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Promotion of Labour Saving Rice Mechanization Technologies in Rain-Fed Low Land and Irrigated Ecologies of Tanzania and Kenya

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Abstract
Rice farming has been conducted in both Tanzania and Kenya mostly under manual operations and has resulted in low outputs due to inefficient production methods. This has resulted into reduced acreage, low yields and labour drudgery. To increase efficiency in agricultural production among small scale farmers, mechanization was found to be the main driving tool. Research on mechanizing rice production activities from land preparation to threshing was conducted in irrigated and rain fed ecologies of Mbarali and Kyela respectively while in irrigated system of Mvomero Morogoro only herbicide effectiveness in weeds control was assessed. Seed treatment was assessed in irrigated ecology of Mwea, Kenya. Randomized Complete Block Design (RCBD) was employed in demonstration plots to assess different rice mechanization technologies. Ploughing and puddling using power tiller, oxen and hand hoe were determined in terms of man-days required. Direct rice seeding and transplanting using a walk behind motorized planter and transplanter were also compared against hand seeding and transplanting respectively. Research results indicated that there were significant differences ($P < 0.05$) for most mechanized operations along the rice production value chain. In order for rice growing farmers to realize the benefits accrued from mechanizing rice production, all levels of production should be mechanized. However for rice mechanization to be successful rice mechanization machines and implement should be subsidized to enable majority of smallholder farmers to access them. Smallholder farmers need also to be mobilized into groups for ease acquisition of rice machines and capacity building.
Keywords: Puddling, Transplanting, Threshing

1. Introduction

Lack of mechanization seriously limits productivity and competitiveness of rice based systems in Sub-Saharan Africa (SSA). At the same time, the continent is littered with wrecks of imported agricultural machinery, abandoned because of inappropriate designs, lack of spare parts or costly maintenance (Rickman *et al*. 2013). Mechanization is crucial but its introduction requires careful analysis of successes and failures and discussion of lessons learned. Machines do not only hasten field operations but also provides a high quality product, making it more attractive to local traders and consumers.

Mechanization is essential for rice production and processing. For farmers to intensify their cropping, they need to mechanize the manual labour-intensive operations. When NERICA production was doubled in The Gambia between 2007 and 2010, farmers found it difficult to harvest and thresh the extra rice, which resulted in reduced quality because of the delays. In Senegal, high rice prices in 2009 prompted many farmers to grow a second crop, but they then discovered that the harvesting of that crop overran into the period when they should have been preparing the land for the main-season crop.

Rice production in SSA in 2010 was estimated at 18.4 million tons (Mt) of paddy (Africa Rice, 2011). Assuming a conservative 20% of postharvest losses, reducing postharvest losses by half would provide an additional 1.84 Mt of paddy, equivalent to 10% of regional imports, with a value of about US$ 550 million per year (Rickman *et al*. 2013) .

Rice stakeholders from sub-Saharan Africa have recently emphasized the value of small-scale, locally adapted machinery specifically targeting labour-intensive activities, such as land preparation, weeding, harvesting and processing. They have also recommended that governments consult research when importing machinery to ensure their efficacy and durability under African farming conditions, and that capacity be built to provide after-sales support for farm machinery (e.g. servicing and repair) and gradually enter into farm machinery production industry (Wopereis *et al*. 2013).

Africa Rice has a long history of adapting and promoting appropriate-scale machinery in West Africa. The best-known example is the ‘ASI” thresher cleaner, which is now used by the majority of farmers on the

Senegal side of the Senegal River valley. The Africa Rice centre's latest import-and-adapt machine is a mini combine-harvester from the Philippines. Inadequate local rice supply, slow harvest and poor quality hamper production and marketing (Rickman *et al*. 2013).

According to the rice agricultural product value chain (APVC) analysis that was conducted towards the end of the year 2010, a number of production constraints were identified. They include the lack of information on the economics of rice production, limited water supply, high cost of farm inputs, problematic soils, poor agronomic practices, and low soil fertility due to depletion of soil nutrients occasioned by grain and straw harvesting and more importantly, lack of mechanization strategies in rice production. Others are storage pests and poor post-harvest handling practices that have contributed to losses in quality and quantity of the rice grain yields (Kimani *et. al*. 2010).

Agricultural mechanization in Sub-Saharan Africa (SSA) has stagnated for several decades. Some countries have formulated national strategies for agricultural mechanization but have not implemented (Tokida *et al*. 2012). Famine and high food prices in many African countries have led to accelerated mechanization interest in agriculture for increased crop productivity. There is need to identify specific constraints in rice production to be addressed through mechanization in order to reduce drudgery along the rice production value chain and improve efficiency in production and quality of the produce.

Rice is one of the important crops in developing countries. Rice supplies more than 30% of total calorie intake and it is a source of employment in the rural areas. Nevertheless, primary land preparation in SSA relies on human muscle power for about 80% of the cultivated land, with draught animals and small tractors being used by 15% and 5%, respectively (Rickman *et al*. 2013). This contrasts strongly with Asia, where land preparation on over 60% of the cultivated land is done by tractors (Mrema *et al*. 2008). These figures are comparable for farm power use in SSA and rice based systems are not an exception to this rule (Rickman *et al*. 2013).

In Tanzania rice is now the second most important food and commercial crop after maize. The rice sector is among the major sources of employment, income and food security for Tanzania farming households. Tanzania is the second largest producer of rice in Southern Africa after Madagascar but with very low average yield of 1.8 tons per hectare (RSDEA, 2012). In Tanzania rice is mostly produced in Mbeya, Morogoro and Mwanza covering more than 48% of national production (Rowhani *et al*. 2011).

In both Tanzania and Kenya, rice production is dominated by smallholder farmers characterized by low acreage and low yields due to most farm operations being labour intensive and time consuming, lack of both machinery and mechanization knowledge. In Kenya the government recognized rice as a strategic crop for food security and poverty alleviation. This led to the transfer of the research mandate from the Irrigation Board to the then Kenya Agricultural Research Institute (KARI) now KALRO. In the past more efforts have been directed to biological research, little effort being directed to mechanization. In rice producing areas the availability of labour at critical times is a major constraint to production. For a full cropping cycle more than 250 man-days/ha are required. Manual land preparation requires more than 140 man days/ha, planting and weeding 70 - 80 man-days/ha while harvesting and transporting require an additional 60 - 80 man-days/ha (Africa Rice 2011).

In the southern Highlands of Tanzania, Mbarali District in particular where adoption of power tiller is higher compared to other parts of the country, only land preparation and transportation are effectively mechanized while puddling, sowing, transplanting, weed control and threshing are manually undertaken, leading to increased labour and time demand hence reduced rice productivity. Paddy rice producing farmers fail to exploit rice mechanization technologies mainly due to low awareness on the existence and benefits to be reaped, and the physical access to affordable but functional machinery. Experience from Southeast Asia show that mechanization combined with improved crop management resulted in increased yields and labor requirements decreased by 60%, and the time required for all of the main rice-farming activities by 70% (Uprety 2010).

This Research work was geared at fabricating, testing and promotion of appropriate rice machines and mechanization technologies for medium and smallholder farmers along the rice production value chain for enhanced productivity.

2. Materials and Methods

Participatory testing and promotion methods of rice mechanization technologies were implemented in Mbarali and Kyela districts in - Mbeya region and Morogoro rural in Morogoro region. Such approaches were used to create awareness and improve farmers' skills in the use of new implements. However implement requirements vary with variation in rice growing ecologies where Mbarali and Kyela are under irrigated and rain-fed rice ecologies respectively. In Kenya design and fabrication was given priority. Experiments were conducted in demonstration trials and research centres. Treatments involved were: Power Tiller technologies (ploughing, harrowing, puddling and direct seeding), motorized transplanting, animal drawn implements (ox-puddlers and ox-furrow openers), and farmer practices (hand hoeing, harrowing, hand transplanting and broadcasting - Control). Ploughing was done using the disc and ox-plough taping power from the power tiller and oxen for the respective treatments while hand hoe was used for control treatment. Puddling was achieved using ox-puddler, power tiller harrow and hand hoe for the control. Weeding for power tiller and oxen treatments was done using 2,4-D selective herbicide. Harvesting was done on 5 m x 10 m plot size at two different locations for each treatment to determine yield and time of threshing for the different treatments. Rice crop was cut using a sickle for all treatments. Rate of threshing was assessed using motorized threshers when compared to hand. A seed dresser was evaluated for efficiency. At each level of field operation, three treatments were employed for both irrigated and rain-fed ecologies. The experiment was laid out in a RCBD. Data collected through demonstration trials were analyzed using GenStat software and means separated using Duncan Multiple Range Test.

Two models, gasoline and motor powered dressers were tested. To determine capacity, rice grains were weighed in batches of 5kg. The drum door was slid open and loaded and switched on with an additional 5kg batch at a time in each model until the machine was unable to rotate the loaded drum in each case. This was done without adding the liquid insecticide; it was rotated by switching on the engine/ motor. In each case when the drum could not rotate, offloading in steps of 1kg was done until the respective drums cold just rotate. Overhanging load was calculated as follows; withdraw. To calculate overhung load, gear drive manufacturers use the formula:

Overhung Load = 126,000 x HP x FC x LF x P.D. x RPM

where:

HP	=	Horsepower
FC	=	Load connection factor
Lf	=	Load location factor
P.D.	=	Pitch diameter of the sprocket, sheave or gear
RPM	=	Revolutions per minute of the shaf

3. Results and Discussion

Research results indicate that the most labour intensive operations in rice production were puddling, transplanting and weeding when done manually (man-days ha^{-1}). It is evident that such operations need mechanization interventions in order to enhance labour saving.

3.1 Ploughing and Puddling

Data collected from demonstration trials in Mbarali and Kyela under different mechanization technologies for ploughing and puddling were compared (Table 1).

Table 1: Ploughing and puddling in rice production in Mbarali and Kyela, Tanzania

Treatment	Ploughing (man-days ha^{-1})	Puddling (man-days ha^{-1})
Power Tiller	2.13a	0.513a
Oxen	2.75a	2.53b
Hand	7.05b	10.92c
GM	3.98	4.65
CV%	24.7	5.1
F Prob.	0.007	<0.001
LSD	2.23	0.54

Means along same column with similar letter(s) are not statistically different at (P >5%)

Note: 1 man-day = 6 hours of work per person

The use of power tillers in Mbarali district for puddling and transplanters for transplanting operations have shown to greatly save labour ten and four times compared to hand and oxen respectively. The use of oxen in ploughing and puddling also saves labour when compared to hand hoe (Table 1). Research results indicate that there were significant difference between power tiller and hand hoe as well as oxen and hand hoe but no significant difference between power tiller and oxen ($P \leq 007$). Considering puddling, there was significant difference ($P \leq 0.001$) between all the three treatments. Power tiller puddling was the most labour saving technology (0.513 man-days ha^{-1}) followed by oxen (2.53 man-days ha^{-1}) while hand being the least (10.92 man-days ha^{-1}). Puddling using oxen and power tiller in irrigated ecologies of Mbarali Tanzania, besides saving labour, the technologies have indicated to reduce drudgery.

Figure 1. Ox-puddling in Mbarali

Figure 2. Power tiller puddling in Mbarali

3.2 Direct rice seeding and transplanting

Rice seeding and transplanting are dependent on ecologies where by rain-fed and irrigated ecosystems are dominated by direct seeding and transplanting respectively. Transplanting was done in irrigated rice ecosystem using walk behind motorized rice trans-planter to transplant rice seedlings of 14 – 21 days old while direct seeding was done in rain-fed ecosystem using a planter that tapped power from a power tiller. Direct planter (Figure 4) open furrows, drop rice seeds and cover the seeds concurrently.

Results showed that direct seeding and transplanting using motorized rice seeders and transplanters are labour saving compared to ox-direct seeders and hand transplanting, indicating significant difference at (P<0.021) and (P<0.001) respectively (Table 2). The use of ox-furrow openers for opening furrows followed by manual placement and covering of rice seeds doesn't save labour and time for the activity thus ox-furrow openers and hand seeding indicated no statistical significant difference. Results show that direct seeder can save time by about twenty three times compared to oxen and hand.

Table 2: Direct sowing and transplanting (man- days ha^{-1}) in Mbarali and Kyela

Treatment	Direct seeding	Transplanting
Direct Seeder /Transplanter	0.92a	1.5a
Oxen	21.20b	-
Hand	21.19b	12.5c
GM	14.44	7.0
CV%	41.0	6.6
F Prob	0.021	0.001
LSD	13.40	1.02

Means along same column with similar letter(s) are not statistically different at (p >5%)

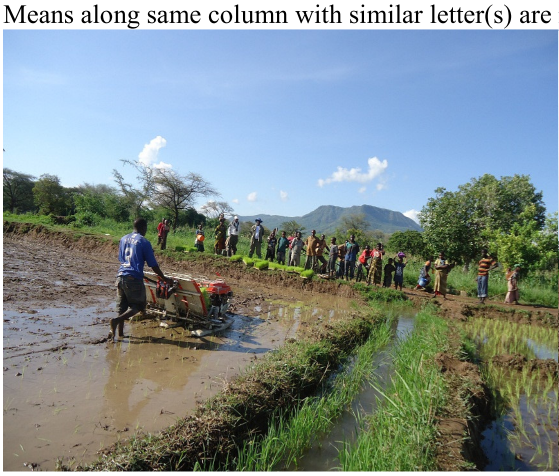

Figure 3. Motorized rice transplanter

Figure 4: Rice direct sowing in Kyela

3.3 Rice Weeding

Results on weeding operation are presented in Tables 3 and 4 for the respective treatments. Timely weeding has been difficulty for most rice farmers especially because weeding is tedious and time consuming as it is done by hand leading to delayed weeding operations that result into reduced yields. Weeding operation was assessed

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using herbicides, manual weeders and hand.

Table 3: Rice weeding using push weeders, herbicides and hand

Treatment	Weeding (man-days ha^{-1})
Herbicide	0.48a
Manual weeders	10.17b
Hand	24.83c
CV%	2.4
LSD	0.65
SED	0.24
F Prob	<0.0001

Means along same column with similar letter(s) are not statistically different at p >5%

Table 4. Effect of weed management on grain yield and benefit-cost ratio

Treatment	Grain yield (kg/ha)		Av. Income (US$)	Variable Cost (US$)	Benefit-Cost ratio
	2011	2012			
Two hand weeding	5600.0a	5597.2a	2132.8	1184.9	1.8
Roundup	4880.0ab	5111.1abc	1903.1	951.5	2.0
No weeding (control)	2160.0c	2777.8d	940.5	783.8	1.2
Tiller Gold (OD)	5360.0ab	5444.5ab	2058	823.2	2.5
Solito	4560.0ab	3638.9d	1561.7	709.9	2.2
Mean	4400.0	4427.1	1681.4	989.0	1.7
SE	344.0	283.0			-

Means along same column with similar letter(s) are not statistically different at p >5%

When manual weeders were employed they reduced time of weeding by 2.4 times (Table 3) when compared to hand weeding. Uprety (2010) also reported about 3 times saving in time and labour when push weeders were employed. Herbicides are more time saving than the two methods but considered expensive for most small scale farmers. Nevertheless, Tiller Gold - Fenoxaprop-ethyl + Ethoxy Sulfuron-sodium + Isoxadifen-ethyl (Safner) and Solito – Pyribenzoxim + Pretilachlor were observed to be highly accepted by farmers who were involved in testing because of their efficiency in controlling many weed species. The same herbicides are the ones which indicated high benefit-cost ratio when compared to other treatments.

Regardless of outstanding labour saving as a result of herbicide use, most smallholder farmers prefer use of push weeders due to the cost implications. The use of manual weeders in rice weeding helps to avoid bending for hand pulling of weeds that is back breaking. Transplanting using the transplanter maintained inter-row spacing which facilitated the use of push weeders for weeding (Figure 5).

Figure 1: Rice weeding using push weeders in Mbarali, Mbeya

3.4 Rice Threshing

Rice threshing is generally labour and time consuming when manually done. Results (Table 5) have showed that motorized thresher can save labour three times compared to manual threshing.

Table 5: Machine and Hand Threshing (Man-days and tha^{-1})

Treatment	Threshing (man-days ha^{-1})	Yield (t ha^{-1})
Motorised thresher	2.77a	3.0a
Oxen (Motorized Thresher)	3.05a	3.27a
Hand	9.1b	3.45a
GM	4.97	3.24
CV%	29.7	13.3
F Prob	0.027	0.501
LSD	3.943	0.978

Means along same column with similar letter(s) are not statistically different at P >5%

Threshing in Mbarali and Kyela, Tanzania is done manually which involves hitting the panicles against a stationary object like log of wood or beating the cut crop with a stick to remove the grain. Though popular because of its low cost, it is labour intensive. Results from the trials reported in this paper show it's evidence that threshing rate and efficiency is very high when using motorized rice thresher and there was statistical significant difference ($P \leq 0.027$) between hand threshing and use of motorized thresher (Table 5). This means that mechanizing rice threshing will greatly reduce time spent and fatigue to farmers on the same operation. It is simple to use, completely threshes the heads, performs winnowing, and reduces fatigue especially to women and encourages men participation in rice threshing.

Figure 2: Demonstration of rice threshing using motorised Thresher, Mbarali

3.5 Seed Dressing

Carrying capacities rating for the two models tested were determined as 30 kg for the electric dresser and 50 kg for the gasoline one. The amounts of chemical used per kilogram were the same in each case according to their manufacturers' recommendation. The coefficients of dye on individual seeds compare favourably in the two types of seed dressers, for which coefficients of variation approaching 100%. The difference between the two coefficients of variation in this study is likely due to the effects of the difference in prime mover capacity which led to a differential in ability to take overhanging load. Though increased motor horse power will lead to increased cost of production and power requirement, the ability to take overhanging load may disappear. Time for attaining those respective coefficients was found to be 30 and 40 seconds for electric and gasoline dressers respectively.

Table 6: Special features for the seed dresser

Characteristic	Gasoline	Electric
Drum size	0.21m^{-3}	0.21m^{-3}
Prime mover rating, Hp	5.5Hp	2Hp
Mean drum speed, rpm	41	37
Coating uniformity coefficient	0.98	0.96
Time to acquire desired coating, sec	40	30
Offloading time, minutes	3	5
Rate of output, Kg/hr	545.5	490.9
Labour requirement, md	2	2
Cost of the assembly, $	568	524

Figure 3: Electric Seed Dresser at a Field Day, Njoro Kenya

4. Conclusions

In order for rice growing farmers to realize the benefits accrued from mechanizing rice production, all levels of production from land preparation to harvesting should be mechanized. Farmers realized the fact that mechanizing rice production operations leads to labour and time saving at the same time profitable. Results show that fully mechanization of main rice production activities from land preparation to harvesting can be 10 times labour saving compared to manual. However for rice mechanization to be successful local manufacturers and suppliers of implements should ensure they supply quality and reliable materials that will not discourage resource poor farmers. Outputs of the two models were found to be 515 kg/h and 720 kg/h for electric and gasoline driven seed dressers respectively. The treatment method outlined above provides relatively uniform application of liquid seed dressings to batch quantities of seeds with less man-days requirement.

5. Recommendations

- Promotion of rice mechanization technologies require joint efforts of researchers, farmers and implement manufacturers and suppliers
- Implements for rice mechanization should be subsidized to enable majority of smallholder farmers to access them. Otherwise farmers' mobilization into groups would help them join effort to purchase farm machinery that can serve 10-15 people e.g. motorized rice trans-planters and threshers.
- Building capacity among local manufacturers of rice mechanization implements would increase their accessibility and at low cost. Imported machines and implements most of the time they tend to be expensive to most small scale farmers.
- Work should be undertaken to standardize pesticide application into the drum. Operators should be trained before using the machine. More work is required to establish energy requirement and germination trends of seed treated by the dresser.

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