UPLAND RICE VARIETIES DEVELOPMENT THROUGH PARTICIPATORY PLANT BREEDING

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ABSTRACT

Farmers' participation during variety development and selection can promote adoption of the released cultivars. Open Semi Structured Household Level Questionnaires (OSSHLQ) were administered to randomly selected sixty seven households in the major rice production areas in Kenya, to obtain information on varietal preferences and production constraints. To supplement on this survey information, focus group discussions and key informants were incorporated. To ensure farmers desired traits were firmly anchored in the breeding programme, an on station research managed parent selection trial was established where farmers were involved in assisting the selection of lines to be used as parents based on their own selection criteria. The farmers preferences were high yielding and good grain quality, hybrid rice and high nutrient use efficient varieties. These four traits accounted for about 54% of their wishes. Rice was the most important crop among the selected farmers followed by maize, but the hectarage of maize was the highest followed by rice; probably this was because of larger spacing for maize. Labour cost was identified as a factor limiting production, especially for irrigated rice and thus they preferred upland rice which is easy to produce. They identified land preparation, inputs, planting, weeding and harvesting as the most expensive activities. The majority of the respondents (66%) grew irrigated rice, while 25% grew upland rice. This disparity was attributed to the fact that upland rice was new, the varieties having been officially released in 2009. This is in contrast to the irrigated varieties that they have been growing since 1951 when the irrigation scheme was established as a pilot scheme. However, the majority of the farmers expressed their desire to grow upland rice but lack of seeds, appropriate varieties and production knowledge was a major setback. The existing varieties were viewed as high input based and farmers could not afford the inputs. The main fertilizers used were Diammonium Phosphate (DAP), Sulphate of Ammonia (SA), Calcium Ammonium Nitrate (CAN) and NPK (23:23:0), though the amounts used were very low and contributed little to any consequential yields. This was the case even though the farmers were aware and indicated that soil fertility was poor due to continuous cropping under irrigation. Fourteen varieties were selected by farmers including Nerica1, Duorado, IR79913-B-176-B-4, CT16333(1)-CA-20-M, CT16333(1)-CA-22-M, CT16333(2)-CA-18-M, CT16313-CA-19-M, WAB964-B-3A 1.2, CT16317-CA-4-M, CT16307-CA-14-M, CT16337-CA-12-M, CT16345-CA-3-M, WAB 905-B-4A 1.1 and WAB 450-B-136-HB - NERICA9; but only nine of them were successfully used due to hybridization incompatibility.

Keyword: rice varieties, participatory plant breeding, farmers, preferences, Kenya.

1. INTRODUCTION

Involvement of farmers in variety development has been viewed by many authors as very important if the variety is to gain wide acceptability (Atlin *et al*., 2006; Joshi and Witcombe, 1995; Poussin *et al*., 2006; Sperling *et al*., 1993; Witcombe and Joshi, 2003). In rice production, farmers' preferences are varied and range from plant type, ability to perform under their growing environments, panicle size and shape, plant height, grain characteristics with regard to taste, grain shape and cooking qualities, their digestibility and maturity period. Other issues of interest to farmers included availability of market and credit facilities, yielding ability under different soil fertility conditions, availability of clean seeds, easiness of threshing, percent head rice yield, availability of labour, cost of production inputs, mechanization, top biomass, utilization of rice products, and resistance to insect pests and diseases (Rosemary *et al*., 2010; Witcombe, 2000). The information on farmers' participation in rice variety development in Kenya is scanty and even "grey" literature is not available on this. There has been limited rice breeding work until very recently (2007), and the practice has been the evaluation of accessions from International Rice Research Institute (IRRI), International Institute of Tropical Agriculture (IITA) and recently Africa Rice Centre (AfricaRice) for upland rice. Farmers were involved during on-farm verification trials and later, the recommended or promising varieties were supplied to them for commercialization by the National Irrigation Board (MoA, 2009; NIB, 2008). Farmers adopted some of these varieties for production, while others became obsolete. The participation of farmers at the beginning of varieties development such that farmers' preferences are incorporated in the breeding programme is very vital (Nanda, 2001; Poussin *et al*., 2006; World Bank Group, 2007). It has been found that, participatory plant breeding (PPB) that involves farmers in selecting genotypes for use as parents or from segregating populations is very effective for wide adoption of varieties as opposed to participatory rural appraisal (PRA), and participatory variety selection (PVS) that provides merely polished breeding products to farmers for evaluation in their farms (Atlin *et al.*, 2006; Witcombe, 2000; Witcombe *et al.*, 2003).

Rice is an important staple crop in Kenya, ranking 3rd after maize and wheat and most of its production is by small-scale farmers as a food and a commercial crop. Its production has stagnated at around 45-80,000 metric tons (MT), while consumption is above 300,000 MT (Jiddah, 2009; MoA, 2009; Muchiri, 2009). This stagnation can partly be explained by the following factors: lack of newly released irrigated varieties tolerant to diseases, insect pests, low soil fertility and low yield under existing production environments. However, there is ample opportunity to unlock this stagnation by exploiting the enormous potential of rainfed rice that exists. The current production is in favour of irrigated rice (95%) , while rainfed agriculture contributes a paltry 5% despite its huge potential. Kenya has a land area of 580,367 km^2 of which only 20% is suitable for agriculture, the rest being arid and semi-arid land. The potential production area for irrigated rice is about 540,000 hectares (ha), while rainfed potential area is 1.0 million ha (MoA, 2009; Rosemary *et al*., 2010). This rainfed production ecology needs to be explored as it can offer immense potential of meeting the gap between production and consumption. This gap currently is being met by imports that cost the country about USD 87.5 million, thus straining other sectors of the economy (MoA, 2009). The productivity of irrigated rice is about 4-6 tons (t) ha^{-1}, while that of rainfed production is about 1 ton ha^{-1}. This is far below the optimum of about 10 t ha^{-1} and 7 t ha^{-1} for irrigated and rainfed rice, respectively (MoA, 2009). This can generally be attributed to; lack of newly improved and adapted varieties, certified seeds, high input costs, climate change, low soil fertility, insect pests and diseases, poor agronomic practices, lack of mechanization, limited water availability and lack of credit facilities. To reverse this condition, there is need to actively involve farmers' at various stages of variety development in order to meet the end-users' desirable traits and qualities, thus enhancing wide variety adoption that will result into higher productivity.

Upland rice genotypes were introduced in Kenya in the 1980s in the western part of the country where on station evaluations were conducted. However, the information on their progress is scarce and it was not until 2003 when New Rice for Africa (NERICA) upland testing kits were introduced from AfricaRice by the Kenya Agricultural Research Institute (KARI) and other regional bodies (Jiddah, 2009). These helped the revival of upland rice production again. The kits comprised of 18 genotypes and were tested mainly in Nyanza, Western, Rift Valley, Central and Coast regions. In 2009, four varieties; NERICA1, NERICA4, NERICA10, NERICA11 and a local variety *Dourado precoce* were released for commercialization. These varieties are being increased through seed certification for the farmers in the country. These varieties are being slowly adopted and produced by both farmers under the NIB and out growers (jua kali) who have taken up the advantage of rice sector liberalization to produce rice outside the scheme. Due to shortage of irrigation water many farmers are opting for rainfed rice production as its less labourious and less expensive to produce. Also knowledge of its agronomic production practices is slowing diffusing out through various avenues both public and private, such as from national research system (KARI), NIB, extension services (Rice Promotion Unit, MoA), JICA, farmer to farmer, collaborators and other stakeholders in the sector. This is a clear indication that despite the enormous potential these varieties have for meeting food self-sufficiency, they are yet to be produced in large quantities by the farmers. Farmers have been producing *Dourado precoce* mainly in western part of the country, while coastal region have been growing lowland varieties of which some have been lost. Farmers in central part of the country have been growing irrigated rice, mainly aromatic Basmati370, Basmati217 and non-aromatic BW196 (MoA, 2009; Rosemary *et al*., 2010). These varieties are poorly adapted to low soil fertility, and famers have less choice on the varieties to grow.

The introduction of NERICA and other rainfed varieties offer immense potential for promoting upland rice production through farmers' early participation in variety development, and therefore, develop products with traits they prefer. These varieties have an advantage over irrigated rice, because it is possible to intercrop with other crops such as beans, bananas, coffee, maize and many others, thus less competition on available land. However, without farmers broader active participation and training in the whole rice value chain the intended impact may not be realized. No systematic documentation of farmers' preferences, production constraints and participation in breeding to incorporate their traits of interest in new varieties has been carried out before. The current varieties in production are low yielding, old and un-adapted to conditions of low soil fertility in which they are produced. They have low grain quality, are susceptible to insect pests and diseases, information on upland rice production preferences and constraints is lacking; despite the enormous potential that exists; and rice imports to meet consumption needs are thus huge. It is with this in mind and the fact that rainfed rice production is hardly exploited despite the colossal potential that exists of producing enough and even surplus for export market, that this work was conceived. Already the policy makers have realised the enormous potential of the rice sector and a comprehensive national rice development strategy (NRDS) master plan, under the coalition of Africa rice development (CARD) in line with comprehensive Africa agriculture development (CAADP), has been developed for implementation (MoA, 2009). This research was to establish the researchable areas for improved rice productivity and thus enhanced household incomes, food and nutritional security.

1.1 Study objective

The broad objective was to document farmers problems, preferences, social-economic data, and involve them in participatory plant breeding (PPB) for parental genotypes selection for the establishment of a breeding programme.

The specific objectives were to:

a) identify farmers upland rice preferences, production constraints, and gather other socio-economic information, and
b) indentify the best lines from the germplasm accessions together with farmers for use as parents in hybridization block.

2. MATERIALS AND METHODS

The study was conducted in the central region of Kenya that produces 80% of the national rice production (MoA, 2009). With the help of the Ministry of Agriculture (MoA) extension staff, four locations were selected based on their potential of producing upland rice. Out of these, six villages within the locations were selected based on their potential to grow upland rice, and farmers' from each village were randomly selected from the list of farmers' kept by the agricultural office, to which 67 Open Semi Structured Household Level Questionnaires (OSSHLQ) were administered. These were meant to capture and collate the perceptions on production constraints and preferred genotype traits. One important factor that was also considered was the ability for the willing members in these villages to visit the research trials for parents' selection that were to be used in the crossing block. The farmers from far off places were reimbursed their bus fare ticket as a way of defraying their cost and as a way of encouraging them to participate and aid in parental genotype selection from the adaptation trial.

Further, because some of the farmers had not grown upland rice before, although many of them had heard about dry land rice; they did not understand how the new upland varieties were to be produced. They had however, been searching for information from fellow farmers, research station and NIB, and during the survey they requested that they be trained on its production. A Participatory Plant Breeding (PPB) approach was therefore, adopted to aid in selection of parents for the crossing block. The twin purpose of this approach was to demystify and expose farmers to practical upland rice production and ensure parents selected for the crossing block had farmers' traits of preferences. This essentially meant that a hybrid participatory system had to be devised to benefit from Participatory Rural Appraisal (PRA), Participatory Variety Selection (PVS) and PPB.

The breeding programme being new and that only one cultivar was being used, materials had to be assembled from diverse origins, (314 lines from CIAT-Columbia, 75 lines from AfricaRice, 31 lines from the International Rice Research Institute (IRRI) and 30 lines from Mali rice breeding program. This gave a total of 450 advanced genotype lines. To put the new breeding programme from the beginning on the right footing, and being aware that farmers were not fully conversant with upland rice production; though some knew of its existence and production, farmers' participation therefore, started from the adaptation trial of these materials on Kenyan conditions. Three casual workers and extension staff were requested to search for about 15 potential farmers to participate in the planting of the trial and thereafter be involved in further evaluations.

2.1 Trial layout

The materials were planted under four environments; no phosphorus (P) and nitrogen (N) application (N-P-), P application only (N-P+), N application only (N+P-) and finally both P and N applied (N+P+) blocks on 27th-30th November, 2007. The fertilizer used to supply these elements was Triple super phosphate (TSP) 60 kg P ha^{-1} and Calcium ammonium nitrate (CAN) 90 kg N ha^{-1}. Because of limited seeds, the plots were single rows of 4 metre length at hill spacing of 15 cm intra- and inter-plant and replicated twice for each fertility experimental environment. Farmers and their colleagues were encouraged to freely visit the station for observation and learning of the agronomic practices being undertaken up to crop maturity. Their visits were recorded on a register kept by the two casuals who were manning the trials and details of dates visited and their comments or observations were recorded, plus any other issue they may have raised or observed.

At about 80% crop maturity, the original fifteen farmers plus ten others were invited to the trial for selection of the lines they preferred based on their own set criteria. The major aspects that they used were, panicle general appearance, grains type, stature, maturity period, plant general aspect and yielding potential. This also helped the breeder to discard those materials that were extremely medium-late and late genotypes. Out of the 390 advanced breeding lines in the field trial (61 lines arrived late from IRRI and Mali and were evaluated separately in the screen house, where IR79913-B-176-B-4 was selected as a parent), they selected forty five, a selection pressure of 11.5%. Farmers observed and discussed various lines that met their preferences, where they tagged five best plants in a row being evaluated by using brightly colored netting strings. These were harvested as bulk for further research work. Since these lines were still too many (and seed had been increased) for the PPB programme to be used as parents; these lines were immediately planted out again in a smaller area as an offseason trial where sprinkler irrigation was used to supplement rainfall. After 45 days the same lines were planted in the crossing block as potted plants and thereafter at every 24 days to end up with three sets in the hybridization block. This was to synchronize the flowering and thus ensure complete success of the complete diallel mating design. When the PPB farmers' materials approached 85% maturity, a group of twenty farmers who were to train other farmers, further selected the final 14 lines from the 45 as indicated in Table-1, this time a selection pressure of 31% was applied. The PI discarded the 31 lines the farmers selected against and the remaining 14 genotypes were maintained as parents in the hybridization programme in the crossing block.

2.2 Data collection and analysis

The formulated Open Structured Household Level Questionnaires (OSHLQ) were pre-tested before actual administration by a team made up of the principal investigator (PI), two enumerators and the extension staff in charge of the village. Data on farmers' preferences in varieties, production constraints, hectarage, fertilizer use, perceived solutions, crops grown, and other socio-economic data was collected. The data collected was analyzed using Statistical Package for the Social Sciences (SPSS) version 15 computer package. Focus group discussions and key informants were used to supplement the data collected by questionnaire method and also to gain more insight of farmers' perceptions and desires. The farmers' preferences, production constraints and possible solutions were listed and ranked. None structured general information was gathered from the PPB farmers by jotting down salient issues raised or observed during the discussions, field trial visits and evaluations. The parents with preferred traits were selected by the PPB participants and were used in the crossing block to develop new segregating populations.

3. RESULTS

3.1 Parents selected and preferred traits

The fourteen parents selected by farmers and their characteristics and needs for improvements are indicated in Table-1. The materials selected were from CIAT, Africa Rice Centre and IRRI (the IRRI lines were evaluated under screen house as they arrived late and farmers selected IR79913-B-176-B-4 line). The main selection criteria were nutrient use efficiency, earliness, grain quality and insect pests and disease resistance among others. They also selected the cultivar they grow as a parent due to its grain quality.

Table-1. Rice lines and their traits that were selected by farmers as parents for the hybridization block at KARI-Mwea.

Diallel No.	Final selected line	Line	Source of lines	Traits	Improvement required
1	36	NERICA 1	WARDA	High grain quality, early, blast resistant	Yield, height, early
2	35	Duorado	Cultivar	Local cultivar, high grain quality	Yield, high quality, height, low fertility tolerance
3	34	IR79913-B-176-B-4	IRRI	Early, low soil N and P Tolerant	yield, good panicle aspect
4	25	CT16333(1)-CA-20-M	CIAT-Columbia	Medium maturity, high yielding	Low soil N and P tolerance
5	22	CT16333(1)-CA-22-M	CIAT-Columbia	Tall, Low soil N and P tolerant, good panicles	Yield, earliness
6	13	CT16333(2)-CA-18-M	CIAT-Columbia	Low soil P tolerant, narrow long grains	Yield, tallness
7	9	CT16313-CA-19-M	CIAT-Columbia	Early, blast tolerant, good plant aspect	Yield, threshability
8	11	WAB964-B-3A 1.2	WARDA	Early, high yielding, good plant aspect	Low soil N and P tolerance
9	20	CT16317-CA-4-M	CIAT-Columbia	Low soil N tolerant, high tillering, tall	Yield, grain shape
10	2	CT16307-CA-14-M	CIAT-Columbia	Narrow slender long grains, tall	Yield, low soil N and P tolerance
11	3	CT16337-CA-12-M	CIAT-Columbia	Long panicles, medium maturity, tall	Yield, low soil N and P tolerance
12	6	CT16345-CA-3-M	CIAT-Columbia	High tillering, early, low N and P tolerance	Yield, pest and disease resistance
13	7	WAB 905-B-4A 1.1	WARDA	Tall, Low soil N and P tolerant, good plant aspect	Yield, pest and disease resistance
14	21	WAB 450-B-136-HB - Nerica9	WARDA	Early, medium yield, disease resistance	Tallness, low soil N and P tolerance

3.2 Participating farmers' distribution per village

Seventy three percent of the farmers engaged in OSHLQ were males. The number of participating farmers was as follows; Red soil 10, (14.9%); Kiorugari 15, (22.4%); Kirimara 21 (31.3%); Kathiriku 5(7.5); Mugumoini 7(10.4%) and Mathangauta 9, (13.4%). Kirimara village had the largest number. This village is far from the main irrigated rice farming region and probably when they got information about upland rice that can grow in their local aerobic conditions, they were highly interested and wanted to learn more thus the large number. In fact, during the PPB trial, they were always requesting for seeds to go and try in their farms. This indicates how eager the farmers were, such that they could not wait for new varieties to be developed.

3.3 Farmers preferred traits

The farmers disclosed a number of characteristics they wished to be improved. The top three preferences were high yield, hybrid (heterotic vigour), and input efficiency (Table-2). Some farmers felt that tall plants with long slender white grains and drought tolerant were important. More than half of the farmers (53.7%) considered yield and nutrient use-efficient varieties to be very important. Surprisingly, rice hybrids were preferred as they thought that these could yield more as it is the case with hybrid maize and tomatoes. They compared hybrid maize to open pollinated maize varieties (OPVs), and they were convinced that, although no hybrid rice is grown, it could be high yielding. Almost 15% of the farmers considered pests and disease tolerance as an important factor in varieties they would wish to grow.

Table-2. Traits that farmers wished to be improved in rice varieties they could prefer to grow.

Trait	No. of farmers	Percent
Hybrids rice	12	17.9
Pest and disease resistance	10	14.9
Drought tolerance	8	10.4
Varieties with less fertilizers use	11	16.4
High yielding and easy to thresh varieties	13	19.4
Varieties with better grain quality	7	11.9
Early maturing varieties	3	4.5
Taller varieties with weed suppression traits	3	4.4
Total	67	100.0

Some farmers felt that varieties combining pests and diseases resistance, early maturity, high yielding and easy to thresh to be important. Others indicated drought tolerant varieties as being important for areas without irrigation water. The upland NERICA 4 variety was viewed as being difficult to thresh and farmers have complained of this issue and probably this was one reason of desiring varieties with intermediate shattering for easy threshing. Weeds were also indentified as a problem, where farmers believed that some varieties have capacity to suppress the weeds, thus leading to few weeding rounds and thus savings on labour and herbicide costs. This was because of fewer sprayings of both pre- and post-emergent herbicides that can lead to adverse effects to the environmental health and sanitation, especially where aqua-culture is being practiced.

3.4 Crops grown by the farmers and hectarage per village

Farmers grew a variety of crops, among which rice was the most widely grown followed by maize. The majority of the farmers who grew the widest range of crops were those of Kirimara village (Table-3), they had maize followed by rice as the main crops grown in terms of hectarage.

At Red Soil location, the lowest crop diversity was observed with rice being second after Kiorugari village. The number of respondents growing rice were 44 (65.7%), those not growing 18 (26.9%), while 5 (7.5%) did not respond. Mathangauta and Kirimara villages had farmers who did not grow rice, possibly because they are rainfed areas away from the irrigated rice scheme and they did not have rainfed rice seeds. There were 65.7% of respondents growing irrigated rice, while 17 grew upland rice. The irrigated varieties grown were aromatic Basmati 370, Basmati 217 and other non-aromatic; BW 196, IR2793-80-1, ITA 310 and Sindano. The main variety grown was Basmati 370 (34%) followed by BW 196. The latter is mainly used for domestic consumption, while, the Basmati 370 is a cash crop thus the popular term 'white gold' due to its aromatic white grain colour, hence it fetches premium price in the market. The upland rice varieties grown were NERICA 10 (29%), NERICA 4 (3%) and NERICA 1 (1%). The low number of farmers growing NERICA 4 and NERICA 1 was that, NERICA 4 is hard to thresh, while NERICA 1 despite being aromatic had very low yields. It also emerged that these varieties require high inputs, which were not affordable by the respondents. Other reasons given were that seed was not available unlike for irrigated rice; production procedures for upland rice were not well known since they were new, and no advice or information of their production was available to the farmers. The reasons given for growing upland rice was that, it was less tasking to grow, requires less water, less spraying, availability of land was not a problem, it's easy to weed and move around, and it can be intercropped. The respondents who preferred growing irrigated rice was 14.9%, 38.8% preferred upland and 46.3% had a preference for both production ecologies.

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Table-3. Types of crops grown and area of production (hectares) for surveyed farmers.

Crop	**Village** (hectares)						**Total** (hectarage)
	Red soil	**Kiorugari**	**Kirimara**	**Kathiriku**	**Mugumoini**	**Mathangauta**	
Rice	20	33.00	9.80	0.00	9.50	9.00	81.30
Beans	10	10.50	7.20	1.30	2.00	5.30	36.20
Maize	5	10.50	10.50	2.50	10.25	16.5	55.30
Water melons				6.30			6.30
Kales			0.60				0.60
Irish potatoes			2.10				2.07
Sorghum			4.50				4.50
Cowpeas			4.50				4.50
Tomatoes				1.30	3.80		5.00
Bananas				1.30	2.00		3.30

3.5 Rice hectarage and number of participating farmers

The hectarage for rice production ranged from 0.00 to 4.00 hectares among villages, with majority of the farmers (25.4% of respondents) each owning 0.00 and 2.00 hectares. This was followed by 12 respondents (17.9%) who each produced rice on a 1.00 hectare. The Figure of 0.00 hectares indicates farmers who rent land for rice production because they are landless (Figure-1).

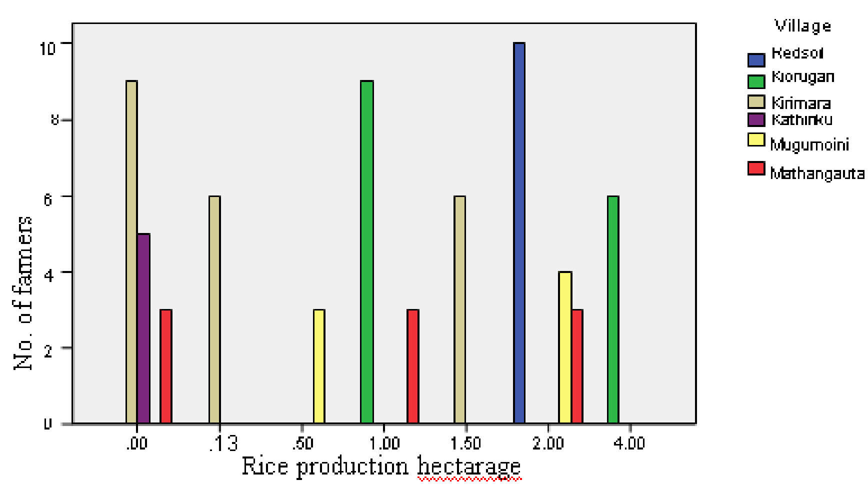

Figure-1. The hectarage and number of farmers involved in rice production per village.

3.6 Fertilizer usage and other farm inputs for rice production

The majority of respondents 77.6% used inorganic fertilizers with only 9 indicating non-use, while 6 did not answer from Kirimara village. On rice production in particular, 70.1% of the respondents used fertilizer, while 29.1% did not. The main fertilizers used were Diammonium super phosphate (DAP) followed by Calcium ammonium nitrate (CAN) and 23:23:0. These fertilizers were used in different combinations or singly depending on the crop and resource availability. The amounts used were in the region of 17 to 35 kg hectare^{-1} which is low (representing 19 to 40% of the recommended rates) for any meaningful crop productivity. The price of fertilizers has sharply gone up in the last three years and policy intervention by the government has not helped much. This has made many farmers to become desperate, in fact, many opting to scale down agricultural activities, while others resorting to use of more manure.

The majority of farmers also used various forms of manure, though the quantities used were very small. There were three main types of manure used. Most of the farmers (52.2%) used farm yard manure (FYM), 37.3% farmers used animal manure and 28.4% of the farmers used compost manure (data not shown), but these were used in varied amounts according to availability. It emerged that more fertilizer and manure were used on rice production though the amounts used were far below the recommended rates, with irrigated rice being top dressed with sulphate of ammonia (SA), while for upland rice

CAN was the one used. In terms of usage, Diammonium Phosphate (DAP), CAN and SA were the most applied fertilizers in that order.

The manure usage has resulted in other unforeseen problems like emergence of new weeds and diseases, more so because it's normally not well prepared or decomposed to kill any weed seeds, pests and pathogens. The farmers have consequently been forced to use more labour, pesticides and fungicides.

3.7 Number of farmers and hectarage used for other crop apart from rice production

In the rice production region, land is very competitive as it is near Nairobi city. This area is predominantly used to grow horticultural crops. The land holdings are small and hence, farmers have to make important decisions on what to grow based on returns and seasons. However, rice is very important as indicated by area of its production. The hectarage devoted to rice production ranged from 0.13 to 4.00 ha, with the latter being found at Kiorugari village. The lowest hectarage was found at Kirimara followed by Mugomoini and Mathangauta locations. Farmers from Kirimara, Kathiriku and Mathangauta used mainly rented land to produce rice. This was in contrast to other crop production, as the lowest hectarage was 0.75 ha (data not shown).

A good number of respondents felt that the area under crop production was decreasing. Respondents from three villages; Kiorugari, Kathiriku and Mathangauta felt that it was diminishing, while those of Red soil village felt that it was increasing. However, two villages; Kirimara and Mugumoini had divided opinion but in favour of increasing crop land. In total, 65.7% and 34.3% of the respondents indicated decreasing and increasing crop land area, respectively. The main reasons advanced for decreasing land area were growing population, infrastructure, high cost of inputs, poor soil health, crop diseases, lack of rain, decreasing returns from rented land, lack of markets for farm produce and high labour cost. The increase was due to opening of new land and farmers opting for rice production after scaling down production of other crops.

3.8 Respondents perceived farming challenges

There were many problems enumerated by the farmers during the focus group discussion, and key informants as listed in Table-4. The most limiting problems emerged to be high input costs, lack of funds, low and unpredictable rain. Even though the region has irrigation water, the farmers still considered water as a problem, mainly because the open earth canal water levels were low most of the times, especially when they needed it most. The low water levels were cited as the cause of most of their land remaining idle as water was rationed and directed to only one part of the irrigation scheme. They also felt that the water conveyance system had a lot of wastage through direct evaporation, transpiration from the luxuriant vegetation growing along the canal and seepage during its transmission. Climate change resulting from forest cover depletion was cited as having caused reduced rainfall and thus low water levels in the river.

Table-4. Farmers perceived rice production constraints and their rankings in Central Kenya.

Problem	**% of respondents** (n = 67)	**Rank**
Lack of production knowledge	19.4	13
Lack of certified seeds	28.4	9
High input costs	52.2	1
Pest and diseases	20.9	12
Lack of appropriate varieties	29.9	8
Lack of affordable machinery and implements	32.8	7
Lack of market for the produce	22.4	11
Low prices for the produce	34.3	6
High labour costs	37.3	5
Lack of water	38.8	4
Lack of resources (capital)	44.8	2
Low and unpredictable rainfall	41.8	3
High cost of rented land	25.4	10

When respondents were asked how they tried to solve the above problems, their coping strategies were varied and their success too differed in addressing some of the problems as indicated in Table-5. The problem of poor soil fertility was widely known to the majority of them. They indicated that due to continued cultivation and lack of or expensive manure, the land had greatly degenerated in fertility and soil structure. They indicated that they sought help and advice from the research station, extension services and from fellow farmers. The lack of certified rice seeds was a serious one and farmers had to resort to using their own farm saved seed or form groups and buy from research stations or national irrigation board (NIB) and in the worst cases they just bought from the local market.

Table-5. Farmers coping strategies for the perceived rice production constraints.

Problem	Coping strategy
Lack of production knowledge	Visit KARI, extension services and fellow farmers
Lack of certified seeds	Use farm saved seed, buy as a group, and from market
High input costs	Use manure and botanicals pesticides and fungicides
Pest and diseases	Spraying, field rotation and sanitation, use of resistant varieties
Lack of appropriate varieties	Seek from KARI, NIB, and seed companies for improved varieties
Lack of affordable machinery and implements	Switch to less demanding crops
Lack of market access for the produce	Store crop for better prices, direct sales without brokers
Low prices for the produce	Process, are helpless and desperate
High labour costs	Self hand till, rent out land
Lack of water	Switch to crops with less water requirement
Lack of resources (capital)	Borrow from friends, banks, merchants, rent out land
Low and unpredictable rain	Do water conservation farming
High cost of rented land	Rent land during low crop season

3.9 Rice productivity

The rice yields were reported to be generally low, unlike in the 1970-80's when they were high and the country was self sufficient. According to focussed group discussions and key informants, the yields were perceived to have dropped by more than half, while the cost of production had more than tripled. This was attributed to lack of rice research (rice has been an orphan crop, until around 2003 when it was recognized to have immense potential and thus research mandate was transferred from NIB to KARI), use of old varieties that have deteriorated over time and decline in soil fertility. They were in agreement that new varieties were long overdue and that these should be able to cope and be productive under the prevailing farmers' production environments. The majority of the respondents did not produce more than 2500 kg paddy ha^{-1}. However, Red soil and Kiorugari locations were able to surpass this as these are the so called "jua kali" farmers, meaning they are opening new fertile land for rice production outside the traditional NIB scheme.

4. DISCUSSIONS

4.1 Preferred variety traits by the farmers

Farmers ranked the top three among others traits of rice varieties of their interest as high yields (19.4%), hybrids varieties (17.9%) and nutrient use efficiency (16.4%) (Table-2). The preference for hybrid rice varieties was a surprise, and probably they were influenced in making that choice because of performance of other hybrids like maize, pepper and tomatoes. It may have again occurred as a result of low yields despite fertilizer use that was now common in their fields and they may have heard about hybrid rice. Hybrid rice was successfully introduced in Asia and it's a success case in china where over 70% of the rice area is under hybrid rice (Virmani *et al*., 2003). Today over 20 countries worldwide are producing hybrid rice with yields of up to 10.5 t ha^{-1} from two line hybrids, by use of either photoperiod sensitive or thermosensitive genetic male sterility. Thus there is no doubt hybrid rice has superior yields but these are high input dependent currently (Virmani *et al*., 2003). The solution for low yield was thought to come from use of hybrid varieties, use of nutrient use efficient varieties and growing pests and disease resistant varieties. Varieties that are easy to thresh and taller were also preferred. Even though farmers preferred hybrid and taller rice, there are implication and challenges such as hybrid seed production and yield penalty due to lodging in case of high N use and reduced harvest index (HI). This could mean searching for parents and breed for higher yield and non-lodging taller plants for easy harvesting and use of culms for feeds and other by products like making hats and thatching. The hybrid rice production could imply use differential day light length or temperature to cause pollen sterility and thus allow non-sensitive pollen donor lines to produce viable pollen as it is the case in China.

The top biomass is a trait valued by farmers for animal feed, and in recent years in Kenya, it has gained popularity as it is baled for animal feed. The cost of a bale is USD 3.3 serving as an extra income to the farmers. Thus the more the biomass, the higher the profit. Otherwise, the farmers used to burn the culms and thus control pests and diseases as well as enhancing soil fertility. This situation has changed and due to mining of soil nutrients through culm export for animal feed, and farm inputs being expensive, the soils are bound to deteriorate even further in terms of fertility and resurgence of diseases and pests may occur. The lack of organic matter and carbon, the important soil traits like soil texture and structure, C: N, C: K, N: K and other ratios may be disturbed negatively. This could further have an effect on soil microbial activities, and may reduce the rate of organic matter decomposition and nutrients availability. This behaviour of removing culms probably has led to silicon mining, an important element for cell wall membrane integrity and thus reduced defence mechanism against certain diseases. The recent highly devastating outbreaks of rice blast may have been influenced by culm removal (Newspaper, 2008). It is now a concern that transport of culms to other part of the country may introduce new pests and diseases, or elevate them to cause economic damage.

The respondents argued that some yield loss was associated with difficult threshing varieties like NERICA 4 as some grains remained behind and that it was also expensive because more labour was needed (Jiddah, 2009). They felt that easy to thresh varieties were cost effective as many bags would be threshed within a short period, especially given that labour is expensive, let alone the low head rice (% of milled grain compared to dehulled grains) and broken grains that results from sticky varieties due to use of excessive force for dislodging the firmly held grain. They further observed that, the resulting milled grains were of low quality and thus fetched low market prices, leading to lowering of profits.

4.2 Diversity of crops grown by the farmers

Among the crops grown by farmers, rice was ranked top followed by maize and in third place beans. The widest range of crops grown was found in Kirimara village, while lowest crop diversity was at Red soil village (Table-4). The number of respondents growing rice was 65.7% and this indicates how rice as an economic activity is very important. Mathangauta, Kathiriku and Kirimara had farmers who did not grow rice, probably because of lack of upland rice seeds and lack of irrigation water. This is despite their desire to have rice crop as an economic activity, given that rice is one of the most profitable enterprises and storage of dry grains does not require elaborate means like for the fresh vegetables such as French beans, tomatoes and baby corn among others. In terms of hectarage, farmers with about two hectares were 47.8%, while those with more than 2.5 ha were 52.3% (Figure-1). Kiorugari village had the highest proportion of farmers growing rice on bigger hectarage when compared to the other villages. It was revealed that this village produced the best quality rice, a belief that had been held but not confirmed, it has been argued that this is because of the moderately warmer water in the Thiba River in that area and generally the environmental temperatures were a bit cooler than in the other areas during rice maturing stage (Bhattacharjee *et al*., 2002).

4.3 Perception of farmers on rice varieties

Among the varieties grown by farmers were the recently released NERICA varieties and farmers were of the opinion that these were high input dependent varieties and since the inputs were expensive, the farmers were only growing them on small plots. The farmers also cited lack of information on their production and lack of seed as the other reason for low adoption. It emerged that if farmers had less capacity to buy inputs they were more interested in producing an old variety BW196 that is used for domestic consumption due to poor grain quality, although its yields were higher on average; because they felt that it was a nutrient use efficient variety that gave economic yield even with minimum inputs. Although farmers (77.6%) used fertilizers (Figure-not shown) the amounts used were low (17-35 kg ha^{-1}) for any significant economic gain. The recent rise in fertilizer prices has forced farmers to reduce further the quantities used and even some farmers abandoning crops perceived to be highly dependent on high inputs. They argued that producing these high input dependent crops and even rice is uneconomical because yield realized could not meet the cost of production, especially given that labour is also expensive. This has forced farmers to scale down on magnitude of hectarage of such crops like rice, maize and beans, and some farmers have resorted to upland rice production. The upland rice seemed popular due to its flexibility in its production practices that resulted into lower labour costs, especially for land preparation, planting, weeding and even spraying, unlike the paddy rice grown under difficult paddy conditions. It emerged that while the majority of males preferred growing both upland and irrigated rice, majority of the women preferred upland rice. Kirimara and Kiorugari village had the highest respondents opting for upland and both rice cultures, respectively (Figure-not shown).

It emerged that the input cost was a major inhibitory factor to rice production among other factors like lack of new varieties adapted to the production environments and unavailability of certified seeds. It is imperative then that ways of addressing these constraints be devised, and such solutions should be sustainable if consistent high yields are to be realized. Development of such new genotypes that meet the farmers' preferences is one way and this can be achieved by actively involving the farmers in the whole development process (Walker, 2008; World Bank Group, 2007). Of course not all farmers' problems can be addressed as some are more of policy issues, but some key ones like variety development can be accomplished. It was clear from the study that local farmers as is the case elsewhere, generally preferred high yielding varieties with high nutrient and water use efficiency and that some farmers favoured tall rice plants (Atlin *et al.*, 2006; Efisue *et al.*, 2008; Morris and Bellon, 2004). The reasons for farmers preference of tall varieties was due to biomass that provide an extra income generated from sale of the by-product (culms) as animal feed and that it is easy to work and harvest the crop a notion expressed also in West Africa (Efisue *et al.*, 2008; Kimani, 2010). The drought that occurred in the year 2008 was severe such that the demand for rice culms was high and this pushed its price up. However, harvest index is negatively associated with taller plants due to factors like lodging, photosynthetic partitioning. The other reason farmers gave for preference of tall plants is that short varieties are near the ground and thus rodents, flooding and splash water, ground walking birds and termites tend to destroy the grains. They also argued that birds find it easy to perch on them because they are relatively stronger than the taller varieties that are easily swayed by slight wind movement.

The development of dual purpose varieties is an option that should be explored. The varied farmers' preferences or tastes can widely be incorporated through a breeding programme because most of the traits are heritable. The challenge is how the farmers' best should participate in the breeding process so that their aspirations are met and incorporated in the end product. This is one way of ensuring that farmers know the products and can therefore easily adopt them leading to high and sustainable productivity.

4.4 Farmers participation in breeding

The outcome of the survey and PPB in the aspect of parent selection for hybridization was that farmers knew what traits were important (Table-2). The farmers were able to express their preferences and for a broader participation, given that upland rice production was relatively new to them, a PPB approach was adopted. The more resource based PPB was chosen, instead of the rapid and cost effective PVS, because there were no choices of cultivars (Witcombe *et al*., 2003; Witcombe and Joshi, 2003). The other reason was that this approach would help expose them to a wide array of agronomic practices and thus build their confidence in production of the newly released upland varieties. The farmers were involved in the actual planting of the accessions plus the cultivar and were free to visit the site located in the research station. When the crop was mature, they were invited to select the best materials based on their preferred traits of which 45 genotypes were selected, and later narrowed them to 14 from 390. The major selection criteria was high yield, large and well filled panicles, narrow long grains, healthy and tall plants that were fairly early maturing (Table-2). The farmers' selection and preference criteria differed with that of breeders in that their quest was for hybrid varieties and taller plants. However breeders go for shorter varieties that do not lodge under heavy N use and have high HI. They also go for pure lines or other varieties because mass production of hybrid seed and its sustainability is not easy for rice which is self pollinated crop.

One major issue that respondents highlighted was lack of certified seeds and this was obvious as they desperately wanted the little seeds that were harvested for further hybridization and even selections from segregating materials. These genotypes are now in the fiveth filial generation and soon they will be put into national performance trials for release by the regulatory authority. Sthapit *et al*., (1995), Joshi and Witcombe (1995) have used PPB to develop chilling tolerant rice and broadly based maize composite in Nepal and India, respectively. Salazar (1992) used PPB in rice breeding in Philippines where farmers selected promising materials from progenies of crosses involving traditional and modern varieties, but the method used is not explained.

5. CONCLUSIONS AND RECOMMENDATIONS

It has been revealed that farmers are faced with many problems and limitations and that farmers are very particular on the varieties they desire to cultivate based on various attributes and for what purpose; such as for domestic consumption, local market or far market for income generation. The main production constraints were high input costs, drought, high labour costs, lack of certified seeds, limited mechanization and lack of production knowledge. The farmers had preferences such as high yields (as indicated by farmers wishing to even grow hybrid rice), nutrient use efficiency, easy to thresh varieties, high grain quality especially fragrance and tall varieties that provide biomass for animal feed. It became evident that there was no variety that meet majority of farmers preferences probably because the existing varieties were developed without farmers involvement and thus their desires in a variety were not met. It was also disclosed that farmers are more eager to participate and adopt new varieties that will meet their perceived set criteria such as high yields, less input requirements, easy to thresh and tolerant to pests and diseases.

From this, it is highly recommended that farmers' participation be part and parcel of the breeding programmes and that farmers' preferences be incorporated in the programmes so that the end products are complete package of farmers' aspiration and wants. It is also important to adopt the PPB approach where farmers input and preferences will be captured in the variety development in the rice value chain and this may spur wider varietal adoption and thus higher rice productivity and an economical venture.

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