INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Distribution, Prevalence and Incidence of Potato Bacterial Wilt in Nakuru County, KENYA

Mwaniki, P. K.
PG Student, Department of Biological Sciences, Egerton University, Kenya
Birech, R.
Associate Professor, Department of Crops, Horticulture & Soil Science, Egerton University, Kenya
Wagara, I. N.
Associate Professor, Department of Plant Pathology & Biological Sciences, Egerton University, Kenya
Dr. Kinyua, Z. M.
Plant Pathologist & National Coordinator, Crop Helth Programme, National Agricultural Research Laboratories-KARI, Kabete, Kenya
Dr. E. Schulte-Geldermann, E.
Potato Science Leader, International Potato Center, Nairobi, Kenya
Bernhard Freyer
HOD, University of Natural Resources and Life Sciences (BOKU), Division of Organic Farming, Vienna, Austria

Abstract:
A biological survey was carried out in 145 potato farms in nine divisions in Nakuru county, Kenya during the short rains between October and December 2012. The purpose of the survey was to provide comprehensive information on the distribution of bacterial wilt incidence, prevalence and contributing factors in the County. Percentage disease prevalence and incidence, and contributing factors were determined through observation and farmers' interview respectively. Descriptive statistics were used to determine percentages and frequencies of data collected. Chi-square tests and spearman's correlation coefficient analysis were used to determine significance of the data and examine relations between different variables respectively. Spot altitudes of the fields were recorded using Geographical Positioning System (GPS). Results showed that besides potatoes, other crops of economic importance in the area are wheat, tea, maize and beans. The average yield of potato in the nine divisions was 14.5 ton/ha. Bacteria wilt prevalence in the County varied from 100% in Bahati sub-County to 35.7% in Mauche and was found to be spread across all the sub Counties surveyed. The incidence also varied form 0 - 41% in the farms surveyed. There was a significant relationship between altitude and bacterial incidence at x^2 *(36, N=111) =78.6,* $p<0.01$*. The Pearson's correlation coefficient of* r_s*= -0.30, (n=111,* $p<0.01$*) indicated a reduction in bacterial incidence as altitude increased. The disease also reduced with an increase with the number of seasons the field was occupied by other crops besides potatoes as indicated by a chi square test* x^2 *(20, N=46) =35.235,* $p<0.05$*, and the spearman's correlation* r_s*= -.092, (n=46). Bacterial wilt symptoms on plants were more prevalent from the principal growth stage 6 (2 digit BBCH 60) and this is important in determination of the right stage of positive selection of mother plants for seed purpose. Major contributing factors to bacterial wilt in the region include; seed source, potato variety, lack of seed renewal, etc. Promotion of improved seed development techniques such as positive seed selection, production of mini tubers in the affected areas would improve the seed quality and give high yields. The relevant stakeholders should ensure accessibility of released varieties to all farmers and restrict seed movement to control spread of bacterial wilt. Development of cultural practices that are applicable and affordable in the specific regions and capacity building would contribute in reducing the bacterial wilt spread in the sub-Counties.*

Keywords: *Potato, bacterial wilt, Incidence, Prevalence,*

1. Introduction

Potato (*Solanum tuberosum* L.) is an important food crop in Kenya's food security and ranks second after maize. In Kenya most potato production is done on the slopes of Mount Kenya, along the Aberdare ranges, Mau ranges and some other highland areas in Nyanza, Western and Trans –Nzoia (Ministry of Agriculture, 1998). Several surveys have been undertaken in Kenya on the prevalence and incidence of bacterial wilt in a number of potato producing zones in Central and North Rift Valley (Ateka *et al*., 2001;

Nyangeri, 2011, Kwambai *et al*, 2011) and have shown bacterial wilt to be an important potato disease in Kenya. Bacterial wilt caused by *Ralstonia solanacearum* R3b2 (formerly known as *Pseudomonas Solanacearum*), is one of the most damaging pathogens on potato worldwide (Janse, 1996). It is reported to affect 3.75 million acres in approximately 80 countries with global damage estimates exceeding $950 million per year (Floyd, 2008), thereby contributing to yield losses in potatoes of about 75% at medium to high altitudes (1500-2800 m) (Stansbury, *et al.,* 2001).

In Kenya the potato industry is threatened by bacterial wilt (BW) because soils in most production areas are infested with the wilt-causing bacterium and over 50% yield losses have been reported (Ajanga, 1993). In the North Rift region of Kenya, bacterial wilt is highly prevalent in Elgeyo Marakwet and Uasin Gishu Counties (Bationo *et al*., 2011; Kwambai *et al*, 2011). A study on the occurrence of *R. solanacearum* in the major potato productions zones of Kenya showed that 58.7 % of the farms assessed were infested with *R. solanacearum* (Nyangeri, 2011). A study on acreage, yield and output in the 10 highest potato producing districts showed that Nakuru County had the second highest potato acreage with a yield of 9.2 tons/ha (Kaguongo *et al.*, 2009). Other crops grown in Nakuru County are cabbages, garden peas, onions, carrots, tomatoes, snow peas, spinach, kales and maize. Infected seed and soil are the main modes of bacterial wilt spread and the main control method preferred by farmers in this area is uprooting of wilting plants (Kaguongo *et al.,* 2009).

Geographic distributions of pathogens are highly influenced by factors such as availability, susceptibility and abundance of the host and suitability of the climatic conditions (Shaw and Osborne, 2011). Information on the geographic distribution of bacterial wilt, host availability, suitability of climatic conditions and farming practices is vital in combating epidemics and for regional risk preparedness. Such information gives the relevant stakeholders a better focus in improving the farmers' practices to increase potato yield. However, little information is available on the geographic distribution of potato bacterial wilt in Nakuru County despite being a major potato production zone (Kaguongo *et al.,* 2009). This study provides comprehensive information of the potato bacterial wilt status in terms of distribution, incidence and prevalence in Nakuru County. It points out areas of high risk in order to allow for appropriate control strategies to be employed. It also identifies key farming practices that could be contributing to the bacterial wilt status in the area. This knowledge is useful for site-specific management of bacterial wilt in the County.

1.1. Survey Protocols

The survey was carried out in five of the nine Sub-Counties in Nakuru County, Kenya. A biological survey was carried out in 145 potato farms in nine divisions in the county during the short rains of October to December 2012. At least fifteen potato fields were randomly selected at a distance of not less than 7 kilometers in each potato producing divisions to determine the disease prevalence and incidence. Disease prevalence was determined by counting the number of potato fields with bacterial wilt expressed as percentage of the total number of fields assessed in each divisions

$$Disease\ Prevalence = \frac{No.of\ potato\ fileds\ with\ bacterial\ wilt}{Total\ No.\ of\ fields\ assessed}\ x\ 100\%$$

Disease incidence was determined through observation. Four plots of 6 rows by 10 plants per row were demarcated in each field and bacterial wilt symptomatic plants (wilting leaves and stems, oozing tubers) counted against the total number of plants in each plot. Bacterial wilt incidence was calculated using the following formula:

$$Bacterial\ wilt\ Incidence = \frac{No\ of\ plants\ with\ symptoms}{No.\ of\ plants\ observed}\ x\ 100\%$$

A semi-structured questionnaire and personal observation were used to collect data on economic, social and physical aspects influencing bacterial wilt status in the area. The questionnaire was administered to 66 farmers in the County. Spot altitudes, latitudes and longitudes of the fields were recorded using Geographical Positioning System (GPS) equipment (Garmin eTrex 30) for subsequent mapping of bacterial wilt occurrence. Mapping for bacterial wilt occurrence was done using Arcgis, version 9.3, programme (Esri Company). Descriptive statistics were used to determine percentages and frequencies of data collected. Chi-square test was used to determine significance of the data and spearman's correlation coefficient analysis was performed to examine relations between different variables. This was done using IBM SPSS software statistics version 20.

2. Results and Discussion

2.1. Potato Production in the Nine sub-Counties

Five of the nine sub-Counties did not have potatoes as their major crop but majored on other crops during the short rains (October – October 2012). A large part of Njoro sub-County was under large scale production of wheat and maize as also had been observed by Walubengo, (2007), however there was significant production of potatoes in divisions such as Mau Narok and Mauche. Most of the farmers in Rongai sub-County had tomato production in their farms and other farms were fallow. The main crops in Lare division were beans, wheat and maize. Mbogoini division also did not have potato production during this period and most of the land was fallow. Gilgil and Naivasha sub Counties are mainly ranch farming areas. Nakuru municipality is an urban area where minimal potato farming takes place (Figure 1).

Potato production is concentrated along the Eastern and Western Mau forest and along Bahati forest. Production of potato was found to occur in nine divisions namely; Mau Narok, Mauche, Kuresoi, Keringet, Kamara, Olenguruone, Molo, Bahati and Elburgon. Most of these divisions are found in the highlands (2353-2942m asl) with an exception of Bahati divisions where potato production was in the lower highlands (2032-2344m) asl. The household area under potato production as a percentage of the total farm acreage in Mau Narok and Mauche was high compared to the other divisions such as Bahati, Kuresoi, Molo and Olenguruone (Fig 2). This is because

potato farming in Mau Narok and Mauche is considered as a commercial venture while in other divisions they practice mixed farming to maximize on food security. Other crops such as wheat, tea, maize and beans are of importance in Molo, Kuresoi, Kamara and Olenguruone,

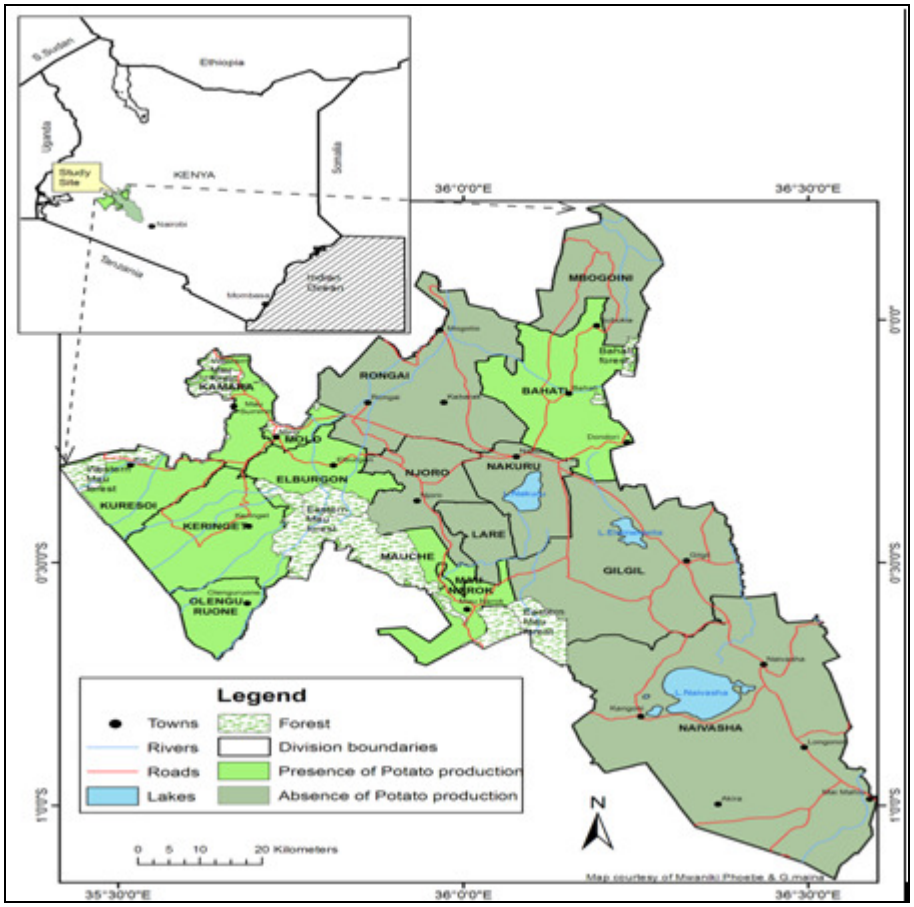
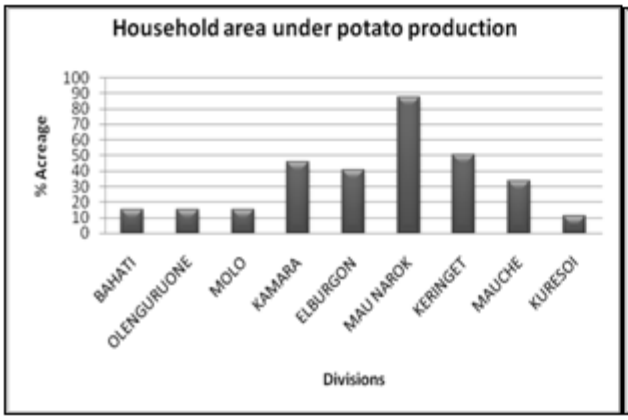


Figure 1: Potato production zones surveyed in Nakuru County (Short rains, October-December 2012)

In all the nine divisions, the farm sizes ranged from small scale production (half acre) to large scale production (125 acres) with 25 % to 100% under potato production respectively. The findings indicated that most farmers (82.1%) grow potatoes for ware, whereas 9 % either grow them for seed or for seed and ware. The smaller the farm sizes the less the area under potato production and this shows the need of diversification for food security among the small scale farmers. Potato yield was low in Keringet and Kuresoi divisions with 8.2 and 5.9 tonnes per hectare respectively. Mauche and Mau Narok divisions had the highest yields of 26.8 and 25.1 tonnes per hectare respectively. Generally, the average yield in the nine divisions was 14.5 tonnes per hectare (Fig. 3). This shows an increase in the average yield compared to what was earlier observed by Kaguongo *et al*., (2009) as 9.2 tonnes/ha.

The high yields per hectare in Mau Narok and Mauche may also be attributed to the existing organized programmes on fertilizer application, pest and disease control as observed in the study compared to other farmers having small scale production in other sub Counties. This is also supported by the high correlation $r_s = 0.78$, ($n=66$, $p \leq 0.01$) between the acreage under potato production and the yield (Table 1). The prices of potatoes varied from one division to another with the highest prices in Molo, Mau Narok and Elburgon at Kshs 4000 (US$50) / 130 kgs bag and the lowest prices were in Keringet and Kuresoi at kshs 700 (US$9) and 1100 (US14)/ bag respectively. These divisions recording the high prices are along the Eastern Mau forest (Figure 4) which are closer to Nakuru town; a major town along the Nairobi Kisumu highway in the County. Accessibility to Nakuru town and the organized farmer's groups were found to be contributing factors to better prices of their produce. This translates to motivated farmers and thereby intensive potato production in these divisions.

The common potato varieties grown in the area include Cangi, Tigoni, Dera mwana, Kenya mpya, Kenya Karibu, Nyayo, "Mwezi moja", Tarime," Kimaitho" and "Thima thuti". The findings indicated that 70.6 % of the farmers produce Cangi potato variety and most of the farmers grow different varieties in their farms. Other crops grown in the potato growing divisions are carrots, garden peas, maize, kales, cabbages, tea, spring onions and rapeseed. 77% of the farmers reported that potato is the highest income earning crop. According to 9.8 % of the farmers, garden peas gave them the highest income and 3.3 % considered maize to be the crop that gave them the highest returns.



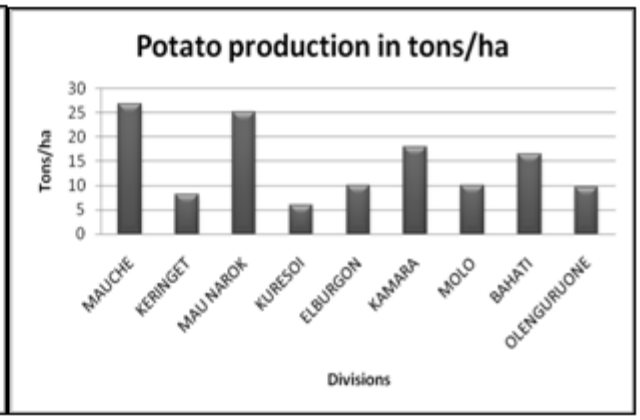


Figure 2: Household area under potato production *Figure 3: Average potato yield in the 9 divisions*

2.2. Pest and Diseases Affecting Potato Production in Nakuru County

Pests are a major challenge to potato production in the County. The most common pests are cutworms and aphids. Others include termites, tuber moths, moles, white flies and millipedes. The most common diseases are late blight caused by *Phytophthora infestans* and bacterial wilt caused by *Ralstonia solanacearum*.

2.3. Farming Practices Contributing to Bacteria wilt in Nakuru County

The study indicated that most of the farmers sourced their potato seeds from their neighbors or used their own seed (Fig 7). Replanting tubers collected from the same farms (Self sourcing) infested with bacterial wilt increases the disease incidence in these farms. Sourcing seeds from the neighbors is also an important factor contributing to the high disease prevalence in these divisions because it facilitates spread of the pathogen from one field to another. This is a concern that has also been highlighted by National potato council of Kenya, (2013). Use of latently infected seed with *R. solanacearum* has been reported to contribute significantly to bacterial wilt spread, Champoiseau, *et al,* (2010) and therefore the use of self sourced, neighbours and market seed is not recommendable. One variety "Cangi" was very common with farmers across the entire sub Counties. Despite the farmers reporting it to have a short growing season and high yields, they also observed it to be susceptible to bacterial wilt. The availability of a susceptible cultivar or a variety is very significant in the proliferation of any disease. The potato variety may be a contributing factor to bacterial wilt spread in the area since host availability; susceptibility and abundance contribute significantly to the geographic distributions of pathogens (Shaw and Osborne, 2011). Thirty-six percent of the farmers did not change their seed and just sort the seed for the next planting from their previous harvest, whereas 54.1% do change their seed after at least one to 10 generations of potato production. Only 8.7 % of the farmers change their seed and source for new varieties. This contributes to the increase of bacteria wilt in these farms. Use of the same seed over several generations as observed in this study contributes to low quality seed potato.

Lack of knowledge among several farmers on the significance of bacterial wilt to potato production was also found to be a contributing factor in its proliferation. Seventy-eight percent of the farmers were aware that diseases can be spread through seed potato tubers while 21.3 % did not know that tubers could be a source of disease spread. Ninety-three percent of the farmers indicated that they incurred losses due to bacterial wilt and 6.3 % were not aware of the significance of the disease to their produce. The farmers reported experiencing yield losses ranging from 5% to 80% due to bacterial wilt. Crop rotation was practiced by some farmers with pre crop seasons to potato varying from one season to five seasons. There was significant effect on the number of seasons of other crops in rotation with potato crop on bacterial wilt incidence in the farm. A chi square test showed a significant relationship between number of seasons other crops were grown before the potato crop to the bacterial incidence; x^2 (20, N=66) =35.235, $p<0.05$. The Pearson's R correlation coefficient of (r_s= -0.092, n=46 indicated a reduction of bacterial wilt with an increase in the number of seasons under other crops. This is a positive indicator of the contribution of crop rotation in farmers' fields.

Bacteria wilt symptoms were apparent in potato plants at the principal growth stage of 6 (BBCH-Scale 60) onwards. The symptoms of bacterial wilt were evident at an early principal growth stage 2 (formation of basal side shoots below and above the soil surface) and this could be attributed to high pathogen population or very infected seeds, however symptoms were not frequently observed at 0, 1, 3,4 and 5 (Sprouting, leaf development, main stem elongation, tuber formation and inflorescence emergence) growth stages respectively (Hack *et al.,* 1993). Symptomatic plants were observed from the inflorescence (BBCH 5) stage. This is an important lead to the stage at which positive or negative selection of seed should be done in the farmer's fields (Fig 8).

2.4. Distribution of Bacterial wilt by Location

Bacteria wilt prevalence varied from 100% in Bahati divisions to 35.7% in Mauche (Fig 5). Bacterial wilt was found to be spread within the entire sub Counties surveyed (Figure 4) at varying disease incidences.

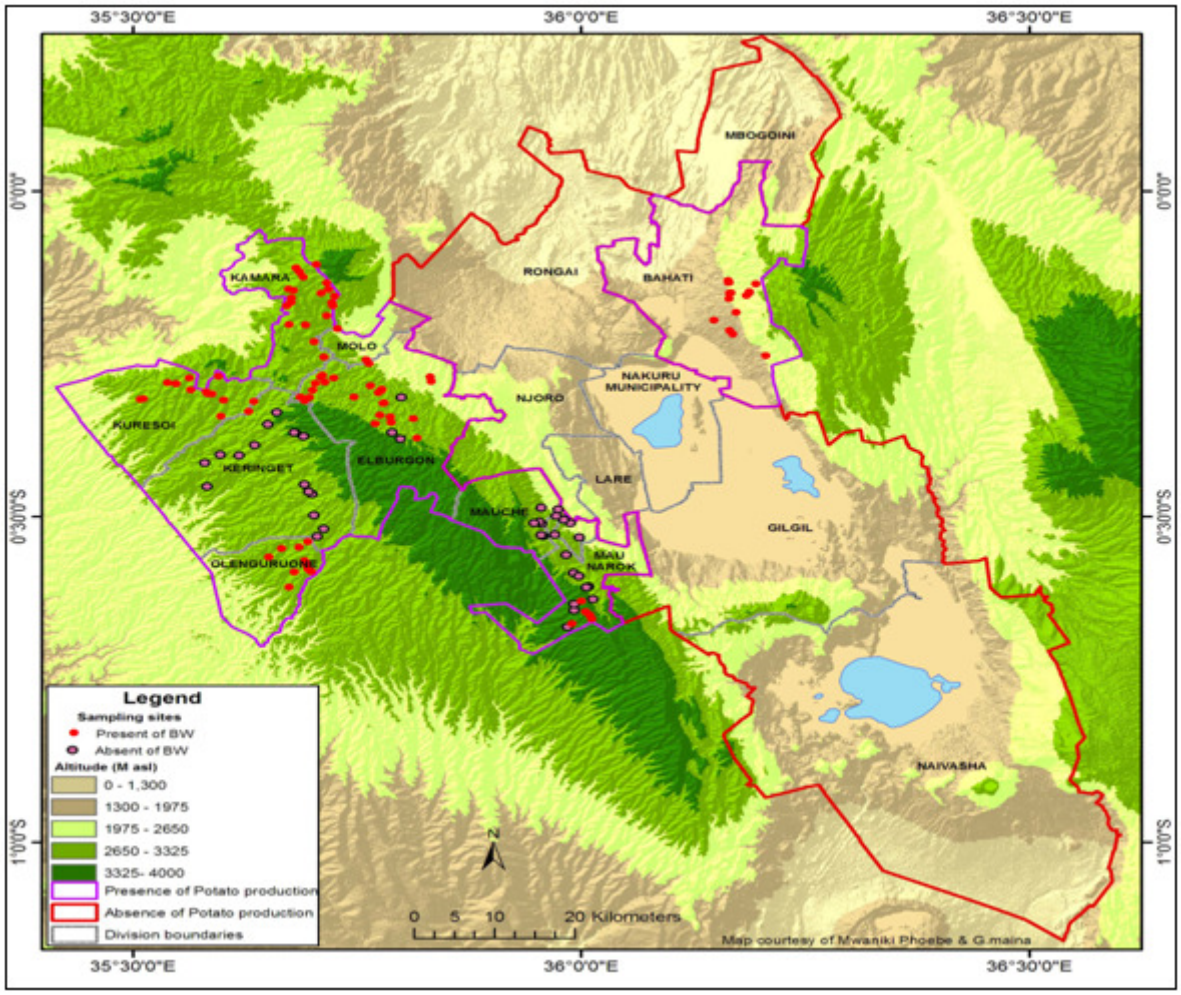


Figure 4: Distribution of Bacterial wilt in potato producing regions in Nakuru County, Kenya

The high prevalence in Kuresoi and Olenguruone divisions may be exacerbated by spread of the disease from the neighboring Bomet County which was reported to have a bacterial wilt prevalence of 91% (Gildemacher *et al*., 2009). This is also evident in Bahati divisions which borders Nyandarua County reported to have a bacterial wilt prevalence of over 50 % (Ateka *et al*., 2001; Gildemacher *et al*., 2009). The observed disease prevalence could be attributed to the informal seed systems especially the seed sources in areas such as Olenguruone, Mau Narok, Bahati and kuresoi (Fig. 5 & 7). It was evident that most farmers in the County used their own seed or sourced from their neighbor which was found to be a major contributing factor in the spread of bacterial wilt (Fig. 7).

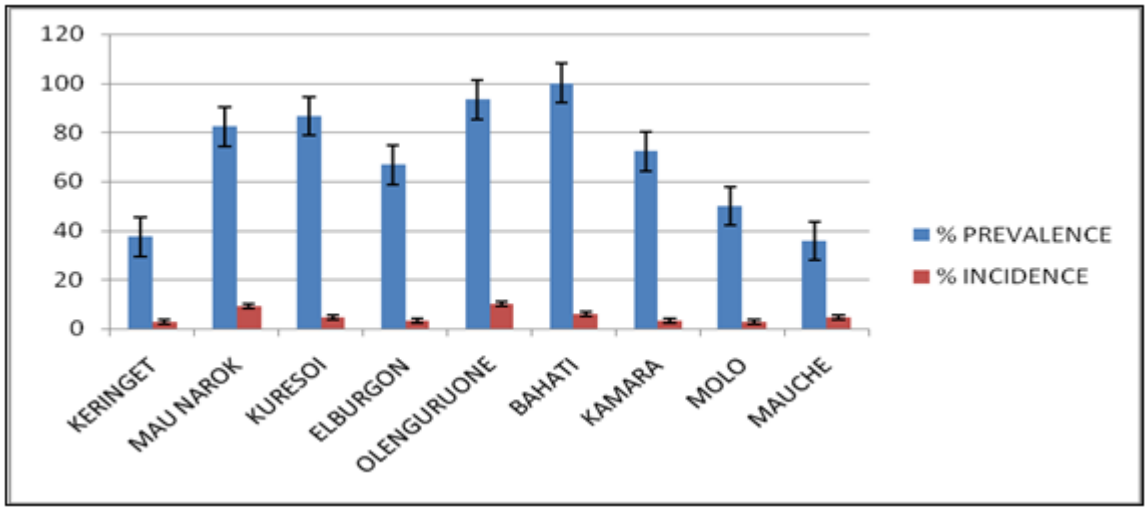


Figure 5: Bacterial wilt prevalence and mean disease incidence (%) across the sub Counties.

2.5. Bacterial Wilt Distribution by Altitude

A chi square test showed that there was a significant relationship between altitude and bacterial incidence at x^2 (36, N=111) =78.6, p<0.01. The Pearson's correlation coefficient of (r_s= - 0.30, n=111, p<0.01) indicated a reduction in bacterial wilt with an increase in altitude (Table 1). The disease incidence in farms surveyed decreased significantly beyond 2300m asl, however the farms still had bacterial wilt at lower percentage incidence distributed across the farms in the higher altitudes up to 2942 m asl (the highest altitude sampled in the study) (Figure 6). Bacterial wilt has been reported to occur in higher altitudes as reported by Ateka *et al.,* (2001). The prevalence and incidence in the higher altitude may be attributed to factors such as seed sources. Bacteria wilt was found to occur in the high altitude areas despite the very cold temperatures. *Ralstonia solanacearum* is reported to survive in soil temperatures as low as 4°C and is considered a worrisome pathogen (Sullivan *et al*., 2013; Milling *et al*., 2009).

Variable	Altitude	B W Incidence (%)	Growth stage (BBch)	Yield
Altitude	-	-0.301**		
Incidence (%)		-	0.236*	
Acreage under potato production	0.186*		-	0.78**
No. of seasons before potato crop		-.092		

Table 1: Pearson correlation coefficients for the relationships of altitude, Bacterial wilt incidence, crop growth stage, yield and acreage under potato production.
***Significant at p<0.01, *Significant at p<0.05, NS*

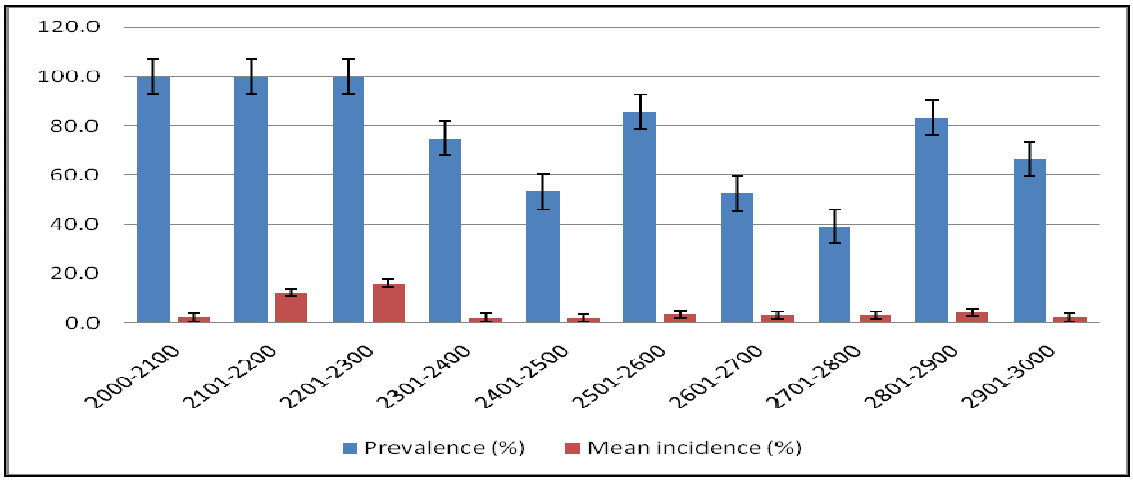


Figure 6: Bacterial wilt prevalence (%) and Mean disease incidence in the study area across altitude

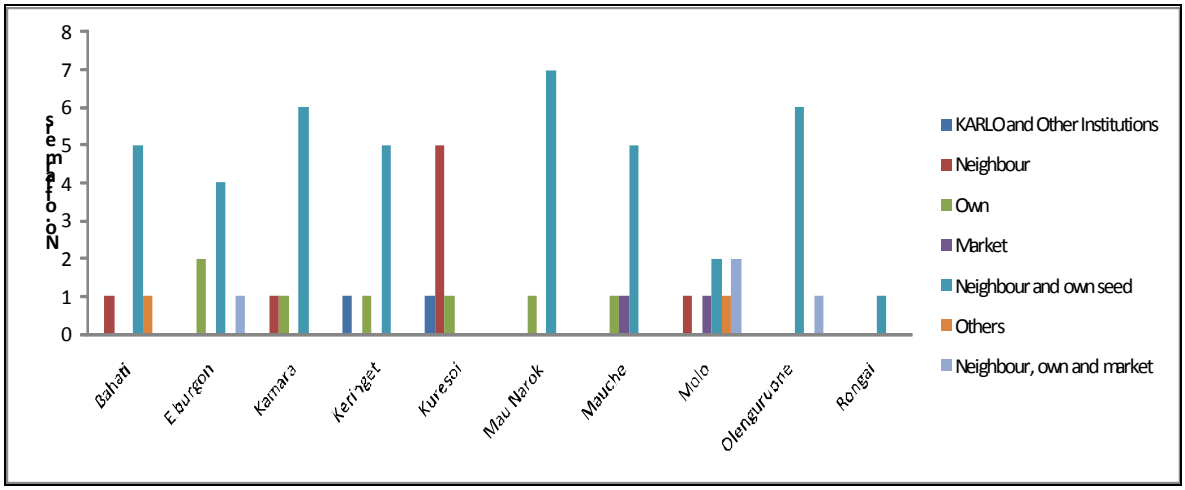


Figure 7: Farmers seed sources by location

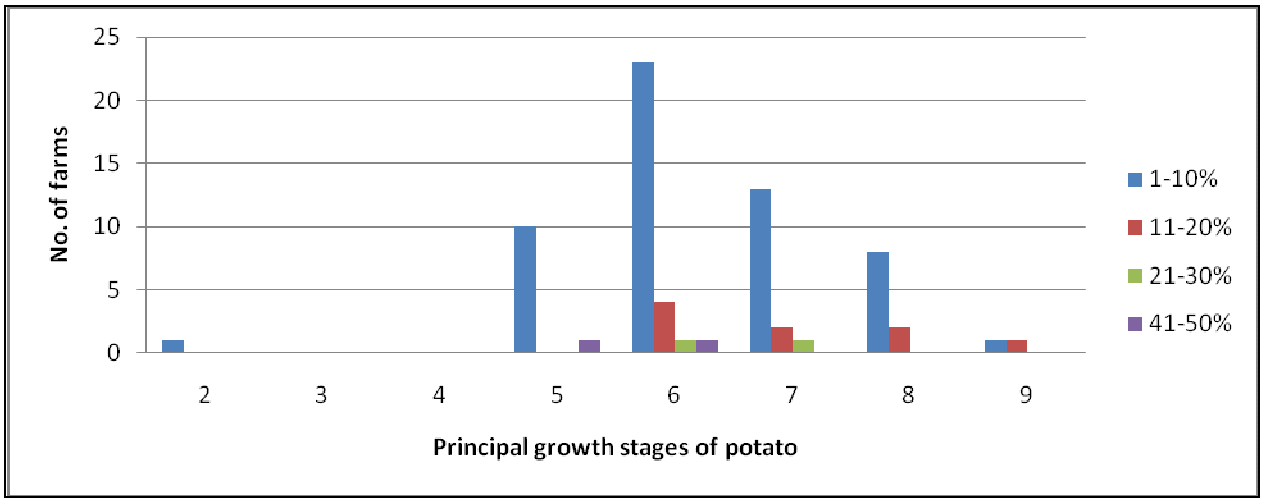


Figure 8: Bacterial wilt incidence across different growth stages of potato in the farms.

3. Conclusion

The findings indicated that potato production in the short rain season is done in more than 40% of Nakuru County. Bacterial wilt is a widespread disease affecting all the potato producing areas surveyed. Although unexpected, bacterial wilt was found to occur in high altitudes due to reasons such as seed sources. The main factors that contributed to the bacterial wilt incidence and prevalence are the seed sources, seed variety, non renewal of seed, poor crop rotations and lack of knowledge on disease management. Promotion of techniques such as positive seed selection and multiplication of seed potato through the seed-plot technique as well as production of mini tubers through soilless methods in the affected areas would improve the seed quality and give high yields (Kinyua *et al*., 2012). The study indicated that the best time for positive selection should be between principal stage 6 (first flowers open) and 7 (development of fruit) so as to allow development of symptoms on all infected plants. Pegging plants before and after the described growth stages may lead to selection of asymptomatic plants infected with bacterial wilt or poor selection due to plants exhibiting senescence. Gildemacher *et al*., (2007) recommends selection of mother plants for seed purpose (positive selection) to be carried when the first flowers appear. Provision of clean seed by the relevant authorities to the farmers in the high risk areas such as Mau Narok, Kuresoi, Bahati, Kamara, Elburgon and Olenguruone is essential to avoid further spread of the disease. Control of seed movement would also be a necessary precondition to limit spread of the pathogen to areas of low prevalence such as Keringet and Mauche. Production of clean seed should also be promoted in these divisions with low prevalence since the risk of field contamination is relatively lower as compared to the other divisions. Development of cultural practices that are applicable and affordable in the County would contribute in reducing the bacterial wilt spread in the sub-Counties. Exchange of information on wilt management practices from one division to another would be of benefit since the management differs in these divisions as observed by (Muthoni *et al*., 2013). More capacity building is necessary to make the farmers aware of how the disease is spread.

4. References

i. Ajanga, S. (1993). Status of bacterial wilt in Kenya in Bacterial wilt. Hartman, G. L. and Hayward, A. C. (Eds.). ACIAR Proceedings 45: 338-340

ii. Ateka, E. M., Mwang'ombe A. W. and J. W. Kimenju, (2001) Reaction of Potato Cultivars to Ralstonia solanacearum in Kenya. Afr Crop Sci J, 9: 251-256

iii. Bationo, A., Boaz S., Waswa J. and M. Okeyo, (2011) Assessment of potato bacterial wilt disease status in North Rift valley of Kenya. In: Innovations as key to the green Revolution in Africa. Curr trends biomed. Life sci., 2: 456

iv. Champoiseau, P. G., Jones, J. B., and C. Allen, (2009). Ralstonia solanacearum race 3 biovar 2 causes tropical losses and temperate anxieties. Plant Health Progress doi:10.1094/ PHP-2009-0313-01-RV. Accessed 12th June 2012

v. Champoiseau, G., Jeffrey, B.J., Timul, M.M. Catilyn, A., Norman, D.J., Harmon, C., Miller, S.A., Shubert, T., Bell, D., Floyd, D., Bulluck R., Smith, K. and K. Carwell, (2010). Ralstonia solanacearum race 3 biovar 2 causing brown rot of potato, bacterial wilt of tomato and southern wilt of geranium. National plant disease recovery system, 9.

vi. Gildemacher, P., Demo, P., Kinyae, P., Wakahiu, M., Nyongesa, M. and T. Zschocke, (2007). Positive selection to improve farm saved seed potatoes; Farmers field aid. 8pp.

vii. Gildemacher, P.R., Demo, P., Barker, I., Kaguongo, W., Woldegiorgis, G., Wagoire, W.W., Wakahiu, M., Leeuwis, C. and P.C Struik, (2009) A Description of Seed Potato Systems in Kenya, Uganda and Ethiopia Am. J. Pot Res 86: 373–382

viii. Hack, H., Gall, H. Klemke, T., Klose, R., Meier, U., Stauss, R. and A. Witzenberger, (1993) Phanologische entwicklungsstadien der Kartoffel (Solanum tuberosum L.) Nachrbl Dtsch Pflanzenschutzd: 45:11–19.

ix. Janse, J. (1996). Potato brown rot in Western Europe – history, present occurrence and some remarks on possible origin, epidemiology and control strategies. Bulletin OEPP/EPPO 26: 679 - 695.

x. Kaguongo, W., Ng'anga N. and J. Landeo, (2009). Seed potato use and Projected Demand in Kenya. Preliminary report. http//: sweetpotato knowledge.org. ONLINE: Accessed 22nd March 2012.

xi. Kinyua, Z.M., Bararyenya, A., Schulte-Geldermann, E., Obura, B.O., Kashaija, I.N., Tindimubona, S., Opio, F., Oyena, D., Rwomushana, I., Muriithi, W.M., Kinoti, J., Namugga, P., Kimoone, G., Inamahoro, M., Niko, N. and P. Ndayihanzamaso (2012) Overcoming seed potato quality constraints to tackle food insecurity and poverty in eastern and central Africa in the 21st Century. Paper presented during the 1st ASARECA General Assembly, 14-16 December 2100; Entebbe, Uganda

xii. Kwambai, T.K. Omunyin, M.E. Okalebo, J.R. Kinyua Z.M. and P. Gildemacher (2011). Assessment of Potato Bacterial Wilt Disease Status in North Rift Valley of Kenya: A Survey. Innovations as Key to the Green Revolution in Africa: 449-456

xiii. MoA, Kenya (1998). Postharvest systems of potato and sweet potato in Kenya: Final report. Nairobi (Kenya). Ministry of Agriculture; Deutsche Gessellschaft fur technische Zusammenarbeit (GTZ).

xiv. Milling, A., Meng, F., Denny, T.P. and C. Allen, (2009) Interactions with hosts at cool temperature, not cold tolerance, explain unique epidemiology of Ralstonia solanacearum Race 3 Biovar 2. Phytopathology 99: 1127-1134

xv. Muthoni J.,Shimels H. and R. Melis (2013) Potato Production in Kenya: Farming systems and production constraints: JAS; 5; 182

xvi. National Potato Council of Kenya, (2013). Potato seed catalogue, Kenya. 28pp

xvii. Nyangeri, J.B., (2011) Occurrence, variability and management of R. solanacearum in potato production systems in Kenya, Ph. D. Egerton University, Kenya

xviii. Shaw, M. W. and T. M. Osborne, (2011) Geographic distribution of plant pathogens in response to climate change. Plant Pathol. J. Special Issue: Climate Change and Plant Diseases 60: 31–43

xix. Stansbury C., McKirdy, S., Mackie, A. and G.P. Hortguard, (2001) Bacterial wilt Ralstonia solanacearum - race 3 Exotic threat to Western Australia. ISSN 1443-7783 No. 7/2001March 2001, Fact sheet, Agriculture, Western Australia

xx. Sullivan, M., Daniells, E., Southwick, C. and D. Mackesy, (2013) CPHST Pest Datasheet for Ralstonia solanacearum race 3 biovar 2. USDA-APHIS-PPQ-CPHST.

xxi. Walubengo, D. (2007). Community-led action to use forestry in building resilience to climate change: a Kenyan case study, Njoro Division, Nakuru District, Kenya. Institute for Environment and Development (IIED).