SORGHUM PRODUCTION PRACTICES IN AN INTEGRATED CROP-LIVESTOCK PRODUCTION SYSTEM IN MAKUENI COUNTY, EASTERN KENYA[†]

[PRÁCTICAS DE PRODUCCIÓN DE SORGO EN UN SISTEMA DE PRODUCCIÓN ANIMAL INTEGRADO EN EL CONDADO DE MAKUENI, KENIA DEL ESTE]

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SUMMARY

Productivity of sorghum has been below potential in arid and semi-arid lands of Kenya, due to poor agronomic practices and soil nutrient deficiency. Sorghum crop is fairly drought tolerant, resistant to waterlogging, and yields are reasonably better in infertile soils compared to other crops. Proper agronomic practices would significantly increase yields as well as nutrient content in grains and crop residues used as livestock feed. The objective of this study was to investigate the existing sorghum production practices and sorghum use as food and feed sources. A survey involving 90 farmers from sorghum producing areas in Makueni County was conducted. The survey focused on the varieties and fertilizers used, trends in yields, constraints to sorghum production and the present strategies used for sorghum as animal feed. Most farmers (84.4%) used uncertified seeds from own saved sources, and the commonly grown variety was Seredo (44.5%) due to resistance to bird damage. The majority (32.1%) of farmers recorded very low yield of sorghum grain, from151 to 250 kg ha^{-1}. Most farmers (68.9%) used farmyard manure in sorghum production, while 30.9% of the farmers did not use any fertilizer. All farmers indicated that their greatest challenge in sorghum production was inadequate rainfall. Bird damage to the crop was a chronic problem to most (73.3%) farmers. The majority (58.9%) of farmers conserved sorghum residue for feed as hay. The findings show the need to provide technical information and guidance on the production practices, such as choosing best-yielding seed varieties, proper methods of pest and disease control and proper use and conservation of sorghum residue as animal feed.

Key words: Dry land crops**;** Multipurpose sorghum; Sorghum varieties; Sorghum ratooning.

RESUMEN

La productividad del sorgo se ha manifestado por debajo de su potencial en las tierras áridas y semi-áridas de Kenya, debido a las pobres prácticas agronómicas y a las deficiencias en los nutrientes del suelo. El cultivo del sorgo es bastante tolerante a la sequía, resistente a las inundaciones, y los rendimientos son razonablemente mayores en suelos poco fértiles, que los obtenidos con otros cultivos. Prácticas agronómicas adecuadas podrían incrementar significativamente los rendimientos y el contenido de nutrientes de los granos y de los residuos de cultivos usados para la alimentación animal. El objetivo de este estudio fue conocer las prácticas existentes para la producción de sorgo, y los usos del sorgo para la alimentación humana y animal. Se realizó una encuesta a 90 agricultores de áreas productoras de sorgo en el Condado de Makueni. La encuesta se enfocó en las variedades usadas, los fertilizantes empleados, tendencias en rendimientos, las limitantes para la producción de sorgo y las estrategias actuales usadas con el sorgo para la alimentación animal. La mayoría de los agricultores (84.4%) usó semilla no certificada de la que ellos mismos guardan, y la variedad Seredo fue la más comúnmente sembrada (44.5%) debido a su resistencia al daño por aves. La mayoría (32.1%) de agricultores registraron muy bajos rendimientos de sorgo en grano, de 151 a 250 kg ha^{-1}. La mayoría de los agricultores (68.9%) usó estiércol en la producción de sorgo, mientras que 30.9 % de productores no uso ningún fertilizante. Todos los agricultores indicaron que su mayor reto en la producción del sorgo fue el régimen errático de lluvias. El daño causado por aves al cultivo fue un problema crónico de la mayoría de los agricultores (73.3%). Más de la mitad (58.9%) de los agricultores conservaron los residuos del sorgo para usarlo como forraje. Estos resultados mostraron la necesidad de proveerles información técnica y orientación en las prácticas de producción,

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tales como el escoger las variedades de semilla con los rendimientos más altos, métodos adecuados de control de plagas y enfermedades, y adecuado uso y conservación de los residuos del sorgo como alimento animal.
Palabras clave: Cultivos de secano; Sorgo multipropósito; Variedades de sorgo.

INTRODUCTION

Generating a sustainable food and feed supply that can match expected increasing demand is, by far, the most formidable challenge facing sub-Saharan Africa (SSA) agriculture (Hounkonnou *et al.,* 2012; Jayne and Rashid, 2013). Enormous increases in human and livestock populations are projected to occur in the decades to come, coupled with massive increases in levels of urbanization. The anticipated population growth is also projected to generate heightened competition for land and increased scarcity of cropland (Strassburg *et al.,* 2014; Mueller and Binder, 2015), especially in the rangelands, which may, in turn, induce agricultural intensification, particularly integrated crop/livestock production (Baudron *et al.,* 2014; Kindu *et al.,* 2014; Castellanos-Navarrete *et al.,* 2015). This is already happening in Kenyan arid and semi-arid lands (ASAL). Thus, crop residues may become the dominant feed resources for livestock in these eco zones as more rangeland is already being converted into cropland.

Sorghum is an under-utilized crop and one of the most important cereal crop in semi-arid tropics (Muui *et al.,* 2013; Jacob *et al.,* 2013). In Kenya, sorghum is grown in the often drought prone marginal agricultural areas of Eastern, Nyanza and coast provinces (Muui *et al.,* 2013). Within these growing areas, people associate sorghum as a poor man's crop and some still prefer to grow maize even in areas where it does not do well. As a result, there is increasing food insecurity (Dicko *et al.,* 2006; Orr *et al.,* 2016). A wide range of naturally occurring biotic and abiotic constraints including poor soil fertility, water scarcity, crop pests, diseases, weeds and inadequate temperatures are well known to reduce the productivity of sorghum, leading to low efficiencies of input use, suppressed crop output and reduced food security (Strange and Scott, 2005; Gregory *et al.,* 2005). In semi-arid Kenya, soil water evaporation can take up to 50% of total rainfall (Kinama *et al.,* 2005).

Nitrogen losses through gaseous plant emissions, soil denitrification, surface runoff, volatilization and leaching are increasing with time, especially in nutrient-poor soils. Sorghum and other cereal crops do not have the ability of nitrogen fixation, resulting in low yields (Raun and Johnson, 1999). Other constraints in sorghum production include waterlogging, runoff and soil erosion, which contribute to major yield constraints (Murty *et al*., 2007). Low temperatures, low soil Phosphorus (P) and Nitrogen (N), Iron (Fe) toxicity, acid soils, and wind damage (blown sand) also affect crop yields, while downy mildew, insect pests, and weeds such as Striga also cause severe losses in sorghum in the arid lands (Clay, 2013).

Although many producers view sorghum as a low maintenance crop, with its deep fibrous root system, sorghum responds well to nutrient application, especially in soils that are not very fertile. Nitrogen is the most often limiting nutrient in sorghum production; hence if managed efficiently, it can cause a significant increase in the yields (Vanlauwe *et al*., 2015; Potgieter *et al*., 2016). To address the many aforementioned challenges to sorghum production in the arid and semi-arid environments, the present study sought to evaluate the existing sorghum production practices and use as feed and food, with the aim to promote the efforts for integrated crop-livestock production system in the semi-arid rangelands of Kenya.

MATERIALS AND METHODS

Study area

The survey was conducted in three sub counties of Makueni County, Kenya; Wote, Kathonzweni and Makindu. The three sub counties lie in two agroecological zones (AEZ); Wote is in Lower Mid Land zone IV (LM4), while Kathonzweni and Makindu sub counties are both in Lower Mid Land zone V (LM5). Makueni County is located in the South Eastern Part of Kenya and covers an area of 8 034.7 km^2. It lies between 1˚35'-3˚00' S, and 37˚10'-38˚30' E. The county lies in the arid and semi-arid zones of the Eastern region of the country and is prone to frequent droughts (Makueni County, 2013). The county experiences two rainy seasons, the long rains occur from mid-March to April and the short rains between November and December. The hilly parts of Mbooni and Kilungu receive 800 to 1200 mm of rainfall per year with temperatures ranging from 20.2 °C to 24.6 °C. The low lying areas receive 150 to 650 mm of rainfall per year and have temperatures as high as 35.8 °C, typical of ASAL in Kenya (De Jalón *et al.,* 2015). The main source of livelihood in this county is subsistence agriculture and most of the crops produced are consumed at the household level (Mwangangi *et al.,* 2012). Other socio-economic activities in this area include bee keeping, small-scale trade, sand harvesting and charcoal burning. The major crops grown are maize, green grams, pigeon peas and sorghum (Makueni County, 2013).

Data collection survey

A total of 90 farmers were interviewed using a semi structured questionnaire. A snowball sampling method was used to target only sorghum producing farmers. Sorghum farmers were identified with the aid of key informants and agricultural extension officers in the region. A total of 24 farmers were interviewed in Wote, 39 in Kathonzweni, and 27 in Makindu. The questionnaire focused on sorghum varieties grown, fertilizers used, average sorghum yield, challenges and constraints of sorghum production and present strategies used for sorghum as animal feed.

Data analysis

Data obtained from the survey was analyzed using SPSS ver. 20. Descriptive statistics were used to derive the existing farmers' sorghum production practices and uses for both food and feed. Response variables were analyzed for percentages, frequencies and averages, and were presented in tables.

RESULTS

Farmer's objectives in sorghum production

In the three sub counties, most (85.6%) farmers produced sorghum for their own consumption (Table 1). Notably, in Lower Mid zone V (Kathonzweni and Makindu), production for animal feed was higher than in Lower Mid Land zone IV (Wote).

Land used for sorghum production

Although many farmers owned more than 1 ha of land, most (48.9%) farmers grew sorghum in an area smaller than 1 ha (Table 2). Wote had more farmers (25.0%) using an area larger than 1 ha for sorghum production compared to Kathonzweni and Makindu (<19.0%).

Source of information on sorghum production

The main source of information on sorghum production used by sorghum farmers was from the Ministry of Agriculture Extension staff (32.4%). Majority of the farmers (44.6%) did not have access to any information regarding sorghum production (Table 3). Of the respondents, 22.9% received information from farmer groups.

Challenges and constraints in sorghum production in Makueni County

The most mentioned major constraint to sorghum production across the three sub-counties by all respondents was inadequate rainfall. Bird damage was the second most important challenge, with 73.3% of farmers indicating it as a problem. Farmers also indicated that bird damage can be devastating in sorghum production, and it could lead to 100% loss of the crop (Table 4). Head smuts (*Sphacelotheca reiliana* (J.G. Kühn) G.P.Clinton) (Microbotryales: Microbotryaceae) were only reported by farmers in Wote and Kathonzweni, while stalk borer (*Busseola fusca* (Fuller)) (Lepidoptera: Noctuidae) was also noted across all the three sub-counties in Makueni

Table 1. Percentage of farmers with different objectives for sorghum production.

n = 90	Woten = 24	Kathonzwenin = 39	Makindun = 27	Weighted mean
Objective	LM4	LM5	LM5	
Own consumption	91.7	82.1	85.2	85.6
To feed animals	8.3	15.4	11.1	12.2
For sale	0.0	3.7	3.7	2.7

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Table 2. Percentage of farmers with various land sizes used for sorghum production.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	Weighted mean
Land size	LM4	LM5	LM5	
0-0.5 ha	37.5	28.2	33.3	32.2
0.6-1 ha	37.5	56.4	48.1	48.9
>1 ha	25.0	15.4	18.5	18.9

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Table 3. Percentage of farmers obtaining information on sorghum production from various sources.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	Weighted mean
Source	LM4	LM5	LM5	
Ministry of Agriculture	50.0	37.5	9.5	32.4
Farmer groups	25.0	31.3	9.0	22.9
No information	25.0	31.2	81.5	44.6

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Source of sorghum seeds used by farmers in Makueni County

The most common source of seeds used by farmers in Makueni County is their own saved seed (68.9%). Farmers reported to be using their previous harvest for next season planting. The second source of seeds used was from certified seeds, although it was done by very few farmers (15.6%) and was reported to have been supplied by the Ministry of Agriculture at subsidized prices (Table 5). Very few farmers (<10.0%) reported to be obtaining seeds from the market or from other farmers. Kathonzweni is the only county that reported a non-governmental organization (NGO) as a source of sorghum seed, which was confirmed to be hybrid seed provided by an NGO under the climate smart adaptation program.

Varieties of sorghum produced and preferred in Makueni County

The most common (44.5%) sorghum variety produced in Makueni, mostly by farmers in Makindu, was Seredo. (Table 6). Notably, Gadam was highly produced in Wote and Kathonzweni, unlike in Makindu (Table 6). The farmers who grew Gadam reported it as a high yielding variety. The varieties being promoted by extension officers were Gadam and Kari Mtama 1, with more farmers in Wote and Kathonzweni sub counties adopting these varieties than in Makindu. Serena variety was the least adopted across the three sub counties due to its low productivity and susceptibility to bird damage.

Intercropping with sorghum in Makueni County

Cowpea (*Vigna unguiculata* (L.) Walp.) is the most (25.6%) used intercrop in sorghum production in Wote sub County, while most of the farmers in Makindu sub county reported mono-crop of sorghum (44.4%) (Table7). The second intercrop in the county was maize, followed by green grams (*Vigna radiata* (L.) R. Wilczek). Most of the farmers who did intercrop reported the reasons of increasing yields and also diversification of household diets. Most of the farmers in Makindu (74%) practiced mono-cropping due to moisture limitations and that most intercrop fields increased competition for water and reduced yields. Also, they reported the crops used were less tolerant to droughts than the sorghum crop. Bean was the least used as intercrop across the three sub counties.

Cropping system and fertilizer use in sorghum production in Makueni County

The most common cropping system was to have the plant "one season" in all the three sub-counties (>90%). Very few farmers (5.6%) reported to harvest sorghum and allow for re-growth for the next season (ratooning). Farmers reported that the ratoon crop produced low yield, explaining why many farmers were not practicing this cropping system. The common practice was "one season" and land was cleared for the next crop (Table 8). Farmyard manure was the most commonly used (68.9%) fertilizer in Makueni County. A reasonable proportion of the farmers in the county (27.8%) did not use any fertilizer in sorghum production (Table 8).

Table 4. Percentage of farmers who reported various constraints in sorghum production.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	Weighted mean
Constraint	LM4	LM5	LM5	
Bird damage	70.8	84.6	59.3	73.3
Stalk borers	8.3	5.1	40.7	16.6
Head smuts	20.8	10.3	0.0	10.0
Inadequate rainfall	100	100	100	100

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Table 5. Percentage of farmers using various seed sources.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	Weighted
Sources	LM4	LM5	LM5	mean
Farm saved	70.8	61.5	77.8	68.9
Certified	16.7	23.1	3.7	15.6
Market	12.5	7.7	0.0	6.7
From other farmers	0.0	2.6	18.5	6.7
NGO (Anglican Development Services)	0.0	5.1	0.0	2.2

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Table 6. Percentage of farmers producing various sorghum varieties.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	
Sorghum varieties	LM4	LM5	LM5	Weighted mean
Gadam	45.8	53.8	11.1	38.9
Kari M 1	12.5	23.1	3.7	14.5
Serena	8.3	0.0	0.0	2.2
Seredo	33.3	23.1	85.2	44.5

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Table 7. Percentage of farmers using various crops as intercrop.

n = 90	Wote n = 24	Kathonzweni n =39	Makindu n =27	Weighted mean
Crop	LM4	LM5	LM5	
Cowpea	41.7	28.2	7.4	25.6
Pigeon pea	12.5	0.0	3.7	4.4
Beans	4.2	2.6	0.0	2.2
Maize	12.5	20.5	0.0	12.2
Green grams	4.2	12.8	14.8	11.1
No intercrop	25.0	35.9	74.0	44.4

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Table 8. Percentage of farmers using various sorghum production systems and fertilizer use.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	Weighted mean
Production System	LM4	LM5	LM5	
Plant one season	91.7	92.3	100.0	94.5
Ratooning	8.3	7.7	0.0	5.5
Fertilizer use				
Urea	-	-	-	-
DAP	0.0	2.6	0.0	1.1
CAN	0.0	5.1	0.0	2.2
FYM	79.2	87.2	33.3	68.9
None	20.8	5.1	66.7	27.8

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V, DAP = diammonium phosphate, CAN = calcium ammonium nitrate, FYM = farm yard manure.

Sorghum yield in Makueni County

Sorghum grain yield was low with most (32.1%) of the farmers harvesting between 151-250 kg ha^{-1}. A very low proportion of the farmers (18.9%) harvested more than 300 kg ha^{-1} (Table 9). The reasons for the low productivity of sorghum in the county were low and unpredictable precipitation, bird damage and also other farmers cited pest and diseases as reasons for low yields.

Sorghum use and conservation as animal feed in Makueni County

The majority of the farmers (44.4%) use straw and grain to feed the animals while 26.6% do not use sorghum residue as animal feed (Table 10). Farmers using sorghum straw reported it to be a useful feed source during dry seasons and could be easily stored after harvest. Hay from straw (58.9%) was the most common form of sorghum conservation for feed purposes. Other farmers (41.1%) grazed the land after harvest and did not do any conservation (Table10).

DISCUSSION

In this study, most farmers grow sorghum for their own consumption. Study by Agrama and Tuinstra (2003) showed that sorghum is a staple food for millions of people in Africa and in India, while in the United States, livestock feeding accounts for most sorghum usage. Muui *et al*., (2013) also indicated that in Eastern Kenya, most farmers plant sorghum for their own consumption alongside other crops like cowpea, pigeon pea, green grams, maize, while only a few growers sell sorghum to generate income. Most farmers consider sorghum as a less important cash crop and hence they do not invest in its production. This view is traditional; in most African societies, sorghum was viewed as a poor man's crop (Dicko *et al.,* 2006; Orr *et al.,* 2016).

Table 9. Percentage of farmers with various estimated sorghum yields ha^{-1}.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	Weighted mean
Yield (kg ha^{-1})	LM4	LM5	LM5	
0 to 150	37.5	23.1	18.5	25.6
151 to 250	25.0	33.1	37.0	32.1
251 to 300	12.5	28.2	25.9	23.3
>300	25.0	15.4	18.5	18.9

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

Table 10. Percentage of farmers using various sorghum parts as animal feed.

n = 90	Wote n = 24	Kathonzweni n = 39	Makindu n = 27	Weighted mean
Sorghum Part used as feed	LM4	LM5	LM5	
Straws	45.8	23.1	11.1	25.6
Grain	4.2	7.7	0.0	4.5
Straws and grain	37.5	48.7	44.4	44.4
Do not use as feed	12.5	23.1	44.4	26.7
Conservation strategy				
Hay	75.0	76.9	18.5	58.9
Do not conserve	25.0	23.1	81.5	41.1

n = sample size, LM4 = Lower Mid Land zone IV, LM5 = Lower Mid Land zone V.

The increasing crop failures of the common crops preferred by farmers in the arid and semi-arid areas like maize and beans, has also increased the need for farmers to shift crop choices to more drought tolerant ones, including varieties that are resistant to drought and diseases (Khan *et al.,* 2014; Hadebe *et al.,* 2016). Early adopters of technologies have realized the importance of moving to dry land crops from conventional crops, especially after observing successive crop failures in the past (Chivenge *et al.,* 2015; Vunyingah and Kaya, 2016).

This study shows that farmers owned more land, but they allocated less than one hectare for sorghum production and as a result the sorghum production was low. Muui *et al.* (2013) also indicated that the crop is grown by majority of farmers on very small portions of land, either in mixed crop or as few strips along the farm edges. A report by USAID (2010) shows that sorghum has been considered as the crop for the small-scale, poor farmers in the arid and semi-arid lands, and this could be an explanation as to why most farmers do not allocate much land for sorghum production. The other reason for small areas of land allocated to sorghum production could be the low commercialization of the crop and the lack of streamlined marketing channels that consider value addition (Rao *et al.,* 2014; Kavoi *et al.,* 2014). Chepng'etich *et al.* (2014) also reported low commercialization of sorghum in lower eastern, same area where this study was conducted.

The major source of production information was from the Ministry of Agriculture through the Agricultural Extension officers. Past study by Rees *et al.* (2000) showed that government extension is a major source of production information. The second source of information in this study was the small farmer groups. Research has shown that there is a reduced effectiveness in extension services; as a result, many farmers do not access important information on how to improve their crop productivity, leading to poor crop performance (Mwadalu and Mwangi, 2013). In the study area, the recent devolved system of governance into county governments also has been reported to have increased access to information at local level (Recha *et al.,* 2016). Many counties are focusing on improving the livelihoods of the communities in their areas, and this has seen massive investments into agriculture, with other counties also working hard to mechanize agricultural activities (Madegwa *et al.,* 2016; Berre *et al.,* 2016). Makueni County is one of the counties that have worked hard to increase food production, and one of the efforts has been to adapt farmers to climate through choice of appropriate crops and market linkages (Ontiri and Robinson, 2015). Other players (NGOs, development and research partners) also have come into play in supporting communities in the arid and semi-arid counties in Kenya.

Despite the potential of sorghum to do well in areas that experience drought and with poorly-fertile soils, sorghum sub sector is faced with many challenges (Mwadalu and Mwangi, 2013). In this study, all the farmers interviewed indicated that inadequate rainfall was the major challenge to sorghum production. The study also shows that invasion of the crop by quelea birds were a major challenge that could result in 100% crop loss. This is in line with earlier study by Miano *et*

al. (2010), which showed that quelea birds make sorghum production more labor intensive, causing majority of farmers to opt for maize production, which has even more risks due to climatic requirements. The observed low productivity of the sorghum in the study area could be attributed to poor agronomic practices, where some farmers reported not to apply fertilizer at all. Karanja *et al.* (2014) indicated that agronomic practices like fertilizer application regimes highly determine sorghum yields. There are opportunities for increased yields in sorghum in Makueni County if water harvesting technologies are adopted, in combination with access to drought tolerant seed varieties and resistant to bird damage. Rai *et al.* (1999) and Timu *et al.* (2014) reported access to good cultivars and varieties of sorghum can significantly increase sorghum yields in Africa.

Majority of farmers in this study use farm saved seeds and those who cannot save, borrow from neighbors or buy from the market. Labeyrie *et al.* (2014) also reported farmers to be using their social organization in accessing seeds for sorghum, where farmer groups highly shaped the source of seeds used. This study also shows that very few farmers use certified seed in sorghum production. Other studies also showed that many farmers use farm saved seed, market seed or borrow from the neighbors (Muui *et al*., 2013). More than 90% farmers in ASAL use informal seed (farm saved and market seed) (Omanga and Rossiter, 2004). A study by Ayieko and Tschirley (2006) shows that many farmers use farm saved seed because certified seed is expensive and small holder farmers cannot afford it. Other reasons could be marketing challenges, especially due to poor transport and communication infrastructure, unavailability of clean seed in the market and cases of fake seed, which demoralize farmers. Use of farm saved seeds also could explain the reported low yields by farmers. Farm saved seeds have high chances of carrying pests and diseases to the next crop, and also germination and viability could be low if not well processed and stored as seeds (Mucioki *et al.,* 2016). Hybrid or certified seeds are known to have quality checks and hence ensure farmers get value for their money. Breeding programs that answer farmers' needs are needed if sorghum productivity is to be increased in East African region.

The most commonly grown variety among interviewed farmers was Seredo. Farmers prefer this variety because it is very resistant to bird damage, a big challenge in sorghum production. It also matures early while still being drought tolerant. On the other hand, Gadam is early maturing and has high yields, however it is not highly preferred by farmers because of its susceptibility to bird damage. A study conducted by Muui *et al.* (2013) shows that farmers in Makueni prefer to grow landraces to hybrids due to some variable traits that are shown by the local varieties. Breeding programs that address farmers' needs should increase adoption of preferred varieties that have traits of interest to the community, such as drought tolerance, resistance to bird damage and high yielding, as identified by the respondents.

This study reveals that most farmers plant sorghum in mixed cropping systems. Commonly used intercrop is cowpea. Other crops such as pigeon pea, green grams, maize and beans are also used. Most farmers are known to practice intercropping in Africa to reduce food insecurity and improve their livelihoods (Musa *et al.,* 2011). Intercropping increases productivity per unit area and allows efficient use of space and time to optimize output, and promotes diversification (Singh and Usha, 2003). In this study, majority of farmers do not practice the ratooning cropping system. Although studies show that the ratoon crop yields more than the first crop, very few farmers in Makueni practice it. In addition, many farmers interviewed do not use inorganic fertilizers in sorghum production, which has contributed to poor performance and yields. Muui *et al.* (2013) also indicated that most farmers do not use fertilizers and still they do not control pests and diseases. This could be explained because sorghum is grown under marginal rainfall conditions and fertilizer prices are high in relation to grain price.

Sorghum grain yield in the study area was very low, compared to the potential yield of 10.5 t ha^{-1} when grown under ideal conditions (Jordan *et al.,* 2012). Low yields could be attributed to lack of fertilizers use, failure to control pests and diseases, inadequate rainfall and unavailability of hybrid seed. The use of their own saved seeds by farmers could be responsible to the reported high pest and disease, and hence low productivity. Low adoption of certified seeds and hybrid seeds also explain why yields are lower than the expected per unit of land.

This study shows that sorghum residue is widely used to feed livestock in Makueni County. Majority of farmers conserved sorghum residues as hay because it is the cheapest and easiest method of conservation. Other farmers grazed animals in the sorghum field directly after grain harvesting. Sorghum being a dry land crop that can produce high biomass, even with limited moisture supply, makes it one of the potential strategic feed sources for livestock (Mwangi *et al.,* 2017; Kashongwe *et al.*, 2017; Oyier *et al.,* 2017). There is a need to provide information on the potential uses of sorghum residue as animal feed (Timu *et al.,* 2014; Habyarimana *et al.,* 2017). The existence of opportunities for value addition in sorghum residues to make quality feed is also a good reason to increase its production and conservation in Makueni county. Sorghum is an adequate energy source to livestock; if

well blended with other leguminous crop varieties that can be produced as intercrop, farmers will realize increased productivity from crop-livestock integration. Breeding programs for high yielding dual purpose sorghum varieties is also an opportunity that needs to be tapped by farmers in Makueni County (Hassan *et al.*, 2015; Chikuta *et al.*, 2015). This will increase production of grain for human food, as well as will solve the imminent challenge of low feed for livestock. The study findings did not show any farmer making silage from sorghum residues. This is another opportunity that is not tapped, more so, with the current breeding efforts by ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) to develop high sugar straw sorghum that are high yielding, and hence quality residues for animal feed making as silage. Notably, the present conservation as hay is not well done by households, with the observed poor storage on rooftops, tree tops that exposes it to quality deterioration and reduced feed value when fed to animals. Most of the famers reported no training received of crop residue use and conservation from sorghum and other intercrops.

It is recommended to strength the existing farmer groups and increase their capacity through training on better sorghum production practices, seed multiplication, processing and storage, feed processing and conservation from sorghum and other legume residues to increase productivity and support crop livestock integration for better livelihoods.

CONCLUSION

Sorghum production is faced with many challenges in Makueni County, ranging from poor agronomic practices, pest and diseases, poor soil fertility management as well as traditional production as a subsistence crop. There is need to increase adoption of hybrid and certified sorghum varieties, increase commercialization and mechanization of the production process. The opportunity to develop dual purpose varieties that have the traits demanded by farmers of drought tolerance, high yielding and bird damage resistance will contribute to increased crop-livestock integration in Makueni County.

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