EFFECT OF MILLET AS TRAP CROP FOR CONTROL OF BIRDS ON WHITE SORGHUM IN EASTERN KENYA

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ABSTRACT
The semi-arid regions of Kenya have few crop enterprise options. One of the major constraints of white sorghum production is bird damage on the grain from soft to hard dough stage. A two seasons study was established at Katumani of Machakos County, Kampi Mawe of Makueni County and Ithookwe Kitui of County to delimit bird damage levels when a trap crop such as millet was incorporated in the farm. A complete randomized block design (CRBD) of three replicates of pure sorghum, sorghum alternate rows with sorghum and sorghum-encircled with millet plants was established for evaluation of millet as a trap crop of birds. The results showed that the highest bird infestation was at Katumani plots where *Serirus reichonowi* cumulatively reached over 2,000 individuals at two sites in a month. It was noteworthy that the *Quelea quelea* species was missing at Katumani site during the stated production periods. The second highest bird infestations was at Kampi by *Q. quelea* of a month's cumulative number of 842. Grain yield loss was highest at Katumani (99-100%), corresponding to the high bird infestation numbers. The second highest yield loss occurred at Kampi (60%), which had also the second highest bird numbers. The highest yield achieved due to effect of millet as a trap crop was at Ithookwe (19.3 t ha-1) with less than 10% grain loss compared to Katumani at 100% loss. The results showed partial protection of sorghum damage by birds when intercropped with millet, although factors of bird level of hunger at the different sites have to be considered.
Keywords: Livelihoods, White Sorghum, Millet, Birds, Semi-Arid-Lands

INTRODUCTION
Sorghum crop, *Sorghum bicolor* (L.) is an important cereal staple worldwide known for its carbohydrate quantity for both animal and human consumption (Kilambya and Witwer, 2013). The years of 1980s and 1990s most breeding programmes in Africa have released more improved varieties (Ahmed *et al.*, 2000). In eastern Africa sorghum is among the food security crops (Muui *et al.*, 2013; Kilambya and Witwer, 2013). Though human consumption has remained stagnant probably due little value addition, the new option of use in the brewing industry has awaken demand for sorghum grain (Mutisya and Willis, 2009; Van Wijk and Kwak, 2011). Production levels depend from country to country as reasons for production depending on socio-economic and government policy factors (Muui *et al.*, 2013). Reported improvements on agronomy technologies have increased volumes of production though some constraints remain and beg further improvement (Ndjeunga and Bantilan, 2005). Bird damage leads as the major constraints of production of sorghum in most Sub-Sahara countries (Mastersa *et al.,* 1998). Besides field scaring efforts like use of scarecrows and loud noises little other options have been tried and evaluated at field level. In Ethiopia and Senegal use of chemical control was documented in the last three decades (Bruggers, 1976; Jaegar and Erickson, 1980). The damage was mainly caused by several species of birds, most notable the Red-billed Dioch *(Quelea quelea)* and the Village and Black-headed Weavers *(Ploceus cuculiatus* and *Ploceus capitalis)* in Senegal (Bruggers, 1976). In Ethiopia it was the Village weaver (*Ploceus cucullatus*), Red bishops *(Euplectes fransiscanus*), doves (*Streptopelia* spp.) and mostly the Red-billed *Quelea* (*Guelea quelea*) (Erickson *et al.,* 1980). In Kenya the common species is *Q. quelea* though doves and others are reported by farmers from one region to another (Brooks *et al.*, 2009). In eastern Kenya production constraints include bird damage due to the fact that few options of control measures exist. There has been no report of use of the more preferred millet as a trap crop of birds in sorghum production. The present work was aimed at evaluating effect of millet as a trap crop since birds readily prefer the former to sorghum. Three sites were selected and assumed to reflect different densities of bird species as they infested the fields sourcing for food while synchronization of sorghum and millet ripening stage was explored as important.

MATERIAL AND METHODS
Field Plots Establishment
At the beginning of long and short rains in October-December 2014 and March-July 2015 8 m by 10 m subplots making three treatments of Gadam variety. The treatments were pure sorghum, millet-alternate and millet-encircle of 38 m-length by 32 m-width established in rain-fed production systems at Katumani, Kampi and Ithookwe of eastern Kenya. Sorghum crop in the intercrop system was maintained

at 70% while millet was 30% in both millet-alternate and millet-encircle subplots. A four metre path was demarcating the plots within each block. The treatments were randomized and replicated three times in the three blocks. Fertilizer application of diammonium phosphate (DAP) was carried out at the rate 40 kg/hectare for uniform nutrition. Crop top dressing with calcium ammonium nitrate (CAN) was carried out at the rate of 40 kg/kg once after emergence at the plots of the three sites. Weeding by hand hoe was done three times before crop maturity. Duduthrin insecticide at the rate of 200 ml per hectare was applied once three weeks after crop emergence against shoot fly and stem borers. The amount of rainfall (mm) during the production period was recorded for comparable production potential of sorghum at the sites.

a) Katumani site

The plot at KALRO-Katumani located at 01°34.949 S, 037° 14.426 E, Elev.1609 m above sea level (asl) was within the experimental plots of various crops. The site is 11 kilometers south of Machakos. Around the plot were two trees which harbored some nests of weaver bird species. Rarely would large swamps of birds infest the fields. Some 102 mm of rainfall was recorded monthly during the production seasons.

b) Kampi Mawe Site

The KALRO-Sub-Centre Station is located at 01° 5.248 S, 037° 39.846 E, Elev. 1164 m asl 10 Kilometres east of Wote Town. The field is sparsely populated with acacia tree species with some bird species of *Amadina* species found making nests. Rainfall of 112 mm/monthly was recorded during the production period.

c) Ithookwe site

The KALRO-Sub-Centre Station is located at 01° 22. 522 S, 037° 59.079, Elev. 1147 m asl 3 Km western side of Kitui Town. The field is surrounded by acacia tree vegetation where birds of varied species visit and occupy the trees breeding in nests. Rainfall amount recorded on monthly mean was 93 mm spread over two months of production.

Data Collection

The study quantified level of bird damage on sorghum panicles from milky kernel stage to when the seed was physiologically mature in treatments of pure stand, sorghum-millet alternate rows and sorghum plot encircled with millet crop. Bird damage data collection (day 1) was done when 60% of the crop was at grain milk stage at each site. In each field some 10 panicles were randomly scored of visual bird damage (1 = 0, 2 =25, 3 = 50, 4 = 75 and 5 = 100%) as the unprotected set. Similar another 10 panicles were covered (protected set) with khaki paper bags for complete protection against bird damage. Crop physiology from flowering was recorded for each site. Later further bird damage recording was carried out on day 5, 10, 15, 20 and 30. After dry-maturity stage, total salvaged grain yield was threshed and weighed by electronic weighing machine (Sartorius Basic-BA3105) in khaki papers. Duration for developmental days at flowering and physiological maturity was scored for sorghum (Gadam) and millet (KAT PM 1). Bird species identification was carried out at Kenya National Museums where specimens were deposited for reference. The grain yield was converted to tons per hectare for comparable standards. Bird infestation at each treatment plots was recorded during observation time and daily cumulative for the 30 days period total. Sorghum grain physiological maturity was determined for each agro-ecological zone as safe harvest time of the crop before further bird damage.

Data Analyses

Data analyses included comparing treatments yield in each site and progressive bird damage, by analysis of variance (ANOVA) using SAS (Version 8, 2001) for the analyses to statistically compare the mean value by Fisher's Least Significant Difference (LSD) at 5% level. Means separation was done by General Linear Method (GLM) of Student-Newman Keuls (SNK) Post Hoc Test at 5% level.

RESULTS

Sorghum and Millet Development

Sorghum crop development seemed to tail behind millet by 18 days at Katumani while at Kampi and Ithookwe the two crops flowered and matured at close similar times (Figure 1). At Kampi and Ithookwe sorghum matured at 93 days while millet took 85 days. It was observed that where the temperatures were low sorghum developed slowly than millet crop. The warmer the environment the closer was the maturity period of the two crops as was observed at Kampi and Ithookwe.

Bird Species and Abundance at Sites

Bird species abundance differed significantly ($P <$ 0.0001) by locality. Katumani site had the highest cumulative numbers of bird infestation (Table 1). The most abundant species in the three sites was the Yellow-rumped seed eater, *Serirus reichonowi* Salvodori (Passeriformes: Fringillidae) at 2,817 at Katumani in Jan-Feb 2015. During the June-July 2015 season, *S. reichonowi* had strong presence at Katumani and Kampi at 2,563 and 1,261 respectively. The *S. reichonowi* species was highest.

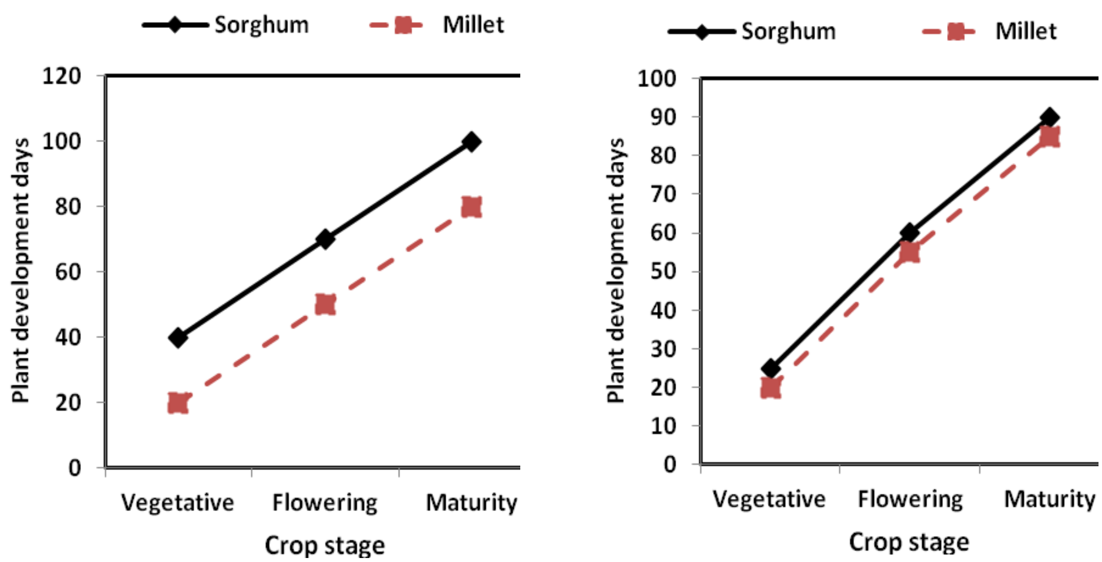

Figure 1: Developmental of sorghum and millet at different agro-ecological zones at Katumani and Kampi/ Ithookwe. A = LM 4 Katumani (20-24°C).B = LM 2 Kampi/Ithookwe (24-28°C)

Table 1: Number of bird species infestations on sorghum in specific periods and sites during 2014-2015

			Bird infestations on sorghum on specific observation days						
Site	Bird species	Period	1	5	10	15	20	30	Total
		Jan-Feb 2015							
Katumani	*P. mahali*		0e	3.4de	2.0f	3.0cd	2.0e	2.3d	16h
	S. reichonowi		45.2a	103.2b	136a	125a	131.3b	11.0c	2,817a
Kampi	*P. mahali*		8.0d	15.0c	9.0de	11.0b	146.0a	17.0b	281e
	S. reichonowi		11.0c	110.0b	13.3c	9.3bc	17.5c	135.0a	1,482b
	A. fasciata		2.6e	4.0de	6.3e	6.0bcd	9.0de	2.0d	149fg
	Q. quelea		27.4b	108c	10.0cd	8.0bcd	7.0de	0d	702c
Ithookwe	*P. mahali*		2.8e	3.0de	2.0f	0d	5.0de	1.6d	674c
	S. reichonowi		8.5d	6.0de	8.0de	11.8b	12.0cd	16.8b	238cf
	A. fasciata		2.0e	0.5e	1.5f	8.3bcd	2.0e	3.6d	58gh
	Q. quelea		11.4c	116.3a	17.0b	9.0bc	0e	0d	465d
	F		38.2	265.6	987.9	160.3	321.9	113.3	383.7
	P		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	<0.0001	< 0.0001
		June-July 2015							
Katumani	*P. mahali*		0e	0.8h	0f	0d	1.0e	1.3d	15f
	S. reichonowi		26.1b	63.3b	72.0a	78.2a	71.3a	3.0d	2,563a
Kampi	*P. mahali*		1.6de	1.7gh	3.6f	4.6e	70.0a	5.6c	432d
	S. reichonowi		16.6c	8.0e	11.3d	15.3cd	20.5b	25.0a	1,261b
	A. fasciata		0.1e	11.0d	0.3f	12.0d	13.0cd	7.0c	167e
	Q. quelea		25.4de	136a	20.2c	6.0e	1.6e	0d	842c
Ithookwe	*P. mahali*		0.8c	4.4f	4.6f	16.0c	3.0e	2.0d	183e
	S. reichonowi		14.5c	18.0c	11.0de	21.2b	16.0bc	10.8b	458d
	A. fasciata		4.0d	4.1gh	6.0ef	2.3e	7.0de	1.4d	24f
	Q. quelea		37.4a	62.2b	35.2b	3.0e	0e	0d	182e
	F		150.7	2319.8	110.6	249.2	83.5	82.0	651.6
	P		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Different lowercase letters denote significant ($P < 0.0001$) bird numbers of specified species at the sites (Fisher's Significant Different, LSD, df =12, 39) at 5% level.

The White-browed sparrow weaver, *Plocepasser mahali melanorhynchus* Smith (Passeriformes: Passeridae) though present at the three sites it was noted for its low numbers at the plots. The Cut-throat finch, *Amadina fasciata alexanderi* Neumann (Passeriformes: Estrildidae) was absent in Katumani but present at Kampi and Ithookwe in low numbers during the production period. The red billed species *Quelea quelea* Linneaus (Passeriformes: Ploceidae) infestation was initially observed at Ithookwe at first part of the period but absent in the last two observation periods of 20th and 30th days. At Kampi the *Q. quelea* species was cumulatively highest at 702 during the 2015 observation period but at low infestation of 182 at Ithookwe. Highest bird peak numbers at Katumani were recorded on 20th day observation time of *S. reichonowi* at 131.3 in 2015 production period. At Kampi *P. mahali* led at 146 in the same observation time. In the same period *Q. quelea* species led at 116.3 abundance. Comparably, during second season *S. reichonowi* infestation peak was at 78.2 during the 15th day observation time. The Kampi site had *P. mahal* bird species peak at 70.0. Likewise at Ithookwe, *Q. quelea* led at 62.2 during the 5th day observation.

Grain yield loss over maturation duration

Treatments of production of pure sorghum, millet row-alternate and millet-encircle plots layout indicated no significant yield difference among treatments at the sites of Katumani, Kampi and Ithookwe (Table 2). The treatments showed an insignificant (P > 0.05) difference of grain yield among the sites. There was significant (P < 0.0001) yield difference on the unprotected treatments which appeared to increase with longer exposure to bird damage at the three sites. Highest yield loss (tons/ ha) correlated to increased exposure to the 30 day observation period at Katumani plot (R^2= 0.9563) reaching a peak maximum of 28.0 t ha^{-1} (Figure 2). This was correspondingly close to 99% loss. Kampi and Ithookwe attained yield levels of 18 and 4 t h^{-1}, corresponding to 60 and 20% yield loss respectively. Katumani site had an exponential yield loss of 30% occurring from day 10 reaching 99% in the next 20 days. Similarly, Kampi site had yield loss of 25% recorded on 20th day and peaked by 60% on the 30th day, respectively. Comparatively, yield loss at Ithookwe peaked on day 15th day and reached a plateau (10%) from 20th to 30th days.

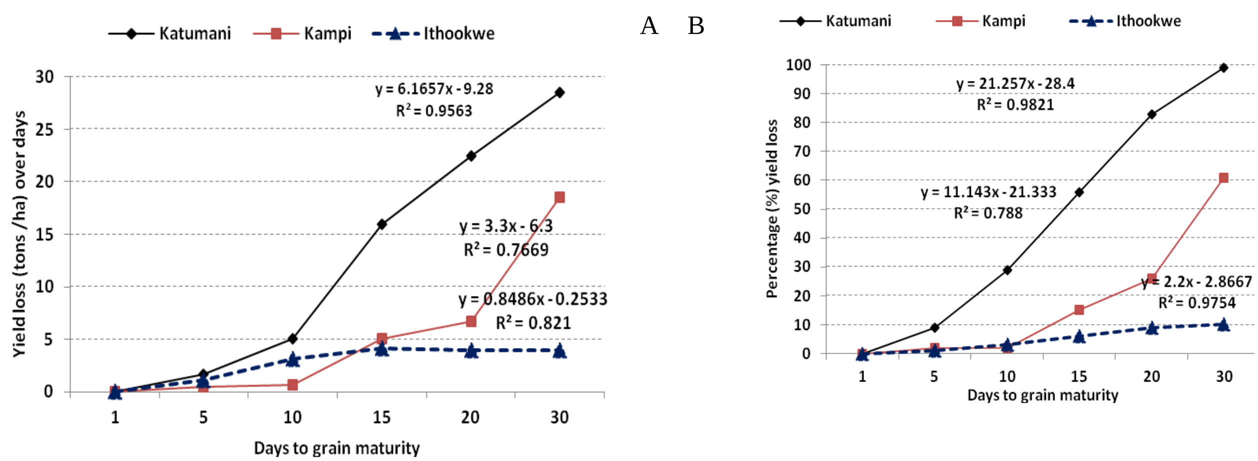

Figure 2: Sorghum yield loss due to bird attack over days at Katumani, Kampi and Ithookwe in Kenya

Grain physiological maturity

Sorghum physiological maturity was achieved on 20th day of the observation period at Katumani. This was when grain had attained 50% of hardening of the seed. This was noted as the time when 80% yield had already been lost to the birds (Figure 3).

The Kampi site sorghum attained grain maturity stage on 15th day with 10% yield loss. Similarly, grain maturity at Ithookwe was achieved on day 15 with less than 10% yield loss.

Bird risk and economic value

Even in the presence of bird menace farmers involved in sorghum production are likely to make huge benefits where Kampi site led with highest earnings of USD$ 4,740 (KES = 474,000) per hectare. The second least risk production area of sorghum was at Ithookwe with farm earnings being at US$ 3,860 (KES = 386,000). Katumani demonstrated the highest risk area of sorghum production due to expected yield loss as a result of bird menace where the farm earnings were only UD$ 840 (KES = 84,000) per hectare.

Table 2: Sorghum yield in tons/hectare under different production systems (treatments) of protected and unprotected panicles in interval observation of 1, 5, 10, 15, 20 and 30 days

	Site / Days	**1**		**5**		**10**		**15**		**20**		**30**		
Treatment	**Katumani**	Protect	Unprot.	Protect.	Unprot.	Protect	Unprot.	Protect	Unprot.	Protect	Unprot.	Protect.	Unprot.	*F-value* *P-value*
Pure sorghum		28.9a	28.8aA	29.0a	27.1aB	28.7a	23.7aC	28.6a	12.8aD	27.2a	6.3aE	27.1a	0.3aF	470.8 < 0.0001
Millet-alternate		24.2a	24.1aA	24.1a	21.7aA	24.2a	14.0aB	24.0a	10.8aB	24.0a	4.4aC	24.0a	0aD	57.1 < 0.0001
Millet-encircle		16.5a	16.6aB	23.1a	20.6aA	23.0a	16.2aB	16.5a	9.9aB	22.8a	2.0aC	3.4a	0.7aC	166.2 < 0.0001
F		0.77	0.68	0.76	0.78	0.73	0.76	0.74	0.69	0.76	1.2	0.73	1.3	
P		0.6031	0.6021	0.6030	0.6033	0.6122	0.6032	0.6023	0.5032	0.4034	0.2343	0.3454	0.3812	
	Kampi													
Pure sorghum		27.9a	28.6aAB	27.3a	28.8aA	28.0a	28.1aA	27.2a	23.8aB	28.3a	24.1aB	28.3a	10.1aC	43.4 < 0.0001
Millet-alternate		30.5a	30.1aA	30.6a	30.0aAB	30.2a	29.6aAB	30.3a	27.2aB	30.4a	24.0aC	26.5a	13.6aD	38.9 < 0.0001
Millet-encircle		24.1a	24.0aA	23.8a	23.9aA	23.8a	24.0aAB	24.1a	21.4aAB	24.0a	20.3aB	23.9a	10.2aC	20.0 < 0.0001
F		2.6	2.3	3.2	2.7	2.5	2.4	2.9	0.78	0.67	0.54	0.58	2.4	
P		0.1377	0.1234	0.1199	0.1378	0.1647	0.1361	0.1567	0.5978	0.1689	0.1278	0.1532	0.1321	
	Ithookwe													
Pure sorghum		23.7a	23.8aA	23.5a	24.1aA	23.3a	21.5aB	22.5a	21.3aBC	23.1a	20.8aBC	23.7a	20.4aC	37.8 < 0.0001
Millet-alternate		18.4a	19.0aA	18.1a	19.1aA	18.3a	18.0aA	18.1a	17.6aAB	18.2a	17.2aAB	18.4a	14.9aB	2.2 0.1515
Millet-encircle		22.7a	22.6aA	22.8a	22.2aA	22.6a	23.4aA	22.1a	18.9aB	22.5a	17.7aB	22.7a	16.4aC	50.7 < 0.0001
F		1.73	1.71	1.04	0.98	1.97	0.56	1.31	1.41	1.26	1.16	1.07	1.33	
P		0.2618	0.2108	0.1865	0.1765	0.3211	0.5743	0.2123	0.2322	0.3256	0.1465	0.2432	0.2134	

Similar lowercase letters within treatments indicate no significant ($P > 0.05$) yield difference among treatment at 5% level (Fisher's Least Significant Difference, df =2, 11). Different uppercase letters across sample periods on unprotected treatments denote significant ($P < 0.05$) difference among yield levels (LSD, df = 7, 17)

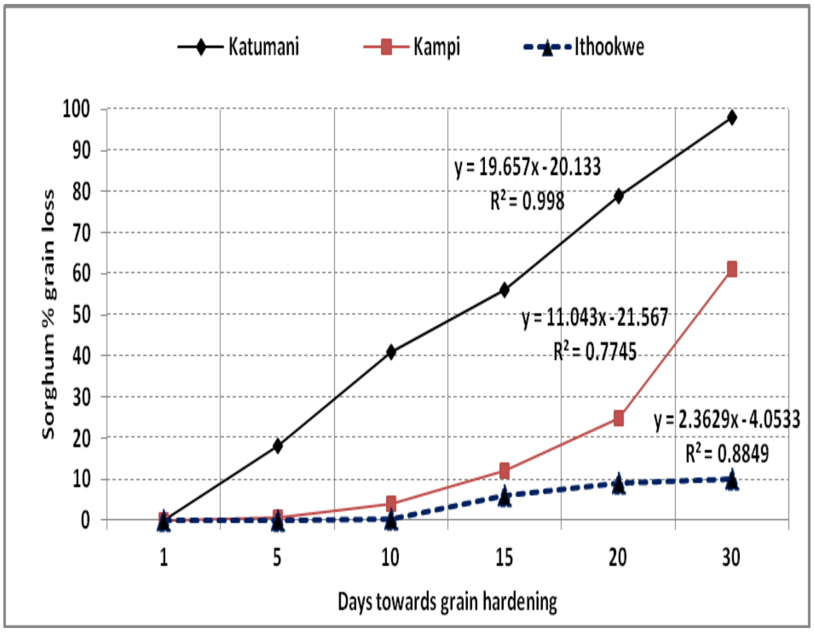

Figure 3: Percentage grain loss with increased sorghum grain maturity at Katumani, Kampi and Ithookwe

Table 3: Economic benefit of sorghum production in E. Kenya in the presence of bird damage risk status

Site	Tonnage /ha (kg)	Price US$	Farm earnings per hectare	
Katumani (Machakos)	4.2 (4,200)	0.2*	UD$840	KES 84,000
Kampi (Makueni)	23.7 (23,700)	0.2*	UD$4,740	KES 474,000
Ithookwe (Kitui)	19.3 (19,300)	0.2*	UD$3,860	KES 386,000

*US$ to Kenya Shillings (KES) = 100; (29/9/2015) and price of 1kg of sorghum Gadam at KES 20.

DISCUSSION

Various factors were analyzed in the present study related to bird damage menace on white sorghum of Gadam variety production in Eastern Kenya counties of Kitui, Machakos and Makueni. Millet as a trap crop for protecting sorghum against bird damage was partially effective at Kampi and Ithookwe sites where both crops matured together and attained grain ripening stage. This was not the case at Katumani where the colder weather delayed time of physiological maturity of sorghum and consequently birds moved on to feed on what other palatable grain was present being the slowly maturing milk kernels of sorghum. Roger (1978) reported on how birds in Ethiopia selected food material from most palatable to less palatable ones in absence of millet, rice and wheat. This led to use of Methiocarb as repellent of birds to protect sorghum against damage, reported as high as 80 and 60% in Ethiopia and Senegal, respectively (DeGrazio *et al.*, 1971; Rogers, 1974). In those years Methiocarb was used against birds on most crops inclusive of cherries as well as cereals (Guario *et al.*, 1979). The present results indicate some partial protection of sorghum grain when intercropped with millet, depending on the area and time of the production as most important level of hunger of the birds at the localities.

Highest bird infestation was recorded at Katumani plot where species *S. reichonowi* cumulatively reached over two thousand individuals. It was noteworthy that the *Q. quelea* species reported for its destructive potential was not recorded at Katumani in 2015. The second highest bird infestations on the treatment plots was at Kampi of *Q. quelea* at cumulative level of 842. Most of these bird species in Kenya are different from the ones reported in Ethiopia and Senegal besides *Q. quelea* species (Bruggers, 1976; Erickson *et al.*, 1980). Nevertheless feeding habits of bird species are closely related where on arrival they move about identifying the panicles of late soft dough ripening stage and start feeding from the top part of grain seed to the lower part of the panicle (Dyer and Ward, 1977). In most cases millet heads could not support more than one bird. This could serve as delayed feeding rate and less removal of grain from the plant.

Grain yield loss was highest at Katumani, corresponding to the highest bird infestation level, leading to 99-100% loss in the treatment plots. The second highest yield loss occurred at Kampi which had also the second highest bird numbers. Exploring the possibility of early harvest of sorghum grain as the birds fed on millet, it was noted that this would be at the physiological maturity of the grain more specific on the onset of late grain ripening stage. As a result of this scenario the highest yield was salvaged at Ithookwe of less than 10% grain loss compared to Katumani's 99%. The two crops matured at the same time and birds fed mostly on millet than on sorghum, giving enough time for latter to harden. It was noted that after 15 days period of observation no further increase beyond the 10% maximum loss was attained by the 30^{th} day. The results were excellent performance of preserving 19.3 t ha^{-1} of grain yield. The Kampi site had 40% of yield salvaged leading to valid profit from the sorghum production enterprise.

Yield value analysis at the two sites of Ithookwe and Kampi showed that it was possible to grow sorghum for real economic benefits even in the presence of bird damage, fetching between USD 3,860 and USD 4,740 within three months. This justifies why more farmers should grow more sorghum even in the presence of the menace of bird damage. Ogola and Mungai (2011) suggested that farmers should take advantage of increased corporate support from beer brewing industry and increase production levels. As more farmers enroll in production clusters bird damage will be minimally reduced per field as bird will be shared among the many sorghum plots, more so where the more palatable millet is incorporated in the production system.

CONCLUSION

The study has detailed that some partial benefits occur when sorghum is intercropped with millet. Birds visiting the field would be partially attracted to millet than sorghum grain. It was observed that higher sorghum yield was attained when millet physiological grain maturity synchronized with the former. The warmer environment makes sorghum and millet crops attain physiological grain maturity at the same time and thus the millet traps more avian pests visiting the fields.

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