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Smallholder Farmers' Understanding, Disease Incidences and Management Strategies for Late Blight of Tomato in Northern Tanzania

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Abstract: ***Survey was conducted to 50 farmers and their field close to mount Meru using the Snowball approach; to assess farmers' understanding of late blight disease caused by the pathogen Phytophthora infestans (Mont.) de Bary, disease incidences and management strategies. 97% of farmers are familiar with Late blight disease, but some confuse stem symptoms with damping off diseases. Late blight symptoms in the field were observed at Mbuguni Ngarenanyuki and Himo areas, which is about 30 to 40% of the fields visited. Incidences were reported to be higher at high altitude areas (Akeri) close to mountain than low altitude areas (Moivaro). High altitude areas of Tanzanian highlands are more affected by Late blight than low altitudes. It was also observed that, wilting diseases are more serious than Late blight in the low altitude areas (Moivaro). 44% of farmers from surveyed areas reported to experience high disease pressure between April to June. 55% of farmers prefer to grow late blight susceptible tomato variety Tanya, which we attributed to its shelf life, oval shape and being determinate. Farmers apply different types of chemical sprays to tackle late blight, with Ebony M72 (Mancozeb 640g/Kg + Metalaxyl 80g/Kg) being the most common and the cheapest in the market. Late blight is still a challenge with farmers complain about costs of control measures. Farmers agree that late blight management strategies which will reduce or remove pesticides use will be valuable. This survey gives an insight of farmers' perception and curre nt late blight situation hence vital for planning management strategies to both agrochemical dealers and tomato breeders,***

Keywords: Late blight disease, Phytophthora infestans, Snowball approach, Mancozeb, Metalaxyl.

1. Introduction

Late blight disease is caused by the pathogen *Phytophthora infestans* (Mont.) de Bary, which is considered to be most destructive plant pathogen ever. Late blight is among the most destructive disease of potato and tomato worldwide [1]. *P. infestans* is famous as the causal of the Great Irish Famine in 19th century that resulted in starvation, death and migration of millions of Irish people to the United States [2]. Yield losses due to late blight are estimated to be $6.7 billion on an annual basis worldwide [2]. The yield losses are of massive contribution to hunger and starvation [2]. These yield losses have great impact also on the livelihood of smallholder farmers in developing countries [1], [3]. Late blight could be particularly very destructive in the highland tropics including those of Africa, when tomato and potatoes are grown yearly round [4].

P. infestans pathogen infects mainly solanaceous plants [5, 6]. It has been reported for several solanaceous plants include; *Solanum lycopersicum* (Tomatoes), *Nicotiana* spp, *Solanum nigrum* (Black nightshade), and *Solanum tuberosum* (Potato) [6]. However, all *P. infestans* isolates are pathogenic to potato worldwide but not all isolates infect tomato [7], [8]. In that regard, there is host specialization ranging from aggressive to nonaggressive among isolates. The aggressiveness to tomato is believed to be recently acquired trait [9]. It is now known that some potato strains behave differently from tomato strains when inoculated onto tomato plants [5].

In Tanzania, tomato is among the most important horticultural crops with total yield of about 4.2 tones / ha. It is grown by almost all smallholder farmers in northern and southern highlands of the country due to favorable altitude, climate and sufficient rainfall [10]. In northern part particularly Arusha, the yearly monthly average temperature is around 19^0C with daily minimum temperature of about 14^0C. Moreover, the annual precipitation is 1148mm and water vapor pressure of around 16% [11]. Tomato production is hindered by several reasons including diseases [10]. Late blight is among oomycetes diseases affecting tomato production worldwide. The management of blight disease all over the world including Tanzania involves; cultural practices, chemical management strategies and resistant tomato cultivars. Cultural practices can be achieved by the use of disease free plant materials, certified seeds, and crop rotation as well as sanitation measures [10]. Crop rotation involve two or three years of non-host crops. However, crop rotation in Tanzania is not very well planned except for commercial vegetable farmers around Arusha with larger plots, who rotate tomato, cabbage, cauliflower eggplants etc. [Personal communication between Sabrina and Agbicodo at Afrisem, October. 2010]. Integrative cultural control strategies are important to improve *P. infestans* management strategies in Tanzania.

The application of synthetic fungicides is a major and promising management strategy to date. It is still believed to be most important even when other measures are taken. Tomato ranked the first in terms of fungicides application in Tanzania [12]. Sherf and Macnab (1986) reported that, sprays of metalaxyl once or twice per week can reduce the late blight disease and consequently reduce yield loss by increasing fruit numbers. There are also applications of combined products in order to overcome the challenges of blight, including Ridomil (metalaxyl + mancozeb) (Maerere et al. 2006). These combinations of products have been

proved effective against late blight in different places including Tanzania (Mpina et al. unpublished report). However, excessive use of fungicides and adulterations has led to the increase in health and environmental concerns [12]. Furthermore, *P. infestans* reported to have shown resistance to metalaxyl in other parts of the world including Morocco. Therefore, the use of resistant tomato cultivars remains the only late blight management option, which is economically and environmentally friendly [13].

In this study we focused on understanding the awareness of tomato farmers around Mount Meru (Akeri, Kwaugolo, Kikwe, Moivaro, Mbuguni, Ngarenanyuki, and some places in Kilimanjaro areas (Sanya juu and Himo) particularly in low and high attitude. The survey enabled to assess the incidences of disease mainly late blight in the farmer's field. We also extracted more information about disease incidences as well as late blight management strategies used.

2. Materials and Methods

Field survey was conducted to farmers' field around selected tomato growing villages with low and high elevation close to mount Meru (Fig. 2). This is to compare late blight incidences. The villages namely; Akeri (high altitude) and in low altitude are; Moivaro, Kwaugolo, Kikwe, Mbuguni, Ngarenanyuki and Sanya Juu were visited. To assess the incidences of late blight in these villages, farmers' fields were visited and simple estimates were made for incidences in their tomato field. In order to reach farmers, we used snow ball approach with assumption that, farmers know each other. Moreover, more information on the incidences of late blight and the management practices used by farmers was extracted from particular farmers by using unstructured questionnaire. Late blight infested leaves; stem and fruits were collected in plastic bags according to instructions given by Rijk Zwaan expert, for late blight pathogen isolate identification.

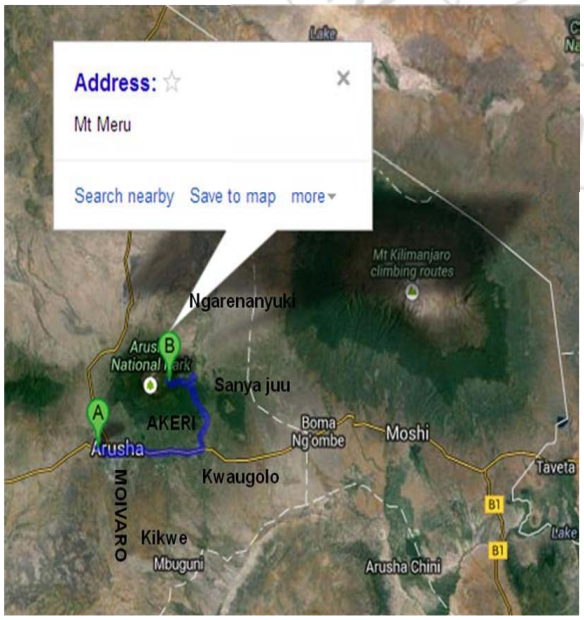

Figure 1: Survey to farmers' field. A map showing the surveyed area around Mount Meru. The locations of some villages (Black in color) are not to scale.

3. Results and Discussion

3.1 Late blight disease incidences differ and still a serious problem in the tomato growing areas.

Survey was conducted in the tomato growing villages close to Mount Meru area. This survey considered elevations (low and high altitude) to compare the incidences of the disease. 25 farmers were visited in their respective tomato fields.

The thorough evaluation of their field for late blight symptoms were done and rough estimation of the incidences were done when infestation was observed. This evaluation was followed by open discussion about disease challenges facing them particularly late blight throughout tomato growing lifetime Fig.2 (A). During the discussion, we extracted more information by using questionnaire. The questions include how long a particular farmer is in tomato cultivation, number of growing times per year, their familiarity with the late blight disease, management strategies, their general take about the problem etc. Pictures of late blight symptoms Fig.2 (B, C, D and E) were shown to farmer, to make sure that the discussion is clear and we all refer to the same disease. Moreover, these pictures were shown after the farmers to be asked how they know late blight. This is just to get some feeling on how far the farmers are familiar with late blight disease particularly its symptoms.

Figure 2: Late blight incidences differ, still a serious problem in the tomato growing areas. (A) Field discussion with tomato farmers at Mbuguni village (B, C, D and E) images of different late blight symptoms used during farmers visits, (B) symptoms on the leaves (C) Symptoms on the stem with whitish appearance as sings of sporulation, (D) symptoms on the fruits (E) symptoms in both leaves and fruits. Pictures adopted from https://www.google.co.tz/search?biw=1241&bih=584&tbm=isch&sa=1&q=tomato+late+blight&btnG= (B, C and D) and E from Afrisem pictures.

During these visits, it was revealed that farmers grow different tomato varieties, with variety Tanya (55%) being the most common (Fig.3). Other varieties include Tengeru, Eden-F1 and Onyx. There is a tendency of farmers in the same village to grow the same variety. The kind of variety was also determined by the business focus of the particularly farmer(s). Some farmers work as contract farmers of seed agencies like East African seed agency. This influenced the variety grown since seeds and other agricultural inputs are supplied to the farmers by the agencies. The contract farmers have to grow tomatoes, extracting the seeds and sell them back to the particular agency. These farmers were seen in Mbuguni and Kikwe villages. In the villages where tomato is grown for selling to the market, the farmers grow Tanya and Onyx. Tanya and Onyx are highly preferred by most of the farmers due to their long shelf life at least, as compared to other varieties found in the market. Shelf life gives the farmers guarantee to reach market even in other regions like Dar es Salaam (6561km), Iringa (687km) and Mbeya (991km). Farmers are not supporting tomatoes with sticks in most of the places due to the big tomato field and scarcity of supporting materials. This is not having noticeable effect to their production for Tanya and Onyx variety .However; it was observed that for Tengeru variety, down touching of the tomato fruits lead to rotting of fruits. This was observed in Mbuguni area but the farmers show no concerns since their tomato are for seed extraction (according to farmers themselves). All these tomato varieties are inbred lines except Eden-F1. This gives some farmers the chance to extract and serve some seeds for next season. Some farmers (Ngarenanyuki village) show their confidence with the seeds they extracted out of the produce more than buying new seeds from the Agro dealers.

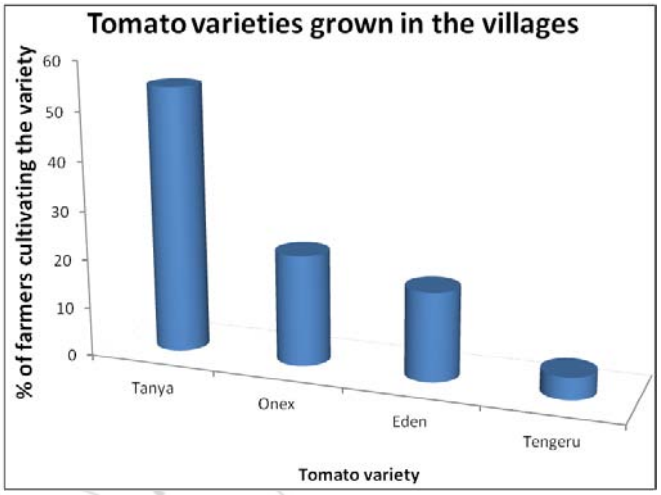

Figure 3: Late blight disease incidences differ, still a serious problem in the tomato growing areas. A graph showing different varieties of tomato grown by farmers in the visited villages

Despite farmer's preference of Tanya Variety and Onyx, these varieties are susceptible to diseases including early and late blight. Farmers are not highly concerned about the particular trait of the varieties due to the availability of chemical sprays as control measures. Most of the farmers are familiar with late blight disease and symptoms which they name it as ''UKUNGU'' or ''chomachoma''. Ukungu is Swahili word refers to humidity (English) and Choma choma is burning. They use these two words due to the occurrence of disease in the humid conditions and due to its blight effect. It was noted also that farmers are dividing late blight in up to three classes due to the area where symptoms appear (leaf, stem and fruit). However farmers sometimes mentioned damping off disease as ''UKUNGU''. Farmers use different chemical sprays namely; Victory 72/80 WP, Ebony M72/80WP, Farmerzeb, Linkmil72WP, Thiovit Jet WP, Ridomil Gold 68WG, Banco 720SC and Milthane Super with Ebony M72/80WP most dominating product (Fig.4). Most of these chemical sprays contain the same chemical inregredients (Mancozeb and Metalaxyl or Mancozeb alone. These fungicides are mixed together with insecticides in most cases for insect pests' control. The insecticide mention by these farmers is Thionix. However, late blight still challenging control measures used by these farmers to date. Farmers in all areas reported increase in production costs due to the price of chemicals sprays for late blight control. Moreover, they also showed their disappointment to chemical products for late blight control. This is because of some chemical products cannot meet their purpose.

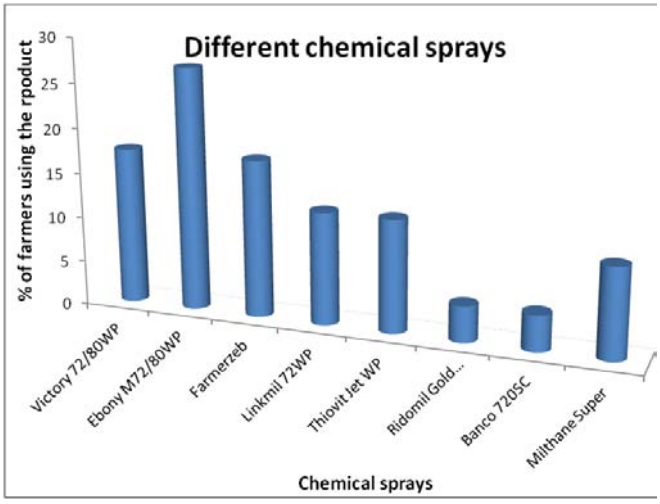

Figure 4: Chemical sprays used by farmers in tomato growing areas. Graph showing chemical sprays used by tomato farmers in the visited villages.

Late blight symptoms were observed at Mbuguni, Ngarenanyuki and Himo, no late blight symptoms were observed in high elevation (Akeri). This is because tomato field visited were just planted (one week old or two weeks) hence tomato were still small. In Akeri, farmers mention late blight is a big problem during rainy season particularly when compared to other places in low elevations. Late blight causes economic loses even when chemical sprays are used during rainy season at Akeri. These reports were supported by farmers from low elevation particularly Moivaro area where we saw wilting symptoms Fig.7 (A) and not late blight. Symptoms of early blight Fig.7 (C) were also observed in some tomato field particularly at Sanya juu village. Moreover, Moivaro and Sanya juu farmers said early and late blight is not their economic problem as compared to wilting disease since they can easily tackle the problem with chemical sprays. Although farmers in low elevation reported the existence of late blight in April 2013 (Fig. 5), they reported serious economic losses in 1998.

Wilting symptoms at Moivaro appeared as *bacterial wilting* and were randomly seen in the tomato fields. We randomly uprooted some tomato plants to asses for root knot nematodes symptoms, but the symptoms were not seen in the roots Fig.7 (B). Many farmers at this area stopped growing tomato and some of them they abandoned the crops in the field. In Mbuguni and Ngarenanyuki, we observed late blight symptoms involved the leaves and in few cases stems were also affected, and no symptoms reached the fruits Fig. 6 (A, B and C). These late blight symptoms appeared to be the ones of may be April, 2013 during rainy season. This can be supported even with the respond of the farmers (Fig.5). In situation where farmers see the symptoms of late blight, they keep on spraying with different types of chemical up to the time when they don't see disease progress (Farmers reported). Moreover, the disease progress was may be stopped due to excessive chemical spray. The infected leaves and stems were seen to be already dried (Fig.6A, 6B).Late blight symptoms were not observed to attack fruits in all villages (Fig.6C). It was somehow challenging to identify late blight symptoms due to appearance of mixed kind of symptoms and drying of the leaves (Fig.6D). Reports given by farmers concerning the last time they experienced late blight in their field differs even within the same village. The most common reported year in all areas is April, 2013 with 44% of the farmers reported to see the disease (Fig.5). It was also noted in the later visits that, farmers mention that they see blight in many cases when symptoms reach fruits and cause economic loses.

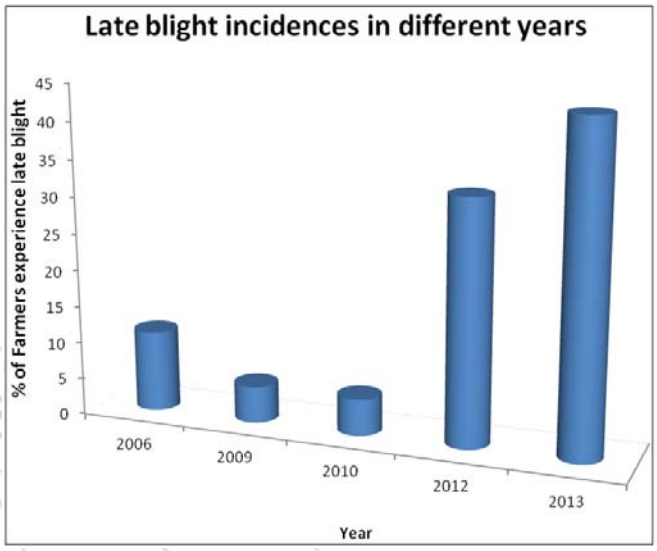

Figure 3: The last time farmers experienced late blight disease. Late blight incidences within five years in the tomato growing villages

Figure 6: Late blight disease incidences differ, still a serious problem in the tomato growing areas.(A) Wilting symptoms at Moivaro village (B) Uprooting of the tomato plants to

check for symptoms of root knot nematodes on the roots, (C) early blight symptoms on the leaves and fruits.

3.2 Tomato varieties grown and late blight incidences in the growing areas

In Tanzania, there are several tomato varieties sold including Moneymaker, Cal J, Tanya, Tengeru 97, Onyx, Rio grande, Eden F1, Kiboko, Meru to mention but a few coming from different seed companies. In the surveyed areas, farmers grow only Tanya, Onyx, Tengeru and Eden F1. Tanya and its related variety Onyx was observed to be preferred by most of the farmers with Tanya being the best to them. It was noted that commercial farmers are real concerned about the value of their produce to win the market. In that case, famers consider they have solution for late blight which is chemical sprays to the extent of preferring Tanya, despite its susceptibility to many fungal and oomycete diseases. Tanya is known to be susceptible not only to late blight disease but to other diseases including bacterial speck and bacterial spot. In our survey, we did not observe or hear complaints from farmers about bacterial speck and bacterial spot. This is contrary to what has been reported by [14]. Tanya has been reported to be good in terms of shelf life, making it a first choice of farmers in Tanzania. We did not bother to find the seed price for these varieties but being open pollinated varieties can easily be afforded by farmers. Farmers real showed that they need a solution for late blight which will reduce their use of agricultural inputs. Tomato variety namely; Kiboko and Meru released in 2007 claimed to be resistant to late blight [3] were not found at least in the surveyed areas. Failure to find these two varieties in surveyed areas can be attributed to lack of farmers' preference to other traits found in these varieties. In that regards, farmers need to see combination of different traits to meet their demands.

Our intention was to compare late blight incidences and epidemics in tomato growing areas from high altitude and low altitude. We selected 8 villages as named above which are all from low altitude except Akeri. Our idea was to compare Akeri and other locations in terms of late blight incidences and epidemics. It was easy to compare these two locations with the results of questionnaire than with evaluation of farmers' tomato field. This is because the age of the tomato in these two locations differ. While only tomato at the age of two weeks was observed at Akeri, in other locations the harvest of the fruit was already done at least ones or was about to harvest. We finally realize that, Akeri farmers don't grow tomato in the period between April and June Using farmers' response to the questionnaire; it was observed that Akeri areas are highly affected by late blight than other places in the lower altitude. This is due to lower temperatures and high humidity of these places because of being very close to Mount Meru. Farmers at Akeri reported that, it is difficult to control late blight with chemical sprays during heavy rainfall. In low altitudes areas it was reported that late blight can be controlled by chemical sprays and hence farmers in those areas they don't consider late blight as serious problem. The presence of late blight at Ngarenanyuki, Mbuguni and Himo is not comparable to Akeri due to lack of tomato at the same age in the area. It was also supported by almost all farmers that, growing tomato at high altitude (Akeri) needs more attention in terms of chemical sprays for late blight than low altitude areas. Therefore, it was concluded that, within Tanzania highlands tomato growing areas, high altitude farmers experience late blight more than low altitude tomato farmers. However, farmers in low altitude are not completely free from disease epidemics. It was observed and reported by farmers in some areas including Moivaro that, wilting disease (Bacterial disease) is seriously affecting their tomato production. Farmers complain that they don't know which chemical to spray for this wilting and hence don't have solution for the wilting disease yet. No any registered chemical sprays for bacterial wilting, we advise the farmers to pay attention to other control measures including sanitation. Wilting disease has forced lots of them to engage in the production of other vegetables crops at Moivaro areas.

3.3 Management practices for late blight disease in the tomato growing areas.

Farmers showed to be familiar with late blight disease symptoms although few of them confuse late blight symptoms with other diseases particularly damping off. This confusion is not real affecting their control measures as late blight and damping off can be controlled by chemical sprays they use. However, understanding properly disease symptoms is important for proper management practices. Farmers classification of late blight according to symptoms show their long time experience of the disease. However, farmers in both low and high altitude complain about high costs for controlling late blight in their farms. It has been observed that farmers use different types of chemical for the control of oomycetes and fungal pathogens including late blight. The application of chemical sprays is already reported to be the major means of late blight control [6]. Moreover, tomato is only challenged by onions to be the leading high frequency in pesticides use in Tanzania [12].Chemical spray Ebony M72/80WP were observed to be most common. They did not specify which one they prefer most between Ebony M72 and Ebony 80WP but there is circumstantial evidence that they prefer most Ebony M72. Ebony M72 could be better for late blight control due to its combination of (Mancozeb 640g/kg and Metalaxyl 80g/kg). These results are contrary to the survey done to farmers in Morogoro in which Dithane (Mancozeb) is the most preferred product (Maerere et al. 2006). Ebony M72 is similar in composition to Ridomil Gold 68WG (Metalaxyl-M 40g/kg +Mancozeb 640g/kg) but Ridomil is not the choice of many farmers due to its price. It was also noted that due to their low income, the low price of the chemical product is among the preference of the farmers. Moreover, farmers showed to spray at the dose (High) different from what is written on the label. May be this is due to their long time experience of pesticides use and failure of the recommended dose to work properly. However, this situation is very dangerous to health of farmers themselves, consumers and the environment. Pesticides misuse and adulteration has been very common in Tanzania resulting into the health effects [12]. It has been also reported by the farmers sometimes agrochemical sellers are misleading them on the proper chemical products. Moreover, late blight pathogens can overcome synthetic pesticides due to its genetic diversity. This genetic diversity is caused by among other reasons; sexual recombination which is due to global

migration of *P. infestans* A_2 mating type resulting into the existence of both A1 and A2 in some parts of the world . *P. infestans* reported to have shown resistance to metalaxyl in other parts of the world including Morocco.

It was reported by some farmers that, they use crop rotation as a control measures for late blight and other diseases. But this rotation is mainly done by those who have large field or more than one farm. Some farmers rotate tomato, cabbage, and maize. It is known that, among the proper approaches to reduce late blight incidences are to reduce amount of inoculums in the field. This can be achieved by crop rotation and other control measures. However, these farmers reported to rotate crops in their field in a short period of time (three months) which is not enough as spores can stay in the field more than three months. It is known already for late blight, crop rotation should take more than one year by growing non host crops including removal of the susceptible weedy plants .Moreover, it was good to hear that most of the farmers include non-host crops (non solaneceous plants) like maize in their rotation.

Tomato varieties resistant to late blight will remain as proper solution for the control of late blight incidences in Tanzania. Moreover, these resistant varieties will reduce the use of chemical sprays and hence reduce human and environmental concerns caused by these chemicals. Despite the release of two tomato varieties resistant to late blight in 2007 by AVRDC, none of them are grown by farmers in the surveyed areas. Many resistant varieties including those of Rijk Zwaan Afrisem are in pipeline. Failure to know the need of local Tanzanian farmers will probably results into the poor acceptance of varieties. Moreover, thorough identification of *P. infestans* isolates found in Tanzania will bridge the gap between tomato varieties and longtime control measures.

4. Conclusions and Recommendations

During the study for screening of Afrisem tomato lines for resistance to early and late blight the trial was set only at Afrisem field plots. The trial did not result into appearance of early and late blight disease. It is better next time to set other trials outside this area so that we can avoid failure of the infestations. If the infestations will appear in all places then it will be better for comparisons and to increase confidence of the data. It can also be reasonable to start with artificial infestations in the greenhouse and later on conduct the open field and natural infestation trials. I will suggest having trials in Akeri due to the high incidences of late blight as reported by farmers. Understanding the *P.infestans* isolates found in Tanzania is very important. These isolates can be used for screening purposes and for getting an idea of what late blight pathogens the resistances are breeding for. It will also be better to set our own trials for the collection of samples for *P. infestans* identification rather than depending on the farmers' field, at the worst without good communications before as we did this time. Farmers cannot keep their tomato field without spraying as they real concerned about the harvest. Moreover, it is better to conduct this trial during heavy rain which normally start in April or June when all low and high altitude areas have tomato in their field.

It was observed that, farmers are growing mainly Tanya despite its susceptibility and availability of other resistant varieties like Meru and Kiboko. This is showing that in breeding programs, breeders are supposed to know farmers needs before going into the breeding work. For public breeding organizations, it is better to consider the introgression of resistant late blight traits into Tanya, so as to maintain other traits favorable to farmers. In other situations, breeders can evaluate traits found in Tanya and use tomato materials similar to what found in Tanya. Moreover, breeding companies could use parental lines which will results into varieties with traits like the ones found in Tanya. Our rough investigation show that farmers prefer Tanya because of its shelf life, fruit shape and being determinate. In that case, tomato variety resistant to late blight should also possess this trait to be accepted by farmers.

It was also noted that, farmers lack knowledge of resistant varieties and whether when you have this varieties you don't have to spray their particular chemicals. Therefore, farmers have to be involved in the development process, at least during field trial to make them confident to the products. Moreover, it is now in the farmers' ''gut feeling'' to spray their tomato farms and this will bring difficulties for the farmers to abandon their experience and accept the resistant varieties. This is because hybrid tomato varieties will definitely come with higher price as compared to the present in bred lines varieties. Farmers experience can easily be knocked down with setting field trials close to their tomato so that can witness the performance of resistant varieties before they buy the seeds.

Our little experience from farmers' visits is showing that, most of Tanzanian tomato farmers are still poor. This will affect their acceptance of the hybrid varieties especially if there will be higher price to the extent of increasing their experienced costs of productions. Lack of education to Tanzania farmers' affect many of the agricultural plans particularly when strategies do not have tangible and visible effect to them. For instance, to defend the point of introduction of resistant varieties for late blight control can only be by mentioning to the farmers, the health and environmental effects of pesticides. These only will not make farmers accept and buy tomato resistant hybrid varieties. Thorough knowledge of pesticides effects has to be imparted to the uneducated farmers with concrete examples to make them appreciate resistant tomato varieties. ''Changing Tanzanian tomato farmers' beliefs on pesticides is just like changing someone religion beliefs, without vivid examples the whole effort will end in vain'' (My opinion). It is wealthy to know that, breeding for African tomato growers should involve improving their crops and offering proper education

5. Acknowledgements

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