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Farmers' Perception On Main Technical Factors Affecting Irish Potato Production In Rwanda: Case Of Musanze District

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Abstract – The potato (*Solanum tuberosum L.)* is one of the most common foods consumed in Rwanda and all over the world. However, the yields of potato remain low, ranging from 5 to 20 tons per ha in Rwanda. The average yield obtained during this research is 8.873 t per ha. This low potato yield is mainly caused by technical factors, including low seed quality, pests and diseases, agriculture input that are not well applied, and crop rotation. The objective of this study was to identify the main technical factors affecting potato production based on farmer perception in Musanze district of Rwanda. For this study, seven sectors of the district were selected, and in each sector, 27 potato farmers were randomly selected and interviewed using formal, informal, and expert interviews based on the prepared questionnaires. The qualitative and quantitative data were recorded and analysed using Microsoft Excel and STATA 14. Among the 192 farmers from all seven targeted sectors of the district, 17.19% used a formal seed system, while 82.81% used an informal seed system. The obtained results showed that the prevalence of diseases and pests such as late blight, bacteria wilt (BW) and aphids was perceived at 31.9, 68.8, and 86.8%, respectively. The study recommends an increase in awareness of certified seeds, their presence on the market, a reduced price for certified seeds, and the management of soil-borne diseases using appropriate crop rotation and biological and chemical control, among other things.

Keywords – Technical factor, farmer's perception, potato, Musanze district

I. INTRODUCTION

The potato (*Solanom tuberosum L.)* is grown in more than 125 countries and consumed everyday by more than one billion people in the world [1]. The production of potatoes in Rwanda is primarily influenced by technological considerations. In order to overcome the factors that hinder potato production, different measures could be taken to ensure the sustainability of the potato sector. Those measures include improvements in the quality of planting material that is resistant to pests and diseases and in farming systems. Regarding agricultural input suppliers, there are inappropriate varieties, a very limited supply of good-quality seed, and their poor distribution in rural areas. Moreover, the small farmers in potato sector must be empowered with input, improved potato seed, among others [2]. Potatoes are very important for income generation, nutrition, and food security. Though potato is very important, yields still remain low, ranging from 5 to 20 t/ha, compared to expect potential yields of 30 t/ha. Among the causes of low yields are diseases, a lack of quality seeds, and inadequate farming practices. These causes of low potato production can be overcome by using many approaches. The close collaboration of agronomists with farmers and the private sector, elaborating agriculture extension models to inform potato farmers about potato growing constraints, in this context, the diseases are sometimes induced by soil that has not been rotated with other non-potato crops. In Rwanda, the potato seed multipliers are still few, and even the improved potato seeds are expensive so that they cannot afford them. Therefore, potato farmers are found using their own home-made potato seeds. Another way is that the farmers should be instructed on appropriate agriculture practices in order to boost potato yield.

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II. Objectives Of The Research Study

The objective of this research was to assess the farmer's perception on the main technical factors affecting potato production in Rwanda, particularly in Musanze district. This study was specifically focus on assessing farmer's perception on the following

- Seed quality (formal or informal potato seed system),
- Prevalence of pest and diseases,
- Agriculture input (fertilizers) used,
- Crop Rotation
- Potato production

2.1. Importance of potato

In the years ahead, world potato production is expected to grow at a rate of 2.5 percent per year, presenting opportunities for expanded utilization and opening up new market segments. To realize the full potential of this crop, developing countries must address both supply- and demand-side constraints. Many of the poorest producers in developing countries and most undernourished households depend on potatoes as primary or secondary sources of food and nutrition. Under conditions where other crops may fail, the crop yields are relatively consistent, and they produce significant amounts of nutritional energy. Notably, compared to the majority of other important crops, potatoes produce more nutrient-dense food faster, on less land, and in harsher conditions. Unlike cereals, where only around 50% of the plant is used as human food; up to 85% of the plant is [3]. Potato is very important to human beings as it contains important nutrients and can also be used to increase the income generation of farmers and enhance food security among people. Moreover, potato can be consumed in different forms, including as a fresh vegetable for cooking at home, as raw material for processing into potato-based products, as food ingredients (such as starch and alcohol), and as animal feed, as explored by Lutaladio et al. [1]. As the potato has great importance in developing countries, there is a need to sustain the potato sector by reducing or preventing different factors that lead to low production. In this regard, there is a need to take measures that are aimed at improving the quality of planting material, developing potato varieties that are more resistant to insect pests and diseases, addressing climate change, and developing farming systems that make more sustainable use of natural resources.

2.2. Potato in Rwanda

Potato is a very important crop in the agriculture sector in Rwanda as it contributes more to food security and generates income for the growers [4]. The annual consumption of potatoes is very high at 125 kg per person per year, and it is the second most important source of energy after cassava [5]. In addition, the average yield of potatoes is still low, ranging between 5 and 20 tons per hectare, compared to the target yield of 30 tons per hectare [6].

In Rwanda, low Potato yield is also attributed to different factors include diseases, inappropriate crop rotation, among others. Regarding to disease, there is seed borne pathogens in crops species that are detrimental to potato yield as explored by Chiarappa [7]. Besides, when potato tuber or crop is affected by bacterial wilt, viral diseases, it very difficult to cure or save the plant [8]. Therefore, the prevention of initial infection of potato using healthy potato seed and appropriate crop rotation could be the only efficient control measure. Using healthy and quality seed is essential for growing an optimal potato crop [9]. In Rwanda, provision of healthy, improved quality potato seed to growers necessitates initial mini-tuber production in research stations (University of Rwanda and INES-Ruhengeri) and subsequent are taken to the field multiplications by trained seed growers to obtain adequate healthy seeds [10].

2.3. Rwanda potato chain problems

The absence of organization and the poor level of output in the Rwandan potato industry are two fundamental characteristics. The individual potato growers suffer from inefficiencies in obtaining quality potato seeds and are also poorly connected themselves. Among the input suppliers, there are inappropriate varieties, a very limited supply of available good-quality seed, and poor distribution of quality seeds into rural areas. These factors mentioned above are among the ones that lead to low potato yields in Rwanda and or in the world [11].

2.4. Factors affecting potato yield

Growing healthy potatoes for maximum yield and quality requires that all the essential inputs be supplied at the right rate, at the right time, and at the right place. As the potato production is constrained by many factors, during the International Year of the Potato, celebrated in 2008, FAO and the International Potato Center (CIP) explored all critical aspects to address the sustainability of the potato production. Some of the factors that were agreed to affect potato production were technical, socio-economic, and policy-related in tropical and subtropical countries. In addition, these factors can be controlled by good agricultural practices (GAP) by improving seed quality systems, soil management, insect pest and disease control, and other opportunities for value addition. In a study on factors influencing potato yield, Lutaladio et al. [1] found that the greatest way to end hunger and poverty would be to regulate the elements indicated above.

III. Main Technical Factors

3.1. The biological makeup of potatoes

The biological properties of the potato itself serve as several limitations. These include the low multiplication rates of seed tubers and the costs associated with maintaining seed quality through successive multiplications, as well as soil- and seed-borne insect pests and diseases.

3.2. Insufficient and inadequate formal seed systems

Potato yield is also affected by a quality seed system that is not appropriately respected. The use of good-quality seeds with other appropriate crop management systems could be maximized to counteract low potato yield and production as well. Seed is the main component of potato production and profitability, which often depends on access to quality seeds. However, good quality seed is relatively expensive and is not affordable for all farmers as a result of using their own home-made and stored potato seeds from previous harvests.

In many developing countries, there is a lack of effective systems for the regular multiplication and distribution of certified potato seed tubers and the rapid deployment of new and improved varieties. These problems are attributed to the limited capacity of human resources, a lack of managerial expertise, and inadequate resource allocations to seed systems and the potato sector in general. Moreover, this influenced farmer-based potato seed systems to be highly used by providing planting material of limited quality over the years, which contributed to expanding cultivation of the crop [12].

3.3. Pests and diseases

Diseases and pests are the main constraints on potato production. Late blight was one of the diseases that posed the most serious threat to increased potato production. In this context, the bacterial wilt is ranked second after late blight in lowering potato production. The impact of insect pests varies from one region to another. In Rwanda, disease pressure has been increasing due to a failure to respect an adequate crop rotation period and the low integration of good pest management practices.

3.4. Potato production and crop rotation

High cropping frequencies of potatoes, particularly continuous cultivation, can lead to physical and economical yield losses because the population densities of soil-borne pathogenic organisms are enhanced. Such organisms diminish crop growth and often necessitate costly control measures [13].

A number of technical innovations including rotation could offer possibilities for improving the productivity and biophysical sustainability of the cropping systems. Rotation breaks soil pathogen and pest cycles, reduces pesticide use, declines soil erosion, facilitates weed control, enhances crop yield, productivity and restores fertility if legumes are included [12, 14, 15, and 16]. Crop rotation represents a systems approach in crop production research, enabling the available natural resources to be preserved and more efficiently utilized. In crop rotation experiments a monoculture is generally compared to various crop sequences. The fact that in most cases the yields of cultivated crops are higher in crop rotation, compared to a monoculture under identical conditions as it was observed by Berzsenyi et al. [17]. Rees et al. [18] reported that continuous production can lower yield. Soil borne diseases are persistent, recurrent problems in potato production, resulting in reduced plant growth and vigor, lower tuber quality, and reduced yield. These and other soil-borne diseases can be difficult to control, and current control measures, such as regular crop rotation, chemical seed treatments, promoting rapid emergence of sprouts, and early harvest of

tubers [19, 20 and 21], are not always practical or effective. Alternative or supplemental management practices are needed. Crop rotation is generally understood to be crucial for maintaining crop productivity and preventing the spread of diseases and soil-borne pathogens [22 and 23]. When compared to continuous potato planting, 2-year rotations have been demonstrated to lower soil-borne disease levels in potatoes [24 and 25]; it is known that longer rotation periods of three or four years between potato crops are more efficient at containing soil-borne diseases [26, 27, 28 and 29]. However, another important function of crop rotations is that they also need to increase profitability, either through the addition of profitable rotation crops themselves or through increased production or reduced losses of the potato crop [30].

Most crops that are not hosts to the same pathogens as the primary crop are considered suitable rotation crops, which for potatoes have traditionally been primarily small grain crops, such as barley (*Hordeum vulgare L.*) and oats (*Avena sativa L.*). Such rotational crops result in disease reduction primarily by serving as breaks in the host-pathogen cycle. However, there may be substantial differences among different crop types, species, and cultivars in their effects on soil-borne diseases and productivity. Disease-suppressive crops grown as rotational crops have distinct and active mechanisms for decreasing soil-borne infections. These crops can significantly reduce disease levels compared to normal or non-suppressive crops. For instance, the study conducted on crop rotation indicated that crops in the Brassicaceae family used in rotations or as green manures have been observed to reduce soilborne diseases or populations of fungal pathogens and nematodes [31, 32, 33 and 34].

IV. Research Methodology

4.1. Description of study area

The study was conducted in seven selected sectors of the Musanze district, located in the Northern Province of Rwanda. This district is known for its potato farming activities, among others in Rwanda. This district has a total surface area of 530.4 km2 and is neighbored in the north by Uganda, the DRC, and Volcanoes National Park; in the south by Gakenke district; in the east by Burera district; and in the west by Nyabihu district (Figure 1). Musanze district has 15 sectors, 68 cells, and 432 villages. Due to its high altitude, temperature of 20ºC, and annual rainfall ranging from 1400mm to 1800 mm, the district is suitable for potato farming. In this district, about 20542 farmers are engaged in Irish potato farming activities. Therefore, the choice of this study in Musanze district was made based on the high altitude and tropical climate and temperature that favor Irish potato farming and the high potato production compared to other regions in Rwanda.

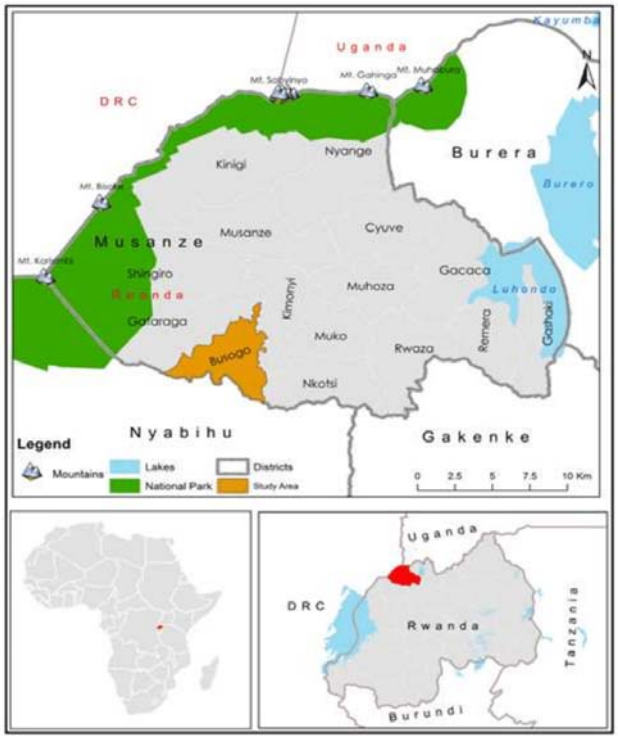

Figure1: A map of Rwanda illustrating sectors of Musanze districts where the survey was conducted

4.2. Sampling and data collection

Based on the mentioned choice criteria, seven sectors (Nyange, Gataraga, Cyuve, Busogo, Shingiro, Musanze, and Kinigi) among fifteen were selected for this study. The purposive sampling technique was used for the selection of sectors in order to maximize the required information. A simple random sampling was also performed among the potato farmers in each sector under consideration. Therefore, in each sector, 27 potato farmers were randomly selected; a total of 192 farmers were obtained and interviewed on these factors: use and source of quality seeds, prevalence of pests and diseases, agriculture input (fertilizers) used, crop rotation and production, and whether they were satisfied or not with potato production. To perform this survey, a questionnaire including all the aforementioned factors was developed to collect potato-related information. The potato farmers grouped in cooperatives and or individually working ones were identified by means of district and sector agronomists using formal-informal and expert interviews based on the prepared questionnaires.

4.3. Focus Group Discussions

Potato farmers and key informants in Musanze district were engaged in focus group discussions. Focus group discussions were held in order to strengthen the evidence of the responses from the individual farmer interviews and to find a wide range of responses into the use of potato seeds, fertilizers, crop rotation, and production satisfaction. The focus group discussions involved key persons such as district agronomists, directors of agriculture at district level, sector agronomists, SEDOs (Social Economic Development Officers) at the cell level, and farmers who had not participated in answering the structured questionnaires. The focus group discussions involved small groups, consisting of 3–10 farmers, in order to have a more controlled, all-inclusive, and efficient discussion. The group was as balanced as possible between male and female potato farmers. The discussions had one moderator, while the other two enumerators took notes on the discussions. The moderator ensured that every person participated. In total, four focus group discussions were held in all seven sectors of Musanze district, which involved 40 farmers in total.

4.4. Data analysis

The collected data were analyzed using STATA 14, and Microsoft excel (Windows Office 2019; Microsoft Inc., Redmond, WA).

4.5. Theoretical framework (logistic Model)

Logistic regression analysis has also been used mainly to investigate the relationship between binary or ordinal response probability and explanatory variables, as it was explored more by Maddala (1983) and Greene, (1993). For bankruptcy prediction, the binary response probability is usually the default probability, while a high number of explanatory variables can be used [35]. Let yi denote the response of respondents i with respect to the outcome of the explanatory variables x1i,... xki. Let Y = 1 denotes the default of the respondents who were satisfied with potato production and Y = 0 denotes no as not satisfied by potato production. According to Maddala, (1983) and Greene, (1993), in defining the model, the logistic model can be written as follows:

$$logit(P(Y = 1|x_1, \ldots, x_k)) = \beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n$$

Where Y is the response or satisfaction of the farmers as to whether the obtained production is enough or not (Yes = 1/No = 0), β0, β1,…,βn are the constants X x1,…,xn are explanatory variables (use of seed quality, pests and diseases, fertilizer use, crop rotation, and being in a cooperative, potato production) on farmers satisfaction with potato production.

V. Results And Discussion

5.1. Descriptive analysis

This study considered only 192 potato farmers in the Musanze district of Rwanda. Table 1 shows descriptive statistics for all variables in the study. The number of male respondents was higher than female. The males represented 77.60%, while the females were 22.40%. Only 17.2% of the 192 potato farmers were satisfied with their potato production. The average occurrence of late blight, bacteria wilt (BW), aphids, and others was perceived at 31.9, 68.8, and 86.8%, 49.7%, respectively. The total cultivated land (farm size) in this study was averaged at 2933.531 square meters. The potato rotation with other crops for at least one year was perceived at 89.6%. It is indicated that only 5.5 percent of the farmers use formal quality potato seed. The results of this study in terms of the low use of formal potato seed were also captured in the work done by Ferrari et al. [36]. This low use of

the formal seed system (certified seed) was reported to be attributed to less awareness of the presence of certified seed on the market, an associated high price, and low seed availability in the region, among others [36]. The same low potato production due to low use of certified seed was observed by Shimira et al. [37]. The study indicates that the minimum and maximum potato production per hectare is 4581.98 kg and 50000 kg, respectively.

Table1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Satisfaction	192	.172	.378	0	1
Gender	192	.776	.418	0	1
Formal	181	.055	.229	0	1
Late blight	191	.319	.467	0	1
Bacteria wilt	192	.688	.465	0	1
Others	191	.497	.501	0	1
Farm size attacked	192	237.359	458.965	0	3000
Aphids	189	.868	7.265	0	100
Farm size	192	2933.531	5448.752	100	60000
Production(kg)	192	2602.917	4581.987	45	50000
rotation	192	.896	.306	0	1
FBO	192	.464	.5	0	1

5.2. The perception on main factors affecting potato production

The results of this study indicates that the contribution of each independent variable to the satisfaction of farmers in terms of potato production.

Table2. Marginal effect of independent variables to farmer's perception on potato production

Average marginal effects Number of obs = 176
Model VCE: OIM
Expression: Pr (Satisfaction), predict()
dy/dx w.r.t.: gender Formal LateblightBactwilt Others Farmsizeattacked, Aphids Farmsize, Productioninkg rotation FBO

Delta-method

	dy/dx	Std.Err.	z	P>z	[95%Conf.	Interval]
gender	0.005	0.056	0.090	0.927	-0.105	0.115
Formal	0.222	0.074	3.020	0.002	0.078	0.367
Lateblight	0.015	0.055	0.270	0.791	-0.094	0.123
Bactwilt	-0.091	0.055	-1.660	0.097	-0.198	0.017
Others	-0.058	0.047	-1.230	0.220	-0.151	0.035
Farmsize attacked	-0.001	0.000	-2.570	0.010	-0.001	-0.000
Aphids	-0.004	0.016	-0.230	0.815	-0.035	0.027
Farmsize	-0.000	0.000	-1.850	0.065	-0.000	0.000
Productioning	0.000	0.000	3.160	0.002	0.000	0.000
rotation	0.013	0.091	0.140	0.890	-0.166	0.191
FBO	0.111	0.062	1.770	0.077	-0.012	0.233

5.3. Farmer's perception or satisfaction on informal and formal seed system

The probability of being male increases the farmer's satisfaction with potato production by 5.5% (table 1). It is indicated that the farmers who are using the formal potato system increase their satisfaction by 22.2%. This implies that when farmers use

certified potato seeds, their production increases, as confirmed by a 10% increase in satisfaction due to a 1 kg increase in potato production. Though the majority of farmers (82.81%) are not satisfied by their potato production as a result of using informal systems that do not yield well (Table 3), These results are very consistent with those reported by Shimira et al. [37], who indicated low potato production due to inadequate supply of certified potato seed and use of home-made seeds from their harvest, buying from other farmers, among other unknown sources [36].

Table3: Tabulation of gender Satisfaction on potato production

	Satisfaction		
Male	No satisfied	satisfied	Total
Female	37	6	43
	86.05	13.95	100.00
Male	122	27	149
	81.88	18.12	100.00
Total	159	33	192
	82.81	17.19	100.00

First row has *frequencies* and second row has *row percentages*

5.4. Farmers perception on cultivated land as farm size

The additional increase of one square meter (m^2) in farmer size reduces the farmer's satisfaction by 0.0% (Table 1). The additional increase in square meters (m^2) of farmer size does not bring satisfaction to farmers in terms of potato production. The cultivated land, whether small or large, does not bring satisfaction to farmers, as they said that as long as production is high, they are able to solve their own problems. These results indicate that the cultivated land is not relevant to explain farmer satisfaction in relation to potato production. The study conducted by Barrett et al. [38] indicated that large farms are not as productive as small ones. This takes into account different factors of production that can be used in a small farm, for instance, low labor and low input, and makes the farm more manageable.

5.5. Farmers perception on the production

The additional increase in potato production by one kilogram increases farmer satisfaction by 10% (table 1). The findings indicate that 86.05 % of female and 81.88% of male farmers were not satisfied with potato production, while only 13.95% of female and 18.12% of male farmers among the total number of potato farmers were happy with their production. These low percentages of satisfaction are well captured by the low use of certified potato seeds (5.5%) in Musanze district [36]. Besides, less use of certified seeds has been associated with many factors, such as less awareness of the certified seed, the use of homemade seeds, its high price, and low seed availability in the region, among others. Their study shows that the high use of non-certified potato seeds is due to the fact that farmers source the seeds from friends, neighbors, the local market, and their own stock, among others. These practices represent 94.48%, which was similarly reported by Forbes et al. [39] in low-income countries.

5.6. Farmers perception on cultivated land attacked by pests and diseases

The average of 237.359 square meters was attacked by pests, late blight, bacteria wilt, and others. The findings indicated that an additional increase in land size caused by these diseases and pests would reduce potato production while affecting the potato farmer's satisfaction. It indicated the non-significant effect of the presence of late blight in the field, while bacterial wilt was found to have a negative impact (9.1%), which is not significant ($P > 0.05$), on potato production and farmer satisfaction.

The bacterial wilt is known as potato brown," which mostly attacks and reduces potato production. Uwamahoro et al. [40] explored the presence of these bacteria in the soil and found that it may remain in the soil for a long period of time. It was found that the presence of BW affects more some potato cultivars such as kinigi, kirundo, and Gikungu, among others, which are highly grown in Musanze district and in developed countries such as New Zealand, Europe, the USA, and Mexico [39]. Besides, Muhinyuza et al. [41] and Razukas et al. [42] conducted a study on late blight and found it to be the most severe disease that attacks potatoes and tomatoes, among others, and is likely to lead to a huge loss of their production.

The severity of late blight on potato production in different states in India, which cover about 65% of the potato area, was reported by Lal et al. [43]. However, the potato farmers showed dissatisfaction with late blight due to its negative impact on their potato production. The green peach aphid (*Myzus persicae*) was reported to have a negative and non-significant impact on potato production and farmers satisfaction when found on the field. Larrain et al. [44] indicated the severity of the green peach aphid to produce potato leaf roll virus (PLRV), which causes leaf-rolling and tuber stem necrosis, thickening, curling, chlorotic spotting, among others, in potatoes and subsequently leads to low potato yield.

5.7. Farmer's perception of crop rotation

The presence of soil borne diseases (bacteria wilt, late blight, and others), aphids, and attached areas significantly affect potato production ($P<0.05$). Being in a cooperative does not contribute to potato production. This can be explained by many factors that are ignored by the farmers, like using an informal potato seed system that always led to low potato production [39]. The crop rotation for potatoes is done by replacing it with cabbage, beans, and/or carrots within one or two seasons to avoid soil-borne diseases like BW [45]. The findings of this study are contrary to those found by Shimira et al. [37], who showed the reduction of BW through the application of crop rotation. The crop rotation was perceived at 89.58%, and potato farmers rotate potatoes with other crops at least once a year, and this is seen not to contribute to potato production and farmer satisfaction. No or a limited contribution of crop rotation to potato production may also be attributed to its inappropriate application [46].

VI. Conclusion And Recommendation

This study was conducted to assess the perceptions of farmers on the main technical factors affecting potato production in Rwanda, particularly in Musanze district. Farmer's perceptions in terms of satisfaction on how farmers were satisfied by their potato production were assessed based on the use of seed quality (formal or informal seed systems), the prevalence of pests (aphids) and soil-borne diseases (Bacterial wilt, Late blight, among others), fertiliser use, crop rotation, and potato production. The findings showed a statistically significant effect of using certified potato seeds on potato production. It is indicated that the only farmers (17.19%) who use a formal potato seed system increase their satisfaction by 22.2%. The attached cultivated land affected by bacterial wilt, late blight, aphids, and other diseases showed a negative, significant effect on potato production and farmer satisfaction by 0.1%. The overall results of this study indicate that potato production is only affected by the prevalence of soil-borne diseases and pests and the high use of uncertified potato seed (82.81%). The study recommends an increase in awareness of certified seeds, the presence of certified seeds on the market, a reduced price for certified seeds, and the management of soil borne diseases using appropriate crop rotation, biological and chemical control, among other things.

References

[1] Lutaladio, N.; Ortiz, O.; Haverkort, A.; Caldiz, D. 2009. Sustainable potato production. Guidelines for developing countries. Rome (Italy). Food and Agriculture Organization. 91 p.

[2] Escobal, J., & Torero, M. (2006). Access to Dynamic Markets for Small Commercial Farmers: The case of Potato Production in the Peruvian Andes Access to Dynamic Markets for Small Commercial Farmers: The case of Potato Production in the Peruvian Andes 1. Food Policy.

[3] Cromme, N.; Prakash, A.B.; Lutaladio, N.; Ezeta, F. 2010. Strengthening potato value chains: Technical and policy options for developing countries. Workshop. Rome (Italy). Nov. 2008. Food and Agriculture Organization of the United Nations (FAO). ISBN 978-92-5-106627-0. 147 p.

[4] REMA, (2009). Rwanda state of environment and outlook report. Source: http://www.unep.org/pdf/rwanda_outlook.pdf. Rhizoctonia solani in potato. Potato Research 30: 187–199.

[5] RIU Rwanda, 2010. Potato innovation platform. Source : http:// www.researchintouse.com/programmes/riu-rwanda/riu-rw42innovplatpotato

[6] Frans, G. (2002). Potato Marketing in Rwanda. Agricultural Policy Development Project Research Report No. 12. United States Agency for International Development/Rwanda, Kigali, Rwanda. 38-56.

[7] Chiarappa, L. 1992. Worldwide losses due to seed-borne diseases. In: Seed Pathology. Proceedings of the CTA seminar held at Copenhagen, Denmark, in June 1988. Wageningen, p17-23

[8] Peter, G., Paul, D., Peter, K., Mercy, W., Moses, N. and Thomas Z. (2007). Select the best trainers' manual. Positive selection to improve farm saved seed potatoes. CIP, Lima, Peru, 26pp.

[9] Parveen, A., Abbas, S. J., Mudassir, A., Abrar, H. S. and Naushad, A.J.(2010). Effect of growth behavior of potato mini tubers on quality of Seed potatoes as influenced by different cultivars. Pak. J. Pl. Sci.16: 9pp

[10] Idrissa, F., Razika, K. and Philippe, N. (2006). Linking actors for potato production and marketing in Rwanda. ROPARWA and IMBARAGA initiatives in northwestern Rwanda. In"Farmers' organizations and Rwanda Journal, ISSN 2305-2678 Volume 90 28, Series E,

[11] Charles, C and Crissman, 2002. A Proposal for a Rwanda Potato Sector Development Program. Abt Associates Inc.

[12] Karlen, D.L, Varvel GE, Bullock DG, Cruse RM. (1994). Crop rotations for the 21st century. Advances in Agronomy, 53: 1–45. Kigali, Rwanda. 38-56.

[13] Vos, G and Van Loon, C.D. (1989). Effect of Crop Rotation on Potato Production in the Temperate Zones.

[14] Carter, M.R, Sanderson J.B, Ivany JA, White RP. 2002. Influence of rotation and tillage on forage maize productivity, weed species, and soil quality of a fine sandy loam in the cool– humid climate of Atlantic Canada. Soil and Tillage Research, 67: 85–98.

[15] Chalk, P.M. 1998. Dynamics of biologically fixed N in cereal– legume rotations: a review.

[16] Edwards L, Burney JR, Richer G, MacRae AH. 2000. Evaluation of compost and straw mulching on soil-loss characteristics in erosion plots of potatoes in Prince Edward Island, Canada. Agriculture Ecosystems Environment, 81: 217–222.

[17] Berzsenyi Z, Gyrffy B, Lap DQ. (2000). Effect of crop rotation and fertilization on maize and wheat yields and yield stability in a long-term experiment. European Journal of Agronomy, 13(2-3): 225-244.

[18] Rees, H.W, Chow TL, Loro PJ, Lavoie J, Monteith JO, Blaauw A. (2002). Hay mulching to reduce runoff and soil loss under intensive potato production in northwestern New Brunswick, Canada. Canadian Journal of Soil Science, 82: 249–258.

[19] Powelson, M.L., K.L. Johnson, and R.C. Rowe. (1993). Management of diseases caused by soilborne pathogens. In Potato health management, ed. R.C. Rowe, 178. St. Paul: APS Press.

[20] Secor, G.A., and N.C. Gudmestad. (1999). Managing fungal diseases of potato. Canadian Journal of Plant Pathology, 21: 213–221.

[21] Stevenson, W.R., R. Loria, G.D. Franc, and D.P. Weingartner. (2001). Compendium of potato diseases, 2nd ed. St. Paul: American Phytopathological Society.

[22] Cook, R.J. 1986. Interrelationships of plant health and the sustainability of agriculture, with special reference to plant diseases. American Journal of Alternative Agriculture, 1: 19–24.

[23] Krupinsky, J.M., K.L. Bailey, M.M. McMullen, B.D. Gossen, and T.K. Turkington. (2002). Managing plant disease risk in diversified cropping systems. Agronomy Journal, 94: 198– 209.

[24] Honeycutt, C.W., W.M. Clapham, and S.S. Leach. (1996). Crop rotation and N fertilization effects on growth, yield, and disease incidence in potato. American Potato Journal, 73: 45–61.

[25] Specht, L.P., and S.S. Leach. (1987). Effects of crop rotation on Rhizoctonia disease of white potato. Plant Disease 71: 433–437.

[26] Carter, M.R., and Sanderson, J.B. 2001. Influence of conservation tillage and rotation length on potato productivity, tuber disease and soil quality parameters on a fine sandy loam in eastern Canada. Soil and Tillage Research, 63: 1–13.

[27] Hide, G.A., and P.J. Read. (1991). Effects of rotation length, fungicide treatment of seed tubers and nematicide on diseases and the quality of potato tubers. Annals of Applied Biology, 119: 77–87.

[28] Hoekstra, O. (1989). Results of 24 years of crop rotation research at 'De Schreef' experimental site. In Effects of crop rotation on potato production in the temperate zones, ed. J. Vos, 37–43. Dordrecht: Kluwer Academic Publishers.

[29] Peters, R.D., A.V. Sturz, M.R. Carter, and J.B. Sanderson. (2003). Developing disease suppressive soils through crop rotation and tillage management practices. Soil and Tillage Research 72: 181– 192. 12.

[30] Halloran, J.M., T.S. Griffin, and C.W. Honeycutt. (2005). An economic analysis of potential rotation crops for Maine potato cropping systems. American Journal of Potato Research, 82: 155–162.

[31] Brown, P.D., and M.J. Morra. 1997. Control of soilborne plant pests using glucosinolate containing plants. Advances in Agronomy, 61: 167–231.

[32] Larkin, R.P., and T.S. Griffin. (2007). Control of soilborne diseases of potato using Brassica green manures. Crop Protection,26: 1067–1077.

[33] Matthiessen, J.N., and J.A. Kirkegaard. (2006). Biofumigation and enhanced biodegradation: opportunity and challenge in soilborne pest and disease management. Critical Reviews in Plant Sciences,25: 235–265.

[34] Smolinska, U., and M. Horbowicz. (1999). Fungicidal activity of volatiles from selected cruciferous plants against resting propagules of soilborne fungal pathogens. Journal of Phytopathology, 147: 119–124.

[35] Stefan, T., &Svetlozar T., R. (2009). Rating and Scoring Techniques. Rating Based Modeling of Credit Risk, 11–30. https://doi.org/10.1016/B978-0-12-373683-3.00003-8.

[36] Ferrari, L.; Fromm, Ingrid; Jenny, K.; Muhire, A.; Scheidegger, Urs. (2017). Formal and informal seed potato supply systems analysis in Rwanda In: Tropentag 2017: Future Agriculture: Social-ecological transitions and bio-cultural shifts. Bonn, Germany. September 20-22, 2017.

[37] Shimira, F., Afloukou, F. and Maniriho, F. (2020). 'A review on challenges and prospects of potato (Solanum tuberosum) production systems in Rwanda', Journal of Horticulture and Postharvest Research, 3(March), pp. 97–112. doi: 10.22077/jhpr.2020.2854.1099.

[38] Barrett, C. B., Bellemare, M. F. and States, U. (2010). 'Reconsidering Conventional Explanations of the Inverse Productivity – Size Relationship', World Development, 38(1), pp. 88–97. doi: 10.1016/j.worlddev.2009.06.002.

[39] Forbes G.A., Charkowski A., Andrade-Piedra J., Parker M.L., Schulte-Geldermann E. (2020). Potato Seed Systems. In: Campos H., Ortiz O. (eds) The Potato Crop. Springer, Cham. https://doi.org/10.1007/978-3-030-28683-5_12.

[40] Uwamahoro, F., Berlin, A., Bucagu, C., Bylund, H., & Yuen, J. (2018). Potato bacterial wilt in Rwanda: occurrence, risk factors, farmers' knowledge and attitudes. Food Security, 10(5), 1221- 1235. https://doi.org/10.1007/s12571-018-0834-z.

[41] Muhinyuza, J. B., Nshimiyimana, J. C., & Kirk, W. W. (2007). Susceptibility of commonly grown potato cultivars to potato late blight in Rwanda and control with fungicides. African Crop Science Conference Proceedings Vol. 8. El-Minia, Egypt. 27-31 October. pp, 835-840.

[42] Razukas, A., Jundulas, J., &Asakaviciute, R. (2008). Potato cultivars susceptibility to potato late blight (Phytopthtorainfestans). Applied Ecology and Environmental Research, 6(1), 95-106

[43] Lal, M., Arora, R. K., Maheshwari, U., Rawal, S., and Yadav, S. Lal, M. et al. (2016) 'Impact of late blight occurrence on potato productivity during 2013-14', International Journal of Agricultural and Statistical Sciences, 12(1), pp. 187–192.

[44] Larrain P, Kalazich J, Carrillo R, Cisternas E. (2003).Plagas de la papa y sumanejo. Colecciónlibros INIA- N° 9. Instituto de InvestigacionesAgropecuarias, Ministerio de Agricultura. La Serena, Chile.

[45] Kassa, B. (2017). Participatory potato (Solanum tuberosum L.) bacterial wilt (Ralstonia solanacearum (E.F.Smith.)) management in the central highlands of Ethiopia. Agricultural Research & Technology: Open Access Journal, 11(1). https://doi.org/10.19080/artoaj.2017.11.555802.

[46] Danial, D., De Vries, M., &Lindhout, P. (2016). Exploring the potential of hybrid potato cultivars in East Africa. Retrieved from https://knowledge4food.net/wp-content/uploads/2017/02/161130- Report-Solynta-mission-to-East-Africa.pdf.