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Transplanting, plant spacing and water management practices by paddy rice farmers in Mwea irrigation scheme

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Abstract

A survey was done in 2016 across five units of the Mwea Irrigation Scheme using a semi-structured questionnaire in a stratified random sampling approach. Two hundred farmers were interviewed in Wamumu, Karaba, Thiba, Tebere and Mwea sections of the Scheme. Data collected included: method of transplanting, age of seedlings at transplanting, number of seedlings per hole, depth of transplanting, number of years farmers had been in rice production, sizes of land owned by farmers, whether soil testing was done in the fields, net grain yield attained in the field, frequency of irrigation, knowledge on when to irrigate the rice fields, depth of irrigation, whether farmers drained the fields, plant spacing used in the fields and challenges in rice production. All interviewed farmers reported that they transplanted seedlings rather than direct seeding. Over 90% of the farmers transplanted one month or older seedlings at a rate of two seedlings per hole and at a depth of 2cm. Most interviewed farmers had been in rice cultivation for 6-20 years, owned 1-2 acres and produced 2001-5000kg/ha. Farmers irrigated their fields once a week, depending on the field water level at a depth of ≤ 10cm. Majority of interviewed farmers used plant spacing of 30×15 cm and 20×20cm which they associated with increased yields. Water shortage, high input prices, low market prices and pests and diseases were the major challenges in paddy rice production.

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Introduction

Rice is the third most important crop in Kenya and requires the best growing conditions for maximum production. Kenya has a potential of about 540 000 ha that could be used to produce irrigated paddy rice, but only 105 000 ha are being utilized (MOA, 2009). According to GAIN report, (2015), the annual rice production in the Kenya is estimated at 126,400 tonnes compared to the annual consumption of 1.18 million tonnes. Rice production is faced by many constraints: unavailability of quality seed, inadequate farmer knowledge and training, high price of inputs and low market prices, inadequate water, low soil fertility, high temperatures and very low temperatures, pests and diseases, poor post-harvest handling practices, poor extension services, land tenure, poor infrastructure, unfavorable trans-boundary trade practices and labor scarcity (Emong'or *et al.*, 2009; Onyango 2014).

Agronomic practices like transplanting, plant spacing and good water management are skills that when put into practice by farmers can greatly increase rice yields within the same area of production. Baloch *et al.*, (2002) found that transplanting method recorded the highest average yields compared to direct seeding. Proper spacing can increase yields by 25-40% over improper spacing and helps save on inputs, labor and materials (IRRI, 2008). Rice requires abundant water environment but water is becoming increasingly scarce. Growing rice accounts for one-quarter to one-third of the global fresh water withdrawals (Bouman *et al.*, 2007). Agriculture's share of water will decline at even faster rate because of increasing competition for available water from urban and industrial sectors (Toung and Bhuryan, 1994). The future of rice production entirely depends on developing and adopting strategies and practices that will use water efficient methods (Toung *et al.*, 2007). Farmers need to come up with ways to the save on amount of water used; capitalizing on new varieties that use less water, reducing water use during land preparation, reducing percolation and seepage during crop growth period, water distribution strategies, water recycling and conjunctive use of ground water (Bouman *et al.*, 2005). These water saving methods when incorporated with proper spacing can greatly improve rice production (Bouman *et al.*, 2000). The objective of the study was supposed to determine the plant spacing and water management practices used by farmers in Mwea Irrigation Scheme.

Materials and methods

Study site

The survey was carried out in Mwea Irrigation Scheme, Kirinyaga district. Mwea Irrigation Scheme is one of the seven public schemes under the management of the National Irrigation Board. The scheme lies in the agro-ecological zone 3 and has a gazzeted area of 30,350 acres, 16,000 acres of which have been developed for paddy production.

It is designated into seven sections (Karaba, Thiba, Wamumu, Mwea, Tebere and Juakali) and has a total of 77 units and about 5,000 farmer households. Each farmer holds about 2.8 acres, according to a survey done by Rice Mapp in 2012. Initially each farmer used to hold about 4 acres but land size per household has declined due to an increase in population. Each farmer produces 2500-3000kg per acre (JICA, 2012).

The Scheme is served by Nyamindi and Thiba rivers which have fixed intake weirs. A link canal joins the two rivers which transfers water from Nyamindi to Thiba River which serves about 80% of the Scheme (Mburu *et al.,* 2011). Soils in the area are black cotton soils (vertisols) that shrink and swell with changes in moisture content.

Sampling design

Two hundred farmers' were interviewed in five different sections of Mwea Irrigation Scheme namely: Karaba, Wamumu, Thiba, Tebere and Mwea in 2016 using a stratified random sampling approach.

In each section, 40 randomly selected farmers were interviewed using a semi structured questionnaire which had been pre-tested by 20 farmers (Appendix 1). The survey was done under guidance of agricultural extension officers of the National Irrigation Board in Mwea.

Data collection

Information from both males and females was collected on: method of transplanting, age of seedlings at transplanting, number of seedlings per hole, depth of transplanting, number of years farmers had been in rice production, sizes of land owned by farmers, whether soil testing was done in the fields, net grain yield attained in the field, frequency of irrigation, stages at which irrigation was done, knowledge on when to irrigate the rice fields, depth of irrigation, whether farmers drained the fields, plant spacing used in the fields, the reasons for the choice of the plant spacing and challenges in rice production.

Data analysis

Descriptive analyses using frequencies and means were performed using Statistical Package for the Social Sciences (SPSS) program version 20.

Results

Transplanting practices in the Mwea Irrigation Scheme

All interviewed farmers reported that they transplanted their seedlings from the nursery to the fields and none practiced direct seeding (Table 3.1). Majority of farmers (90.5%) in all units transplanted one month old or older seedlings.

Less than 9 and 1% of farmers used three and two weeks old seedlings, respectively. At Thiba, all farmers planted one month old seedlings. Only Karaba and Tebere had farmers (2-2.6%) who grew two-week old and younger seedlings.

The number of seedlings planted per hole varied across the Scheme (Table 1). Majority of the farmers planted two seedlings per hole (61.1%) and some used more than two seedlings per hole (30.5%). Few farmers (7.9%) from the survey planted one seedling per hole. Tebere had the highest number of people planting two seedlings per hole (73.7%).

Depth of transplanting used varied in all units (Table 3.1). Majority of farmers used 2 cm depth (72.1%) with a few using 1 cm (21.3 %). Tebere had the highest number of farmers (78.9%) that used 2 cm as the depth of transplanting.

Table 1. Transplanting practices by farmers in the Mwea Irrigation Scheme (% respondents).

N= 200	Sections in Mwea Irrigation scheme					
	Karaba	Mwea	Thiba	Wamumu	Tebere	Mean
Method of transplanting						
Direct seeding	0.0	0.0	0.0	0.0	0.0	0.0
Transplanting	100.0	100.0	100.0	100.0	100.0	100.0
Age of transplanted seedling						
≤2weeks	2.0	0.0	0.0	0.0	2.6	0.9
3 weeks	6.1	10.8	0.0	12.8	13.2	8.6
≥1 month	91.8	89.2	100.0	87.2	84.2	90.5
Number of seedlings/hole						
1 seedling	8.2	8.1	5.0	5.1	13.2	7.9
2 seedlings	53.1	64.9	52.5	61.5	73.7	61.1
>2 seedlings	38.8	27.0	40.0	33.3	13.2	30.5
Depth of transplanting						
1 cm	20.4	24.3	17.5	25.6	18.4	21.3
2 cm	69.4	73.0	75.0	64.1	78.9	72.1
>2 cm	10.2	2.7	7.5	7.7	2.6	6.1

Farmers experience in rice production, land size under rice and rice yields in Mwea Irrigation Scheme.

Farmers' experience in rice farming varied across units (Table 3.2). Majority of the farmers' reported to have been producing rice for 6-20 years (39.3%) followed by those who had been producing rice for more than 20 years (32.8%). Farmers who had less than 5 years' experience in rice production were the minority. Karaba had the most experienced rice farmers with about 80% farmers being in rice production for over 6 years. Thiba had the highest percentage of farmers with five years or less experience in rice production. Most of the respondents in the Scheme (60%) owned 1-2 acres of land (Table 2). only 1% of the farmers reported to own more than five acres across the five units in

Mwea Irrigation Scheme. None of the farmers in Karaba and Tebere had more than 5 acres of land. Karaba and Thiba had higher proportion of farmers with less than 1 acre of land than Wamumu and Mwea. Across the units, majority of the farmers (52.3%) produced rice yield of 2001-5000 kg/acre (Table 2). Few farmers (7%) produced less than 1000 kg of rice/acre while about 21% produced more than 5000kg of rice/acre.

Wamumu had the highest number of farmers (60.5%) that produced rice yields of 2001-5000kg/acre. Majority of farmers indicated that their soils were not tested before any planting season. In Thiba and Tebere, 100% farmers had not had their soils tested for soil chemical characteristics. Wamumu had the highest number of interviewed farmers (5.3%) that reported their soils to have been tested.

Table 2. Number of years in production, land size owned, soil testing, and rice yield (%respondents).

N=200	Sections in Mwea Irrigation scheme					
	Karaba	Mwea	Thiba	Wamumu	Tebere	Mean
Years of production						
≤5 years	20.4	27.0	40.0	28.2	23.7	27.9
6-20 years	53.1	45.9	25.0	35.9	36.8	39.3
≥20 years	26.5	27.0	35.0	35.9	39.5	32.8
Land size						
< 1 acre	21.1	8.2	25.6	7.9	27.5	18.1
1-2 acres	57.8	69.4	61.6	68.4	45.0	60.4
2.1- 5 acres	18.5	22.4	12.8	21.1	27.5	20.5
> 5 acres	2.6	0.0	0.0	2.6	0.0	1.0
Soil testing						
Yes	2	2.6	0	5.3	0	1.98
No	98	97.4	100	94.7	100	98.02
Yield (kg/acre)						
≤1000	10.5	4.1	15.4	2.6	2.5	7.0
1000-2000	23.7	18.3	25.6	13.2	20.0	20.2
2001-5000	42.1	55.2	51.3	60.5	52.5	52.3
≥5000	23.7	22.4	7.7	23.7	25.0	20.5

Irrigation practices in the Mwea Irrigation Scheme

Majority of the farmers (59 to 82%) in the sampled sections irrigated their fields once a week (Table 3). Some 21% of the farmers reported that they did not have specific frequencies of irrigation due to inconsistency in water distribution, poor drainage system in the scheme, and general water scarcity faced in the country. The highest proportion of farmers' that carried out irrigation once a week across the five sections was in Wamumu area. Karaba registered the highest proportion of farmers who irrigated their rice crops once in two weeks and once a month. Mwea, Thiba, Wamumu and Tebere did not have farmers who irrigated once a month.

An average of 71% of the farmers interviewed in the Scheme reported that they irrigated their rice fields up to two weeks before harvesting, whereas 29.3% of them irrigated their fields during the entire growing season (Table 3). In Karaba, 35% of the farmers irrigated the rice crop during the entire growing season. Mwea and Thiba had the most number of farmers that irrigated rice up to two weeks before harvesting.

Farmers in the scheme the used irrigation field water level and crop appearance to determine when to irrigate their rice fields (Table 3). Majority of them (60.7%) used the irrigation field water level to determine the right time to irrigate while 21% reported that they looked at the crop physical appearance. Wamumu had the highest proportion of farmers (84.6%), followed by Karaba (77.6%) that irrigated their rice fields depending on the field water level.

The depth of irrigation varied across the sections (Table 3). Majority of the respondents in Tebere, Wamumu and Thiba irrigated to a depth of less than 10 cm while majority of respondents in Karaba and Mwea irrigated to more than 10 cm.

On average, drainage of fields was done by 97.5% of the farmers' interviewed. In Thiba, all farmers reported that they drained their fields two weeks before harvesting when crops had matured. Tebere had the highest number of farmers (5.3%) that did not drain their fields during the whole crop growing period.

Table 3. Frequency of irrigation, irrigation crop stages, indicators of when to irrigate, depth of irrigation and drainage of paddy fields (% respondents).

N=200	Sections in Mwea Irrigation scheme					
	Karaba	Mwea	Thiba	Wamumu	Tebere	Mean
Irrigation Frequency						
Once a week	59.2	64.9	67.5	82.1	76.3	70.0
Once in two weeks	18.4	0.0	7.5	7.7	7.9	8.3
Once a month	4.1	0.0	0.0	0.0	0.0	0.8
Others (unspecified)	18.4	35.1	25.0	10.3	15.8	20.9
Irrigation stages						
The entire growing season	34.7	24.3	25.0	33.3	28.9	29.3
Up to two weeks before harvesting	65.3	75.7	75.0	66.7	71.1	70.7
Indicators of need to irrigate						
Irrigation field water level	77.6	67.6	0.0	84.6	73.7	60.7
Crop physical appearance	16.3	29.7	20.0	12.8	26.3	21.0
Others (unspecified)	6.1	2.7	80	2.6	0.0	18.3
Irrigation depth						
≤10 cm	49.0	48.6	55.0	61.5	76.3	58.1
>10 cm	51.0	51.4	45.0	38.5	23.7	41.9
Draining						
No	2.0	2.7	0.0	2.6	5.3	2.5
Yes	98.0	97.3	100.0	97.4	94.7	97.5

Where unspecified refers to irregular irrigation.

Plant spacing used and reason for choice of plant spacing in Mwea Irrigation Scheme

Plant spacing for rice varied across the units in the Scheme (Table 4). The most commonly used plant spacing arrangements by the farmers across the sites were 30×15cm (27.5%), 20×20cm (26.6%) and 1515cm (23.9%). A sizable proportion (15%) of the farmers also reported to have been using 20cm by 15cm. Very few farmers (1%) used 25cm by 15cm. About 6% of the farmers reported that they didn't have a specific spacing but only estimated manually when planting their crop.

Most of the farmers in all the units chose the respective plant spacing to increase their yields (53%) and to increase the number of tillers (26%). A small proportion (10%) did it to ease the crop management while less than 1% of the farmers chose plant spacing to either control weeds or based on their neighbors' practices.

Table 4. Plant spacing and the reasons for the choice of spacing adopted by farmers in the Mwea Irrigation Scheme (% respondents).

N=200	Sections in Mwea					
	Karaba	Thiba	Mwea	Wamumu	Tebere	Mean
Plant spacing						
15*15cm	27.5	31.0	20.0	24.2	16.7	23.9
20*15cm	17.5	20.7	2.9	12.1	22.2	15.1
20*20cm	27.5	10.3	37.1	27.3	30.6	26.6
25*15cm	2.5	0.0	0.0	0.0	2.8	1.1
30*15cm	20.0	31.0	34.3	24.2	27.8	27.5
Others (unspecified)	5.0	6.9	5.7	12.1	0.0	5.9
Choice of spacing						
To increase yields	40.8	48.6	52.5	59.0	65.8	53.3
Ease of crop management	4.1	24.3	7.5	5.1	10.5	10.3
Control weeds	0.0	2.7	0.0	0.0	0.0	0.5
Increase no. of tillers	34.7	18.9	30.0	23.1	23.7	26.1
Neighbors' practice	0.0	2.7	0.0	0.0	0.0	0.5

Challenges in rice production in Mwea Irrigation Scheme

The leading challenge for the interviewed farmers was lack of adequate water for irrigation (63%). Farmers also noted high input prices (37%), low market prices for their produce (26%), pests and diseases (25%), poor infrastructure (21%), weed infestation (13%) and attack by birds as major constraints. Farmers in Wamumu and Mwea were most affected by shortage of water, 74 and 71 % respondents, respectively, while farmers in Karaba were the least affected by the shortage of water (49%).

Most complaints of pests and diseases were reported by farmers in Tebere, Mwea and Thiba. Respondents in Karaba did not consider pests and diseases as a major challenge. Poor infrastructure was mostly reported in Wamumu (34%) and Karaba (33%).

Table 5. Challenges faced by the farmers in rice production in Mwea Irrigation Scheme (% respondents).

N=200	Sections in Mwea Irrigation scheme					
	Karaba	Thiba	Mwea	Wamumu	Tebere	Mean
Lack of enough water for irrigation	49.0	52.5	71.1	73.7	69.2	63.1
High input prices	40.8	32.5	44.7	28.9	35.9	36.6
Low market prices for produce	18.4	27.5	26.3	34.2	25.6	26.4
Pests and diseases	0.0	35.0	36.8	13.2	38.5	24.7
Poor infrastructure	32.7	12.5	10.5	34.2	12.8	20.5
Weeds	20.4	10.0	5.3	7.9	20.5	12.8
Labor expenses	12.2	7.5	21.1	10.5	2.5	10.8
Birds' infestation	4.1	7.5	2.6	7.9	0.0	4.4

Discussion

All the farmers in the Mwea Irrigation Scheme transplanted rice seedlings rather than direct seeded. Transplanting is a popular method of establishing rice in irrigated areas due to perceived higher grain than direct seeding (Allkas *et al.*, 2006). Ehsanullah *et al.*, (2000) also found that transplanting significantly gave higher paddy yield than direct seeding. This agrees with IRRI (2008) that transplanting enables optimal spacing which leads to an increase in number of tillers per plant and net grain yield over poor spacing caused by direct seeding. According to Baloch *et al.*, (2002) the transplanting method recorded the highest average yield because the wider distance between plants allowed air circulation, water and light which are basic for photosynthetic activity.

However, transplanted rice takes a longer time to start tillering because it needs time to recover from the shock of transplanting unlike direct seeded rice. Farooq *et al.*, (2011) pointed out that yield in direct seeding system of rice production is often lower than the transplanting system of rice production. Transplanting is preferred by most farmers because it gives uniform stands in the rice fields unlike direct sowing (Faisul-ur-Rasoo *et al.*, 2012). However, transplanting is time consuming because of the need to establish a seedling nursery before planting seedling in the field (Faisul-ur-Rasoo *et al.*, 2012). This implies that the farming practices employed by these farmers are yield-driven and may suggest that a lack of proper resources to carry out farming may be at play. The preference for transplanting may also be attributed to the fact that yields in direct seeded rice is often lower than transplanted rice (Farooq *et al.*, 2011).

Most of the farmers transplanted one month old seedlings. Seedling age at transplanting is an important factor for the establishment of a uniform stands of rice and regulation of its growth and yield (Bassi *et al.*, 1994).

Mobasser *et al.*, (2007) observed that when seedlings stay for long in the nursery beds, primary tiller buds on the lower nodes of the main culm become degenerated leading to reduced tiller production. In recent studies of Makarim *et al.*, (2002), 14-day old seedlings performed better than 21-23 day old seedlings. Krishna *et al* ., (2009) also observed higher grain yields with 12 day old seedlings than 8-16 and 25 day old seedlings and the yield decline was attributed to reduction in number of tillers per plant. One month old seedlings may be strong enough to survive the first few days of transplanting but could have over stayed in the nursery hence reduced the effectiveness of tillers. This implied that farmers want to ensure survival of the seedlings.

Most farmers transplanted two seedlings per hole. This concurs with some studies that have shown that transplanting two seedlings per hill increased grain yield relative to transplanting one seedling per hill (Faruk *et al.* 2009). Sanico *et al.* (2002) also reported that increasing the seedling number per hill decreased or increased grain yield depending on the season and seedling age. This, however, differs with study a by Mishra *et al.*, (2006) who reported that one seedling per hill increases root length, density and activity and their independence with above-ground canopy development resulting to prolonged photosynthetic activity. San-oh *et al.*, (2006) also reported that planting a single seedling per hill had higher yield than two or more seedlings per hill. Horie *et al.*, (2005) studied that a single seedling per hill reduces competition and minimizes the shading effect of lower leaves thus helping the leaves remain photosynthetically active for much longer. A high number of seedlings per hill can cause competition between the plants which sometimes results in gradual shading and lodging thus increasing production of straw instead of grain. It is therefore important to determine the optimum seedling number per hill for high yield (Hossain *et al.*, 2003). Too many seedlings per hole could also be un-economical for farmers because that requires them to set up large nurseries that translate to buying more seed. Besides, transplanting one seedling per hole may be considered risky by farmers because the seedling could fail to survive after transplanting. Farmers' mostly transplanted seedlings at a depth of 2 cm. This concurs with IRRI knowledge bank (2010) where farmers are advised to plant seedlings to the depth of 1.5-3cm.

Most interviewed farmers owned 1-2 acres of land. The land size has reduced from the original NIB allocation of 4 acres per person (JICA, 2012). A survey done by Rice Mapp 2012 showed that each farmer holds 2.8 acres of land. The current observation is attributed to the increasing population leading to sub-division of land among family members. Interviewed farmers have been cultivating paddy rice for 6-20 years. The Scheme having been established in 1956, it is possible to have farmers that have been in rice production for this long. Most interviewed farmers had a production of 2001 to 5000kg/acre. This concurs with a study by JICA (2012) that each farmer in Mwea Irrigation Scheme produces 2500 to 5000kg/ha.

Most farmers irrigated their rice fields once a week. Under continuously flooded conditions, rice receives two to three times more water than other irrigated cereals (Bouman *et al.*, 2007). Most farmers determined the proper time of irrigation depending on field water level to a depth of ≤10 cm. All farmers in Mwea drained their rice fields two weeks before harvesting to promote grain filling and ripening and also allow drying of soil for easier movement during harvesting. This concurs with Bouman *et al.*, (2007) who reported that after crop establishment, the soil is kept ponded with 5-10cm layer of water until 1-2 weeks before harvesting.

The major plant spacing arrangements used by farmers in Mwea were 30×15 cm and 20×20 cm for all varieties because the farmers interviewed claimed that these increased grain yields. This concurs with Baloch *et al.*, (2002) who reported that the plant density of spacing 20 × 20 cm was more effective than 20×15cm and gave significantly higher grain yield. However, a bigger spacing promotes more tillers per plant which is directly proportional to yield. Studies have demonstrated that plant spacing influences plant physiological activities via intra-specific competition (Oad *et al.*, 2001). Farmers chose their kind of plant spacing due to various reasons: increase in yields, ease of crop management, control of weeds and increase in number of tillers per plant and due to neighbors' practices. Studies have shown that people could choose optimum spacing to ensure that plants grow in both aerial and underground parts through efficient utilization of solar radiation nutrients (Mohadessi *et al.*, 2011). Use of inappropriate plant spacing can result in net grain yield reduction of 20-30% (IRRI, 1997).

The three leading challenges facing farmers in the units were inadequate water, high input prices and low market prices. These challenges have continuously affected the economic status of farmers because they contribute to low yields which after harvesting are sold at poor prices. Mustapha Ceesay and Norman Uphoff, (2006) reported that high yields were significantly increased by water saving methods like intermittent flooding.

Almost all farmers did not do soil tests in their farms before planting. Yield depends not only on genetic characteristics but also on agronomic practices including nutrient management (Zou *et al.*, 2003). A soil test is important before planting because it enables farmers to know what nutrients are deficient in their farms and by what amounts hence only providing enough to avoid excess or under application.

Conclusions

This survey has shown that transplanting of one-month old seedlings at a plant spacing of 30×15cm irrespective of the rice variety was preferred by almost all the farmers interviewed. Majority of the farmers in the Scheme irrigated the fields once a week to a depth of ≤10cm and drained fields two weeks before harvesting.

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