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SCREENING OF ADVANCED CIP POTATO CLONES FOR BIOTIC (PEST, DISEASE) RESISTANCE, ABIOTIC STRESSES TOLERANCE, YIELD ADAPTABILITY & STABILITY UNDER LOCAL ENVIRONMENT CONDITIONS IN & AROUND LWIRO RESEARCH CENTER, IN SOUTH-KIVU PROVINCE, EASTERN DRCONGO

Théodore MUNYULI [1,2], Justin OMBENI2, Bienfait BASHI MUSHAGALUSA[2], Alphonse BISUSA MUHIMUZI[1]

[1]Laboratory of entomology and plant health, Department of Biology, National Natural Sciences Research Center, CRSN-Lwiro, D.S.Bukavu, Sud-Kivu Province, eastern of DRCongo.

[2]Department of Nutrition and Dietetics, Institute of Higher Education in Medical Tehniques, ISTM-Bukavu, Bukavu town, South-Kivu Province, eastern of DRCongo

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ABSTRACT

Understanding farmers' needs and local genetic resources are crucial steps to improve and conserve potato. Based on current farmers' interests and demands, a study was conducted to screen and select potato genotypes that are suitable to local environment in eastern DRCongo from some clones that were sent from CIP-Nairobi in June 2016. The investigations were conducted at the research station as well as in farmers' fields in collaboration with small-scale potato growers from nearby Lwiro research center during the cropping season A (long rain: September-January) and the cropping season B (Short rainy season: February-May) from 2017 to 2021. Each cropping season, the trials were carried out in different fields chosen within Lwiro Research Center following a rotation scale rate. Experimental materials comprised 10 clones from CIP: CIP 39337158, CIP 394611.112 , CIP 398190.404, CIP 398192.41 , CIP 398190.735, CIP 398208.505 , CIP 398202.704, CIP 694474.16 , CIP Shangi Mini tubercule ,CIP 392797.22. These advanced materials were said of being abiotic-biotic and climate-smart tolerant clones. In addition, two local varieties (Kinigi & Cruza) were associated to trials as control. The experiments were conducted following randomized plot designs (on-station), or following simple demonstration plot design with three clones only (on-farm participatory trials). Data collection consisted of recording information about yield and yield components, occurrence and population density of different pest species, incidence and severity of different potato diseases along the production cycle. Results indicated that there was a seasonal and yearly variation in the yield on the clones, during both on-farm and on-station trials. A cross-analysis of on-station and on-farm field data from the seasons and years of field evaluations showed a certain consistency ($P<0.05$) in the high yielding ability, tolerance to pests and diseases of three genotypes, namely CIP-Shangii, CIP 393371.58, CIP 392797.22 & CIP 398190.404. Although these 3 clones were found to perform better (better yield, lower susceptibility to pests and diseases) across field site environments, years and cropping seasons, the most promising clone was CIP Shangi Mini tubercule (29.6 t/ha, research station, 19.81 t/ha on-farm) that produced the greatest yield across years and seasons. The rest of clones showed high yield variability across seasons and years. There was a lack of clone stability across season and years. At the on-farm trials, still Shangii was the most preferred clone by farmers with the highest score for yield, resistance to diseases and tolerance to insect damages. Results indicate significant variations among the clones in the yield no much difference in the response to pest population density pressure. Results revealed significant ($P<0.05$) variability for disease incidence and severity.

Breeders should make sure they collect information from the end-users and incorporate them in conventional/ modern potato breeding programs in eastern and central Africa.

Keywords: Advanced CIP-potato clones, evaluation, adaptability, stability, environmental characteristics, climate smart-genotypes, Lwiro,Kivu, DRCongo.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.: Solanaceae) is considered as the fourth major crop of the world (Beumer et al.2021, Vilvert et al.2022) after rice, wheat and maize (Muhinyuza et al.2012). Potatoes feed more than a billion people worldwide from a global crop production close to 400 million metric tons(Quiroz et al.2018, Aswani & Kusmana 2020) . Potatoes are one of the most important sources of nutrition worldwide (Castelhano 2008, Muhinyuza et al. 2014, Wang et al.2019, van der Waals et al.2013), providing energy, essential vitamins and minerals, as well as important dietary phytochemicals (Deguchi et al. 2016, Koch et al.2020). Potato is a rich source of calcium, iron, potassium, fiber, vitamins, and minerals and its supplement to local diets will contribute to nutritional security (Onofre et al. 2021, Tierno & Ruiz de Galarreta 2016., Onditi et al.2021, Bachmann-Pfabe & Dehmer 2020). Potato is a successful crop in enabling smallholder farmers to achieve food security and tackle poverty with the most diverse distribution patterns globally and is predominantly cultivated in places where poverty, starvation, and malnutrition are all quite high (Subedi et al.2021, Devaux et al.2021)

Despite its importance, potato has not received the attention it deserves in the region (Sharma et al. 2020). Yet, potato plays a great role for the achievement of food security program due to its plasticity to environmental conditions and yielding capacity (Gebru et al. 2017). Potato can give more food, more nutrition and more cash per unit of land and time than would other crops do (Oumer et al.2014). Potato is a crop with a high potential to contribute to poverty reduction through income increase and improved food security. It is largely grown by smallholders, has a high production per hectare, stable prices and a steadily growing demand (Gildemacher 2012, Rukundo 2019b, Onofre et al.2021, Howlader O, Hoque 2018).

Potato production has no doubt increased over the years however, at an alarmingly high cost to human health, soil health and environment. Rising incidence of chronic disease has been associated with the western diet and lifestyle, and improving the health-benefitting potential of our food supply is one way to address this epidemic. Given the popularity and availability of potatoes and potato products, improving their nutritional profiles with the aim of chronic disease prevention has great potential to improve human health.

Potatoes are traditionally grown in highlands of eastern DRCongo. Maize, beans and potatoes are among the major food security crops in eastern DRCongo. Potatoes have been playing a major role in eastern DRCongo agriculture and food systems since independence.

However, potato growers in eastern DRCongo lack access to clean seed and new productive varieties. Not only, there is lack of access to climate-smart adapted varieties or varieties that are tolerant biotic-abiotic constraints (such as low soil fertility, soil erosion and pest-disease pressures), but also, farmers, have limited knowledge on crop husbandry, including seed-related practices while safeguarding the environment. Environmentally-friendly farming practices are largely lacking, yet needed by farmers.

Potato is grown by approximately 1.5 million farmers the Kivu Provinces (eastern DRCongo). Potato production represent 5-16 % of the agricultural economically active population in eastern DRCongo. Between 15,000 to 69,000 hectares of arable land is under potato cultivation in the Kivu provinces. The annual potato production in exceeds at times 100,000 t in that part of the country. In eastern DRCongo for example, the national average productivity is about 1.5-4.5 tons/ha, which is far below the productivity (10-40 tons/ha) of improved varieties achieved in research trials. The gap between research and farmers' field might result from poor practices (Harahagazwe et al.2018), climate change as well as poor seeds (Manishimwe et al. 2019, Almekinders et al.2019, Condori et al.2019).

In eastern DRCongo, currently, the tuber yield is very low with an average of 1.5 to 2.9 t/ha across several villages. Due to the challenges explained above, seed prices are too high at planting, whereas the prices of ware potatoes seem to have low variations in price these years. Even though there is a potential to grow potatoes throughout the year, farmers cannot get higher yields due to lack of resilient or climate-smart potato varieties.

Also, the poor productivity and production of potato across may be a consequence of many factors including weak formal and informal seed system supplying the limited quantity of healthy genetically pure seed, cultivation of varieties that are prone to biotic and abiotic stresses, poor knowledge of management practices, and biophysical properties. Farmer seed systems across are recognized as pivotal to food security, nutrition, crop genetic diversity, and resilience in the face of climate change (Arce et al.2018). Their dynamics involves activities and institutions along a seed supply cycle consisting of production, management, selection, storage and distribution (Arce et al.2018). Formal seed system is at infant stages and early generation of clean seed is mostly produced by research institutions (Tessema et al.2018) in eastern DRCongo. Supply of seed with doubtful genetic integrity or unfamiliar varieties seems may discourage potato cultivation the most (Sharma et al. 2020, Ogola et al.2012). Producer price is the major determinant of the potato seed demand even if it is acquired under unregulated informal seed marketing and distribution system (the informal seed system do not enable farmers to access to certified seed in the right quantities).

Knowledge regarding genetic diversity of breeding materials is essential for crop improvement (Pandey et al.2021). It helps to allow the successful use of genotypes for breeding purposes (Pandey et al.2021). The foundation of potato breeding and the development of new potato varieties is the crossing of parents to produce seeds that contain new combinations of alleles that may be superior to those in either parent (Bethke & Jansky 2021).

There are many factors that reduce the yield (Awasthi & Verma 2017) of the crop among which the diseases (Van der Waals & Krüger 2020) and insect pests. Insect pests are a major cause of crop yield losses around the world and pest management plays a critical role in providing food security and farming income (Zhang et al. 2018). With the increasing demand from a growing world population, optimised pest and disease management are of increasing importance for the sustainability of potato crop (Gartner et al.2021). Potato production is constrained by a number of factors among which diseases, storage problems, low market prices of tubers at harvest, and lack of seed tubers or insufficient quality seed tubers for planting, storage problems (Gebru et al. 2017, Ghebreslassi et al.2014).

Potato suffers from more than 10 diseases and more than 10 pests. Diseases and pests are the most limiting factor in productivity in rural area, likely causing a threat to food security for potato cultivator dependent (Demissie 2019) .Currently, most of the varieties cultivated by farmers are mainly local land races and some few exotic or improved varieties (previously released by researchers) that completely lack satisfactory resistance to pests and diseases. Thus, the need to introduce new advanced materials. Stable and durable resistance materials could be obtained by properly evaluating available germplasm (Altamirano 2011, Subía 2013) to identify sources of resistance genes (Dupuis et al.2019) within the sub-geographical region where the crop is produced in substantial quantity.

In Ethiopia, for example, researches have made estimates of losses attributable to late blight ranging from 6.5 to 61.7%, depending on level of susceptibility of the varieties (Abewoy 2018). In same country, potato tuber moth is the most important constraints of potato production where it can cause up to 42% yield loss in storage (Abewoy 2018). The late blight (*Phytophthora infestans*), remains the most devastating disease of potato (Solanum tuberosum L.) with about 15%–30% annual yield loss in sub-Saharan Africa (Ghislain et al.2019), affecting mainly smallholder farmers. Late blight, caused by *Phytophthora infestans*, is a major disease limiting potato yield and productivity and accounts for up to 70% of the yield losses and sometimes-even results in a total crop destruction in Uganda (Namugga 2017).

Potato Cyst nematodes (Heteroderidae; *Globodera rostochiens*) are quarantine-restricted pests causing significant yield losses to potato growers. Theses nematodes are is causing a loss of approximately US $125 billion annually worldwide, as major root parasitic nematodes (Elkobrosy et al.2022).

Pest infestation and severity may be linked to the landscape, agronomic, biophysical, and socio-economic context in which agricultural production takes place(Zhang et al. 2018). Key challenges of potato industry include, high pressure of pests and diseases (Meno et al.2021,(Otieno 2019, Mohsan et al.2016), insufficient extension services, continuous decrease of soil fertility, and poor use of fertilisers , inappropriate farming practices, limited access to high number of improved and adapted varieties and limited use of quality seeds.

Currently, most potato growers do not have access to high financial support to buy agricultural inputs (pesticides, fertilizers), yet pests and diseases are serious constraints (Mumia et al. 2018). Farmers need varieties that can offer an optimal yield, that are pest-disease tolerant and with good taste and marketable attributes. Farmers are interested in varieties can grow and harvest good yield with limited or no reliance on chemical pesticides and fertilizers that are very costly. The implication of this situation is that there is nothing farmers can do to overcome these abiotic-biotic stresses except using resilient-adapted germplasm materials (i.e. disease-pest tolerant, low soil fertility tolerant or early maturing genotypes). With pest and disease, farmers may lose all the crop especially when they grow local varieties (or previously released genotypes undergoing degeneration process) which are currently extremely susceptible to some pests and diseases.

As previously mentioned, potato is a key livelihood and a profitable value chain crop in the Kivu provinces of eastern DRCongo. However, abiotic and biotic factors generally lower the yield of the crop. Despite the importance of this crop, yield at farmers' level are reported to low and tends to decline due to limitations imposed by biotic and abiotic factors. Reasons for the low productivity of potato fields at the farm level are sub-optimal conditions such as poor crop husbandry, soil nutrient deficiency, planting local varieties of with non-optimal cultivation techniques and the quality of varieties used. So far, the varieties commonly used by farmers are varieties that have been planted for generations with a limited amount. However, high-quality seeds can produce plants that are healthy and grow uniformly.

It has been reported that there are several superior varieties from CIP (International Potato Center) that have high yield potential and are tolerant to biotic stresses under local conditions. With the use of superior varieties and advanced clones, optimal cultivation techniques, and good pest and disease control, potato productivity can reach 20-70 t/ha.

Twenty years ago, many superior varieties (clones) were released by CIP in eastern DRCongo. In general, these clones were early maturing, tolerant to soil erosion to infertile soils/climatic stresses, resistant to several types of pests and diseases, with a yield potential of above 35t/ha (at the farm-level). These varieties were also floor-tolerant, suitable for cultivation on low fertility soil and able to yield in medium (1000-1500m) to high altitude (1600-3500m) in eastern DRCongo. Most of them have currently degenerated. Farmers need new materials. Availing newly improved potato varieties may enable farmers getting additional income from the sale of excess potato and being able to better meet other necessary costs like school fees, for their children (Chindi et al. 2017).

-Quality seed is one of the major bottlenecks hampering the production and productivity of potato not only in Sub-Saharan Africa (Chindi et al. 2017). Seed quality is the most important factor in ensuring the harvest. The use of quality seeds alone may enhance crop productivity by 15-25%. Seed quality account for 40–50% of the cost of potato production, thus improving seed potato quality and availability would be one way of improving potato productivity and profitability among communities where this crop is a mainstay (Chindi et al. 2017, Besufkad et al.2019).

Additionally, potato seed quality is an important determinant of the final yield and quality. Low quality seed is believed to be one of the major yield reducing factors in potato production. Limited supply of high quality seed tubers and high costs are major constraints to potato production in Africa (Chindi et al. 2017).

-Drivers underlying seed renewal include crop failure, seed degeneration and varietal change(Arce et al.2018, (Thomas-Sharma et al.2017) . Although seed production, initial selection, storage and distribution up till the farm gate are generally farmer-managed, the informal seed system involves other actors and institutions as well. Different types of brokers, markets, networks and exchange mechanisms partake in seed trade. These, in turn, are a response to different socioeconomic and regulatory environments (Arce et al.2018). Pathogen build-up in vegetative planting material, termed seed degeneration, is a major problem in many low-income countries(Thomas-Sharma et al.2017) . When smallholder farmers use seed produced on-farm or acquired outside certified programs, it is often infected (Thomas-Sharma et al.2017) .

Adoption of seeds of improved varieties is an important strategy to adapt to the negative implication associated with climate change and variability (Pradel et al.2019,Condori et al.2019). Changing global weather patterns require varieties that are able to grow within the short rainfall cycles and yield optimally under the prevailing conditions (Namugga et al.2018, Handayani et al.2019, Escuredo et al.2018, Yuen 2021) To counter these climatic effects, farmers are forced to embrace some adaptation practices to increase their resilience against climate change and variability. Some farmers either abandon some varieties or increase input use in terms of chemicals sprayed, which are quite costly for the smallholder farmer. The effect of climate factors on seed system functioning is always suspected to diminish levels in quantity and quality of yield. Dispersal and distributional changes in crop pests (including vectored pathogens) poses a threat to both native and agricultural systems. Although much disease spread is human-mediated, latitudinal shifts in pest and pathogen distributions have been documented for a wide variety of groups of insect and pests., suggesting that climate change coupled with other environmental factors may have a significant impact on pest and pathogen distribution(Syfert et al.2017). It has been revealed that patterns may be of importance for the pre-diction of outbreaks and control of disease in the future (Syfert et al.2017).

Also decline in yield is suspected to affect farmer seed saving, seed availability and affordability and it increases food prices due to high demand (Kansiime & Mastenbroek 2016). Therefore seed systems are important in building and enhancing resilience from climate-induced stresses because seed security has direct links to food security and resilient livelihoods in general (Kansiime & Mastenbroek 2016).

In eastern DRCongo, many farmers use low quality seed, recycled over many generations, and leading to low yields. The common practice is use of potatoes from the previous harvest as seed potatoes, which incurs in an accumulation of seed borne diseases or degeneration of the seed potatoes, resulting in lower yields and quality. Thus, replacing the seed each season with high quality seed from specialized seed growers is preferable(Chindi et al. 2017)., it minimizes disease pressure and maximizes production potential. Nevertheless seed potato supply has not been taken up by seed companies and is overlooked in the formal seed system in the country. Due to the absence of a formal and responsible body for the production of quality seed-tuber, research centers have been using various approaches to enhance farmers' access to improved potato varieties in the past several years.

Consequently, the informal seed system still reigns in much of the country. Quality control and certification is very weak to absent because farmers are not willing to pay high(er) prices for quality seed potatoes because they cannot be sure that they are getting a genuine product(Chindi et al. 2017). Therefore, participatory seed production approach is an alternative for accessing quality seed and easy dissemination of potato information in collaboration with various stakeholders(Chindi et al. 2017). Popularization or up scaling of evidence-based best practices and improved technologies (new clones) is essential to improve livelihoods of smallholder potato producers in eastern DRCongo. Enabling farmers to access to high quality varieties is very essential.

Seed potato degeneration, the reduction in yield or quality caused by an accumulation of pathogens and pests in planting material due to successive cycles of vegetative propagation, has been a long-standing production challenge for potato growers around the world (Thomas-Sharma et al.2016).

The problem of potato seed degeneration has been solved in the developed countries through specialized seed potato producers (hereafter called seed growers) who multiply seed potatoes from basic pathogen free starter seed (Gildemacher et al. 2009). Consumption potato producers (hereafter called ware growers) maintain maximum production potential over the seasons by replacing their seed potato stock each cropping season, or at least frequently, with high quality seed potatoes from a seed grower (Gildemacher et al. 2009). However, in Africa, such system does not exist. Farmers rely on researchers or caritative agencies to access to newly developed varieties. Other farmers purchase seed from local market or from their neighbors.

The identification of environmentally stable, multiple resistance and quality traits genotypes and predictable resistance (Lindqvist-Kreuze et al.2021) to diseases is challenge to breeders , especially given the rapid evolution of the pathogen in different environments.

There is a need to find out superior candidate varieties that meet consumer standards and preferences, so new superior genotypes are needed following demand. The potato genotypes should have stable and high yields in different local environments and being likely used by in future potato breeding programs (Haesaert et al.2015, Fort et al.2020, Krüger et al.2020).. Currently, selection of stable and high-yielding genotypes and accordance with consumer and industry preferences is one of the focuses of potato research and development program. Attributes such as high tuber yield, consumer acceptability, palatability, profitability, desirability and sustainability in various environment settings, are often considered while developing and releasing new varieties (Besufkad et al.2019., Kakuhenzire et al. 2004). Most often, cultivar preferences are mostly dictated by availability of markets, yield potential and taste (Muthoni et al.2013, Kumar et al.2015) in rural areas of Sub-Sahara Africa.

Climate smart (Ogola & Ouko 2021) and pests and disease tolerant potato varieties can help relatively poorer farmers to harvest two times a year and overcome food shortages in the months of food scarcity (Oumer et al.2014). Potato can generate cash from the sale of potatoes, therefore reduce vulnerability to food insecurity and other livelihood shocks (Oumer et al.2014).

There is a need to attempt to develop new potato varieties resistant or tolerant to current potato production constraints with market led traits, that can replace the existing having more than 20 years old (Rukundo 2019b). There is need to introduce new materials to the satisfaction of farmers. Since CIP breeding program has new materials that are said to be robust, there is need to evaluate these so said superior clones in order to determine which of them are suitable, stable and locally adopted under local environmental conditions of major growing areas of eastern DRCongo.

Considering that multilocation test of potato clones in the framework of releasing superior varieties has never been carried out in the region , the potential yields of CIP clones have not yet been identified (assessed), so a study of adaptation of superior varieties (new CIP clones) was needed to be developed in Kivu Provinces. It is necessary to obtain adaptive superior varieties that have the potential to be developed and disseminated under local conditions in different agroecological zones of the Kivu provinces.

Finding out new genetic materials can help to overcome abiotic and biotic production constraints, as well covering nutritional requirements of consumers & market and post-harvest desires. Climate-smart agriculture is an important strategy for supporting farmers against climate change challenges (Andati et al.2022). Such climate-smart genotypes need to be developed and tested in local potato farm environments. Breeders have the challenge of finding out varieties that are high yielding, early maturing, marketable, resistant to pest/ diseases and tolerant to declining soil fertility and to climatic variability hazards to the satisfaction of famers.

In Eastern of DRCongo, food security has become a crucial issue since the region is also characterized by climate change, reduction of arable land, increasing population, and frequent occurrence of natural disasters. Farmers can no longer afford growing varieties requiring high chemical inputs

It is important to identify pure clones wit high freedom from pests and diseases, and with high physiological maturity and viability. Researchers found very relevant to select the best performing clones for eventual future release at the farm level in a farmer participatory process. New good materials will be added in the gene bank of the on-going building provincial genetic resources center. The aim of developing a local genetic resource center is serve as foundation for the development of a referential plant material and enable molecular data analysis (barcoding, taxonomic studies) while conserving ancient genetic materials.

It is necessary to find out user-preferred clones with good market traits and high acceptability qualities by farmers, and with high potential for future scale-up, release and broad dissemination as new varieties with high yield performance under varying level of environmental stress in eastern DRCongo. An attempt to respond to these above mentioned environments and climate-related challenges faced by small-scale potato growers in eastern DRCongo is needed.

Reading from the farmers perspective, it appears important to identify clones with higher level and insect-disease resistance in order to develop multiple strategies to control these pests and disease under local conditions. It is important to identify biotic and abiotic tolerant and adapted potato clones so that farmers can plant potatoes and get better yield at least twice a year. It was judged important by researchers to obtain genetic materials that can be released to farmers to help resolving some of the constraints farmers face.

Therefore, this research aimed at developing more adapted and resilient potato varieties that can grow in both long and short rainy seasons and give higher yields with zero expenditure for pesticides and fertilizers by less-resource endowed farmers.

In this end, this initiative aims at improving livelihoods of smallholder potato growers through better food security and increased income by availing to them appropriate potato genetic material. This paper reports a field screening of potato genotypes for resistance to pests and diseases and for yield adaptability in and around Lwiro area environments.

General objective

To screen and select clones that are adapted, stable and suitable to local environment , as well as to explore and increase access of high quality and clean planting material (new clean seeds) from clones that were sent from CIP-Nairobi in 2016

Specific objectives

(i)To identify and select best clones based on agronomic growth characters, flowering abilities, precocity, yield component under local soil and phytosanitary conditions

(ii)To assess the yield performance of 10 clones under local environmental and climatic field conditions of Lwiro Research Center and its surroundings

(iii)To select high quality clones with high levels of tuber yield, of resistance to disease and low level of susceptibility pest infestations under farmers' conditions.

2.MATERIAL & METHODS

2.1. Study area

The experiments were conducted at the Natural Sciences Research Center (CRSN-Lwiro) (Figure-1 & Figure-2) during the short and long rainy seasons of years of 2017 to 2021. The experimental fields of CRSN-Lwiro (02^{o}23' 941'' S, 028^{o} 81'159'' E, 1704m absl) are located on the sides of the buildings. So, trials were conducted in an agro-ecology that could be qualified of mid-elevation with an average altitude. The investigations were conducted at the research stations as well as in farmers' fields with collaboration of small-scale potato growers from nearby Lwiro research center. One the aims of this experiment was to evaluate the performance of potato clones in respect to growth, yield and quality attributes (Getie et al. 2018).The current study was conducted at Lwiro research center. The site is located in Kabare territory, South-Kivu province . The soil is derived from weathered volcanic rocks dominated by silt, clay-loam and sand. The rainfall regime is bimodal September-December, February-May)n with one long dry season (June-August) and 70–80% relative humidity. The South-Kivu province has a mean annual rainfall of 1900 mm and monthly air temperature ranging from 19 to 32 °C, while soil temperature at 10 cm depths decreases from 24 to 14 °C with increasing elevation from 1200 to 2400 m above sea level, respectively.

2.2. Plant materials

Experimental material comprised 10 CIP advanced (Figure-3) abiotic-biotic stress tolerant clones (CIP 39337158, CIP 394611.112 , CIP 398190.404, CIP 398192.41 , CIP 398190.735, CIP 398208.505 , CIP 398202.704, CIP 694474.16 , CIP Shangi Mini tubercule ,CIP 392797.22) , two local varieties (Kinigi & Cruza). These ten clones of potato were investigated for their growth parameters and yield to determine their suitability (Hickey et al.2019) for production in Lwiro environment and its surroundings. The advanced clones were proposed by the CIP Potato Breeding Unit in SSA for their potential in tolerating both pests, diseases (late blight, bacterial wilt) and low-soil fertility tolerance in highland environment. These climate-resilient potato clones were said to be characterized by environmentally adaptable attributes. It was necessary to identify their behaviour under local environments. In fact, The International Potato Center (CIP) has developed a population of improved potato clones with high levels of resistance to this disease, high yields of tubers and other agronomic characteristics and high potential for release as varieties.Theses clones were said to be valuable potato genotypes with high combining ability for high tuber yield and high level of pest and disease resistance (Muthoni et al. 2014., Asakaviciute et al.2017). These clones are said to be heterogeneous and may form excellent source of genetic variation for breeding. They may harbour useful genes such as genes for early maturity, yield potential, disease and pest resistance and other desired traits for producers (Alam et al.2020, Namugga et al.2018, Ong'ayo et al. 2020).

The use of suitable potato cultivars and certified seeds is pivotal from an IPM point of view, as it reduces the need for agrochemicals and the incidence of diseases, therefore increasing the profitability of the crop. Also, inputs-intensive, as opposed to knowledge-intensive agriculture, is environmentally degrading and not always affordable. The reuse of late-generation seeds from one year to the next one as a result of money shortages by poverty-stricken smallholding farmers increases the occurrence of diseases and emerging new pests(Fernández 2018). Certified mini-tubers, namely pathogen-free potato seeds that have been cultivated in sterilised medium, are currently being proposed to farmers as an alternative solution. Mini-tubers allow for the multiplication of seed for several generations before tuber-borne diseases reach dangerous levels that compromise food and economic security (Fernández 2018). The use of mini-tubers may improve the overall sustainability of smallholding agriculture. The incidence of pests and diseases in small-scale farming, can be overcome by introducing mini-tubers in their system, hence the importance of evaluating these clones from CIP Nairobi

Local check-1: Kinigi. This local variety (originated from highland of Rwanda), grown by 15-20% of potato farmers, is tolerant to bacterial wilt (Rukundo et al. 2019a) and resistant to late blight diseases (Muhinyuza et al.2012). The variety is also resistant to major potato pest attacks and is yield 15-25t/ha under minimum levels of fertilization of soils found at medium to high altitude(1450-2200Km).The variety is well known and cultivated by farmers in North and South-Kivu Provinces.

Local check-1: Cruza. The variety (average yield:10-35t/ha), grown by 5-7% of potato farmers, was introduced as a clone in eastern DRCongo. Cruza (a former clone from CIP) is a popular variety that was evaluated and released by researchers in previous years. The variety was released by researchers to farmers 15-20 years ago in Kivu Province. The variety is tolerant to key pests and resistant to major potato diseases (bacterial wilt, and late blight) much as the variety is sensitive to diseases at medium altitude(1200-1500m) under low fertile soils.

2.3. Experimental designs

2.3.1. On-station experimental design

Across cropping seasons and experimental field plots, the experiments were executed using a randomized complete block design (RCBD) with 10 treatments (10 CIP clones) and 3 blocs (replications). The plots were not fertilized and received no pesticide treatments. The initial level of the fertility of experimental plots is shown in Table-1. Pests and diseases were not controlled but were monitored as they appeared alongside the growing cycle of the crops. Yield performances of these clones were purposely assessed in plots that were located in low soil fertile areas and that were known to be under natural pressure of pests and diseases at Lwiro research center during the cropping season A (September-January) and the cropping season B (February-May) of each year (from 2017 to 2021). Tubers were planted at 75 cm in-between rows and 25 cm between plants within rows, meaning a plant density of 5.3 plants m^2. The plots were isolated far away from cultivation of other Solanceae crops. The crop rotation on a single plot was observed between cropping seasons and years. Most of the time, the plot for the new cropping season was changed and located far away from the first one. The former plot could be used after leaving it resting for at least 2 seasons or by growing legume crops on it during two cropping seasons before re-establishing a new potato plantation on that field.

2.3.2. On-farm experimental design: Participatory variety selection approach

Beyond research stations (where randomized plot designs were adopted), some experiments were set on-farm in collaboration with some interested farmers from nearby the research Center of Lwiro. The experimental design adopted in collaboration (participation) with, some volunteer farmers, were involved. The experimental design farm was simple demonstration plot with 3 treatments (3 clones) and 2 blocs (replicates). During the short and rainy seasons, evaluation trials were conducted in some villages (Lwiro, Kavumu, Tshibati). Based on previous field experiences, farmers do not deal with several varieties. They frequently handle 1-3 varieties at a time. Three genotypes were therefore given for evaluation by farmers in each village. Each farmer received 5Kg of seed (tubers) to be planted following a simplified protocol.

Participatory rural appraisal (van Vugt 2018) is a family of approaches and methods to enable local people to share, enhance, and analyse their knowledge of life and conditions, to plan and to act”. It entails involving local people in the gathering of information so that the actual farmer conditions are understood and a dialogue between the scientists and farmers is established. Participatory research integrates different stakeholder perspectives during the research process. In the case of selecting new potato varieties, researchers actively solicit input from farmer and consumer groups differentiated by gender to ensure that the varieties selected will meet the demands of local stakeholders by including traits (Alam et al.2020) that local farmers prioritise but researchers might overlook .

These days, the selection of cultivars based on the criteria, farmers’ practices, known as participatory variety selection, has been gaining marked interest in agricultural research field (Salomón-Díaz et al. 2020). Participatory variety selection is an approach which provides a wide choice of varieties to farmers to evaluate in a given varieties for their own environment to increase production(AbaDura et al.2021). It enhances farmers’ access to diverse crop varieties, increases production and ensures food security and helps faster dissemination and adoption of released varieties. It allows varietal selection in targeted areas at cost-effective and timely manner and helps promotion of community seed production and seed banks(AbaDura et al.2021, Kolech et al. 2015,Oumer et al.2014, Jafar et al.2020).Participatory variety selection (Kolech et al.2019) is an effective tool in facilitating the adoption, extension and selection of the improved technologies to solve the potato grower problems in short period of time (Amdie et al.2021).Furthermore, participatory variety selection (Semman & Mulualem 2020) is more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists (Amdie et al.2021, Chindi et al. 2017). Participatory variety selection approach (Kipkorir 2014, Worku 2017, Dembi et al. 2020) is important for selecting varieties adapted to different agroecologies and growing seasons. Taking farmer interests into account is important for a highly heterozygous, clonally-propagated crop like potato to be accepted by farmers (Kolech et al.2017). Both farmers and breeders participated in the management of the field trials. Planting was done by hand hoe, in ridges, following current farmers practice. Land preparation and seed sorting out was done by the farmers. Each plot measured 3m x 4m. The plantation of tubers was done by participating farmers.

Participating farmers were selected in the vicinity of Lwiro Research Center such as it was easy to reach and monitor the evolution of plot although under management of farmer. As for on-station trials, collaborating farmers were requested to plant the potato tubers in suitable land but not to fertilize or control the pest and diseases so that it was important to observe the sensitivity of the clones to local pathogens and entomofauna pest gut. Only farmers who were willing to be involved were selected. Farmers were encouraged to allocate their plots necessary for the trials and conduct the production management: planting, fertilization, weeding, and cultivation (Degebasa 2019),….. Both farmers and researchers followed up the trials and researchers made periodic observations.

2.4. Data observation-monitoring and collection

Field observations and data collection started at two weeks post-planting. Weeding and earthing of the plants started at one month-post planting. Data collection consisted of recording information about yield components, occurrence and population density of different pest species, incidence and severity of different potato diseases along the production cycle

2.4.1. Physiological and growth parameters:

Several relevant parameters were collected during field visits even if they are not presented in the result section for shortage of the results. Data collection protocol included, plantation dates, emergence rates, germination duration (nbr of days to germination), flowering attributes, age and height at the initiation and ends of flowering seasons, color of flowers couleur, foliage abundance, erectness of the plant, general appearance of the plant, colour of the tubes, age at harvesting day,…

2.4.2. Yield components and total yield

Some data on yield components (plant heigh, foliar surface, base growth diameter, number of branches per plant per clone ,…) was collected. Data were collected on days to flowering, days to maturity, plant height, average tuber number per hill, marketable and unmarketable tuber numbers, total tuber number per plot, marketable tuber yield, unmarketable tuber yield, total tuber yield, tuber dry matter yield., but only data on marketable yield will be presented in the result section. In addition, each clone was grouped in to three based on their tuber sizes (smaller sizes, medium sizes, and larger sizes) according to previous workers (Simon et al.2014).

The day of harvest, the number and weight of small, medium and big tubers were counted per plant and per plot. The tuber yield (number per category and weight) and total yield at harvest were assessed, and the overall total weight of all the tubers in a plot were expressed in tones/ha. Average tuber weight was calculated as the total tuber weight per plant divided by the total tuber number of tubers per plant. The classification of tubes enabled appreciating each clone in terms of production of seeds and in terms of production of marketable tubers.

The yield of each clone was estimated in tones/ha from the aggregation of individual plots yield. For experiments conducted with farmers, market value of tubers were performed in addition to the appreciation of susceptibility to pests and diseases during storage and in the field and other postharvest issues were considered.

2.4.3. Assessing the occurrence of biotic (insects and pathogens) stresses

Clones were evaluated under natural pest-disease infestations and natural level of fertility of soil (the trials were not fertilized). Inspection for phytosanitary observations and parameters measurements, consisted of identifying and recording insects (pests, predators) and disease (bacterial, fungal, viral). The identification of diseases in the field was conducted using photographic guides. For diseases, field guides were used to record and report disease occurrence and severity (plant part attacked, number of plants affected by the disease,….). All data and observations on pests and diseases were conducted randomly along the diagonals of each plot.

Therefore, clones were assessed against several pests and diseases of potato known to cause severe yield loss. The pests and diseases concerned included insects (tuber moth, leaf miners and aphids,.), root knot nematodes, viruses (PLRV and PVY), fungal wilts (Fusarium), early and late blight) and bacterial diseases (van der Waals et al. 2016).

Observations on incidence and severity of pests and pathogens were made between across the growth period (from two-weeks post plantation through flowering to harvest period).

Incidence and severity of disease and pest damage were evaluated on 10 plants selected randomly in the plot each day of visit. Overall, there was some kind of built up of pests and pathogens few days before flowering, during flowering period and onward.

2.4.4. Assessing disease incidence and severity on the 10 clones and local checks

Across seasons and years, different common diseases were monitored from 2 weeks post plantation till harvest in each plot of the experimental field. For each disease type, data collection was limited on incidence and severity recording since the aim of the study was just to observe sensitivity of the clones to local phytopathogens.

Diseases were field identified using symptoms described in various guides published by CIP and other researchers. To confirm the identity of certain causal agents (especially fungi), root/leaf samples were collected and sent to researchers with advanced facilities for disease diagnosis in Uganda (National Agricultural Research organization, NARO) and Rwanda (Rwanda Agricultural board), where the samples were placed in moist chambers to stimulate sporulation and facilitate diagnosis and identification based on standard taxonomic keys of phytopathogens.

Thereafter, the **incidence** was assessed and expressed as the percentage (%) of plants (leaves, stem, tuber) showing symptoms or with presence of a particular disease. This means that the *incidence* was measured as the percentage of all sampled plants affected with a particular disease in relation to the total number of plants sampled of the same genotype in the same plot (3 x 4m). The **severity was** expressed as foliage area /tuber damaged by a particular pathogen over total leaf area on plants. The disease severity was assessed following the scale of **1-5**: where **1**= **Absent**= **0%** damages on leaf area/tuber, 2= **Low severity**=**1-20%** damage on leaf area/tuber, **3= Intermediate severity = 21-50%** damage on leaf area/tuber, 4=**High severity=51-75%** damage on leaf area/tuber., 5**=Very high severity=76-100%** damage on leaf area/tuber.

For **potato bacterial wilt (PBW)** disease assessment in the field, the visual symptoms of PBW (wilting symptoms) and streaming of milky white masses of bacterial cells (ooze) were used to confirm the presence of PBW. The bacterial wilt was assessed on 10 plants randomly selected on 2 main diagonals (meeting in the middle of the 3m x4 m plot). The average percent of wilted leaves for each field gave the percent severity of PBW for the plot field as recommended (Uwamahoro et al. 2018).

For virus's diagnosis on tubers, one tuber from each selected plant was chosen at random among all tubers harvested as recommended (Pérez Barrera et al.2015). The sample was sent to specialists (in Uganda, Rwanda) for identification and conformation of the type of virus. Leaves of the apical part of each suspected plant were collected and sent for virus identification by specialist using DAS-ELISA diagnosis of potato virus, using CIP's operational procedure at Rwanda Agricultural Board. Evaluations of viral infection were made at the end of cropping season.

To evaluate tuber for disease, tubers were harvested individually from plants per plot. The tubers were washed with running water and dried with paper towels, after which they were evaluated for incidence and severity of specific potato diseases damages. Rotten tubers were counted per plot (3mx 4m).

2.4.5. Identifying & assessing activities and population density of arthropod pests and predators

Insect pests were randomly hand collected (with hand-netted) along plot diagonals. Insect pests were recorded for 20 min per field-plots by inspecting plant parts (leaves, stems, roots) morning, mid-day and evening time. The type and amount of damages caused by each insect species were recorded in the field. Field guides were used to identify the species before recording the number of individuals per pest species. For unknown insect pests and nematodes, specimens were saved in alcohol (70%) for further and later taken and brought in the laboratory for further identification confirmation. To confirm pest identification, different insect life stages (egg, larvae, pupae, or adult) were monitored on the plants/ tubers, soil or debris, and then were related to damage caused on leaves/tubers according to reports in specialized potato field guides established by CIP and collaborators. The identification was processed at the entomology laboratory of the Lwiro Research Center.

In details, pest population density was assessed as follow:

(i)root nematodes: The number of nematodes galls counted on roots from 10 plants/plot (3m x4m) selected randomly at harvest., *(ii)cutworms:* the number of cutworm larvae found in the soil nearby stem cuts from the first to the third week post plantation per plot (3m x 4m)., (iii) *white grubs* : the number of individual white grub larvae counted during per plot (3m x 4m) at

harvest of the potato., (iv) l*eafminer* : the number of individual larvae/pupae counted on the leaves on 10 potato plant selected randomly per plot (3mx 4m) between the third and the 10th week post plantation., (v) a*phids*: the number of individual aphids (immatures stages, adults, mummies) counted on stem/leaves on 10 plants (Khan et al.2019) per plot (3m x 4m).,(vi) w*hiteflies*: number of individual adult (and nymph) counted or and visually seen flying on 10 plants per plot (3m/4m)., (vii) p*otato tuber moth (PTM)*: the number of PTM larvae or mines recorded/counted on affected tubers at harvest + the number of adult seen on infested leaves per 10 plants per plot (3mx 4m). For potato tuber moth, holes and larvae were monitored on the tubers, and then were related to damage caused on tubers according to reports in specialized potato guides. Thus, their incidences were measured as the percentage of all tubers affected with a particular disease or pest damage in relation to total tubers of the same genotype., (iix) t*hrips*: the number of individual adult thrips counted on leaves of 10 plants selected randomly in the plot (3m x 4m).,(ix) p*otato leafhoppers*: the number of individual adults counted on leaves of 10 randomly selected plants per plot (3mx 4m).,(x) l*eaf beetles*: the number of individual adult beetles counted on leaves of 10 plants per plot (3m x 4m).,(xi) m*ites:* the number of individual adults seen on leaves of 10 plants per plot (3m x 4m).,(xii) g*rillon*: the number of individual adult seen and counted on leaves of 10 plants per plot (3m/4m).,(xiii) c*riquet*: the number of individual adults counted on leaves of 10 plants per plot (3m x 4m).,(xiv) *ladybeetles (natural predators)*: the number of individual adults seen and counted on leaves of 10 plants per plot (3mx 4m) between the third and the 11the week post plantation. Ladybeetles were not considered as pests but as natural enemies(predators).

2.4.6. Assessment of yield performance and biotic stress sensitivity of clones over local checks:

During the vegetation stage, resistance (tolerance) to pests and disease (late blight, bacterial wilt,…) parameters were assessed (scored). However, only yield and sensitivity to pests and diseases data will be shown in the result section.

2.5. Data analyses

Field collected data was compiled in the computer using Excel 2019. After, compilation, data was sorted out, cleaned, corrected and well checked before conducting the analysis. The normality status of the raw data was checked using the Kolmgorow-Sminirinow test. When necessary, and for not normally distributed data, natural log (Lnx+1) transformation was applied to stabilize the variances. Data for the different traits were subjected to the standard analysis of variance. ANOVA was applied to compare yield, yield component, phytosanitary parameters (pest population density, disease incidence and severity) of the different clones across the different plots of the designs conducted both on-station and on-farm fields. Means were separated the level of $P<0.05$ according to Tukey Test. The version 20 of the Minitab English software was used for the statistical analyses of the data

3.RESULTS

3.1. On-station and on farm potato yield

3.1.1. On-station experiment yield

-Across years and seasons, there was significant ($P<0.05$) variability (oscillation) in yield. The highest yield was registered with CIP Shangi Minitubercule clone followed by CIP393371.58

and CIP392797.22. The lowest average yield was associated with CIP 3988190.735 and CIP 694474.16.

Cropping season B (February-May) of year 2018 was associated with the highest yield (20.33 t/ha), whereas the lowest yield (9.12 t/ha) was recorded during the cropping season B (February-May) of year 2017. Interestingly, these different yields were recorded with the clones being planted with no application of fertilizers and pesticides (Table-2).

3.1.2. On-farm experiment yield

During year 2017, the highest yield (4.63 t/ha) recorded during year 2017 was associated with the clone CIP Shangi Minitubercule while the lowest yield (1.89 t/ha) was associated with CIP 398190.735., across study sites and cropping seasons. The highest yield (4.21 t/ha) was recorded at Katana on-farm study site during the cropping season A (September-December) of year 2017 ; whereas the lowest yield (2.34 t/ha) was recorded during the cropping season A (September-December).

During year 2018, the highest yield (4.07 t/ha) was recorded during the cropping season B (February-May) at Tshibati study site and the lowest during the cropping season A (September-December).

During year 2019, the highest yield (7.88 t/ha) was recorded during the cropping season A (September-December) and they lowest yield (2.98 t/ha) recorded during the cropping season B (February-May).

Year to year, there was a tendency of increase of yield for on-farm study experiments. When started participatory experiments in year 2017, the yields were very low. During year 2019, almost yield doubled. Similar yield oscillation trends were observed in 2020 and 2021 (Table-3).

On-farm yields were very low because farmers were requested for not fertilizing their gardens or apply pesticide. The aim was to observe the performance of clones in different environment when there are no pest-disease control methods applied and when the crops are not fertilized. However, it was expected that yield performance of different clones would be very higher if fertilizations and pest-disease control methods were applied (Table-3).

3.2. Occurrence of the population density of pests:

The list of key pests and diseases that occurred on the 10 clones at Lwiro are presented in Table-4 . Across seasons, years and clones, high variability in the pest population density was observed. The population density was very low (minor). High population densities (high pest infestations) tended to be associated with some clones (CIP 398192.41., CIP 392797.22., CIP 398190.735., CIP 398208.505). Very low population densities were associated with few clones (CIP Shangi , CIP398202.704, CIP 39337158). Overall, thrips and whiteflies occurred with high population densities as compared to other pests. Clones that were not under high pressure of pests were the clones that attracted high population densities of natural enemies (ladybeetles), indicating that ladybeetles were controlling some pests in the field (Table-5).

There was minor oscillation in the population density of some pests. The population density was not very high, among clones, for leafhoppers**,** leaf beetles, potato tuber, cutworms, nematodes, leafminer, mites, grillon, criquets (Table-5). However, relative high variability (oscillation) in the population density was observed of thrips, whiteflies, aphids, millipedes, red & black ants on the different clones as compared to local check varieties (Table-5).

The clones showed excellent response in reducing pest infestation since the population density of pests on these clones was relatively low. Also, the clones showed differential disease intensity or disease resistant categories across seasons and years. The disease resistant categories of potato varieties varied from being susceptible to resistant susceptible, moderately resistant to resistant, susceptible, moderately resistant to highly resistant and other types of resistant ranks change (Figure 7). There was a clonal difference in disease onset. Some clones showed symptoms just two weeks after planting whereas other showed symptoms towards flowering or harvesting periods.

3.3. Disease incidence (%) and severity score

-Across clones, the disease incidence and severity were of low values although there was no consistently high disease pressure across cropping seasons. Overall, some clones appeared to be resistant to multiple diseases (CIP 694474.16, CIP Shangi Mini tubercules, CIP 392797.22, CIP 39337158) whereas other were of intermediate to susceptibility level to multiple diseases. The Bacterial wilt and late blight incidence and severity were relatively high as compared to the rest of diseases. For instance, these clones seemed to be of good genetic materials since they were less sensitive to diseases. Even those that were affected, the incidence as severity were considered to be of low values. The occurrence and incidence of different disease is being monitored in on-farm fields in order to see if there will be change in the behavior of the clones. The first 3 clones that appeared to be very resistant to diseases were also appreciated by farmers for their commercial, germinative and storage qualities (Table-6).

3.4. Yield performance ability of the clones over pest and disease pressure

There were significant yearly ($P<0.001$) and seasonal ($P<0.05$) differences (variabilities) in terms of tuber yields for genotypes tested during short and long rainy seasons from 2017 to 2021. CIP-Shangii, CIP 393371.58, CIP 392797.22 & CIP 398190.404 turned to be the top best genotypes regardless of the type of trials (seasons and years) as compared to the rest of materials. These clones expressed better yields than control varieties (local checks). The variability in year was probably due to several uncontrolled factors that may influence, including emergence rate dates, pests and diseases outbreak periods, weather variability, etc. It was noticed that genotypes reacted differently to prevailing local conditions. There was lack of consistency in the high yielding ability of clones across years and seasons much as three of them had relative stable high yield. The three clones had high yielding ability in Lwiro environment. Other clones showed low but stable yield across the cropping seasons. Some were more productive than the rest of clones. The same three clones outperformed at different plots within Lwiro. The lowest yields were consistently recorded during short rainy seasons and highest yields during long rainy seasons.

There was cyclic trend of increased and then reduced yield in in successive seasons and years . Ranking of genotypes based on tolerance/resistance to pests and diseases differed among cropping seasons and years. On average, there were at least three most resistant clones. These clones may be used as promising parents for subsequent crosses since they appeared to be prolific in pollen production during flowering periods. The overall disease sensitivity of the potato clones assessed (figure-4) and the overall pest tolerance status (figure-5) indicated 3 clones were heading the rest of the clones and local varieties tested. Some clones did not show any symptom of the diseases together with the highly resistant checks (local checks: Kruza, Kinigi), confirming their resistance to the diseases. These clones were significantly different from the highly resistant local checks. Altogether, the concept of a susceptible, tolerant or resistant variety, has to be considered with considerable caution because of different environmental conditions and ecology prevailing in eastern DRCongo

The results of the trials indicated most clones showed symptoms of susceptibility to diseases but at varying degrees of incidence and with varying severity (figure-5, figure-4). Both disease incidence and severity were significantly different (P<0.01) among clones. Some clones were found to be immune while other were highly resistant. Few of the them were very susceptible to moderately susceptible to disease. Overall, some promising clones that were resistant to pests will be proposed to farmers as well being introduced to breeders for further breeding as well as multi-locational trials.

4.DISCUSSION

4.1. Yield performance on the clones

In this study, some clones (CIP Shangi Mini tubercule, CIP 398190.404, CIP 392797.22, and CIP 398192.41) appeared to perform better (better yield, lower susceptibility to pests and diseases) during both on-farm and on-station trials. The most promising clone was CIP Shangi Mini tubercule . These newly CIP created clones were less susceptible to pests and diseases because of recently incorporated genetic traits enabling them to resist to current strains of diseases and pests and with few previous crosses. The three clones showed considerable resistance but their resistance levels (Busnello et al.2019) need to be monitored regularly in future cropping seasons. These three clones may be used as donor parents (Srivastava et al. 2015) for incorporating disease resistant genes to develop new potato varieties by local breeders.

Farmers indicated that they were likely abandoning the cultivation of old local varieties and adopt the new clones from CIP-Nairobi that revealed some kind of trends of stability and adaptability (i.e, Shangi). Trials did not reveal the trends of stability and adaptability of tested varieties.

It is well admitted that varietal and environmental variations as well as their interaction may have considerable influence on tuber yield and the potato’s attributes (Tessema et al.2020) in various agro-ecological regions. The results revealed 3 high yielding but unstable clones during on-station trials. These 3 outstanding clones appeared interesting in terms of adaptation and relative stability across years and cropping seasons under local environmental conditions. Based on results from participatory trials (on-farm experiments), Kavumu village appeared to the most suitable environment for evaluation and selection of clones in the surrounding of Lwiro Research Center. In Ethiopia, it was found that potato yield variability was an inherent characteristic of cultivars and locations (Wassu 2017). Yield variability (genetic variability) reflected quality traits and these traits were genetically controlled/ influenced with growing locations, and seasons and years (Solano et al.2014)

It is not easy to obtain suitable genotypes for different purposes or end products. Most of the time genetic traits with high genotype x environment interaction are often associated with low heritability, which adversely affects the ability to select superior genotypes for all environments (Wassu 2017). Hence the importance of evaluating varieties not only at a single location but also over seasons and years in order to observe the environment favoring or disfavoring one of the genetic traits (Wassu 2017). Most varieties are responsive for the changing environments. Since it is difficult to obtain a specific variety for a specific environment (it is not easy to breed specific varieties that perform better in specific environments) , yield stability (Andrade et al.2021, Ndacyayisenga et al.2014) is becoming the key issue and hence the importance of developing varieties that outperform consistently other competing genotypes and perform well over a range of environments (Wassu 2017,Beata et al. 2017).

In this study, a variability ($P<0.05$) in clone yields was observed across years and cropping seasons and locations during on-farm and on-station trials at different altitudes. On the contrast, in Uganda, it was observed that clone yield variation was not statistically significant across locations and seasons, but was influenced by the environment or altitude (Byarugaba et al.2021).The seasonal and yearly variation in marketable tuber yield might be associated with difference among potato clones. Yield variability depend on gene factors (Getie et al.2018) that usually governed by many local environmental factors(temperature, rainfall, moisture, intercepted radiation, light,..). Inadaptability and instability in yield of clones may be attributed to genetic differences (which in turn influence yield components) in interaction with environmental factors. The variation in marketable and non-marketable tuber number of potato varieties might be associated with inherent ability of potato genotypes in producing these tubers. Other authors indicate that difference in yield is attributable to genetic make-up of varieties (Getie et al.2018, (Muthoni et al.2015). The availability of potato varieties combining good tuber quality and resistance traits (Melito et al.2017) is very important for both processors and supermarkets.

In agreement with the present findings, a significant difference in total and marketable tuber yield among potato varieties was reported in Ethiopia (Getie et al.2018) where it was stated that the yield differences among genotypes were attributable both by the inherent yield potential of genotypes and growing environment as well as the interaction of genotype x environment. Variability between genotypes behaviour in contrasting environments(Harahagazwe et al.2012) is expected and this can enable possible selection (or identification) of material adapted to specific environmental conditions in different agroecological zones of the highlands of eastern DRCongo. Thus, advanced clones may lead to optimum production of marketable under local environmental conditions.

Traits farmers consider to be most important included, storage quality, taste, adaptation to low soil fertility, time to maturity and suitability for multiple harvesting, resistance to both pests and diseases, marketable size of the tubers and the number of small tubers (quality seed potato) harvestable per plant to serve as seeds during the following cropping season.

To effectively breed crops for resistance to both biotic and abiotic stresses, screening method is critical so as to identify superior genotypes. Exposure to another source of stress such insect pest or disease is required during screening to enable identification of genotypes combining biotic and abiotic resistance assessment in local environments.

Before new varieties are released for use in village, it is important that they are assessed to better select superior genotypes in presence of both biotic (climatic variability, soil fertility level) and abiotic (diseases, insect pests) that contribute significantly to yield loss for provide positive results. A well-adapted genotype should posses multiple trait resistance. This is because small-scale farmers rarely use chemical pesticides and chemical fertilizers. Although, it is assumed that variability in local temperature/rainfall can influence the population density of pests and disease severity, meteorological parameters can influence the severity of attacks of pests and the incidence of disease on clones (Munyuli et al.2017).

4.2. Current incidence of pest and disease on CIP new advanced clones in Lwiro environments

Potatoes are one of the most important sources of nutrition worldwide, providing energy, essential vitamins and minerals, as well as important dietary phytochemicals.

Significant crop yield is significantly reduced each year, worldwide, because of wounds and diseases caused by pests and pathogens, despite the use of chemicals, significant (Kim et al.2022). Disease management relies heavily on chemical warfare, i.e., the use of antibiotics, fungicides, and pesticides to control populations of pathogenic microbes and invertebrate herbivores (Kim et al.2022). To achieve sustainable food security while preserving the environment, both crop losses to disease and usage of harmful chemicals should be reduced (Kim et al.2022).

Rising incidence of chronic disease has been associated with the western diet and lifestyle, and improving the health-benefitting potential of our food supply is one way to address this epidemic. Given the popularity and availability of potatoes and potato products, improving their nutritional profiles with the aim of chronic disease prevention has great potential to improve human health. There are health risks and diverse environmental hazards associated with potato (Muthoni et al. 2014).

-Potato is a key livelihood and a profitable value chain crop in the Kivu provinces of eastern DRCongo. However, abiotic and biotic factors generally lower the yield of the crop. The low productivity of potato in the different agro-ecological zones may be due to various constraints include: narrow genetic materials, limited access to high yielding varieties, emerging new pests and disease, lack of accessing improved varieties, climate variability and general degradation of environment and landscapes (Wangombe & van Dijk 2013), declining soil fertility varietal resistance to abiotic and biotic stresses, among other factors. Therefore, farmers need varieties that are high yielding, enriched with nutrients marketable traits, resistant to pest/ diseases and tolerant to declining soil fertility and to climatic variability hazards.

Highly significant differences among potato clones for pest tolerance and disease resistance showed the presence of wide variations among the clones for the reaction to the disease and pest attack. Keeping pests at low densities on potato plants is of primary importance to reduce damages caused to tubers by theses pests (Fréchette et al.2010).

There were significant influences of season, years on pest population densities and all disease scores of clones indicating the differential response of clones to resist the disease across years and seasons. Genetic variations among varieties for disease resistance in various environments has been reported (Wassu 2017, Wulff et al.2007, Nyankanga et al.2014). This might be due to the genetic structure of the genotypes with low levels of heterogeneity for resistance or they may not carry as many resistant R genes or the resistance gene (Thangavel et al.2014). The inherent tolerance to pest character of clones in local environments of Lwiro were most important than resistance to diseases. Varietal and the environment (locations, seasons, years) differences were more important for some clones than others. Variations among different potato varieties in resistance to diseases may be due to varied major dominant resistance genes (horizontal and vertical genes) incorporated during the development of the clones (Wassu 2017).

However, varieties cultivated as resistant to multiple diseases and pests in some areas may not resistant (Mulumba et al.2012) in other areas due to the environment favorable to the pathogen and pest (Mulugeta et al.2020). Also, varieties resistance genes may be considered resistant to diseases in one area because the meteorological conditions are not suitable to the pathogens to occur (Wassu 2017). This research results demonstrated the importance of testing clones over years and seasons though the highest contribution to be resistant for some clones was due to the gene(s) the variety carried (Wassu 2017) This suggested the importance of identifying areas in the country where the environment favor the pathogen and testing potato genotypes in these areas to recommend as resistant variety to a certain disease (Wassu 2017, Wulff et al.2007) .

Analyzing disease resistance helps not only to determine differences in disease development among various potato cultivars (Zevallos et al. 2021, Ali 2017) , but also to find differences in the same potato cultivar every separate research year and cropping season. Some scientists have opinioned that it is necessary to apply a few methods for potato cultivars evaluation for susceptibility to the diseases such as testing of all cultivars in areas where the environment favors the pathogen. Direct selection for stress conditions is more effective in the same environment than selection for the mean of both favorable and unfavorable environments (Wassu 2017, Wulff et al.2007). This may suggested nationally coordinated joint efforts of breeders to identify potato genotypes resistant to diseases in areas where the environment favor the pathogen as opposed to the past potato breeding approach in developing varieties by several research centers independently for different agro-ecologies (Wassu 2017) .

The evaluation of breeding materials across environments if one needs to assess the performance that may help to select varieties that perform well consistently in all environments or to identify specific varieties for each environment. It has been also suggested the differential disease resistance ranks of varieties may be due to the presence of crossover and direct comparison of new and old varieties for yield/disease resistance at one location may not be good indicator of the contribution of the specific varieties to the productivity of the crop (Wassu 2017). However, in the case of selection for environmental stress conditions, the presence of genotype x environment interaction is greatly challenged the breeders. Therefore, the breeders would be more effective by direct selection of varieties in the same stress environment than selection for the mean of both favorable and unfavorable environments (Wassu 2017).Therefore, testing of varieties in areas where the environment favors the pathogen is sound recommendation to identify resistant varieties (Perez et al. 2014, Aboshama & Atwa 2019). The varieties may become resistant and moderately resistant to the disease due to the resistant gene(s) they carry and pathogen interaction in that location. In the favorable conditions for infection and disease development, a plant may develop no disease, only mild disease, or severe disease, depending on the specific genetic make-up of the plant and of the pathogen that attacks it. The variety developed as horizontal resistance may be susceptible because the resistance may also be contributed by R genes that have residual effects against virulent pathogens or defeated R genes(Wassu 2017).The varieties identified as susceptible to disease across seasons and years may become more stable and with high yield genotypes over environments desired (Wassu 2017) .

Therefore, if national potato program consider the resistant varieties as better option to reduce yield loss due to late blight disease, it is necessary to identify environments favorable to the pathogen in the country and test potato genotypes for their reaction to the pathogen before they are released as varieties to producers. This suggestion is supported by many researchers in case of selection of varieties for stress resistance such as bacterial wilt and late blight diseases. As it has been observed in Pakistan, crop losses and low productivity of may due to several biotic & abiotic stresses (Majeed & Muhammad 2018). Different biotic constraints, including pathogenic diseases (such as late blight, early blight, bacterial wilt, viral infections and nematodal parasites) that have a tremendous impact on potato production (Majeed & Muhammad 2018).

Obviously, one of the limiting factors of potato production is biotic stress (disease, pest). Potatoes are probably affected by more diseases (Muthoni et al. 2014) than any other cultivated crop, and most can be spread during propagation from one season to the next, including, bacteria, fungi, viruses,... Many of the diseases of importance are newly discovered, and the international importance of many diseases has changed substantially in the recent years as new varieties are introduced, new technologies are introduced and new areas of cultivation are opened for production.

There are three areas of emerging potato diseases that are a concern to potato producing areas worldwide: emerging diseases, changing pathogens and surviving diseases under current climate change. They are important because they all have on common feature: they are difficult to control, and in most cases, do not have effective control except avoidance through the use of advanced and climate-smart varieties.

Variability in meteorological factors (rainfall, temperature) and lack of availability of quality seed potatoes are among the key abiotic stresses which pose challenges to potato productivity. water and nutrient deficit and soil erosion on hilly slopes exacerbated by land fragmentation and use of steep land, and poor fertilization practices both in quantity and quality are secondary bottlenecks for potato production in Rwanda (Shimira et al.2020) and eastern DRCongo. Poor crop husbandry practices are also among the important underlying issues which result in substantial low yields of potato in eastern DRCongo

Pests and diseases are among the most important constraints to potato production in eastern DRCongo.

Obtaining potato cultivars that are resistant to destructive diseases and pests may help reduce production costs and the need for costly pesticides (Duarte et al. 2014). Similarly, in Vietnam, major yield losses (Loveniers 2019) in potato were mostly attributed to diseases (late blight :*Phytophthora infestans*., bacterial wilt: *Ralstonia solanacearum*) and pests (leafminer flies : *Liriomyza* spp.,…). In Kenya, the major potato production constraints are pests and diseases with bacterial wilt being the most prominent (Muthoni et al.2013, Coca-Morante &Tolín-Tordoya 2013).

Early blight in potato, caused by *Alternaria solani*, is mainly controlled by frequent applications of synthetic fungicides (Stridh et al 2022). Reducing the use of synthetic fungicides in agriculture is desired to reach an overall sustainable development since the active components can be harmful for humans and for the ecosystem (Stridh et al 2022). In integrated pest management, IPM, the idea is to combine various measures, including optimized crop management, crop rotation, use of resistant cultivars, biological control agents, plant resistance inducers, and fertilizers, to decrease the dependence on traditional chemical fungicides (Stridh et al 2022)

Plant pests and diseases are still among the main obstacles in potato production worldwide (Munif & Rachmawati 2020). If not adequately controlled, yield losses from pests and diseases alone can reach up to 70-100%. Also, diseases (viruses, bacterial wilt, late blight,…), pests (aphids, leafminers, potato tuber moth,…), lack of access to clean seeds(degenerated varieties, poor seed quality, low yielding varieties) together with, poor soil health, lack/ inappropriate use of fertilizers, access to extension services and to market, poor storage & post-harvest facilities,… are known to be the drivers of high importance attributable to main yield gap in Sub-Sahara Africa (Harahagazwe et al. 2019, van der Waals et al. 2016, Tafesse et al.2020).

Much as the causes of low yield are not fully known (Manishimwe et al. 2019, Zhang et al. 2018) in eastern DRCongo, currently observed low yields are largely due to pests & disease pressure and current ongoing climate-environment variability in eastern and central Africa. Current yield losses from insect pests have not been quantified although their severity and damage are feared to become important with global warming. The absence of environmentally friendly approaches for management of potato pests and diseases has left farmer switch on option other than use of chemical pesticides on a routine basis. Rainfall and temperature played an important role in disease expression and yield among clones hence these are key climatic factors in variety selection process to establish those resistant to pests and diseases and stable in terms of tuber yield among environments.

5.CONCLUSION

This investigation pioneered clones selection research in eastern DRCongo. In this study, it was important to find out valuable and promising clones expressing high tuber yield with combining ability for resistance (Muhinyuza 2014) to multiple pests and diseases. Interesting clones are planned to be released to farmers later. Genetic variation is necessary for crop improvement (Hosaka & Sanetomo 2020).The larger the genetic diversity in the breeder 's gene pool, the greater the potential genetic gain (Hosaka & Sanetomo 2020). Pests and diseases significantly reduce the genetic diversity of potato clones. Identification and development of pest-resistant or tolerant varieties may offer the most efficient and sustainable way to manage the damaging potato diseases and pests (Munyaneza et al.2011).Potato varieties possessing sustainable high yield under varying environmental conditions and other valuable properties (e.g. resistance to diseases and pests), are much appreciated by practitioners (Pakul et al.2019). Seeking for donor plants with high environmental plasticity and stability in specific cultivation zone is a key point, especially in creating highly productive adaptive varieties for diverse agro-climatic conditions(Pakul et al.2019).Improvements in pest and disease resistance and in yield abilities are important as common breeding targets for all purposes. Tuber yield and quality are some of the main potato breeding targets (Melito et al.2017). To develop potato cultivars that meet different needs, breeders have continued efforts to improve these traits (Mori et al.2015).

Global warming causes a range of negative impacts on plants especially due to rapid changes in temperatures, alterations of rainfall patterns, floods or drought conditions, and outbreaks of pests and diseases. These, in turn, affect crop production reducing the quality and quantity of agricultural produce (Munaweera et al.2022). Climatic extremes and high population growth significantly increase the world’s food demand. Therefore, fulfilling the goal of attaining food security for the present and future generations is of prime importance. Biotechnology enables creating dramatic alterations on crops to withstand stress which is difficult to attain using conventional breeding approaches. It is a viable tool used to improve agricultural production. The development of biotechnological approaches such as genetic engineering, genome editing, RNA-mediated gene silencing armored with next-generation sequencing, and genome mapping have paved the way for precise and faster genetic modifications of plants (Munaweera et al.2022). Such intensive efforts are currently underway creating desirable crop cultivars to meet the food demand and to support sustainable agricultural productivity for climate change adaptation (Munaweera et al.2022)

The potato crop is highly heterozygozus, the most important economical characters are governed by additive and non-additive genes(Manuel et al.2019). A breeding program for yield improvement is successful, when clones with high parental value are used, which is not only measured by its phenotypic value, but it is necessary to know its combining ability as an indicator of parental value(Manuel et al.2019, Hirut et al.2017) , selecting clones that when crossed with testers with a broad genetic base, have a high value and can transmit it to their progeny to obtain high yields. High parental value is one of the powerful tools in identifying clones with high parental value that can be used in crosses. High parental value is more important for total tuber yield, marketable tuber yield, average tuber weight under stress conditions. It is very important for important for the tolerant potato clones to various biotic and abiotic stresses(Manuel et al.2019). Some times, the additive effects are predominant for overall tuber yield, suggesting the predominance of additive effects of the genes in the control of a particular trait. The variations of the effects of through the potato generations, may be attributed to the genotype x environment interaction, thus recommending that the selection of the best parents for breeding potato should be done based on years and generations.

At the current level of assessment, it is not yet fully clear about stable clones in local environment since there was high variability in yield across cropping seasons and years. Also, there was seasonal variability and a tendency of yield increasing year to year across the 10 clones compared to local checks. Generally, the B cropping season had lower yield than A cropping season. Some clones (CIP-Shangi, CIP 393371.58, CIP 392797.22, CIP 398190.404) were preliminary rated by assessors as with best-suitable, and with potential adaptability capacity of the yield. The three clones will be later named by farmers before they can be proposed for official release in rural areas and for registration for registration for commercial (Luitel et al 2017) use by the government of DRCongo. The 3 clones were selected as promising clones having resistance to diseases and tuber yield superior to the local varieties (local checks). These 3 clones can be suggested for variety release in similar agroecological environments. On the contrast, clones (CIP396018.241, CIP398190.615) were recently ranked as very good and recommendable clones for release in Rwanda (Rukundo et al.2022)

Moreover, establishing(attributing) a consistent name to a genotype is undoubtedly the first step in registering any cultivar for future development of the crop and for conservation of genotypes in the germplasm.

Utilization of healthy planting material is a key factor to improve potato yields to reduce the dissemination of diseases and pests (Degebasa 2019). Quality seed is one of the major bottlenecks hindering the production and productivity of potato. The formal and informal potato seed supply systems used by farmers by access high quality seed are complementary and mutually dependent (Ferrari et al.2018). Access to good quality seed is the beginning of successful crop production as an enterprise. Unfortunately, this remains a challenge to the smallholder farmers in, whose seed systems are still under-developed. The situation is even worse in conflict burdened parts of some countries like the eastern region of the Democratic Republic of Congo, where socio-economic systems have been progressively disrupted. The increase in access to seeds of marketable varieties is very important for farmers. Improving seed system performance can result in increased smallholder farmers' access to lucrative seed markets.

Less than 5% of the seed potatoes used are sourced from specialized multipliers . Farmers rely on seed potatoes from neighbours and farm-saved seed potatoes (Gildemacher 2012) . This often makes economic sense in the absence of affordable high quality seed potatoes and limited market security (Gildemacher 2012). Seed potato system (Tadesse et al. 2020) interventions need to consider the accessibility to affordable high-quality seed potatoes (advanced and promising varieties). Research is essential in the mitigation of yield-reducing drivers through positive selection. More attention is needed for positive selection (the selection of healthy-looking mother plants for the production of seed potatoes from selected clones). Positive selection (Gildemacher et al. 2012) may benefit smallholder potato producers who select seed potatoes from their own fields, and should thus be incorporated routinely in agricultural extension efforts. Selecting seed potatoes from healthy-looking mother plants (positive selection),may assure lower incidences from virus infection irrespective of the agro-ecology, crop management, soil fertility, variety and quality (Schulte-Geldermann et al.2012) of the starter seed. Positive selection may help to identify varieties with lower virus incidence and higher yields at the farm level (Schulte-Geldermann et al.2012, Taiy et al.2017). Thus, positive selection can benefit smallholder potato producers who at some stage select seed potatoes from their own fields (Schulte-Geldermann et al.2012). Positive selection should be incorporated routinely in agricultural extension efforts.

In this study on resistance/susceptibility to disease and severity of pest infestation (attack), yield adaptability/stability (Eaton et al.2017) of superior clones in Lwiro environment aimed to obtain adaptive superior varieties that could potentially be disseminated in eastern DRCongo. The study revealed 3 superior varieties exhibited high resistance levels to pests. These new promising varieties were associated with high average productivity compared to local varieties(local checks). The yields obtained in this assessment was still low compared to their potential because the trials were not fertilized nor protected against pests and diseases. The present experiment showed the opportunity of breeding potato varieties for higher yield and wider adaptability throughout the eastern Part of DRCongo. Therefore, these 3 clones may be presented for the nationwide cultivation in eastern DRCongo. This information on behavior of new clones in local environment, may help at different stages of breeding for resistance to adverse conditions, including climate variability (Zúñiga et al.2020), resistance to pests and diseases, as elements of adaptability (Oliinyk et al.2016, s Bernal-Galeano et al. 2020).

-Some experiments were run in collaboration with farmers. Active farmer participation in early breeding stages is critical for a successful potato breeding programme (Muhinyuza et al.2012).The implication of the data from the farmers perspective is that breeders should make sure they collect information from the end-users and incorporate them in conventional/ modern potato breeding programs in eastern and central Africa. Positive participatory variety selection (Zakharchuk et al.2020) was found to be an effective approach for identifying important factors for the adoption of new potato varieties (clones). Such approach may enable breeders to identify other criteria that are neglected or not often considered by researchers at research station.

Positive selection can benefit all smallholder potato producers who at some stage select seed potatoes from their own fields, and should thus be incorporated routinely in agricultural extension efforts (Schulte-Geldermann et al.2012, Abebe et al. 2013). Farmers can obtain more than 40% yield increase and more than 30% vigour improvement when positive selection techniques are applied (Degebasa 2019). Participatory selection can help in reducing the movement of dangerous diseases and pests in rural areas due to purchase of not checked and certified seed (Subía 2013).

These three clones were identified as useful sources of resistance to pests and diseases with adaptation to Lwiro environment in eastern DRCongo. These sources of resistance may be explored and used in breeding programmes (Altamirano 2011) for the development of resistant varieties, which may effectively help reduce the damage and yield reduction (Guchi 2015) arising from pest attack under local climatic variabilities conditions. Yet farmers need to access to clean potato seed (Tufa et al.2015, Sharma et al. 2020) production to ensure timely access to good quality seed at a more affordable price (Taiy et al.2017). They also need to do collective marketing of their farm produce and purchase of farm inputs in order to benefit from the economies of scale (Taiy et al.2017,Myrick et al.2021) with improved potato clones (Kolech et al. 2015, Okello et al.2019). Agronomic traits of potato variety preferences of medium and large farmers are highly related to market preferences, but for small farmers they are related to quality for their own consumption, and resistance to abiotic or abiotic factors that allow them to obtain yields under their crop management conditions.

Thus, evaluating genotypes across various environments for their stability of performance and range of adaptation is crucial and is an important component of the research activity of the national as well as regional research program(Miheretu 2014). It is also recommended to policy-makers and breeders to better prioritize investments into breeding for specific traits and dissemination strategies (Pradel et al.2019,Fréchette et al.2010).Breeders require sufficient genetic variation (Iragaba 2014, Islam et al.2020) when developing new cultivars adapted to changing environmental conditions and emerging pests and diseases (Kolech et al.2016). Such cultivars are especially important for farmers, where low input agriculture is the norm, and weather variability has increased in recent years (Kolech et al.2016).

These promising clones may be recommended as promising for new varieties at mid to high elevations or in environments below 3500 masl in highlands of eastern DRCongo . It is expected that these clones may show good adaptation in these environments. However, more trials are needed before recommendation for any of these clones to be registered as new varieties in various elevations and highland environments globally of eastern DRCongo. These 3 clones were found to be the most stable for earliness and high fresh tuber yield across years and seasons. Therefore, these 3 interesting clones could be used as part of the foundation for a national potato breeding program (Kolech et al.2016). The 3 clones were likely expressing higher adaptability and stability, as well as better performance, than the local cultivars, making them good candidates for release and dissemination as good new cultivars in rural areas. Therefore based on the findings, these 3 clones may be recommended to potato growers in the vicinity of Lwiro and similar agro-ecology (Jafar et al.2020) for further promotion and the 3 varieties could be used by potato breeders (Shehroz et al.2018) in their breeding program to exploit their merits. Future studies of environmental factors in relation to vector population and disease severity may be not only helpful in determining the response against diseases (Iftikhar et al.2020) but also for the monitoring of the progression of disease (Nacheva et al.2014, Mahmud et al.2016, Luthra et al.2018) . Active involvement of the private sector in seed production in conjunction with integrated pest and disease management is the promising future research path and most effective approach to be adopted for sustainable potato production and food security in the country (Shimira et al.2020).

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Figure-1.The country study area

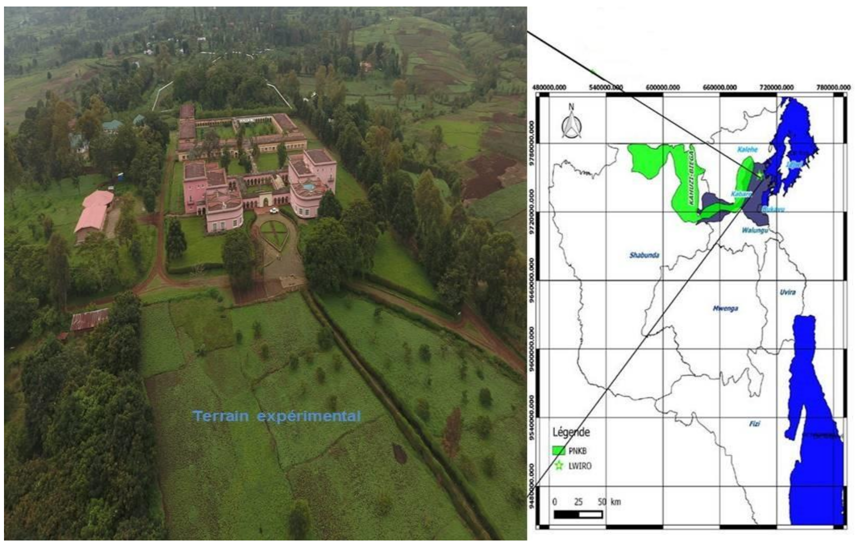

Figure-2: Lwiro Reseach center location within South-Kivu province

Received Potato clones from CIP Nairobi			
			
CIP394611.112	***CIP398192. 41***	***CIP393371.58***	***CIP Shangi***
			
CIP398190. 404	***CIP398190.735***	***CIP398208.505***	***CIP392797.22***
			
CIP398190.735	***CIP398208.505***	***CIP398208.704***	***CIP694474.16***

Figure-3: Clones material obtained from CIP Nairobi in 2016

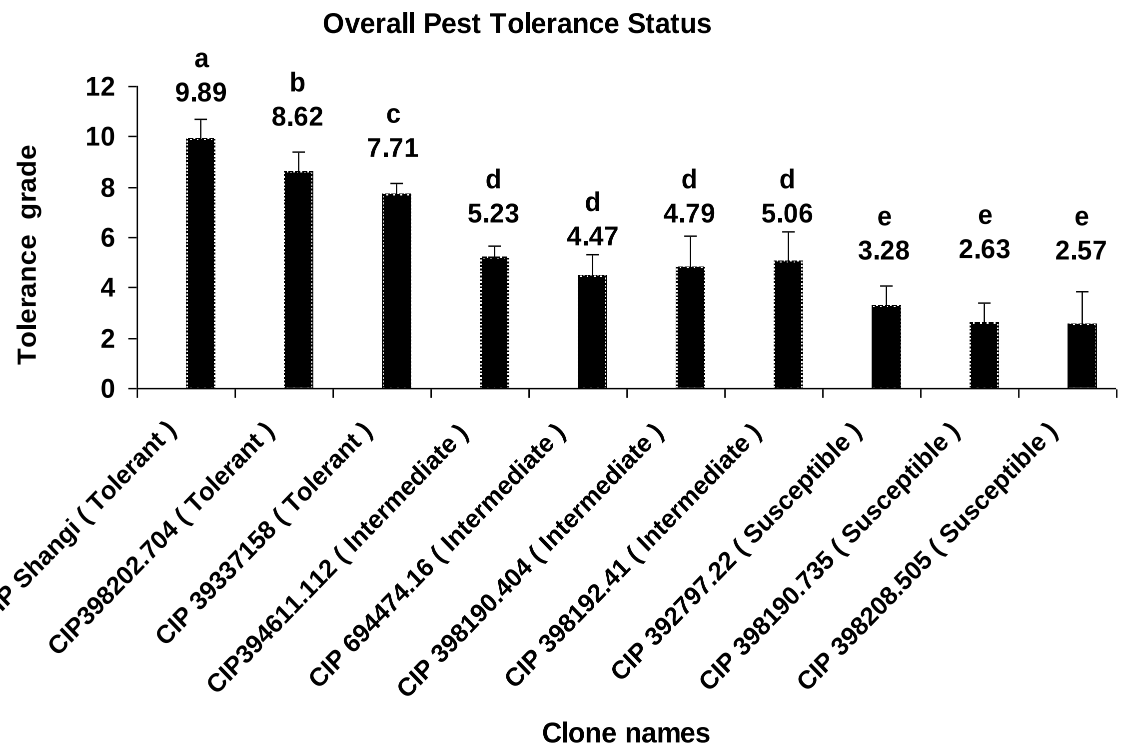

Figure-4: Overall pest Tolerance status on potato genotypes tested

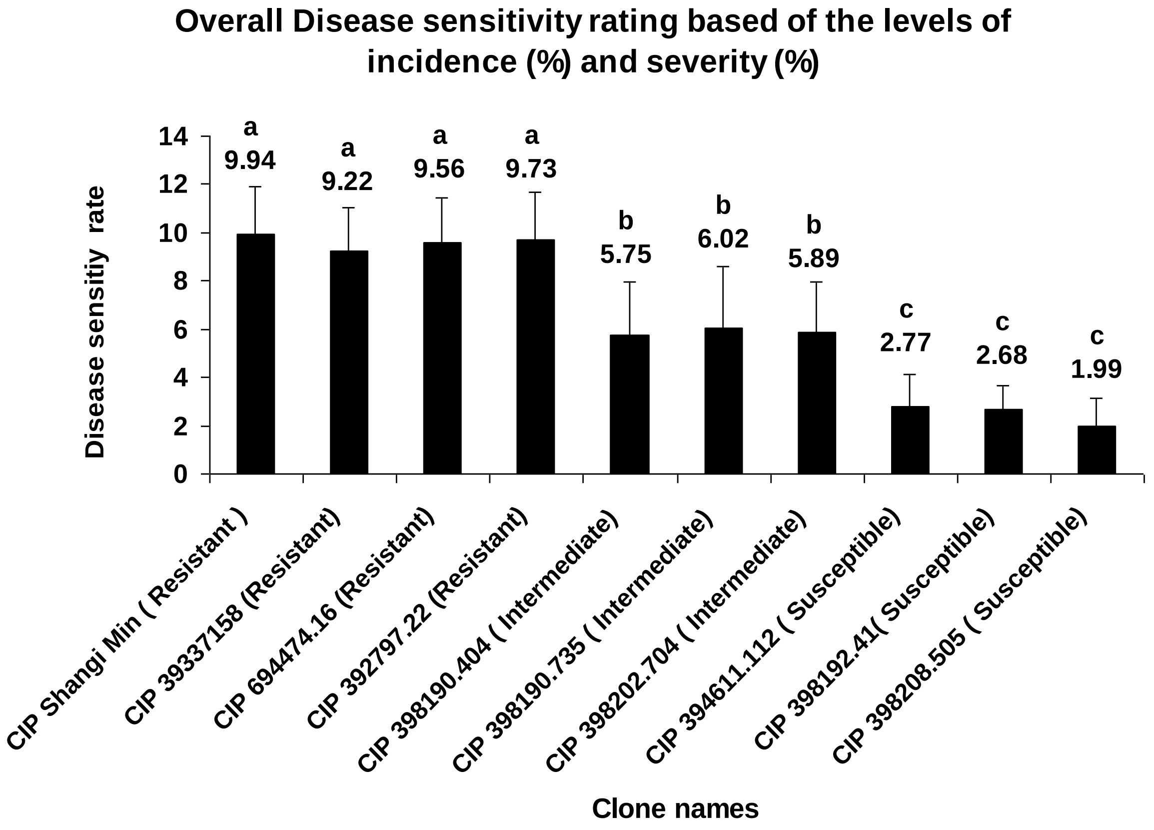

Figure-5: Overall disease sensitivity of the potato genotypes assessed.

Table-1: Initial physico-chemical characteristics of the soils from experimental sites measured before installation of potato experiments at Lwiro.

	Field location	Chez Mugema	Ancien Verger	Derriere labo phyochimie	Derriere Bureau DG
		2019A	2017 A	2020B	2021 B
Property	Unit	Mean (X±SE)	Mean (X±SE)	Mean (X±SE)	Mean (X±SE)
pH(H20)		6.74 ± 1.52	5.72 ± 1.08	5.83 ± 0.87	6.23 ± 0.87
pH (CaCl2)		4.54 ± 0.78	4.37 ± 0.55	4.59 ± 0.45	4.65 ± 0.68
Organic carbon (C)	(g/Kg soil)	46.51 ± 12.45	39.92 ± 9.67	43.15 ± 7.84	43.22 ± 11.61
Total nitrogen (N)	(g/Kg soil)	2.68 ± 0.67	2.56 ± 0.78	2.99 ± 0.45	2.76 ± 2.22
Extractable Phosphorus (P)	(mg /Kg)	18.84 ± 2.35	9.81 ± 1.34	19.89 ± 2.45	6.81 ± 0.87
Exchangeable Potassium (K)	(cmol $_c$ /Kg soil)	0.14 ± 0.05	0.36 ± 0.06	0.33 ± 0.07	0.18 ± 0.06
Exchangeable Magnesium (Mg)	(cmol $_c$ /Kg soil)	4.99 ± 0.12	2.13 ± 0.03	1.19 ± 0.04	2.25 ± 0.04
Exchangeable Calcium (Ca)	(cmol $_c$ /Kg soil)	2.81 ± 0.23	3.89 ± 0.99	2.52 ± 0.43	1.89 ± 0.02

Exchangeable Sodium (Na)	(cmol $_c$ /Kg soil)	0.09 ± 0.01	0.06 ± 0.02	0.09 ± 0.02	0.08 ± 0.01
Exchangeable Manganese (Mn)	(cmol $_c$ /Kg soil)	0.41 ± 0.06	0.43 ± 0.14	0.39 ± 0.05	0.75 ± 0.08
Cation exchange capacity (CEC)	(cmol $_c$ /Kg soil)	9.95 ± 3.98	7.32 ± 0.98	6.99 ± 0.07	5.99 ± 0.78
Soil content : Clay	(g/Kg soil)	298.45 ± 47.12	398.23 ± 67.34	412.34 ±112.45	397.23 ± 54.33
Soil Content : Silt	(g/Kg soil)	391.33 ± 67.18	498.33 ± 89.12	498.32 ± 56.21	562.55 ± 78.98
Soil Content : Sand	(g/Kg soil)	55.27 ± 7.52	145.22 ± 14.56	68.54 ± 9.54	92.13 ± 15.97
Soil analysis at Lwiro experimental fields: Soil samples were collected following classical pedological procedure et sent at RAB (Rwanda agricultural Bureau) for soil properties analyses. The data was supervised by Dr. Placide Rukundo (Head of Potato Research program of Rwanda)					

Table-2: Some diseases (A) and arthropod pests (B), their categorical identity, status, & infestation and infection severities on newly introduced potato clones in Lwiro region

(A): List of diseases of potato, their categorical identity, status at Lwiro region & infection severity on new clones						
Disease	**Pathogen identity**	**Diseases status**	**Stage & plant parts affected**	**Infection severity**	**Pest categories**	
Late blight of potato	*Phytophtora infestans* (Family: Pythiaceae, Order: Peronosporales)	Major	Vegetative, leaf, stem	High	Fungi	
Phytophthora tuber rot	*Phytophtora infestans* (Family: Pythiaceae, Order: Peronosporales)	Minor	Tuber	Low	Fungi	
Early blight of potato	*Alternaria solani* (Order: Pleosporales, Family: Pleosporaceae)	Minor	Seedling, whole plant	Low	Fungi	
Stem rot of potato	*Sclerotinia sclerotiorum* (Order: Atheliales, Family: Atheliaceae)	Minor	Vegetative, leaf	Low	Fungi	
Stem canker/Black scurf of potato	*Rhizoctonia solani* (Order: Ceratobacidiales, Family: Ceratobacidiaceae)	Minor	Seedling, stem, root	Low	Fungi	
Fusarium wilt	*Fusarium oxysporum* (Order: Hypocreales, Family: Nectriaceae)	Minor	Vegetative, tuberization)	Low	Fungi	
Dry rot of potato	*Fusarium solani* (Order: Hypocreales, Family: Nectriaceae)	Minor	Potato tuber	Low	Fungi	
Verticilium wilt	*Verticilium albo-atrum* (Order: Hyphomycetales, Family: Moniliaceae)	Minor	Tuber	Low	Fungi	
Common scab potato	*Streptomyces scabies* (Order: Actinomycetales, Family: Streptomycetaceae)	Minor	Tuber	Low- to-Medium	Bacteria	
Soft rot of potato	*Erwinia carotovora* (Order: Enterobacteriales, Family: Enterobacteriaceae)	Minor	Tuber	Low	Bacteria	
Bacterial wilt & brown rot of potato	*Ralstonia solanacearum* (Order: Burkholderiales, Family: Burkholderiaceae)	Major	Whole plant, tuber	Low	Bacteria	
Potato tuber nematode	*Ditylenchus destructor* (Order: Tylenchida, Family: Anguinidae)	Minor	Tuber	Low	Nematode	
	Potato virus Y (PVY), (Genus Potyvirus, Family: Potyviridae)	Minor	vegetative leaf	Low	Virus	Aphids
	Potato virus **A** (PVA)	Minor	vegetative leaf	Low	Virus	
Potato leafcurl virus	*Potato leafroll virus* (PLRV) (Family: Luteoviridae, Genus: Polerovirus)	Minor	vegetative leaf	Low	Virus	Aphids
	*Potato virus **M***(PVM)	Minor	vegetative leaf	Low	Virus	aphids
	Potato virus ***S*** (PVS) (Genus: Carlavirus)	Minor	vegetative leaf	Low	Virus	Aphids
Potato mottle virus	*Potato virus-**X*** (PVX) (Order: Tymovirales, Family: Alphaflexiviridae, Genus: Potexvirus)	Minor	vegetative leaf	Low	Virus	Aphids
Potato mosaic disease	Potato yellow mosaic virus (Family: Geminiviridae)	Minor	vegetative leaf	Low	Virus	Whitefly
(B) : Insect pests of potato, their identity, status & Infestation severity						
Common name of insect pest	**Pest identity**	**Pest status**	**Stage & Plant parts affected**	**Infestation severity**		
Potato cutworm	*Agrostis ipsilon* (Order: Lepidoptera, Family: Noctuidae)	Major	Seedling, whole plant	High		
Potato aphids	*Myzus persicae, Aphis gossypi* (Order: Hemiptera, Family: Aphididae)	Major	Vegetative, leaf, stem	High		
Potato tuber worm	*Phthorimaea operculella* (Order: Lepidoptera, Family: Gelechiidae)	Minor	Tuber	Low		
Potato leafhopper	*Empoasca fabae* (Order: Hemiptera, Family: Cicadellidae)	Minor	Vegetative, leaf	Low		
Potato leaf miner	*Agromyza* sp. (Order: Diptera, Family: Agromyzidae)	Minor	Vegetative, leaf	Low		
Field cricket	*Gryllus* spp. (Odre: Orthoptera, Family: Gryllidae)	Minor	Seedling, stem, root,	Low		
Mole cricket	*Gryllotalpa Gryllotalpa* (Order: Orthoptera, Family: Gryllotalpidae)	Minor	Seedling, stem, root,	Low		
Golden cyst nematode	Globodera rostochinensis (Order:Tylenchida, Family: Heteroderidae)				Nematode	

Table-3: On-field research station average($\bar{x}$±SE) potato yield (t/ha) recorded from 2017 to 2021

Year	**2017**	**2017**	**2018**	**2018**	**2019**	**2019**	**2020**	**2020**	**2021**	**2021**
Cropping Seasons	**A (Sept-Dec)**	**B (Feb-May)**	**A (Sept-Dec)**	**B (Feb-May)**	**A (Sept-Dec)**	**B (Feb-May)**	**B (Feb-May)**	**A (Sept-Dec)**	**A (Sept-Dec)**	**B (Feb-May)**
Clone names (t/ha)	Mean ($\bar{x}$±E)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)
Local check-1(Kinigi)	13.37 ± 1.87	9.67 ± 1.43	20.54 ± 3.12	19.17 ± 3.34	21.98 ± 4.32	14.21 ± 1.78	15.56 ± 4.67	21.17 ± 4.34	23.34 ± 4.32	12.45 ± 1.78
Local check-2(Cruza)	16.45 ± 2.17	14.34 ± 18.43	20.65 ± 4.18	19.16 ± 1.56	23.32 ± 2.43	18.34 ± 2.12	16.43 ± 1.89	23.11 ± 1.79	24.38 ± 1.93	16.34 ± 2.62
CIP 393371.58	10.76 ± 1.34 f	8.26 ± 1.84 b	19.97 ± 2.84 c	27.87 ± 2.31 c	26.79 ± 1.65 b	19.26 ± 3.21 b	16.28 ± 2.19 c	24.89 ±3.32 b	28.59 ± 185 b	20.66 ± 4.21 b
CIP 394611.112	9.52 ± 1.35 g	12.77 ± 1.43 a	9.64 ± 1.87 h	11.87 ± 1.78 g	24.26 ± 2.56 c	11.77 ± 1.16 e	13.17 ± 0.16 d	14.67 ± 1.99 g	25.16 ± 2.76 c	14.78 ± 2.12 e
CIP 398190.404	22.65 ± 0.89 b	7.26 ± 0.88 c	26.23 ± 0.61 a	21.76 ± 3.12 e	10.58 ± 0.89 g	18.26 ± 0.94 c	9.31 ± 1.12 f	22.78 ± 3.18 b	12.18 ± 0.39 g	15.27 ± 1.03 d
CIP 398192.41	15.75 ± 3.15 e	11.73 ± 1.41 a	15.56 ± 0.95 d	17.85 ± 1.55 f	9.73 ± 0.87 l	11.63 ± 1.61 e	6.57 ± 0.24 h	19.56 ± 185 e	8.93 ± 0.97 i	10.83 ± 1.81 e
CIP 398190.735	7.48 ± 1.25 h	6.44 ± 0.97 d	7.48 ± 0.68 k	7.45 ± 0.65 k	5.87 ± 0.106 k	5.23 ± 1.97 h	5.02 ± 0.35 k	9.85 ± 0.85 k	8.53 ± 0.19 k	7.23 ± 2.07 h
CIP 398208.505	17.91 ± 1.78 d	5.21 ± 0.96 e	14.91 ± 0.96 e	22.31 ± 1.98 d	18.75 ± 2.28 e	14.21 ± 1.93 d	4.77 ± 0.35 k	23.81 ± 2.18 b	19.91 ± 4.26 e	16.26 ± 1.55 c
CIP 398202.704	15.85 ± 3.15 e	8.34 ± 1.84 b	15.15 ± 0.93 d	19.92 ± 3.78 e	17.89 ± 2.22 f	9.43 ± 1.84 f	22.20 ± 2.14 b	21.23 ± 2.48 c	16.96 ± 4.24 f	11.54 ± 1.05 f
CIP 694474.16	7.81 ±1.25 h	7.38 ± 0.87 c	8.85 ± 0.31 f	9.98 ± 0.69 h	14.76± 1.67 h	8.39 ±1.87 g	11.14± 0.11 e	11.68 ± 0.89 f	15.71± 1.88 h	8.99 ±1.37 g
CIP Shangi Mini	26.23 ±3.12 a	11.86 ± 1.43 a	20.95 ±2.85 c	34.76 ± 3.85 a	29.53± 4.17 a	21.86 ±2.06 a	21.77 ± 3.62 a	36.29 ± 2.72 a	32.33± 5.16 a	24.16 ±1.09 a
CIP 392797.22	20.95 ± 0.95 c	9.12 ± 2.13 b	22.65± 0.84 b	29.45 ± 1.45 b	23.52 ± 3.16 d	8.78 ±3.03 b	6.61 ± 0.24 h	21.87± 1.68 d	24.92± 4.16 d	7.78 ±1.03 i
ANOVA *:* *F*(9,119)	12.540	9.690	11.930	7.780	25.780	9.670	62.986	13.890	34.8902	12.9311
P-Value	P<0.001	P<0.001	P<0.0001	P<0.001	P<0.0001	P<0.001	P<0.0001	P<0.001	P<0.0001	P<0.001

Table-4: Average ($\bar{x}$±SE) potato yield (t/ha) registered with participative farmers from different villages (Lwiro, Tshibati, Katana, Kavumu) from 2017 to 2021

On-farm sites	**LWIRO**		**TSHIBATI**		**KATANA**		**KAVUMU**	
Year	**2017**	**2017**	**2017**	**2017**	**2017**	**2017**	**2017**	**2017**
Cropping season	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**
Clones	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**
CIP Shangi Mini tubercule	3.85 ± 0.25 a	5.11 ± 0.55 a	2.94 ± 0.13 a	6.64 ± 0.89 a	4.07 ± 0.12 b	4.78 ± 0.97 b	3.99 ± 0.31 a	5.65 ± 1.56 a
CIP 398190.404	2.87 ± 0.21 b	4.31 ± 0.23 b	2.78 ± 0.13 a	2.67 ± 0.45 b	5.72 ± 0.91 a	5.76 ± 0.23 a	1.95 ± 0.07 b	3.76 ± 0.45 b
CIP 398190.735	1.79 ± 0.11 c	2.28 ± 0.91 c	1.99 ± 0.08 b	1.39 ± 0.11 c	2.84 ± 0.39 c	1.55 ± 0.12 c	1.09 ± 0.18 c	1.71 ± 0.47 c
ANOVA: *F* (2,26)	3.871	7.210	3.990	8.320	8.890	4.780	3.810	6.810
P-Value	P=0.011	P<0.001`	P=0.0271	P<0.001	P<0.001	P<0.001	P=0.038	P<0.001
Year	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**
Cropping season	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**
Clones	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**
CIP Shangi Mini	4.45 ± 0.61 a	5.13 ± 0.93 a	3.64 ± 0.52 b	5.64 ± 0.43 a	2.04 ± 0.25 b	4.68 ± 0.76 a	1.56 ± 0.87 b	4.49 ± 0.65 a
CIP 398190.404	2.37 ± 0.41 b	4.21 ± 0.45 b	4.41 ± 0.54 a	2.84 ± 0.98 b	2.79 ± 0.43 a	3.29 ± 0.56 b	1.17 ± 0.41 c	2.27 ± 0.21 b
CIP 398190.735	1.98 ± 0.11 c	2.88 ± 0.71 c	1.94 ± 0.23 c	1.98 ± 0.07 c	1.63 ± 0.21 c	1.87 ± 0.08 c	1.88 ± 0.09 a	1.87 ± 0.16 c
ANOVA: *F* (2,26)	3.760	8.710	5.611	4.010	4.750	7.450	3.960	3.870
P-Value	P=0.0276	P<0.01	P=0.035	P=0.017	P=0.006	P<0.01	P=0.021	P=0.0048
Year	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**	**2019**
Cropping season	**A (Sept-Dec)**	**B (Feb-May)**	**A (Sept-Dec)**	**B (Feb-May)**	**A (Sept-Dec)**	**B(Feb-May)**	**A (Sept-Dec)**	**B(Feb-May)**
Clones	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**
CIP Shangi Mini	8.85 ± 0.95 a	7.43 ± 1.43 b	7.94 ± 0.83 a	8.64 ± 0.91 a	5.07 ± 0.59 b	5.03 ± 0.88 b	5.99 ± 0.51 a	4.01 ± 0.92 a
CIP 398190.404	4.87 ± 0.71 b	8.27 ± 0.66 a	5.78 ± 0.93 b	5.47 ± 0.33 b	12.72 ± 0.66 a	6.29 ± 1.17 a	4.95 ± 0.47 b	3.25 ± 1.12 b
CIP 398190.735	3.79 ± 0.29 c	4.78 ± 0.87 c	2.99 ± 0.28 c	3.94 ± 0.45 c	5.84 ± 0.59 b	3.04 ± 0.93 b	3.09 ± 0.18 c	1.67 ± 0.89 c
ANOVA: *F* (2,26)	8.450	15.540	7.611	10.140	5.680	14.870	6.560	5.210
P-Value	P=0.008	P<0.001	P=0.013	P<0.01	P=0.032	P<0.001	P=0.011	P<0.01
Year	**2020**	**2020**	**2020**	**2018**	**2018**	**2020**	**2020**	**2020**
Cropping season	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**
Clones	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**
CIP Shangi Mini	15.45 ±1.81 a	9.13 ± 0.95 a	13.6 ± 1.89 a	9.64 ± 0.83 a	12.04 ± 1.45 b	9.68 ± 1.76 c	11.56 ±1.87 b	8.49 ± 1.65 c

CIP 398190.404	8.37 ± 2.41 b	6.91 ± 1.45 b	11.81 ± 0.94 b	6.84 ± 1.98 b	12.79 ± 3.43 a	10.09 ± 0.97 a	10.17 ± 1.43 c	12.28 ± 0.71 a
CIP 398190.735	6.98 ± 1.12 c	5.18 ± 0.99 c	10.94 ± 1.93 c	5.98 ± 0.78 c	9.63 ± 2.21 c	10.87 ± 2.08 a	13.88 ± 1.06 a	10.87 ± 0.18 b
ANOVA: *F* (2,26)	6.781	9.760	12.611	4.010	8.780	7.450	13.560	9.870
P-Value	P=0.0196	P=0.001	P=0.006	P=0.004	P=0.006	P=0.017	P=0.001	P=0.023
Year	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**
Cropping season	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**	**A(Sept-Dec)**	**B(Feb-May)**
Clones	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**	**Mean ($\bar{x}$±SE)**
CIP Shangi Mini	10.85 ± 0.95 a	9.43 ± 1.43 b	9.94 ± 0.83 b	10.64 ± 0.91 a	7.07 ± 0.59 b	8.83 ± 0.88 a	9.99 ± 0.51 a	8.01 ± 0.92 a
CIP 398190.404	6.87 ± 0.71 b	12.7 ± 0.66 a	15.8 ± 0.93 a	8.47 ± 0.33 b	14.72 ± 0.66 a	7.29 ± 1.17 b	7.95 ± 0.47 b	6.25 ± 1.12 b
CIP 398190.735	5.79 ± 0.29 c	6.78 ± 0.87 c	7.99 ± 0.28 c	5.94 ± 0.45 c	5.84 ± 0.59 c	4.04 ± 0.93 c	5.09 ± 0.18 c	4.67 ± 0.89 c
ANOVA: *F* (2,26)	9.460	12.540	9.611	14.140	12.680	10.870	8.560	8.810
P-Value	P=0.004	P=0.001	P=0.024	P<0.001	P=0.002	P=0.003	P=0.011	P=0.023

Aa

Table-5: Population density of arthropods and nematodes on different potato clones across the long (A: September-December) & short (B: February-May) rainy cropping seasons of year 2017 to 2021 at Lwiro Research Center. [For the population density (nbr of individuals per 3mx 4m plot area), data presented in the table are average of observations recorded at 2, 4, 6, 8, 10, 12 weeks post planting]

	Clones	**CIP Shangi**	**CIP398202.704**	**CIP 39337158**	**CIP394611.112**	**CIP 694474.16**	**CIP 398190.404**	**CIP 398192.41**	**CIP 392797.22**	**CIP 398190.735**	**CIP 398208.505**
Overall	**Pest Tolerance**	**Tolerant**	**Tolerant**	**Tolerant**	**Intermediate**	**Intermediate**	**Intermediate**	**Intermediate**	**Susceptible**	**Susceptible**	**Susceptible**
Pest names	Seasons	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)
Cutworms	A (2017)	0.49 ± 0.05	0.89 ± 0.09	4.12 ± 9.46	0.32 ± 0.05	1.78 ± 0.26	4.21 ± 0.48	0.67 ± 0.08	1.64 ± 0.21	4.12 ± 0.44	0.93 ± 0.11
	B (2017)	1.89 ± 0.18	0.76 ± 0.07	0.45 ± 0.05	0.67 ± 0.08	1.71 ± 0.24	1.34 ± 0.15	1.56 ± 0.09	1.59 ± 0.22	1.19 ± 0.12	0.45 ± 0.08
	A (2018)	0.44 ± 0.04	1.67 ± 0.17	0.78 ± 0.09	0.43 ± 0.05	0.98 ± 0.14	0.78 ± 0.09	0.82 ± 0.06	1.39 ± 0.18	1.92 ± 0.21	0.81 ± 0.06
	B (2018)	1.34 ± 0.13	1.32 ± 0.12	1.98 ± 0.27	0.87 ± 0.11	0.45 ± 0.08	1.34 ± 0.15	2.34 ± 0.19	2.69 ± 0.35	1.23 ± 0.16	0.78 ± 0.04
	B (2019)	0.98 ±0.09	2.34 ± 0.22	0.55 ± 0.07	0.97 ± 0.12	0.34 ± 0.06	0.45 ± 0.05	1.31 ± 0.18	0.92 ± 0.11	0.88 ±0.05	1.78 ± 0.27
	A (2019)	3.12 ± 0.33	3.43 ± 0.32	1.89 ± 0.21	2.12 ± 0.26	2.44 ± 0.35	3.21 ± 0.39	6.67 ± 0.89	5.45 ± 0.72	7.78 ± 0.93	3.81 ± 0.45
	B (2020)	2.89 ±0.31	3.12 ± 0.28	1.12 ± 0.16	0.89 ± 0.11	0.23 ± 0.04	1.22 ± 0.14	4.93 ± 0.67	5.23 ± 0.69	3.78 ± 0.41	7.43 ± 1.16
	A (2020)	0.45 ± 0.06	1.69 ± 0.19	0.79 ± 0.08	0.48 ± 0.06	0.99 ± 0.17	0.81 ± 0.08	0.89 ± 0.09	1.43 ± 0.19	1.99 ± 0.23	0.88 ± 0.07
	B (2021)	1.35 ± 0.16	1.38 ± 0.11	1.99 ± 0.22	0.87 ± 0.16	0.49 ± 0.09	1.39 ± 0.12	2.39 ± 0.22	2.79 ± 0.41	1.41 ± 0.19	0.74 ± 0.09
	A (2021)	3.16 ± 0.31	3.33 ± 0.31	1.79 ± 0.17	2.17 ± 0.28	2.56 ± 0.39	3.22 ± 0.41	6.87 ± 0.99	5.95 ± 0.55	7.98 ± 0.54	3.91 ± 0.34
Millipedes	A (2017)	1.78 ± 0.18	0.67 ± 0.08	0.34 ± 0.04	0.79 ± 0.09	0.88 ± 0.12	1.23 ± 0.14	2.54 ± 0.32	0.34 ± 0.05	2.54 ± 0.27	0.43 ± 0.02
	B (2017)	1.12 ± 0.13	1.65 ± 0.15	1.83 ± 0.22	0.84 ± 0.11	1.45 ± 0.21	2.72 ± 0.31	3.65 ± 0.46	5.89 ± 0.78	6.23 ± 0.68	4.45 ± 0.68
	A (2018)	1.34 ± 0.14	1.67 ± 0.15	0.68 ± 0.08	1.43 ± 0.18	1.23 ± 0.16	1.53 ± 0.17	0.29 ± 0.04	1.38 ± 0.18	0.89 ± 0.09	0.32 ± 0.07
	B (2018)	1.45 ± 0.15	1.43 ± 0.13	1.67 ± 0.19	0.32 ± 0.04	1.23 ± 0.18	0.54 ± 0.07	2.92 ± 0.37	2.27 ± 0.31	1.43 ± 0.15	0.94 ± 0.16
	B (2019)	0.43 ± 0.05	0.55 ± 0.05	1.44 ± 0.16	1.77 ± 0.22	0.88 ± 0.07	0.99 ± 0.12	0.91 ± 0.11	0.21 ± 0.03	1.43 ± 0.17	1.72 ± 0.26
	A (2019)	0.87 ± 0.10	0.47 ± 0.04	0.67 ± 0.08	0.54 ± 0.07	0.82 ± 0.08	0.67 ± 0.07	1.43 ± 0.18	0.34 ± 0.04	1.49 ± 0.18	1.45 ± 0.22
	B (2020)	1.98 ± 0.21	1.45 ± 0.13	1.78 ± 0.20	0.89 ± 0.12	2.93 ± 0.41	2.12 ± 0.25	2.17 ± 0.27	2.54 ± 0.31	4.34 ± 0.47	2.62 ± 0.34
	A (2020)	1.24 ± 0.10	1.57 ± 0.11	0.58 ± 0.06	1.33 ± 0.13	1.27 ± 0.17	1.57 ± 0.18	0.33 ± 0.08	1.45 ± 0.22	0.92 ± 0.06	0.27 ± 0.09
	B (2021)	1.35 ± 0.16	1.43 ± 0.14	1.77 ± 0.16	0.35 ± 0.07	1.27 ± 0.19	0.57 ± 0.09	2.96 ± 0.43	2.44 ± 0.37	1.67 ± 0.19	0.99 ± 0.12
	A (2021)	0.67 ± 0.12	0.49 ± 0.07	0.69 ± 0.08	0.56 ± 0.08	0.86 ± 0.09	0.69 ± 0.06	1.53 ± 0.16	0.38 ± 0.09	1.69 ± 0.15	1.65 ± 0.28
Nematodes	A (2017)	1.99 ± 0.19	1.34 ± 0.12	1.67 ± 0.19	0.78 ± 0.09	1.78 ± 0.21	0.99 ± 0.11	1.56 ± 0.21	1.76 ± 0.23	1.44 ± 0.16	1.45 ± 0.22
	B (2017)	0.67 ± 0.76	0.71 ± 0.08	1.56 ± 0.17	1.78 ± 0.22	2.23 ± 0.28	1.67 ± 0.19	2.91 ± 0.38	8.91 ± 1.18	2.55 ± 0.27	0.45 ± 0.02
	A (2018)	0.34 ± 0.04	0.43 ± 0.03	0.55 ± 0.06	1.91 ± 0.23	1.45 ± 0.21	0.45 ± 0.05	1.87 ± 0.23	1.56 ± 0.21	0.45 ± 0.06	1.56 ± 0.25
	B (2018)	1.43 ± 0.14	1.65 ± 0.15	0.87 ± 0.09	0.45 ± 0.05	0.89 ± 0.11	0.34 ± 0.03	0.45 ± 0.07	1.44 ± 0.19	1.64 ± 0.17	2.32 ± 0.31
	B (2019)	1.34 ± 0.14	1.34 ± 0.12	1.45 ± 0.17	1.67 ± 0.21	1.23 ± 0.17	3.67 ± 0.42	6.66 ± 0.81	2.69 ± 0.35	7.32 ± 0.79	1.78 ± 0.26
	A (2019)	1.43 ± 0.17	1.34 ± 0.11	2.23 ± 0.24	2.88 ± 0.36	2.45 ± 0.35	3.69 ± 0.39	7.78 ± 0.99	11.45 ± 1.52	8.67 ± 0.94	9.68 ± 0.17
	B (2020)	1.67 ± 0.78	2.89 ± 0.25	0.67 ± 0.08	1.67 ± 0.21	7.77 ± 1.11	2.89 ± 0.22	3.34 ± 0.42	6.92 ± 0.92	4.28 ± 0.46	5.43 ± 0.84
	A (2020)	0.39 ± 0.05	0.48 ± 0.08	0.57 ± 0.08	1.99 ± 0.21	1.48 ± 0.28	0.68 ± 0.07	1.89 ± 0.24	1.57 ± 0.22	0.48 ± 0.09	1.66 ± 0.21
	B (2021)	1.47 ± 0.11	1.68 ± 0.18	0.89 ± 0.04	0.75 ± 0.09	0.99 ± 0.19	0.54 ± 0.09	0.47 ± 0.07	1.48 ± 0.19	1.88± 0.19	2.56 ± 0.38
	A (2021)	1.46 ± 0.18	1.39 ± 0.13	2.25 ± 0.28	2.89 ± 0.36	2.75 ± 0.35	3.99 ± 0.39	7.78 ± 0.91	11.45 ± 1.45	8.67 ± 0.87	9.48 ± 0.18
Ground	A (2017)	1.78 ± 0.18	1.88 ± 0.16	0.56 ± 0.06	1.76 ± 0.22	0.78 ± 0.11	0.45 ± 0.06	0.72 ± 0.09	1.78 ± 0.23	0.98 ± 0.11	0.77 ± 0.12
	B (2017)	0.74 ± 0.08	0.89 ± 0.07	0.56 ± 0.08	0.56 ± 0.08	2.41 ± 0.34	0.64 ± 0.07	4.45 ± 0.57	0.65 ± 0.08	4.11 ± 0.44	0.69 ± 0.13
	A (2018)	0.55 ± 0.07	0.78 ± 0.07	0.81 ± 0.09	1.32 ± 0.17	1.33 ± 0.19	0.61 ± 0.04	1.25 ± 0.16	1.65 ± 0.21	0.53 ± 0.06	1.78 ± 0.28
	B (2018)	1.66 ± 0.16	0.87 ± 0.06	1.56 ± 0.17	1.54 ± 0.19	0.45 ± 0.06	1.12 ± 0.12	1.28 ± 0.17	0.68 ± 0.09	0.92 ± 0.08	0.67 ± 0.15
	B (2019)	1.78 ± 0.19	1.65 ± 0.15	2.61 ± 0.32	2.45 ± 0.31	2.16 ± 0.31	3.65 ± 0.42	4.45 ± 0.57	2.31 ± 0.31	1.49 ± 0.17	2.45 ± 0.38
	A (2019)	0.75 ± 0.06	1.89 ± 0.14	1.45 ± 0.16	0.67 ± 0.08	2.43 ± 0.34	3.41 ± 0.39	4.33 ± 0.55	4.56 ± 0.61	3.56 ± 0.38	2.74 ± 0.43
	B (2020)	1.62 ± 0.15	1.93 ± 0.14	1.55 ± 0.17	2.69 ± 0.34	2.23 ± 0.31	1.49 ± 0.17	1.23 ± 0.16	3.61 ± 0.48	1.71 ± 0.18	1.69 ± 0.26
	A (2020)	1.72 ± 0.18	1.82 ± 0.16	0.57 ± 0.08	1.77 ± 0.2	0.79 ± 0.13	0.67 ± 0.09	0.79 ± 0.011	1.79 ± 0.25	0.99 ± 0.18	0.71 ± 0.11
	B (2021)	0.76 ± 0.04	0.99 ± 0.09	0.51 ± 0.05	0.66 ± 0.08	2.51 ± 0.45	0.74 ± 0.08	8.15 ± 0.87	0.69 ± 0.08	6.12 ± 0.77	0.77 ± 0.15
	A (2021)	0.52 ± 0.04	0.78 ± 0.09	0.89 ± 0.09	2.31 ± 0.16	1.63 ± 0.15	0.69 ± 0.06	2.25 ± 0.15	1.89 ± 0.24	0.583 ± 0.08	1.79 ± 0.28
Red & Black	A (2017)	1.76 ± 0.19	1.67 ± 0.15	1.65 ± 0.18	2.78 ± 0.34	0.87 ± 0.11	1.76 ± 0.21	2.31 ± 0.29	1.87 ± 0.24	0.86 ± 0.09	0.89 ± 0.13
	B (2017)	2.29 ± 0.18	0.87 ± 0.06	2.87 ± 0.32	2.62 ± 0.32	0.67 ± 0.07	2.34 ± 0.27	2.29 ± 0.31	0.77 ± 0.11	0.56 ± 0.04	0.88 ± 0.14
	A (2018)	1.56 ± 0.15	1.32 ± 0.12	0.78 ± 0.08	0.95 ± 0.18	0.77 ± 0.08	0.34 ± 0.04	1.82 ± 0.23	0.69 ± 0.09	7.54 ± 0.91	10.21 ± 1.67
	B (2018)	1.32 ± 0.16	3.27 ± 0.28	1.44 ± 0.17	1.65 ± 0.21	1.55 ± 0.12	1.67 ± 0.19	1.93 ± 0.24	0.88 ± 0.11	2.59 ± 0.28	4.86 ± 0.76
	B (2019)	0.68 ± 0.07	1.58 ± 0.14	1.78 ± 0.21	0.87 ± 0.11	0.68 ± 0.09	0.89 ± 0.11	1.79 ± 0.22	0.81 ± 0.04	0.89 ± 0.05	0.99 ± 0.02

	A (2019)	2.34 ± 0.26	3.76 ± 0.33	4.45 ± 0.48	16.67 ± 2.09	33.78 ± 4.82	22.34 ± 2.61	36.78 ± 4.71	33.55 ± 4.49	19.23 ± 2.09	45.44 ± 6.78
	B (2020)	0.97 ± 0.09	1.27 ± 0.11	3.67 ± 0.41	9.92 ± 1.24	1.76 ± 0.23	7.12 ± 0.82	5.18 ± 0.66	9.21 ± 1.22	3.16 ± 0.25	6.34 ± 0.97
	A (2020)	1.86 ± 0.16	1.36 ± 0.11	0.68 ± 0.07	0.98 ± 0.14	0.74 ± 0.08	0.38 ± 0.04	1.89 ± 0.23	0.99 ± 0.07	7.84 ± 0.94	14.25 ± 1.89
	B (2021)	1.36 ± 0.18	3.29 ± 0.24	1.74 ± 0.16	1.69 ± 0.21	1.59 ± 0.12	1.57 ± 0.19	1.63 ± 0.24	0.89 ± 0.11	2.69 ± 0.22	8.86 ± 1.76
	A (2021)	2.36 ± 0.27	3.78 ± 0.35	4.85 ± 0.98	13.67 ± 1.59	23.76 ± 4.22	12.24 ± 2.61	16.68 ± 4.71	23.55 ± 4.44	29.23 ± 2.09	345.41 ± 6.58
Leafminer	A (2017)	0.77 ± 0.08	0.45 ± 0.03	0.76 ± 0.09	1.76 ± 0.22	1.59 ± 0.22	0.56 ± 0.07	1.92 ± 0.24	1.58 ± 0.22	0.88 ± 0.04	1.87 ± 0.27
	B (2017)	0.87 ± 0.09	0.89 ± 0.06	0.99 ± 0.11	0.89 ± 0.11	2.56 ± 0.36	6.67 ± 0.77	3.67 ± 0.47	8.83 ± 1.17	4.65 ± 0.65	0.84 ± 0.06
	A (2018)	1.79 ± 0.18	1.66 ± 0.14	0.76 ± 0.08	1.45 ± 0.18	0.91 ± 0.12	3.54 ± 0.41	4.34 ± 0.55	2.45 ± 0.32	5.45 ± 0.45	1.56 ± 0.23
	B (2018)	0.76 ± 0.08	0.77 ± 0.09	1.54 ± 0.17	2.54 ± 0.32	0.92 ± 0.14	1.87 ± 0.22	2.67 ± 0.21	0.99 ± 0.04	0.98 ± 0.11	1.34 ± 0.21
	B (2019)	1.67 ± 0.13	1.34 ± 0.13	1.52 ± 0.18	0.88 ± 0.11	1.71 ± 0.24	0.95 ± 0.11	0.96 ± 0.13	1.87 ± 0.23	0.88 ± 0.06	1.23 ± 0.15
	A (2019)	1.78 ± 0.11	0.76 ± 0.08	1.51 ± 0.16	3.39 ± 0.42	2.41 ± 0.34	2.76 ± 0.32	3.54 ± 0.31	3.78 ± 0.03	4.45 ± 0.48	5.45 ± 0.67
	B (2020)	0.76 ± 0.09	2.27 ± 0.21	2.29 ± 0.28	3.33 ± 0.41	1.76 ± 0.23	1.43 ± 0.17	0.78 ± 0.07	1.54 ± 0.21	0.95 ± 0.13	0.66 ± 0.11
	A (2020)	1.71 ± 0.11	0.79 ± 0.08	1.51 ± 0.16	3.39 ± 0.48	2.44 ± 0.34	2.79 ± 0.32	3.44 ± 0.31	3.78 ± 0.05	5.45 ± 0.68	7.45 ± 0.97
	B (2021)	0.78 ± 0.06	2.28 ± 0.28	2.34± 0.28	3.36 ± 0.41	1.88 ± 0.23	1.83 ± 0.17	0.99 ± 0.07	1.04 ± 0.21	0.75 ± 0.13	0.69 ± 0.11
	A (2021)	1.99 ± 0.12	1.68 ± 0.24	0.78 ± 0.08	1.85 ± 0.18	0.98 ± 0.12	3.59 ± 0.41	4.84 ± 0.55	2.95 ± 0.32	5.75 ± 0.45	1.96 ± 0.23
Aphid	A (2017)	7.56 ± 0.77	7.56 ± 0.68	10.56 ± 1.18	12.67 ± 1.58	23.45 ± 3.35	35.98 ± 4.16	17.45 ± 2.23	23.28 ± 3.10	7.93 ± 0.86	34.43 ± 5.29
	B (2017)	2.89 ± 0.29	2.67 ± 0.23	5.53 ± 0.62	6.88 ± 0.89	11.31 ± 1.61	7.87 ± 0.91	12.23 ± 1.61	4.54 ± 0.61	45.93 ± 4.92	9.45 ± 1.46
	A (2018)	7.78 ± 0.78	23.67 ± 2.13	11.45 ± 1.30	45.45 ± 5.71	79.89 ± 11.42	167.4 ± 19.48	178.77 ± 22.87	34.17 ± 4.56	176.45 ± 19.17	145.31 ± 22.56
	B (2018)	9.89 ± 0.99	9.89 ± 0.88	12.78 ± 1.45	33.54 ± 4.19	12.45 ± 1.77	14.43 ± 1.67	16.45 ± 2.11	8.45 ± 1.12	17.41 ± 1.89	18.78 ± 2.88
	B (2019)	11.43 ± 1.19	7.89 ± 0.89	7.78 ± 0.89	67.76 ± 8.47	17.39 ± 2.16	89.78 ± 10.45	12.78 ± 1.67	34.27 ± 4.57	56.16 ± 6.104	76.32 ± 11.76
	A (2019)	0.67 ± 0.07	2.34 ± 0.24	0.97 ± 0.12	12.32 ± 1.54	121.8 ± 17.39	0.99 ± 0.12	49.54 ± 6.35	5.45 ± 0.65	34.17 ± 3.71	67.23 ± 10.98
	B (2020)	3.34 ± 0.54	9.45 ± 0.86	5.86 ± 0.34	12.61 ± 1.58	39.41 ± 5.63	29.87 ± 3.48	18.48 ± 2.36	48.78 ± 6.45	34.19 ± 3.73	23.78 ± 3.78
	A (2020)	4.56 ± 0.77	5.56 ± 0.68	8.57 ± 1.18	14.67 ± 1.68	12.45 ± 3.38	35.92 ± 4.11	18.45 ± 2.27	23.29 ± 3.11	7.98 ± 0.89	38.43 ± 5.59
	B (2021)	2.99 ± 0.39	2.77 ± 0.28	5.73 ± 0.68	6.98 ± 0.69	16.31 ± 1.71	5.87 ± 0.91	11.23 ± 1.61	4.59 ± 0.61	42.93 ± 4.92	9.75 ± 1.49
	A (2021)	0.57 ± 0.07	1.34 ± 0.24	0.67 ± 0.12	8.32 ± 1.54	101.8 ± 17.39	0.91 ± 0.12	41.54 ± 6.35	5.45 ± 0.65	34.17 ± 3.79	67.23 ± 15.98
Whiteflies	A (2017)	0.88 ± 0.09	0.58 ± 0.06	1.78 ± 0.21	3.37 ± 0.42	1.71 ± 0.24	2.89 ± 0.33	7.77 ± 0.99	0.87 ± 0.08	4.65 ± 0.51	5.72 ± 0.89
	B (2017)	0.87 ± 0.08	1.79 ± 0.17	1.89 ± 0.23	2.67 ± 0.33	2.65 ± 0.38	3.49 ± 0.40	4.91 ± 0.62	1.54 ± 0.25	5.54 ± 0.61	1.82 ± 0.28
	A (2018)	0.97 ± 0.12	2.29 ± 0.22	2.45 ± 0.27	3.65 ± 0.45	0.88 ± 0.12	4.78 ± 0.56	4.45 ± 0.57	0.86 ± 0.05	1.78 ± 0.19	0.95 ± 0.04
	B (2018)	0.91 ± 0.15	3.45 ± 0.39	0.42 ± 0.05	1.76 ± 0.22	0.87 ± 0.08	0.66 ± 0.07	5.58 ± 0.71	0.96 ± 0.03	5.39 ± 0.58	0.89 ± 0.08
	B (2019)	0.87 ± 0.06	0.98 ± 0.09	1.76 ± 0.20	5.55 ± 0.69	0.84 ± 0.11	6.58 ± 0.76	1.66 ± 0.21	0.96 ± 0.07	2.78 ± 0.31	9.67 ± 1.56
	A (2019)	2.45 ± 0.26	1.89 ± 0.19	1.89 ± 0.23	2.78 ± 0.34	5.81 ± 0.78	2.69 ± 0.32	2.61 ± 0.33	1.99 ± 0.16	2.48 ± 0.28	3.67 ± 0.51
	B (2020)	1.65 ± 0.23	2.67 ± 0.28	2.34 ± 0.26	8.98 ± 1.17	4.83 ± 0.69	7.43 ± 0.86	6.56 ± 0.84	2.94 ± 0.35	5.92 ± 0.64	4.72 ± 0.76
	A (2020)	0.87 ± 0.09	0.48 ± 0.06	1.779± 0.21	3.47 ± 0.42	1.74 ± 0.24	2.69 ± 0.33	7.79 ± 0.99	0.89 ± 0.08	4.65 ± 0.59	5.88 ± 0.89
	B (2021)	0.67 ± 0.15	2.57 ± 0.22	2.65 ± 0.28	3.69 ± 0.65	0.98 ± 0.17	4.79 ± 0.59	4.58 ± 0.77	0.88 ± 0.08	1.88 ± 0.22	0.98 ± 0.09
	A (2021)	0.95 ± 0.15	3.75 ± 0.38	0.47 ± 0.07	1.77 ± 0.23	0.89 ± 0.03	0.69 ± 0.07	5.68 ± 0.81	0.86 ± 0.03	6.39 ± 0.48	0.99 ± 0.09
Pot tuber	A (2017)	0.76 ± 0.07	8.39 ± 0.98	2.78 ± 0.31	3.83 ± 0.47	1.96 ± 0.28	4.67 ± 0.54	0.85 ± 0.11	1.87 ± 0.23	6.57 ± 0.71	0.96 ± 0.04
	B (2017)	0.99 ± 0.08	0.97 ± 0.06	3.33 ± 0.38	6.37 ± 0.79	0.89 ± 0.13	1.98 ± 0.23	1.75 ± 0.22	0.99 ± 0.03	0.93 ± 0.11	0.97 ± 0.05
	A (2018)	1.54 ± 0.12	3.24 ± 0.43	2.68 ± 0.30	3.63 ± 0.45	12.76 ± 1.82	4.54 ± 0.52	7.78 ± 0.99	1.67 ± 0.13	12.91 ± 1.41	16.43 ± 2.56
	B (2018)	1.67 ± 0.18	3.56 ± 0.41	2.69 ± 0.29	7.76 ± 0.97	8.91 ± 1.27	8.41 ± 0.97	6.43 ± 0.82	7.65 ± 1.03	2.91 ± 0.31	9.92 ± 1.55
	B (2019)	1.76 ± 0.16	1.78 ± 0.12	1.99 ± 0.22	2.78 ± 0.34	1.54 ± 0.22	4.67 ± 0.54	5.87 ± 0.75	1.47 ± 0.18	6.38 ± 0.69	7.86 ± 1.23
	A (2019)	1.98 ± 0.22	1.98 ± 0.21	1.97 ± 0.21	2.38 ± 0.29	2.56 ± 0.36	1.94 ± 0.22	21.67 ± 2.77	2.91 ± 0.35	7.55 ± 0.82	2.48 ± 0.23
	B (2020)	1.78 ± 0.13	2.98 ± 0.29	1.95 ± 0.23	2.67 ± 0.33	3.59 ± 0.51	4.46 ± 0.52	3.91 ± 0.51	5.45 ± 0.76	2.81 ± 0.31	5.62 ± 0.87
	A (2020)	1.44 ± 0.12	3.64 ± 0.43	2.78 ± 0.30	6.63 ± 0.45	17.76 ± 1.82	3.54 ± 0.52	8.78 ± 0.91	2.67 ± 0.16	19.31 ± 1.41	12.43 ± 1.56
	B (2021)	2.67 ± 0.18	2.56 ± 0.41	3.69 ± 0.29	5.76 ± 0.97	7.91 ± 1.27	7.41 ± 0.97	5.43 ± 0.82	9.65 ± 1.03	5.91 ± 0.31	14.92 ± 1.55
	A (2021)	2.98 ± 0.22	5.98 ± 0.21	3.97 ± 0.21	7.38 ± 0.29	5.56 ± 0.36	3.94 ± 0.22	41.67 ± 2.72	4.91 ± 0.38	8.55 ± 0.85	1.49 ± 0.28
Thrips	A (2017)	0.67 ± 0.07	0.99 ± 0.08	0.78 ± 0.09	0.89 ± 0.11	0.94 ± 0.14	0.96 ± 0.12	0.95 ± 0.12	0.87 ± 0.11	1.65 ± 0.45	0.88 ± 0.07
	B (2017)	3.66 ± 0.38	4.59 ± 0.56	6.68 ± 0.71	2.55 ± 0.32	5.97 ± 0.86	12.45 ± 1.45	17.12 ± 2.21	15.78 ± 2.14	8.91 ± 0.97	9.56 ± 1.46
	A (2018)	14.65 ± 1.45	11.12 ± 1.56	16.17 ± 1.78	23.76 ± 2.97	67.78 ± 9.67	34.56 ± 4.01	78.16 ± 10.07	56.55 ± 7.98	123.56 ± 14.65	167.4 ± 24.56
	B (2018)	1.77 ± 0.19	0.79 ± 0.09	3.41 ± 0.37	4.78 ± 0.61	6.45 ± 0.91	8.76 ± 1.01	9.19 ± 1.18	43.47 ± 6.78	12.38 ± 1.34	34.35 ± 5.67
	B (2019)	1.72 ± 0.18	6.92 ± 0.67	12.34 ± 1.43	23.34 ± 2.99	23.39 ± 3.34	56.43 ± 6.56	66.21 ± 5.34	121.43 ±18.67	54.43 ± 5.87	33.86 ± 5.76
	A (2019)	2.76 ± 0.54	3.78 ± 0.37	34.67 ± 3.88	56.65 ± 7.09	4.43 ± 0.41	55.57 ± 6.46	66.25 ± 5.98	89.21 ± 11.68	77.78 ± 8.54	12.76 ± 1.96
	B (2020)	2.61 ± 0.22	2.32 ± 0.19	3.45 ± 0.39	1.39 ± 0.17	3.44 ± 0.34	4.89 ± 0.56	5.56 ± 0.21	3.97 ± 0.54	1.98 ± 0.21	1.92 ± 0.34
	A (2020)	0.47 ± 0.07	0.91 ± 0.08	0.48 ± 0.09	0.79 ± 0.11	0.44 ± 0.14	0.76 ± 0.12	0.85 ± 0.12	0.89 ± 0.11	1.69 ± 0.45	0.98 ± 0.07
	B (2021)	4.66 ± 0.38	7.59 ± 0.56	5.68 ± 0.71	4.55 ± 0.36	6.97 ± 0.88	19.45 ± 1.45	22.12 ± 2.26	25.78 ± 6.14	5.91 ± 0.97	7.56 ± 1.46
	A (2021)	1.76 ± 0.54	2.78 ± 0.37	38.67 ± 3.88	66.65 ± 7.09	7.43 ± 0.41	58.57 ± 6.46	69.25 ± 5.98	99.21 ± 11.68	79.78 ± 8.54	19.76 ± 1.96
Leafhoppers	A (2017)	0.87 ± 0.09	0.77 ± 0.09	0.87 ± 0.09	0.99 ± 0.12	0.98 ± 0.12	0.94 ± 0.11	0.78 ± 0.07	0.67 ± 0.07	0.78 ± 0.06	0.79 ± 0.09
	B (2017)	0.76 ± 0.07	0.99 ± 0.07	0.98 ± 0.11	0.45 ± 0.05	0.89 ± 0.11	0.91 ± 0.08	0.92 ± 0.11	0.88 ± 0.06	0.95 ± 0.03	0.93 ±0.03
	A (2018)	0.87 ± 0.06	1.98 ± 0.19	1.69 ± 0.19	2.88 ± 0.36	2.78 ± 0.39	3.78 ± 0.43	8.88 ± 1.14	2.55 ± 0.34	0.98 ± 0.06	1.81 ± 0.16
	B (2018)	1.67 ± 0.17	1.67 ± 0.16	0.87 ± 0.09	0.98 ± 0.13	2.54 ± 0.31	0.79 ± 0.09	3.85 ± 0.45	4.56 ± 0.61	0.97 ± 0.04	0.85 ± 0.04
	B (2019)	1.87 ± 0.16	7.87 ± 0.78	12.54 ± 1.41	5.66 ± 0.70	8.56 ± 1.22	1.43 ± 0.16	2.78 ± 0.36	34.43 ± 4.56	4.79 ± 0.56	6.95 ± 1.03
	A (2019)	0.87 ± 0.06	0.92 ± 0.08	0.94 ± 0.12	1.87 ± 0.23	0.99 ± 0.09	2.92 ± 0.33	3.91 ± 0.51	4.78 ± 0.56	0.92 ± 0.05	0.94 ± 0.04
	B (2020)	0.88 ± 0.09	0.97 ± 0.06	12.68 ± 1.42	23.21 ± 2.87	0.87 ± 0.11	6.78 ± 0.78	7.65 ± 0.98	37.87 ± 5.98	8.98 ± 0.97	27.69 ± 4.12
	A (2020)	0.85 ± 0.06	1.91 ± 0.19	1.69 ± 0.22	2.89 ± 0.36	2.88 ± 0.39	3.78 ± 0.73	7.88 ± 1.18	2.59 ± 0.35	0.99 ± 0.08	1.84 ± 0.18
	B (2021)	1.78 ± 0.17	1.71 ± 0.16	0.67 ± 0.06	0.99 ± 0.17	2.74 ± 0.61	0.99 ± 0.05	3.88 ± 0.45	4.96 ± 0.68	0.94 ± 0.05	0.89 ± 0.06
	A (2021)	0.89 ± 0.06	0.99 ± 0.09	0.98 ± 0.15	1.97 ± 0.26	0.89 ± 0.06	2.99 ± 0.33	3.99 ± 0.51	4.71 ± 0.56	0.52 ± 0.05	0.64 ± 0.04

Leaf Beetles	A (2017)	1.76 ± 0.15	1.78 ± 0.16	1.34 ± 0.15	2.87 ± 0.36	1.56 ± 0.22	3.43 ± 0.39	4.87 ± 0.62	0.99 ± 0.06	2.99 ± 0.32	1.54 ± 0.23
	B (2017)	0.77 ± 0.05	0.99 ± 0.07	2.67 ± 0.31	2.87 ± 0.39	0.95 ± 0.14	2.89 ± 0.33	2.66 ± 0.34	0.97 ± 0.12	2.88 ± 0.45	0.98 ± 0.02
	A (2018)	1.45 ± 0.06	0.87 ± 0.08	2.55 ± 0.28	1.57 ± 0.19	3.98 ± 0.56	4.67 ± 0.54	10.98 ± 1.54	23.31 ± 3.14	0.87 ± 0.09	3.67 ± 0.43
	B (2018)	0.79 ± 0.04	0.79 ± 0.08	0.98 ± 0.11	0.93 ± 0.12	0.98 ± 0.14	0.89 ± 0.11	0.87 ± 0.11	0.87 ± 0.05	0.84 ± 0.03	1.51 ± 0.23
	B (2019)	0.98 ± 0.08	1.53 ± 0.15	1.88 ± 0.21	1.89 ± 0.24	2.69 ± 0.39	1.69 ± 0.19	1.72 ± 0.22	2.64 ± 0.45	3.62 ± 0.39	3.34 ± 0.51
	A (2019)	1.87 ± 0.19	0.99 ± 0.06	0.88 ± 0.09	1.56 ± 0.19	0.45 ± 0.06	2.87 ± 0.33	3.66 ± 0.46	2.67 ± 0.34	0.94 ± 0.12	0.95 ± 0.04
	B (2020)	0.88 ± 0.06	0.89 ± 0.09	1.78 ± 0.20	1.87 ± 0.24	0.99 ± 0.14	1.67 ± 0.19	1.94 ± 0.17	2.49 ± 0.33	2.59 ± 0.28	0.94 ± 0.07
	A (2020)	1.48 ± 0.05	0.88 ± 0.08	2.85 ± 0.28	1.87 ± 0.19	6.98 ± 0.56	7.67 ± 0.54	18.98 ± 1.54	33.31 ± 3.14	0.67 ± 0.09	8.67 ± 0.43
	B (2021)	0.71 ± 0.04	0.75 ± 0.08	0.88 ± 0.11	0.98 ± 0.18	0.95 ± 0.14	0.84 ± 0.15	0.89 ± 0.17	0.87 ± 0.09	0.84 ± 0.09	1.51 ± 0.28
	A (2021)	1.89 ± 0.19	0.99 ± 0.09	0.87 ± 0.09	1.76 ± 0.19	0.55 ± 0.08	2.89 ± 0.39	3.69 ± 0.46	2.87 ± 0.34	0.74 ± 0.12	0.85 ± 0.04
Mites	A (2017)	0.99 ± 0.09	0.89 ± 0.09	0.79 ± 0.09	0.98 ± 0.12	0.76 ± 0.09	0.99 ± 0.11	0.98 ± 0.03	0.79 ± 0.11	0.87 ± 0.09	0.88 ± 0.03
	B (2017)	1.54 ± 0.18	0.83 ± 0.07	1.76 ± 0.20	1.78 ± 0.22	0.98 ± 0.11	1.62 ± 0.18	1.66 ± 0.11	1.87 ± 0.24	0.99 ± 0.06	0.79 ± 0.07
	A (2018)	1.54 ± 0.18	1.76 ± 0.16	2.59 ± 0.28	1.78 ± 0.25	1.65 ± 0.23	1.85 ± 0.21	1.87 ± 0.13	2.56 ± 0.45	1.66 ± 0.23	1.78 ± 1.27
	B (2018)	1.66 ± 0.15	2.89 ± 0.27	2.88 ± 0.32	3.54 ± 0.44	3.78 ± 0.45	0.78 ± 0.09	0.89 ± 0.14	1.76 ± 0.24	0.87 ± 0.06	0.99 ± 0.06
	B (2019)	0.89 ± 0.09	0.87 ± 0.07	1.89 ± 0.21	1.34 ± 0.17	0.69 ± 0.09	1.45 ± 0.16	2.76 ± 0.35	0.89 ± 0.08	0.98 ± 0.03	0.88 ± 0.06
	A (2019)	1.65 ± 0.18	1.89 ± 0.17	0.88 ± 0.09	0.99 ± 0.12	1.88 ± 0.25	0.98 ± 0.05	2.34 ± 0.18	1.75 ± 0.24	2.98 ± 0.32	1.65 ± 0.25
	B (2020)	2.77 ± 0.29	1.88 ± 0.16	0.98 ± 0.11	0.88 ± 0.11	2.76 ± 0.39	0.86 ± 0.01	1.43 ± 0.16	1.85 ± 0.21	0.79 ± 0.06	0.87 ± 0.05
	A (2020)	1.04 ± 0.18	1.36 ± 0.16	1.59 ± 0.28	1.48 ± 0.28	1.79 ± 0.26	1.89 ± 0.26	1.97 ± 0.15	2.86 ± 0.48	1.69 ± 0.26	1.88 ± 1.47
	B (2021)	1.68 ± 0.17	3.89 ± 0.29	5.88 ± 1.32	4.54 ± 0.47	3.88 ± 0.49	0.79 ± 0.06	0.87 ± 0.18	1.79 ± 0.26	0.89 ± 0.8	0.93 ± 0.07
	A (2021)	1.62 ± 0.18	1.59 ± 0.17	0.98 ± 0.06	0.91 ± 0.18	1.89 ± 0.35	0.99 ± 0.08	2.38 ± 0.28	1.85 ± 0.26	2.99 ± 0.36	1.69 ± 0.28
Grillon	A (2017)	0.78 ± 0.05	0.79 ± 0.09	0.76 ± 0.08	0.87 ± 0.11	0.88 ± 0.12	0.98 ± 0.07	0.99 ± 0.11	0.89 ± 0.06	0.69 ± 0.07	0.87 ± 0.02
	B (2017)	0.89 ± 0.09	1.28 ± 0.13	0.98 ± 0.12	0.87 ± 0.13	1.54 ± 0.22	0.89 ± 0.04	0.97 ± 0.18	0.87 ± 0.08	0.93 ± 0.08	0.91 ± 0.05
	A (2018)	1.77 ± 0.19	0.78 ± 0.08	1.27 ± 0.14	1.45 ± 0.19	4.89 ± 0.69	1.78 ± 0.21	2.89 ± 0.38	0.85 ± 0.02	0.96 ± 0.06	4.78 ± 0.48
	B (2018)	2.76 ± 0.29	0.79 ± 0.06	0.79 ± 0.08	2.87 ± 0.34	3.67 ± 0.52	3.78 ± 0.34	4.89 ± 0.62	0.98 ± 0.05	0.96 ± 0.04	0.89 ± 0.07
	B (2019)	0.87 ± 0.08	0.88 ± 0.07	2.56 ± 0.28	1.85 ± 0.23	5.43 ± 0.77	1.98 ± 0.23	0.88 ± 0.11	0.99 ± 0.07	0.87 ± 0.09	0.97 ± 0.08
	A (2019)	4.76 ± 0.56	1.67 ± 0.14	0.78 ± 0.08	0.96 ± 0.12	1.23 ± 0.18	2.56 ± 0.29	3.54 ± 0.45	0.05 ± 0.007	4.34 ± 0.32	5.54 ± 0.97
	B (2020)	2.98 ± 0.32	2.35 ± 0.19	1.34 ± 0.14	3.43 ± 0.43	3.98 ± 0.56	3.88 ± 0.45	2.59 ± 0.33	1.65 ± 0.22	2.54 ± 0.27	2.56 ± 0.39
	A (2020)	0.75 ± 0.05	0.69 ± 0.09	0.66 ± 0.08	0.67 ± 0.11	0.58 ± 0.12	0.88 ± 0.07	0.89 ± 0.11	0.89 ± 0.08	0.69 ± 0.05	0.89 ± 0.06
	B (2021)	0.89 ± 0.05	1.48 ± 0.16	0.91 ± 0.16	0.88 ± 0.16	1.58 ± 0.26	0.89 ± 0.08	0.91 ± 0.19	0.82 ± 0.08	0.95 ± 0.08	0.97 ± 0.05
	A (2021)	1.75 ± 0.19	0.79 ± 0.08	1.29 ± 0.14	1.85 ± 0.19	4.89 ± 089	1.88 ± 0.21	1.89 ± 0.38	0.95 ± 0.07	0.99 ± 0.08	4.88 ± 0.88
Criquets	A (2017)	0.78 ± 0.09	0.67 ± 0.06	0.87 ± 0.09	0.78 ± 0.09	0.87 ± 0.12	0.98 ± 0.11	0.99 ± 0.09	0.98 ± 0.02	0.79 ± 0.08	0.87 ± 0.06
	B (2017)	0.99 ± 0.09	1.78 ± 0.15	1.87 ± 0.21	1.76 ± 0.22	1.54 ± 0.22	1.47 ± 0.17	1.92 ± 0.16	0.98 ± 0.05	1.45 ± 0.16	0.69 ± 0.03
	A (2018)	0.96 ± 0.07	2.54 ± 0.22	1.56 ± 0.17	3.79 ± 0.48	1.43 ± 0.21	2.98 ± 0.34	0.98 ± 0.13	3.45 ± 0.23	0.78 ± 0.08	1.78 ± 0.65
	B (2018)	0.87 ± 0.06	0.78 ± 0.06	2.83 ± 0.31	3.77 ± 0.48	0.89 ± 0.12	1.99 ± 0.23	3.56 ± 0.45	1.43 ± 0.19	3.16 ± 0.34	3.21 ± 0.49
	B (2019)	1.54 ± 0.17	5.78 ± 0.59	1.34 ± 0.14	1.66 ± 0.21	2.45 ± 0.35	1.99 ± 0.21	3.54 ± 0.46	4.58 ± 0.61	4.13 ± 0.47	5.24 ± 0.98
	A (2019)	1.78 ±-0.16	2.89 ± 0.25	1.45 ± 0.16	1.78 ± 0.22	4.98 ± 0.71	1.78 ± 0.21	1.87 ± 0.24	7.67 ± 1.06	1.67 ± 0.19	5.65 ± 0.78
	B (2020)	1.98 ± 0.21	1.95 ± 0.16	1.66 ± 0.18	2.67 ± 0.33	1.76 ± 0.25	3.88 ± 0.45	4.54 ± 0.58	1.59 ± 0.21	5.43 ± 0.59	1.87 ± 0.23
	A (2020)	0.95 ± 0.08	2.59 ± 0.25	1.86 ± 0.17	4.79 ± 0.48	2.43 ± 0.22	2.91 ± 0.64	0.99 ± 0.13	3.65 ± 0.28	0.79 ± 0.07	1.71 ± 0.68
	B (2021)	0.88 ± 0.06	0.79 ± 0.08	2.83 ± 0.33	3.76 ± 0.48	0.99 ± 0.15	1.99 ± 0.28	3.59 ± 0.45	1.73 ± 0.19	4.16 ± 1.34	2.21 ± 0.59
	A (2021)	1.98 ±-0.16	3.89 ± 0.25	2.45 ± 0.16	3.78 ± 0.22	6.98 ± 0.76	1.78 ± 0.71	1.97 ± 0.74	9.67 ± 1.08	1.97 ± 0.19	4.65 ± 0.79
Lady*	A (2017)	3.45 ± 0.36	11.33 ± 1.09	3.56 ± 0.39	0.89 ± 0.11	6.67 ± 0.96	5.67 ± 0.65	8.81 ± 1.05	3.78 ± 0.51	8.13 ± 0.56	11.35 ± 1.76
	B (2017)	8.11 ± 0.89	6.76 ± 0.73	6.76 ± 0.75	7.77 ± 0.97	7.71 ± 1.11	9.87 ± 1.14	0.88 ± 0.06	9.99 ± 1.45	4.76 ± 0.54	5.39 ± 0.82
	A (2018)	7.54 ± 0.78	5.78 ± 0.52	14.71 ± 1.63	12.12 ± 1.51	19.76 ± 2.92	22.65 ± 2.63	2.76 ± 0.36	8.54 ± 1.31	23.47± 2.67	4.78 ± 0.73
	B (2018)	24.78 ± 2.78	5.35 ± 0.48	7.45 ± 0.82	17.14 ± 2.15	28.98 ± 4.14	35.07 ± 4.08	4.54 ± 0.68	5.96 ± 0.79	7.98 ± 0.98	2.87 ± 0.44
	B (2019)	23.11 ± 2.87	7.65 ± 0.78	17.47 ± 1.94	17.18 ± 2.13	3.79 ± 0.54	3.65 ± 0.42	3.47 ± 0.44	2.96 ± 0.43	8.67 ± 0.67	5.87 ± 0.87
	A (2019)	15.65 ± 1.67	12.87 ± 1.24	18.78 ± 2.08	13.26 ± 1.78	13.98 ± 1.99	6.77 ± 0.78	7.78 ± 0.99	5.67 ± 0.74	8.45 ± 0.91	9.95 ± 1.56
	B (2020)	15.17 ± 1.62	13.9 ± 10.45	12.83 ± 1.43	13.29 ± 1.72	14.93 ± 2.12	24.45 ± 2.13	5.89 ± 0.75	2.65 ± 0.34	6.65 ± 0.56	7.83 ± 1.23
	A (2020)	17.54 ± 0.72	15.78 ± 0.52	18.71 ± 1.63	12.12 ± 1.71	39.76 ± 2.92	32.65 ± 2.93	4.76 ± 0.16	6.54 ± 2.31	43.47± 2.87	6.78 ± 0.83
	B (2021)	34.78 ± 3.78	6.35 ± 0.38	8.56 ± 0.82	23.14 ± 2.15	22.98 ± 4.14	45.07 ± 3.08	6.54 ± 0.78	8.96 ± 0.79	8.98 ± 0.98	4.87 ± 0.49
	A (2021)	19.65 ± 1.67	16.87 ± 2.24	28.78 ± 4.08	43.26 ± 4.78	33.98 ± 5.99	8.77 ± 0.78	9.78 ± 0.91	5.67 ± 0.74	6.49 ± 0.91	8.95 ± 1.26

Root Nematodes (*Meloidogyne* spp, *Pratylenchus* spp**.), Cutworms** (*Agrotis ipsilon* Hufnagel 1776, *Agrotis segetum* Denis & Schiffermüller 1775) (Lepidoptera: Noctuidae**), Ground=**White Grubs larvae infestation (*Melolonthini* sp & *Anomala* sp., Coleoptera:Scarabeidae) , **Leafminer fly** (*Liriomyza huidobrensis*)., **Aphid species** (*Aphis gossypii, Myzus persicae, Aphis fabae*)., **Whiteflies** (*Bemisia tabaci* Gennadius 1989), (Homoptera: Aleyrodidae)., **Pot tuber**=**Potato tuber moth** (*Phthorimaeae operculella*)., **Thrips** (Frankliniella occidentalis Pergande), (Thysanoptera, Thripidae)., **Potato Leafhoppers (***Empoasca fabae* Harris 1841 (Hemiptera: Cicadellidae), **Leaf Beetles (** *Diabrotica viridula* Fabricius, (Coleoptera: Chrysomelidae)., **spider Mites,** *Tetranychus urticae* C. L. Koch, (Arachnidae: Trombidiformis, Tarsonemidae), **Grillon** (*Brachytrupus membranaceus*)., **Criquets** (Gryllolodaptere**).,** **Lady*** = **Lady beeles** (Coccinnelidae)= this is not a pest but a predator(natural enemy)

Aa

Table-6: Incidence (%) and severity score of common bacterial, fungal and viral diseases on different potato clones at Lwiro Research center. *The data are means of several cropping seasons (2017A, 2017B, 2018A, 2018B, 2019B, 2019A, 2020A,2020B, 2021A, 2021B).*

	Clones	CIP 39337158	CIP 394611.112	CIP 398190.404	CIP 398192.41	CIP 398190.735	CIP 398208.505	CIP 398202.704	CIP 694474.16	CIP Shangi Mini	CIP 392797.22
	Disease assessment	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)	Mean ($\bar{x}$±SE)
Potato viruses	Incidence (%)	1.43 ± 0.18	1.34 ± 0.15	3.12 ± 0.44	4.12 ± 038	2.12 ± 0.24	1.96 ± 0.25	3.67 ± 0.62	4.12 ± 0.74	3.96 ± 0.84	4.54 ± 0.52
	Severity (1-5)	1.34 ± 0.17	1.32 ± 0.14	1.09 ± 0.16	2.12 ± 0.19	1.45 ± 0.16	1.99 ± 0.26	2.34 ± 0.39	1.43 ± 0.25	1.23 ± 0.26	1.11 ± 0.13
Bacterial wilt	Incidence (%)	6.45 ± 0.81	10.78 ± 1.20	7.98 ± 1.14	5.89 ± 0.53	4.89 ± 0.56	7.45 ± 0.95	6.56 ± 1.09	3.34 ± 0.59	1.76 ± 0.37	2.34 ± 0.27
	Severity (1-5)	2.45 ± 0.31	2.14 ± 0.24	2.12 ± 0.31	2.19 ± 0.19	2.13 ±0.24	2.65 ± 0.34	1.79 ± 0.30	1.04 ± 0.18	0.89 ± 0.19	0.79 ± 0.09
Late Blight	Incidence (%)	4.45 ± 0.56	12.56 ± 1.40	7.89 ± 1.13	15.12 ± 1.38	1.99 ± 0.23	2.56 ± 0.32	5.78 ± 0.97	5.89 ± 1.06	1.89 ± 0.41	3.89 ± 0.45
	Severity (1-5)	2.78 ± 0.35	2.75 ± 0.31	2.56 ± 0.37	1.88 ± 0.17	1.45 ± 0.76	1.54 ± 0.19	1.12 ± 0.17	1.03 ± 0.18	1.13 ± 0.24	0.95 ± 0.11
Early Blight	Incidence (%)	0.89 ± 0.12	1.45 ± 0.17	2.56 ± 0.36	3.78 ± 0.34	2.12 ± 0.24	1.66 ± 0.21	2.99 ± 0.51	1.78 ± 0.31	3.32 ± 0.71	2.23 ± 0.25
	Severity (1-5)	1.11 ± 0.14	1.45 ± 0.16	0.89 ± 0.12	1.45 ± 0.13	0.78 ± 0.09	1.32 ± 0.17	0.99 ± 0.16	0.79 ± 0.14	0.81 ± 0.17	0.87 ± 0.11
Dry Root Rot	Incidence (%)	0.56 ± 0.07	0.45 ± 0.05	0.78 ± 0.11	0.34 ± 0.03	0.89 ± 0.11	2.45 ± 0.31	1.78 ± 0.29	1.89 ± 0.33	2.17 ± 0.46	1.76 ± 0.21
	Severity (1-5)	1.67 ± 0.21	1.78 ± 0.19	1.34 ± 0.19	2.11 ± 0.19	1.32 ± 0.15	1.76 ± 0.22	1.11 ± 0.18	1.43 ± 0.25	1.14 ± 0.24	1.16 ± 0.14
Common Scab	Incidence (%)	0.34 ± 0.04	0.78 ± 0.08	0.88 ± 0.13	0.44 ± 0.04	0.32 ± 0.03	0.31 ± 0.04	0.39 ± 0.06	0.41 ± 0.07	0.53 ±0.11	0.48 ± 0.06
	Severity (1-5)	1.11 ± 0.14	1.09 ± 0.12	1.07 ± 0.15	1.19 ± 0.11	1.43 ± 0.16	1.87 ± 0.24	1.13 ± 0.18	1.06 ± 0.18	1.07 ±0.22	1.27 ± 0.14
Stem Canker	Incidence (%)	0.12 ± 0.02	0.34 ± 0.03	0.41 ± 0.05	0.22 ± 0.02	0.91 ± 0.12	0.18 ± 0.02	0.22 ± 0.04	0.15 ± 0.02	0.16 ±0.03	0.11 ± 0.02
	Severity (1-5)	1.23 ± 0.16	1.76 ± 0.19	1.98 ± 0.28	1.99 ± 0.18	1.42 ± 0.17	1.32 ± 0.17	1.23 ± 0.21	1.19 ± 0.21	1.13 ± 0.24	1.06 ± 0.12
Stem Rot	Incidence (%)	0.08 ± 0.01	0.19 ± 0.02	0.78 ± 0.11	0.11 ± 0.01	0.56 ± 0.07	0.12 ± 0.02	0.17 ± 0.03	0.45 ± 0.08	0.11 ± 0.23	0.09 ± 0.02
	Severity (1-5)	1.56 ± 0.19	1.43 ± 0.16	1.23 ± 0.18	1.43 ± 0.13	1.21 ± 0.15	1.24 ± 0.16	1.31 ± 0.22	1.26 ± 0.22	1.16 ± 0.24	1.09 ± 0.12
Powdery	Incidence (%)	0.11 ± 0.02	0.34 ± 0.04	0.67 ± 0.09	0.69 ± 0.06	1.43 ± 0.17	1.67 ± 0.21	0.45 ± 0.08	0.65 ± 0.12	0.52 ± 0.11	0.34 ± 0.04
	Severity (1-5)	2.12 ± 0.27	2.23 ± 0.25	2.45 ± 0.35	2.54 ±0.23	2.76 ± 0.32	1.67 ± 0.23	1.34 ± 0.22	1.23 ± 0.22	1.13 ± 0.24	1.07 ± 0.13
	Overall rating	Resistant	Susceptible	Intermediate	Susceptible	Intermediate	Susceptible	Intermediate	Resistant	Resistant	Resistant

Potato viruses (**PVX=**Potato virus X, **PVY**=Potato virus Y**, PLRV**=Potato leafroll virus), **Bacterial wilt** (*Ralstonia solanacearum*), *Late Blight* (*Phytophthora infestans***), Early Blight** (*Alternaria solani*), **Dry Root Rot & Wilt** (*Fusarium* spp.), **Common Scab** (*Streptomyces scabies*), **Stem Canker and Black Scurf** (*Rhizoctonia solani*), **Stem Rot** (*Sclerotium rolfsii*), **Powdery Mildew** (*Erysiphe cichoracearum*)