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Editorial

Promoting dissemination and application of African Universities' research outputs

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ABSTRACT

In the current context of demographic explosion, particularly in Sub-Saharan Africa, empirical research on aspects that relate to livelihoods is deemed to have considerable long-term implications for societal well-being and sustainable development. Whereas these aspects are various and include a wide range of specific issues from agriculture and food security to health sciences and environment, it is increasingly becoming evident that impacts on society are greater when research outputs are practical and locally exploitable. This editorial introduces the third issue of the fourth volume of the African Journal of Rural Development (AFJRD: Vol. 4, Issue 3), which presents seven research and one review papers on topics that are relevant to the journal audience. In particular, the issue highlights research studies that have investigated complementary aspects of (i) livestock productivity; (ii) crop productivity and marketing; and (iii) interdisciplinary research capacity and scholarly publishing in African universities. The work presented in this issue provides recommendations that enable livestock farmers attain profitable returns and assure economic sustainability of dairy, piggery and small ruminant farming. Further, it highlights the importance of managing infected soil and debris to address the spread and control of plant pathogens. Finally, the results of the studies in this issue highlight some of the challenges faced by universities in Africa in producing original research output and building research collaboration, in particular, the need to evaluate existing capacities and map out strategic areas of development in higher education institutions. Our goal in collating and sharing these findings is to catalyze understanding of the issues being addressed, promote research application and facilitate advancement in scientific research on the continent.

Key words: African universities; agricultural productivity; livelihoods; plant breeding; postharvest stability

RÉSUMÉ

Dans le contexte actuel de poussée démographique, plus particulièrement en Afrique subsaharienne, la recherche scientifique sur des aspects liés aux conditions de vie des populations a d'importantes implications pour le bien-être social et le développement durable. Quand bien même ces aspects couvrent des questions spécifiques dans des domaines variés de l'agriculture aux sciences de la santé, il demeure de plus en plus évident que l'impact sur la société est encore plus important si les résultats de recherche sont pratiques et exploitables. Cet éditorial présente le troisième numéro du quatrième volume de la Revue Africaine pour le Développement Rural (AFJRD: Vol.4, Numéro 3), avec sept articles de recherche et une revue sur des sujets pertinents pour les lecteurs. En particulier, il met en évidence des études qui ont examiné des questions de recherche sur

(i) la productivité animale; (ii) la productivité agricole et la commercialisation; puis (iii) la capacité de recherche interdisciplinaire et la publication dans les universités en Afrique. Les travaux présentés dans ce numéro mettent en exergue des recommandations qui permettent aux éleveurs d'atteindre des rendements rentables et d'assurer la durabilité économique de leur élevage. De plus, il souligne l'importance de gérer le sol et les débris infectés pour contrôler et lutter contre la propagation des phyto-pathogènes. Enfin, les résultats des études dans ce numéro soulignent quelques défis auxquels sont confrontées les universités en Afrique en ce qui concerne la production des résultats de recherche originale et la collaboration, en particulier la nécessité d'évaluer les capacités existantes et de définir des domaines stratégiques de développement. Notre objectif en rassemblant et en partageant ces résultats est de catalyser la compréhension des problèmes abordés, de promouvoir la recherche scientifique et son application sur le continent.

Mots clés: Universités africaines; productivité agricole; moyens de subsistance; amélioration des plantes; stabilité après récolte

INTRODUCTION

Improving the quality of life in rural areas and the economic well-being of people has not only remained a constant goal but also and long term challenge. Worldwide, rural areas are undergoing rapid transformations caused by demographic explosion, policy interventions, environmental change and globalization, among other processes. Sustaining both rural development and improved livelihoods requires practical solutions that target social expectations. The importance of quality research output for local development is acknowledged, widely. Scientific outputs are critical to pave the way to develop new innovations or technologies, solve practical problems, and make informed decisions. They also contribute to build knowledge and satisfy curiosity. In the current context of demographic explosion, particularly in Sub-Saharan Africa, evidence based research on aspects that relate to livelihoods is deemed to have considerable long-term implications for societal well-being, development and sustainability.

The agriculture sector has remained a vital pillar across the African continent, as it provides employment for millions. Improved agricultural productivity is central to achieving inclusive development and reducing poverty (Akande et al., 2017). However, Sub-Saharan Africa, like many parts of the world, has long been grappling with challenges related to growth and development, notably decreasing agricultural productivity, food insecurity and malnutrition. Research providing solutions along the agricultural value chain can significantly contribute to enhancing the living standards of most people in sub-Saharan Africa, but these research outputs are practical and locally exploitable only if they reach the right audience.

The African Journal of Rural Development (AFJRD), like many other development-oriented journals, contributes to facilitate dissemination of research outputs deemed to significantly promote changes in the society. In this third issue of the fourth volume, scientists sought to address specific questions along the agricultural and educational value chains and discussed how these findings can inform interventions in the agriculture and education sectors. Our goal in collating and sharing these findings is to catalyze understanding of the issues being addressed, promote research application and facilitate advancement in scientific research on the continent.

Highlights

Papers in this third issue highlights various topics that are relevant to the journal audience. In particular, the issue highlights among others, studies that have investigated aspects on (1) livestock productivity; (2) crop productivity and

marketing; and (3) interdisciplinary research capacity and scholarly publishing in African universities. In this editorial, we the shed some lights into the context and applicability of these findings.

Livestock productivity

In places where the lands are arid smallholders farmers make they living by keeping and raising livestock. In smallholder dairy farms, milk production is often intensified through genetics, ecological and socioeconomic interventions, but viability of the interventions may be an impediment towards sustainability. Agutu *et al*. (2019) studied the relationships between herd productivity indicators and intensification interventions within smallholder dairy farms to inform management interventions for sustainable dairy farming in Kenya. Using a cross-sectional survey, these authors showed that socioeconomic interventions (concentrate use and milk sales) had the greatest contribution to both milk yield and margins earned while both genetic (insemination cost) and ecological (manure recycling) interventions had little influence. Thus, the use of dairy inputs especially concentrates will enable farmers attain profitable returns and assure economic sustainability of dairy farming. However, the authors recognized the importance of an enabling environment for supporting intensification of dairy production because unreliable milk markets can impede commercialization and discourage intensification process.

Beyond, dairy farming, piggery production is common as income generating activity among smallholder farmers in East Africa. However, as a result poor market linkages, pig farmers, particularly in Uganda are taken advantage of by middlemen who pay low prices, recline the weight of pigs and default on payments. Building on the potential of farmer innovation, Mugonya *et al*. (2019) examined the influence of socio-economic factors on the phases of innovation behaviour among pig farmers in Northern Uganda. They found that that personal selling affects all phases of innovation behavior, while access to extension and credit services boosts farmers' adaptation and modification of technology, thus ensuring competitive and sustainable. They suggested that interventions

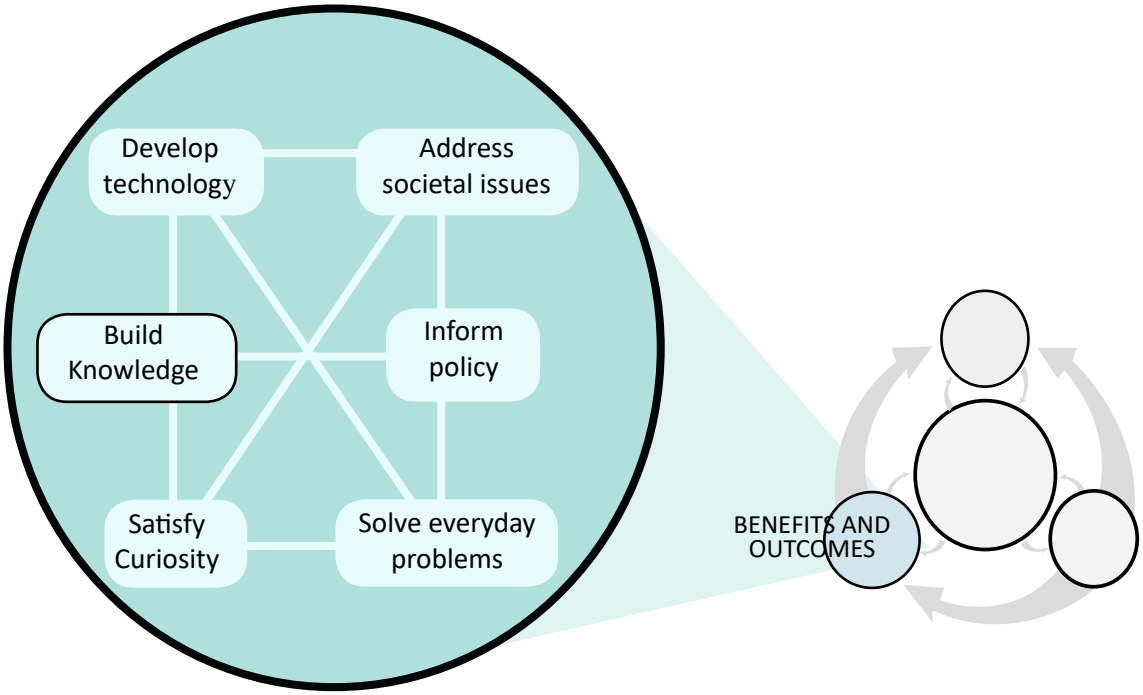

Figure 1. The benefits of science. https://undsci.berkeley.edu/article/0_0_0howscience works_18

for improvement of the pig value chain should encourage farmers to actively involve themselves in marketing their pigs so as to earn better prices (Mugonya *et al*., 2019). This is more valid for pig farmers operating in poorly developed value chains. They further argue for the need to entrench farmer financial inclusion and the use of well-trained agricultural extension agents to offer agricultural educational programs and trainings to pig farmers for better farmer innovation and gains.

The third paper that addressed livestock productivity in this issue was presented by Ogolla *et al*. (2019), with a specific focus on coccidiosis control in rabbit farming. Coccidiosis is known as the most common and devastating disease, with in huge economic losses (Bhat *et al*., 1996). In Kenya, most farmers rely on poultry-based synthetic chemical anticoccidials for both prevention and treatment rabbit coccidiosis in Kenya. As such, they use unreliable poultry dosages with little or no knowledge of their safety and efficacy against rabbit coccidian parasites. Ogolla *et al*. (2019) studied the efficacy of three most commonly used off label (poultry based) anticoccidials in treatment of rabbit coccidiosis by smallholder rabbit farmers in Kenya. They recommend prudent use of available efficacious anticoccidial drugs in the country to prevent development of resistance.

Crop productivity and marketing

With the current demographic explosion, agriculture remains the most significant pillar to achieve food security, economic growth and development. Whereas, gross domestic product (GDP) in Sub-Saharan Africa increased slightly from 2000 to 2014, aggregate agricultural productivity growth has remained low, and poverty reduction discouragingly slow. Ramping up agricultural productivity will be critical to reducing malnutrition, increasing farmers' income and lifting rural households out of poverty. In this issue, two papers addressed crop productivity and marketing (Kimani *et al*., 2019; Nyakundi *et al*., 2019).

Nyakundi *et al*. (2019) research focused on ways to eliminate crops pathogens to increase productivity. The work investigated the transmission of maize lethal necrosis disease causing viruses focusing crop debris and soil. They built their study on assumption that plant debris and contaminated soil play an important role in the epidemiology and management of the disease. From a greenhouse experiment, Nyakundi *et al*. (2019) found that infected soil and debris are crucial in the survival and spread of the viruses causing maize lethal necrosis disease. They argued for the need to put measures in place to ensure maize debris are appropriately managed, and to encourage farmers to carry out crop rotation to reduce the chances of picking the viruses from the infected soil. Nyakundi *et al*. (2019) study thus shed light into the importance of managing infected soil and debris to address the spread and control of plant pathogens.

A review paper by Kimani *et al*. (2019) in this issue highlights market-oriented approaches for legume breeding in eastern Africa. The authors presented a brief review of the evolution of market-oriented legume breeding from 1970 to 2000, and provided evidence of progress made to date. Kimani *et al*. (2019) argue that demand-led approach is business oriented, and based on six cardinal principles: client preferences, value chain analysis, market research, market trends and drivers, integration of public and private sector expertise, and a multidisciplinary approach in variety design and solution development. They suggest that application of this approach requires breeders to learn new skills, working with non-traditional partners and understanding market dynamics.

Interdisciplinary research capacity and scholarly publishing in African universities.

Two papers in this issue fall under this sub-section (Awaah and Munkaila 2019; Ekepu and

Egeru 2019). These papers address different aspects of research and publication in higher education institutions. For instance, Awaah and Munkaila (2019)'s study particularly dealt with scholarly publishing, with focus on students' misconduct in Sub-Sahara African higher education institutions. The authors found that the most prevalent form of student related academic corruption is plagiarism (75.6%) with the least being 'falsification of entry results' (45.1%). They recommend appropriate measures to curb the menace.

Interdisciplinary research is being widely accepted as suitable approach for addressing complex global development challenges. Nevertheless, its applicability within the African research context is still at its embryonic stage (Ekepu and Egeru 2019). Building from a cross-sectional survey, Ekepu and Egeru (2019) provides some insights into an assessment of research capacity of African universities. The authors found that African universities are engaged in international networks, conduct collaborative research, and take a strategic approach to management, reward faculty for publications, participating in conferences and professional organizations. They recommend strengthening research support, supervision and mentorship structures and stress the need for universities to evaluate their existing capacities and map out strategic areas of development as key ingredients for fostering interdisciplinary in African universities.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there have been no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

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Advances in market-oriented approaches for legume breeding in eastern Africa

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ABSTRACT
The overall objective of plant breeding is genetic improvement of whole plants or specific parts or traits to increase their economic value and meet needs of end-users. In eastern Africa, several approaches have been used in legume breeding ranging from classical to molecular. However, emphasis has been genetic and agronomic improvement with limited attention given to the business side. This has contributed to low adoption and utilisation of improved varieties in Africa (38%) compared to 60-80% reported in other regions of the world. Before 1985, breeding programmes were monolithic focusing on yield and disease resistance with little consideration of farmer and consumer preferences. Farmer participatory and on-farm approaches developed in the early 1990s, focused on household food security resulted in slightly improved adoption. Market-led strategy was developed in 2000, and implemented in bean breeding programmemore than 20 African countries, further improved adoption but only to modest rate of 36%. Between 2014 and 2017, a demand-led breeding strategy was developed by a consortium of institutions. Unlike previous breeding approaches, demand-led breeding is business oriented, and is based on six cardinal principles: client preferences, value chain analysis, market research, market trends and drivers, integration of public and private sector expertise, and a multidisciplinary approach in variety design and solution development. Case studies of breeding pigeonpea, dry and canning beans indicate that application of this approach requires breeders to learn new skills, working with non-traditional partners and understanding market dynamics.

Key words: Adoption, demand-led, breeding, East Africa variety, development

RÉSUMÉ
L'objectif global de la sélection végétale est l'amélioration génétique de plantes entières ou de parties ou de traits spécifiques pour augmenter leur valeur économique et répondre aux besoins des utilisateurs finaux. En Afrique de l'Est, plusieurs approches ont été utilisées dans la sélection des légumineuses, allant du classique au moléculaire. Cependant, l'accent a été mis sur l'amélioration génétique et agronomique avec une attention limitée accordée aux entreprises. Ce qui a contribué à une faible adoption et utilisation de variétés améliorées en Afrique (38%), contre 60 à 80% dans d'autres régions du monde. Avant 1985, les programmes de sélection étaient monolithiques, se concentrant sur le rendement et la résistance aux maladies, sans tenir compte des préférences des agriculteurs et des consommateurs. Les approches participatives et sur ferme des agriculteurs développées au début des années 1990, axées sur la sécurité alimentaire des ménages, ont permis une légère amélioration de l'adoption. Une stratégie axée par le marché a été élaborée en

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2000 et exécuté dans le programme de sélection de haricots dans plus de 20 pays africains, améliorant encore l'adoption, mais seulement à un taux modeste de 36%. Entre 2014 et 2017, une stratégie de sélection végétale axée sur la demande a été élaborée par un consortium d'institutions. Contrairement aux approches de sélection précédentes, la demande est orientée vers les entreprises et est basée sur six principes fondamentaux: les préférences des clients, l'analyse de la chaîne de valeur, les études du marché, les tendances et les facteurs du marché, l'intégration de l'expertise des secteurs public et privé et une approche multidisciplinaire dans la conception de variétés et développement de solutions. Des études de cas de sélection de pois cajan, de haricots secs et de conserves indiquent que l'application de cette approche nécessite que les sélectionneurs acquièrent de nouvelles compétences, travaillent avec des partenaires non traditionnels et comprennent la dynamique du marché.

Mots-clés: adoption, induite par la demande, sélection, variété d'Afrique de l'Est, développement.

INTRODUCTION

The overall objective of plant breeding is genetic improvement of whole plants or specific parts or traits to increase their economic value and meet needs of end-users. In eastern Africa, several approaches have been used in legume breeding ranging from classical to molecular. However, emphasis has been on genetic and agronomic improvement with limited attention given to the business side. This has contributed to low adoption and utilisation of improved varieties in Africa (38%) compared to 60-80% reported in other regions of the world. The overall goal of public policy in most countries in eastern Africa is not only to accelerate growth of the agricultural sector, but also to transform it from subsistence to an innovative, commercially oriented modern agriculture (GOK/ACDS, 2010; ADB, 2018). Public policy, production environment, consumer behavior, urban migration, lifestyles, technological advances and population growth are key drivers of the transformation in the agricultural sector. Transformation of smallholder agriculture in Africa demand a change or at least a re-orientation of breeding strategies and training of breeders. The development and growth of the agricultural sector is anchored in two strategic thrusts: i) increasing productivity, commercialization and competitiveness of agricultural commodities and enterprises, and ii) developing and managing key factors of production. This implies that new varieties should not only be productive, but also must have market demanded traits, especially those that add to their competitiveness compared to existing varieties. Predicted challenges due to climate change and variability, and declining soil fertility in production environments, demand that future varieties must be more resilient to temperature fluctuations, moisture stress, water logging, and should have better nutrient use efficiency and resistance to emerging strains of fungal, bacterial and viral pathogens, pests, which are key components of climate smart agriculture (FAO, 2010; AGRA, 2014).

Smallholder farmers are generating surpluses of products to sell in local, regional and international markets (AGRA, 2014). However, effective participation in local and regional markets requires accurate identification of market demands, and developing products with suitable characteristics to meet market requirements. Demand for products is rising with population growth, urbanization and changing lifestyles. Africa imports food worth US$40 billion per year. By 2030, World Bank estimates food market for middle class will be US$1 trillion. Consumers are becoming more health conscious; selective of food they buy and

are ready to pay for quality. Projections based on population growth and food consumption patterns indicate that agricultural production will need to increase by at least 70 percent to meet demands by 2050 (FAO, 2010). Agriculture in developing countries must therefore undergo a significant transformation in order to meet the related challenges of achieving food security and responding to climate change. Although all breeding programmes are client oriented, the degree differs (Witcombe *et al.,* 2005). Moreover, few programmes adopt the more demanding techniques required to meet client needs effectively. Even fewer consider the full range of the needs of most, or all actors along a commodity value chain.

Several approaches designed to create varieties that better respond to farmer' needs and preferences and to accelerate adoption of new varieties have been used by breeding programmes in Africa and other regions in the world over the last two decades. In eastern Africa, approaches used in legume breeding range from classical to molecular. The objectives of this paper are, i) to briefly review the evolution of client oriented breeding in eastern Africa from 1970 to 2000 with emphasis on legume breeding; ii) Present evidence of progress made from 2001 to date, and iii) highlight the new directions in market oriented breeding in the region.

Market oriented breeding approaches before 1970s. Breeding programmes in eastern Africa before 1970s largely followed top down, traditional approaches in which breeders made all decisions on variety development. New varieties were disseminated through extension services. Smallholder and large scale commercial farmers basically had no contribution in the variety development process and relied wholly on extension officers for variety and management recommendations. Examples of such programmes include maize improvement at Njoro before 1939, and at Kitale from 1959 (Harrison, 1970). Others include cotton improvement at Ukiriguru in the Lake region of Tanzania which started in 1939, and at Namulonge in Uganda (Arnold, 1970). As Arnold notes, cotton improvement, production and ginning was controlled by government. The government provided seed to farmers and bought seed cotton from them. No individual was permitted to gin his/her own produce, but must deliver his seed cotton to a buying post. Similar control applied to other 'cash crops' such as coffee, tea and pyrethrum. The situation for food security crops was not much different. The programmes were conceived, developed and implemented by government officers including breeders and agricultural extension officers. For example, bean improvement work in eastern Africa was based on a World Health Organization recommendation that a crop improvement programme for pulses be initiated (Leakey, 1970). The pulse improvement work was concentrated in Uganda, where Mukasa was assigned to work full time as a breeder at Kawanda Research Station. He was later joined by Leakey as a pathologist in 1961. For sorghum, early improvement work was done by government botanists and agricultural officers from Kenya, Uganda and Tanzania (Dogget, 1970). They made collections of local sorghum cultivars, screened them, and then multiplied the best yielding ones for distribution. From these collections, some good local types were found. In Uganda, L28 and T15; Bukura Mahemba and Msubiji in Tanzania, and Dobbs variety which originated from Nyanza in Kenya, were the best known varieties. The then Tanganyika government started a sorghum breeding program at Ukiriguru in the Lake Region from 1948 to 1957. In 1958, the sorghum work was taken over by the East Africa Agricultural and Forestry Organization (EAAFRO) and moved to Serere Research Station in Uganda.

The role of Lord Delamere on wheat improvement in eastern Africa, is probably an

exception. Wheat improvement at Njoro, Kenya, is probably the earliest breeding programme in eastern Africa. This programme was initiated in 1907 by Lord Delamere, a large scale wheat and dairy farmer (Guthrie and Pinto, 1970). Delamere lost more than 1200 acres grown with wheat varieties introduced from Australia, Italy, Canada and Egypt, which succumbed to stem rust (*Puccinia graminis f.sp tritici*) and yellow rust (*Puccinia striiformis* Westend (Guthrie and Pinto, 1970). Delamere responded by hiring a plant breeder, Evans. For several years, Evans was employed by Delamere, and later by the Department of Agriculture. Evans developed a wheat cultivar called Equator from crosses involving Australia cultivars Gluyas, Thew and Bobs, the Italian Rieti, Red and Yellow Fife from Canada, and the durum wheat cultivar, Egypt 3. Evans work was later taken up by the government in 1915.

1970s to 1990s. Despite the progress in developing improved varieties before 1970, adoption was very low especially among smallholder farmers. These farmers practiced subsistence agriculture focusing mainly on food crops. They were probably neither aware of the improved varieties nor the benefits they provided. In some cases, the improved varieties were not available when needed, or not appropriate for the diverse farming systems, ecologies and end-uses. Moreover, breeding programmes and seed delivery systems focused on crops produced by large scale farmers where more profitable bulk sales could be made. However, considering the bulk of the farming population were smallholder farmers, new approaches were needed to develop varieties that better responded to the smallholder needs. This led to on-farm testing of breeding materials in the 1970s and 1980s. The objective of on-farm testing was to involve farmers during technology development, understand their preferences and to test new materials under farmers' conditions. On-farm testing gradually evolved into participatory plant breeding in the 1990s. Breeding short duration pigeonpea for semi-arid regions in eastern Kenya illustrates the role of on-farm testing in variety development (Onim, 1983; Kimani, 1990).

The case of Pigeonpea. Pigeonpea (*Cajanus cajan* L. Millsp) is woody perennial legume, which is grown as an annual in eastern Africa by smallholder farmers in Kenya, Tanzania, Uganda, Malawi, Mozambique and in other countries to a lesser extent. It is particularly valued by these farmers because it is drought tolerant and is a source of protein, fire wood, livestock feed and even construction materials. There were no improved varieties in the region up to 1980 (Kimani, 2001). Farmers relied on tall (up to 3m), traditional varieties that took up to 11 months to mature. These landraces were susceptible to Fusarium wilt (*Fusarium udum*), leafspot (*Mycovellosiela cajani*) and insect pests, especially pod borers, pod suckers and pod fly. The first pigeonpea programme in the region was initiated in 1968 at Makerere University in Uganda, to breed short-duration, high yielding grain type cultivars (Khan and Rachie, 1972). The Ugandan programme was disrupted by civil strife between 1973 and 1986. Although no cultivars were released from this programme, some of the materials were used to initiate the breeding programme at the University of Nairobi in 1975. The objectives of the University of Nairobi programme was to develop varieties with improved grain yield, earliness, reduced plant height, resistance to Fusarium wilt, large cream or white seeds, drought tolerance and suitability for intercropping (Kimani, 2001). The early stages of the University of Nairobi programme focused on germplasm collection and evaluation, followed by on-farm testing and participatory selection, and later on hybridization and selection (Kimani, 1990; Kimani, 2001). Earlier attempts to popularize early maturing varieties from ICRISAT, India failed because farmers rejected the varieties, despite their early maturity and short stature,

due small seed size and brown or tan seed coat colours. Moreover, the Indian cultivars were not suitable for intercropping, losing up to 80% of their grain yield when intercropped with maize (Onim, 1981). The first early maturing cultivar developed was NPP670, which originated from crosses made in 1977 between early maturing lines from ICRISAT and West Indies, and locally adapted landraces. This variety was disseminated and adopted in Mbeere, Kirinyaga, Embu and Kitui Counties, where is it popularly known as 'Katumani' pigeonpea. Seeds were disseminated through formal channels in early stages, and by informal channels from 1987 (Kimani, 1990; Kimani and Mbatia, 1990). It became very popular with farmers because of its earliness, large cream seeds (19 g per 100 seeds). NPP 670 yields about 1 t ha^{-1}, but requires spraying against insect pests (Kimani, 2001) and reduced height (about 1m tall).

ICRISAT conducted a survey in 1996 to determine the adoption of NPP670 and factors which influenced its rapid diffusion in three sub-locations (Karaba, Riakanau and Wachoro) in Mbeere County, which is in the semi-arid eastern Kenya (Jones *et al.,* 2001). Farmers in this region grow the traditional indeterminate local varieties that mature in about 11 months. NPP670 is determinate and matures in 5 to 6 months, and produces a second harvest about two months later. It was first introduced into this area by the University of Nairobi in 1986. They reported that within a relatively short period of 10 years, virtually all the farmers in the study area knew about NPP 670. More than 75% of those were interviewed had grown the variety. Adoption rates varied from 73% in Karaba to 96% in Wachoro (Jones *et al.,* 2001). They attributed the rapid diffusion and adoption to four factors. First, NPP 670 was easily distinguishable from local pigeopea varieties because of its determinate growth habit, short-stature and bold-white seeds. Secondly, the high market value of the crop due its attractive bold white seeded grain, and its availability before the main pigeonpea harvest; thirdly, the earlier maturity of NPP 670 makes it less susceptible to terminal drought stress in an area where long rain season which occur in March to June are unreliable; and fourthly, the ease with which farmers were able to maintain the seed purity. More than 30 years since NPP 670 was introduced in this region, farmers have continued to maintain the variety, produce and market their seed through an informal seed system. Diffusion has continued to the drought-prone areas of neighbouring Kirinyaga and Muranga counties. Apart from the initial injection of seed by the University of Nairobi Pigeonpea Improvement Programme, which was facilitated by the extension service, neither the formal seed system nor the extension service has played a major role in the diffusion process. Jones *et al.* (2001) noted that other factors that contributed to the rapid diffusion was the willingness of people to pay for the seed and the relatively low planting rate (<15 kg ha^{-1}). NPP 670 was officially released in 1999, more than 10 years after it was first tested with farmers in semi-arid regions of eastern Kenya (Jones *et al.,* 2001).

THE 1990S: PARTICIPATORY PLANT BREEDING. Farmer participatory research, which became prominent in the 1970s and 1980s, was followed by various forms of participatory breeding approaches. Participatory plant breeding was developed as a distinct breeding approach in the 1990s. In its broadest sense, it can be defined as the involvement of farmers and other end-users in the process of developing improved varieties of crop plants. It has also been defined as 'approaches that involve close farmer-researcher collaboration to bring about plant genetic improvement within a species' (Weltizien *et al.,* 2003). Involvement of farmers in crop improvement is neither new nor revolutionary (Ceccareli *et al.,* 2000). Farmers have been selecting improved crop varieties since their wild progenitors were domesticated more than 10,000 years ago, and therefore long

before the science of plant breeding developed as a distinct field of professional studies.

During the last two decades of the 20th century, researchers felt the need to involve farmers and other end users of their products in the research process. This was partly due to failure to make desired changes in improving crop productivity, despite release of many crop varieties. Specifically, adoption rates were generally low, and in some cases, farmers stopped growing some of the recommended varieties altogether and reverted to the old varieties. Initial experiences indicated that involving farmers and other end user may be a useful research strategy because it could enhance understanding of their preferences, improve targeting of germplasm to specific niches and user-needs. In addition, involving farmers could reduce pressure for land in research stations and labour costs, and improve adoption of new varieties. Researchers in public research centres were under pressure to demonstrate results in farmers' fields. The pressure increased as percentage of people living under the poverty line rose, instead of the expected decrease with dissemination of relevant research products. A consensus gradually emerged that empowering farmers through strengthening decision making, skill building and improved access to local and introduced germplasm, could be achieved through their involvement in participatory crop improvement programs. Participatory bean improvement in eastern Africa is an example of such an attempt to empower farmers by involving them during, rather than at the end of the variety development process.

Case of participatory bean improvement in eastern Africa. The overall objective of participatory bean improvement in east and southern Africa was to develop higher yielding, marketable bean varieties with resistance to major biotic and abiotic stresses, and with acceptable organoleptic and cooking characteristics (Kimani *et al.,* 2005). Improved bean varieties should be compatible with major cropping systems, and with broad or specific adaptation to one or more of the major agroecological zones.

Before 1985, breeding activities focused mainly on developing cultivars of dry bush beans with little collaboration between countries. These programmes followed traditional approaches of introduction, mass selection and limited hybridization (notably in Uganda) followed by selection by breeders and on-station testing of promising lines in preliminary, intermediate and national performance trials (Kimani *et al.,* 2005). Best lines compared to landraces were released formally by national variety release committees and their seed multiplied and distributed by publicly owned seed companies or seed projects. In the initial stages, farmers were not involved in the variety design, selection or testing and were expected to grow the officially released varieties as recommended by extension agents. It soon became evident that most farmers failed to adopt the improved varieties and continued to grow their own selections or landraces (Sperling e*t al.,* 1993). In other cases, lines selected from introductions because of excellent resistance to diseases had poor seed and plant characteristics. In all, farmers complained that new varieties were poorly adapted to their growing conditions and did not meet other important requirements including cooking quality, taste, physical appearance and compatibility with cropping systems. Supply of seeds of these new varieties was erratic and did not reach farmers in remote regions, if at all in good time for planting. Indeed, the few successful varieties were selections from the land races, which had retained most of the attributes of their parental populations. The need to involve farmers in the evaluation of the new cultivars was realized and researchers included on-farm tests as part of their cultivar development programmes. However, this feature was incorporated, as the last step prior to release of new varieties, and in most cases was not meticulously followed. It was not a condition for releasing new varieties. The overall result for this period was poor adoption of new cultivars

and lack of significant impact, which in turn contributed to frustration among national scientists, extension officers, farmers and policy makers.

Beginning 1985, the International Center for Tropical Agriculture (CIAT) in collaboration with national programmes, while emphasizing the significance of farmer involvement in on-farm trials, started in earnest to experiment with farmer participatory methods in variety development. The first programme started at Rubona in collaboration with the Rwandese Institut des Sciences Agronomiques du Rwanda (ISAR). This programme was initiated to compare the performance of farmer selected cultivars using a system of farmer participatory selection with those selected by breeders under the conventional breeding scheme of on-station and on-farm testing. Evaluation of the two approaches was based on on-farm yields, long-term varietal use, maintenance of genetic diversity and the costs of the screening process (Sperling *et al.,* 1993). The trial was conducted at three ISAR research stations: Rubona (1630m), Rwerere (2300m) and Karama (1400m). Rubona with a bimodal rainfall of about 1170mm, and Rwerere have more fertile soils and adequate moisture for bean production. In contrast, Karama is located in semi-arid region with less fertile sandy soils and frequent droughts. Disease pressure is generally higher at Rubona and Rwerere due to high humidity. The on-station trials were designed not only to screen sets of cultivars for their farmer acceptability, but also to encourage dialogue among breeders, pathologists and farmers, and to determine the correlation between farmers' and breeders selection criteria. The on-farm trials compared performance of farmer-selected cultivars with those selected under the conventional scheme.

Results showed that farmers selected for a range of characteristics. They selected, not only varieties with higher yields, but those in the middle range. Selection was based on preferences of plant aspects they valued, and performance and uses in different and diverse home conditions. Main selection criteria in addition to yield were earliness, grain colour and seed shape. Grain type was important for varieties destined for markets, which preferred uniformity. Performance traits selected for included adaptation to cropping systems, tolerance to poor soils, pod clearance and disease (''rain'') tolerance. Some varieties were judged as appropriate to large areas within a region, while others were appropriate for specific niches. For example, in Karama, farmers selected a variety they believed was drought tolerant, while at Rwerere, the same variety was rejected because of its late maturity (and hence susceptible to terminal moisture stress). This implied a need to decentralize selection early in the screening process to cater for regional variability. Farmers selected 21 bush bean cultivars, which outperformed their local mixtures 64-89% of the time, with average production increases of up to 38%. Although breeders selections could not be compared directly with those of farmers (since few comparable on-farm trials were conducted in the same region and years), comparisons with data from trials conducted in 1987-88, showed that varieties selected by breeders outperformed local mixtures in 34-53% of the time with insignificant yield increases in one region. However, they out yielded local mixtures by up to 8% in 41-51% of on-farm trials countrywide.

Analysis of survival rates three to six seasons after the first on-farm testing, showed that farmers' selections compared favourably with the very best of releases from ISAR's standard programme. Farmers' selections had a 71% chance of being grown compared with a popular bush bean variety ''Kilyumukwe'' in the Central Plateau (Sperling and Loevinsohn, 1993). Longer retention of farmers' selections was attributed to their compatibility with

local mixtures (Sperling, 1993). About 32% of the varieties were found in newly constituted mixtures, and 35% had been incorporated into the existing blends. An added benefit of this compatibility is broadening or maintaining the existing genetic diversity. Results also indicated that farmers were indeed aware of genotype x environment (G x E) interactions, a common hurdle in breeding for marginal, low input areas (Ceccareli *et al.,* 2000). They were able to predict, with some accuracy, on-farm performance from what they observe on-station. This program was later expanded to the adjacent bean farmers in eastern region of the Democratic Republic of Congo.

Regional networks. Development of regional networks was another crucial step in institutionalizing and promoting participatory approaches in bean improvement and also in ensuring research benefits were shared across national boundaries (Kimani *et al.,* 2005). Two networks were created in the mid 1980's soon after the arrival of CIAT scientists in the region. These were East African Bean Research Network (EABRN) comprising the national programmes of Uganda, Kenya, Tanzania, Ethiopia, Sudan, Madagascar and Mauritius, and RESAPAC which catered for Rwanda, Burundi and DR Congo. In 1995, RESAPAC and EABRN were replaced by the East and Central Africa Bean Research Network (ECABREN) with a responsibility of nine countries (DR Congo, Uganda, Rwanda, Burundi, Kenya, northern Tanzania, Sudan, Madagascar and Ethiopia). At the same time the Southern Africa Bean Research Network (SABRN) comprising national programmes of Angola, Botswana, Lesotho, Malawi, Mozambique, South Africa, southern Tanzania, Swaziland, Zambia and Zimbabwe was formed. These networks provided forum for exchange of information, materials and technologies. Technologies developed in one country could be used in another country with similar conditions. For example, although climbing bean production technology was originally developed in Rwanda, it spread rapidly to Kenya, Uganda, Congo, Ethiopia, Malawi and Tanzania facilitated by exchange of visits, meetings, publications and germplasm. Regional working groups were created with representation from all member countries. Breeding and constraint nurseries were constituted and made available to all countries. Variety releases increased considerably. However, most of the germplasm originated from CIAT bean programme and later from regional programme in Uganda, which served as the distribution hub for the region. Unfortunately, due to a constant and regular flow of germplasm from CIAT, many national programmes failed to initiate crossing programmes or create new breeding populations.

From 2000: Market-led breeding. Despite the success in developing and releasing new bean cultivars using participatory approaches among the network members, a bean market research study revealed a need to develop cultivars that were more responsive to market demands (Kimani *et al.,* 2005a). This was based on the observation that although most smallholders grew bean for their domestic consumption, sizeable quantities were traded in domestic, regional and international markets. It was evident that increased production was driven not only by need to meet food needs for households, but also to generate income from sale in their localities (neighbours, retail traders, schools and other institutions), larger domestic markets in urban centres, regional and international markets. For example farmers in northern Tanzania, eastern and south western Uganda were producing red mottled bean for sale in Nairobi and other urban centres in Kenya; in Rift valley region of Ethiopia, farmers exported over 90% of navy bean; in Madagascar farmers were producing the large white bean mainly for export; and eastern Congo farmers produced bean for sale to neighbouring Rwanda

and Kinshasa. Moreover, preferences for bean types differed with markets, countries, regions and no one variety could be expected to meet the diversity of market needs. Production priorities differed among countries in response to consumption preferences and market demands. To respond to these challenges, a new decentralized breeding strategy was developed in mid 2000 (Kimani *et al.,* 2005b). The overall strategy was to develop breeding programmes for the seven most important market classes following participatory approaches (Table 1). For each programme, breeding objectives and methods were defined; germplasm requirements to meet breeding goals, the expected outputs, lead National Agricultural Research Systems (NARS), collaborating partners and test sites were identified and described (Table 1). Lead NARS were selected on the basis of importance of a particular market class in their country, interest in providing regional leadership and presence of other comparative advantages. Collaboration in each programme was open to all NARS, farmers, non-governmental organizations, seed companies, processors, exporters and other stakeholders. Test sites were selected to represent the major bean growing environments for each market class, which were previously defined and described by Wortmann *et al.* (1998).

The strategy was approved by the ECABREN steering committee in 2001, and subsequently by respective steering committees for southern Africa and West African countries. It has been operational for the last 19 years. The market-led breeding programmes incorporated aspects of participatory approaches and has been adopted by programmes and guided research in more than 28 African bean producing countries. This approach was designed not only to respond to local farmer preferences, but also to meet market demands with potential for production across countries (Kimani *et al.,* 2005). Market led breeding was informed by regional surveys that showed similarities in production conditions and preferences (Wortmann *et al.,* 1998). Lines developed by one country were available for validation and release by other member countries. This contributed to unprecedented release of new varieties in more than 20 bean producing countries in east, central, southern and west Africa from 2001 to the present (Buruchara *et al.,* 2011). However, the level of commercialization has remained low, partly because of the limited attention to client focused variety design, product profiles and performance standards which are critical in refining the breeding goals and objectives, and ultimately influence performance in the market. In addition, although dry bean for household consumption remains the dominant market class in most countries, demand for snap bean and runner bean (*Phaseolus coccineus* L.) for fresh market and processing, canning beans, and niche market grain types such as yellow, speckled sugars is rising in countries where they were previously considered as minor market classes as predicted by Kimani *et al.* (2005a). These types of beans received little attention except at the University of Nairobi where considerable progress has been made in the last decade as described in other sections of this paper.

From 2010 To Date: Towards the demand led approach. A review of breeding approaches in crop improvement in eastern Africa in the last three and a half decades reveals several gaps. First, breeding objectives were largely based on producer preferences with limited attention to other end users such as processors, traders and diverse consumer needs. To some extent this led to skewed goals and objectives. Secondly, participatory approaches often targeted marginal environments where farmers cannot modify their environments. For example, decentralized selection was defined as selection in target environment (Ceccareli and Grando, 2007). However, Witcombe *et al.* (1999) recognized that despite the lower benefits for participation in more productive environments, the range of client needs was more diverse.

Table 1. Decentralized, market-led bean improvement programs in East and Central Africa

Program	Production (ha) (Africa total > 4 million ha)	Priority constraints*	Program Leader	Collaborators**
Programme 1. Red mottled	740,000	ALS, Anth/RR, low N and P, drought, BSM	Uganda	Kenya, DR Congo, Rwanda, Madagascar, Tanzania, Sudan,
Programme 2A. Large red kidneys	350,000	ALS, Anth/RR, low P and N, Bruchids	Tanzania	Ethiopia,Rwanda, Kenya, Madagascar, Uganda, Burundi, Sudan
Programme 2B. Small and medium reds	670,000	Rust, ALS, RR, low P and N	Ethiopia	Rwanda, Burundi, Kenya, Uganda, Tanzania, DR Congo, Madagascar, Burundi
Programme 3. Cream 3 A. Pinto 3 B. Sugars/cranberry 3 C. Carioaca	360,000	Pinto : Rust, CBB Sugar : Rust, CBB, HB, ALS, low N and P, Bruchids	Kenya Congo Ethiopia	Kenya, Ethiopia, Uganda, Madagascar, DR Congo, Rwanda
Programme 4. Climbers	40-100,000(?)	Anth., ALS, Aschochyta, BCMV, RR, HB, low P and N, drought	Rwanda	Burundi, DR Congo, Kenya, Uganda
Programme 5. Snaps 5A. Bush 5B. Climbers 5C. Runner Climbers	?	Rust, RR, ALS, BCMV, Anth,, BSM, thrips and nematodes	5a. Uganda 5b&C: Kenya	Kenya, Uganda, Tanzania, Ethiopia, Madagascar, Burundi
Programme 6A. . Navy	310,000	Rust, CBB, ALS, Anth, drought, low P and N, BSM	Ethiopia	Leader: Ethiopia, Collaborators: Kenya, Sudan, Uganda, Tanzania, DR Congo
Programme 6B. Large white kidney	220,000	Rust, ALS, Anth, low N and P	Madagascar	Leader: Madagascar, Collaborators: Tanzania, DR Congo
Programme 7. IIIa. Yellow IIIb. Brown IIIc. Tan	380,000	ALS, Anth/CBB, RR, rust, HB and low N and P	D R Congo	Angola, Tanzania, Kenya, Madagascar, Sudan
Programme 8 Parental source nurseries		Als, Anth, RR,Rust, Low N, pH and P	University of Nairobi	ALL
§BILFA		Low N, Low P and Low PH	D R Congo	ALL
§BIWADA		Drought and earliness	Tanzania	ALL

*Anth=anthracnose; ALS= angular leaf spot; RR= root rots; P=phosphorus; N= nitrogen; CBB= common bacterial blight; HB=halo blight; BSM= bean stem maggot; A slash (/) between two constraints indicate equal importance; § BILFA, Bean improvement for low soil fertility soils in Africa; BIWADA, Bean improvement for water areas in Africa

Source: Kimani *et al.,* 2005b

Thirdly, breeding approaches failed to consider needs of all actors in a value chain. These approaches were largely limited to supply side. Fourthly, because the approaches were highly localized and specific, several selection schemes each targeting a different environment are required. Fifthly, the approaches targeted local food security and not processing and commercialization. Sixthly, sustainability beyond the project period was not guaranteed. There was no exit strategy. Most of the breeding projects were and still are supported by external donors with little input from national governments and commercial sector. Consequently, these programmes ended with donor support, which was detrimental because of the long term nature of plant and animal breeding activities. Furthermore, these projects were poorly linked to private sector. Consequently synergy and learning opportunities were lost. Seventh, market research was not used to define the performance standard. Few programmes were aware of the value of market research in defining their objectives, performance standards, diversity of market needs and their implications. Consequently, research products did not match the market demands. This contributed to poor adoption and limited commercialization of these products. The primary focus was productivity and not market demands. Eighth, the regulatory agencies responsible for testing and validation of candidate varieties were not in sync with advances in plant breeding and used productivity as the overriding release criteria. Thus, varieties identified through participatory plant breeding were not recognized by regulatory agencies despite having unique traits valued by end users such as taste, cooking time, grain type and plant architecture. Finally, many breeding programs did not consider seed supply and tracking adoption as part of their activities (Schnell, 1982; Witcombe *et al.,* 2005). Demand led approach was developed in last three years to address some of these limitations (Kimani, 2017; Parsley and Anthony, 2017).

Demand led plant variety design. This approach was developed between 2014 and 2017 by a consortium of universities with leading education programmes in plant breeding (University of Nairobi, Kenya; Makerere University, Uganda; University of Ghana, Legon, Ghana; University of Kwa-Zulu Natal, South Africa; University of Queensland, Australia); a CGIAR center (CIAT); the Syngenta Foundation for Sustainable Agriculture, Switzerland; ASARECA, Entebbe, Uganda; RUFORUM (Makerere University, Uganda); regional crop improvement programmes (Biosciences for East and Africa (BECA) Nairobi, Kenya; African Center for Crop Improvement (ACCI), Kwa-Zulu Natal, South Africa; West African Centre for Crop Improvement (WACCI), Accra, Ghana, with financial support from the Syngenta Foundation for Sustainable Agriculture, the Crawford Fund (Australia) and Australian Centre for International Agricultural Research (ACIAR) (Parsley and Anthony, 2017; Kimani *et al.,* 2018). Demand led plant variety design follows an innovation system and value chain approaches, with bridging institutions linking plant breeding research with business and enterprise domains. It is designed to develop improved products which enable small scale farmers to access the expanding local and regional markets, which is one of the critical challenges facing policy makers in Africa. However, the participation in local and regional markets requires identification of market demands and development of products with suitable characteristics to meet the market requirements. A more focused approach is required in public and private breeding programs. Decisions on determining the preferred traits which new varieties must have are paramount to success. A demand led variety design based on the needs of customers can undoubtedly add value to breeding programs in Africa. New varieties which do not meet changing customer demands and emerging market opportunities has

contributed in a significant way to low adoption rates in Africa compared to other regions. Demand-led variety design also seeks to build on experiences gained in the last three decades. The following case study on development of new canning beans for processing industry illustrate some of the challenges and key elements of a demand led variety design.

Case study of canning beans for processing industry. Production of canning beans in eastern Africa started in 1937 in Arusha, Tanzania. Varieties with canning characteristics were introduced from United States and other sources, and screened for canning quality based on Heinz standard quality specification (Macartney, 1966; Leakey, 1970). Between 1937 and 1958, production was based on the well known cultivar, Comtesse de Chambord. Production increased rapidly from 252 t in 1949, to 2029 t in 1950, and 2553 t by 1952. Beans were produced by contracted smallholder farmers for export by a company known as Arusha Ltd, because there was no canning industry in the region. However, quality of beans deteriorated in subsequent years due to an increasing number of inexperienced producers and middlemen. Producers were supplying beans of mixed varieties, while the canners were demanding specific varietal characteristics and purity. By 1953, the entire crop was rejected due to poor quality. By 1954, the export market had largely been lost despite the interest in growing the crop. By 1957, production had declined to just 172 t. Michigan pea bean, internationally recognized as ideal for canning, was introduced in an attempt to keep the industry operational. However, it was highly susceptible to East African races of bean rust and was almost totally destroyed by rust. This led to initiation of canning bean research programme in Tanzania lead by Macartney, Joy and others, backed by the Bean Rust Unit at the East African Agricultural and Forestry Research Organization (EAAFRO), the well known regional research organization (Macartney, 1966). The aim of this programme was to develop a high yielding pure white canning bean, resistant to East African races of bean rust for export. Other selection criteria included maturity within 120 days, high soakability, good ground clearance and freedom from hard seed trait.

Between 1955 and 1959, more than 74 introduced canning bean cultivars were introduced and screened for suitability of production under East African conditions and for canning criteria. Of these, 20 satisfied the soakability criteria. Of the 20 varieties, three were discarded because of their seed size. Only three of the remaining 17 cultivars which met the soakability and seed criteria, were also resistant to races A and B of bean rust prevalent in northern Tanzania. These were Mexico 119, Mexico 142 and Criolla from Puerto Rico. Of these three varieties, only Mexico 142 ('Mex 142' for short) had satisfactory yield potential (>1300 kg ha^{-1}). However, it was susceptible to race C. Mexico 142 was subsequently distributed to Kenya and Uganda. However, in Uganda this variety was not considered suitable as food because of its size, colour and shape despite its high yield potential. In Kenya, Mexico 142, popularly referred to as 'Mex 142', was adopted and became the main canning variety for industries from 1960 to 2000. It was introduced in Ethiopia in the early 1970s, where it became the main canning bean to date (Assefa *et al.,* 2007). The rift valley region of Ethiopia led in production of this variety with more than 1000 exporters based in Adama (Nazareth) by end of 2010.

In Kenya, production of Mex 142 to support local canning industries continued up to 2000. By this time, Mex 142 had become susceptible to races of rust prevalent in Kenya, common bacterial blight, bean common mosaic virus, angular leaf spot and anthracnose, root rots and drought stress (Warsame and Kimani, 2014). Yields declined drastically such that in some seasons, yields were below 200 kg ha^{-1}. Farmers abandoned growing the variety because of its susceptibility to drought and diseases. Certified

seed was no longer available because the local companies were not willing to grow the variety due to poor seed yields. Local companies resorted to imported grain from Ethiopia to keep the factories running. Unfortunately supplies of canning bean become erratic, and beans supplied were of poor quality (Kimani *et al.,* 2018).

In 2010, the canning companies requested the University of Nairobi Bean programme to develop a better canning bean variety to replace Mex 142. A regional canning bean programme was initiated in 2011 supported by Bioinnovate Network based in Nairobi. This programme brought together a multi-disciplinary team of bean researchers from Kenya, Ethiopia, Tanzania, Rwanda and Burundi, and two bean canning industries. The objective of this programme was to develop high yielding varieties which met canning requirements of the processing industry. The requirements included drought tolerance, resistance to major diseases and canning quality. Between 2011 and 2014, more than 427 lines from University of Nairobi bean programme were systematically evaluated for tolerance to drought stress, diseases and canning quality. These lines were selections from a larger nursery of more than 1400 entries which were previously field tested for drought tolerance under severe early season, mid-season, intermittent and terminal drought stress in 2007, 2008 and 2009 at Kabete and Thika. Of the 445 lines, 73 were red mottled, 57 red kidney, 48 speckled sugars, 44 pintos, cariocas and purples, 144 navy, 42 small reds, and 57 were of mixed colours. The red mottled, red kidneys and speckled sugars are large seeded, and represented the Andean gene pool. The other four market classes are medium or small seeded and represented the Mesoamerican genepool of *Phaseolus vulgaris* L. Although, the small white, also known as navy or the white pea bean, is the major canning bean type, other market classes such as red kidneys, speckled sugars and small red were included because they are important in the regional and global canning bean industry, and will provide future niche markets for local canning factories.

Of the 445 lines evaluated, 295 lines were discarded because they showed susceptibility to drought, one or more diseases, poor vigour and undesirable growth habit. The remaining 150 lines were subjected to farmer participatory selection under drought stressed and no-stress conditions at Mwea and Kabete. Twenty-four navy bean lines which met criteria for drought tolerance, high yield potential, multiple disease resistance and upright growth habit and farmers' additional selection criteria (earliness, marketability, fast cooking, non-shattering and foliage), were tested for canning quality at the Pilot Food processing plant at the Department of Food Science, Technology and Nutrition at Kabete. Laboratory testing for canning quality was a challenge because there were no suitable facilities in the region. Samples had to be sent to Italy or South Africa which made selection more expensive and time consuming. Only a limited number of breeding lines could be tested. Facilities for laboratory testing were installed at the Pilot Plant as part of project activities in 2012.

Results showed that there were significant differences in drought tolerance, yield potential, resistance to disease and 35% reduction in cooking time compared to Mex 142, the industry standard check variety. Drought stress reduced grain yield by 18 to 31%. Several new lines out-yielded local and international drought checks (Tio Canella) by as much as 100% in drought stressed conditions (Fig 1). Grain yield under stress was positively associated with pod partitioning index (r=0.89***), pod harvest index (r=0.40**), and stem biomass reduction (r=0.32**) (Table 2). Fourteen new lines were rated superior to industrial standard check variety Mex 142, for agronomic potential,

drought tolerance, combined resistance to angular leaf spot, rust, anthracnose, bean common mosaic virus, culinary and canning characteristics (Tables 3 and 4).

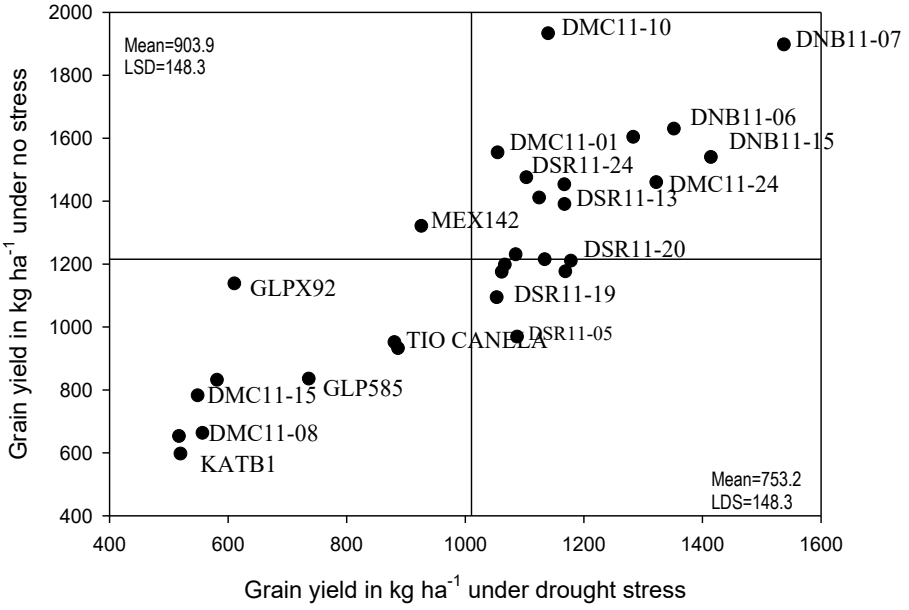

Figure 1. Grain yield of new drought tolerant navy (DNB), small red (DSR) and mixed colour (DMC) bean lines under drought stressed and non-stressed conditions at Kabete and Thika. KAT B1 (yellow), GLP (small red), Tio Canella (small red), GLP 92 (pinto), Mex 142 (navy) were the check varieties

Table 2. Correlation between grain yield with shoot characteristics of small and large seeded bean lines grown under drought stressed and irrigated conditions at Kabete and Thika, Kenya

Plant traits	Irrigated	Rainfed (Moisture Stressed)
Canopy biomass (kg/ha)	0.64***	0.25**
Pod harvest index (%)	0.62** *	0.40***
Pod harvest index (%)	0.62***	0.40***
Grain harvest index (%)	0.50***	0.39***
Pod partitioning index (%)	0.57***	0.89***
Pod wall biomass proportion (%)	0.26**	0.19*
Stem biomass reduction (%)	-0.18*	0.32**
Total chlorophyll content (SPAD)	0.24**	0.18**

*, **, *** Significant at p<0.05, p<0.01 and p<0.001 probability levels respectively

Table 3. Grain yield, reaction to diseases, cooking time and water uptake of the new candidate canning bean lines developed at the University of Nairobi

Candidate variety	Market class	Mean grain yield	Disease reaction				Cooking time (min)#	Water uptake (%)
		(kg ha^{-1})	Root rots	ALS	CBB	Anthracnose		
KCB13-01	Red mottled	2336	2	3	2	3	46.3	104.0
KCB13-02	Red mottled	2529	3	3	3	5	42.8	115.5
KCB13-03	Red kidney	2617	3	3	2	5	31.3	101.1
KCB13-04	Red kidney	2771	2	2	3	5	41.6	115.3
KCB13-05	Speckled sugar	2732	2	2	2	2	36.1	128.8
KCB13-06	Speckled sugar	2934	2	3	2	3	30.1	101.8
KCB13-07	Small red	2398	3	3	2	5	40.8	105.5
KCB13-08	Small red	2278	2	3	3	3	35.1	110.8
KCB13-09	Navy	2663	2	3	2	2	34.6	99.2
KCB13-10	Navy	2752	2	3	2	2	41.3	98.7
KCB13-11	Navy	3071	3	2	2	3	35.3	140.6
KCB13-12	Navy	2902	2	2	3	3	39.2	102.4
Checks								
Mex 142	Navy	2472	7	3	4	2	47.3	89.7
GLP 24	Red kidney	2063	7	5	4	4	70.9	92.8
Miezi Mbili	Speckled sugar	1748	6	5	6	7	67.1	97.3
GLP 585	Small red	1879	8	5	5	7	81.3	75.9
GLP 2	Red mottled	2207	7	4	4	7	67.1	97.3
Trial mean		1106	4	2	4	3	45.5	85.6
$LSD_{0.05}$		296.8	0.5	0.4	0.7	0.6	5.2	11.5
CV(%)		27.5	21.3	15.8	20	24	6.9	6.5

Mexican 142 used as the check. It had a cooking time of 41.6 minutes, and water uptake of 89.7% after 16 hours. CV= coefficient of variation; ALS= angular leaf spot, CBB= common bacterial blight. Disease score based on CIAT (1987)/international scale, where 1-3 =resistant, 4-6=intermediate and 7-9= susceptible

Table 4. Canning characteristics of the new drought tolerant and disease resistant candidate bean varieties developed at the University of Nairobi

Line	Market class	HC	WDWT	PWDWT (%)	Size	Shape	Uniformity	Splits	Clumping	Brine clarity
KCB13-09	Navy	1.92	272.4	66.0	2.33	4.7	6.3	5.7	6.3	7.0
KCB13-10	Navy	1.70	294.4	71.1	2.67	2.7	4.7	2.3	5.7	6.0
KCB11-11	Navy	1.64	267.1	64.8	2.67	5.0	4.7	2.3	5.7	6.0
KCB11-12	Navy	1.78	273.6	67.8	3.67	5.3	5.0	3.3	6.0	6.7
KCB13-08	Small red	1.59	276.6	67.1	2.67	5.7	5.3	2.7	3.7	3.0
KCB13-07	Small red	1.58	269.0	64.8	1.67	6.0	6.0	5.3	4.3	2.3
KCB13-01	Red mottled	1.55	284.0	69.0	5.3	4.0	6.0	5.7	5.7	3.0
KCB13-02	Red mottled	1.49	284.3	69.4	4.7	5.3	5.0	5.0	6.0	3.0
KCB13-03	Red kidney	1.52	279.9	67.6	5.3	5.0	4.0	4.0	5.7	3.7
KCB13-04	Red kidney	1.52	279.1	67.5	6.3	2.0	2.7	3.0	5.7	3.0
KCB13-05	Sugar	1.61	274.3	67.0	5.3	3.0	5.7	3.0	6.0	2.3
KCB13-06	Sugar	1.43	278.7	71.6	5.3	3.0	5.0	4.0	4.3	2.7
Mex142	Navy	1.74	282.8	69.7	2.67	5.0	3.7	3.3	5.3	6.0
Trial mean		1.8	274.2	65.7	2.5	5.0	5.7	4.3	5.2	4.6
$LSD_{0.05}$		0.04	7.6	3.9	1.3	0.7	1.1	1.0	1.3	0.9
CV (%)		1.5	1.7	3.6	23.3	8.8	11.9	13.8	14.9	11.8

HC= Hydration coefficient; WDWT=washed drained weight; PWDWT= per cent washed drained weight

Note: Market classes; navy, small red are small /medium seeded; red mottled, red kidney and sugar are large seeded

Validation for agronomic performance and canning quality. Of the 14 lines, 12 were submitted for validation by regulatory agency for agronomic performance, and for canning quality by the industry. The multi-location national performance trials were conducted in 2014 and 2015 by Kenya Plant Health Inspectorate Service. The new lines showed agronomic superiority compared with Mex 142 and other check varieties. For example, Mex 142 succumbed to bean common mosaic virus at Kabete. KAT B1, another drought tolerant check variety succumbed to severe anthracnose and haloblight attack in a farmer's field in Bahati, Nakuru County. KAT B1 gave a yield of 536 kg ha^{-1} compared to 740 to 3000 kg of the 12 candidate varieties during the prototype, large plot (0.5 to 1 ha) testing in farmers' fields. Industrial testing by two collaborating companies confirmed the laboratory canning tests conducted at the pilot plant in Kabete. Post canning evaluation of canned products was done in partnership with processors. Professional tasters from two companies independently conducted carefully managed sensory analysis for the candidate lines and obtained similar results. All 12 candidates fully met canning and sensory criteria set by the local industry and internationally. The two firms started contracting farmers to produce grain for processing during the 2014 short rain season. In March 2015, the companies purchased the first grain consignment of 3950 kg of the new varieties from the 41 farmers contracted. Five of the candidate varieties were officially released between 2015 and 2018. These were: Kenya Cheupe, Kenstar, Kenya Mamboleo, Kenya Salama and Kenya Red Kidney. Reports indicate that the companies are satisfied with new varieties since they have multiple advantages compared with Mex 142.

CONCLUSION

This paper presents a brief review of the evolution of client oriented breeding in eastern Africa from 1970 to 2000 with emphasis on legume breeding and provides evidence of progress made to date. Case studies of pigeopea, participatory improvement of dry beans, and the development of new canning bean varieties are presented. Adoption of the market led approaches can increase the chances of adoption as demonstrated in the case studies, facilitate access to larger markets, lead to better returns to investment in research, attract partnerships with private sector as demonstrated by development of new canning bean varieties, and make significant and sustainable contributions towards the national and regional goals of food and nutrition security.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Transmission of Maize lethal necrosis disease causing viruses from crop debris and soil

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ABSTRACT
Maize lethal necrosis (MLN) disease, a result of synergistic interaction between Maize chlorotic mottle virus (MCMV) and Sugarcane mosaic virus (SCMV), is a serious threat to maize production in the eastern Africa region. The role of plant debris and contaminated soil in the epidemiology of the disease is important for its management. A greenhouse study was carried out to determine the transmission of the two viruses causing MLN from crop debris and soil to healthy plants. Treatments included Sugarcane mosaic virus (SCMV), Maize chlorotic mottle virus (MCMV), co-infections (SCMV+MCMV), inoculum obtained from MLN-infected plants and healthy plants. Maize varieties used were three hybrids (H614, H513, and Duma43), and two landraces (Kikamba and Kinyanya). The plants were inoculated at three leaf stage with the respective viruses, after two months, plant materials were chopped and incorporated into one set of planting bags while another set had the soil previously holding infected plants but without debris. In the third season, all plant debris were removed from the bags and replanted with same maize varieties to assess if the viruses were still present in the soil. Disease severity was scored on a scale of 1-5 and area under disease progress curve (AUDPC) determined. Viral presence was confirmed using DAS-Elisa. There was no significant difference in infection of plants by viruses either from the soil with debris or with contaminated soil alone, although treatments with combination of the two viruses had higher levels of infection. However, the landraces recorded high disease incidences, severity and AUDPC for most of the treatments in comparison to the hybrids. On the Elisa test results, 58.3% of the samples tested positive for MCMV while on the subsequent planting 28.3% were positive. None of the samples were positive for SCMV. This demonstrates that MCMV can be easily acquired from the soil with or without debris so long as there was infection before. Hence field hygiene and crop rotation will help in reducing the recurrence of the disease.

Key word: AUDPC, coinfections, Das-Elisa, maize lethal nercosis, MCMV, SCMV

RÉSUMÉ
La maladie de la nécrose létale du maïs (NLM), résultat d'une interaction synergique entre le virus de la marbrure chlorotique du maïs (VMCM) et le virus de la mosaïque de la canne à sucre (VMCS) constitue une menace sérieuse pour la production de maïs dans la région de l'Afrique de l'Est. Le rôle des débris végétaux et des sols contaminés dans l'épidémiologie de la maladie est important pour sa gestion. Une étude en serre a été réalisée pour déterminer la transmission des deux virus responsables du NLM a partir des débris de culture et du sol et aux plantes saines. Les traitements comprenaient le virus de la mosaïque de la canne à sucre (VMCS), le virus de la marbrure chlorotique du maïs (VMCM), les co-infections (VMCS +

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VMCM), l'inoculum obtenu à partir de plantes infectées par le NLM et de plantes saines. Les variétés de maïs utilisées étaient trois hybrides (H614, H513 et Duma43) et deux variétés locales (Kikamba et Kinyanya). Les plantes ont été inoculées aux trois stades de feuilles avec les virus respectifs, Après deux mois, le matériel végétal a été haché et incorporé dans un ensemble de sacs de plantation tandis qu'un autre ensemble avait le sol contenant auparavant des plantes infectées mais sans débris. Au cours de la troisième saison, tous les débris végétaux ont été retirés des sacs et replantés avec les mêmes variétés de maïs pour évaluer si les virus étaient toujours présents dans le sol. La sévérité de la maladie a été notée sur une échelle de 1 à 5 et l'aire sous la courbe de progression de la maladie (CPM) a été déterminée. La présence virale a été confirmée à l'aide de DAS-Elisa. Il n'y avait pas de différence significative dans l'infection des plantes par des virus provenant du sol avec des débris ou avec un sol contaminé seul, bien que les traitements avec une combinaison des deux virus aient eu des niveaux d'infection plus élevés. Cependant, les variétés locales ont enregistré une incidence, une sévérité et un AUDPC élevés pour la plupart des traitements par rapport aux hybrides. Les résultats du test Elisa montrent que 58,3% des échantillons ont été testés positifs pour VMCM tandis que lors de la plantation suivante, 28,3% étaient positifs. Aucun des échantillons n'était positif pour VMCS. Cela démontre que le VMCM peut être facilement acquis du sol avec ou sans débris tant qu'il y a eu une infection antérieure. Par conséquent, les bonnes conditions d'hygiène des champs et la rotation des cultures aideront à réduire la récurrence de la maladie.

Mot clé: CPM, coïnfections, Das-Elisa, nécrose létale du maïs, VMCM, VMCS

INTRODUCTION

Maize lethal necrosis (MLN) is a complex disease caused by synergistic interaction between Maize chlorotic mottle Machlomovirus (MCMV) and any of the maize infecting potyviruses (Scheets, 1998). The potyviruses involved include Wheat streak mosaic Rymovirus (WSMV), Maize dwarf mosaic Potyvirus (MDMV) and Sugarcane mosaic virus (SCMV). The disease is widespread all over the world including Peru, USA, Argentina, Mexico and China (Xie *et al*., 2011). In Kenya, the disease was confirmed to be caused by the synergistic interaction between MCMV and SCMV (Wangai *et al*., 2012).

In the USA, repeated outbreaks of MLN (also referred to as Corn lethal necrosis, CLN)) was attributed to MCMV surviving in the soil and hence causing disease outbreaks season after season (Uyemoto, 1983). The spread was enhanced by the presence of maize rootworm (Uyemoto, 1983). The virus can overwinter and survive in ploughed-in maize stubble and maize residues in the absence of maize (Montenegro and Castillo, 1996). Experiments to demonstrate the efficiency of crop rotation confirmed that disease incidents were high in plots that had maize the previous year while those that had other crops remained free of the disease. This is a clear demonstration that the virus overwinters in the soil and plant debris (Uyemoto, 1983).

Sugarcane mosaic virus (SCMV) has been isolated from most parts of infected plants (Jiang *et al*., 1992). These include leaf, stem, roots, cob, seed, sheath tissues, kernel, anther, husks and silk. The virus was also detected in immature kernel, root and terminal leaf tissues of dry eared plants (Jiang *et al*., 1992). In studies done to confirm soil transmission of the virus, non inoculated sorghum plants became infected with the SCMV when grown in containers with infected plants, indicating the possibility of soil transmission (Bond and Pirone, 1970). The

scenario in Kenya since the outbreak of MLN disease is similar to that observed in the USA where there was an outbreak after every season of maize planting. For proper management of this disease, it is important to determine the role of the soil and plant debris in continuous cropping systems to the disease outbreak. This study aimed at unraveling the role of the debris and contaminated soil to the outbreaks experienced in Kenya.

MATERIALS AND METHODS

Source of plant materials, virus and inoculations. Maize crop was used for the experiments which ran from November, 2013 to September, 2016. All experiments were carried out in a screenhouse for two seasons at the University of Nairobi, Kabete Campus field station. Five maize genotypes H614, H513, Duma43, Kikamba and Kinyanya were used. These were grown in different Agro Ecological Zones (AEZ) with the first three representing hybrids while the last two were landraces. The maize genotypes were acquired from the University of Nairobi, Kabete Campus field station seed store. The seeds had been in the store before the MLN disease outbreak and were sown in soil: sand: organic manure mixture at a 2:1:1 ratio, respectively in a 5-litre bag at the rate of two seeds per bag and maintained in a screen-house treated prior to planting with an insecticide (Abamectin + Dynamec). Weekly insecticide spraying was done to control the insect vectors.

Two viruses, Sugarcane mosaic virus (SCMV) and Maize chlorotic mottle virus (MCMV) were used in this experiment either as single or co-infections. In total, there were five treatments; plants inoculated with SCMV alone, plants inoculated with MCMV alone, plants inoculated with a combination of SCMV and MCMV (abbreviated as SCMV+MCMV), and plants inoculated with both viruses from an MLN-infected plant (abbreviated as MLN) and a control (no virus). Each treatment had two bags of a variety replicated four times. These were arranged in a completely randomized design (CRD).

The viruses were obtained from the Maize lethal necrosis lab at Kenya Agricultural and Livestock Research Organization (KALRO). Viral inoculations were done at 3-4 leaf stage, with only the three upper leaves being inoculated with the viral extract acquired by homogenizing 10g of plant material in 0.01M phosphate buffer with 0.2g of carborandum.

After two months, the experimental plants were chopped into pieces and the debris incorporated into the soil of half of the bags used earlier for planting while the other half remained with the soil alone. The bags were then planted with the same maize varieties planted earlier. Planting was done two weeks after debris incorporation. After six weeks of data collection, the crop was destroyed and the soil re-used for planting the same varieties for the third time. There was no debris incorporation this time round. This constituted the third planting on the same soil.

Disease assessment, data analysis and serological analysis. Disease severity was assessed using a scale of 1 to 5 adopted from KALRO/CIMMYT where 1= no symptoms observed, 2= fine chlorotic streaks on upper leaves, 3= chlorotic mottling throughout the plant, 4= excessive chlorotic mottling and dead heart and 5= complete plant necrosis. The average severity per treatment combination was determined. To further assess the severity of the treatments, the Area under disease progress curve (AUDPC) was determined using the formula $AUDPC=\sum [(0.5) (Yi+1 +Yi) (Ti+1 +Ti)]$ from Shaner and Finney (1977), where Y=Disease severity score and T=Time (Weeks) of the severity assessment. Percent disease incidence was assessed by using the formula n/N*100, where; N=Total No. of plants per treatment and n=Total no. of plants with disease symptoms.

All data collected were subjected to Analysis of Variance using Genstat statistical package (Version 12) to determine the effects of the different treatment; differences among the means were separated using the Fischer's Protected LSD test at 5% probability level (P=0.05).

The top most leaf samples were collected on the last day of viral scoring and taken through Das-Elisa using Agdia kit and following the procedure provided with the kit.

RESULTS

Initial inoculation of the maize genotypes. After mechanical inoculation, all the varieties recorded more than 90% disease incidence both for single and coinfection (Figure 1). Only the coinfections had significant differences between varieties at P=0.05. The coinfections also recorded high severity with the landraces having an average of 4.72 while the hybrids had an average of 4.2 (Figure 2). Conversely, the coinfections had a large AUDPC when compared with the single infections with the landraces having larger areas as compared to the hybrids (Table 1).

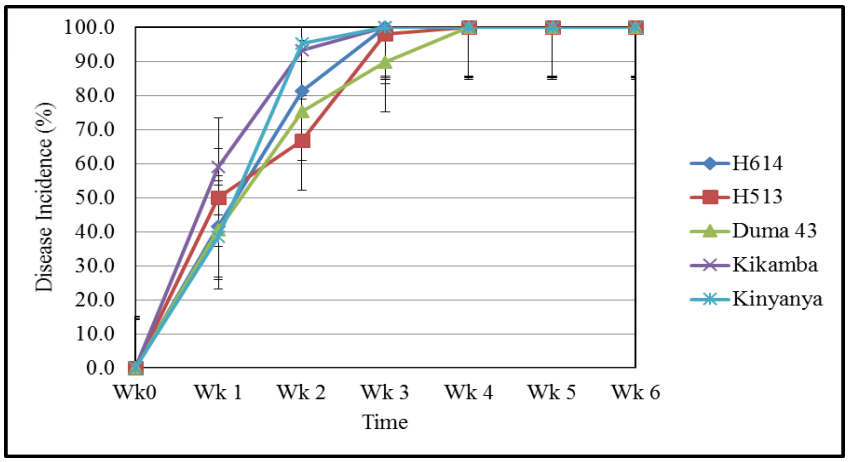

Figure 1. Disease incidence of different maize genotypes due to the infection by a combination of MCMV+SCMV. All the varieties had a 100% disease incidence by week four post inoculation. (Wk=Weeks after inoculation)

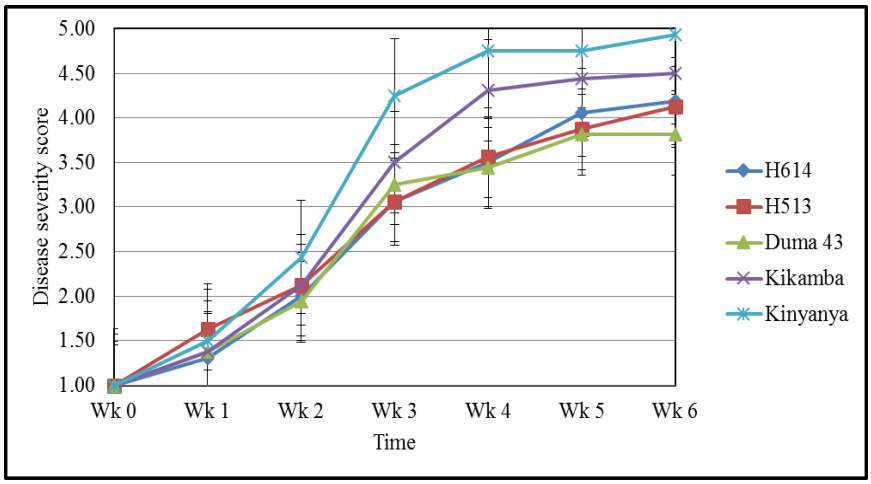

Figure 2. Disease severity on different maize varieties due to infection by a combination of MCMV+SCMV. (Wk=Weeks after inoculation)

Table 1. Area under disease progress curve for the initially inoculated crop, those with debris incorporated and contaminated soil and the third planting in contaminated soil alone

Inoculation	Variety method	SCMV	MCMV	SCMV+ MCMV	MLN	Control (-Ve)	LSDp=$^{0.05}$	Pvalue
Mechanical	H614	15.00	13.72	17.10	17.05	0.00	2.562	<.001
Mechanical	H513	14.59	13.35	15.59	17.47	0.00	1.632	<.001
Mechanical	Duma 43	14.78	14.22	17.56	17.06	0.00	2.908	<.001
Mechanical	Kikamba	14.84	13.94	21.90	15.28	0.00	2.427	<.001
Mechanical	Kinyanya	15.09	14.72	22.70	20.47	0.00	3.073	<.001
Plant Debris	H614	7.88	8.31	7.63	6.69	0.00	1.52	0.17
Plant Debris	H513	8.00	8.75	7.88	6.88	0.00	1.97	0.26
Plant Debris	Duma 43	7.50	7.50	7.50	6.69	0.00	0.19	<.001
Plant Debris	Kikamba	9.62	8.62	11.69	6.88	0.00	5.83	0.36
Plant Debris	Kinyanya	9.06	7.50	7.50	7.88	0.00	2.39	0.44
Soil (2nd planting)	H614	7.94	7.75	7.63	6.50	0.00	0.49	<.001
Soil (2nd planting)	H513	7.50	7.56	8.06	7.62	0.00	0.96	0.56
Soil (2nd planting)	Duma 43	7.50	7.50	7.81	6.50	0.00	0.50	0.00
Soil (2nd planting)	Kikamba	7.69	7.81	14.44	7.62	0.00	5.13	0.04
Soil (2nd planting)	Kinyanya	8.25	7.56	8.50	8.06	0.00	7.15	0.01
Soil (3rd planting)	H614	8.22	8.06	8.50	8.00	0.00	0.97	<.001
Soil (3rd planting	H513	7.91	7.84	8.12	8.00	0.00	0.72	<.001
Soil (3rd planting	Duma 43	8.69	8.28	8.41	8.00	0.00	1.34	<.001
Soil (3rd planting	Kikamba	8.88	7.72	8.41	8.88	0.00	1.39	<.001
Soil (3rd planting	Kinyanya	8.22	8.09	8.00	8.62	0.00	1.19	<.001

SCMV= Sugarcane mosaic virus; MCMV= Maize chlorotic mottle virus; MLN= Maize lethal necrosis

Infected plant remains incorporated in soil versus contaminated soil alone. For the SCMV, the landraces showed disease symptoms immediately on emergence while the hybrids exihibited symptoms later. Generally, they had a higher incidence and severity rate than the hybrids. The plants in contaminated soil plus debris generally had more incidence and higher severity than those in contaminated soil alone. However, no significant difference was noted between varieties.

For MCMV, plants in soil with debris showed symptoms earlier than those in soil alone. The symptoms observed included chlorosis and mottling of the leaves. Kikamba had high disease incidence and severity in the soil incorporated with debris.Generally, the maize varieties acquired the viruses almost equally from the soil and debris although Duma 43 showed no symptomatic plants in soil with debris.

For the co-infection, the landraces showed symptoms immediately after emergence with or without debris. There was general chlorosis which led to necrosis and eventual death of some of the infected plants. Plants in soil with no debris were more diseased compared to those in the soil with debris albeit not significantly different. On disease severity, the same trend was observed where the plants in soil without debris were more affected. Kikamba was more affected than the other varieties and had some of its plants dying from the infection. There was however no significant difference among the varieties. For the MLN, Kikamba had more affected plants than the other varieties and it was significantly different from all the others through weeks 4-6 for the plants in soil without debris. On disease severity, there was no difference noted among

the varieties, however those in the soil without debris recorded more severity when compared to those in the soil with debris.

Area under disease progress curve. The AUDPC was high in plants coinfected with both viruses whereby those in soil plus debris and without debris had the same area (Table 1). Plants in the SCMV infected soil and debris had the second highest symptoms (although they were negative on serological test) and closely followed by those in the MCMV infected soil and debris. Plants in soil and debris infected with MLN coinfection had the least area (Table 1).

Assessing the AUDPC for the five varieties used in the experiment, Kikamba without debris had a large area under disease followed closely by Kikamba with debris. Duma 43 had the least AUDPC. Differences were also recorded in Duma 43 with and without debris, H614 without debris and Kikamba without debris. In the first three scenarios, MLN was significantly different from the rest while in the last case, the combination was different from the rest of the treatments (P=0.05).

Confirmation of the Maize chlorotic mottle and Sugarcane mosaic viruses through serological tests. In each treatment, two leaf samples were collected for serological analysis, making a total of four samples per variety and 20 samples per each virus treatment. None of the samples for SCMV virus tested positive upon serological analysis while 35 of the 60 samples tested for MCMV were positive with 17 of them from the soil with debris while the other eighteen were from the soil without debris. Duma 43 had a sample from asymptomatic plants testing positive for MCMV (data not shown).

Third planting with no debris incorporated

Disease incidence and symptoms severity. For SCMV, Duma 43 and Kikamba showed symptomatic plants one week after planting. The symptoms included fine chlorotic streaks on all the leaves. On incidence, Kikamba was significantly different from the rest of the varieties at P=0.05 with more affected plants. Generally, the severity on the affected plants was low with most of the plants showing only the fine chlorotic streaks. However, some few plants for Duma 43, Kikamba and Kinyanya recorded severe chlorosis and dead heart.

For MCMV, the varieties started exhibiting symptoms on emergence. By week three all the varieties had plants showing chlorotic mottling and stunting which is characteristic for the MCMV. The landraces recorded higher disease incidence while mild severity was recorded on the affected varieties. There was however no significant difference between the different maize varieties tested.

In the co-infection, few plants for Duma 43 and Kikamba showed disease symptoms on emergency. These included mild mottling and streaks on all the leaves. The plants that showed symptoms late had only their upper young leaves with symptoms while those that showed symptoms one week after planting had all the leaves symptomatic. On the disease severity, Kikamba recorded a higher score. Overall, no difference was noted among the varieties.

For the MLN, only the landraces had plants showing disease symptoms one week after planting. H614 only showed one symptomatic plant in the 5th week of data collection while H513 showed a symptomatic plant only in the last week of data collection. Some differences were noted in weeks 4 and 5 when the incidences for the landraces were significantly higher than those for the hybrids. The disease severity recorded was low for this treatment with Kikamba recording a higher severity score but no significant difference between the varieties.

Area under disease progress curve. The Sugarcane mosaic virus had a large AUDPC as compared to the rest of the treatments, followed

closely by the MLN and the combination respectively, while MCMV had the least area (Table 1). There was however no significant difference between the treatments. On varieties, Kikamba had a large area under disease progress curve followed closely by Duma 43. Kinyanya was third with H513 recording the least.

Confirmation of the presence of the maize chlorotic mottle and sugarcane mosaic viruses through serological tests. Four samples were collected per treatment for serological analysis. This made a total of 20 samples per viral treatment. All samples tested negative for SCMV. However for MCMV, 17 of the 60 samples analysed tested postive for the virus while the rest were negative.

DISCUSSION AND CONCLUSION

Recurrence of Maize lethal necrosis (MLN) disease season after season is a worrying trend threatening food security in Kenya and the African continent at large, as the highest population depends on maize. There is a clear indication that the viruses causing the disease survive either in the soil, the plant debris or in both and most of the varieties planted were susceptible. The rate at which the maize plants are able to acquire the viruses from the soil with or without infected debris formed the core of this work.

When infected plant debris were incorporated into the soil, the plants were able to acquire the viruses one week after planting. All varieties exhibited symptoms related to the two viruses, MCMV and SCMV. The landraces seemed to acquire the viruses more easily since they showed symptoms earlier than the hybrids. There was however no major difference among the varieties whether the soil had debris or not. Plants that were planted in soils previously containing plants coinfected with the two viruses had the largest AUDPC while at variety level, the landrace Kikamba without debris had a large AUDPC followed closely with that for the same variety but with debris. Duma 43 had the least area under disease progresss curve. Albeit not significant, the addition of debris seem to enhance disease acquisition as was previously demonstrated for MCMV (Uyemoto, 1983). Plants that had acquired the viruses immediately on emergence developed severe chlorosis resulting in necrosis and eventually dead hearts. These plants were generally stunted. This is a clear demonstration that the disease can cause severe damage if it attacks early.

Irrespective of whether the soil is incorporated with the plant debris or not, the viruses can still be acquired from the soil that has not been given a rest to allow for the viruses to degrade. The small roots left behind after harvest and uprooting of the maize plants also play a significant role in the survival of the viruses. As earlier demonstrated (Jiang *et al*., 1992), both viruses can be found in any part of the maize plant so long as the plant was infected. This is important in planning the disease management strategy. Plant residues have also been demonstrated to play a very crucial role in the survival of the MCMV when the maize plants are off season (Montenegro and Castillo, 1996). In earlier experiments the role of crop rotation was emphasised in managing the outbreaks (Uyemoto, 1983). In the third planting in the infected soil without any debris incorporated, few plants were able to acquire the viruses, an indication of viral load reduction with time.

On the serological analysis of the collected samples however, all the samples for the SCMV tested negative despite the fact that they had very clear symptoms on the plants during data collection. The propable reason could be that the antisera used for this test was of a diffferent strain from the one used for this experiment. There are varied strains of SCMV in East Africa where the Kenyan strain has 87% identity to the Rwandan strain which is 95% related to the SCMV-DMB

strain (Adams *et al*., 2014). Handling of the samples also during storage could have affected the results. More investigations need to be done to explain the scenario for the SCMV.

The acquired virus on the few plants act as focal points for further spread of the virus.These are the sources of inoculum which is spread to healthy plants mechanically or through the insect vectors. Earlier studies of SCMV in sorghum had shown that the virus can be easily aquired from infected soil or contaminated containers (Bond and Pirone, 1970).

From the above results, its evident that infected soil and debris are crucial in the survival and spread of the viruses causing MLN disease. Their management is critical in addressing the spread and control of this disease. It is therefore important to put measures in place to ensure maize debris is properly managed and the farmers encouraged to carry out crop rotation to reduce the chances of picking the viruses from the infected soil. The role of few infected plants in the field should also be addressed to avert spread to other non infected plants by vectors and mechanically through the crop management processes. Asymptomatic plants also play a role in reoccurrence of the outbreak as demonstrated by the asympromatic Duma 43 hence proper field sanitation should be encouraged during the crop production period to avoid unnecessary spread of the disease.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Associations between intensification interventions and herd productivity in smallholder dairy farms in the Kenyan Highlands

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ABSTRACT
Smallholder dairy farms intensify their milk production through genetics, ecological and socioeconomic interventions to attain increased milk production for food and income security, but viability of the interventions may be an impediment towards sustainability. This study established the association between intensification interventions and herd productivity for a random sample of 140 smallholder dairy farms benefitting from Kenya Market led Dairy Program (KMDP) in Kiambu and Meru Counties in Kenya. Data obtained in cross sectional survey were processed in excel spreadsheet for descriptive statistics, Principle Component Analysis (PCA) and regression modelling to derive optimal predictive models for describing association of intensification intervention and herd productivity indicators. All the indicators showed large variations between farms in intensification interventions and herd productivity. From the indicators, PCA extracted two principle components (PC) of which positive associations were realized between indicators of intensification interventions and herd productivity. Socioeconomic interventions (concentrates, milk sales, credit uptake) had the most contributions (50.7% and 39.7%) towards the total variations in milk yield (R^2 =58%) and margins per litre of milk (R^2 = 45%) respectively as compared to genetic (insemination costs-6.7% and 3.7%) and ecological (manure recycling-0% and 2.4%). Sensitivity analysis with the optimal predictive model showed that a ten percent increase in concentrate fed would increase milk yield by 0.13% but reduce the margins earned by 0.09% per liter of milk. Spending more on insemination, however, would marginally reduce yield and margins while ten percent more milk sales would increase margins by 9.16%. Overall, socio-economic intervention contributed more towards positive externalities in herd productivity. As such use of dairy inputs especially concentrates is necessary to enable farmers attain profitable returns and assure economic sustainability of dairy farming.

Key words: Diary farming, Kenya, milk yield, principle component analysis, regression analysis

RÉSUMÉ
Les petites exploitations laitières intensifient leur production de lait grâce à des interventions génétiques, écologiques et socio-économiques dans le but d'atteindre une production accrue de lait pour la sécurité alimentaire et des revenus, mais la viabilité des interventions peut être un obstacle à la durabilité. Cette étude a établi l'association entre les interventions d'intensification et la productivité du troupeau pour un échantillon aléatoire de 140 petites exploitations laitières bénéficiant du programme laitier dirigé par le marché du Kenya (KMDP) dans les comtés de Kiambu et de Meru au Kenya. Les données obtenues dans le cadre de l'enquête transversale ont été traitées dans le tableur Excel pour les statistiques descriptives, l'analyse en composantes

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principales (ACP) et la modélisation de régression afin de dériver des modèles prédictifs optimaux pour décrire l'association de l'intervention d'intensification et les indicateurs de productivité du troupeau. Tous les indicateurs ont montré de grandes variations entre les exploitations dans les interventions d'intensification et la productivité du troupeau. À partir des indicateurs, l'ACP a extrait deux composantes principales (PC) dont des associations positives ont été réalisées entre les indicateurs des interventions d'intensification et la productivité du troupeau. Les interventions socioéconomiques (concentrés, ventes de lait, utilisation de crédits) ont eu le plus de contributions (50,7% et 39,7%) aux variations totales du rendement en lait (R^2 = 58%) et des marges par litre de lait (R^2 = 45%) respectivement par rapport au génétique (coûts d'insémination-6,7% et 3,7%) et à l'écologique (recyclage du fumier-0% et 2,4%). Une analyse de sensibilité avec le modèle prédictif optimal a montré qu'une augmentation de 10% du concentré nourri augmenterait le rendement en lait de 0,13% mais réduirait les marges gagnées de 0,09% par litre de lait. Dépenser davantage pour l'insémination, cependant, réduirait légèrement le rendement et les marges tandis que les ventes de lait de plus de dix pour cent augmenteraient les marges de 9,16%. Dans l'ensemble, l'intervention socio-économique a davantage contribué aux externalités positives de la productivité du troupeau. Une telle utilisation des intrants laitiers, en particulier des concentrés, est nécessaire pour permettre aux agriculteurs d'obtenir des rendements rentables et assurer la durabilité économique de l'élevage laitier.

Mots-clés : Laiterie, Kenya, rendement en lait, analyse en composantes principales, analyse de régression

INTRODUCTION

Dairy farmers intensify their milk production to attain more output per unit input (The Montpellier Panel, 2013). In dairy farms, indicators of output are productivity measures represented by milk yields resulting from improved high yielding livestock breeds, better feeding and nutrition and practicing best animal husbandry practices. Muia *et al*. (2011) indicated that milk production per hectare increased with increasing level of intensification and attributed this to access to extension services which aid in knowledge provision on better dairy husbandry management and practices. However, Kibiego *et al*. (2015) observed that as milk yield increases, gross margin and profit per litre of milk may decrease with increase in the level of intensification within smallholder dairy farms. This was attributable to increase in production costs involving feeds, drugs and labour costs. The authors further observed that farmers need extension services and finances to improve on feed production and utilization technologies essential for increasing profitability. This is partly achieved through cooperative movements where farmers are able to access supplementary feeding through provision of feeds on credit arrangements (Bebe, 2008). The objective of this study was to establish relationships between herd productivity indicators and intensification interventions within smallholder dairy farms to inform management interventions for sustainable dairy farming in Kenya.

MATERIALS AND METHODS

Study area. The study was undertaken in Kiambu and Meru Counties on smallholder dairy farms benefitting from the Kenya Market Led Dairy Program (KMDP) interventions being beneficiaries of intensification interventions. The farms represent the leading milk sheds in Kenya with a large population of smallholders intensifying their dairy production, favorable climatic conditions for dairy production, the high participation in dairy farmer cooperatives and small land holdings on which dairy is integrated with crops (Bebe *et al*., 2003; Bebe, 2004).

Survey methodology. A cross sectional survey was undertaken between February and June 2016. A sample size of 140 farms was determined (Anderson *et al.,* 2003):

$$n = \frac{z^2 . p . q}{e^2}$$

Where z is desired confidence interval level set at 1.96 for 95% confidence interval, p is the proportion of a characteristic of the population to be sampled, which was set at 0.735 being the proportion of households in the Kenya highlands that keep dairy obtained from (Bebe *et al*., 2003), q = (1- p), and e is the error margin allowable for detecting a difference in the sample and was set at 0.1.

The farms were randomly selected from lists provided by SNV, the NGO implementing the KMDP program in Meru and Kiambu Counties in Kenya for the members of the Cooperatives.

Data collection. Data collection was through observations and farm household interviews using a pre-tested structured questionnaire designed to capture individual animal and farm level data on indicator variables of genetics, ecological, socioeconomic interventions and herd productivity. The indicators were either measured directly in scale variable units or computed from the raw collected data. The computed indicator variables included concentrates, Napier, crop residues, legumes and off farm sourced feeds per Tropical Livestock Unit (TLU) on the farm. The TLU was computed from herd composition on the basis of 1 for bull, 0.7 for cow, 0.5 for heifer and 0.2 for calves (Bebe, 2004). Production costs and gross margin per litre of milk was computed from revenues and input costs.

Data analysis. The analysis aimed at detecting the association between intensification interventions and herd productivity indicators. The analysis involved processing indicator variables on each sample farm in excel spreadsheet to generate descriptive statistics, Principle Component Analysis (PCA) using Statistical Package for Social Sciences (SPSS) version 20 (SPSS, 2011) and multiple linear regression modelling using the regression procedures of Statistical Analysis System (SAS, 2009) version 9.1. Data analysis proceeded in two stages involving PCA to reduce dimensionality in the data set and to select indicator variables for regression analysis. The goodness of fit of PCA was assessed on basis of Varimax rotation with Kaiser-Meyer-Olkin Normalization procedure (KMO). The varimax rotation aided in extracting fewer PCs with highly correlated variables that maximize sum of variances to simplify interpretation of the extracted PCs. Hair *et al*. (2006) and Che *et al*. (2013) explains application of the KMO as a measure of sampling adequacy which is satisfied when KMO value is at 0.5 and is significant ($p<0.05$). In addition, Bartlett's test of sphericity was computed to check that the correlation matrix was not an identity matrix for which a p value <0.05 is indicative. A factor loading of ±0.3 was set prior and a rule of thumb applied in which an extracted PC had to explain at least 100/PC% of the variance to be selected for the next stage of regression modelling (Afifi and Clark, 1984; Rougoor *et al*., 2000).

The second stage of data analysis involved fitting selected indicator variables from the PCA into a multiple regression model to determine optimal predictive model that explains association of herd productivity with the three groups of intensification interventions.

The multiple linear regression model fitted was in the form:

$$Y_{ij} = a + b1(x1) + b2(x2) + b3(x3) + \ldots + bn(xn) + e_{ij}$$

where a is the intercept, b_1, b_2, b_3 … bn are the coefficients for variable x_1, x_2, x_3 … x_n respectively and e_{ij} is the random error.

In this model, x predictor variables are represented by indicators of the intensification interventions while the y dependent variables are herd productivity. The model goodnes of fit was judged on the criteria of smallest

AIC or BIC and SSE and largest adjusted R^2 to obtain an optimal predictive model that defines the association between intensification interventions and herd productivity.

RESULTS

Table 1 presents the descriptive statistics for herd productivity indicators from sampled smallholder dairy farmers. The means have large standard deviations, indicative of large heterogeneity between the farms in levels attained in herd productivity.

In Table 2, the PCA fitted for indicators defining intensification interventions and herd productivity was satisfactory in sampling adequacy (KMO=0.616) and the correlation matrix was not an identity matrix (Bartlett's test Chi square =1457.48, p=0.000). Two PCs were extracted that explained 99.63% of the total variance and applying the rule of thumb (100/2PCs=50%), only variables loading on PC 1 explaining 90.06% of the total variance were selected for further regression analysis. The variables loading highly on it were three socioeconomic indicators (credit uptake, milk sales and concentrate use), one ecological indicator (manure recycling) and one indicator of genetics (insemination costs) interventions and all had positive associations with milk yield and margins per litre of milk. Two regression models were subsequently fitted to explain milk yield and margin per litre with the indicators of ecological, genetic and socioeconomic interventions in intensification of dairy production.

Table 1. Descriptive statistics for indicator variables of herd productivity in sampled dairy farms (n=140)

Herd productivity	Units	Mean	SD
Production cost	KES/ kg of milk	20.4	5.3
Milk yield	Kg/cow/month	342	130
Calving interval	Months	17.0	2.0
Age at first calving	Months	30.1	3.2
Margin/litre	KES/litre of milk	4.2	7.5

KES= Kenya shillings

Table 2. Retained variables for herd productivity and intensification interventions from PCA

Indicator variables	Principle component 1	Principle component 2
Credit uptake	0.944	
Replacement cost		0.767
Milk sales	0.551	
Insemination cost	0.399	
Concentrates use	0.382	
Milk yield	0.342	
Manure recycling	0.340	
Margin per litre of milk	0.331	
Total variance explained (%)	90.063	9.566

Rotation method: Varimax with Kaiser-Meyer-Olkin Normalisation. Sampling adequacy (KMO=0.616). Bartlett's test of sphericity (Chi square =1457.477, Sig=0.000).

The retained variables were submitted to regression model to derive an optimal predictive model for milk yield and margins per litre of milk. The results are presented in Table 3 for optimal model from a selection of 15 and 31 models evaluated for milk yield and margins per litre of milk respectively on the basis of smallest AIC, BIC, C(p) and SSE values and largest R^2. More than half (58%) of the variations in milk yield was explained by socioeconomic interventions (concentrate use, milk sales and credit uptake) and genetic intervention (insemination costs) without ecological intervention indicators. In contrast, about half (45%) of the variations in margins per litre of milk were explained by socioeconomic (concentrates use, milk sales), genetics (insemination costs) and ecological intervention (manure recycling) indicators.

The optimal models derived for estimating the milk yields (M) and margin per litre of milk (G) respectively were:

$$M = 6.38007 + 0.00061571(C) + 0.23152(S) - 0.00001009(L) - 0.00051878(I)$$

$$G = 6.34086 + 0.59428(S) - 0.00111(C) - 0.00100(I) - 0.82356(MU)$$

Where M = milk yield in kg per cow, G = margins per litre of milk, C = concentrates used in kg dry matter per tropical livestock unit, S = milk sales in kg per herd, L = credit uptake in Kenyan Shillings per year, I = insemination costs in Kenya shillings per animal and MU = manure recycling. The optimal model for milk yield show that socioeconomic indicators of significance (Table 4) are concentrate use, credit uptake and milk sales which accounted for 50.7% of the variance and genetics has one indicator variable of significance, insemination costs, which accounted for only 6.7%. Concentrate use and milk sales show positive association with milk yield while credit and insemination costs had negative associations. In the optimal model for explaining margins per litre of milk, the socioeconomic indicators of significance were concentrate use and milk sales which accounted for 39.7% of the variance, much higher than variance accounted for by genetics (3.7%) intervention represented by insemination costs or ecological intervention (2.4%) represented by manure recycling. The margin per litre of milk was positively associated with milk sales but was negatively associated with manure recycling, insemination costs or concentrate use.

With the regression equation, sensitivity analysis of the selected optimal intensification intervention variables on milk yield and margins per litre of milk was performed and results are presented in Figure 1. The analysis showed that, a ten percent increase in concentrate feed would increase milk yield by 0.13% but reduce the margins earned by 0.09% per liter of milk. Spending more on insemination, however, would marginally reduce milk yield and margins while ten percent more milk sales would increase margins by 9.16%.

Table 3. Optimal model selected for explaining milk yield and margin per litre of milk

Model	Variables in the model	Adj R^2	AIC	BIC	C(p)	SSE
Milk yield	Concentrates, Milk sales, Credit uptake, Insemination cost	0.58	318.03	320.40	5.00	1263.75
Margin per litre of milk	Concentrates, Insemination cost, Milk sales, Manure recycling	0.45	498.71	501.15	4.06	4593.56

Table 4. Coefficients and variance contribution explaining milk yield and gross margins/litre of milk

Intensification indicators	Milk yield (kg/cow/month)		Gross margin (KES/Litre milk)	
	Coefficients	Variance (%)	Coefficients	Variance (%)
Insemination costs (KES/cow)	-0.00051878	6.7	-0.00100	3.7
Concentrate use (kg/TLU)	0.00061571	7.0	-0.00111	3.5
Milk sale (KES/herd/month)	0.23152	41.3	0.59428	36.2
Credit uptake (KES/year)	-0.00001009	2.4		
Manure recycling (kg/year)			-0.82356	
Constant	6.38008		6.34086	
Total variance explained (%)		57.5		45.8

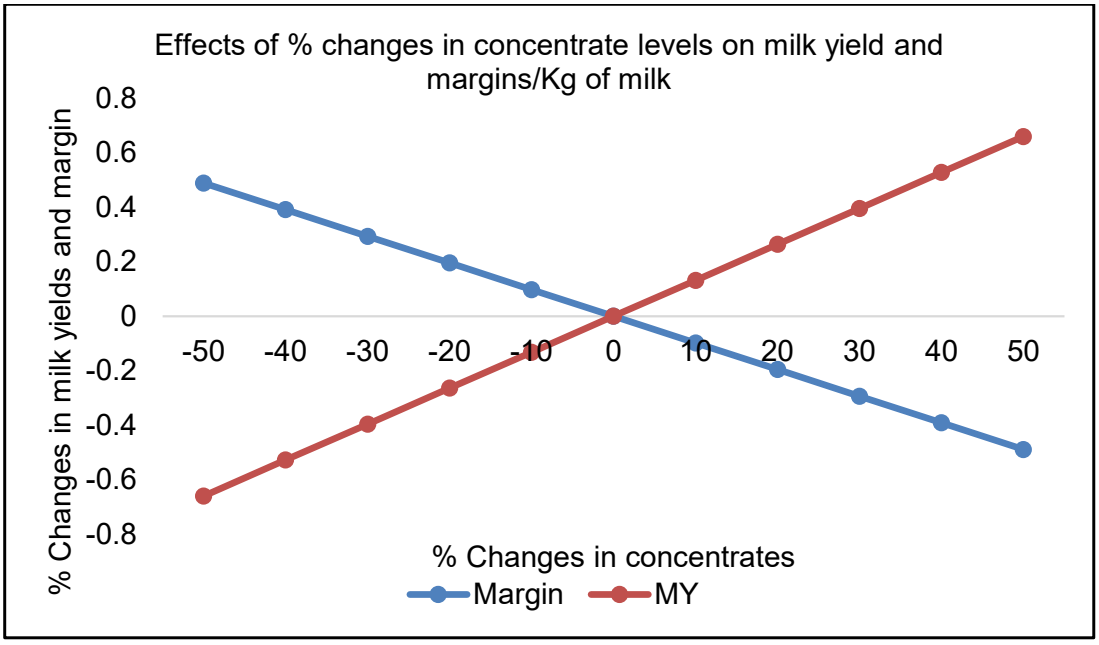

Figure 1. Effects of % changes in concentrates on milk yield (MY) and margins

DISCUSSION

The indicator variables of significance in the association between intensification interventions and herd productivity were milk yield and margins per litre of milk, which represent positive externalities. Milk production was estimated at 324.4 litres per cow per month (Table 1), which translates to about 10 litres per cow per day, comparing well with 309 litres per cow per month observed in the Kenya highlands (Mburu *et al*., 2007; Tegemeo, 2016). The margins per litre of milk was estimated at KES 4.2 which also compares well to KES 3.45 to 8.25 range obtained in previous empirical studies (Mburu *et al*., 2007; Kibiego *et al*., 2015; Tegemeo, 2016). However, the means of milk yield and margins per litre of milk had large standard deviations, typical of recall data, which in this study was one year recall data because record keeping is not well practiced

in smallholder farms (Murage and Ilatsia, 2011; Bett, 2016). Production costs of up to KES 20.40 per litre of milk are comparable to KES 18.10 and KES19.00 reported by Mburu *et al*. (2007) and Tegemeo (2011) and points to farmers spending more on inputs to maximize milk production, but this stepping up of production costs erodes profitability despite supporting increased milk productivity. Milk production per cow per year is influenced by calving intervals, which averaged 17 months, typical of smallholder farms (Bebe *et al*., 2003) which can be explained by imbalanced feeding, poor heat detection and insemination failures and long periods of lactation in excess of 330 days (Staal *et al*., 2001).

The optimal model for milk yield had an explanatory power of 57.5% of which the socioeconomic indicators contributed the most (50.7%) and the genetic indicators just a little (6.7%) while the ecological interventions had no contribution. The socioeconomic indicator variables were concentrate use, credit uptake and milk sales while the genetics indicator variable was insemination costs. The socioeconomic indicator variables of significance in the derived model demonstrate interventions that were targeted to provide an enabling environment for accessing input and output markets while the genetic indicator variable demonstrate interventions that targeted improving genetic quality of the herd, and investments in reproductive technology to attain high milk yielding potential. Linking farmers with markets for both inputs and outputs provide a pathway to intensification adoption because milk is a perishable commodity that requires marketing arrangements for collection, distribution and sale.

Results showed that farmers would obtain more milk yield with feeding more concentrates and selling more milk because these indicator variables had positive association with milk yield. Lukuyu *et al*. (2007) in a study of the feeding regimes in smallholder dairy farms explained that concentrates provide balanced supplementary diets to milking cows which are pervasively underfed with crop residues and roughages of poor quality. Supplementing concentrates will therefore have marked effect on increasing milk yield in smallholder dairy cows, as demonstrated in the studies of Duncan *et al*. (2013), Kashongwe *et al*. (2014) and Kashongwe *et al*. (2017). The production of large volume of milk is expected to trigger market participation with the surplus milk on the farm, hence the positive association between milk yield and milk sales because income from milk sales is a major goal in the decision to intensify dairy production.

On the other hand, uptake of credit and insemination costs had decreasing effects on milk yield. Several situations in smallholder farms could possible explain this. The credit though obtained for dairy investments, may be invested in other farm productive activities that support but take long to influence milk yield. These can include improving quality of the breed, housing and equipment and on-farm feed production. The credit uptake referred to last one year recall data. Results on the insemination costs imply that increased investments in insemination services were associated with a decline in milk yield. Increased insemination is likely aimed at improving quality of breeding stock but it may be that farmers failed to match quality of the breeding stock with their management standards, especially feeding and health, resulting in improved stock failing to express full genetic potential.

The optimal model explaining margins per litre of milk had socioeconomic, genetics and ecological intervention indicator variables. The model explained 45.8% of the variation in margins per litre of milk and the socioeconomic indicator variables accounted for the largest

variance (39.7%) compared to the genetic (3.7%) or ecological (2.4%) indicator variables. The socioeconomic indicator variables were concentrate use and milk sales while the genetics indicator variable was insemination costs and ecological indicator variable was the amount of manure recycled on the farm. The large variations in margins per litre explained by the socioeconomic indicators further serve to demonstrate the importance of an enabling environment for supporting intensification of dairy production because unreliable milk markets can impede commercialization and discourage intensification process.

Margins per litre of milk had positive associations with milk sales but negatively associated with concentrate use, manure recycling and insemination costs. The positive association of margins per litre of milk with milk sales may be explained by better milk price obtained by the farmers delivering more milk to cooperatives because they can negotiate price (Rademaker *et al*., 2016) as the sample farmers were members of farmer cooperative societies. The negative association of insemination costs and concentrate use with the margins obtained per litre of milk could have resulted from increased production costs incurred in using these inputs, because they are highly priced in Kenyan markets, hence decreasing the margins as obtained in the studies of Kibiego *et al*. (2015) and Tegemeo, (2016). Spending more on semen would mean that farmers were ordering for higher quality semen but not realizing immediate benefits of quality genetics, because of increased cost of production and hence the negative associations with the margins earned. This applies as well to feeding more concentrates purchased at high market price thereby increasing the production costs and subsequently lowered margins earned. This could be related to inefficient resource use on the farms as suggested in the findings of Kibiego *et al*. (2015) that economic efficiency in producing milk under intensive systems is 65% and that margins per litre of milk decreases with increasing costs of feeds. This is possible via enhanced resource management and allocation as demonstrated by Cortez-Arriola *et al*. (2016) in smallholder dairy intensification in North-West Michoacán of Mexico that just re-allocating the current resources itself leads to economic, social and/or environmental improvements.

CONCLUSION

Socioeconomic interventions had the greatest contribution to both milk yield and margins earned. Both genetic and ecological interventions had little influence. Concentrate use is important for increasing milk production, but the price will be prohibitive to more use of concentrates, because of reduced margins.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Validation of efficacy of rabbit anticoccidial drugs commonly used in Kenya

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ABSTRACT
The objective of this study was to determine the efficacy of three most commonly used off label (poultry based) anticoccidials in treatment of rabbit coccidiosis by smallholder rabbit farmers in Kenya. The test drugs as independently identified by farmers and agro-veterinary suppliers in a baseline survey were sulphachloropyrazine, amprolium and trimethoprim-sulphamethoxazole and were benchmarked against diclazuril (diclosol 1%) as the standard drug in experimental and natural coccidial infections. Sixty weaner rabbits of New Zealand white and California white breeds were randomly allocated to six treatment groups (A, B, C, D, E and F) each with 10 rabbits in a controlled laboratory trial. Groups B, C, D, E and F were experimentally infected with mixed *Eimeria* species while group A served as uninfected-untreated (negative) control group. Four of the infected groups were respectively treated with sulphachloropyrazine (E), amprolium hydrochloride 20% (B), trimethoprim-sulphamethoxazole combination (F) and diclazuril (diclosol 1%) (D) at dosages recommended by the manufacturers (poultry reference dosages). Group C was the infected untreated (positive) control group. Field efficacy trials in naturally infected rabbits were then conducted to validate the laboratory results. Results revealed high efficacy of suphachloropyrazine and diclazuril manifested by reduced oocysts counts, faecal and lesion scores in the controlled laboratory trial approaching those of the negative control group. Similarly, sulphachloropyrazine and diclazuril recorded high efficacies against natural coccidiosis in the field trials which was manifested by significant reduction of oocysts shed. Trimethoprim-sulphamethoxazole recorded moderate to satisfactory efficacy in the field trial but was not efficacious in the laboratory trial. Amprolium was not able to control coccidiosis in both laboratory and field trials at the recommended poultry reference dosages. This study recommends prudent use of available efficacious anticoccidial drugs in the country to prevent development of resistance.

Key words: Amprolium, diclazuril, *Eimeria*, Kenya, oocyst, rabbit coccidiosis, sulphachloropyrazine

RÉSUMÉ
L'objectif de cette étude était de déterminer l'efficacité des trois anticoccidiens les plus couramment utilisés sans étiquette (à base de volaille) dans le traitement de la coccidiose du lapin par les petits éleveurs de lapins au Kenya. Les médicaments d'essai identifiés indépendamment par les agriculteurs et les fournisseurs agro-vétérinaires dans une enquête de référence étaient la sulphachloropyrazine, l'amprolium et le trimethoprim-sulphaméthoxazole et étaient comparés au diclazuril (diclosol 1%) comme médicament standard dans les infections coccidiennes expérimentales et naturelles. Soixante (60)

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lapins sevrés de race blanche de Nouvelle-Zélande et de race blanche de Californie ont été répartis au hasard dans six groupes de traitement (A, B, C, D, E et F), chacun avec 10 lapins dans un essai contrôlé au laboratoire. Les groupes B, C, D, E et F ont été expérimentalement infectés avec des espèces mixtes d'*Eimeria* tandis que le groupe A a servi de groupe témoin non infecté-non traité (négatif). Quatre des groupes infectés ont été traités respectivement par la sulphachloropyrazine (E), le chlorhydrate d'amprolium 20% (B), l'association triméthoprime-sulphaméthoxazole (F) et le diclazuril (diclosol 1%) (D) aux doses recommandées par les fabricants (doses de référence pour la volaille). Le groupe C était le groupe témoin infecté (positif) non traité. Des essais d'efficacité sur terrain des lapins naturellement infectés ont ensuite été menés pour valider les résultats de laboratoire. Les résultats ont révélé une efficacité élevée de la suphachloropyrazine et du diclazuril manifestée par une diminution du nombre d'oocystes, des scores fécaux et de lésions dans l'essai de laboratoire contrôlé approchant ceux du groupe témoin négatif. De même, la sulfachloropyrazine et le diclazuril ont enregistré des efficacités élevées contre la coccidiose naturelle dans les essais sur le terrain qui se sont manifestées par une réduction significative de la perte d'oocystes. Le triméthoprime-sulphaméthoxazole a enregistré une efficacité modérée à satisfaisante dans l'essai sur le terrain mais n'a pas été efficace dans l'essai en laboratoire. Amprolium n'a pas été en mesure de contrôler la coccidiose dans les essais en laboratoire et sur le terrain pour les doses de référence de volaille recommandées. Cette étude recommande l'utilisation prudente des médicaments anticoccidiens efficaces disponibles dans le pays afin d'empêcher le développement d'une résistance.

Mots-clés: Amprolium, diclazuril, *Eimeria*, Kenya, oocyste, coccidiose de lapin, suphachloropyrazine

INTRODUCTION

Farmers in Kenya spend significant amount of money to control rabbit diseases (Okumu *et al.,* 2014). The most common and devastating of these diseases is coccidiosis which results in huge economic losses (Bhat *et al.*, 1996). Rabbit coccidiosis mainly affect weanlings resulting in high mortality and morbidity. It presents with clinical signs of dehydration, diarrhoea, rough hair coat, inappetence, poor performance, and reduced productivity (Jithendran, 2010). Two forms of coccidiosis occur in rabbits and is caused by 11 different species of *Eimeria* (Pakandl, 2009). One form is intestinal coccidiosis where *Eimeria* spp. invade the intestines resulting in varied pathogenicity (Sivajothi *et al.,* 2014). The other form is hepatic coccidiosis caused by *E. stiedae* that invades the biliary epithelial cells (Bhat *et al.,* 1996). Mixed infection by both forms are common in Kenya (Okumu *et al.,* 2014). Transmission of both forms occur through feco-oral route and is exacerbated by poor hygiene (Pakandl, 2009). Several control strategies are used to control coccidiosis. These include strict biosecurity and hygiene (Pakandl, 2009), use of vaccines (Drouet-Viard *et al.*, 1997), and natural extracts from plants, fungus and microorganisms (Quiroz-Castañeda and Dantán-González, 2015). However, the use of synthetic chemical anticoccidials labelled for poultry remain the most commonly used prevention and treatment method against rabbit coccidiosis in Kenya. To date there are no specific rabbit anticoccidials in Kenya and farmers use poultry anticoccidials to treat rabbit coccidiosis. This, they do using the poultry dosages with little or no knowledge of their safety and efficacy against rabbit coccidian parasites. No literature exist in Kenya on the efficacies of these drugs against rabbit *Eimeria* spp. The purpose of this study was to determine the efficacy of most commonly used poultry based anticoccidial drugs by rabbit farmers in Kenya benchmarked against a standard drug (Diclosol 1%) that have proven efficacy

elsewhere and have not been used in Kenya, under experimental and/or field conditions.

MATERIALS AND METHODS

Description of the study. The three most commonly used anticoccidials by rabbit farmers were determined through an already published baseline survey (Ogolla *et al.,* 2017) as suphachloropyrazine, trimethoprim-sulphamethoxazole and amprolium. A total of 60 rabbits were randomly allocated into six groups each consisting of 10 rabbits (A, B, C, D, E, and F). Groups A and C served as uninfected untreated (negative control) and infected untreated (positive control), respectively. Rabbits in groups B, C, D, E and F were challenged with 120,000 mixed *Eimeria* sporulated oocysts administered orally using a syringe. Treatments were commenced either when oocyst per gram o.p.g counts reached at least 500,000 o.p.g and/or when clinical signs of coccidiosis were observed. Group B was treated with amprolium administered at 1g/liter for 7 consecutive days. Group D was treated with diclazuril (Diclosol 1%) at 10 ppm for 48 hours. Group E was treated with sulphachloropyrazine 30% for six days as follows: 1st, 2nd, 3rd, 5th, 7th, and 9th day. Group F was treated with trimethoprim-sulphachloropyrazine combination administered at 1g/litre for 7 consecutive days. All the treatments were administered according to the manufacturer's instructions in fresh drinking water changed on a daily basis. Fecal samples were collected from the 2nd day to day 30 post infection. The number of oocysts per gram of feces of each group was determined using modified McMaster technique (MAFF, 1986). Daily number of dead rabbits was recorded and mean weight gain for each group determined at the end of the experiment. In order to assess the lesion score, three rabbits from each group were picked randomly for necropsy examination at the end of the experiment, in addition to those that died during the trial. Lesion scores were determined through macroscopic examination of the duodenum, jejunum, ileum, caecum, colon and the liver of each rabbit. The lesions were scored as 0 when no evident lesion was seen while a score of 3 was assigned to the severely infected rabbits as described by Elbahy *et al.* (2006). Feces voided were observed and scored from day 1 post infection to day 20 post treatment according to Ramadan *et al.* (1997). Field trials were then conducted in 10 farms to validate the laboratory results.

Field trials. Any rabbit with oocyst counts 500,000; or <500,000 oocysts but presenting with clinical signs of coccidiosis such us diarrhea, inappearence and dehydration met the inclusion criteria. The rabbits were randomly assigned to four treatment groups: FA, FB, FC and FD. Each treatment group had 90 sick rabbits. Each treatment group was further subdivided into 18 sub-treatment groups each containing five rabbits giving 18 replications distributed randomly on a prorate basis in all the ten farms. Group FA received diclazuril (diclosol 1%) at 10ppm for 48 hours while group FB were given sulphachloropyrazine at 2g per liter on days 1, 2, 3, 5, 7 and 9. Group FC received trimethoprim-sulphachloropyrazine combination at 1g per liter administered daily for 7 days and finally, group FD was put under amprolium hydrochloride (20%) treatment at 1g per liter (1000ppm) for 7 consecutive days. Oocyst counts were pooled for each sub-treatment group and mean oocyst counts determined after every two days up to day 20 post treatment.

Assessment of drug efficacies. Efficacy of the drugs was assessed through fecal oocyst counts, fecal scores, lesion scores, mortality and survival rates and mean weight gains of various treatment groups. The effectiveness of the test drugs was determined by comparing the above parameters for the treated groups with those for positive and negative control groups.

Data analysis. Analysis of variance was performed by one or two way ANOVA as described by GenStat. Significant differences of

the means of the various treatment groups were assessed by Bonferroni multiple comparison test to control overall significance levels as described in Genstat statistical analysis program (GenStat 15th Edition). The resulting data were presented as mean ± SEM and significance levels stated at $p<0.05$.

RESULTS AND DISCUSSIONS

Mean fecal scores and standard error of means (SEM). Diclazuril (diclosol 10ppm) and sulphachloropyrazine 1.5g/ liter showed satisfactory results 9 days after treatment in alleviating diarrhea and promoting production of normal fecal pellets as shown in Table 1. Additionally, diclazuril and sulphachloropyrazine treatment groups revealed a significant ($p<0.05$) reduction in fecal score 1.17±0.17 and 1.33±0.21, respectively, compared to positive control group (3.0±0.32). This was in agreement with previous studies that also demonstrated the superior efficacy of curative diclazuril against coccidiosis in rabbits (Vereecken *et al.,* 2012) and avian coccidiosis (El-Banna *et al.,* 2005). There was no significant difference ($p>0.05$) in fecal scores between amprolium and trimethoprim-sulphamethoxazole treatment groups with that of the positive control group as presented in Table 1.

Oocysts sheding. Sulphachloropyrazine and diclazuril caused a significant ($p<0.05$) reduction in mean oocyst shed by the 7th day post treatment at 0.83±0.401 x 10^4/g and 0.122±0.0958 x 10^4/g, respectively compared to the infected untreated group 170.20±68.921 x 10^4/g. By day 13 post treatment, diclazuril group recorded 0.00±0.00 oocyst count impressively better than even that of negative control group 0.173±0.068 x 10^4/g while sulphachloropyrazine group recorded an oocyst counts of 2.03±0.829 x 10^4/g. On day 20 post treatment when the experiment was terminated, the mean number of oocysts shed remained extremely low in the diclazuril group 0.002±0.00167 x 104/g and sulphachloropyrazine group 3.31±0.857 x 10^4/g compared to the infected untreated group, amprolium group and trimethoprim-sulphamethoxazole group as presented in Table 2. The efficacy of sulphachloropyrazine in reduction of oocysts shed has also been elaborated in poultry anticoccidial trials (Das *et al.,* 2017). Likewise, the superior efficacy of diclazuril in elimination of oocysts shed has been reported by several studies on rabbit coccidiosis (Vanparijs *et al.,* 1989; Vereecken *et al.,* 2012) and poultry coccidiosis (El-Banna *et al.,*2005). Trimethoprim-sulphachloropyrazine group had a higher reduction in oocysts shed on day 7 post treatment 61.17±10.603 x 104/g relative to amprolium and infected untreated groups. However, the mean number of oocysts shed by the trimethoprim-sulphamethoxazole group started to rise again from day 13 post treatment and by 20 days post treatment had reached 231.67±51.43 x10^4/g. Nevertheless, this was still significantly lower ($p<0.05$) compared with the infected untreated group 737.50±213.478 x 10^4/g. On the other hand, the number of oocysts shed by the amprolium group 7 days post treatment was higher 357.67±123.451 x 10^4/g compared to that of infected untreated group 170.20±68.921 x 10^4/g though not significantly different ($p<0.05$). In this study, amprolium had the least efficacy compared to the other test drugs. These results agree with earlier studies by Laha *et al.* (1999), Hunduma and Kebede (2016), Das *et al.* (2017), and deviates from results reported by others (Laha e*t al.,* 2015; El-Ghoneimy and El-Shahawy, 2017).

Clinical presentation and gross lesions. The clinically sick rabbits in the various treatment groups presented with distended abdomen, matted perineal region, loss of weight and varying degree of dehydration. Few rabbits from positive control (1 rabbit) and amprolium (1 rabbit) treatment groups had jaundice. No significant clinical findings were observed in

Table 1. Fecal scores from day of treatment to day 20 post treatment in a drug efficacy trial on rabbit coccidiosis in Kenya

Groups	Treatment day 0	5 days after treatment	9 days after treatment	13 days after treatment	17 days after treatment	20 days after treatment
Negative control (A)	1.33±0.21[a]	1.0±0.0[a]	1.33±0.21[a]	1.33±0.24[a]	1.17±0.19[a]	1.17±0.18[a]
Amprolium (B)	3.0±0.26[b]	3.17±0.31[c]	3.17±0.40[b]	3.0±0.24[bc]	2.50±0.24[b]	2.25±0.23[b]
Positive control (C)	3.17±0.31[b]	3.0±0.32[c]	3.0±0.32[b]	3.20±0.26[c]	2.75±0.24[b]	3.0±0.00[b]
Diclazuril (D)	2.67±0.2[1b]	2.17±0.40[bc]	1.17±0.17[a]	1.33±0.24[a]	1.17±0.19[a]	1.0±0.18[a]
Sulphachloropyrazine (E)	2.67±0.21[b]	1.83±0.31[ab]	1.33±0.21[a]	1.17±0.24[a]	1.20±0.21[a]	1.0±0.20[a]
Trimethoprim-sulphamethoxazole (F)	2.83±0.3[1b]	2.33±0.42[bc]	2.0±0.37[ab]	2.0±0.24[ab]	2.67±0.19[b]	2.33±0.18[b]
SD	0.838	1.051	1.043	0.985	0.860	0.844
p-value	<0.001	0.001	<0.001	<0.001	<0.001	<0.001

Values within a column without common superscript are significantly different at p 0.05

Fecal score was done according to Ramadan *et al.* (1997) with 1 indicating normal well-formed fecal pellets through 5 indicating severe diarrhea with/out profuse amount of blood.

Table 2. Oocyst counts from day 1 to day 20 post treatment in the laboratory trial

Group	Mean oocyst shed per treatment group x 10^4/gram of feces					
	Day 1 before treatment	Day 3 post treatment	Day 7 post treatment	Day 13 post treatment	Day 17 post treatment	Day 20 post treatment
Negative control (A)	0.059±0.023[a]	0.093±0.022[a]	0.090±0.0304[a]	0.173±0.0679[a]	0.141±0.0396[a]	0.138±0.0383[a]
Amprolium (B)	19.01±9.567[a]	351.00±127.691[b]	357.67±123.451[b]	416.83±129.864[a]	429.60±129.847[ab]	430.00±62.450[ab]
Positive control (C)	34.93±16.280[a]	151.67±52.180[ab]	170.20±68.921[ab]	432.40±142.793[a]	642.40±177.504[b]	590.02±96.128[b]
Diclazuril (D)	59.700±12.351[a]	14.198±9.178[a]	0.122±0.095[8a]	0.00±0.00[a]	0.00±0.00[a]	0.002±0.00167[a]
Sulphachloropyrazine (E)	149.00±110.392[a]	61.91±37.202[a]	0.83±0.401[a]	2.03±0.829[a]	2.03±0.698[a]	3.31±0.857[a]
Trimethoprim-sulphamethoxazole (F)	197.17±92.657[a]	95.08±35.184[ab]	61.17±10.603[a]	230.50±154.302[a]	358.00±163.169[ab]	231.67±51.43[a]
p-value	0.154	0.004	<0.001	0.008	<0.001	<0.001

Values within a column without common superscript are significantly different at p 0.05

rabbits treated with diclazuril while only one rabbit from the sulphachloropyrazine group had rough hair coat and slight dehydration, other rabbits from the group appeared normal. At necropsy, moderate to severe hepatic and intestinal gross lesions were observed in rabbits in the amprolium, trimethoprim-sulphamethoxazole and positive control groups. Lesions observed were marked congestion of caecum (Fig. 1), ileum and duodenum, greyish to dark luminal contents, few with blood stains (Fig.1), necrotic spots in the caecum (Fig.1), serosal surfaces had hyperemia and echymotic haemorrhages, discoloration of epithelial mucosa of ileum, jejunum and duodenum with haemorrhagic areas, and ballooning of sections of the ileum and caecum. Rabbits from diclazuril and sulphachloropyrazine treatment groups had few to no gross intestinal and hepatic lesions, appearing almost similar to those from negative control group. Conversely, amprolium and trimethoprim-sulphamethoxazole were not effective in reversing intestinal and hepatic gross lesions. Liver of rabbits from amprolium and trimethoprim-sulphamethoxazole presented with hepatic gross lesions of congestion, hepatomegaly, raised multinodular lesions on the liver surface that sometimes coalesced to form larger nodules (Fig. 2), distended bile ducts and entire biliriary tree, discoloured and firm consistency, enlarged gallbladder with thick to solid yellowish-white contents (Fig. 2 and 3), as also observed in liver organs of rabbits from positive control group. These lesions were mild in the sulphachloropyrazine and almost non-existent in diclazuril treatment groups (Fig 4) which did not have any significant lesions and appeared as those of negative control groups.

Figure 1. Gross intestinal lesions from amprolium treatment group (B) showing areas of extensive congestion and hyperemia (white arrow), ballooned sections of caecum and intestine (white arrow heads) and necrotic foci (black arrow)

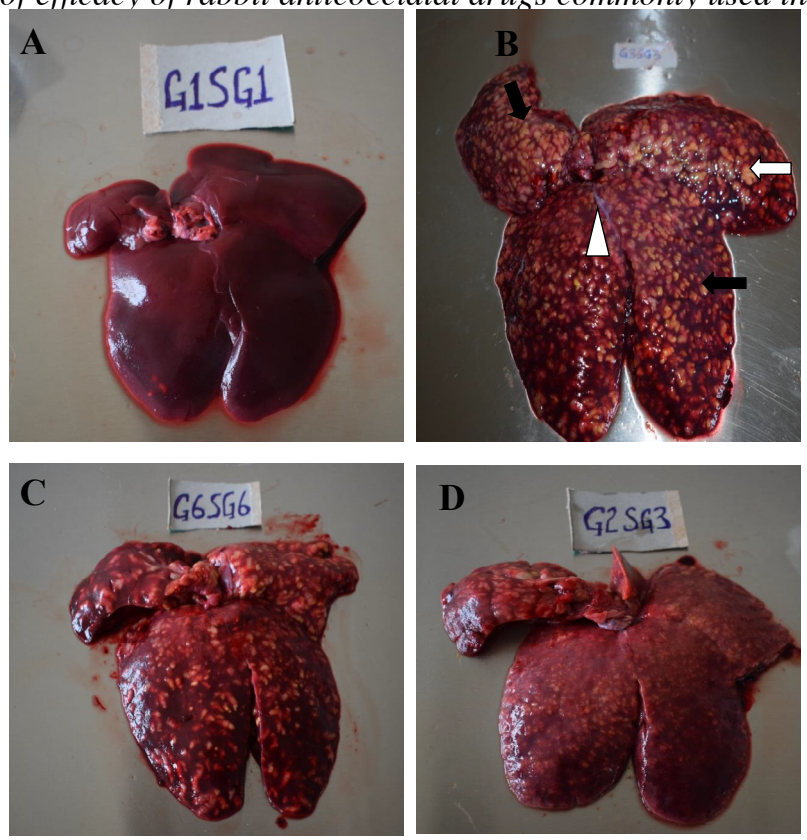

Figure 2. Gross lesions on liver organs at termination of the experiment: A-normal liver from the negative control group, B- Enlarged liver (hepatomegaly) from positive control group with multinodular yellowish-white lesions (black arrow) that sometimes coalesced to form larger nodules (white arrow) and fibrinous strands (white arrow head), C and D- enlarged livers from trimethoprim-sulphamethoxazole and amprolium treatment groups, respectively with multinodular lesions affecting entire hepatic parenchyma.

Figure 3. Rabbit livers from diclazuril (E) group appearing normal with no visible gross lesions and sulphachloropyrazine group (F) presenting with few non-raised gross lesions (arrows) at termination of the experiment

Table 3. Oocysts shed from day of treatment to day 20 post treatment in the field trial

Group	Oocysts shed per treatment group x 103/gram of feces					
	1st day of treatment	Day 2 of treatment	Day 6 of treatment	D ay 10 after treatment	Day 16 after treatment	Day 20 after treatment
Diclazuril FA	473.44±176.01[a]	506.44±187.63[a]	1.13±0.73[a]	0.13±0.10[a]	0.04±0.03[a]	0.00±0.00[a]
Sulphachloropyrazine FB	280.33±44.67[a]	300.50±52.94[a]	15.54±3.96[a]	1.07±0.22[a]	0.59±0.14[a]	0.44±0.14[a]
Trimethoprim/ sulphamethoxazole FC	266.78±37.03[a]	235.72±31.68[a]	40.34±9.80[a]	1.36±0.31[a]	0.75±0.11[a]	0.91±0.11[a]
Amprolium hydrochloride FD	454.06±93.93[a]	513.50±115.82[a]	318.43±72.94[b]	188.31±45.86[b]	232.47±61.97[b]	258.92±70.15[b]
p-value	0.345	0.212	<0.001	<0.001	<0.001	<0.001

Values within a column without common superscript are significantly different at p<0.05

Field trial. In the field trial, diclazuril and sulphachloropyrazine were efficacious against coccidiosis as indicated by decreased oocysts shed of 0.00±0.00 x 103 and 0.44±0.14 x 103 o.p.g, respectively. Trimethoprim-sulphamethoxazole combination had moderate to satisfactory efficacy while amprolium hydrochloride was not able to control clinical coccidiosis in the field. Response to treatment in natural cases validated the laboratory results, with respect to oocyst shedding as shown in Table 3.

CONCLUSION

The present study has demonstrated the efficacy of diclazuril and sulphachloropyrazine in treatment of clinical coccidiosis of rabbits at the recommended poultry dosages. Insofar as timing of treatment is concerned, better results are achieved when treatment is commenced at onset of the disease when clinical signs are still mild or non-existent. These drugs should be used judiciously in treatment of clinical cases of rabbit coccidiosis in combination with strict biosecurity and sanitation to prevent development of drug resistance. On the other hand, therapeutic use of trimethoprim-sulphachloropyrazine and amprolium were not efficacious at the recommended poultry dosages against clinical rabbit coccidiosis. This study recommends their use strictly as prophylactics against rabbit coccidiosis.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Effect of intrinsic clay soil composition on the properties of fired clay bricks

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ABSTRACT
In many developing countries, clay bricks are manufactured by cottage industries with little regards to the intrinsic properties of the clay soil used. This study aimed at determining the properties of fired clay bricks fabricated under similar conditions from clay soils of varied intrinsic properties. The clay soils were collected from different locations in Kenya and their chemical composition analyzed using an Energy Dispersive X-ray Fluorescence. The bricks were fabricated using a consolidation pressure of 2.5 MPa, oven-dried at 100˚C for 24 hours followed by firing at 1000˚C for eight hours. The effect of chemical variation of zonal clay soils on the physical and mechanical properties of clay bricks was established. The determined properties of fired clay bricks investigated in this study emphasizes the need for thorough clay soil characterization and chemical properties standardization before producing bricks for structural applications.

Keywords: Brick shrinkage, clay brick porosity, clay composition, compressive strength

RÉSUMÉ
Dans de nombreux pays en développement, les briques d'argile sont fabriquées par des industries artisanales sans considérer les propriétés intrinsèques du sol argileux utilisé. Cette étude visait à déterminer les propriétés des briques d'argile cuites fabriquées dans des conditions similaires à partir de sols argileux aux propriétés intrinsèques variées. Les sols argileux ont été collectés à différents endroits au Kenya et leur composition chimique analysée à l'aide d'une fluorescence X à énergie dispersive. Les briques ont été fabriquées en utilisant une pression de consolidation de 2,5 MPa, séchées au four à 100 C pendant 24 heures, puis cuites à 1000 C pendant huit heures. L'effet de la variation chimique des sols argileux zonaux sur les propriétés physiques et mécaniques des briques d'argile a été établi. Les propriétés déterminées des briques d'argile cuites étudiées dans cette étude soulignent la nécessité d'une caractérisation approfondie du sol argileux et d'une normalisation des propriétés chimiques avant de produire des briques pour des applications architecturales.

Mots clés: Retrait plastic de la brique, porosité de la brique d'argile, composition de l'argile, résistance à la compression

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INTRODUCTION

Clay soil is majorly composed of alumina (A_l2O_3) and silica (S_iO_2) in a layered structure (Kaolinite) that contains chemically bound water. In addition, it contains other compounds (usually oxides) of iron, calcium, sodium, barium, potassium, and also some organic and soluble matter (Murthy, 2002). The plasticity of clay when mixed with water is attributed to lubrication effect of water film adsorbed on the layered crystal structure of clay mineral. The evaporation of water during drying of water-clay mixture results in a rigid structure (green body). Firing of the green body at temperatures above 1000˚C results in vitrification where a liquid glass is formed from the alumina, silica, free oxides and fluxes in the clay material. The liquid glass flows around the remaining un-melted particles and fills in the pores as a result of capillary action. On cooling, a glassy matrix is formed by the fused phase resulting in a dense, strong body. The final microstructure of the fired clay product thus consists of a vitrified phase, any un-reacted quartz particles, and some porosity (NPCS Consultants, 2007).

The formation of clay soil is a natural process and therefore its chemical composition may vary depending on the geological and environmental conditions (Bergaya and Lagaly, 2013). Since the production of a fired clay product is based on a chemical process, its mechanical and physical properties may vary depending on the chemical composition of the clay soil used. As reported by (Okunade, 2008), clay soil with different physical properties produces fired clay bricks with varying densities, compressive strength and porosity. A study on ancient clay bricks from different regions, reported a variation in their chemical, physical and mechanical properties (Lourenço *et al.,* 2010). Consequently, it is important to understand how inherent chemical variations of different clays impact on the properties of fired clay bricks. This may thus assist in developing standardization protocols for clay soil chemical composition so as to allow the safe usage of fired clay bricks in load bearing applications.

Most studies on the characterisation of clay brick focuses on the physical and mechanical properties (Baronio and Binda, 1984; Baronio and Binda, 1985; Dondi *et al.,* 1999; Elert *et al.,* 2003; Sedat *et al.,* 2006) with little regard to the effect of composition on such properties. In Kenya, clay brick is a popular building material in the rural areas owing to its availability, durability and affordability compared to other building materials such as concrete blocks. However, majority of these clay bricks are produced from cottage industries and their physical and mechanical properties have been reported (Ayoro and Osemo, 2015; Shihembetsa and Madete, 2018) to vary from region to region. To ensure safety of clay bricks as a building material, it is important to establish the reasons behind these variations. Since clay soil is a natural product with inherent chemical variations, its application for clay brick manufacture requires a systematic study to ascertain the effect of such variations on the brick's properties. This is the aim of the current study, where fired clay bricks were made under similar conditions using chemically characterized clay soils obtained from different locations in Kenya with varied weather patterns, vegetation, soil formations and altitudes. The bricks were then characterized to determine their mass density, colour, apparent porosity and compressive strength.

MATERIALS AND METHODS

Study area. The current work is based in Kenya which lies between latitudes 4˚ N and 4˚ S and between longitudes 34˚ E and 42˚ E. The country has climatic and ecological extremes with altitude varying from sea level to over 5,000 m in the mountain region. The climate is warmer and humid along sea level regions and gradually becomes cooler towards

the highlands. The mean annual rainfall ranges from less than 250 mm in semi-arid and arid areas to more than 2,000 mm in high potential areas (Mariara and Karanja, 2007; Ayugi *et al*., 2016). The country can be divided into three broad climatic zones: humid, sub-humid and arid. Humid zones in Kenya have an altitude of over 1,500 m and receive an annual rainfall in excess of 1,000 mm (Mariara and Karanja, 2007; John and Onyando, 2013). They have volcanic rocks and their soils are formed through laterization process where heavy precipitation results in rapid weathering of rocks with basic cations of silica and some alumina leaching from the upper soil profile. Iron and aluminium compounds, however, are not leached out. In volcanic areas, soils also contain volcanic materials such as ash, pumice and cinders. Under humid conditions, these materials hydrolyze to form aluminium and silica rich materials such as allophane and imogolite (under high rainfall) or halloysite (under low rainfall) (Jones *et al*., 2013). Volcanic soils and alluvial soils are also rich in carbonates (Verheye, 2009). Sub-humid zones in Kenya have slightly less rainfall than the humid areas (John and Onyando, 2013). They have volcanic and basement rocks and lie between 1000 to 1500 m above sea level with red clay and loamy sandy soil types (Mariara and Karanja, 2007). These areas experiences soil calcification owing to evapo-transpiration where ground water containing dissolved alkaline salts rises to the surface due to high temperatures. Thus, the soil in this zone exhibits high accumulations of calcium carbonate (lime), dehydrate calcium sulphate (gypsum) and silicon dioxide (silica) (Pidwirny, 2006). Semi-arid and arid zones in Kenya receives on average 300–500 mm of rainfall annually and are characterized by shallow soils developed mainly from sedimentary rocks (Mariara and Karanja, 2007; John and Onyando, 2013). In this study, fired clay bricks from different locations in Kenya were evaluated to determine the effect of clay soil chemical composition on physical and mechanical properties of bricks.

Materials. Clay soils studied were collected from five different locations in Kenya where brick making was an economic activity. These locations have different weather patterns, vegetation, soil formations and altitudes. Zone sampling method was used to identify locations for clay soil collection. The clay soil samples were collected at altitude of 17 m in Mombasa, 2100 m in Eldoret, 1500 m in Maseno, 1800 m in Nakuru and in Nairobi at altitude of 1650 m above sea level. From each location, five clay soil samples weighing 5 kilograms were collected at depths of 40 cm (Njoka, 2015) through manual digging. The collected soils from each location were then mixed using quartering technique to obtain a representative sample. The samples were then sun-dried to constant weight, ground and sieved using a metallic mesh of 3.25 mm apertures. The sieved samples were then coded as S1, S2, S3, S4 and S5 following the collection locations given above and also shown in Figure 1.

Determination of clay soils chemical composition. Chemical composition of the clay soil samples was determined using an X-Ray Fluorescence (XRF) analyser. From each location, five random samples of ground clay soil weighing 50 grams were analysed and average chemical composition reported. The elemental analysis was based on characteristic fluorescent X-rays emitted by elements in the clay soil when irradiated using X-ray. From the X-ray spectrum generated, the positions of the fluorescent X-ray peaks allowed qualitative identification of the elements present while the intensities of the peaks allowed quantitative determination of elemental composition. The instrument was calibrated using a standard sample with known concentrations (%wt.) of elements. The relative weight composition was therefore determined by relating the heights of peaks obtained from the standard sample to those

obtained from the clay soil sample. Quantitative data computation and reporting was done entirely by the XRF instrument. For each clay sample, the cumulative weight percentage of all elements therein added to 100%. Since clay soil contain many elements, only major elements that are known to affect brick's performance such as silica, alumina, lime and iron oxide (Gani *et al*., 2015) were presented in this work. The cumulative weight percentage of these major elements was greater than 98% for most of the samples analyzed. A One-way ANOVA was used to analyze the chemical composition data obtained from different locations to check if they were statistically different. The analysis was conducted at 95% confidence level and p-values reported.

Production of clay bricks. The ground and sieved clay soil was mixed with water and kneaded to form a smooth plastic paste. The paste was poured into 80 mm x 50 mm x 50 mm mould and compacted at 2.5 MPa for 5 minutes using a hydraulic compressing machine (Githinji *et al*., 2015). The green bricks were dried in an oven for 24 hours at a temperature of 100 C. The dried bricks were then fired at 1000˚C for 8 hours in a furnace followed by slow cooling inside the closed furnace for about 12 hours. In this study, each clay soil sample from a given location was used to produce 10 bricks and only average values are reported. The fabricated clay bricks were given similar coding as their corresponding clay soil samples.

Determination of mass density and porosity of the fired clay bricks. The mass density was calculated from the measured mass and volume of the fabricated clay bricks. The dimensions were determined following Kenya Standard KS EAS 54:1999 (KeBS, 1999). The determination of apparent porosity was based on the net mass gain of oven-dried clay bricks soaked in boiling water (Duggal, 2009). The apparent porosity was given by the ratio of the volume of water absorbed to the volume of the saturated clay bricks.

Figure 1. A map of Kenya showing locations where clay soil samples were collected. (Adopted from Google map)

Determination of compressive strength of the fired clay bricks. Determination of dry compressive strength of the fired clay brick was conducted following Kenya Standard KS EAS 54: 1999. Whole brick samples were tested in a uniaxial testing machine set in a displacement controlled mode. A constant crosshead speed of 2.5 mm/min was used and the height/width ratio of the brick was more than 1.5. This ratio was sufficient to minimize the boundary effect during the compression test. By dividing the peak compressive load by the original cross-sectional area of the brick, the compressive strength was obtained.

RESULTS AND DISCUSSION

Clay soil chemical composition. The chemical composition (wt. %) of clay soil samples collected from different locations in Kenya is given in Table 1. Only the major compounds in the clay samples are indicated. It is evident from the results that the chemical composition of clay soils from different locations is significantly different at 95% confidence level ($p<0.05$). The variation of clay soil composition in different regions has also been reported by (Njoka, 2015). Different compounds found in clay have diverse effects on the properties of fired clay bricks. Silica prevents shrinkage, cracking and warping of raw bricks and its typical range is between 50-60% (wt.). Alumina affects the plasticity of wet aluminosilicates clay and a high content results in excessive shrinkage and warping of bricks (Punmia *et al*., 2003). Lime serves to reduce brick's shrinkage on drying and also enhances fusing of silica during firing which binds bricks particle together. Iron oxide plays a role in the ultimate colour of the fired clay brick.

Clay collected from S4 region had the highest silica content which may be attributed to volcanic soil found in the region. The relatively high calcium carbonate in region S5 may be ascribed to reduced mineral leaching owing to limited rainfall and presence of black cotton soil in the region. Since alumina is an amphoteric substance which reacts with bases and acids, it relatively high content in region S1 may be attributed to relatively low base content in the soil in this region compared to other regions. The reported variation in chemical compositions in this study can be attributed to differences in factors such as climatic conditions, soil formation mechanism and underlying rocks types (Neall, 2002; Pidwirny, 2006; Saat *et al*., 2009).

Fired clay bricks physical properties. A comparison of mass densities of the fabricated clay bricks from different regions in Kenya is shown in Figure 2. The differences in mass densities may be ascribed to variation in alumina content of the clay soils studied. Clays are aluminosilicates, being composed of alumina (Al_2O_3) and silica (SiO_2) that contain chemically bound water (Bergaya and Lagaly, 2013). Aluminosilicates have a layered crystal structure on which water molecules forms a thin lubricating film thus contributing to plasticity of

Table 1. XRF chemical composition (wt. %) analysis of clay soils

Compounds	Locations in Kenya					
	S1	S2	S3	S4	S5	p value
Alumina (A_l2O_3)	23.7	21.8	19.0	12.1	18.2	< .00001
Silica (SiO2)	71.4	60.0	73.0	81.1	72.8	< .00001
Lime (CaO)	0.5	0.3	0.5	0.5	0.7	< .00001
Iron oxide (Fe_2O_3)	2.0	3.3	3.1	2.6	4.0	< .00001
Potassium oxide (K_2O)	1.7	3.2	3.2	2.5	3.1	< .00001

P value is based on One-Way ANOVA analysis at 95% confidence level

the clay soil. The higher the aluminosilicate content the more plastic is the clay and subsequently the higher the shrinkage and mass density owing to evaporation of large amount of water during drying. As reported by Olajide *et al*. (2015), aluminosilicate content of the clay soil affects bulk density, porosity and shrinkage of the fired clay bricks. As shown in Table 2, brick samples from region S1 had the highest alumina content and mass density while samples from region S4 had the lowest alumina content and mass density. The mass densities of these two samples were found to be significantly different.

The variation in mass densities of the clay bricks may also be attributed to presence of voids within the brick structure. As seen in Table 2, an increase in mass density occurs as the fraction of void in the brick structure decreases. Voids in fired clay brick may arise when organic matter and/or compounds in the clay decomposes during the firing stages. In a previous study, porosity in clay brick was linked to clay soil composition (Cultrone *et al*., 2004). It is possible that sample S4 had a high content of decomposable matter owing to its large apparent porosity compared with other brick specimens. Additionally, the high apparent porosity could have been due to limited fusing of silica owing to reduced content of K_2O which serves as a modifier oxide. Consequently, the voids in the fired bricks remain unfilled. The effect of apparent porosity on the overall mass density is significant between S4 bricks and the other bricks as seen in Figure 2 and Figure 3. Importantly, the determined porosities were

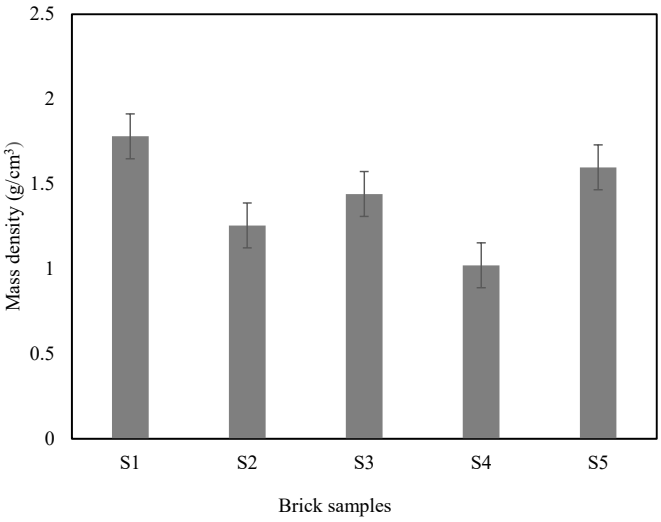

Figure 2. Mass densities of clay bricks obtained from different locations in Kenya. The indicated error bars are based on standard deviation of the measurements

Table 2. Fired clay bricks properties

Sample	Mass density (g/cm3)	% Porosity	Alumina content (wt. %)
S1	1.78	0.16	23.7
S2	1.26	0.11	21.8
S3	1.44	0.17	19.0
S5	1.59	0.17	18.2
S4	1.02	0.24	12.1

within the range reported previously (Engineers, 2007; Phonphuak, 2013). The variation of mass density of clay bricks has also been previously linked to composition of clay and porosity (Phonphuak, 2013).

Table 3 relates the colour of the fabricated clay bricks to their iron oxide content. From the qualitative colour assessment of the clay bricks, dark shades were obtained at relatively high iron oxide content. This can be attributed to 'earthy' colour of this oxide in nature. Several studies have linked the colour of fired clay bricks to their iron oxide content (Kriemeyer, 1987; Fernandes *et al*., 2009; Ingham, 2013). The colour of clay brick is also a function of firing temperature as reported by Karaman *et al*. (2012). However, in this study the firing temperature was kept constant and therefore the observed variation in colour may be attributed to iron oxide content.

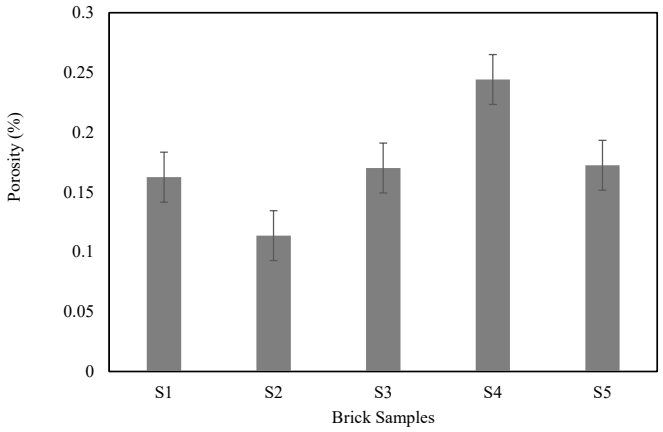

Figure 3. Porosity of clay bricks made with clay soils obtained from different locations in Kenya

Table 3. Variation of fired clay brick colour as a function of iron oxide content

Sample	Colour	Iron oxide content	Brick's colour
S1	Yellow- orange	1.98	
S2	Orange	2.34	
S3	Orange- red	3.10	
S4	Brown- red	2.64	
S5	Dark- red	3.91	

Characterisation of clay bricks. Figure 4 shows the compressive strength of the fabricated bricks from different locations in Kenya. Compressive strength of bricks is an important engineering property since it allows them to be stacked vertically together during construction. A higher compressive strength increases other properties such as flexure and resistance to abrasion. From the results, bricks from region S2 had a significantly higher average compressive strength than those made from region S1, S3, S4 and S5. This difference may be attributed to its relatively low silica content compared to the other clay soils studied. Silica is a non-plastic ingredient of clay which occurs as finely ground quartz. The quartz experiences little change during firing owing to its high melting temperature. The presence of large amount of un-reacted quartz particles in the final microstructure of fired bricks may reduce their compressive strength owing to limited bonding of clay particles by the vitrified phase. It is possible, therefore, that the relatively low compressive strength of S1, S3, S4 and S5 bricks may be as a result of their premature brittle failure during the loading cycle owing to their relatively high silica content. Additionally, the S2 brick had relatively low apparent porosity, which may have reduced initiation and propagation of cracks during loading thus increasing its load carrying capacity. Porosity and clay soil composition have been shown previously to influence compressive strength of the clay brick (Baiden *et al*., 2014; Milyaso *et al*., 2015; Olajide *et al*., 2015). It is clear from the results that the mean compressive strengths of bricks from different regions were significantly different at 95% confidence level ($p<0.05$) as shown in Table 4. This result, therefore, underpin the importance of clay soil composition on the final compressive property of fired clay bricks. The standardization of the clay soil composition through controlled addition of various clay soil compounds is necessary for uniform properties in the fired clay bricks produced at cottage industries. Notably, the clay soil from Eldoret (S2) produces the best clay bricks for construction industries since their average compressive strengths (14 MPa) were better than that specified by EAS 54:1999 Standards (7 MPa) for ordinary construction bricks. The determined compressive strengths also agree with literature findings (Okunade, 2008; Fernandes *et al*., 2009; Lourenço *et al*., 2010; Milyaso *et* al., 2015; Olajide *et al*., 2015).

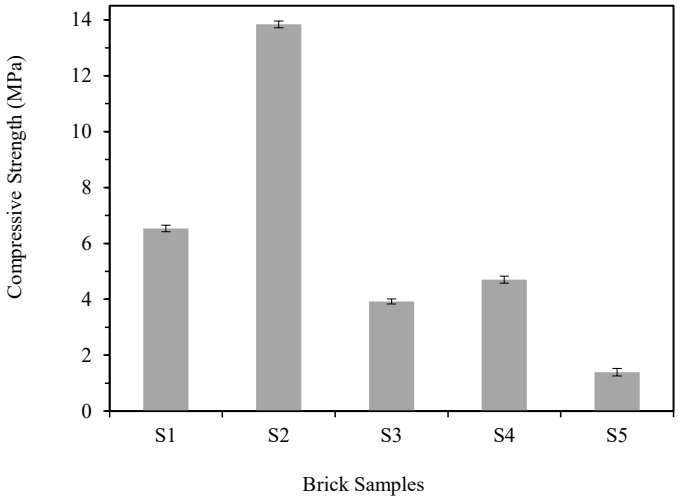

Figure 4. Compressive strengths of fired clay bricks made with clay soils obtained from different locations in Kenya

Table 4. One-way ANOVA analysis of compressive strength of bricks from different locations in Kenya

Source	SS	df	MS	
Between locations	444.4714	4	111.1178	F = 47243.97959; p < 0.00001
Within locations	0.047	20	0.0024	
Total	444.5184	24		

CONCLUSION

In this study, fired clay bricks were made using clay soils with intrinsic chemical variations. The soils were collected from different locations in Kenya having varied weather patterns, vegetation, soil formations and altitudes. Fabrication was conducted under similar conditions and the resultant bricks characterized in terms of their physical and mechanical properties. From the study, the following conclusions are drawn:

- Clay soils from different locations have significantly different chemical compositions thought to arise from climatic and geological variations of these areas. The main compounds in the clay soils studied are silica, alumina, iron oxide, potassium oxide and lime, in a decreasing order of weight percent. The clay soils with the highest amount of silica, alumina, iron oxide, potassium oxide and lime were found in Maseno, Mombasa, Nairobi, Eldoret and in Nairobi region, respectively.
- Clay chemical composition has a significant effect on physical properties of bricks. High alumina content increases brick's shrinkage during drying resulting in an increase in brick's mass density. Clay soil from Mombasa region has the highest alumina content and produces bricks with the highest mass density compared to bricks from other locations studied. The final colour of fired clay bricks depends to a large extend on the iron oxide content of the clay, with dark shades obtained at relatively high iron oxide content.
- Clay chemical composition has a significant effect on the compressive strength of fired clay bricks. Clay soil with relatively low silica content produces bricks with relatively high compressive strength and low apparent porosity. Clay soil from Eldoret region has the lowest silica content and produces bricks with the highest and required compressive strength compared to bricks from other locations studied. The bricks from this region are therefore the most suitable for load bearing applications in construction industries.

The variation of fired clay brick properties as a function of intrinsic composition of clay soil used, underpin the importance of clay soil characterisation and chemical properties standardization prior to production of bricks for structural applications.

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STATEMENT OF NO-CONFLICT OF INTEREST

The author declares that there is no conflict of interest in this paper.

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Determinants of innovation behaviour among pig farmers in Northern Uganda

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ABSTRACT
Attributable to poor market linkages, Ugandan pig farmers are taken advantage of by middlemen who pay low prices, recline the weight of pigs and default on payments. Farmer innovation can remedy the situation; however, the factors influencing pig farmers' innovation behaviour are not fully known. Further, extant studies on the subject tend to report findings on innovation behaviour as a composite variable other than its decomposed phases of exploration, experimentation, adaptation and modification of farming practices. This study therefore aimed at examining the influence of socio-economic factors on the phases of innovation behaviour among pig farmers in Northern Uganda. A cross sectional survey of 239 respondents was carried out and primary data were collected using pre-tested, semi-structured questionnaires between the month of October and November 2018. Tobit regression was employed for data analysis. The results revealed that personal selling affects all phases of innovation behaviour. In addition, i) exploration of new practices was affected by stock size, educational level and gender; ii) experimentation of new practices also depended on educational level; iii) adaptation of new practices was predicted by farming experience, extension service, access credit, non-farm employment, distance to town market and pork selling, and lastly iv) modification of existing practices was contingent on farming experience, access to extension service, access to credit, price negotiation ability, selling pigs to peer farmers and selling pork. Therefore, pig farmers operating in poorly developed value chains should as much as possible do personal selling of their pigs and pig products through informing their community members about the availability of piglets for sale on their farms, taking their pigs to the market or slaughtering pigs to sell pork instead of live pigs.

Keywords: Innovation phases, middlemen, pig production, pig value chain, Uganda

RÉSUMÉ
Les éleveurs de porcs ougandais profitent des médiocres liens du marché avec des intermédiaires qui paient des prix bas, inclinent le poids des porcs et font défaut de paiement. L'innovation paysanne peut remédier à la situation; cependant, les facteurs qui influencent le comportement d'innovation des éleveurs de porcs ne sont pas entièrement connus. De plus, les études existantes sur le sujet ont tendance à rapporter les résultats sur le comportement d'innovation en tant que variable composite autre que ses phases décomposées d'exploration, d'expérimentation, d'adaptation et de modification des pratiques agricoles. Cette étude visait donc à examiner l'influence des facteurs socio-

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économiques sur les phases du comportement d'innovation chez les éleveurs de porcs du nord de l'Ouganda. Une enquête transversale auprès de 239 répondants a été réalisée et les données primaires ont été collectées à l'aide de questionnaires semi-structurés pré-testés entre le mois d'octobre et novembre 2018. La régression Tobit a été utilisée pour l'analyse des données. Les résultats ont révélé que la vente personnelle affecte toutes les phases du comportement d'innovation. De plus, i) l'exploration de nouvelles pratiques a été affectée par la taille du stock, le niveau d'éducation et le sexe; ii) l'expérimentation de nouvelles pratiques dépendait également du niveau d'éducation; iii) l'adaptation des nouvelles pratiques était prédite par l'expérience agricole, le service de vulgarisation, le crédit d'accès, l'emploi non agricole, la distance au marché de la ville et la vente de porc, et enfin iv) la modification des pratiques existantes dépendait de l'expérience agricole, de l'accès au service de vulgarisation, accès au crédit, capacité de négociation des prix, vente de porcs à des pairs agriculteurs et vente de porc. Par conséquent, les éleveurs de porcs opérant dans des chaînes de valeur peu développées devraient autant que possible vendre personnellement leurs porcs et leurs produits en informant les membres de leur communauté de la disponibilité des porcelets à vendre dans leurs exploitations, en amenant leurs porcs au marché ou en abattant vendre du porc au lieu de porcs vivants.

Mots-clés: phases d'innovation, intermédiaires, production porcine, chaîne de valeur porcine

INTRODUCTION

Pig rearing is an important economic activity worldwide (FAO, 2011). The production and consumption of pig products such as pork have been on the rise in recent decades (Thornton, 2010). Pork production increased by factor 3.5 from 24.7 to 86.6 million metric tonnes between the year 1961 and 2002 in response to a comparable increase in demand (Speedy, 2003; Hartog, 2004; Ngapo *et al*., 2004), and this trend is unlikely to change in the near future. For instance, the Food and Agriculture Organisation of the United Nations (FAO) along with the International Food Policy Research Institute (IFPRI) and the International Livestock Research Institute (ILRI) projected an increase in meat production and consumption from 233 to 300 million metric tonnes between the year 2000 and 2020 (Delgado *et al*., 1999). Such projection statistics coupled with the fact that pork exports are said to be four times more profitable compared to the export of grains (Hartog, 2004), shed light of a bright future on the narrative of the market outcomes for pig and pork marketing.

The importance of pig production and consumption is not any different in Sub Saharan Africa (SSA), and specifically, Uganda as a country. While emphasizing the importance of pigs, IFPRI pig production report shows that Uganda is ranked third in SSA producing about 12% of the region's pig meat following Nigeria and South Africa (Guo, 2015). That aside, at an annual consumption rate of 3.4 kg per person, Uganda has the highest per capita pork consumption in SSA (Ballantyne, 2012).

Unquestionably, pork is a good source of high-quality proteins and so responds to both the nutritional and food security needs of many households (Mutetiika and Nabasirye, 2010; Eliakunda and Milan, 2017). For this reason Tatwangire (2013) and Mulindwa (2016) contended that pig production could accelerate Uganda's economic development through improving livelihoods of smallholder farmers and provision of employment. Moreover,

many smallholder farmers have a desire to rear pigs due to their unique characteristics. These include i) faster growth rates; ii) ability to be kept on a small piece of land; iii) high rate of multiplication; iv) ability to be fed on many different crops and animal products and by-products; v) high feed conversion efficiency; and vi) early maturity and short generation interval (Muhanguz*i et al*., 2012; Ndyomugyenyi and Kyasimire, 2015).

The massive opportunities and benefits that pig rearing offers to smallholder farmers and to the economy notwithstanding, production and marketing in Uganda is still limited by inadequate pork processing facilities and practices; parasites and diseases; derisory access to market information; inadequate access to inputs, extension services, financial services and insurance; poor market linkages; absence of institutional frameworks for marketing and low levels of export of pigs and pig products (Ouma *et al*., 2013; Tatwangire, 2013; Birungi *et al*., 2015; Mulindwa, 2016). Such constraints hinder the development of the pig value chain in the country.

Many scholars have suggested that the key to pig value chain development is nurturing farmers' capacity for innovation. This in the long run results in improved competitiveness of the pig-based farms. In turn, this contributes to the redistribution of value added benefits across the value chain actors, and most particularly, the smallholder farmers (Johan and Alm, 2014; Chopeva *et al*., 2015; Makosa, 2015).

Notably, innovation behaviours among pig farmers are important for value chain upgrading and overall agribusiness. However, farmers have hardly engaged in innovations that would guarantee higher gains from the value chain, for instance, in slaughtering and processing of pig products or making off-farm efforts of searching for the best market (Tatwangire, 2013; Access, 2017). As a result farmers are reduced to only 'price takers' since they are taken advantage of by middlemen who purportedly pay low prices for the pigs, recline the live weight of animals and often do not pay on time (Muhanguzi *et al*., 2012; Riedel *et al*., 2012; Etwire *et al*., 2017; Kamaghe *et al*., 2017).

Research on pig value chain (production and marketing) in Uganda is very rich. For example, the International Livestock Research Institute (ILRI) highlights opportunities and limitations in the pig value chain (Access, 2017). There are also breeding studies done by Makerere University in which Mutetiika *et al*. (2010) and Noce *et al*. (2015) have suggested that artificial insemination is an appropriate technology which when embraced by farmers could enhance disease control. Other studies have also given attention to feed conservation technologies (Asindu *et al*., 2017; CIP, 2017). Yet again, Tatwangire (2013) and Mulindwa (2016) articulated that the Government of Uganda has been supplying piglets to farmers through several development interventions such as National Agricultural Advisory Services (NAADS) and "Bona-bagaggawale" (prosperity for all) programmes. However, studies that examine the innovation behaviour of smallholder pig producers, that would guarantee improvement and/or development of the pig value chain, are limited in research literature.

Previous research has tended to rely on socio-economic factors (for instance education, age, and sex) to explain farmer innovation behaviour (Tirfe, 2014; Chopeva *et al*., 2015). Nevertheless, there is hardly any research that attempts to analyze the effect of these socio-economic factors on the phases of innovation behaviour (exploration, experimentation, adaptation and modification of farm practices) in agribusiness. Even then, such reseach has largely been in the context of seed and crop production systems which present perspectives differing from those in the pig value chain (Tirfe, 2014).

Therefore, this study sought to determine the influence of socio-economic factors on the

phases of innovation behaviour among pig farmers in Northern Uganda. The results will inform how the interventions to improve the pig value chain should be tackled using the innovation phases' approach.

METHODOLOGY

Description of the study area. The study was conducted in communities of Acholi Sub-region in Paicho sub-county, Gulu district and Koro sub-county, Omoro district, Northern Uganda. The geographical coordinates are 2.8186 N, 32.4467 E and 2.7152 N, 32.4920 E for Gulu and Omoro, respectively. The region has fertile soils, a hot dry climate with two rainy seasons, and an altitude that ranges between 600 and 1,200 m above the sea (JICA, 2011). Agriculture in the study area is largely rain-fed with a mixed crop-livestock system in which annual crops such as soybean, sunflower, sesame, sweet potatoes, finger millet, beans, cassava, groundnuts, maize and vegetables are grown alongside rearing of animals such as pigs, goats, sheep and cattle (FAO, 2018).

Gulu has two constituencies, Aswa county and Gulu Municipality. Paicho sub-county is situated in Aswa county and has a total land area of 457.8 square kilometers (UBOS, 2013a). On the other hand, Omoro district is made up of two counties and seven sub-counties. Koro sub-county is located in Tochi county and has a total area of 215.5 square kilometers with a total population of 28,611 (UBOS, 2017b). The two districts were selected because they were rated among the lowest pig producing districts in Uganda (Tatwangire, 2014). It was expected that Omoro district would give the study perspective on events in the rural markets while Gulu district would give the outlook of urban/ terminal markets.

Sampling. The study employed a cross sectional design where data were collected from smallholder producers of pigs between October and November 2018. The design was chosen because it is a one-time research approach and thus it is cost effective in terms of time and financial resources (Levin, 2006). It was also appropriate for collecting data for achieving objectives and hypothesized relationship in the conceptual framework of this study.

A multi-stage sampling technique was employed to select study participants. Firstly, the two districts, Gulu and Omoro, were selected purposively because pigs in these districts have been reported to have a lucrative market and high turnover (Ikwap *et al*., 2014), yet farmers hardly exploit existing opportunities for own gain. Secondly, Paicho sub-county in Gulu and Koro sub-county in Omoro district were also selected purposively since they have the highest number of pig rearing households in the two districts (UBOS, 2017a, 2017b). Thirdly, a list of all pig-rearing households which had benefited from the National Agricultural Advisory Services (NAADS) program was obtained from the respective sub-county headquarters. The list had 393 farmers from Paicho and 201 from Omoro bringing the sampling frame to 594 farmers. Systematic random sampling was done to obtain a study sample of 239 respondents using a skip interval of eight. The sample size was arrived at based on Slovin's formula (Yamane, 1967) as shown below;

$n=N/1+Ne^{2}$, $n=594/1+594^{2}$, $n = 239$. Where; N = population, n = Sample size, e = Degree of confidence level at 95%.

The enumerators interviewed 96 pig farmers from Omoro and 143 pig farmers from Gulu district. This is because Gulu contained 1.49 times more pig farmers than Omoro (UBOS, 2013b).

Data collection. Before starting data collection, the study was approved by Gulu University Research Ethics Committee (GUREC) under application number GUREC-094-18 and an informed consent was sought from every respondent prior to commencing the interview.

Face to face interviews were employed to collect primary quantitaive data using pre-tested, semi-structured questionnaires which allowed for clarification of ambiguous answers and completion of all questions in the tool (Opdenakker, 2006; Akidi, 2016). Pre-testing was done on 10 pig farmers in Unyama sub-county because the sub-county had many pig farmers and yet it was not one of the sub-counties under study. Additionally, it was also not far away from the study area. After the pretest, some amendments were made in the questionnaire such as re-wording and re-ordering some questions to ensure clarity, logical question sequence and instruction adequacy. The questionnaires were administered by research assistants recruited and trained from the study area for purposes of conducting the interview in the local dialect.

The questionnaire comprised of closed and Likert scale questions in which participants were requested to rate various items so as to ensure clarity of the questions to the respondents for easy answering. Some questions were multi-choice requiring respondents to choose one or more items from a list of choices which resulted in a faster processing speed because the study participants did not have to answer in wordy statements.

The data collection tool consisted of two parts. Part one captured socio-economic information which included age of the household head, education level, sex, household size, marital status, non-farm employment and group membership. The second section gathered data on pig production, marketing and access to institutions and institutional services. The variables included; farming experience (years), current pig stock size (number of pigs), pork selling (1=yes, 0=no), price negotiator (1 = yes, 0 = no), distance to the nearest market (km), access to extension services (1 = yes, 0 = no) and access to credit (1 = yes, 0 = no).

Farmer innovation behaviour was captured under the four phases of the innovation process namely :i) exploration, ii) experimentation, iii) adaptation of new pig rearing techniques/ practices, and iv) modification of existing farm practices as adapted from previous research (Ho and Wu, 2011; Aubert *et al*., 2012; Wilson *et al*., 2014; Coussy, 2015; Björklund, 2018; Tunde *et al*., 2018). A total of 12 items were used to collected data on innovation behaviour. Each item was rated on a five point Likert scale where 1 = not at all and 5 = always to ensure a high response rate. A sample item on innovation behaviour from the domain of exploration of new farming practices reads as follows: "I am very curious about learning how to appropriately feed pigs".

Data analysis. Previous research has shown that the innovation process of the farmers involves four phases namely exploration of new practices, experimentation of new practices, adaptation of new practices and modification of existing practices (Tidd *et al*., 2001; Khorakian, 2011). Accordingly, this study constructed the dependent variable based on these four indicators of the innovation process. Likert scale data were used to compute the indices for the dimensions of the innovation behaviour as shown in equation

$$X_{i,k} = \sum_{j=1}^{j=n} a \Big/ b \quad \text{.....(1)}$$

where;

X = index for the phase of innovation behaviour

$i = i^{th}$ sampled pig producer

$k = k^{th}$ phase of the innovation behaviour which includes exploration, experimentation, and adaptation of new pig rearing practices; and modification of the existing farm rearing practices

j = number of items for a given phase of innovation behaviour

a = individual score for a specific item by i^{th} sampled farmer involved in pig production

b = the sum of ratings of the i^{th} respondent for the k^{th} phase of innovation behaviour

All items were rated on 1-5 point Likert scale with 1 (not all) being the lowest score and 5 (always) being the highest score.

A sample item for exploration is "I like to learn new ways of housing pigs"; that of experimentation is "among my peers, I am usually the first to try out new pig rearing practices". For adaptation, the sample item is "I alter new pig feeding practices to fit my situation" and lastly for modification of existing pig rearing practices "I use new knowledge to modify existing pig feeding practices on the farm". In this study, and based on research literature, innovation behaviour was postulated to be a function of socio-economic factors. Thus, the factors that influence innovation behaviour among pig producers were analysed as

$$Inno\_Behaviour_{i,k} = \beta_0 + \beta_i[Soc.Econ]_i + \varepsilon_i$$

.....(2) where;

Inno_Behaviour = level of innovation behaviour of the pig producers
$i = i^{th}$ sampled pig producer
$k = k^{th}$ phase of the innovation behaviour and includes exploration, experimentation, and adaptation of new pig rearing practices; and modification of the existing farm rearing practices
β_o = constant
β_i = various parameters to be estimated
Soc.Econ = social economic factors (described in Table 1)
ε = the error term
Since the dependent variable comprised of indices that ranged between zero (0) and one (1), it meant that ordinary least squares methods would not be an appropriate estimator. Accordingly, the Tobit model that efficiently analyses data censored between 0 and 1 was preferred to analyse the effect of the independent variables which included farming experience, gender, stock size, access to extension services and access to credit on the phases of farmer innovation behaviour using STATA 13.0. The predictors in the model were first tested for multicollinearity using the Variance Inflation Factor (VIF). All predictors had VIF below 4.0 and the mean VIF was 1.4 indicating that the explanatory variables were not associated with each other in the model. Table 1 shows the variables used in the data analysis.

RESULTS AND DISCUSSION

Characterization of pig farmers in the study area. Results in Table 2 revealed that a large number of pig farmers (73.6%) were males probably because the activity has quick financial returns and males still dominate ownership, access and control of key production resources such as land and finance in many households in SSA and thus find it easy to invest in pig rearing (Njuki *et al*., 2011). This is in agreement with the finding of Mwanyumba (2010) who reported that women farmers were less likely to have control let alone ownership over these resources which possibly hinders their engagement in many agricultural enterprises.

The majority of the farmers (52.3%) were aged between 30 and 50 years old with the mean age of the dataset standing at 37.732 years which is similar to the findings of Chindime *et al*. (2017) among dairy farmers in Malawi. Oladee bo and Oladeebo (2008) asserted that this age bracket of farmers is able to explore and make sound decisions which may result in innovation.

All farmers in the sample had at least received some form of formal education and it was only the level attained that differed amongst them. The mean number of complete years spent in school was 7.209. This may be attributed to the effect of Universal Primary Education (UPE) which was introduced by the Government of Uganda in 1997 to enable all children to attain at least primary education (Bategeka and Okurut, 2006). Predictably, there were more farmers with primary education compared to those with secondary and post-secondary education.

Table 1. Description of explanatory variables

Independent Variable	Description	A priori sign expectation and source
Farming experience (years)	Continuous	+ (Ndambiri *et al*., 2012; Ndunda and Mungatana, 2013; Tirfe, 2014)
Stock size (number of pigs)	Continuous	+(Garcна-Martнnez *et al*., 2016)
Access to extension	Dummy 1 if yes, 0 no	+ (Ndunda and Mungatana, 2013)
Access to credit	Dummy 1 if yes, 0 no	+(Ndunda and Mungatana, 2013)
Non-farm employment	Dummy 1 if yes, 0 no	+ (Tirfe, 2014)
Price negotiation ability	Dummy 1 if yes, 0 no	+/-
Personal selling (indices)	Continuous	+ (Chindime *et al*., 2017)
Group membership	Dummy, 1 if yes, 0 no	+ (Tirfe, 2014)
Distance to market (km)	Continuous	+ (Chopeva *et al*., 2015; Chindime *et al*., 2017)
Age (years)	Continuous	+/- (Chopeva *et al*., 2015; Tirfe, 2014)
Education level (years)	Continuous	+ (Chindime *et al*., 2017; Chopeva *et al*., 2015; Tirfe, 2014)
Gender	Dummy 1 if male, 0 female	+/- (Chindime *et al*., 2017; Chopeva *et al*., 2015; Tirfe, 2014)
Sell pigs to peer farmers	Dummy 1 if yes, 0 no	+/-
Sell pork	Dummy 1 if yes, 0 no	+ (Tatwangire, 2013)

The number of pig farmers with access to credit and extension services was below 40% which points to the need for a boost in efforts geared towards agricultural extension services and financial sector deepening in the country. Further, 42.30% of the respondents participated in some form of non-farm employment; 16 % of these were involved in running small retail shops in trading centers while others earned from the provision of labor to other farms, riding boda boda (passenger service motorcycles), and running pork joints, burning charcoal and brewing alcohol, among others.

As regards the effect of socio-economic factors on phases of innovation behaviour, the Tobit regression results (Table 3) revealed that all the four specified models were highly significant at P≤0.01. Interestingly, the findings show fewer significant socio-economic factors that affect the farmer innovation behaviour for the first two phases of the innovation process compared to the latter two phases of the same process. Promotional activities for pigs and pig products using personal selling had a positive significant effect across the four phases of farmer innovation process. For exploration of new pig rearing practices, this explanatory variable was statistically significant at P≤ 0.1 and at P≤ 0.01 for all the other phases of innovation behaviour. Farmers who do personal selling, for instance by informing peer farmers about the availability of piglets for sale on the farm, and taking pigs to the market or trading center were found to be 16.6% more explorative, 30.5% more experimental, 42.4% more adaptive and 47.4% more able to improve existing pig rearing techniques. This could be attributable to the fact that through personal selling farmers interact with different people which enables them to access knowledge, markets, and finance (Chindime *et al*., 2017). This information access through appropriate market searches is likely to offer farmers knowledge of the market outlook prompting them to innovate suitable ways of staying afloat.

It was detected from the results that stock size has a negative significant effect on the exploration index of farmers (P≤ 0.05). A unit percentage increase in the number of pigs leads to a 0.003 decrease in exploration index of the farmer. This result suggests that the bigger the size of the pig stock kept by a farmer, the less the level of exploration of new pig rearing practices. Farmers

with many pigs tend to have a greater experience about pig husbandry than those with few pigs. On the other hand, farmers with fewer numbers of pigs were largely new in the pig farming business and thus needed to explore to learn and gain knowledge and skills required for them to succeed in their new venture.

Education status significantly affected farmers' exploration and experimentation of new pig production and marketing techniques ($P \leq 0.05$). An additional year of schooling increased both exploration and experimentation indices by 0.009 and 0.010, respectively. More educated farmers tend to have a better attitude towards innovation which enhances their potential to acquire, analyze and utilize information (Tirfe, 2014; Chopeva *et al*., 2015; Chindime *et al*., 2017). Additionally, formal education exposes farmers to experiments while in school which makes them appreciate the value of testing something new to know its demands and actual benefits before taking it up.

Gender only significantly affected the level of exploration of the farmer ($P \leq 0.05$). Males were found to be 7.7% less explorative than females. This could be attributable to the fact that males do rarely attend agricultural extension meetings and trainings compared to the females (Anandajayasekeram *et al*., 2008). Further, Tirfe (2014) articulated that women have specific socio-economic challenges which hinder implementation of their ideas such as the burden of household care and less endowment with capital assets such as land. This may prompt them to inspect their surroundings in the quest for a lasting solution to these challenges which limit their pig production and marketing potential.

The results provided statistically significant evidence that farming experience predicts the adaptation of new practices and the modification of existing practices by farmers ($P \leq 0.05$). A unit percentage increase in farming experience increases the farmers' adaptation index by 0.005 and their modification index increases by 0.007.

Table 2. Respondents' socio-economic profile (n=239)

Profile	Category	Frequency	Percentage (%)	Mean	SD
Gender	Male	176	73.6	-	-
	Female	63	26.4		
Non-farm employment	Yes	101	42.3	-	-
	No	138	57.7		
Access to credit	Yes	82	34.3	-	-
	No	157	65.7		
Price negotiator	Yes	185	77.4	-	-
	No	54	22.6		
Pork seller	Yes	29	12.1	-	-
	No	210	87.9		
Sells pigs to peer farmers	Yes	118	49.4	-	-
	No	121	50.6		
Access to extension services	Yes	86	36.0	-	-
	No	153	64.0		
Personal selling (indices)				0.713	0.419
Education (years in school)				7.209	3.452
Age (years)				37.732	13.364
Stock size (Number of pigs)				5.782	6.491
Farming experience (years)				16.933	13.692
Distance to town market (km)				0.611	2.949

Ndambiri *et al*. (2012), Ndunda and Mungatana (2013) and Tirfe (2014) asserted that experience gives farmers more knowledge about their agricultural system and the requirements to develop an ability to skillfully assess features of new farming techniques so as to make informed decisions. These firm choices may be related to resource deployment and may be backed up by deliberate efforts of adaptation through information search to understand consumer needs so as to devise cost-effective means of meeting these needs (Hofer and Schendel, 1978; Perez *et al*., 2010). This could be the basis for adaptation and modification of pig rearing practices.

Access to extension services had a positive significant effect on adaptation of new practices (P≤ 0.05) and modification of existing pig production and marketing practices (P≤ 0.10). Farmers who had access to extension services were found to be 7.6% more adaptive and 6.6% more able to modify existing practices than those who did not have access to extension services. This is because extension services avail farmers with information and knowledge required to adjust their pig rearing practices to suit their unique farming situations (Kibwika, 2013; Läpple *et al*., 2015). This result corroborates with that of Ndunda and Mungatana (2013) in which access to agricultural extension was found to significantly impact the farmers' use of innovative approaches for risk reduction in water irrigated farming. Additionally, agricultural extension through demonstrations and farmer field schools enables peer learning and adaptation of tools and techniques to fit individual farmer's conditions (Hermans *et al*., 2015). This particular finding is of paramount importance to the farmers and the State because

Table 3. Tobit results of socio-economic factors affecting innovation behaviour

Predictor	Farmer Innovation behaviour			
	Exploration of new practices	Experimentation of new practices	Adaptation of new practices	Modification of existing practices
	β (SE)	β (SE)	β (SE)	β (SE)
Farming experience	-0.002 (0.002)	0.002 (0.002)	0.005 (0.002)**	0.007 (0.003)**
Stock size	-0.003 (0.001)**	-0.000 (0.002)	0.002 (0.002)	0.002 (0.003)
Access to extension	0.018 (0.026)	0.034 (0.028)	0.076 (0.030)**	0.066 (0.040)*
Access to credit	-0.044 (0.030)	0.010 (0.034)	0.075 (0.032)**	0.092 (0.043)**
Non-farm employment	-0.043 (0.027)	0.033 (0.029)	0.061 (0.030)**	0.061 (0.038)
Price negotiation ability	-0.027 (0.032)	0.046 (0.035)	0.048 (0.034)	0.116 (0.044)***
Personal selling	0.166 (0.094)*	0.305 (0.107)***	0.424 (0.112)***	0.474 (0.130)***
Group membership	-0.011 (0.028)	0.022 (0.034)	0.004 (0.032)	-0.024 (0.043)
Distance to the market	0.003 (0.003)	-0.003 (0.003)	-0.007 (0.003)*	0.002 (0.007)
Age of household head	0.001 (0.002)	-0.001 (0.002)	0.000 (0.002)	-0.002 (0.002)
Education level	0.009 (0.004)**	0.010 (0.005)**	0.007 (0.005)	0.005 (0.006)
Gender	-0.077 (0.034)**	0.002 (0.037)	-0.022 (0.035)	0.047 (0.044)
Sell pigs to peer farmers	0.031 (0.027)	0.047 (0.030)	0.040 (0.029)	0.123 (0.038)***
Sell pork	-0.038 (0.371)	0.060 (0.040)	0.168 (0.043)***	0.194 (0.065)***
Constant	0.974 (0.102)***	0.421 (0.106)***	0.133 (0.100)	-0.067 (0.120)
Log likelihood	-42.369	-19.686	-5.570	-56.416
F (15, 224)	2.57	2.42	7.54	10.06
Prob > F0.002	0.004	0.000	0.000	
Pseudo R^2	0.2395	0.4421	0.8846	0.4338

*****Significant at P ≤ 0.01, **Significant at P ≤ 0.05, *Significant at P ≤ 0.1**

it alludes to the fact that reinforcement and promotion of an effective agricultural extension system could yield better innovation performance by farmers and thus better household food and nutrition security and income.

Access to credit had a significant positive effect on farmer adaptation index and modification index (P≤0.05). Farmers with access to credit were 7.5% more adaptive and 9.2% more able to improve existing rearing practices than those who did not have access to credit. This is attributable to the fact that access to credit equips farmers with financial resources to enable them to look for new technology, purchase appropriate farming tools, adapt new practices and modify existing tools and techniques. This result is consistent with the findings of Ndunda and Mungatana (2013) and Chindime *et al*. (2017) in Kenya and Malawi, respectively. Therefore, there is a need for the provision of affordable credit schemes to enable farmers to borrow easily to boost their farm innovation activities for better competitiveness.

Empirical results revealed that non-farm employment had a significant positive effect on adaptation (P≤ 0.05). Farmers engaged in non-farm activities had a 6.1% higher adaptation index than those without non-farm engagement. Non-farm employment tends to expose farmers to other individuals who could share with them new ideas and new ways of doing things through social interaction. Further, the additional non-farm income reduces the liquidity constraint of farmers and may be used to inquire and alter new ways of rearing pigs giving an innovative edge to farmers with non-farm employment. This result is consistent with the findings of Tirfe (2014) among farmers in Ethiopia in which diversification was linked to more capital availability, access, implementation and improvement of new ideas. Therefore to reduce the credit constraint and enhance innovation behaviour of pig farmers, there is a need for them to access off-farm income.

Distance to the town market negatively affected the adaptation index of farmers (P ≤ 0.10). A unit increase in distance to the town market decreased the adaptation index by 0.007. This finding suggests that farmers who live near to the market adapt new farming techniques more than their counterparts who live farther away from the market. This is attributable to the fact that farmers who live near markets tend to easily get information and knowledge of the changing market demands from the town dwellers which enables them to quickly adjust new techniques so as to meet the revealed customer needs. Additionally, transaction costs such as transportation and storage costs involved in accessing the market are low for farmers who live near markets. This may motivate them to innovate so as to capture the market which exists in their proximity.

The sale of pork instead of live pigs was found to have a significant effect on adaptation and modification index (P ≤ 0.01). That is farmers who sold pork were found to be 16.8% and 19.4% more able to adapt new practices and modify existing practices respectively than their peers who sold live pigs. This could be attributed to the fact that selling live pigs is the norm in many pig farming households (Tatwangire, 2013), therefore, selling pork perhaps requires some level exposure, awareness and a disruption of the status quo which likely makes these farmers more innovative.

Price negotiation ability had a positive significant effect on modification index (P≤ 0.05). Farmers who negotiated the selling price with buyers were found to be 11.6% more likely to modify existing pig rearing practices than those who determined the price by other means such as taking the buyers' price or prevailing market price. Farmers who negotiate prices tend to be more inquisitive, confident and determined. These three characteristics could propel them to improve existing pig rearing practices.

The sale of pigs or pig products to peer farmers significantly affected the modification index ($P \leq 0.05$). Farmers who sold their pigs to peer farmers were found to be 12.3% more able to modify existing practices compared to those who sold to others such as butchers and middlemen. This is possibly because peer farmers would easily connect and interact with the seller which favors sharing of experiences while middlemen and butchers, on the other hand, would be interested in keeping as much market information as possible from the selling farmer.

CONCLUSIONS AND RECOMMENDATIONS

This study has shown that personal selling of pigs and pig products by farmers greatly enhances their innovation behaviour which translates into better income from the enterprise. Therefore, it is worth recommending that interventions for improvement of the pig value chain should encourage farmers to actively involve themselves in marketing their pigs so as to earn better prices. Based on the findings of this study, it can be inferred that access to extension and credit services boosts farmers' adaptation and modification of technology thus ensuring competitive and sustainable agriculture. Accordingly, there is need to entrench farmer financial inclusion and the use of well-trained agricultural extension agents to offer agricultural educational programs and trainings to pig farmers for better farmer innovation and gains. On their part, farmers need to attend agricultural extension trainings and utilize the information acquired to improve their pig farming and marketing activities.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Mitigating student related academic corruption in Sub-Sahara Africa

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ABSTRACT

Empirical scholarly work on student related academic corruption in higher education in sub-Sahara Africa is scanty. This study contributes to filling the gap. An anonymous self administered online questionnaire was used and emails sent to students from the database of the All-Africa Students Union, University of Burundi Doctoral School and 2nd Year Banking and Finance students of the University of Professional Studies Accra. Researcher observations was also employed to corroborate participant responses. With a sample of n=164, percentages and graphs were generated for analysis. Anchored on the Bad Apple Theory, the research suggests that, the most prevalent form of student related academic corruption is plagiarism (75.6%) with the least being 'falsification of entry results' (45.1%). The originality value of this research is hinged on the empirical findings on the phenomena from respondents' direct experiences, and media reports of specific instances of the phenomena. We recommend appropriate measures to curb the menace.

Keywords: Academic corruption, Africa, Students

RÉSUMÉ

Les travaux empiriques sur la corruption académique des étudiants dans l'enseignement supérieur en Afrique subsaharienne sont rares. Cette étude contribue à combler ce vide. Un questionnaire en ligne auto-administré anonyme a été utilisé et des e-mails ont été envoyés aux étudiants à partir de la base de données de l'Union panafricaine, de l'école doctorale de l'Université du Burundi et des étudiants de 2e année en banque et finance de l'Université des études professionnelles d'Accra. Les observations des chercheurs ont également été utilisées pour corroborer les réponses des participants. Avec un échantillon de 164 etudiants, des pourcentages et des graphiques ont été générés. Ancrée dans la théorie de la mauvaise pomme, la recherche suggère que la forme la plus répandue de corruption universitaire liée aux étudiants est le plagiat (75,6%), le moins étant la «falsification des résultats d'entrée» (45,1%). L'originalité de cette recherche repose sur les résultats empiriques sur les phénomènes tirés des expériences directes des répondants et sur les rapports des médias concernant des cas spécifiques de ces phénomènes. Nous recommandons des mesures appropriées pour endiguer la menace.

Mots clés: Corruption académique, Afrique, Etudiants'

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INTRODUCTION

The massification in higher education comes with it attended plethora of problems including academic corruption (Macfarlane *et al*., 2014). The expansion is partly in response to the development of knowledge economies and developing nations like Africa are only supportable in the long-term if there are ethical standards of conduct among members of the academic community: students, policy makers, faculty, administrators, industry and regulatory bodies. It appears that the labour market attracts graduates with very good academic grades as opposed to examining their competence to perform. This culture has heighten the demands for excellent certification with good grades rather than education with the intention to develop competencies. In conformance to this culture, students have devised strategies to enhance their grades to meet the demands of the labour market. Most of these strategies adopted are unethical and tantamount to academic corruption.

The phenomenon of academic corruption recurrently appear in the global news media, undermining the reputation and good standing of academic institutions and their stakeholders (Macfarlane *et al*., 2014). Academic corruption reflects every aspect of unethical practices that seek to gain unfair advantage pertaining to the academic community. This relates to all forms of unethical academic activities and/or behaviors that undermines academic integrity as demonstrated by academic stakeholders. Student related academic corruption thus refers to every form of unethical practices that students embark upon to gain undue advantage in an academic enterprise. Globally, regular forms of academic corruption include, plagiarism, cheating in examinations, grade buying/ selling, impersonation, hacking of institutional IT systems to alter student academic records, filling in after examinations, outsourcing of thesis, assignments and projects.

Eckstein (2003) notes that academic corruption encompasses among other aspects, degree and paper mills, system-wide bribery, facilitation of impersonation, plagiarism, and many other forms of academic misconduct. The reoccurrences of such practices has made the phenomenon a global issue (Macfarlane *et al*., 2014). The situation has bedeviled many nations and Africa's higher education is not immune to these concerns. In recent times, the myriad of reported incidence of academic corruption in African universities has resulted in the quest to undertake this study and to unravel best practices to curb the situation. The underlying necessity for the research is hinged on new media evidences that, student related academic corruption is on the rise on the continent.

For instance in Ghana, the University of Professional Studies – Accra (UPSA) dismisses 22 students for hacking into the University's system to change their grades; University of Ghana in partnership with the Bureau of National Investigation (BNI) arrested 20 students for allegedly hacking into the university system to change their exams results; students of Kumasi Polytechnic sacked for using fake West African Examination Certificate results.

Student related academic corruption is mostly not done in isolation by students – sometimes it is done in collaboration with university staff (lecturers, invigilators etc). For instance, some staff and administrators of the Accra based Wisconsin International University College (WIUC) were implicated by the university's leadership for selling grades to students.

These reported cases in the public domain coupled with unreported cases are on the rise and the situation is becoming worrisome in Africa's higher education. This gives room for worry that, Africa's performance, image and ranking in higher education globally may be negatively affected by the proliferation of academic

corruptions issues if measures are not taken to curb it. Sadly of the many researches that are done in Africa on academic corruption, little attention has been given to the media reportage on the issues from a student perspective coupled with empirical studies from students who are directly involved in the menace.

This reasoning finds support in the works of Macfarlane *et al*. (2014) that academic corruption has emerged as an area of scholarly and policy-based interest among stakeholders in the academic community in Africa. Notwithstanding, little empirical studies have yet been conducted, especially in emerging and newly developed higher education systems.

It is against this backdrop that the current study becomes much relevant as the research seeks to unravel the factors that triggers the phenomenon from an empirical regional view point and from African student's perspectives to recommend practical measures to forestall its occurrences in the region.

The research begins with an introduction, brief literature review of academic corruption and theoretical underpinning, methodology, presentation and discussion of findings, recommendations, conclusions and suggestion for future research.

What exists in literature. Corruption is the abuse of entrusted power for personal gain or for the benefit of a group to which one owes allegiance (Stapenhurst and Langseth, 1997). This definition reflects circular corruption in everyday life. Its scope does not reflect the academic environment, thus there is need to understand what corruptions entails in an academic environment.

Yang (2015) localizes the concept from a Chinese view point; the term academic corruption in mainland China usually refers to such violations as misrepresenting one's educational background or work experience, plagiarism, distortion of research data, affixing one's name to someone else's publications, and making false commercial advertisements, as well as other acts.

From the above discussions, it will be inferred that, academic corruption is such a large phenomenon which cannot be limited by a single definition or limited view point. It has therefore become necessary to digest the phenomenon from a specific view point: higher education.

Academic corruption in higher education. Heyneman (2004) provided an overview of the categories of corruption in higher education and distinguished between corruption in selection, corruption in accreditation, corruption in procurement, professional misconduct, and corruption in educational property and taxes. Altbach (2004) covers this deficit by differentiating between professorial corruption and corruption in examinations. The first group includes favoritism in hiring and promotion, whereas the second category includes paying bribes for examination grades. It is the second categorization of Albatch's definition which defines this work since it has direct bearing on student related academic corruption. Emphasizing on its existence globally, Janashia (2004) described corruption in higher education in the Republic of Georgia that occurs in admissions, regular examinations, and in the process of private tutoring. Private tutoring as identified by Janashia (2004) seem a regular practice in educational corruption in many parts of the world.

In Africa, it is not uncommon to hear or read about lecturers having private tutoring for specific class of students. These categories of students usually agree to pay special sums of money to the lecturers outside of the regular tuition fees. In most instances, there are suggestions that examination questions are made known to these students ahead of time;

giving them an edge over their colleagues.

Corruption in higher education is by no account a new phenomenon. It was commonplace in medieval universities, including in Bologna and the Sorbonne (Osipian, 2004). Corruption may be found not only in colleges, but in doctoral education as well (Osipian, 2010). This has become so especially in institution of higher learning in Africa where the requirement for lecturers to remain in employment is to earn a terminal degree. Many faculty would therefore find fishy and unethical means of meeting this requirement by engaging in diverse forms of academic corruption.

Corruption in higher education is often considered more detrimental than corruption in other sectors because of its long-term effects. Not only does corruption hinder equal access to quantity and quality of education, it is harmful to society as businesses and employers find that many college and university graduates do not have the proper skills to compete in the real world (McCornac, 2012).

Factors that promote academic corruption. Factors such as greed, competition for promotions, faculty demands and personal ambitions have contributed to the rise of academic corruption in higher education.

As Ararat Osipian has noted, limited *"access to education in Nigeria contributed to the use of bribes and personal connections to gain coveted places at universities, with some admissions officials reportedly working with agents to obtain bribes from students. Those who have no ability or willingness to resort to corruption face lost opportunities and unemployment*." (Osipian, 2013).

The main causes of academic corruption are students' poor study habits and poor entry qualifications, Dimkpa, (2011) adds. Dimkpa's opinion seem interesting and speaks more to this research. Unlike in the past, recent happenings seem to suggest that, students in higher educational institutions are keener for certificates than knowledge. This leads to many unethical practices that aptly constitute academic corruption.

Entry into higher educational institutions has become one of the most corrupt practices in recent times. Osipian (2010) posits that, in a survey conducted by the Institute of Social and Political Psychology of the Academy of Pedagogical Sciences in 2006 which targeted students in the leading educational centers of the country, including Kiev, Kharkov, Donetsk, Lviv, and Odessa, the following responses were obtained to the question "How in your opinion has the situation with corruption in entering higher education institutions changed compared to the previous years?". Around 20 percent of the respondents indicate that they know of the cases of bribery, but the number of such cases has declined; around 27 percent of students said that bribes were accepted by the faculty members at about the same level, as they were in previous years and that nothing has changed; 7 to 8 percent think that bribery is now flourishing. The number of students who admitted paying bribes for entering the college or university declined from 19 percent in 2005 to 13 percent in 2006 (ibid). The ensuing is a very obvious reflection of the level of student related academic corruption in institutions of higher learning.

Theoretical underpinnings of the study. The study adopted the Bad Apple Theory. The theory primarily focus on the individual as the cause of corruption in the world. The theory postulates that corruption exist because we have people with immoral traits and these group of people are called 'bad apples' (De Graaf, 2007). Graaf (2003) opines that "there is a causal chain from bad character to corrupt acts; the root cause of corruption is found in defective human character and predisposition toward criminal activity."

This theory also argues the causes of corruption is linked with human weaknesses like greed. The theory also postulates that when the concentration is on the defective characters of an office holder, morality then begin to regulate behavior. By the postulations of this theory, people engage in academic corruption because they have defective behaviors that influence their actions.

Similarly, Klitgaard (1988: 70) states, "if the benefits of corruption minus the probability of being caught times its penalties are greater than the benefits of not being caught, then an individual will rationally choose to be corrupt." In this theory, the actions of people who engage in corrupt activities is influenced by rationality and deliberate weighing of options by the perpetrators.

This theory shall be used in this study because it helps explain why students engage in academic corruption in higher education institutions in Africa. Another reason for adopting this theory is that it has a close focus. Schinkel (2004:11) states that "Instead of looking for general determining factors, it concentrates on a specific situation of an agent (a corrupt official) who calculates pros and cons."

METHODOLOGY

Research design. The study employed a quantitative approach to assess the phenomenon of academic corruption to identify the level of existence of student related academic corruption and suggested interventions and best practices in some African universities to solve the menace. The population of the study comprised undergraduate students in sub-Sahara African universities.

Sample and procedure. An anonymous, self-administered online questionnaire was distributed to students from the database of the All-Africa Students Union, University of Burundi Doctoral School and 2nd Year Banking and Finance students of the University of Professional Studies in Accra, Ghana. In this method, which belongs to the category of probability sampling techniques, sample members are selected on the basis of a random procedure. 164 valid questionnaires were returned (n=164) and analyzed. Random sampling was used to select respondents for this research. Also, researcher observation was employed for firsthand information on use of CCTV cameras to check exam malpractice, and existence of posters for contract writing on university campuses.

The survey instrument was pre-tested with students' participants. The survey was pre-tested with Internet Explorer version 4.0, Windows 10, and two types of Internet access (wifi and eternet). Three different Internet service providers (MTN, Airtel Tigo and Vodafone) were also used for the pretesting. The pilot test did not uncover any technical problems. However, minor internet fluctuations at intervals were observed. 164 valid questionnaires were returned (n=164) and analyzed.

One key instrument was used for this study – Curbing Student Related Academic Corruption Questionnaire (CSRACQ).

Curbing Student Related Academic Corruption Questionnaire (CSRACQ). The questionnaire was drafted and reviewed by 10 experts in the area of Quality Assurance in higher education. The drafting and review of the questionnaire took three weeks.

Methods of data analysis. The preliminary findings of the study were presented and discussed for inputs at the 9th and 10th International Conferences on Quality Assurance in Higher Education in Africa in Ghana in 2017 and in Cameroun in 2018.

The data from the final study was analysed using google forms to present the information

in tables, percentages and frequencies. Content analytical technique was used in discussing patterns, themes and drawing conclusions from the study.

RESULTS AND DISCUSSIONS

The study suggests that the perception of academic corruption is renowned and prevalent amongst students in Africa's higher education. Critical among the findings of the research and reasons students get into such practices are discussed.

The phenomenon of projects contractors is gaining momentum in Africa's higher education. This is a situation where contractors accepts to write thesis, dissertation and project work for students for fees. Enquiries into whether students outsource thesis revealed an overwhelming 68.9% (see Figure1) answering Yes, showing the extent to which this practice is prevalent on university campuses. Respondents noted that, they outsource academic writing because they lack the requisite writing skills and academic writing seem difficult to them. This finds coherence with the works of Awaah (2020a) that while efforts are made by African universities to ensure the enabling environment in terms of classroom infrastructure, lectures, libraries, security and other factors which may inhibit learning are made relatively adequate for the conducive study, students usually will have difficulty in understanding some concepts within the period of study. Researcher observer on the participant response further revealed posters advertising services of academic contractors on walls trees and notice boards of selected universities. This practice may be as a result of universities not introducing academic writing very early in the academic journey of students. Most universities have academic writing introduced after the second year, by which time student had gone through the wrong ethics of achieving academic writing – outsourcing

Responding to the question "Some student outsource their thesis for others to do for them" an overwhelming 68.9% answered Yes, revealing the extent to which this practice is prevalent on campuses. Observations on a number of campuses reveals that, the situation has resulted in some contractors circulating flyers and promotional materials to attract sizeable number of students for such practices glaringly on the notice boards of many African universities. The essence of making students do projects or write long essay or even take home assignments has been lost as contractors are now seen championing this agenda on behalf of students for their selfish ambitions.

Plagiarism. We found 75.6% of respondents

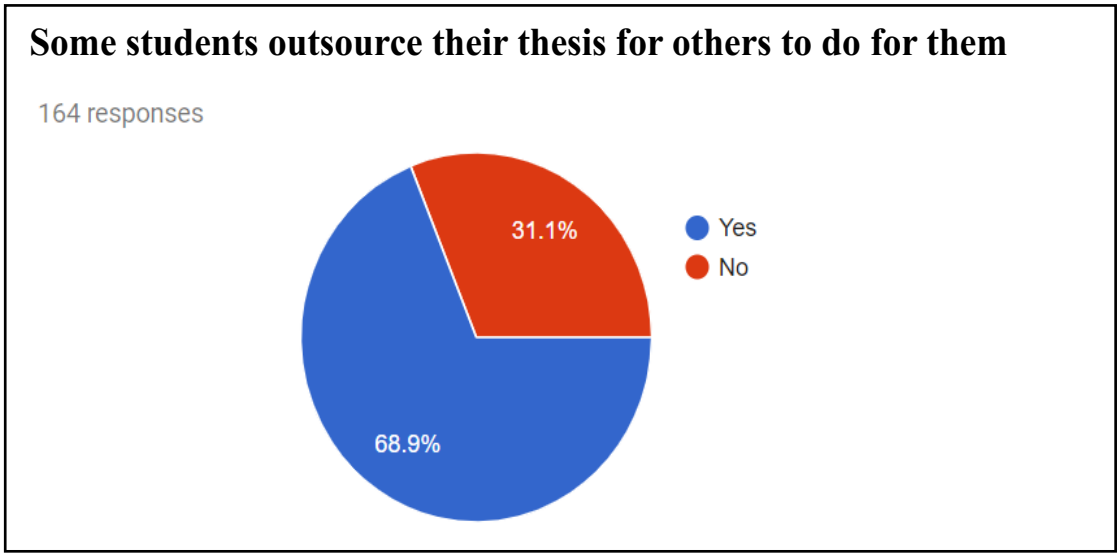

Figure 1. Responses on whether students outsource their thesis

agreeing that students plagiarize in undertaking their academic work. Szabo and Underwood (2004) report that the internet has aided plagiarism among students and that students could easily use the internet to copy and paste information without referencing. The problem of plagiarism is growing in universities. A 2011 survey of over 1000 college Presidents in the US revealed that 55 percent thought that plagiarism was on the rise. Business Schools such as those at UCLA and Penn State have recently begun scanning the admission essays of their MBA applicants because of the scale of the problem (Parker *et al*., 2011). This could be as a result of students not knowing the implications of the crime related with plagiarism. Also, Most Higher Education Institutions (HEIs) do not have plagiarism software's for checking students' assignments and activities.

Hacking of IT systems. Evidences from this research reveals that, though there is prevalence of this in African universities, it is not very dominant as suggested by the figures (48.8%) agreeing to its existence. This is supported by Underwood and Szabo (2003), that there is a positive correlation between the increased use of technology in education settings and academic corruption. This implies that as the use of technology in the administration of school systems increases, there is the tendency of increase in the hacking of the system by students and other administrators.

Further evidence suggests that some twenty persons of the University of Ghana were interdicted by the Bureau of National Investigations (BNI) for an attempt to compromise the school IT system in their favour. Furthermore, the University of Professional Studies in Accra also dismissed twenty students for attempting to hack into the school's IT system to change their grades. Hacking of IT systems of universities may be as a result of weak IT infrastructure of the universities and increased IT knowledge of students.

Falsification of entry results. The study also found that students sometimes falsify their results in order to gain admission into various higher education institutions in Africa (45.1%) as shown in figure 4 above. Some university officials do collaborate with such students to aid them in falsifying their results. For instance, twelve students from the Kumasi Technical University were sacked from the institution for

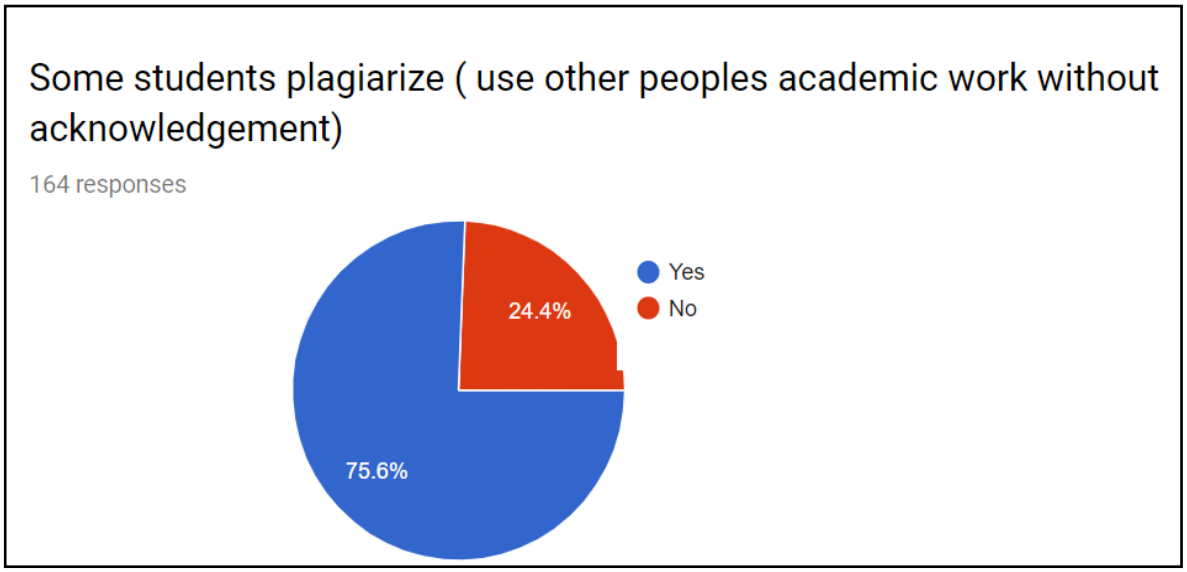

Figure 2. Responses on whether students Plagiarise

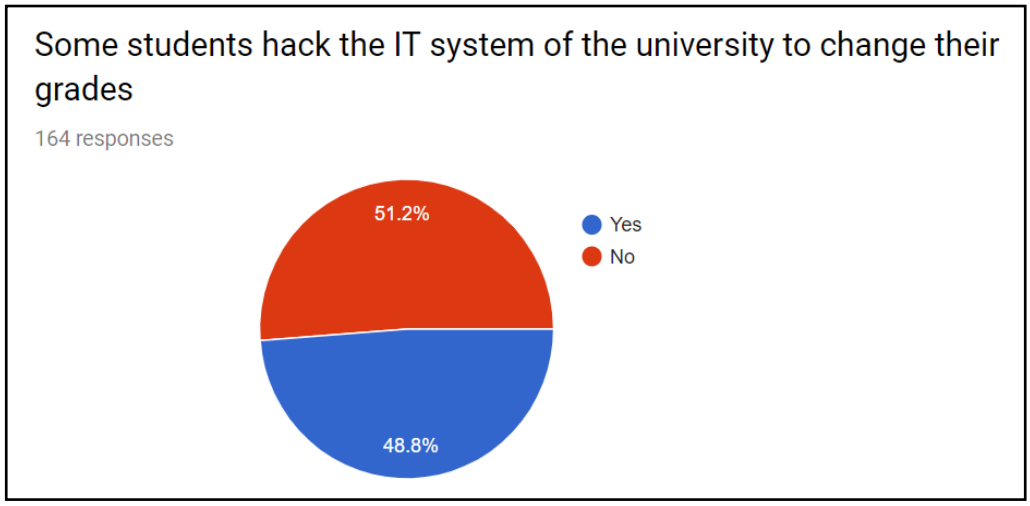

Figure 3. Responses on whether students hack IT systems of universities to change Grades

falsifying entry results from the West Africa Senior Secondary Certificate Examination. This findings is in line with the works of Chapman and Lindner (2016) that the impact of corrupt practices in higher education can have a wider negative influence to the extent that it breaks the link between personal effort and anticipation of reward.

The polarization of technology in the administration of higher education has aided the falsification of entry results. This takes the form of the usage of computer software to alter results in order to gain admissions into institutions of higher education.

Cheating in exams. Figure 5 indicates that 76.2% of the respondents agreed that cheating in examination is common in their universities. This takes the form of students making notes on their skin and also smuggling of pieces of papers with notes into the examination centers.

Again, with the invention of mini technological devices such as programmed wrist watches, and calculators has aided in the storing of notes which students take into examination halls. Johns (2003) found that university students engaged in massive cheating in exams he administered on them. He further reported that discussions in the course of the examination, looking up answers in textbooks, copying from colleagues where among other practices the students engaged in during the course of the exams. His findings find coherence with a survey by Awaah (in press) that, the top most occurring form of students related academic corrupt practice is students communicating with or copying from any other student during an examination by exchanging answers sheets with the view of getting answers to questions representing 52.8% of responses on the survey of ranking student related academic corruption in Ghana.

It is noteworthy that these findings are in sync with the results of this study that cheating during examinations abound in the sub Saharan Africa context. McCabe and Trevino's (1993) for instance suggest that students who do not cheat during examinations feel disadvantaged. In the UK over 17,000 cases of cheating were recorded at universities in 2009–2010, an increase of 50 percent from four years previously (Barrett, 2011).

Grade buying. The study further found that grade buying is one of the forms of academic corruption dominant in African universities as depicted in figure 6 above. Sometimes,

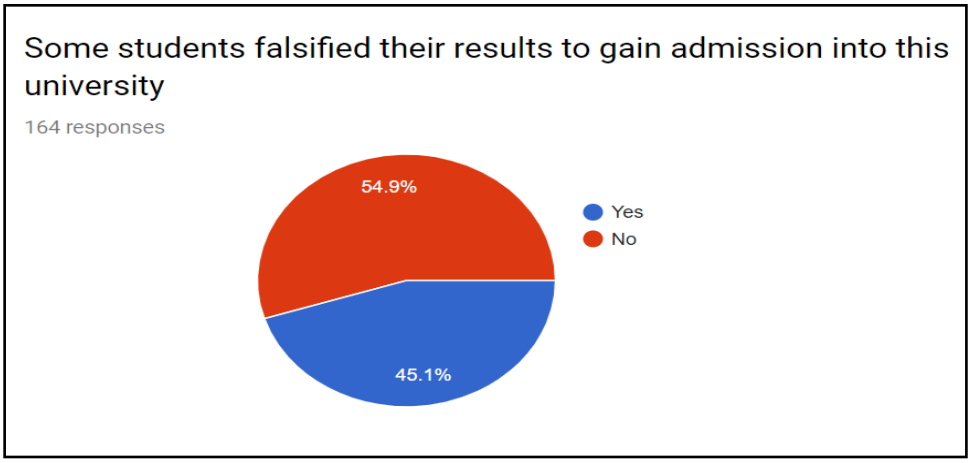

Figure 4. Responses on whether students falsify entry results into universities

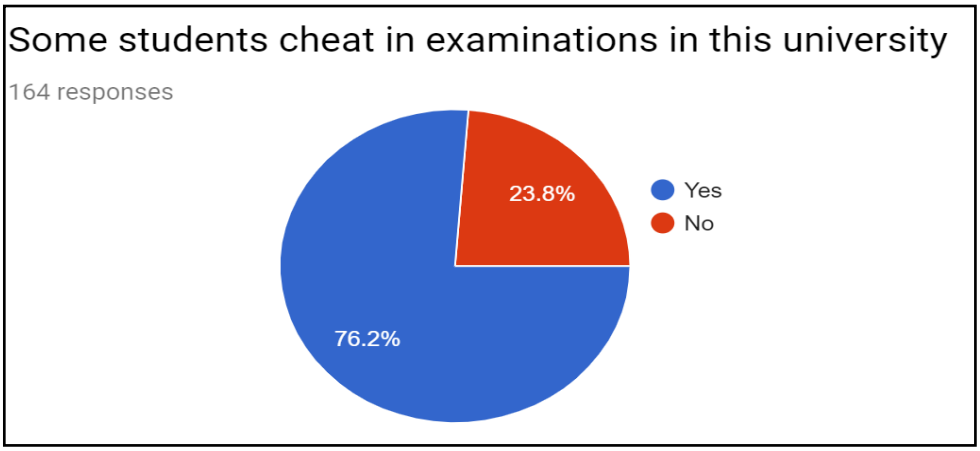

Figure 5. Responses on whether students cheat in Examinations

instead of cash payments to the faculty, students offer sexual intercourse in exchange of a pass grade as evidenced in this research (60.4%) of participants responded yes to the statement "Some students offer sex to lecturer for marks"). In most instances, faculty being aware that the scripts may be vetted by university management for unfair award of grades, allows students to fill in blank spaces to cover their deeds. Others collide with schools administrators and lecturers in altering their grades. For instance, it has been reported that specific staff and administrators of Accra based Wisconsin International University College have been accused by the University's authorities for selling grades to students.

In a different dimension, Altbach (2013), posits that professors and administrators connive with students by selling them the examination papers in advance or by fixing the results. This finding is however in line with the results that students go the extent of buying the conscious of professors and administrators in changing their grades. In Georgia, there a repots of professors handing out price lists for passing exams. A student can buy his or her way through the institution, paying for every examination and, ultimately, a diploma. Moreover, students can bypass the higher education system altogether by simply buying a diploma from an established university (Meier, 2004).

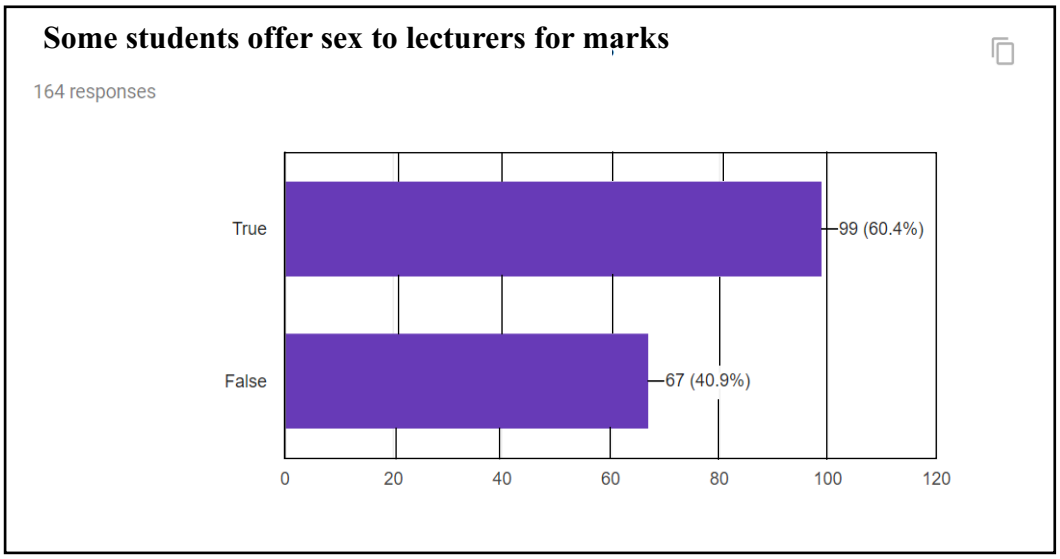

Figure 6. Responses on whether students buy grades in universities

Particular in respect of sexually related grade buying, Awaah (2020b) posits that sometimes, this sexual barter for grades is not as a result of genuine trade between the lecturer and student, yet in those instances, only 20.5% of respondents will not report lecturers who demand sex for grades.

Policy recommendations. To mitigate the menace of student related academic corruption in Africa's institutions of higher learning, a number of policy drives and good practices have been suggested for implementation.

Honour code. This has to do with individuals making personal pledges to abide by rules and regulations governing the conduct of examinations and personally responsible for flouting those rules. As a best practice, institutions of higher educations should develop and implement honour codes to serve as check on the academic activities of both students and officials. This can help lessen academic corruption by lauding students who have diligently observed rules and regulations laid down in the codes.

Suggestions from the 9th ICQAHEA held from 18th – 22nd September 2017 Accra, Ghana and the 10th ICQAHEA in Yaoundé revealed that, Asheshi university in Ghana is using this code to effectively curbing the menace, thus worth replicating at other institutional, national and continental levels. Searcher observation of these suggestions was corroborated by visits of the researchers to the university. Benchmarking from the Asheshi experience, this recommendation will need the collaborative efforts of students and institutions of higher learning.

Software. Anti-plagiarism software developed to track students' assignments and other academic works is recommended as a measure of curbing student related academic corruption. This can be made possible by students submitting assignments and theses electronically to check for plagiarism. Opinions from the 9th and 10th ICQAHEA suggest that, the University of Ghana has used this and it's proven efficient in managing the menace.

Technologies. Despite the fact that technology happens to be the major tool that aids in the practice of academic corruption, it can be used to lessen if not eradicate the practice of academic

dishonesty among students and academics. This can be achieved by the installation of CC TV cameras in the examination rooms to aid in the easy detection of cheating during examination. Cursory examination researcher observations of the Ghanaian system reveals that, the Laweh Open University College uses cameras for invigilating examinations and it has proven efficient. This is recommended for replication in all universities within sub-Sahara Africa.

Encourage conference marking. To curb the possibilities of students compromising lecturers with money and sex for grades, it is recommended that lecturers are made to mark scripts at an agreed venue (hall) in the university. This will check the tendency of lecturers conniving with students to fill in blank spaces pre-agreed with lecturer for the purposes of awarding unfair marks. Researcher observation at the University of Professional Studies – Accra reveals that, this method has been implemented and its proven effective. Replicating same for sub-Sahara African universities will help curb student related academic corruption.

Introduce scholarly writing at the commencement of university education. Introducing scholarly writing helps in curbing the fraud related with academic writings such as plagiarism. When students are introduced to scholarly writing at a very early age, they get to understand the consequences of not adhering to the rules, thus compelling them to avoid such crimes. Laweh Open University College has successfully adopted this model for its students per the researcher observations to that university.

Punishment. Punishing students who are engaged in academic corruption will serve as a deterrent to other students, thus helping curb the menace on African campuses.

Review mode of teaching and learning. Teaching and learning in a number of African universities are very outmoded; requiring students to memorize and reproduce the same material in examination. This seem to encourage academic fraud since student's inability to memorize leads to cheating. It is recommended that teaching be made in more applied and practical forms, allowing students the flexibility of using initiatives by applying knowledge rather than reproducing knowledge.

Reduce class size for examination. The convenience to cheat in examinations is usually fuelled by sitting proximity of students to each other. In response, African universities should ensure the class sizes for examinations are reduced and students sparsely distributed to ensure they are unable to communicate to each other either verbally or non-verbally.

Contributions to comparative and international higher education. From an African perspective the research introduces acts that may not be considered academic corruption in other environs as a result of cultural and systemic factors that ensure conformance to acts deviant by students in this paper considered academically corrupt by students. This contributes to comparative and international higher education in a way that pulls from the empirical evidences of other forms of academic dishonesty from the developing world which may not existent in the developed world. This gives room for a relook at the concept from a broader perspective in comparative and international higher education.

CONCLUSION

Student related academic corruption is widespread among students in African universities and its prevalence is largely as a result of the quest for students to make good grades in order to fulfil the grade expectations of the labour market. To respond to this, academic stakeholders would largely need to harmonize their efforts toward reexamining the mode of

teaching, learning and examining students in African universities.

We conclude that, practitioners of higher education have key roles in curbing the canker of student related academic corruptions in Africa's higher education space. Prescribed measures include honour codes, anti-plagiarism software, Close Circuit Cameras in class rooms during examinations, conference marking by lecturers, and the arrest and prosecution of thesis contractors who have notices on campuses.

Suggestions for future research. Considering that a gender twist to this study has not been thoroughly examined, it is recommended that future studies will examine the relationships between female student seduction on male lecturers and academic corruption in Africa universities.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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Building interdisciplinary research capacity in African universities: insights from the Sentinel project

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ABSTRACT
Interdisciplinary research has emerged as a suitable research approach for addressing complex global development challenges, however, its applicability is still limited within the African research context. To this note, collaborative arrangements between North and South based universities and institutions developed an interdisciplinary project called "Social and Environmental Trade-offs in African Agriculture (Sentinel)' to build capacity of African and UK researchers and their institutions to co-develop interdisciplinary research on the impacts, risks, and trade-offs within and between socio-economic and environmental dimensions of different agricultural development pathways. Building capacity for interdisciplinary research requires an understanding of the research context of African universities to support planning for capacity building activities. This paper provides insights on the assessment of research capacity of African universities through a cross-sectional survey of Principals and Deans who attended the RUFORUM Annual General Meeting in Lilongwe, Malawi in 2017. A survey questionnaire consisting of both open-ended and structured questions was administered to a randomly selected sample of 53 respondents. Quantitative data was analysed using SPSS (V.21) while qualitative data was analysed using thematic analysis. The major themes were summarised into frequencies and/or percentage of the overall number of responses for each open-ended question. Results showed that African universities are engaged in international networks, conduct collaborative research, and take a strategic approach to management, reward faculty for publications, participating in conferences and professional organisations. The study recommends strengthening research support, supervision and mentorship structures and that universities need to evaluate their existing capacities and map out strategic areas of development as key ingredients for fostering interdisciplinarity in African universities.

Key words: Africa, capacity, interdisciplinarity, Sentinel, Universities

RÉSUMÉ
La recherche interdisciplinaire est apparue comme une approche de recherche appropriée pour relever les défis complexes du développement mondial, mais son applicabilité est encore limitée dans le contexte de la recherche en Afrique. Pour ce faire, des accords de collaboration entre les universités et les institutions du Nord et du Sud ont développé un projet interdisciplinaire appelé «Arbitrages sociaux et environnementaux dans l'agriculture en Afrique –Sentinelle en siegle pour renforcer la capacité des chercheurs africains et britanniques et leurs institutions à co-développer de recherches interdisciplinaires sur les impacts, les risques et les compromis de dimensions socio-économiques et

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environnementales dans les différentes voies de développement agricole. Le renforcement de capacités de recherche interdisciplinaire nécessite une compréhension du contexte de recherche des universités africaines pour soutenir la planification des activités de renforcement des capacités. Cet article donne un aperçu de l'évaluation de la capacité de recherche des universités africaines à travers une enquête transversale auprès de chefs des sections et des doyens qui ont assisté à l'assemblée générale annuelle du RUFORUM à Lilongwe, Malawi en 2017. Un questionnaire d'enquête composé à la fois de questions ouvertes et structurées a été administré à un échantillon de 53 répondants sélectionné au hasard. Les données quantitatives ont été analysées à l'aide du logiciel SPSS (V.21) tandis que les données qualitatives ont été analysées à l'aide d'une analyse thématique. Les principaux thèmes ont été résumés en fréquences et/ou pourcentage du nombre total de réponses pour chaque question ouverte. Les résultats ont montré que les universités africaines sont engagées dans des réseaux internationaux, mènent des recherches collaboratives et adoptent une approche stratégique de la gestion, récompensent les professeurs pour leurs publications, participent à des conférences et à des organisations professionnelles. L'étude recommande de renforcer les structures d'appui à la recherche, de supervision et de mentorat et que les universités doivent évaluer leurs capacités existantes et définir des domaines stratégiques de développement en tant qu'ingrédients clés pour favoriser l'interdisciplinarité dans les universités africaines.

Mots clés: Afrique, Capacité, interdisciplinarité, Sentinel, universités

INTRODUCTION

Universities in Africa have been called upon to spearhead Africa's development Agenda (Adipala and Egeru, 2018). This is a daunting task given the various challenges that are currently affecting the Higher Education sector. For instance, universities are faced with high "massification" rates, limited staff capacity particularly at PhD level, limited infrastructure and equipment, weak monitoring and evaluation frameworks, and generally low investment (Nakayiwa *et al.,* 2016). These African universities have a mandate to contribute to national, regional and global development by performing three key functions namely; teaching, research and outreach (Nampala *et al.,* 2017). Although research has received greater attention over the years in African universities, statistics however show that Africa continues to lag behind all other continents in terms of its contribution to global research knowledge. Recent findings for instance indicate that Africa contributes less than 3% of the word's research output (Confraria, 2013; Nakayiwa *et al.,* 2016; Duermeijer*et al.,* 2018). On the other hand, development challenges are becoming more complex which now requires that problems are tackled from an interdisciplinary research perspective (Siedlok and Hibbert, 2014). A continued push for interdisciplinarity requires, particularly the one that focuses on combining knowledge from the natural and social sciences that scientists "collaborate across disciplinary, epistemic and methodological boundaries" (Lyall and Meagher, 2012). Interdisciplinary research is defined as research that involves a combination of two or more disciplines (Siedlok and Hibbert, 2014). The application of interdisciplinary research methodologies to address complex development challenges has been widely used in parts of the global North such as in the UK (Lyall, Meagher and Bruce, 2015), but it is applicability is still limited within the African research context. African

universities are striving to move beyond the disciplinary focus of its inherited colonial higher education system to a post-colonial era of the 21st century where knowledge forms the cornerstone of the economic progress and where knowledge production is based on the aggregative power of collaboration, partnership and cooperation across disciplines, countries and regions (Zittoun *et al.,* 2007; Huutoniemi *et al.,* 2010; Wu, Baggio and Janssen, 2016) . Accordingly, African universities are in a state of transition in developing systems, nurturing processes and strengthening interdisciplinary research focus. There is a dearth of information on the institutional and organisational gaps that require to be addressed in this transition.

It is within the above context that the collaborative arrangements between North and South based universities and institutions developed a project called the "Social and Environmental trade-offs in Africa Agriculture (Sentinel)". This project addresses the challenge of achieving 'zero hunger' in sub-Saharan Africa, while at the same time reducing inequalities and conserving ecosystems. The project enhances the capacity of UK and African researchers and their institutions to co-develop interdisciplinary research on the impacts, risks and trade-offs within and between social, economic and environmental dimensions of different agricultural development pathways. This will contribute to achieving the Sustainable Development Goals (SDGs) on zero hunger (SDG 1), reduced inequalities (SDG 10) and ecosystem conservation (SDG 15). The project tackle these goals through a programme of collaborative research and learning, training and mentoring of junior staff, and direct engagement with senior university managers. Capacity building was embedded throughout the programme as an integral part of the research agenda. Sentinel works towards achieving these development goals in three African countries – Ethiopia, Ghana and Zambia. Research capacity needs assessment was the foundation for the development of the capacity building. A key component of the capacity building strategy is the assessment of the organisational/institutional capacity in the context of African universities. A supportive environment or context is particularly important in fostering interdisciplinary research by providing the necessary infrastructure, administrative support, an organisational culture, platforms for interdisciplinary discussion and eradicating barriers to interdisciplinary research (Technopolis Group, 2018). Morse *et al.* (2007) argue that interdisciplinary research should work across disciplines as an entire research process that is not bounded by institutional barriers. In addition, interdisciplinary research is considered fully operationalised when the research users are fully engaged through definition of the research process and the research agenda, monitoring and evaluation as well as facilitating the processes of knowledge co-creation, co-production and co-generation (Bridle *et al.,* 2013; Lyall *et al.,* 2015) . The key researcher indicators of interdisciplinarity addressed under Sentinel include working across disciplines, professional development, mentoring for interdisciplinary research, linking research to teaching and curriculum development, co-designing research with research users and writing proposals to answer funding calls to address global challenges, people management, monitoring and evaluation, collaboration and networking, communication and advocacy across stakeholder groups (Chausson, 2018). In terms of research context, the study identified research capacity issues in six key areas including: strategic approach to research management and identification of research priorities, engagement in international networks and collaborative research, research capacity evaluation and identification of priority areas, research support and mentorship structures for researchers, structures and procedures for dissemination of research knowledge and university policies for promoting knowledge transfer.

METHODOLOGY

A cross-sectional survey design was employed for this study. A randomly selected sample of 53 RUFORUM Principles and Deans who attended the RUFORUM Annual General meeting in Lilongwe, Malawi took part in the survey. A survey questionnaire consisting of structured and open-ended questions was designed, drawing on the Vitae framework and the Higher Education Institutional Capacity Assessment tool (IREX, 2016). The Vitae framework (www.vitae.ac.uk/rdf) identifies areas of research capacity in four (4) domains, 12 sub-domains and 63 descriptors. It includes knowledge, intellectual abilities, techniques and professional standards to do research, personal qualities, knowledge and skills to work with others and ensure the wider impact of research, research governance and organization, Engagement, influence and impact. The Vitae methodology is focused on individual research skills. Meanwhile, the IREX tool provides information on institutional strengthening. Based on these two frameworks, the survey questionnaire obtained data that facilitated the formulation of a Likert-scale scoring matrix based on the following items: mission, vision and strategic planning, senior management governance and accountability, data and institutional research, finance, staff and faculty management, academic operations, workforce development, students and alumni engagement, research, knowledge transfer and external relations, facilities equipment and learning resource, quality assurance and enhancement. Descriptive statistics (frequencies) were used to analyse quantitative data in SPSS (v.21). In addition, qualitative data was analysed using thematic analysis. The major themes were summarised into frequencies as percentage of the overall number of responses for each open-ended question.

RESULTS

Organisational research capacities of African universities. Figure 2 presents a summary of the assessment of the organisational capacity

Figure 1. Part of the vitae researcher development framework showing domains and subdomains
Source: https://www.vitae.ac.uk/vitae-publications/rdf-related/researcher-development-framework-rdf-vitae.pdf/view

of universities in research. Results show that universities are engaged in in international networks, conduct collaborative research, and share experiences; universities take a strategic management approach to research management, identify areas of institutional strength; encourage and reward faculty members for publications in professional journals, presenting at conferences and taking part in professional organisations. However, there were slightly weak levels of agreement that universities provide strong support, supervision and mentorship structures for researchers; and that universities have evaluated existing research capacity and have identified areas of strategic development.

Research management, research priorities and Incentives that encourage university research. Figure 3 shows that Strategic planning at the university, national development priorities and needs assessment surveys emerged as the major ways by which universities identified their research priorities. Seminars, workshops, policy review forums were not seen as important avenues for identifying research priorities in African universities. From Figure 4, the key incentives identified by respondents in the survey include availability of research grants, career promotion of university scientists and monetary rewards for research publications. Very few respondents indicated that Intellectual property rights, staff leave time and decentralized management of research as incentives that encourage university research.

Perceived factors influencing conduct of research. Figure 5 shows the factors that limit faculties or universities from expanding their research. The main barriers to faculty and the universities expanding their research included: limited research funding, low staff capacity to conduct research, poor research infrastructure and heavy teaching load for university researchers. To a smaller extent, poor internet connectivity and inadequate strategic networks as barriers to expanding research in African universities.

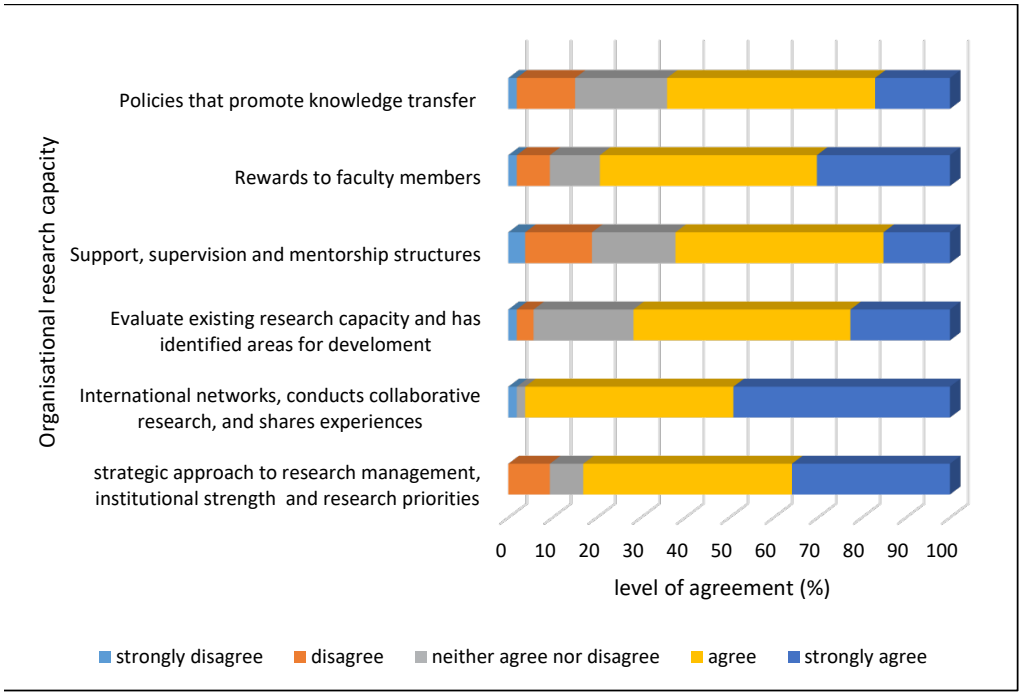

Figure 2. Individual assessment of organisational research capacity in African universities

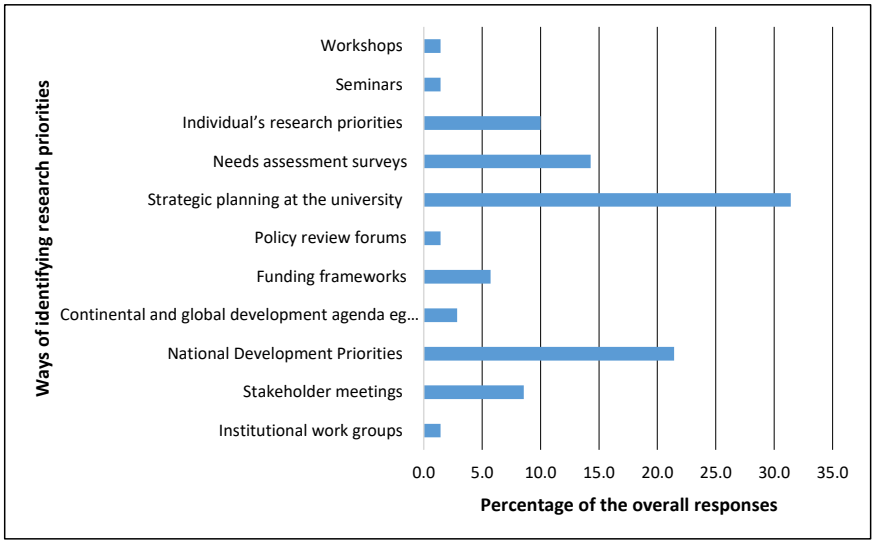

Figure 3. The ways of identifying research priorities in African Universities

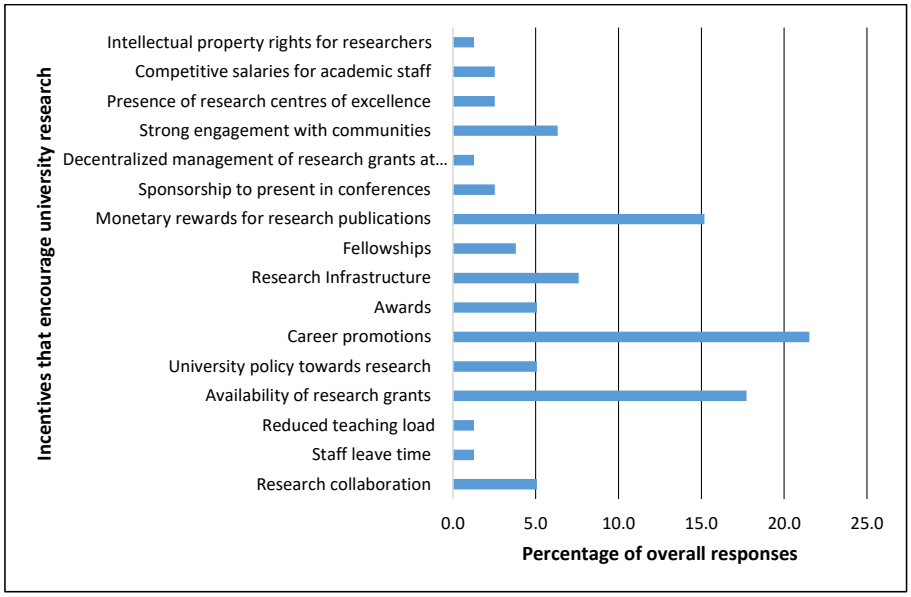

Figure 4. Incentives that encourage university research in African Universities

Engagement in international networks, collaborative research and shared experience
Results indicated that universities under the RUFORUM network are highly engaged in collaborative working relationships, research and networking. As shown in Figure 6, most respondents indicated that their universities enter relationships with other institutions mainly through signing Memoranda of Understanding (MoUs), partnerships, and research collaborations involving faculty and students. Very few universities entered relationships through service contracts. Universities at the same time had some partnerships with the private sector. In terms of engagement with the private sector, 90.6% of the participants indicated RUFORUM member universities engage with various private sector institutions including farmer cooperatives, banks and other industry actors.

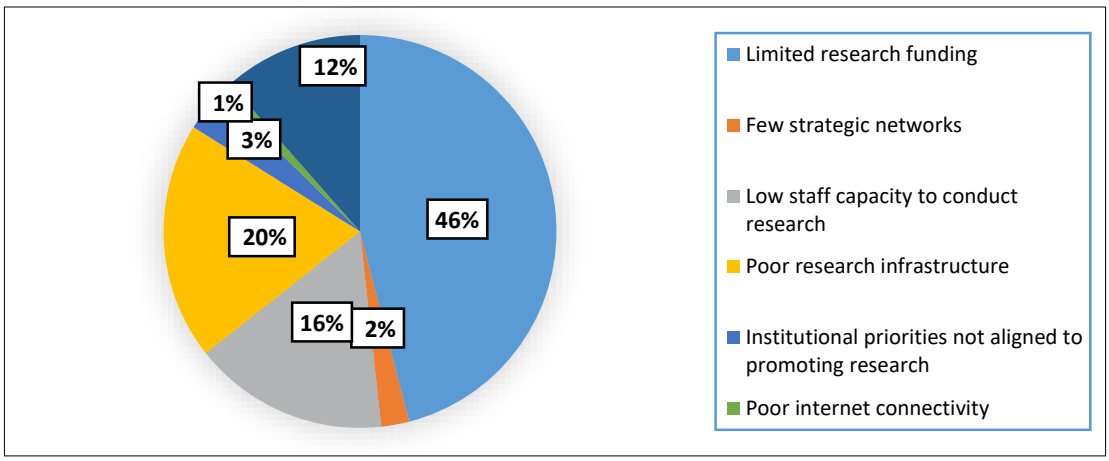

Figure 5. Factors limiting faculty/universities from expanding their research

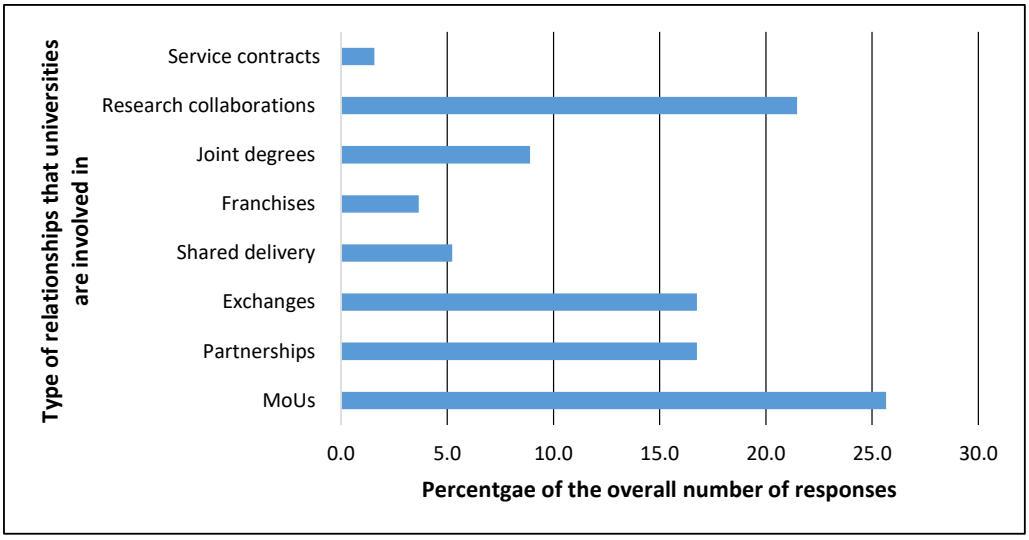

Figure 6. Type of relationships that universities are involved in

Research capacity and research priority areas. Results (Figure 7) revealed that most participants indicated that grant proposal writing and research proposal writing are the areas of capacity in greatest need of development. This was for both the research proposals and competitive grants proposal development and skills development in transdisciplinary research approaches. Further grants management, fund raising for research, and research priority identification are some of the skills that the university managers and administrators deem fit to be developed (Figure 8).

Research support, supervision and mentorship structures for researchers. For results shown in figure 9, the majority of the respondents indicated that the core types of support provided to faculty members to encourage research activities are provision of research funds, training to write for publication and training in research proposal writing. In addition to research support, supervision and mentorship, universities provided an array of cchannels through which university researchers communicate their findings and inform policy debates with the government are workshops, conferences, research publications and newspapers as shown in Figure 10.

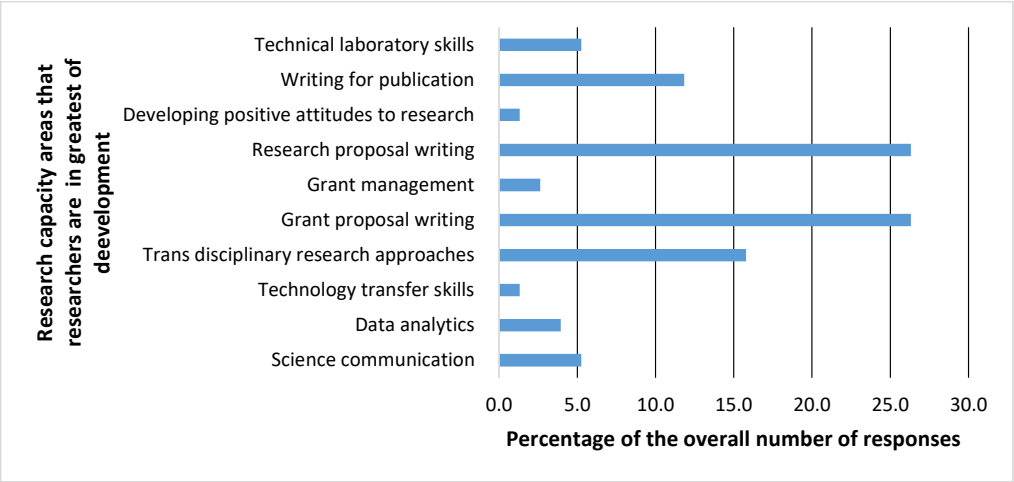

Figure 7. Research capacity areas that African universities are in greatest need of development

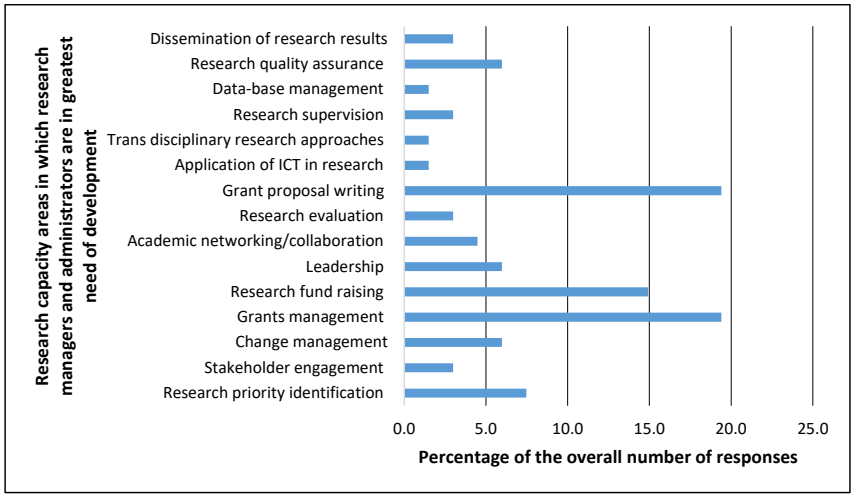

Figure 8. Research capacity areas in which research managers and administrators are in greatest need of development

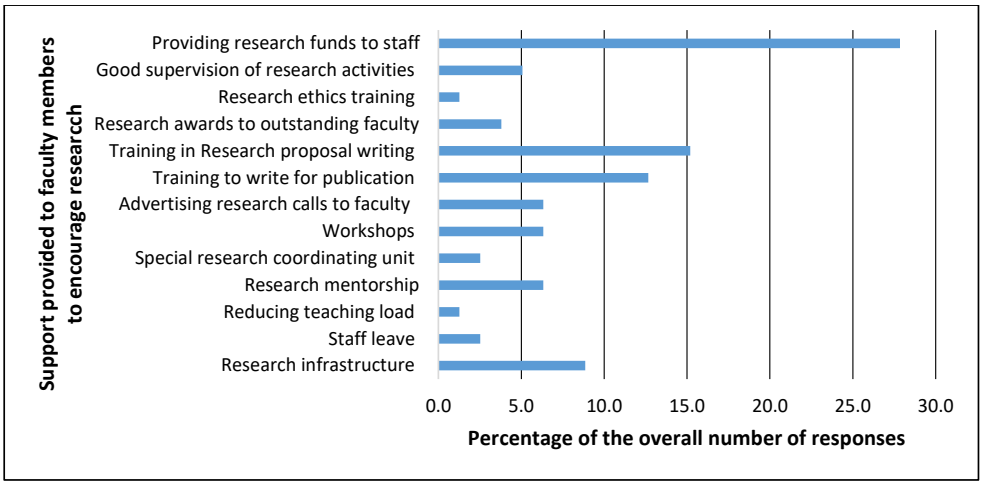

Figure 9. Type of support provided to faculty members to encourage research

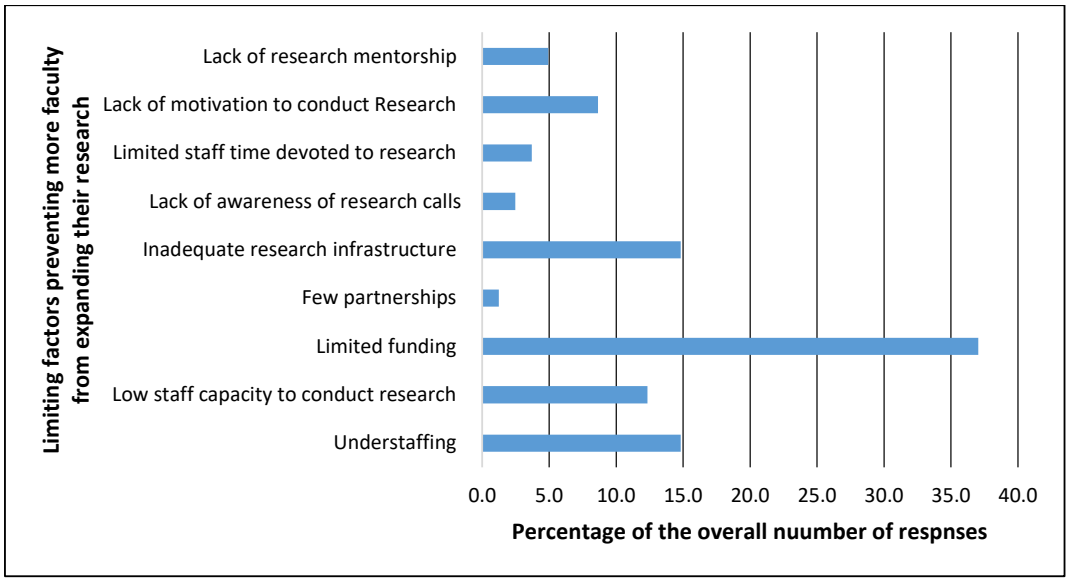

Figure 10. Channels for communicating research findings and informing policy debates with government

DISCUSSION

Engaging in international networks, conducting collaborative research and sharing experiences is useful in developing communities of practice for interdisciplinary research. Networks allow members of the interdisciplinary research community to develop trust, a sense of community and guidelines of conduct (Mansila *et al.,* 2012). Mapping out strategic areas of research focus is useful in advancing interdisciplinary research so as to manage scarce resources and at the same time build formidable communities of practice. The sentinel project aims to increase the research capacity of African researchers to conduct interdisciplinary by engaging with research users such as policy makers, private sector and civil society organisations. Although most of the respondents in this study indicated that their universities engage with the private sector, the partnerships with the private sector in most universities are still few and weak to provide substantial investment in research activities and guiding research agenda. It is argued that for African universities to contribute to national economic development, they have to establish strong linkages with industry including the private sector (Ssebuwufu *et al.,* 2012). In its vision 2030 strategy, RUFORUM seeks to enhance cooperation with the private sector to leverage scarce resources and enhance creativity and innovation in university research and training (RUFORUM, 2017).

Provision of incentives, both monetary and non-monetary rewards generally increases incentive for Knowledge production (Cloete *et al.,* 2015). These incentives are also necessary in stimulating interdisciplinary research among university faculty. It was surprising that very few respondents indicated Intellectual Property Rights (IPR) as an incentive to expanding research. This is probably due to the limited awareness of the value of IPR in protecting innovations and other creations of the human mind. Studies show that African research institutions are still weak in designing and administering IP systems (Sikoyo *et al*., 2006; Syam Nirmalya, 2016).

The findings from the study also indicate that mentorship structures are weakly developed in African universities. The limited mentorship capacity is disadvantageous particularly for early career researchers who are trying to find their trade in research. Recent findings also show that research mentorship structures remain

underdeveloped in African Higher Education institutions (Cloete *et al.,* 2015). On the other hand, universities have to identify their research capacities if they are to be competitive in conducting interdisciplinary research. The challenge to decision-making has been limited access to reliable data. RUFORUM is working to address this gap for example through establishment of the Agricultural Science and Technology Indicators (ASTI) portal in collaboration with the International Food Policy Research Institute (IFPRI). The portal provides information on staff and student population in Africa's Agricultural Universities including staff numbers, age, gender, position and discipline. These indicators are useful in establishing research capacities in African universities to guide decision making to aid strategic planning and setting of priorities not limited to the Higher Education institutions but extending to the broader Agricultural Innovation System (Kitone *et al.,* 2018).

CONCLUSION AND RECOMMENDATIONS

The study shows that African universities are striving to improve research capacity in their institutions, but there efforts are still inadequate largely due to limited financial resources. However, the context of African universities provides potential for enhancing interdisciplinary research capacity. Elements like co collaboration, networking and partnerships are being implemented in African universities. These are critical facets for promoting interdisciplinary research. We recommend that African universities should establish strong partnerships with other well-endowed institutions, private sector and international organisations in order to rationalize resource use and build capacity of weak institutions to participate in interdisciplinary research. Additionally, there is a need to strengthen research support, supervision and mentorship structures and universities must evaluate their existing capacities and map out strategic areas of development as key ingredients for fostering interdisciplinary in African universities.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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