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Screening of Potato (*Solanum tuberosum* L.) Genotypes for Adaptability in the Western Highlands of Cameroon

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

[1]Department of Crop Production, College of Technology, University of Bamenda, Cameroon.
[2]Institute of Agricultural Research for Development, Dschang Station, Cameroon.
[3]School of Tropical Agriculture and Natural Resources, Catholic University of Cameroon.

Authors' contributions

This work was carried out in collaboration among all authors. Author ETT carried out the field work, managed the literature searches. Author SSM followed up field work activities and wrote the first draft of the manuscript. Author DKN designed the experiment, performed statistical analysis and reviewed the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted from 20th April to 11th August 2016 at Upper Farm Bambui with 16 potato genotypes to select those with best performance as promising candidates for variety release. The treatments were arranged in a randomised complete blocked design with four replications. Data were collected on vegetative, disease and yield parameters and subjected to analysis of variance (ANOVA). All results obtained were significantly different (P=0.05). The mean Leaf Area Index (LAI) ranged from 123.83± 7.00 (for variety Cipira) to 206.70± 25.49 (for genotypes 392639.34). Mean number of stems ranged from 3.60± 0.60 (for genotype 392039.4) to 7.20± 1.04 (for genotype 392639.34). Plant heights ranged from 34.40± 1.59cm (for variety Jacob) to 51.67± 4.39cm (for genotype 395011.13). Stem diameters ranged from 0.65± 0.09cm (for genotype 395011.12) to 0.91± 0.07cm (for genotypes 395524.9, 396241.4) and were superior to the check varieties. Late blight was most severe in the check varieties compared to the genotypes evaluated indicating that

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

genotypes with minor genes were resistant to late blight than existing varieties selected with major genes. The rAUDPC was used to rank late blight severity and it ranged from 0.01± 0.01 (for genotypes 393617.64) to 0.59±0.00 (for check variety Jacob). There was an inverse correlation between yield and late blight severity. Low rates of bacterial wilt and virus incidence were obtained, with maximum bacterial wilt incidence of 8.8% for genotype 393633.34 and virus incidence of 26.7% for 392639.34. Five genotypes were selected with good yields compared to the check varieties. The best five genotypes were 393084.31 (23.33 ton/ha), 393633.34 (23.22 ton/ha), 395524.9 (20.78 ton/ha), 396036.201 (20.56 ton/ha) and 395011.13 (20.0 ton/ha), compare to 12.89 and 17.00 ton/ha for Cipira and Jacob respectively. These five genotypes are therefore recommended for further screening to develop new varieties.

Keywords: Diseases; genes; genotypes; potato; screening; varieties; yield.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.*)* is an important crop in the world and the fourth most important food crop after rice, wheat and maize [1]. Its production represents almost half of the annual output of all roots and tubers with a production figure of 321.69 million tons [2]. It is produced on an estimated area of 69000 ha with an annual production of 219192 tons in Cameroon [3].

In Cameroon, potato is grown in the highland regions between 1000 to 3000 m above sea level in six of the 10 regions [4]. In the Western Highlands of Cameroon, it is estimated that over 200,000 smallholder farmers, most of them women, are involved in the production of potato. Their production accounts for more than 80% of the national production, estimated at 142 000 tons per year cultivated on 45 000 hectares [5]. A large proportion of potato produced in Cameroon is consumed locally as food. This is either consumed as boiled, pounded, chips or porridge. According to Nadine and Erin [6], potatoes are a healthy source of nutrition. It is rich in starch which is used by the body for energy supplies. Potato contains at least 12 essential vitamins and minerals where vitamin B, C, thiamine, folic acid, iron, potassium, phosphorus, iron and magnesium are in reasonable proportions though low in protein, it is also an excellent source of antioxidants [7]. Potato also contains some toxic chemicals such as solanines and chaconines when tubers are exposed to sun light for a long time [3].

Part of the potato produced in Cameroon is exported to neighbouring countries such as Chad, Congo and Gabon [8]. Hence potato also serves as foreign exchange crop increasing the country's income. The same authors reported that estimates of potato yield vary from 3.3 to 6.7 t/ha based on production zone with an overall mean of 6.0t/ha. Potato production also faces some constraints such as diseases, including virus, bacterial and late blight. Njualem [4] stated that 94% of farmers have diseases as a major constraint and 76% suffer from shortage of adapted materials. In the same vein, Achancho [9] reported that constraints such as the absence (or the high cost) of certified seeds and the use of degenerated seeds, manual cultivation realised on small plots, low usage of inputs, poor cultivation and management techniques are responsible for low yields averagely 6 t/ha of potato production in Cameroon. Furthermore, potato production is handled mostly by small peasant farmers who will prefer varieties that can resist diseases and demand less use of pesticides. The Institute of Agricultural Research for Development (IRAD) in Cameroon has succeeded in valorising six genotypes as varieties namely: Tubira, Cipira, Bambui Wonder, Jacob 2005, Maffo, and IRAD 2005). All these varieties were released because of their endowment with major genes characterised by vertical resistance which degenerates over time. Cipira and Tubira were produced after screening 30000 clones from CIP from 1987-1992 [10]. At the time of release, these varieties could resist some major diseases and had yield potentials of 25 to 35 ton/ha. These yield potentials have decreased over time due to degeneration of major genes and the presence of systemic diseases which attack the plant at late stages of their development [11].

Minor genes tend to possess stable resistance to late blight [12]. This form of resistance can also be referred to as horizontal resistance and plants with such characteristics are more stable. Due to the reduction in yield potentials of the six IRAD varieties, new potato genotypes bred for minor genes were imported and subjected for screening with the aim of selecting new varieties. Likewise, to sustain the constant fight against food insecurity and the rise in environmental awareness, it will be necessary to develop varieties that are high yielding and diseases resistant while limiting the use of pesticides. Therefore, this work aimed at screening genotypes that have horizontal resistance and are stable in terms of disease tolerance and yield, to replace the existing varieties that have degenerated over time.

2. MATERIALS AND METHODS

2.1 Experimental Site

The research was carried out in IRAD Bambui. IRAD Bambui is located in Agro-ecological zone III (Western Highlands) of the North West Region in Cameroon. It is the Regional Centre of this agro-ecological zone. This area has an annual rainfall of 1500 to 2000 mm and a temperature range of 21 to 24^{o}C. The experimental plot was located at upper farm of IRAD Bambui. The land here is on an altitude of 2000 m above sea level.

2.2 Plant Materials

Sixteen potato genotypes obtained from the International Potato Centre (CIP) were screened. Two varieties, Cipira and Jacob were used as checks (control). 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 in Cameroon in 1988. Most were late blight resistant, possibly due to R-genes from their Mexican blight resistant parents and high-yielding. After five years of intensive selections in eleven environments, five varieties were released in 1992 with the most cherished being Cipira [13]. Jacob was released by IRAD in 2005 as variety [14].

2.3 Experimental Design

A total of 16 genotypes were screened along with two checks (Cipira and Jacob 2005 varieties). A randomised complete block design (RCBD) of three blocks was used. Each treatment was replicated three times giving a total of 54 experimental units. Each experimental unit comprised of a ridge of 3 m long and 1 m wide.

2.4 Management Practices

The agronomic package for potato production comprising land preparation, fertilizing, planting, moulding, pest and disease control and harvesting was used as follows:

2.4.1 Fertilizer application

First fertilizer application was done at planting using N-P-K 14-24-14, at the rate of 120 kg ha^{-1} of N, 180 kg ha^{-1} of P2O5 and 100 kg of K2O ha^{-1}. The whole amount of P2O5 and K2O and 60 kg of N were applied at planting. A split dose of nitrogen was applied at 4 weeks after planting to supplement nitrogen which is easily lost when applied due to its high volatility.

2.4.2 Planting

The seeds were sown to the same depth of 10 cm into the ground, with the eyes facing upwards. A planting distance of 1 m between rows or ridges and 0.3 m between plants, was used giving a planting density of 33,333 plants per hectare.

2.4.3 Disease control

The main disease that was controlled was late blight. This was done using a contact fungicide with trade name Penncozeb 80 WP, having as active ingredient mancozebe at appearance of the symptoms of late blight. Bacterial wilt was controlled by roguing out the wilted plant after collecting data on the incidence. Viruses were controlled by application of insecticides during the early development stages of the plant to kill aphids which are vectors to viruses.

2.5 Data Collection

2.5.1 Vegetative parameters

The number of plants emerged was recorded 4 weeks after planting. Plant height was recorded on the 75th day after planting.

2.5.1.1 Number of stems

A sample of 5 plants was randomly selected. The number of stems was counted and the average values obtained were recorded for each treatment.

2.5.1.2 Leaf Area Index (LAI)

For each experimental unit, three plants were sampled and three leaves were taken from a plant from top, middle and bottom. The average was then calculated and was obtained by measuring the leaf lengths and widths 75 days after planting. The LAI was then calculated using the formula: LAI = (0.75) x (leaf length) x (leaf width) [15]. Flower Colour was recorded at full blooming exactly 70 days after planting (DAP).

2.5.2 Disease parameters

Diseases were recorded from when the first symptoms were observed. The following diseases were of interest:

2.5.2.1 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 1 as guide. It was recorded at weekly intervals for six weeks and the data collected was used to calculate the area under the disease progress curve (AUDPC) [16], where y_i= disease severity, t_i= time in DAP.

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

Collection began from day 56 and ended on day 91, and for each unit the plants were monitored.

2.5.2.2 Virus incidence

Virus incidence was measured from day 56 to 91 (a period of six weeks). The data was recorded early in the morning to prevent reflection during sunny weathers from falsifying the results. A white sheet of paper was placed below each plant before observing to clearly see the colour. After observation the signs and symptoms were compared to those of CIP disease manual before confirmation.

2.5.2.3 Bacteria incidence

Bacteria wilt was recorded from day 21 when the first symptoms were seen till day 91. This data was collected and recorded cumulatively and after reading, each infected plant was rogued and carried out of the field to prevent the contamination of other plants.

2.5.3 Data collected at harvest

The parameters collected at harvest were as follows: number of tubers per plant, total weight of tubers, and average weight of tubers per experimental unit, tuber skin colour, tuber shape, eye depth, tuber uniformity, and flesh colour.

2.6 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) using the SAS [19] version 6.0. The performance of genotypes were separated using the least significance difference test at P=0.05, using the Statgraphic Plus Version 5.0.

3. RESULTS AND DISCUSSION

3.1 Vegetative Parameters of Potato Genotypes

The vegetative parameters of potato genotypes are presented in Table 2.

Table 1. Estimation guide for late blight severity

Scale value	Late blight severity (%)		Symptoms
	Mean	Limits	
1	0	/	No blight lesions
2	2.5	Trace- 5	Maximum 10 lesions per plant
3	10	5-15	Plants look healthy, lesions easily seen at close distance. Foliage affected by lesions or destroys up to 20 leaflets.
4	25	15-35	Blight seen in most plants. About 25% of foliage covered with lesions or destroyed.
5	50	35-65	Plants look green, all plants affected, lower leaves dead and about half foliage destroyed.
6	75	65-85	Plants green with brown flecks. 75% of each plant affected. Lower half plant leaf dead.
7	90	85-95	Only top leaves green, many stems have large lesions.
8	97.5	95-100	Plots brown in colour, few top leaves with some green areas.
9	100	0	All leaves and stems dead.

Source: Cruickshank et al. [17] and James [18]

Table 2. Mean values of growth parameters of potato genotypes evaluated at upper farm, Bambui

	Treatments	Number of plants emerged	Leaf area index (LAI)	Average number of stems	Average plant height/ cm	Stem diameter/cm
1	395011.13	9.33 ± 0.58^{ab}	203.90 ± 86.23^{abc}	4.67 ± 0.23^{cdef}	51.67 ± 4.39^{a}	0.86 ± 0.12^{ab}
2	392039.4	9.33 ± 1.15^{ab}	145.00 ± 29.35^{bcd}	3.60 ± 0.60^{f}	39.73 ± 6.05^{ef}	0.79 ± 0.06^{abcd}
3	396038.107	9.67 ± 0.58^{ab}	182.83 ± 11.72^{abcd}	3.73 ± 0.90^{def}	50.07 ± 6.21^{ab}	0.86 ± 0.03^{ab}
4	393084.31	9.33 ± 1.15^{ab}	192.10 ± 53.43^{abc}	7.13 ± 1.47^{a}	41.13 ± 3.60^{def}	0.85 ± 0.01^{ab}
5	393617.64	8.00 ± 1.73^{c}	168.87 ± 21.31^{abcd}	3.67 ± 0.83^{ef}	44.73 ± 4.54^{abcde}	0.84 ± 0.03^{abc}
6	392318.13	10.00 ± 0.00^{a}	197.80 ± 49.97^{abc}	7.13 ± 0.41^{a}	37.87 ± 3.50^{ef}	0.74 ± 0.07^{bcde}
7	396046.105	9.00 ± 1.00^{abc}	148.30 ± 15.19^{abcd}	3.80 ± 0.40^{def}	37.73 ± 3.97^{ef}	0.71 ± 0.07^{cde}
8	392639.34	9.67 ± 0.58^{ab}	206.70 ± 25.49^{a}	7.20 ± 1.04^{a}	39.87 ± 3.41^{ef}	0.68 ± 0.05^{de}
9	396036.201	8.67 ± 1.52^{bc}	169.67 ± 44.19^{abcd}	4.20 ± 0.40^{cdef}	45.00 ± 7.45^{abcde}	0.80 ± 0.12^{abcd}
10	395524.9	10.00 ± 0.00^{a}	179.37 ± 16.22^{abcd}	3.80 ± 1.04^{def}	42.53 ± 4.29^{cde}	0.91 ± 0.14^{a}
11	395529.4	10.00 ± 0.00^{a}	175.87 ± 35.86^{abcd}	4.93 ± 1.14^{bcdef}	41.13 ± 6.23^{def}	0.89 ± 0.06^{a}
12	396241.4	9.67 ± 0.58^{ab}	165.60 ± 21.22^{abcd}	4.07 ± 0.50^{cdef}	47.80 ± 2.60^{abcd}	0.91 ± 0.07^{a}
13	393633.34	9.67 ± 0.58^{ab}	206.50 ± 18.37^{ab}	4.73 ± 1.10^{cdef}	48.73 ± 5.75^{abc}	0.79 ± 0.14^{abcd}
14	396004.33	10.00 ± 0.00^{a}	142.93 ± 22.74^{cd}	5.47 ± 1.45^{bcd}	$40.60 \pm 3.41d^{ef}$	0.73 ± 0.08^{bcde}
15	391068.69	10.00 ± 0.00^{a}	195.33 ± 40.62^{abc}	5.07 ± 0.42^{bcde}	39.47 ± 2.70^{ef}	0.81 ± 0.03^{abc}
16	395011.12	10.00 ± 0.00^{a}	185.13 ± 45.32^{abcd}	5.13 ± 0.50^{bcde}	42.13 ± 1.67^{cde}	0.65 ± 0.09^{e}
17	CIPIRA	10.00 ± 0.00^{a}	123.83 ± 7.00^{d}	6.27 ± 0.76^{ab}	43.53 ± 1.79^{bcde}	0.67 ± 0.04^{de}
18	JACOB 2005	10.00 ± 0.00^{a}	174.63 ± 35.37^{abcd}	4.93 ± 0.92^{bcdef}	34.40 ± 1.59^{f}	0.83 ± 0.02^{abc}
	Mean	9.57	175.80	4.97	42.67	0.80
	LSD (P=0.05)	1.31	63.01	1.42	6.77	0.12
	CV (%)	8.27	21.61	17.27	9.56	9.34

Means with same letters (a,b,c,d,e,f) are not significantly different according to Fisher's LSD (P=0.05)

3.1.1 Leaf Area Index (LAI)

ANOVA revealed significant difference (P=0.05), among treatments (Table 2). The mean LAI ranged from 123.83 ± 7.00 (for variety Cipira) to 206.70 ± 25.49 (for genotypes 392639.34). High leaf area index values suggest greater affinity for a crop to undergo photosynthesis and therefore higher yields. A high LAI index could also be an indication of good plant vigour [15].

3.1.2 Number of stems per plant

ANOVA indicated significant differences (P=0.05) between treatments. Mean number of stems ranged from 3.60 ± 0.60 (for genotype 392039.4) to 7.20 ± 1.04 (for genotype 392639.34). The number of stems per plant ranged from 3.60 to 7.20. High number of stems could probably indicate that greater number of tubers will be produced. Admire et al. [20] conducted a test on effect of stem density on potato yield and reported that plants with 2 stems gave a greater marketable yield than those with 6 stems. Therefore seed producers whose objective is to have greater number of smaller tubers will go in for genotypes with high stem density while ware potato producers will prefer genotypes with lower number of stems due to their ability to produce greater sized tubers.

3.1.3 Stem diameter

ANOVA showed significant differences between treatments and replications. Mean stem diameters ranged from 0.65 ± 0.09 cm (for genotype 395011.12) to 0.91 ± 0.14 cm (for genotypes 395524.9, 396241.4). Genotypes 395011.12 therefore had tiny stems while genotypes 395524.9 and 396241.4 had the largest, compared to the others. Mean values for stem diameters are presented on Table 2. Plants with larger stem diameters are also stable and are not easily lodged by the wind. This report tallies with the findings of Tesfaye et al. [21] who observed that wider intra row spacing resulted in less competition among plants, availability of resources; high light interception and large quantity of photo assimilate production as well as assimilation and thus increased plant growth and development ultimately increased stem diameter.

3.1.4 Plant height

Results of ANOVA showed significant differences (P=0.05) between the treatments. Plant heights ranged from 34.40 ± 1.59cm (for variety Jacob) to 51.67 ± 4.39cm (for genotype 395011.13) (Table 2). High mean values of plant height could also indicate an increase in yield and biomass production. This result tallies with the findings of Fayera [22] who observed that yield of tuber per hectare was significantly and positively correlated with plant height, number of stem per plant, fresh weight, number of tuber and weight of tuber per plant. Therefore plants with higher values of plant height and stem diameters could be high yielding than those with lower values.

3.2 Results of Disease Parameters Evaluated on Potato Genotypes at Upper Farm

3.2.1 Late blight severity

Genotypes that show some level of resistance to late blight were 393617.64, 395011.13, 396036.201, 396038.107 and 393633.34. Genotypes 393617.64 was the most resistant while 391068.69, Cipira and Jacob were highly susceptible (Fig. 1).

The rAUDPC was calculated from the severity curve. ANOVA revealed interactions (P=0.05) between the treatments. rAUDPC ranged from 0.01 (for genotypes 393617.64) to 0.59 (for variety Jacob as check). Jacob was therefore the most susceptible to late blight as compared to the others. The mean results of rAUDPC are presented in Table 3. In this study, the genotypes with population B3 genes (minor genes) showed higher resistance to late blight than Cipira and Jacob with R-genes (major genes). These results are in line with the reports of Njualem [4] who conducted a similar trial using some genotypes with B3 genes with Cipira and Tubira as checks with R-genes. Perez & Forbes [12] also confirmed that genotypes with minor genes are more resistant to late blight than those with major genes. Potato yields (Y) was negatively correlated with rAUDPC. The regression coefficient showed that late blight severity was inversely correlated to yields. The regression equation was $Y=-5.612X+18.4$ ($R^2=0.067$, $P<0.05$) Regression analysis showed a negative correlation between potato yield and rAUDPC. This relationship had also been reported by Njualem [4]. Perez & Forbez [23] reported the use of AUDPC as an effective way to evaluate losses attributed to late blight infection. Late blight has been reported as the most important constraint in potato production [24]. Njualem [4] also reported a yield loss of 53% at Upper farm.

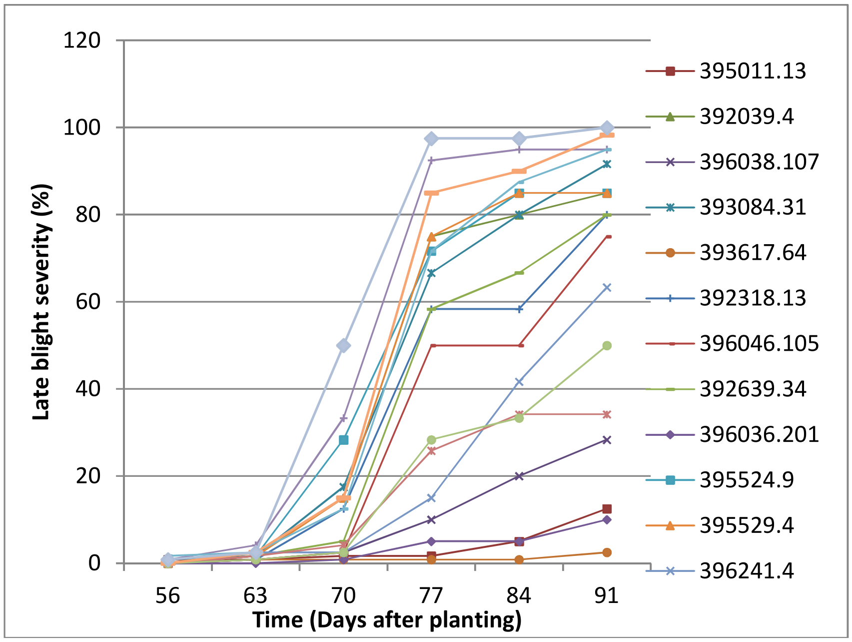

Fig. 1. Late blight progression curve for potato genotypes and varieties evaluated at upper farm-IRAD Bambui

3.2.2 Bacterial wilt incidence

ANOVA revealed significant differences among the treatment means (Table 3). Mean percentage incidence ranged from zero in ten genotypes and the two check varieties to 8.8% (for genotype 393633.34). Most of the genotypes were therefore resistant to the disease. Fig. 2 shows a plot of bacterial wilt incidence against time. In this study, a maximum mean incidence of 8.8% was recorded in one genotype. The low rate of incidence could be explained from the fact that the research field had been fallowed for a period of 5 years, which provided enough time to break the life cycle of the pathogen for it to degenerate. Also any plant that was found to be attacked during the period of evaluation was rogued and carried out of the field. Only four of the genotypes showed incidence to bacterial wilt. The use of fallowing and roughing can therefore be considered as one major means of controlling bacterial wilt. The low level of incidence could also be due to genetic make-up of the plants. However, due to biotic and abiotic conditions, the actual yield of potato is much lower than its potential yield [25]. According to a recent study by Haverkort and Struik [26], there is a gap of 10% to 75% between the actual and potential yield of potato due to various socio-ecological problems. Njualem et al. [10] also reported 100% yield losses in Bansoa in West Region of Cameroon.

3.2.3 Virus incidence

All potato genotypes and varieties showed symptoms of viral infection. Genotype 392639.34 reached the highest point on the graph, indicating that it was more susceptible, while genotype 396038.107 showed the least. 396038.107 was therefore more resistant to viruses as compared to the others (Fig. 3).

ANOVA showed interactions between treatments and mean virus incidence. Mean values of viral incidence ranged from 0.24 that is 2.4% (for genotype 392639.34) to 2.67 that is 26.7% (for genotype 392639.34). Viruses are a serious threat to potato production in Cameroon. Njukeng et al. [27] reported a prevalence rate of 82% at Upper farm in potato seed tubers. In this study, a maximum incidence of 26.7% was recorded in one genotype (392639.34). The low level of incidence can be backed by the point that the research plot was located at an altitude of 2000 m.a.s.l. Aphids do not excel well in high altitudes with low temperatures [4]. Furthermore, virus incidence on potato clones and varieties was insignificant. Same results have been reported by Njualem [4]. A low level of virus incidence could also be attributed to the genetic make-up of the plants.

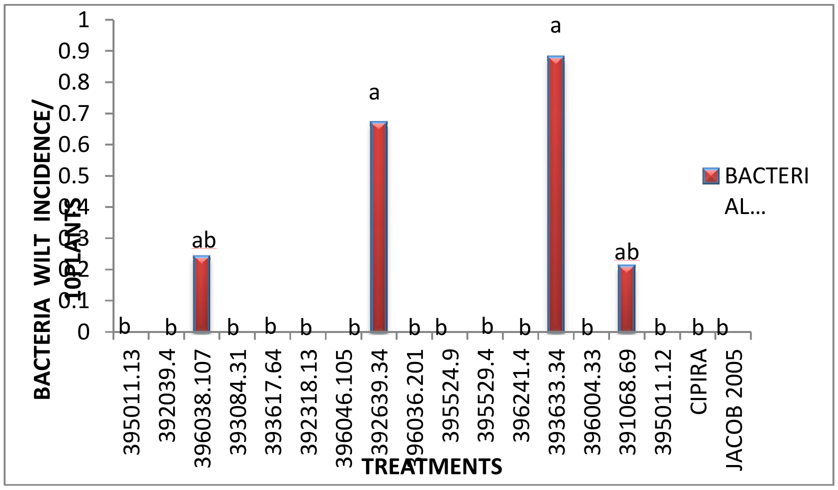

Fig. 2. Bacterial wilt incidence on potato varieties and genotypes evaluated at upper farm-IRAD Bambui

Treatments with same letters (a, b) are not significantly different at 95% Confidence Interval (CI)

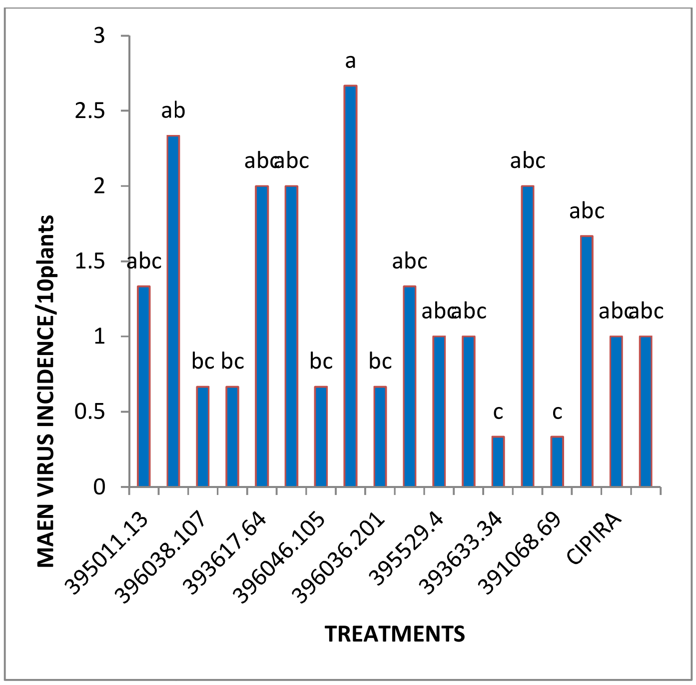

Fig. 3. Virus incidence of potato clones and varieties evaluated at upper farm-IRAD Bambui

Means with same letters (a, b, c) are not significantly different at 95% Confidence Interval

3.3 Yield and Yield Parameters of Potato Genotypes and Varieties at Upper Farm

Yield per hectare was calculated from the average yield per plant. Yield per hectare ranged from 9.78 $\pm$ 3.02 tons (for genotypes 392039.4 and 396046.105) to 23.33 $\pm$ 4.51 tons (for genotype 393084.31). ANOVA results showed interactions between treatments. Genotype 393084.31 was the best followed by 393633.34 with an average yield of 23.22 $\pm$ 3.98 tons/ha (Table 3).

Table 3. The mean values of stem diameters, average tuber yield per plant, tuber yield per hectare and disease parameters

	Treatments	Yield (tons/ha)	Mean bacteria wilt incidence	Mean virus incidence	rAUDPC
1	395011.13	20.0 ± 2.03^{ab}	0.00 ± 0.00^{b}	1.33 ± 2.31^{abc}	0.03 ± 0.02^{g}
2	392039.4	9.78 ± 3.47^{c}	0.00 ± 0.00^{b}	2.17 ± 0.44^{ab}	0.43 ± 0.06^{bc}
3	396038.107	19.00 ± 1.86^{ab}	0.24 ± 0.42^{ab}	0.24 ± 0.42^{bc}	0.10 ± 0.03^{fg}
4	393084.31	23.33 ± 4.51^{a}	0.00 ± 0.00^{b}	0.56 ± 0.51^{bc}	0.42 ± 0.07^{bc}
5	393617.64	14.67 ± 3.71^{abc}	0.00 ± 0.00^{b}	2.00 ± 1.00^{abc}	0.01 ± 0.01^{g}
6	392318.13	15.78 ± 5.87^{abc}	0.00 ± 0.00^{b}	1.50 ± 0.83^{abc}	0.34 ± 0.06^{cd}
7	396046.105	9.78 ± 3.02^{c}	0.00 ± 0.00^{b}	0.61 ± 0.54^{bc}	0.28 ± 0.00^{dc}
8	392639.34	16.89 ± 3.17^{abc}	0.67 ± 1.16^{ab}	2.40 ± 1.30^{a}	0.34 ± 0.05^{cd}
9	396036.201	20.56 ± 11.08^{ab}	0.00 ± 0.00^{b}	0.56 ± 0.51^{bc}	0.03 ± 0.02^{g}
10	395524.9	20.78 ± 11.64^{ab}	0.00 ± 0.00^{b}	1.10 ± 1.93^{abc}	0.46 ± 0.10^{bc}
11	395529.4	13.44 ± 3.67^{bc}	0.00 ± 0.00^{b}	1.00 ± 1.73^{abc}	0.44 ± 0.04^{bc}
12	396241.4	15.33 ± 3.76^{abc}	0.00 ± 0.00^{b}	0.78 ± 0.19^{abc}	0.19 ± 0.07^{ef}
13	393633.34	23.22 ± 3.98^{a}	0.88 ± 1.52^{a}	0.33 ± 0.58^{c}	0.16 ± 0.02^{ef}
14	396004.33	13.78 ± 2.70^{bc}	0.00 ± 0.00^{b}	1.89 ± 0.84^{abc}	0.18 ± 0.09^{ef}
15	391068.69	14.67 ± 7.80^{abc}	0.21 ± 0.37^{ab}	0.28 ± 0.48^{c}	0.54 ± 0.05^{ab}
16	395011.12	15.11 ± 5.10^{abc}	0.00 ± 0.00^{b}	1.56 ± 0.51^{abc}	0.44 ± 0.09^{bc}
17	Cipira	12.89 ± 3.89^{bc}	0.00 ± 0.00^{b}	0.89 ± 1.02^{abc}	0.48 ± 0.03^{ab}
18	Jacob	17.00 ± 4.63^{abc}	0.00 ± 0.00^{b}	0.78 ± 0.84^{abc}	0.59 ± 0.00^{a}
Mean		16.44			
CV (%)		32.70			

Means with same letters (a, b, c, d, e, f, g) are not significantly different according to Fisher's LSD (P=0.05)

One of the greatest challenges in the world today is to increase food security. One way to tackle this is to produce varieties that are high yielding compared to local varieties with low yields. Mean tuber yield for the trial was 16.6 ton/ha. This is by far greater than the annual mean yield of 6 ton/ha in Cameroon as reported by Fontem et al. [8]. Therefore, promising candidates could be selected from this study to be released as new varieties. The best high yielding genotypes were: 393084.31 (23.33 ton/ha), 393633.34 (23.22 ton/ha), 395524.9 (20.78 ton/ha), 396036.201 (20.56 ton/ha) and 395011.13 (20.0 tons/ha).

3.4 The Phenotypical Characteristics of Potato Genotypes and Varieties Studied

Tuber shapes were of two types: regular and irregular. The round or regular tubers had the highest frequency of 14 while the irregular had a frequency of zero. Two types of eye depths were reported shallow and deep. Shallow had the highest frequency of 15 while deep had a frequency of 1. Genotypes and varieties with uniform tubers had the highest frequency of occurrence (13) while the non-uniform had the lowest frequency (2). Tuber uniformity was recorded in two categories as uniform and non-uniform. The results are presented in Table 4.

Tuber uniformity is important, especially with regards to the uses of potato. Many users prefer tubers with smooth skin for it can easily be peeled. Chips producers also prefer tubers with smooth skins and uniform shapes that can be cut to various shapes for frying. Uniformity has also been seen to be closely related to eye depth. Most tubers with deep eye depths were not uniform [28].

Three skin colours (Table 4) consisted of cream, pink and red. Cream had the highest frequency of 12 while pink had the lowest frequency of 2. Cream skin colour is an indication that the peel contains carotenoids while red and purple skin colour is an indication of the presence of anthocyanine. Grudzińska et al. [29] revealed that potatoes with coloured flesh also have higher antioxidant activity than do potatoes with

Table 4. Phenotypical characteristics of 18 potato genotypes and varieties screened in Bambui

N°	Treatment	Tuber shape	Tubers uniformity	Eye depth	Skin colour	Flesh colour	Flower colour
1	395011.13	IR	NU	S	P	W	LP
2	392039.4	R	NU	S	C	C	W
3	396038.107	R	U	S	Rd	W	W
4	393084.31	R	U	S	C	C	W
5	393617.64	R	U	S	Rd	W	DP
6	392318.13	R	U	S	C	C	W
7	396046.105	R	U	S	Rd	W	LP
8	392639.34	R	U	S	C	C	W
9	396036.201	R	U	S	C	W	W
10	395524.9	IR	NU	S	Rd	W	LP
11	395529.4	R	U	S	P	W	LP
12	396241.4	R	U	D	C	W	W
13	393633.34	R	NU	D	C	W	LP
14	396004.33	IR	U	S	C	C	LP
15	391068.69	IR	NU	S	C	C	W
16	395011.12	R	U	S	C	W	W
17	CIPIRA	R	U	S	C	W	W
18	JACOB	R	U	S	C	W	W

Legend: C=Cream; D=Deep; IR=Irregular; NU=non uniform; P=pink; R=Round; Rd=red; S=shallow; U=Uniform; W=white; LP= Light purple; DP=Deep purple

white flesh, most likely due to the presence of anthocyanins besides the presence of phenolic acids. Potato skin is rich in phenolics which contribute to the organoleptic properties of potato and it is also an important antioxidant. Pink skin potatoes contain high levels of anthocyanine, while red contains a lower level. White and yellow skinned potatoes are rich in carotenoids [30].

Two types of flesh colour were observed: white and cream. White flesh colour dominated with a frequency of 12 while cream was least with a frequency of 6. Flesh colour has an important role to play in the nutritional composition of potato. Potatoes with cream or yellow fleshed colours are rich in carotene [31]. Therefore yellow fleshed colour tubers can be recommended for people with carotene deficiency. White fleshed potatoes are higher in starch content and can be recommended for industrial uses. Three flower colours were observed which involved white, light purple and deep purple. White had the highest frequency of 11 followed by light purple with 6. The least was deep purple with a frequency of one.

4. CONCLUSION

It was concluded that potato yield is inversely linked with late blight infection acting as limiting factor to potato production. Population B genotypes with minor genes were more resistant than Cipira and Jacob. The top four resistant genotypes in the study were 393617.64, 395011.13, 396036.201, 396038.107 and 393633.34. Upon all the genotypes evaluated, only four (4) showed bacterial wilt incidence indicating that population B plants possess some resistance to this disease. Virus incidence on plants was low for all treatments with the top three resistant genotypes being 396038.107, 391068.69 and 393633.34. Potato yields were moderate due to subjection under disease conditions for evaluation. The best five genotypes were 393084.31 (23.33 t/ha), 393633.34 (23.22 t/ha), 395524.9 (20.78 t/ha), 396036.201 (20.56 t/ha) and 395011.13 (20.0 t/ha), compare to 12.89 and 17.00 t/ha for Cipira and Jacob respectively.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Zhang H, Xu F, Wu Y, Hu H, Dai XF. Progress of potato staple food research and industry development in China.

Journal of Integrative Agriculture. 2017; 16(12):2924–2932.

2. FAOSTAT, FAO Statistics Database. Food and Agriculture Organisation of the United Nation, Rome, Italy; 2013.
3. FAO International Year of the Potato, Plant production and protection division FAO; 2008.
4. 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;138.
5. Takoutsing B, Asaah E, Yuh R, Tchoundjeu Z, Kouodiekong L. Impact of organic soil amendments on the physical characteristics and yield components of potato (*Solanum tuberosum* L.) in the highlands of Cameroon. Middle-East Journal of Scientific Research. 2013; 17(12):1721-1729.
6. Nadine A, Erin B. Potatoes College Seminar 235 Food for Thought: The Science, Culture, & Politics of Food Spring. 2008;22.
7. DAFF (Department of Agriculture, Forestry and Fisheries). Potatoes Production Guidelines. South Africa. 2013;60.
8. Fontem DA, Demo P, Njualem DK. Status of potato production, marketing and utilisation in Cameroon. In: Advances in root and tuber crops technologies for sustainable food security, improved nutrition, wealth creation and environmental conservation in Africa (Mahungu NM & Manyong VM, eds). Proceedings 9th ISTRC-AB Symposium. Mombasa, Kenya. 2004;18-25.
9. Achancho V. Review and analysis of national investment strategies and agricultural policies in central Africa: The case of cameroun, In: Rebuilding West Africa’s food potential, Elbehri A (ed.), FAO/IFAD. 2013;115-149.
10. Njualem DK, Ifenkwe OP. Field evaluation of seedlings tubers for seed tubers production in Jos Plateau State of Nigeria. Bioscience Proceedings. 2001;8:414-423.
11. Tita MA, Fotso, Njualem DK, Nwaka CA, Mbouobda DH. Screening responses of potato (*Solanum tuberosum L.*) varieties in liquid and solid media. African Journal of Biotechnology. 2014;13(15):1650-1656
12. Perez W, Forbes W. Field assessment of resistance in potato to Phytophthora infestans. Lima (Peru). International Potato Center (CIP). 2014;35.
13. Njualem DK, Meka SS, Tchio ET. Genotype by environment interaction on potato (*Solanum tuberosum* L.) Cipira variety in the Western Highlands of Cameroon. Journal of Scientific Research & Reports. 2018;19(3):1-9.
14. IRAD (Institute of Agricultural Research for Development) Annual Report, Nkolbisson. 2005;6.
15. Gordon R, Brown DM, Dixon MA. Estimating potato leaf area index for specific cultivars. Potato Res. 1997;40: 251–266.
16. Jeger MJ, Viljanen-Rolinson SLH. 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.
17. Cruickshank G, Stewart HE, Wastie RL. An Illustrated Assessment Key for Foliage Blight of Potatoes. Potato Res. 1982; 25:213-214.
18. James C. An illustrated series of assessment keys for plant diseases, their preparation foliage blight of potatoes. Potato Res. 1971;25:213-214.
19. SAS. Statistical Analysis System guide for Personal Computers. Version 6.03 edition. SAS Institute Inc. Cary N.C. (USA); 1991.
20. Admire S, Robert M, Taurira M, Upenyu M. Effect of stem density on growth yield and quality of potato amethyst. African Journal of Agricultural Research. 2014;9(17):1391-1397.
21. Tesfaye G, Derbew B, Solomon T. Yield and growth parameters of potato (*Solanum tuberosum* L.) as influenced by intra row spacing and time of earthing up: In Boneya Degem District, Central Highlands of Ethiopia. International Journal of Agricultural Research. 2012;7:255-265.
22. Fayera WN. Yield and yield components of potato (*Solanum tuberosum* L.) as influenced by planting density and rate of nitrogen application at Holeta, West Oromia region of Ethiopia. African Journal of Agricultural Research. 2017;12(26): 2242-2254.
23. Perez W, Forbes W. Potato late blight. Technical manual, International Potato Centre, Lima, Peru. 2010;38.

24. Fontem DA, Gumedzoe YD, Olanya M. Quantitative effects of late blight on potato yields in Cameroon. African Crop Science Conference Proceedings. 2001;5:449-453.
25. Shiferaw T, Rico L, Barbara van Mierlo, Paul CS, Berga L, Cees L. Analysis of a monitoring system for bacterial wilt management by seed potato cooperatives in Ethiopia: Challenges and FUTURE DIRECTIONS. Sustainability. 2020;12: 3580.
26. Haverkort AJ, Struik PC. Yield levels of potato crops: Recent achievements and future prospects. Field Crops Res. 2015;182:76–85.
27. Njukeng PA, Chewachong GM, Sakwe P, Chofong G, Nkeabeng LW, Demo P, Njualem KD. Prevalence of six viruses in potato seed tubers produced in informal seed system in the North West Region of Cameroon. Cameroon Journal of Experimental Biology 2013;09(01):44-49.
28. Hasan MN, Uddin KS, Monayem MMA. Growth and structural stability in area and production of potato in Bangladesh: A time series analysis. Ann. Bangladesh Agric. 2009;13(1 & 2):121-129
29. Grudzińska M, Czerko Z, Zarzyńska K, Borowska-Komenda M. Bioactive compounds in potato tubers: Effects of farming system, cooking method, and flesh color. PLoS One. 2016;11(5):e0153980.
30. Rajarathnam E, Narpinder S, Shagun S, Amritpal K. Beneficial phytochemicals in potato-a review. Food Research International. 2011;50:487–496.
31. Ernest B, Joe M, Edward E, Kwadwo O, Essie T, Vemon E. Constraints and breeding priorities for increased sweet potato utilisation in Ghana. Sustainable Agriculture Research. 2015;4(4):16.

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