Tanzania Journal of Science 45(4): 650-660, 2019 ISSN 0856-1761, e-ISSN 2507-7961

Crop Pests, Control Measures and Potential Impacts in Kihansi Catchment Area

Beatrice Pallangyo[1*], K. Mdily[1], C. Mkondo[1] and A. Kibola[2]
[1]*Plant Health Services, Ministry of Agriculture, Livestock and Fisheries, P. O. Box 9071, Dar es Salaam*
[2]*National Environmental Management Council, P. O. Box 63154 Dar es Salaam*
**Corresponding author, e-mail: beatricepallangyo@yahoo.com*

Abstract

A baseline survey which covered 349 households in Bomang'ombe and Masisiwe (Kilolo district), Kibengu and Mapanda (Mufindi district) and Chita and Chisano (Kilombero district) was conducted to identify major pests, control measures and potential impacts in Kihansi catchment area. Maize was the most predominant crop being cultivated by 55% of the total respondents in all the study districts. Pests and diseases were the major constraints to crop production, whereby cereal stem borers were the most serious pests being reported by 88.2% of respondents. Application of synthetic pesticides was the major pest control measure, being applied by 66% of the respondents. Increase in pest populations, decline of biodiversity and human health effects were reported by 85%, 61% and 38% of the respondents, respectively, as negative impacts associated with pesticides use. Dissemination of Integrated Pest Management (IPM) packages targeting the key crops and public awareness on good agricultural practices is recommended to sustainably manage the pests and enhance crop production, human health and biodiversity in the catchment.

Keywords: Pests, Pesticides, Good Agricultural Practices, Integrated Pest Management, Kihansi.

Introduction

Agriculture is the dominant sector in Tanzanian economy, providing livelihood, income and employment to over 80% of the population, accounting for 60% of export earnings and 56% of the country's Gross Domestic Product (GDP) (NBS 2015). It is an important economic sector in terms of food production, employment generation, production of raw materials for industries and generation of foreign exchange. Over 80% of the arable land is used by smallholders (NBS 2017). Food crops account for about 65% of agricultural GDP, with maize crop accounting for over 20% (NAP 2013). About 50% of the cultivated land in Tanzania is allocated to cereal crops (FAOSTAT 2014) which serve as major staple crops.

Maize is the most important cereal crop accounting for 70% of the cereals produced in the country; with per capita consumption being estimated at 80–135 kg/person/year (USDA 2018). Maize is also identified as a key crop to enhance food security and income (FAOSTAT 2015). Although maize is produced almost throughout the country, the southern highlands zone, which includes Iringa, Rukwa, Ruvuma, Njombe, and Mbeya regions, is the major producing area.

Rice is the second most important staple crop followed by wheat and sorghum. Of the total area under rice cultivation, rain fed lowland rice accounts for about 74%, whereas irrigated rice accounts for 26%, respectively (Kanyeka et al. 1994), with Morogoro region being one of the highest rice producing regions (MAFC2009, MALF 2011).

Average yield per hectare for cereals is mainly low with an average yield of 1.2 tons/ha (NBS 2015) which is lower than the

estimated potential yields of 4-5 tons/ha (NAP 2013). The main causes of low yields and sporadic production include pests and diseases, small landholding, drought stress, poor agricultural practices, high costs, poor access to inputs and poor infrastructure (Nyaligwa et al. 2017).

A baseline survey was therefore conducted to identify major crop pests occurring in the area, their control measures and potential impacts of the control measures in the Kihansi catchment in order to recommend mitigation measures.

Materials and Methods

Kihansi Catchment area, which covers three districts; Kilolo and Mufindi (Iringa region) in the upstreams, and Kilombero (Morogoro region) in the downstream of the Kihansi River, is among the major agricultural producing areas in Tanzania. The area is also significant in terms of biodiversity conservation including the Kihansi Spray Toads. The area has a diversity of climatic and geographical zones, which support the production of large quantities and a wide variety of crops.

Kilolo district has 4,181.8 km^2 of arable land with 1,810 ha of irrigated land including Ruaha and Mahenge valleys. The district lies between 900 and 2,700 metres above sea level, with temperatures ranging from below 15 °C to 29 °C and rainfall ranging from 500 to 1,600 mm per annum. Agriculture is main source of livelihood, employing about 90% of the district workforce (Kilolo District Agricultural Development Program, 2013).

Kilombero covers 445,896 ha of arable land with 655 ha of irrigated land that includes the Kihansi valley. It lies between less than 300 to 1700 metres above sea level with average temperature and rainfall ranging from 26 °C to 32 °C and 1200 to 1600 mm, respectively. The greatest part of the district is comprised of Kilombero valley, which consists of alluvial flood plains, while a part of it is in the Rufiji Basin and Selous Game Reserve, which extends to the Udzungwa Mountains. More than 80% of the population is involved in agriculture as a major source of food and income (Kilombero District Agricultural Development Program, 2012).

Mufindi district has mountainous landscapes with cool and rainy climate that supports the production of diverse crops including the temperate fruits.

Despite the agro ecological diversity, crop productivity is low due to crop pests, while the biodiversity conservation is at risk due to poor agricultural practices including the unjudicious use of pesticides near water sources.

The survey was conducted by the Ministry of Agriculture, Livestock and Fisheries in collaboration with the National Environment Management Council and funded by the Global Environmental Facility under Kihansi Catchment Conservation Project. It was conducted for two weeks towards the end of the rainy season in June 2015 covering three districts, namely; Kilolo, Mufindi and Kilombero.

A questionnaire designed by scientists from the Ministry of Agriculture, Livestock and Fisheries was used which covered information on major crops, pest types, inputs application (pesticides and fertilizers), pest control measures and associated impacts. The pre- testing of the questionnaire was conducted to enable familiarization, identification of gaps and make necessary adjustments. Focus Group Meetings (FGM) comprised of 10 people including District Agricultural Irrigation and Cooperatives Officers (DAICO), District Agricultural Extension Officers (DAEO) and District Plant Protection Officers (DPPO) were conducted in each district to enable the selection of wards and villages where the survey would be conducted. Two wards were selected from each district based on geographical locations and disparity of the farming systems. In each ward, key informants meetings involving Village Agricultural Extension Officers, Village Chairman, Village Executive Officers and paraprofessionals were conducted to

enable the selection of villages where survey would be conducted. Data were collected using a check list and structured questionnaires through key informants meetings, focused group discussions and household surveys.

A total of 349 respondents were interviewed from 12 villages sampled in 6 wards, which included Bomang'ombe and Masisiwe (Kilolo district), Kibengu and Mapanda (Mufindi district) and Chita and Chisano (Kilombero district) (Table 1). Coloured photographs were used to enable the identification of pests by the respondents. Photographs of pests and damage symptoms were taken as references in identification. Data editing involved the sorting and discarding of questionnaires with anomalies. The data from numbered questionnaires were coded and analysed using Microsoft Excel and Statistical Package for Social Studies (SPSS).

Table 1: Participating wards and villages in the baseline survey

District	Ward	Village	Number of respondents
Kilolo	Bomalang'ombe	Bomalang'ombe	32
		Mwatasi	36
	Masisiwe	Masisiwe	35
		Mbawi	21
Mufindi	Kibengu	Igeleke	30
		Kipanga	32
	Mapanda	Uhafiwa	28
		Ukami	30
Kilombero	Chita	Chita	31
		Udagaji	33
	Chisano	Chisano	17
		Mngungwe	24
Total	**6**	**12**	**349**

Results and Discussion

Types of crops

Several types of crops were cultivated in the survey area including cereals (maize, rice, wheat, sorghum and finger millet), legumes (common beans, garden peas, pigeon pea), round potatoes, vegetables (tomatoes, cabbage and onions), tropical fruits (oranges, mangoes and bananas), root crops (sweet potatoes and cassava), temperate fruits (avocado, plums and apple), oil seeds (sunflower) and perennial cash crops including tea, coffee, and cocoa. Table 2 shows the major crops cultivated by the respondents.

Table 2: Crop pests associated with maize, rice and round potatoes in Kihansi catchment area

Common name	Scientific name	Host crop
Spotted stem borer	*Chilo partellus*	Maize
Pink stem borer	*Sesamia calamistis*	
African Stalk borer	*Busseolla fusca*	
Elegant grasshopper	*Zenocerus elegans*	
Armyworm	*Spodoptera exempta*	
Cutworm	*Agrotis* spp	
Maize aphids	*Rhopalosiphum maidis*	
Maize leaf hopper	*Cicadulina mbila*	

Common name	**Scientific name**	**Host crop**
Termites	*Microtermes* spp	
White and chaffer grubs	*Phyllophaga* spp.	
Large grain borer	*Prostephanus truncatus*	
Maize lethal necrosis disease (MLND)		
Maize stalk and ear rot		
Maize streak (maize streak virus–MSV		
Maize smut	*Ustilago maydis*	
Mycotoxins	*Aspergilus* spp. *Fusarium* spp.	
Dark headed stem borer	*Chilo polychrysa*	Rice
Stalk-eyed fly	*Diopsis*	
African rice gall midge	*Orseolia oryzivora*	
African armyworm	*Spodoptera exempta*	
Rice whitefly	*Auleurocybotus occiduus*	
Stink bugs	*Aspavia armigera*	
White tip nematode	*Aphelenchoides hesseyi*	
Rice blast	*Pyricularia grisea*	
Rice Bacterial leaf blight	*Xanthomonas oryza e*pv. *Oryzae)*	
Rice yellow mottle virus diseases (RYMV)		
Leaf miner	*Liriomyza spp*	Round Potatoes
Potato cutworm	*Agrotis spp.*)	
Aphids	*Myzus persicae*	
Whitefly	*Bemisia tabaci*	
Red spider mites	*Tetranynchus spp.*	
Root knot nematodes	*Meloidogyne spp*	
Early blight	*Altenaria solani*	
Late blight	*Phytophthora infestans*)	
Bacterial wilt	*Ralstonia solanacearum*	
Fusarium wilt	*Fusarium oxysporum*	
Rhizoctonia canker	*Rhizoctonia solani*	
Weeds		
Wood sorrels	*Oxalis spp.*	
Nuts and sedges	*Cyperus spp.*	
Goat weed	*Argeratum conyzoides*	
Fern plant	*Polypodium vulgare*	
Mexican poppy	*Argemone mexicana*	
Black jack	*Bidens pilosa*	
Spurge	*Euphorbia spp.*	
Wild marigold	*Sida spp.*	
Pigweed	*Amaranthus spp.*	
Fanpetals	*Tegetes minuta*	
Wild rice	*Oryza longisterminata*	

Common name	Scientific name	Host crop
Cogon grass	*Imperata cylindrical*	
Wandering jew	*Commelina bengalensis*	
Spurges	*Euphorbia spp*	
Goat weed	*Argeratum conyzoides*	
Witch weed	*Striga* spp	
Itch grass	*Rottboelia exaltata*	
Guinea grass	*Panicum maxima*	
Goose grass	*Eleucine indica*	
Jungle rice	*Echinochloa* spp	
Nutgrass/nut sedge	*Cyperus* spp.	

Among the crops, maize, beans, rice, round potatoes, peas and finger millets were the most predominantly cultivated. Maize was cultivated most by 55% of the total respondents in all the districts, followed by beans (32.5%), peas (24.6%), rice (17.5%), round potatoes (13.6%) and finger millets (9.8%) (Figure 1). The leading producing area for maize, beans, peas and round potatoes was Bomang'ombe ward (Kilolo district) by 100, 80, 61 and 51% of the respondents, respectively. The leading producing area for rice was Chita ward (Kilombero district), whereby 63% of the respondents cultivated the crop. Finger millets were predominantly cultivated in Mapanda ward (Mufindi district) by 10% of respondents; which is lower compared to those who cultivated other crops.

Distribution of the crops varied according to agro ecological conditions. For example, beans, peas and round potatoes, which prefer high elevation, cool temperatures, and well-drained soil with adequate moisture, were predominantly cultivated in Kilolo and Mufindi districts where such conditions are found. On the other hand, rice crop which prefer low altitude, warm temperatures and clay loamy soils was predominantly cultivated in Kilombero district.

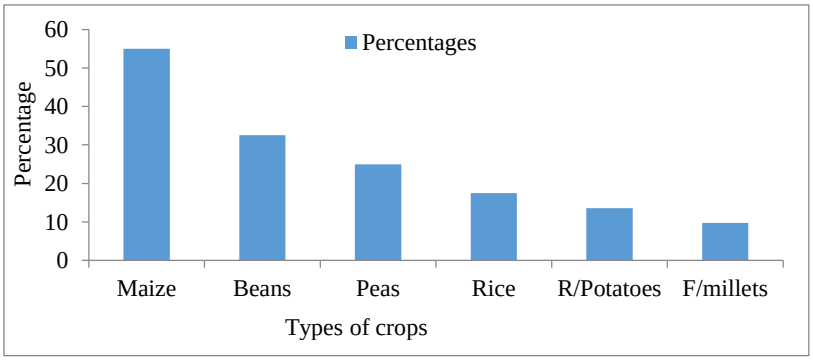

Figure 1: Types of crops cultivated in Kihansi catchment.

Crop yields

More than 80% of respondents harvested less than 25 bags of maize/acre (Figure 2). The reported yields were low compared to the estimated national average yield of 1.2 tons/ha (NBS 2015) and 4-5 tons/ha (NAP 2013). Yields for rice were also low, whereby only 4.3% of the respondents harvested more than 15 bags/acre. Yields of beans and peas were also low with only 8.3 and 9.7% harvested more than 7 and 5 bags of the crops/acre, respectively.

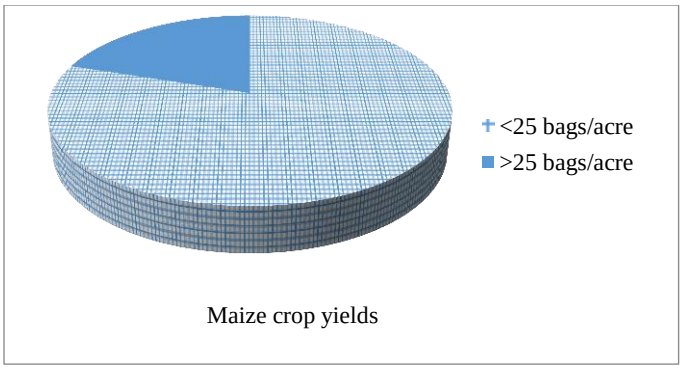

Figure 2: Maize crop yields in Kihansi catchment.

Agricultural practices

At least 60% of respondents reported to own small pieces of land ranging from 0.5 to 3 acre where crops were cultivated either in intercropping or monocropping systems. Due to land scarcity and the topography of the area, cultivation was done even on hillsides and valley bottoms near water catchments. The size of the land reported by the respondents is small compared to typical farm size owned by smallholder farmers in Tanzania, which ranges between 0.2 and 2.0 hectares (NAP 2013), a production scale that is too low to generate significant income streams to farmers for effective poverty reduction and agricultural development.

The types of fertilizers which were applied in the survey area include triple super phosphate (TSP), double ammonium phosphate (DAP), Minjingu rock phosphate (MRP) and urea. A moderate proportion (59.3%) of respondents reported to apply those fertilizers, while less than 10% applied inorganic fertilizers and 40% did not apply any fertilizer (Figure 3). The recommended amount of fertilizers is 10 bags of 50 kgs per acre. Among those who applied fertilizers, 49% applied less than10 bags/acre. Reasons for not using or using low dose rates of fertilizers were reported to be high prices and delay in distribution of the fertilizers. Majority of respondents (86.8%) reported to have observed a decline in soil fertility in the crop lands (Figure 4). which can be associated with continuous use of the land without replenishing the nutrients (Tan et al. 2005).

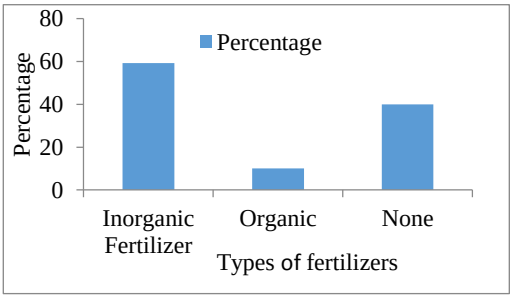

Figure 3: Types of fertilizes applied by farmers in Kihansi catchment.

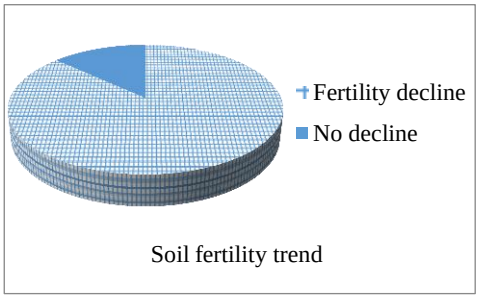

Figure 4: Soil fertility trend in Kihansi catchment.

Types of crop pests

A diversity of crop pests were reported in association with the crops cultivated in Kihansi catchment area (Table 2). Cereal stem borers were the most widespread pests reported by 88.2% of the respondents followed by aphids (35.8%), armyworm (17.5%), cutworm and grubs (15.4% each), rice yellow mottle virus disease (13.7%), whiteflies (9.7%), larger grain borer (9.4%) and Fusarium wilt (9.1%). Within the wards, Bomangombe (Kilolo district) had the highest proportion of respondents who reported stem borers (64%), Fusarium wilt (23%), cutworms (17%), larger grain borer (15%) and whiteflies (14%) as the most serious pests (Figure 5). Chita ward (Kilombero district) had the highest proportion of respondents who reported white grubs (33%), rice yellow mottle virus (RYMV) (32%) and armyworm (27%) as the most serious pests. Mapanda ward (Mufindi district) had the highest proportion (38%) of respondents who reported aphids as the most serious pests.

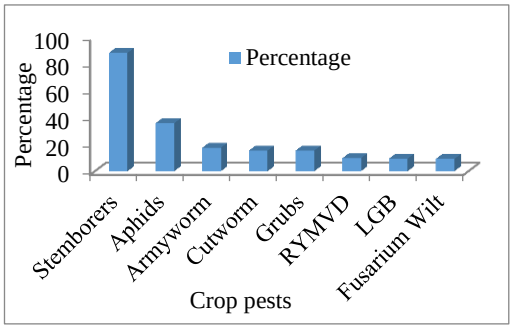

Figure 5: Crop pests in Kihansi catchment.

Distribution of the pests corresponds to the distribution of the host crops. For example, the highest proportion of respondents who reported stem borers as the most serious pests belonged to Bomangombe ward where maize was reported as a major crop, while Masisiwe ward with the least proportion of respondents who reported maize as major crop had the least stem borers. Similarly, for rice crop whereby the highest proportion of respondents who reported rice yellow mottle virus disease as the most serious pest were from Chita ward, where rice was reported as the major crop (Figures 1 and 5). On the other hand, cutworm, whiteflies and aphids, which had a wide range of host crops including maize, rice, round potatoes and vegetable crops were widely distributed, though in less percentage compared to other pests.

Species diversity, distribution and damage due to stemborers have been reported (Nsami et al. 2001, Pallangyo et al. 2002, Le Rü et al. 2006a, 2006b). Maize yield losses of up to 63 and 100% have been reported due to *Chilo partellus* and *Busseola fusca*, respectively, while yield losses of up to 45% and 87% were reported due to larger grain borer and cutworm, respectively (Chabi-Olaye et al. 2005, Mgoo et al. 2006, Golob 1988, Showers et al. 1983). Yield losses of up to 100% have also been reported in maize crop due to RYMVD (Abo et al. 1997). Other pests are reported to transmit diseases such as Cassava Brown Streak Disease (CBSD) and Cassava Mosaic Disease (CMD) (Legg et a. 2011, Mware et al. 2009, Navas-Castillo et al. 2011). Losses in maize yield and mycotoxin contamination are also reported due to Striga weed and storage pests infestation (Suleiman and Rosentrater 2015, Soltani et al. 2016).

Occurrence of those pests in the catchment area could therefore be associated with the low crop yields reported by the respondents.

Pest control measures on major crops cultivated in Kihansi catchment area

Pest control measures included the use of synthetic pesticides, botanicals and cultural methods (mechanical, rouging, crop rotation). Generally, use of synthetic pesticides was the most widely adopted method applied by 66% of the respondents from all the districts. Cultural control measures were applied by 21% of respondents and botanical pesticides by 1.7%, while 11.3% of the respondents applied all measures, i.e., synthetic pesticides, botanical pesticides and cultural control

measures (Figure 6). Bomang'ombe ward had the highest proportion (95%) of respondents who applied synthetic pesticides followed by Kibengu ward with 56%. Unlike synthetic pesticides which were applied in all wards, cultural practices were applied by respondents from Chita, Chisano and Mapanda wards with Chita ward having the highest proportion (30%). Less than 10% of the respondents, mainly from Chisano ward applied botanical pesticides.

Impacts of pest control measures to the Kihansi catchment environment

Regarding the impacts of pesticides to the environments, majority of the respondents (85%) reported to have observed an increase in pest populations in their fields, while 61% reported a decline of biodiversity. Some of the respondents (52%) reported to have observed water pollution and 38% reported to have experienced headaches, vomiting, nausea and skin irritation, which were considered to be associated with pesticides because they occurred during or after applications of the pesticides (Figure 7).

The increase in pest populations which was reported by respondents could be associated with continuous uses of broad spectrum pesticides. Overuse of pesticides has been reported to cause insect resistance to insecticides, and development of secondary pests (Catarino et al. 2015), while the use of broad-spectrum pesticides was reported to hamper the contribution of natural enemies leading to increase of pest population densities (Abrol et al. 2003). Decline in biodiversity could be associated with the use of hazardous pesticides such as endosulfan, which has been reported to cause mortality to aquatic organisms (Nyangababo et al. 2005). Alternative measures are therefore needed to reduce pesticide resilience in the catchment area.

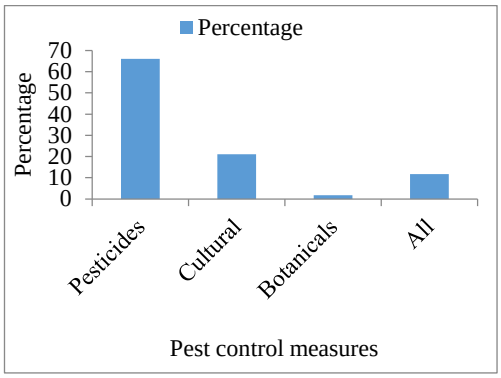

Figure 6: Pest control measures in Kihansi catchment.

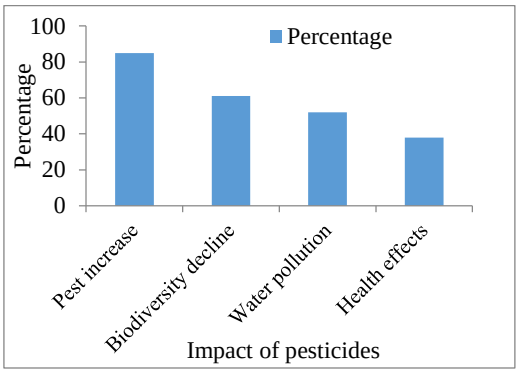

Figure 7: Impacts of pesticide applications in Kihansi catchment.

Biological control and cultural practices including intercropping and use of resistant varieties are among measures that can reduce pest population and associated damage without causing adverse negative impact to the environment. Successful reduction of stem borers, whiteflies, aphids, cutworms and white grubs populations densities have been achieved through biological control (Pallangyo et al. 2003, Pallangyo et al. 2005, Anderson and Morales 2005, Mwanauta et al. 2015). Successful reduction of striga weed through inter- cropping and Push Pull Habitat Management are also reported (Massawe et al. 2002, Pallangyo et al. 2006a, 2006b, Nyaligwa et al. 2017). Integrated Pest Management (IPM) that focuses on the use of many compatible methods can reduce Diamondback moth and aphids with minimal pesticides requirement (Varela et al. 2003).

Conclusion

The findings show that crop pests are the major constraints to crop production in the Kihansi catchment area. Farmers rely on synthetic pesticides as pest control measures. However, continuous use of pesticides tend to increase pest populations leading to reduction in crop yields; decline in biodiversity and human health effects. Integrated Pest Management involving the use of beneficial organisms, host plant resistance, cultural measures and judicious use of pesticides will minimize pesticides resilience leading to enhanced crop yields, food security, biodiversity and human health.

Acknowledgement

Authors are thankful to the Global Environmental Facility (GEF) for providing research funds through the Kihansi Catchment Conservation and Management Project being implemented under the National Environment Management Council (NEMC).

References

Abrol DP and Singh JB 2003 Effect of insecticides on the resurgence of the red spider mite, *Tetranychus cinnabarinus* Boisdual on brinjal in Jammu, India *J. Asia-Pacific Entomol.* 6(2): 213-219.

Abo ME, Sy AA and Alegbejo MD 1997 Rice yellow mottle virus (RYMV) in Africa: evolution, distribution, economic significance and sustainable rice production and management Strategies. *J. Sustain. Agric.* 11: 85-111.

Anderson PK, Morales FJ (eds) 2005 Whitefly and whitefly-borne viruses in the tropics: building a knowledge base for global action. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 351 p. (CIAT publication No. 341).

Catarino R, Ceddia G, Arael F and Park J 2015 The impact of secondary pests on *Bacillus thuringiensis* (Bt) crops. *Plant Biotechnol. J.* 13: 601–612.

Chabi-Olaye A, Nolte C, Schulthess F, and Borgemeister C 2005 Effects of grain legumes and cover crops on maize yield and plant damage by *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) in the humid forest of southern Cameroon *Agric. Ecosyst. Environ.* 108(1): 17-28.

FAOSTAT 2014 Africa maize production-2012/13. http://faostat3.fao.org/browse/Q/QC/E. Accessed on November 10, 2014.

FAOSTAT 2015 Country profile. United Republic of Tanzania. Online available at http://faostat3.fao.org/home/E. Accessed on March 3, 2015.

Golob P 1988 Current status of the larger grain borer Prostephanus truncatus (Horn) in Africa. *Int. J. Tropical Insect Sci.* 9(6): 737-745.

Kanyeka ZL, Msomba SW, Kihupi AN and Penza MF 1994 Rice Ecosystems in Tanzania: Characterization and classification. *Tanzania Agricultural Research and Training Newsletter* 9: 13-15, Ministry of Agriculture Food Security and Cooperatives.

Legg JP, Jeremiah SC, Obiero HM, Maruthi MN, Ndyetabula I, Okao-Okuja G, Bouwmeester H, Bigirimana S, Tata-Hangy W, Gashaka G, Mkamilo G and Alicai T, Kumar LP 2011 Comparing the regional epidemiology of the cassava mosaic and cassava brown streak virus pandemics in Africa *Virus Res.* 159: 161–170.

Le Ru B, Ong'amo G, Moyal P, Ngala L, Musyoka B, Abdullah Z, Cugala D, Defabachew B, Hailei T, Matama-Kauma T, Lada VY, Negassi K, Pallangyo B, Ravolonandrianina J, Sidumo A, Omwega , Schulthess F, Calatayud P and Silvain J 2006a Diversity of lepidopteran stem borers on monocotyledonous plants in eastern Africa and the Islands of Madagasca and Zanzibar revisited**.** *Bull. Entomol. Res*. 96(6): 555-563.

Le Rü B, Ong'amoG, Moyal P, Muchugu E, Ngala P, Musyoka B, Abdullah Z,

Matama-Kauma T, Lada V, Pallangyo B, , Omwega CO, Schulthess F, Calatayud P and Silvain JF 2006b Geographical distribution and host plant ranges of East African noctuid stem borers.In *Annales de la Société Entomologique de France* (Vol. 42, No. 3-4, pp. 353-361), Taylor & Francis Group.

MALF (Ministry of Agriculture, Livestock and Fisheries) 2011 Tanzania Agriculture and Food Security Investment Plan (TAFSIP) 2011-12 to 2020-21 Main Document. www.kilimo.go.tz.

MAFC (Ministry of Agriculture Food Security and Cooperatives) 2009 National Rice Development Strategy. The United Republic of Tanzania.

Massawe CR, Kaswende JS, Mbwaga AM and Hella JP 2002 On-farm verification of maize/cowpea intercropping on the control of Striga under subsistence farming. Integrated Approaches to Higher Maize Productivity in the New Millennium. In Proceedings of the 7th Eastern and Southern Africa Regional Maize Conference. 5-11 Feb 2002, Nairobi (Kenya), pp. 165-167.

Mgoo VH, Makundi RH, Pallangyo B, Schulthes F, Jiang N and Omwega C 2006 Yield loss due to the stemborer *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) at different nitrogen application rates to maize. In *Annales de la Société Entomologique de France* (Vol. 42, No. 3-4, pp. 487-494). Taylor & Francis Group.

Mwanauta R, Mtei K and Ndakidemi P 2015 Potential of controlling common bean insect pests (bean stem maggot (*Ophiomyia phaseoli*), Ootheca (*Ootheca bennigseni*) and Aphids (*Aphis fabae*) using agronomic biological and botanical practices in field *Agric. Sci.* 6: 489-497.

Mware B, Narla R, Amata R, Olubayo F, Songa J, Kyamanua S and Ateka M 2009 Efficiency of cassava brown streak virus transmission by two whitefly species in coastal Kenya *J. Gen. Mol. Virol*. 1(4): 040-045.

Navas-Castillo J, Fiallo-Olivé E and Sánchez-Campos S 2011 Emerging virus diseases transmitted by whiteflies. *Ann. Rev. Phytopathol*. 49: 219-248.

NAP (National Agricultural Policy) 2013 Economic Survey 2012 Ministry of Agriculture Livestock and Fisheries Dar es Salaam, Tanzania pp 2.

NBS (National Bureau of Statistics) 2015 Annual Agricultural Sample Survey Report 2014/15. National Bureau of Statistics, Dar es Salaam, Tanzania.

NBS 2017 National Population Projection Tanzania National Bureau of Statistics.

Nsami E, Pallangyo B, Mgoo V and Omwega C 2001 Distribution and species composition of cereal stemborers in the eastern zone of Tanzania. *Int. J. Tropical Insect Sci.* 21(4): 347-351.

Nyaligwa L, Hussein S, Laing M, Ghebrehiwot H and Amelework B 2017 Key maize production constraints and farmer's preferred traits in the mid altitude maize agroecologies of northern Tanzania *S. Afr. J. Plant Soil* 34(1) : 47-53.

Nyangababo J, Henry L and Omutange E 2005 Organochlorine pesticide contamination in surface water, sediment, and air precipitation of Lake Victoria Basin, East Africa. *Bull Environ. Contam. Toxicol*. 75: 960-967.

Pallangyo B, Mgoo V, Nsami E, Sithanantham S and Matoka C 2003 Egg parasitoid species of African bollworm *Helicoverpa armigera* in Tanzania. A paper presented in the workshop on African Bollworm Bio Control and Vision for Future, held at ICIPE Nairobi, Kenya 4–7 June 2002, ICIPE Science Press, Nairobi.

Pallangyo B and Omwega C 2002 Cereal stemborer species composition and distribution and their control in Tanzania. Proceedings of Integrated Pest Management Conference for Sub–Saharan

Africa held at Hotel Equatoria, Kampala, Uganda 8–12 September 2002.

Pallangyo B and Katundu J 2006a Biological Control: Theory and practices for selected pests in Tanzania. In Makundi R (Ed) *Management of selected crop pests in Tanzania* pp 355-374.

Pallangyo B, Nsami E, Mgoo V, Mkonyi S, Khan Z Pickett J and Wadham L 2006b Implementation and dissemination of push-pull habitat management strategies for stemborer and striga weed in maize based systems of Eastern Tanzania. Workshop Report on Scalling up Farming Technologie: Building on MATF projects' achievements. 3rd MATS Experience Sharing Workshop Arusha, Tanzania 5–9th June 2006, pp 41-43. (www.farmafrica.org/downloads/resources/MATFGrantholders-Report.3.pdf)

Pallangyo B, Nsami E, Mgoo V, Schulthes F and Omwega C 2005 Release, establishment and spread of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) in Tanzania. Programme and list of Abstracts; International Conference of Lepidopteran Cereal Stem and Cob borers in Africa. Duduville, Nairobi Kenya 24th–28th October 2005 pp. 39 (http://www.egce.cnrs-gif.fr/wp content/uploads/2014/09/DEEIT_PAGE_ Colloque_ICLCBA.pdf).

Tan ZX, Lal R and Wiebe KD 2005 Global soil nutrient depletion and yield reduction. *J. Sustain. Agric*. 26(1): 123-146.

Suleiman RA and Rosentrater KA 2015 Current maize production, postharvest losses and the risk of mycotoxins contamination in Tanzania 2015 ASABE *Annual International Meeting Paper Number: 152189434 (*http://lib.dr.iastate.edu/abe_eng_conf/442).

Soltani N, Dille JA, Burke IC, Everman WJ, VanGessel MJ, Davis VM and Sikkema PH 2016 Potential corn yield losses from weeds in North America. *Weed Technol.* 30(4): 979-984.

Showers WB, Von Kaster L and Mulder PG 1983 Corn seedling growth stage and black cutworm (Lepidoptera: Noctuidae) damage. *Environ. Entomol*. 12(1): 241-244.

USDA 2018 Grain and feed annual 2018 Tanzania corn, wheat, and rice report, USDA Foreign Agricultural Service, Gain Report-Global Agricultural Information Network, Washington.

Varela AM, Seif A and Lohr B 2003 A Guide to Integrated Pest Management in Brassicas Production in Eastern and Southern Africa (No. 2003: 14). The International Centre of Insect Physiology and Ecology (ICIPE).