Journal of Scientific Research & Reports

19(3): 1-9, 2018; Article no.JSRR.40588
ISSN: 2320-0227

Genotype by Environment Interaction on Potato (*Solanum tuberosum* L.) Cipira Variety in the Western Highlands of Cameroon

D. K. Njualem[1], S. S. Meka[2*] and E. T. Tchio[3]

[1]*School of Tropical Agriculture and Natural Resources, Catholic University of Cameroon (CATUC), P.O.Box 782, Bamenda, Cameroon.*
[2]*Institute of Agricultural Research for Development (IRAD), P.O.Box 80 Bamenda, Cameroon.*
[3]*College of Technology (COLTECH), University of Bamenda, P.O.Box 39, Bambili, Cameroon.*

Authors' contributions

This work was carried out in collaboration of all authors. Author DKN designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors SSM and ETT managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2018/40588
Editor(s):
(1) Corina Carranca, National Institute of Agricultural Research and Veterinary (INIAV), Research Unit of Environment and Natural Resources (UIARN), Portugal.
(2) Anita Biesiada, Associate Professor, Wroclaw University of Environmental and Life Sciences, Wroclaw 50-363 Plac Grunwaldzki 24a, Poland.
(3) Luigi Rodino, Professor of Mathematical Analysis, Dipartimento di Matematica, Università di Torino, Italy.
Reviewers:
(1) Namo, O. A. Timothy, University of Jos, Nigeria.
(2) Zoran Jovović, University of Montenegro, Montenegro.
Complete Peer review History: http://www.sciencedomain.org/review-history/24612

Review Article

Received 12th February 2018
Accepted 18th April 2018
Published 15th May 2018

ABSTRACT

Variations in biological systems are due to genetic and environmental influences. Climate change has caused serious damages in potato production worldwide. A literature review on previous research works carried out in the Western Highlands of Cameroon aimed at determining the effects of genotype by environmental interaction on Cipira variety yield within 24 years. Yield loss of 35-65% was recorded for the production of ware and seed potato in the Western Highlands. A shift in planting seasons was observed over the years due to changes in climatic conditions. Diseases and pests were found to be on the increase in potato fields. The frequency of chemical control of disease pathogens rose from two to sixteen sprays per cropping season within the 24 years in the Western Highlands. Consequently, the cost of production for fungicides purchased to control late

**Corresponding author: E-mail: meka_sol@yahoo.fr;*

blight in potato increased from US$84 to US$672. This review recommends research on using potato genotypes possessing minor genes to develop varieties of short and long cycles, heat-stress, disease resistance and high yields for the Western Highlands of Cameroon.

Keywords: Genotype; potato; climate change; production; diseases; environment.

1. INTRODUCTION

Genotype by environment has significant influence on the performance of potato varieties. Cipira potato variety whose resistance to late blight was controlled by major genes developed in 1992 witnessed a significant decline in yield within 24 years. [1], reported a yield loss of 53% in upper farms in Cameroon while [2], reported global losses of 40-50% caused by late blight in potato genotypes.

Climate change has caused tremendous changes in potato production worldwide. Potato is a very important crop in the Western Highlands of Cameroon, ranging from consumption as food to exportation to neighbouring countries as a source of income generation.

Potato is best adapted to temperate regions, followed by regions of high altitude in the tropics like the Western Highlands of Cameroon. The effect of climate change on potato production is complex. It is likely that the current observed trend of global warming, which stands at 0.6ºC ± 0.2 since 1990 will continue and that the average global temperature will increase between 1.4 and 5.8℃ over a period of 1990 to 2100 [3].

Following an agreement between the Cameroon government by the Institute of Agricultural Research for Development (IRAD) and the International Potato Centre (CIP), Lima- Peru, signed in 1987, 30,000 potato genotypes were introduced into Cameroon in 1988. Most were late blight resistant, possibly due to R-genes from their Mexican blight resistant parents and high-yielding [4]. After five years of intensive selections in eleven environments, five varieties were released in 1992 with the most cherished being Cipira.

Cipira was most preferred in terms of disease resistance, dry matter content, palatability, and yield and was cultivated by a majority of farmers. At the time of release, Cipira had yields ranging from 35-40 t/ha with late blight rating of 0.21 cm^2 surface area under the disease progress curve (SAUDPC) [1].

Planting season of potato in the Western Highlands were March/April and harvest in June/July for the first season and August/September and harvest in November/ December for the second season [5]. The frequency and cost of late blight control on a hectare of Cipira variety at the time of its release was two sprays estimated at US$ 84. This paper reviews the effect of genotype by environment interaction on the yield of Cipira after 24 years of its release.

2. MATERIALS AND METHODS

2.1 Study Sites

The study was carried out in the Western Highlands of Cameroon, being one of the major potato production areas (Fig. 1).

Climatic data of the study area (Tubah Sub-Division in the North West Region of Cameroon) from 1992 to 2015 are presented in Table 1.

2.2 Selection of the Cipira Potato Variety

The IRAD/CIP potato project was established in 1988 to implement the terms of a scientific and technical agreement signed in 1987 between the Cameroon government and the International Potato Centre (CIP). The objectives of the agreement were to develop adapted potato varieties and set up a seed program for the production and supply of basic potato seeds to farmers.

Introduction trials with 30,000 potato genotypes from CIP were conducted at IRAD Bambui Upper Farm in 1988 and 1989. Advanced yield trials of 750 selected genotypes from the 30,000 genotypes were conducted in 1990 in Bambui, Santa and Dschang.

On-farm trials of nine genotypes from the 750 selected genotypes were conducted in

1991 and 1992 in all the environments (Table 2).

Interviews of some prominent potato farmers were conducted to get information on planting calendar for potato production, yields and other constraints as influenced by potato genotype and environment in the Western Highlands of Cameroon.

Data collected from the experiments on yield, planting season, frequency and cost of late blight control for a period of 24 years were used to determine the effect of genotype by environment on the performance of Cipira variety.

2.3 Late Blight Severity

Late blight severity is the measure of the percentage of spread of the fungus on the plant. It was measured using Table 2 as guide. It was recorded at weekly intervals for six weeks and the data collected were used to calculate the area under the disease progress curve (AUDPC) [7].

Where y_i= disease severity, and t_i= time in DAP.

$$AUDPC = \sum_{i}^{n-1}\left[\left(\frac{y_i + y_{i+1}}{2}\right)(t_{i+1} - t_i)\right]$$

Table 1. Temperature, rainfall and relative humidity data in Tubah Sub-Division (North West Region) from 1992 to 2015

Year	Mean annual minimum temperature (℃)	Mean annual maximum temperature (℃)	Mean annual temperature (℃)	Total rainfall (mm)	Mean annual minimum relative humidity (%)	Mean annual maximum relative humidity (%)
1992	15.0	25.9	19.9	2302.1	56.8	89.8
1993	12.5	25.4	20.2	2455.2	58.0	90.3
1994	13.0	25.2	20.0	2358.1	59.0	89.0
1995	15.7	25.3	20.5	2166.4	61.8	90.0
1996	15.7	26.2	21.0	2162.3	49.8	85.9
1997	13.7	26.3	20.0	2464.3	47.8	87.6
1998	12.9	26.2	19.6	2246.4	47.8	88.0
1999	12.4	24.8	18.6	2592.1	56.4	79.8
2000	12.3	25.3	18.8	2216.2	65.0	71.3
2001	12.9	25.3	19.1	2306.0	56.9	75.2
2002	13.0	25.0	19.0	2634.6	62.8	78.9
2003	13.3	25.3	19.3	1914.6	61.9	81.3
2004	13.3	25.7	19.5	2376.7	58.4	81.4
2005	16.1	24.3	20.2	2625.5	58.5	88.8
2006	16.2	24.3	20.3	2305.4	57.8	87.1
2007	17.0	23.8	20.4	2717.4	58.3	83.0
2008	15.9	24.0	20.0	2321.3	52.8	81.8
2009	17.6	23.5	20.6	2550.1	53.2	86.6
2010	16.9	23.9	20.4	2555.7	53.8	88.3
2011	15.7	24.0	19.9	2463.7	56.0	93.4
2012	14.5	26.9	20.7	2282.4	52.0	94.7
2013	15.9	27.5	21.7	1713.9	60.5	97.6
2014	15.7	27.9	21.8	3482	61.4	99.1
2015	15.4	27.8	21.6	3291	55.6	97.1

**Source: Regional Delegation of the Ministry of Transport, North-West Region, Cameroon*

Table 2. Ecological and experimental characteristics of locations used for selection of potato genotypes in Cameroon [4]

Experimental site	Altitude m.a.s.l.	Rainfall mm	Temperature range °C	Fertiliser N-P-K	Growing period- days	Environmental stresses
Befang	700	1927	17.2-30.2	220-100-100	75	Heat, BW, Excess rain
Babungo	1178	1447	13.7-28.9	100-150-100	75	Heat, BW, LB
Dschang	1500	2000	10.3-21.1	120-180-100	90	Low soil fertility, LB
Mfonta	1330	1834	13.8-26.8	100-150-100	90	Low soil fertility
Santa	1650	1700	13.0-21.0	Poultry manure	90-120	LB
Upper farm	2000	2198	12.3-21.1	120-180-100	90-120	LB, EB, Excess Humidity
Banso	1500	1600	13.5-27.8	100-150-100	90	LB
Nkongle	2200	1800	12.1-20.8	120-180-100	90-120	LB

**BW = Bacteria Wilt, LB = Late Blight, EB = Early Blight*

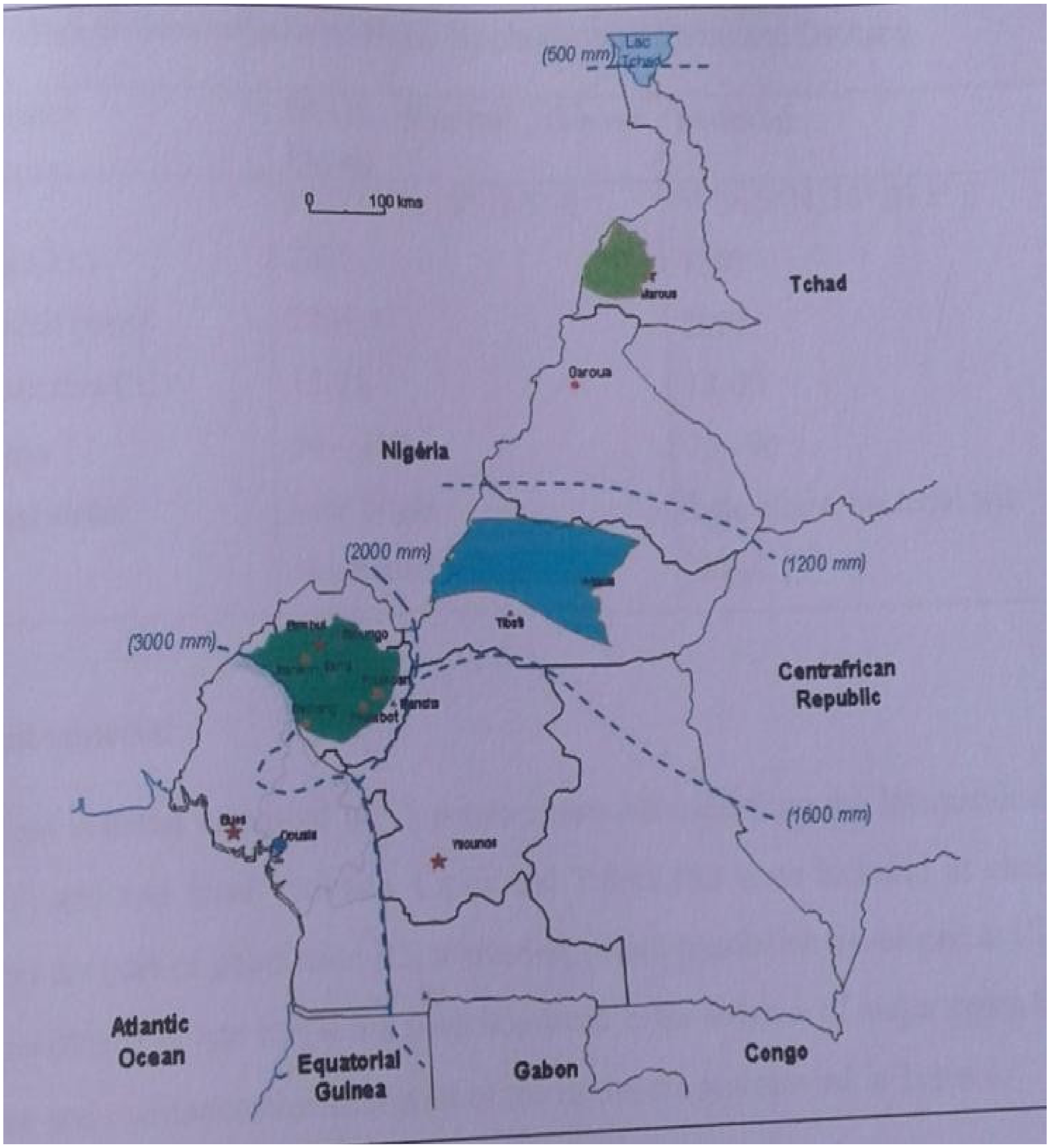

Fig. 1. Major potato production areas in Cameroon [6]

3. RESULTS AND DISCUSSION

3.1 The Effect of Genotype by Environment Interaction on Potato Yields

Potato yields are affected by genotypes, biotic and abiotic factors. Varieties developed under the influence of major genes resistance breakdown over time. Abiotic factors such as temperature (between day and night), radiation, day length, soil fertility, water supply, diseases and pest attack and cropping system affect potato yields [8].

The average yields of Cipira variety were found to decline continuously as the years progressed from 40 $t.ha^{-1}$ in 1992 to 8.4 $t.ha^{-1}$ in 2015 (Fig. 2). Cipira potato variety whose resistance to late blight was controlled by major genes developed in 1992 witnessed a significant drop in yield within 24 years. [1], reported a yield loss of 53% in upper farms in Cameroon while [2], reported global losses of 40-50% caused by late blight in potato genotypes.

The same trend was observed for seed and ware potato within the 24 years. This continuous decrease could be attributed to potato genotype degeneration and climate change. According to [9], at lower altitudes in many tropical and subtropical countries, Ralstonia solanacearum, the causative agent of bacterial wilt, is an important component of degeneration with an incidence of up to 36% in tubers from some farms in Kenya. Also, seed-borne insect pests, such as potato tuber moth, can also be considered important causes of degeneration in tropical countries, as they may readily become seed borne and have multiple generations in the field and in storage [10,11,12]. [13] reported that climate change will lead to 20-30% yield losses. This range is less than those gotten from this study, with an average loss of 79%. The decrease in yield could also be due to increase in soil temperature which was reported by [14] to adversely affect yield. [13] further postulated that high air and soil temperatures have a negative impact on the growth and development of potato. Temperatures of 25℃ or higher than 30℃ shortens the growing period of potato and reduces tuber yield.

[15], stated that yield losses originating from climate change could be as a result of increase in relative humidity which leads to massive emergence of fungal and bacterial diseases. It was also revealed that climate change will lead to increase in disease and pest frequency which will negatively affect potato yields [16,17].

3.2 The Effect of Genotype by Environment Interaction on Late Blight Disease of Cipira Potato Variety Yields

3.2.1 Surface area under the disease progress curve (SAUDPC)

SAUDPC was studied and the results generated from the 1992 to 2015 annual reports on seed and ware potato productions are presented in figure 3. It was noticed that there was a regular increase in the SAUDPC from 0.21 cm^2 in 1992 to 4.11 cm^2 in 2015 in the Cipira variety.

It has been reported that climate change caused several environmental changes suitable for the development of late blight. [14] reported that climate change will lead to increase in relative humidity, and high relative humidity has been found by [15] to increase disease rates.

Climate change has also led to the increase in the intensity of rainfall which increases the spread of diseases [17]. These increases in spread of disease could be due to large rain drops hiting the soil surface and provoking some splashing. These splashes carry spores of late blight to the other parts of the plant hence increasing the severity of late blight.

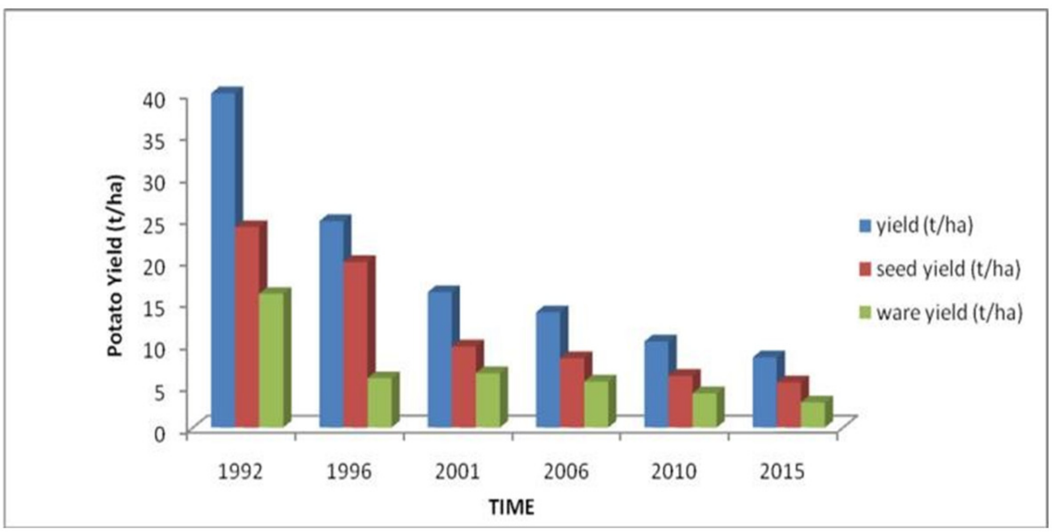

Fig. 2. Average yields for seed and ware Cipira potato variety
Generated from: IRAD Bambui, Annual reports on seed and ware potato productions, 1992-2015. [18]

Increase in temperature due to global warming could also contribute to the increase in SAUDPC over the years. It is known that high temperatures favour the reproduction of fungal spores and also their spread.

3.2.2 Number of sprays

Number of sprays for CIPIRA was found to have risen drastically from 2.0 sprays in 1992 to 16 sprays in 2015 (Fig. 3). This increase in the number of sprays ties with the increase in late blight severity. As disease increases, there is need for control to increase, hence both factors are positively correlated.

At low temperature (<18℃) such as those prevailing in Bambui (Upper farm), Phytophthora infestans reproduces by liberating zoospores, which leads to higher late blight outbreak than sporospore germination. A high mean value of SAUDPC suggests a more late blight disease severity. This high value has been observed in recent times with the increase in the number of sprays per season. This may be attributed to changes in climatic conditions.

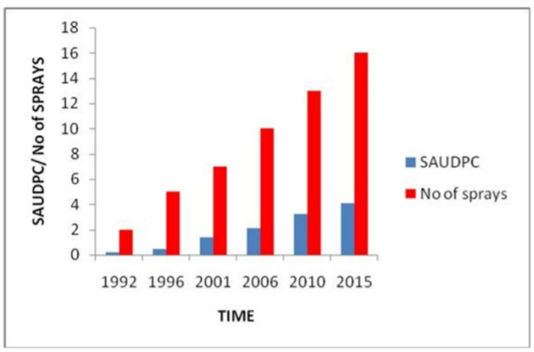

Fig. 3. A representation of the variation in SAUDPC and number of sprays in CIPIRA potato variety

Source: IRAD Bambui, Annual reports on seed and ware potato productions, 1992-2015. [18]

3.2.3 Cost of spray per hectare

From this study, the cost of spray per hectare was calculated and it was found to have risen from US$84 to US$672 (Fig. 4). This is a clear proof that as disease increases, the cost of production had to increase as more chemicals are bought to control the effect. These results corroborate with the findings of [19] who studied the economic impact of potato late blight on US growers and reported an increasingly higher cost of fungicides for control practices over the years. The same trend was observed in the findings of [20] who studied the Societal Costs of Late Blight in Potato and Prospects of Durable Resistance through Cisgenic Modification and reported annual losses (costs of control and damage) caused by *Phytophthora infestans* estimated at more than €1,000,000,000. Chemical control has been under pressure as late blight had become increasingly aggressive with societal resistance against the use of environmentally unfriendly chemicals.

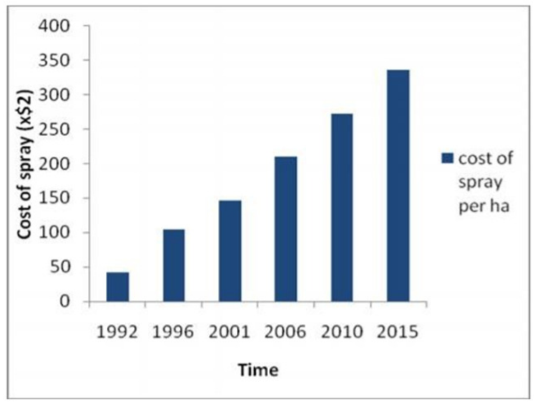

Fig. 4. Evolution of Cost in dollars required to buy fungicides to spray a hectare of potato farm

Source: IRAD Bambui, Annual reports on seed and ware potato productions, 1992-2015[18]

3.2.4 Shift of planting calendar

The two main cropping season of potato in Cameroon are the early season from March to July and the late season from August to November. The crop is therefore planted in March/April in the first season and August/September in the second season. In the early season, subsistent farmers intercrop potato with maize, cocoyam and other annual crops, while in the late season, they intercrop with beans. This is to ensure food security and guide against possible crop failure. In the dry season (November to February), few subsistent farmers plant the crop along river banks and valleys while commercial farmers use irrigation facilities. Consequently, commercial farmers plant up to three crops per year. This cropping pattern has been seriously altered due to climate change. Potato cultivation seasons have gradually shifted to April/May for the first season and September/October for the second season due to climate change.

3.2.5 Storage period

Potato tuber moth constitutes a major obstacle to potato storage. Some farmers in the Western Highlands store potato with local herbs such as *Lantana camara* leaves to avoid tuber moth damage [21]. However, increase in temperature and relative humidity due to climate change has favoured the multiplication of tuber moth in potato storage. A recent study conducted at upper farm revealed 60% loss in weight within 8 months of seed storage and 20% tuber rot within the same period [5]. This might be attributed to increase in relative humidity and temperature.

4. CONCLUSION

Cipira potato variety whose resistance to late blight was controlled by major genes developed in 1992 witnessed a significant drop in yield within 24 years. Although Cipira variety had been preferred by consumers compared to other varieties over the past 24 years, it had suffered a tremendous drop in yield due to genetic degeneration and climate changes, despite the increasing cost of production resulting from pesticide application. Therefore, the current research priority should be focused on developing short and long cycle, heat stress-resistant, disease-resistant and high-yielding potato varieties. In the same vein, the two commonly cultivated potato types, *Tuberosum* and A*ndigina,* should be cultivated in Cameroon, respectively for long and short day lengths. Meristem culture should be used to clean Cameroonian potato varieties so that they can regain their productivity potentials. The potato material used should be renewed to regenerate its genetic potential to resist diseases. Farmers should also adopt better management strategies like integrated pest management, mixed cropping and crop rotation to mitigate the adverse effects of climate change.

ACKNOWLEDGEMENT

The financial contribution of France-Cameroon Cooperation through the C2D/PAR Project is highly appreciated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Njualem DK. Evaluation of potato (*Solanum tuberosum* L.) production and clonal screening for resistance of major diseases and yield characteristics in the Western highlands of Cameroon. PhD Thesis Faculty of Agronomy and Agricultural Sciences, University of Dschang. Cameroon; 2010.
2. Fry WE, Godwin SB, Matuzak JM, Spielma LJ, Milgroom MG, Drenth A. Population genetics and intercontinental migration of Phytophtora infestans. Annual Review. Phytopathology. 1992;30: 107-129.
3. Houghton JT, Ding Y, Griggs DJ, Noguer M, Van Der Linden PJ, Xiaosu D, et al. (Eds). Climate change. The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK; 2001.
4. Martin C, Demo P, Njualem DK, Gass T, Ntonifor C. Late blight resistant varieties for Cameroon. Am. Potato Journal. 1995;72:513-522.
5. Njualem DK, Demo P, Mendoza HA, Koi JT, Nana SF. Reactions of potato genotypes to late blight in Cameroon. African Crop Science Journal. 2001;9: 201-213.
6. Adiabo. Planning a seed program. The Case of IRA-CIP Project, Cameroon; 1992.
7. Jeger MJ, Viljanen RSLH. The use of the area under the disease-progress curve (AUDPC) to assess quantitative disease resistance in crop cultivars. Theoretical and Applied Genetics. 2001;102:32-40.
8. Beukema HP, Van der Zaag DE. Introduction to potato production. PUDOC, Wageningen; 1990.
9. Mwangi JK, Nyende AB, Demo P, Matiru VN. Detection of latent infection by Ralstonia solanacearum in potato (*Solanum tuberosum*) using stems instead of tubers. African Journal of Biotechnology. 2008;7:1644–9.
10. Sileshi G, Teriessa J. Tuber damage by potato tuber moth, Phthorimaea

operculella Zeller (Lepidoptera: Gelechiidae), in the field in eastern Ethiopia. International Journal of Pest Management. 2001;47:109–13.
11. Golizadeh A, Esmaeili N, Razmjou J, Rafiee-Dastjerdi H. Comparative life tables of the potato tuberworm, *Phthorimaea operculella*, on leaves and tubers of different potato cultivars. Journal of Insect Science. 2014;14:1–11.
12. Thomas-Sharma S, Abdurahman A, Ali S, Andrade-Piedra JL, Bao S, Charkowski AO et Al. Seed degeneration in potato: The need for an integrated seed health strategy to mitigate the problem in developing countries; 2015. DOI: 10.1111/ppa.12439
13. Thomas P. Potatoes and climate change. Info Resources Focus No 1/08. Inter Cooperation, CDE and InfoAgrar/Swiss College of Agriculture; 2008.
14. Jovovic Z, Micev B, Velimirovic A. Impact of climate change on potato production in Montenegro and options to mitigate the adverse effects. Academia Journal of Environmental Science. 2016;4(3):047-054.
15. Jovovic Z. Environmental conditions for potato production in the mountain region of Montenegro. Handbook for Agricultural Producers, Centre for Development of Agriculture, Bijelo Polje. 2011;33-42.
16. Jovovic Z, Tiodorovic J, Velimirovic A, Milosevic D. Significant incidence of black rot of the lower stem portion of potato ("Blacking") in Montenegro in 2012. Plant health for sustainable agriculture, 11-12 May 2015a, Ljubljana, Slovenija, Book of Abstracts; 2015.
17. Jovovic Z, Tiodorovic J, Velimirovic A. Climate change and crop production: The impact of floods on potato production in Montenegro. Symposium "Flood risk management and mitigation of damaging consequences, June 4, in Sarajevo, Bosnia and Herzegovina, Proceedings. 2015b;135-140.
18. IRAD Bambui, Annual Reports on Seed and Ware Potato Productions, 1992-2015.
19. Guenthner JF, Michael KC, Nolte P. The economic impact of potato late blight on US growers. Potato Research. 2001;44: 121-125.
20. Haverkort AJ, Boonekamp PM, Hutten R, Jacobsen E, Lotz LAP, Kessel GJT, et al. Societal costs of late blight in potato and prospects of durable resistance through Cisgenic modification. Potato Research. 2008;51(1):47–57.
21. Demo P, Fontem DA, Njualem DK. Status of potato production, marketing and utilization in Cameroon. In: Advances in root and tuber crops technologies for sustainable food security, improved nutrition, wealth creation and environmental conservation in Africa (Mahungu N.M. & Manyong V.M., eds). Proceedings 9th ISTRC-AB Symposium. Mombasa, Kenya. 2004;18-25.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24612