha^{-1} of SA and organic fertilizer is recommended in rice production.

Keywords: Sustainable; panicle; organic fertilizer; plant systems; soil

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops in the world, consumed daily by more than half of the human population [1, 2]. It is consumed in variety of forms of noodles, puffed rice, fermented sweet rice and snack foods [3]. Rice, wheat and maize are the three leading food grains in the world, supplying more than 50% of all calories consumed by entire population [4, 5]. Rice production in Africa has grown rapidly whereby West Africa is the main producing sub region, accounting for more than 45% of African production in 2008-2010 [6]. Rice in Kenya is mainly produced by small-scale farmers through four major irrigation schemes: Mwea in Central province; Bunyala in Western; and Ahero and West

Kano in Nyanza province. Upland rice is also grown in: Migori and Kuria in Nyanza province, and Tana Delta and Msambweni in Coast province. Mwea irrigation Scheme is the largest producer of rice in Kenya [7, 8]. Global demand for food is rising because of population growth, increasing affluence and changing dietary habits and the FAO forecasts that global food production will need to increase by over 40% by 2030 and 70% by 2050 [9]. Demand for rice exceeds country's supply of 40, 000 to 80, 000 tonnes by 200%. The demand stands at 300, 000 tonnes per annum [9, 10] therefore deficit is met through importation [11].
In Bangladesh, Cambodia, Indonesia, Myanmar, Thailand, and Vietnam, rice provides 50–80% of the total calories consumed. Africa tops the chart in terms of percentage increase in total consumption, with an increase of 130% from 2010 rice consumption [6]. Almost a billion households in Asia, Africa and America depend on rice for their main source of livelihood. Rice is in frontline in fight against world hunger and poverty and is also a symbol of cultural identity and global unity. It is the cheapest and most effective means available that is likely to eradicate acute under nutrition [12, 13].
The system of rice intensification (SRI) is a production system that involves the adoption of certain changes in management practices for rice cultivation that create a better growing environment for their growth [14]. Rice growers in general have relied on chemical fertilizers under the belief that they are necessary for high yields. However, achieving high yield based prescriptive use of fertilizers may not be economically warranted [15]. Therefore, organic SRI practices that rely on on-farm produced organic fertilizers and pesticides have drawn attention of scientists and farming communities. On-farm demonstration plots in many tropical and sub-tropical countries have shown the benefits of SRI methods over conventional cultivation methods [16]. With SRI, organic fertilizers could replace some or most of all organic nitrogen in paddy rice production [17]. Introduction of higher yielding varieties like hybrids with the adoption of new farming systems such as System of Rice Intensification (SRI) can increase rice production significantly in the country but little research has been done and with this view, the current study was initiated to study the influence of SRI on rice hybrids yield components and grain yield at two sites in Kenya.

2. MATERIAL AND METHODS

2.1 Study sites

The experiment was carried out at two sites in Kenya. The first site was Mwea Irrigation Agricultural Development (MIAD) research centre at Mwea Irrigation Scheme in Wamumu sub-location, Kirinyaga County of Kenya. The site lies at an altitude of 1175 meters above the sea level, latitude of $00^{o}42'$S and longitude of $37^{o}22'$E. The soils are predominantly black cotton soil. The experiment was conducted under natural climatic conditions. The second site was Ahero Irrigation Scheme in Nyando sub-county of Kisumu County, Kenya. The scheme is located in the Kano plains, at altitude of about 1131m above sea level, Latitude: 0° 10' 60.00" N and Longitude: 34° 54' 59.99" E.

2.2 Experimental design and application of treatments

The experiment was laid out in a split plot arrangement in a Randomized Complete Block Design (RCBD) with the main plots being organic fertilizer at a rate of 2.5 t ha^{-1} Evergrow, 200 Kg ha^{-1} of Sulphate of ammonia, 2.5 t ha^{-1} Evergrow + 200 Kg ha-1 Sulphate of ammonia (SA), 2.5 t ha^{-1} Evergrow +100 Kg ha^{-1} Sulphate of Ammonia and the control where no basal fertilizer was applied while the sub-plots were the two hybrid varieties; Arize Tej Gold, Arize 6444 Gold and a local check (BW196). The treatments were then replicated three times. Each main plot measured 2 m x 4m with 1m path between each main plots and 0.5m between each sub-plots to avoid treatment contamination effects across the plots. A spacing of 25 cm by 15 cm was used with five rows planted and data collected on the inner three rows.

2.3 Cultural operations

The experimental plot sizes were 2m x 4m and an $800m^2$ piece of land ploughed, harrowed and levelled to ensure even growth and to maintain a uniform water depth. Seedlings of each variety was raised in a non-flooded nursery beds measuring 1.5m x 10m and raised to 5 cm above ground level. Seeds were broadcasted evenly on the bed at rate of 5 Kg ha^{-1} (0.5kg/$100m^2$ nursery) and applied 1 kg of N and 1kg P per $100m^2$. The seed bed was divided into five main plots each containing three sub-plots. Main plots being organic fertilizer at a rate of 2.5 t ha^{-1} Evergrow, 200 Kg ha-1 of Sulphate of ammonia, 2.5 t ha^{-1} Evergrow + 200 Kg ha^{-1} Sulphate of ammonia (SA), 2.5 t ha^{-1} Evergrow +100 Kg ha^{-1} Sulphate of Ammonia and the control where no basal fertilizer was applied while the sub-plots were the two hybrid varieties -Arize Tej Gold, Arize 6444 Gold and a local check (BW196). The seedlings were transplanted after 8 days when 2 leaves had developed to hills in the field at single seedling per stand, at a spacing of 25 by 15 cm. Five lines of each variety was planted in each sub-plot. Top dressing was done in two splits, at active tillering stage and at panicle initiation stage except in control. Water control and weeding was done according to SRI management recommendation. The field was intermittently flooded and dried, that is, three days of wetting and seven days of drying.

2.4 Data collection and Statistical analysis

Data was collected on filled and unfilled grains per panicle, 1000-grain weight and grain yield. Data collected were subjected to analysis of variance using SAS statistical software version 9.2 [18] and treatment means separated using Fischer's Protected LSD at $P \leq 0.05$ significance level.

3. RESULTS AND DISCUSSION

3.1 Thousand grain weight

The weight of 1000-seeds was significantly influenced by the SRI fertilizer practices in the 3 varieties under study (Fig. 1). The lowest weight was recorded under the control for all the varieties where the local variety had the least (20.0 g). The highest 1000-seed weight (33.0 g) was recorded under variety Arize Tej Gold on the Evergrow+200 Kg ha^{-1} SA fertilizer treatment which was however not significantly different form that on the Evergrow+100 Kg ha^{-1} SA fertilizer treatment in the same variety. At Ahero, the highest 1000-seed mass was recorded on the Evergrow+200 Kg ha^{-1} SA under all the treatments with that of variety Arize 6444 Gold showing the peak (32 g). The lowest 1000-seed mass was under the control of Arize Tej Gold (24.33 g).

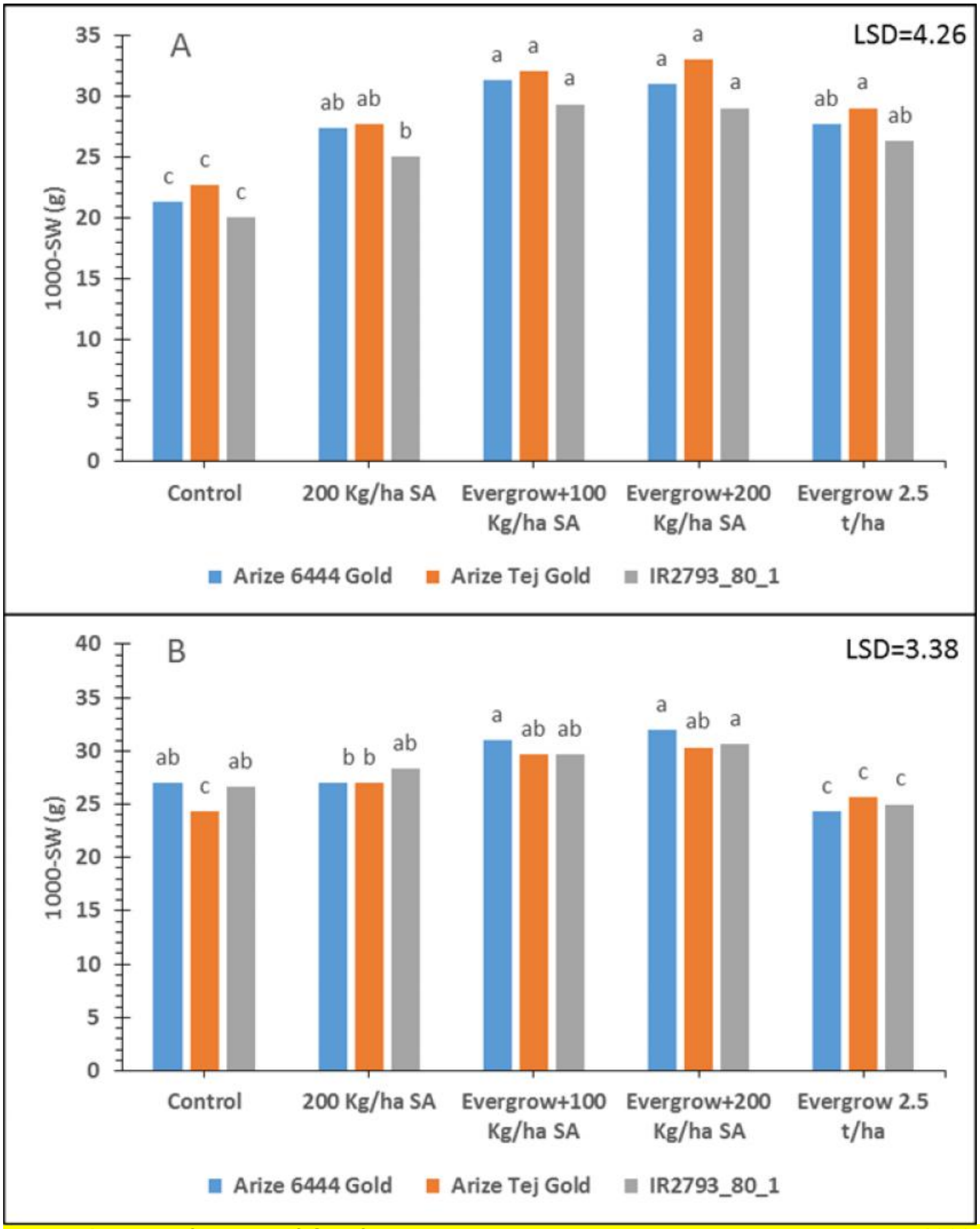

Figure 1: The influence of SRI fertilizer practices treatments and variety on the 1000-seed weight of rice at Mwea (A) and Ahero (B) irrigation schemes

SRI rice plants might have had an advantage in individual tillers over the control due to nutrient availability and usage. Heavy panicles might be the key to the high yield performance playing an important role in single panicle development from the strong individual tiller associated with the SRI as earlier confirmed by Chen et al. [19].

SRI method can increase rice productivity by efficient plant, soil, water, and nutrient management. Soil health maintenance was done to preserve rhizosphere availability that can support root growth and provide nutrient for plants. Enrichment by organic fertilizer can increase soil health. Its utilization in SRI method helps providing nutrients as well as helping roots to absorb nutrient by improvement of soil physical properties. IRRI [6] stated that organic fertilizers have excellent nutrient content for plants if applied in the right time.

3.2 Grains per plant

The number of grains per plant showed significant differences between the SRI fertilizer practice treatments under the 3 rice varieties (Fig. 2). The highest number of grains per plant was exhibited on the Arize Tej Gold variety under the Evergrow+100 Kg ha^{-1} SA fertilizer treatment (293 grains) while the lowest was recorded under the control treatment of variety Arize 6444 Gold (98 grains). The fertilizer treatments showed significant positive influence compared to the control at Ahero with the highest recorded on the 200 Kg ha^{-1} SA treatment that however was not significantly different from that of Evergrow+100 Kg ha^{-1} SA treatment. The local variety, IR2793-80-1 had the lowest number of grains per plant in each treatment with the least under the control (111 grains/plant) during the first season and (111 grains/plant) during the second season.

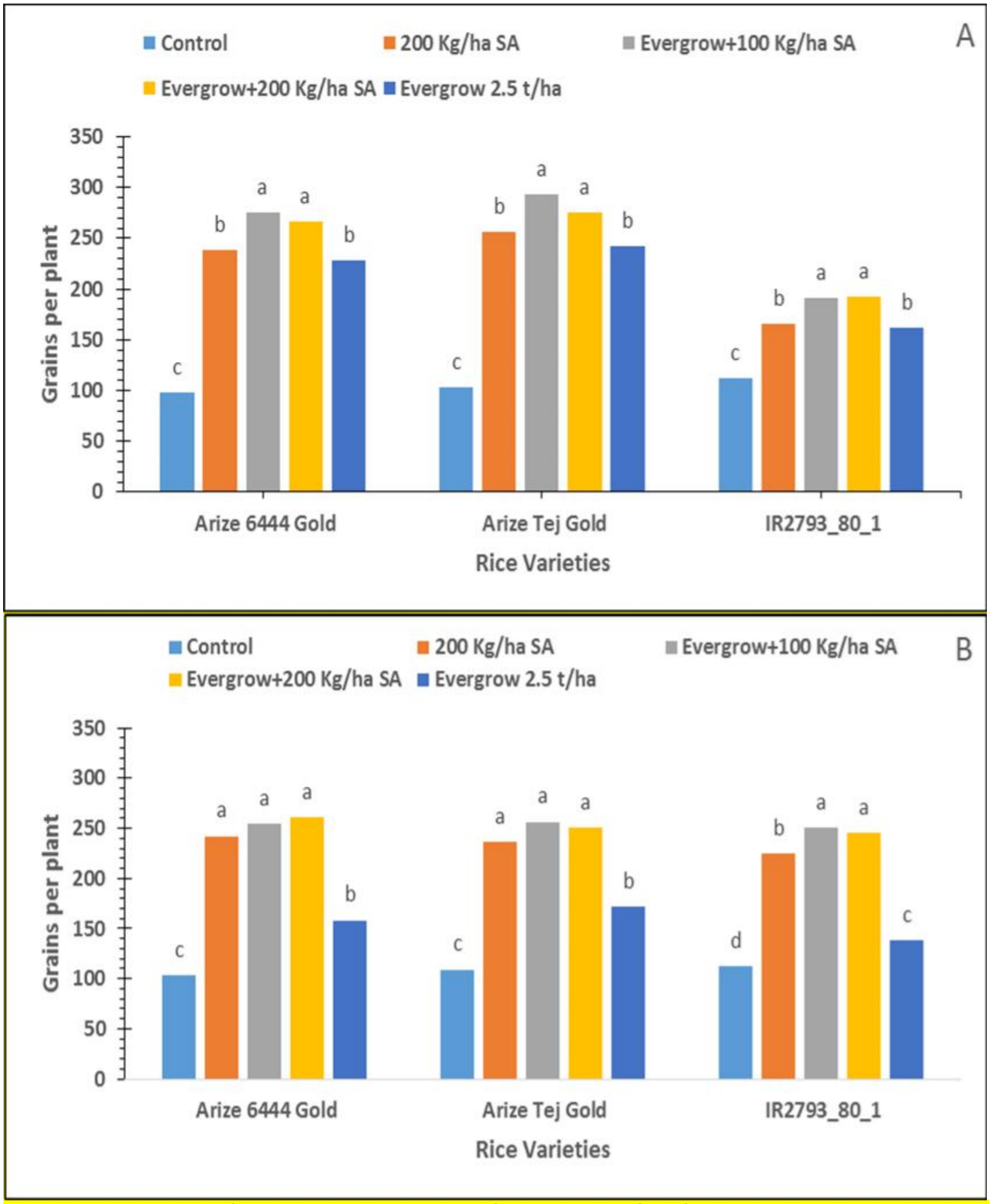

Figure 2: Number of grains per plant as influenced by SRI fertilizer practices and rice varieties at Mwea (A) and Ahero (B) Irrigation Schemes

An augmentation in grain as well as straw yield of rice might be the result of an vigorous vegetative growth enhancing plant height, total number of tillers/hill, total number of productive tillers/hill, number of panicles/hill and dry matter accumulation. Srivastava et al. [20] found that application of 180 kg N ha^{-1} significantly decreased the grain sterility and recorded the maximum grain yield over 120 and 60 kg N ha^{-1} during both the years.

3.3 Grain yield

The grain yield of rice varieties per plot differed significantly under the SRI fertilizer practices treatments at Mwea Irrigation Scheme (Table 1). The highest grain yield was recorded on variety Arize Tej Gold under the Evergrow+100 Kg ha^{-1} SA fertilizer treatment (1202 g) while the lowest (67 g) was recorded on variety Arize 6444 Gold under the control treatment. The highest grain yield at Ahero was under the inorganic plus organic fertilizer in all the varieties. The lowest yield was recorded on the local variety, IR2793-80-1 during the first season (1182 g/plot) and the second season (288 g/plot).

Table 1: Grain yield per plot as influenced by SRI fertilizer practices and rice varieties at Ahero and Mwea Irrigation Schemes

Variety	SRI Treatments	Mwea	Ahero
Arize 6444 Gold	Control	893e	267e
	200 Kg ha^{-1}	2965c	638d
	Evergrow+100 Kg ha^{-1}	3637b	1181a
	Evergrow+200 Kg ha^{-1}	3658b	1149ab
	Evergrow 10 t ha^{-1}	2627d	710c
Arize Tej Gold	Control	924e	273e
	200 Kg ha^{-1}	3143c	667c
	Evergrow+100 Kg ha^{-1}	3910a	1202a
	Evergrow+200 Kg ha^{-1}	4002a	1190a
	Evergrow 10 t ha^{-1}	2811d	744c
IR2793-80-1	Control	1182e	288e
	200 Kg ha^{-1}	2822d	616d
	Evergrow+100 Kg ha^{-1}	3205c	1141ab
	Evergrow+200 Kg ha^{-1}	3269c	1125b
	Evergrow 10 t ha^{-1}	2710d	704c
	LSD	**221.34**	**52.43**
	P-Value	**<0.001**	**0.002**
	CV%	**4.8**	**3.4**

Note: Numbers followed by same letters in the same column have non-significant difference based on LSD test with α = 0.05.

The yield advantage on the application of organic sources is due to their capability to supply essential nutrients other than N, P and K. Application of farm yard manure is known to increase concentrations of Fe, Mn, Zn, and Cu in rice. Higher nutrients uptake with the application of inorganic fertilizer might be due to higher nutrient concentration along with higher biomass production [21]. Application of organic manure along with chemical fertilizer accelerates the microbial activity [22], increases nutrients use efficiency [23] and enhances the availability of the native nutrients to the plants resulting higher nutrients uptake [24]. Vermicompost applied plots built-up residual soil fertility because of slow release of nutrients and reduction of nutrient losses.

Anupama and Ajay [25] reported that SRI recorded the highest grain yield (61.0 q ha^{-1}) as compared to standard practice. SRI was superior due to more number of panicles m^{-2}, panicle weight and 1000-grain weight. Francis and Lokanandhan [26] revealed that SRI recorded higher grain yield of 8.48 t ha^{-1} with B: C ratio of 2.41 followed by ICM with grain yield of 7.79 t ha^{-1} and B: C ratio of 2.28. The mean grain yield recorded in the standard practice was 6.16 t ha^{-1} with B: C ratio of 1.82. Hussain et al. [27] conducted a field experiment during Kharif of 2006 and 2007 to evaluate the performance of system of rice intensification (SRI) under Kashmir valley conditions. Seven treatments comprising SRI method with varied nutrient sources and the conventional methods of rice cultivation included the recommended and farmer's practice. SRI with recommended NPK and FYM outperformed the conventional methods of rice cultivation with regard to yield attributes, grain and straw yield during both the years. The crop raised with SRI technique receiving recommended NPK + FYM at 10 t ha^{-1} registered yield superiority of 15.47 and 19% over farmers practice during 2006 and 2007 respectively and therefore was superior with regard to the net profit realized.

4. CONCLUSION

The rice varieties yield components and grain yield were significantly and positively influenced by the SRI fertilizer practices with the highest grain yield. The 2.5 t ha^{-1} Evergrow+100 Kg ha^{-1} Sulphate of Ammonia fertilizer practice and hybrid variety Arize Tej Gold is recommended for highest rice yields.

REFERENCES

1. Belo, A. (2002). Evaluation of genetic resources for hybrid rice (*Oryza sativa* L.) production. *Genetics and Molecular Biology*, *25*, 257
2. Gross, B. L. and Zhao, Z. (2014). Archaeological and genetic insights into the origins of domesticated rice.*PNAS*, *111*, 6190-6197
3. Luh, B. S. (1991). *Rice utilization*.2nd edition Van Nostrand Reinhold. New York. Pg 413
4. FAO. (2000). Food and Agriculture Organisation Production Yearbook. Vol. 54.
5. Farina, A. (2006).Emerging patterns in the landscape. In H. Decamps, B. Tress and G. Tress, *Principles and methods in landscape ecology*. Dondrecht, the Netherlands: Springer Netherlands. Pp 179-228
6. IRRI. (2013). Rice and climate change for food security and vulnerability.
7. NIB. (2010). National Irrigation Board annual report.
8. Ndiiri, J. A., Mati, B. M., Home, P. G. and Odongo, B. (2013). Water productivity under the system of rice intensification from experimental plots and farmer surveys in Mwea, Kenya. *Taiwan Water Conservancy*, *16*, 63-75.

9. FAO. (2013). "*Rice market monitor," Trade and Markets Division*, Food and Agriculture Organization, Rome, 16, 1.
10. Kihoro, J., Bosco, N. J. and Murage, H. (2013).Suitability analysis for rice growing sites using a multicriteria evaluation and GIS approach in great Mwea region, Kenya.*SpringerPlus*, *2*, 265-274.
11. Mati, B. M., Wanjogu, R., Odongo, B. and Home, P.G. (2011). Introduction of the system of rice intensification in Kenya: experiences from Mwea irrigation scheme. Springer-Verlag 2011.
12. Rahman, s., Sharma, M. P. and Sahai, S. (2006). Nutritional and medicinal values of some indigenous rice varieties. Indian *Journal of Traditional Knowledge*, *5*, 456-458.
13. Bishwajit, G., Sarker, S., Kpoghomou, M., Gao, H., Jun, L., Yin, D. and Ghosh, S.(2013). Self-sufficiency in rice and food security: a South Asian perspective. *Agriculture and Food Security*, *2:10*-16.
14. Tejandra, C., Riseman, A., Yamaji, E. (2011). Assesment of System of Rice Intensification under Organic and Inorganic Management in Japan. Rice science .2011, 18(4) 311-320
15. Heong, K.L. and Escalada, M.M. (1997). Pest Management of Rice Farmers in Asia. Los Banos: International Rice Research Institute (IRRI).
16. Sato, S. and Uphoff, N. (2007). A review of on-farm evaluation of system of rice intensification (SRI) methods in eastern Indonesia. In: CAB Reviews. Perspectives in Agriculture, Veterinary Science, Nutrition and Natural resources. Wallingford: Commonwealth Agricultural Bureau International
17. Cho, Y. S. and Choe, Z. R. (1999). Effects of straw mulching and nitrogen fertilization on growth of direct seeded rice in no tillage / vetch cropping system. Korean J. Crop Sci. 4(4). 97-101.
18. Little, Ramon C., Waiter S. and Rudoff J. (2002). SAS for linear models.4th edition.*Cary Nc: SAS institute.*
19. Chen, S., Xi Z., Dangying W., Chunmei, X. and Xiufu, Z. (2013). Influence of the improved system of rice intensification (SRI) on rice yield, yield components and tillering characteristics under different rice establishment methods. *Australian journal of crop science AJCS* 6:1630-1636.
20. Srivastava PK, Parikh MM, Sawani NG, Raman S. Male sterility systems in wheat and opportunities for hybrid wheat development. 2001; *Acta Physiologiae Plantarum* 25: 179-184.
21. Banik, P., Ghosal, P. K., Sasmal, T. K., Bhattacharya, S., Sarkar, B. K. and Bagchi, D. K. 2006. Effect of organic and inorganic nutrients for soil quality conservation and yield of rainfed low land rice in sub-tropical plateau region, *J. Agro. Crop Sci.*, 192 (5): 331-343.
22. Rani, R. and Srivastava, O. P. 1997. Vermicompost: a potential supplement to nitrogenous fertilizer in rice nutrition. *Int. Rice Res. Notes*, 22(3), pp. 30-31.
23. Narwal, R. P. and Chaudhary, M. 2006. Effect of long-term application of FYM and fertilizer N on available P, K and S content of soil. 18*th World Congress of Soil Sci*, Philadelphia, 9-15 July.
24. Bhandari, A. L., Sood, A., Sharma K. N. and Rana, D. S. 1992. Integrated nutrient management in rice-wheat system. *J. Ind. Society Soil Sci.*, 40: 742-747.