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Research Paper

Rice yield enhancement technologies under rain-fed agriculture in Koraput district, Odisha, India

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Abstract. Rice (*Oryza sativa* L.) productivity is a major concern under rain-fed agriculture. Due to lack or inadequacy of knowledge on modern agricultural practices and technology, smallholder and marginal rural and tribal farmers do not conduct improved agronomic practices. As a result, rice grain yield is low and food scarcity at household level is conspicuous. This study emphasized the impact of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) on rice productivity in tribal villages of Koraput district, India. Participatory rice yield enhancement trials for three rice varieties namely *Khandagiri, MTU–1001* and *Ramachandi* were conducted in 21 villages with 47 farming families. Simultaneous field trials highlighting farmers' or traditional and improved practices were carried out to train farmers. After one growing season that is *Kharif*, yield and agronomic variables were recorded. Results indicated that the upland rice responded very well to the management practices followed by lowland and medium land rice in that descending order.

Keywords: Integrated nutrient management, integrated pest management, smallholder and farmers, yield.

INTRODUCTION

Worldwide, 82% of the agricultural land is rain-fed which contributes 70% of the global staple food production. However, a large proportion of population living in these areas is poor due to low and variation in productivity (Ashalatha et al., 2012). India ranks first in the world that practices rain-fed agriculture in terms of extent and value of production. It is reported that 57% of the total cultivated area in India is rain-fed contributing to 44% of the total food grain to the national food basket supporting 40% of the estimated population (Sharma, 2011). Although rain-fed agriculture is widespread, high incidence of poverty in these regions coexists due to multifarious reasons *viz.,* low cropping intensity, high cost of cultivation, poor adoption of modern technology, unstable weather and low productivity (Singh and Rathore, 2010). The Jeypore tract of Odisha, India is one of the best examples of rain-fed agriculture contemporaneous with high incidences of poverty and malnutrition. The region is well established as one of the centers of origin and genetic diversity in Asian cultivated rice (Ramiah and Ghose, 1951; Oka and Chang, 1962). Contrary to this, a large population which is about 85% of the region endures sometime of food scarcity and subsist below the poverty line index (BPL).

Rice production is low with an average yield of 3.25 to 3.45 t/ha, whereby smallholder and marginal farmers living in remote tribal villages find it difficult to meet their family food needs and are unable to reap the benefits of Green Revolution and modern plant breeding. Nevertheless, large and progressive farmers are also experiencing a similar situation of low yield due to soil degradation, diseases and pests and weed problems although they have adopted Green Revolution production technologies (Mishra et al., 2012). A concept of "*evergreen revolution*" was proposed to achieve productivity in perpetuity (Kesavan and Swaminathan, 2012) by better managing food production without environmental degradation. This is done through

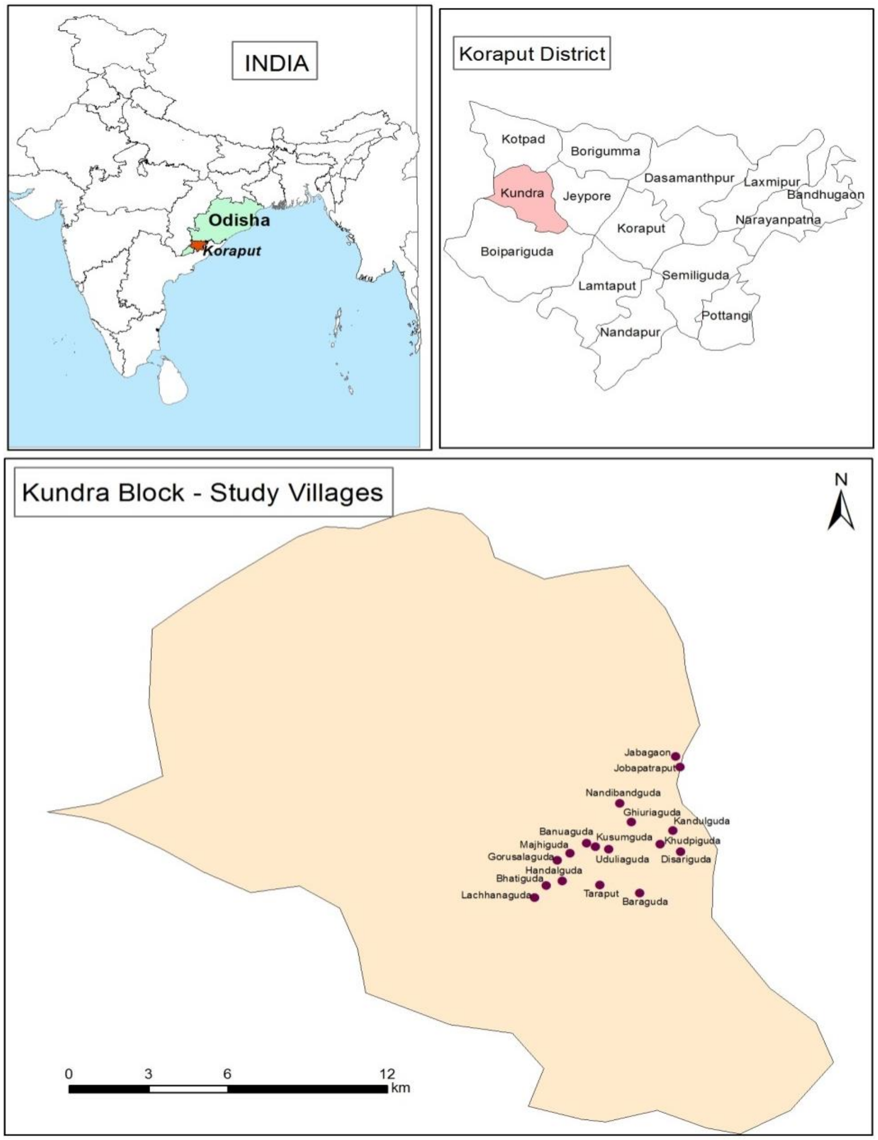

Figure 1. Map showing locations and cluster of study villages in Koraput district, Odisha, India.

Participatory Crop Improvement (PCI) approach by incorporating the marginal and smallholder farmers in crop cultivation (Sthapit et al., 1996; Ceccarelli et al., 2009). This intends to provide opportunities for sustainable crop production systems, improved nutrition and enhanced income earnings (Jarvis et al., 2011).

Alleviation of Poverty and Malnutrition (APM) program is formulated with joint venture of M. S. Swaminathan Research Foundation of India and the University of Alberta of Canada. The program is implemented in tribal villages of Koraput, India to ensure improved food, nutritional security and increased income for small holder farmers at individual, household and community levels. Since 58% of the total cultivated land in the study region is utilized for rice cultivation, rice related interventions were executed to reduce poverty by addressing the low productivity in small and marginal lands. This paper documents the impact of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) on rice production as part of the efforts of participatory yield enhancement.

MATERIALS AND METHODS

Description of the study area

Koraput district is located along the Eastern Ghats in Odisha State, India at latitude (17° 23' 59'' to 20° 42' 0''N) and longitude (81° 14' 24'' to 84° 12' 0''E) and it is rich in biodiversity and human cultural diversity (Figure 1). The district has a population density of 156 per km^2 (Census,

Table 1. Details of rice varieties used in the experimental trials in different land categories.

Land category	Varieties	Duration (days)	Number of local administrative unit	Number of villages	Number of farmers
Upland	*Khandagiri*	100	1	2	3
Medium land	*MTU– 1001*	135	2	6	6
Low land	*Ramachandi*	160	3	13	38

2011). The area experiences 3 major seasons, that is, summer (April to June), rainy (July to October) and winter (November to March) with an annual temperature variation of minimum 12.0 to maximum 38.0°C and the average rainfall recorded is about 1522 mm. Agriculture is the mainstay of the region and about 83% of the population depends on it. The local economy is primarily driven by agriculture and collection of forest products.

Sample population of the study

In the present study, 47 smallholder and marginal farming families from 21 tribal villages where included in yield enhancement experiment of the 3 different rice varieties (Table 1). Each trial was conducted in 0.5 acre land divided into two equal halves. Traditional and improved experimental fields were designed and laid side by side to demonstrate the differences between the two practices. Intermediate experiences of farmers were collected to resolve the problems during the trials.

Rice varieties

Three government controlled organizations *viz.*, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Central Rice Research Institute (CRRI), Cuttack and Odisha Seed Corporation, Bhubaneswar regulate seed production and supply in the region. In the present study, three rice varieties were collected from these organizations with the mutual consent of the trainers and farmers. The rice varieties were *Khandagiri, MTU 1001* and *Ramachandi* for the upland, medium land and lowland, respectively. Variety *Khandagiri* is short duration, moderately drought tolerant, matures in 90 to 95 days. It is resistant to lodging and shattering with high fertilizer response having an average yield potential of 3.2 t/ha. Variety *MTU-1001* is medium duration, matures in about 125 days. It has a good tillering vigour, long, slender and non-glutinous grain with an average yield of 5.5 to 6.0 t/ha; also photo-insensitive, and non-lodging. Variety *Ramachandi* is long duration, photo-sensitive and matures in 155 days; usually, it is semi-dwarf but tolerant to shallow water and flash floods. Panicles are heavy with medium bold grains and white kernel and its yield varies from 4.0 to 6.5 t/ha.

Agronomic practices

All the farmers who participated in the trial from their villages were trained and demonstrated on seed treatment, INM, IPM and quality seed production for 15 days. The guidelines followed were: (i) the field was ploughed 4 to 6 times and 2 to 3 tons of Farm Yard Manure (FYM) per acre was applied, properly mixed with the soil and left for two months. The nursery seedbed of 15m length x 1.5 m width × 30 cm height was prepared separately at a ratio of 1:10 nursery sowing: transplanting area. A 30 cm water channel was maintained between adjacent nursery beds and rice seeds were sown in a trench in north-south direction for appropriate sunlight exposure and growth. Water retention in the nursery bed was maintained at 15 to 20 cm during uprooting and the seedlings were transplanted at 21 to 25 days after sowing. The field was properly levelled and the seedlings were transplanted at 20 × 10 cm spacing and minimum of two weeding regimes were done. The panicles were collected for seed purpose in successive cultivation periods. The date of FYM application, ploughing, transplanting, weeding, days to flowering, physiological maturity and harvest were recorded and maintained by the farmers and the trainers.

Integrated nutrient management (INM)

In the experimental plots, organic manure and chemical fertilizer were applied. In the nurseries of medium and lowland vermi compost at 30 to 50 kg was applied. Farm Yard Manure at 2.4 to 2.5 tons per acre was applied in the medium and lowland fields one week prior to transplanting of the seedlings. The NPK 60:30:30 fertilizers per hectare were applied in three different stages of plant growth that is basal, tillering and booting (Table 2).

Integrated pest management (IPM)

Seeds were treated with saline water, that is, 1 kg of common salt was dissolved in 20 L of tube well water before sowing to prevent early bacterial and fungal diseases. This was followed by of *Neem (Azadiracta indica)* oil, that is, 3 ml was mixed with 1 L of fresh water

Table 2. Fertilizers applied in low land paddy field.

Stages	Urea (kg/acre)	SSP (kg/acre)	MoP (kg/acre)
Basal	26	75	10
Tillering	13	0	0
Booting	13	0	10
Total	52	75	20

SSP - Single Super Phosphate; MoP -Muriate of Potash

Table 3. Comparison of practices of upland rice field.

Traditional practices	Improved practices
1. Applied FYM immediately before sowing	1. Applied FYM well in advance and mixed properly
2. Broadcasting of seeds	2. Direct seeding in lines with space using line marker
3. Hand weeding (once)	3. Applied N:P:K at basal stage
	4. Thinning to maintain the plant population
	5. Three times timely weeding

and applied in nursery after 10 to 15 days of sowing. Pests such as early stem borer, leaf folder or case worm were controlled with *Chloropyriphus* 2 ml mixed with 1 L of water. In some cases, *Monocrotophus, Chloropyriphus and Quinalphus* were sprayed at 2 ml mixed with 1 L of tube well water. To overcome Gall midge and case worm pests, granular form of *Chloropyriphus* and kerosene oil at 2 L per acre were sprinkled, respectively. However, in the upland trial plots, *Chloropyriphus* granules were applied to control white ant.

Farming families involved in the study

Of the 47 smallholder and marginal farmers, 37 men and 10 women participated in the field intervention practices. Almost half of these farmers were the tribal people living in remote areas. Most of them were illiterate and a few of them had attained primary school level education. They own small and marginal land holdings of between 0.5 to 3.0 acres and often cultivate only a few varieties of rice promoted by the government. Based on the farming families, the data on intercultural operations were collected from the trial plots where the local communities were involved. Plant agronomic characters comprising plant height, panicle length, tillering density, grains per panicle, chaffs per panicle, 1000 grain weight were recorded in a prescribed form from traditional and improved plots by randomly selecting 10 plants per plot. To assess the return benefit of the yield enhancement trial (YET), cost: benefit ratio for improved and farmer practice farming were calculated.

RESULTS

The comparison between traditional and improved practices for upland, medium and lowland rice are presented in Tables 3 and 4, respectively. Results indicated that most farmers (86%) who participated in the rice enhancement trial were smallholder and marginal landholders representing most (40%) of the scheduled tribes, 28% were the scheduled castes, 24% other backward castes and 8% belonged to the general categories.

Furthermore, results indicated that for the medium and lowland rice fields, rice grain yield was enhanced by 11 and 32.5%, respectively. At the end of the first growing season, farmers who participated in the training achieved 57.5 and 69.4% growth for medium land and lowland fields, respectively. The cost of production for the medium land was 8.2% high and generated more profit (57.5%). For lowland, it was 21.75% higher with a profit of 69.4%. The cost: benefit ratio for the medium land was 1: 1.6 for both of the practices and for the lowland it was 1:1.7 in improved practice compared to 1:1.5 in the traditional practice showing the effect of cultivation practices on yield. The improvement in rice growth and development traits is presented in Figures 2, 3 and 4.

DISCUSSION

Most of the farmers in India particularly the Koraput district have low or no access to improved farm technologies, but, a large proportion of the family’s source of income is from agriculture and agricultural wage earnings. Lack or inadequate resources for investment in agricultural production, inefficient extension services and improper farm technologies and facilities have accelerated low productivity. The steps involved in rice production in the study area showed that agronomic practices were different for upland as standing water was not available whereas for medium and lowlands water

Table 4. Comparison of practices between medium and lowland rice fields.

Practices	Improved practices
1. No seed treatment	1. Seed treated with salt water
2. Seed rate: 30 kg/acre	2. Seed rate: 24 kg/acre
3. Small piece of land for raising nursery	3. Raised nursery area 1/10th of the planting area
4. Application of FYM only	4. Application of FYM and Vermicompost
5. 30 to 60 days old seedlings	5. 21 to 30 days old seedlings
6. 3 to 4 seedlings/hill	6. 2 seedlings/hill
7. 70% farmers applied fertilizer only at basal stage; lack of knowledge	7. Applied fertilizer in three stages (basal, tillering, panicle initiation); N:P:K (60:30:30) kg/ha; gained knowledge
8. Random transplanting without proper spacing	8. Transplanting of the seedlings at 20 x10cm spacing
9. Weeding once	9. Weeding twice and timely
10. Keeping standing water at 10 cm	10. Intermittent drying and wetting for better crop growth and development
11. Both traditional and chemical pest management	11. Integrated pest management
12. Seed selection from all healthy panicles	12. Seed selection from mother panicles
13. Untimely harvest	13. Timely harvest

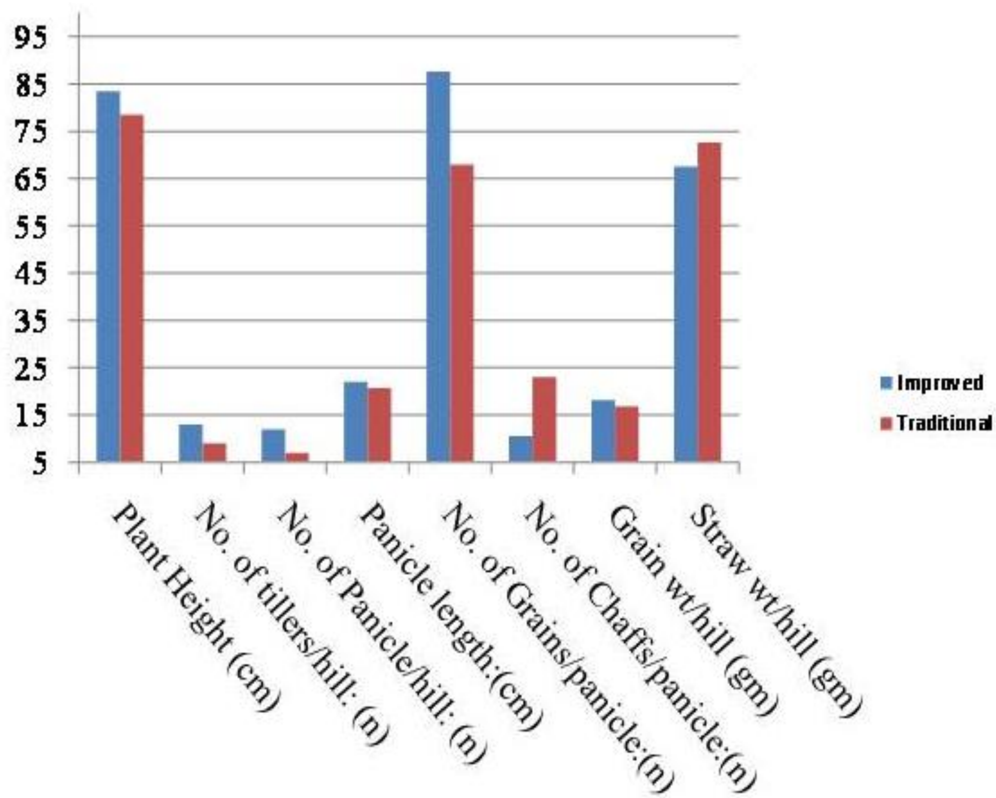

Figure 2. Comparison of improved and traditional practices describing different agronomic characters for upland rice variety *Khandagiri.*

was available throughout the cultivation period.

Farmers who participated in yield enhancement trials achieved an average of 165.6% as more income compared to the traditional practices for uplands in the first growing season. Grain yield in the improved trial was 97.9% more than the yield obtained in the traditional practice. Further to that, the cost of production for the improved practice was 62.3% higher and the profit was 165.6% more than the traditional practice thereby compensating the expenses incurred in the investment.

The findings of this study revealed that agronomic practices were similar for medium and lowland fields except the techniques involved in the water management. Based on the findings of field demonstrations, it was

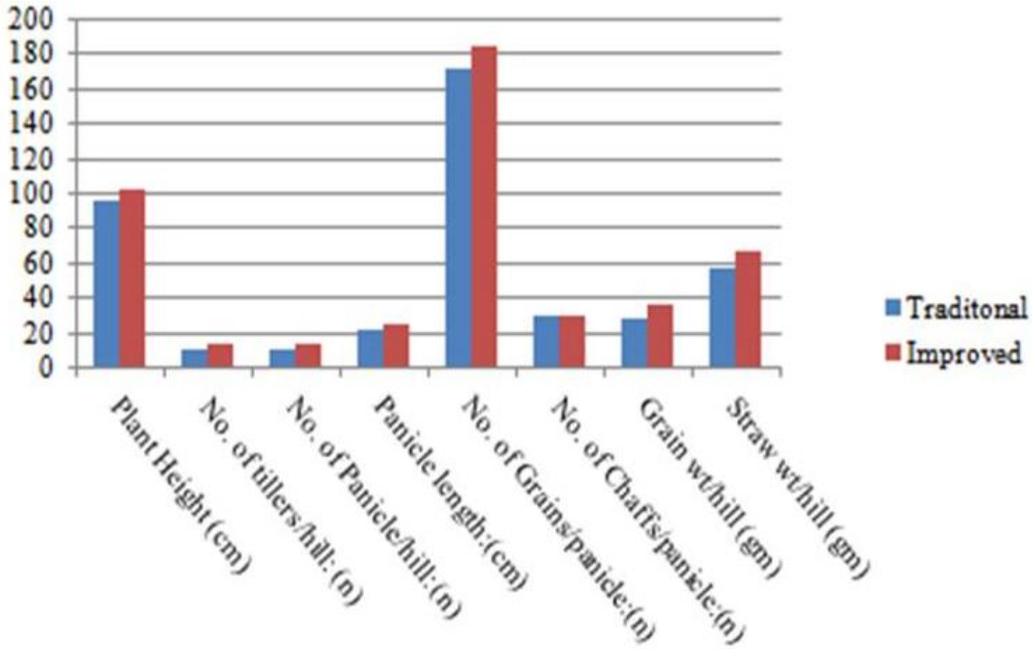

Figure 3. Comparison of improved and traditional practices describing different agronomic characters for medium land rice variety *MTU 1001*.

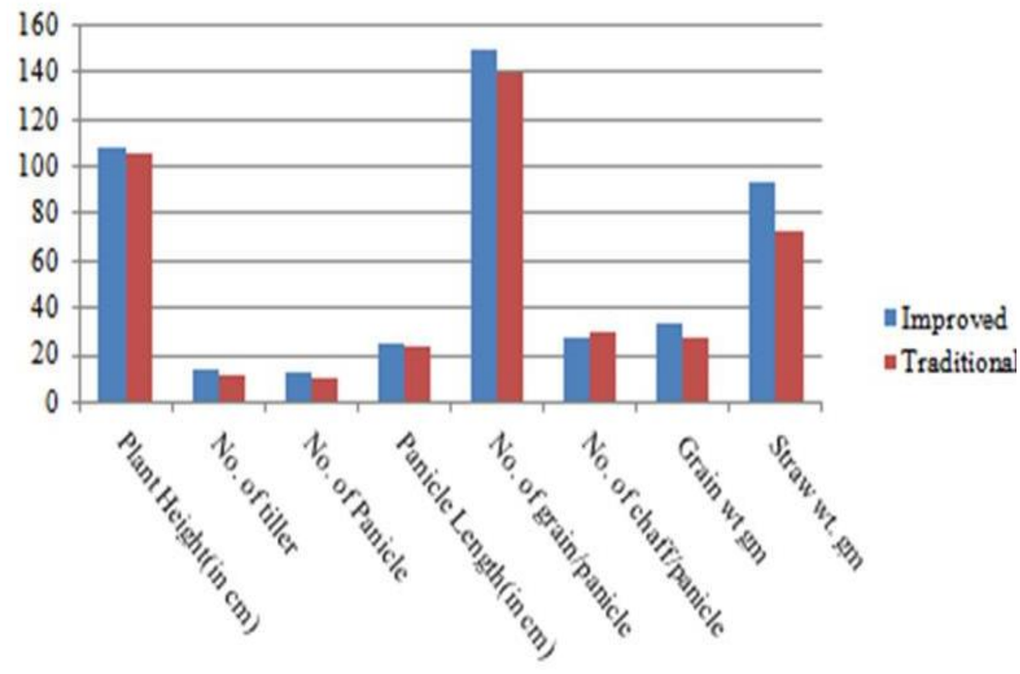

Figure 4. Comparison of improved and traditional practices describing different agronomic characters for lowland rice variety *Ramchandi*.

realized that the number of intercultural practices were almost similar for both fields.The modification of farmers' practice with scientific knowledge and skill had dramatic changes in the rice yield obtained.This is explained by the cost: benefit ratio which for the medium land was 1:1.6 for both practices and for the lowland it was 1:1.7 in improved practice compared to 1:1.5 in traditional practice. This observation shows that there was an effect of cultivation and agronomic practices on rice yield. Besides rice yield improvement observed in the present study, farmers recognized superiority of agronomic characters for their rice crops. The characters included plant height, number of tillers, and the number of panicles, panicle length, and the number of grains per panicle and grain weight in improved practices for all three land types.

Farmers in the upland field followed strictly the guidelines which included line marker for direct seeding in rows and thinning for the first time to maintain appropriate plant population. In addition, they applied N, P, K fertilizers at basal stage and weeded their rice fields once. Because of variation in land settings and agronomic practices used, there was a remarkable difference between the yields of both practice in all the three land types. Similarly, farmers of lowland and medium land fields could not adopt all the agronomic practices demonstrated to them in the field trial. They only considered the recommended seed rate, application of FYM in nursery and planting field, and followed the number of ploughings, method of uprooting the seedlings and transplanting. In contrast, water management was followed properly in traditional practices. The INM and IPM practices were not properly followed and the data generated showed that 58 and 80% less nutrition and pesticides are applied for medium and lowland that probably responsible for the yield difference. In a similar study Mahender et al. (2013) using many local rice varieties in which also variety *MTU-100* was included during dry season found that the system of rice intensification (SRI)-organic recorded on an average 4.4% higher grain yield over normal transplanting (NTP) which was significantly inferior during earlier seasons (that is, 2 wet seasons). However, their findings indicated that the grain yield decrease was to the extent of 21% in SRI-organic over NTP in the first season. According to Mahender et al. (2013), there was a reduction in the incidence of pests in SRI and the relative abundance of plant parasitic nematodes was low in SRI as compared to the NTP. They indicated that about 31 and 37% saving in irrigation water was observed during Kharif and Rabi seasons, respectively in both methods of SRI cultivation over NTP.

CONCLUSION

This study indicates that appropriate management practices have significant impact on the production of rice under rain-fed conditions. The marginal and smallholder farmers achieved higher rice yields within a one year growing season which helped them to meet food needs of their families. Thus, use of low-end rice production technology demonstrated yield enhancement in various land categories under rain-fed condition. Acquired technical and applied knowledge and improved skill is highly beneficial for cultivation of different rice varieties in a large scale under different agro-ecological conditions. These could set appropriate pathways for profitable and sustainable agriculture that ensures food availability at individual household level.

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