

Evaluation of Tomato Varieties for Pest and Disease Adaptation and Productivity in Botswana

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Abstract

Six varieties of tomato were evaluated for pest and disease adaptation and productivity in Botswana. Tomato varieties were planted under a complete randomized block design experiment with four replications at farmers' field in Maun, Botswana (Southern Africa). Tomato varieties were evaluated for yield, nematode and late blight resistance. The quantitative data on yield of tomato and qualitative data on nematode and late blight resistance and farmers perception on the varieties were collected. Inferential and descriptive statistical methods were used for data analysis where two ways analysis of variance and ranking scales were applied. Harvested fruits of tomato were graded into six categories of fruits namely, marketable, small, cracked, cat face, rotten and pest damaged. Tomato variety Zeal produced the highest total yield whereas Six Pack variety gave the lowest total yield. Heinz 1370 was the highest severely affected tomato variety by nematodes as well as by the late blight disease and thus produced the lowest marketable fruit percentage. On an average, FA 593 was the least affected variety by nematode and late blight. None of the six tomato varieties was found resistant to nematode pest and late blight disease. Therefore, there is a need to develop nematode and late blight resistant tomato varieties. Farmers' preferred tomato variety Zeal followed by FA 593. Based on the yield performance, nematode and late blight resistance rating and the farmer's perception, Zeal was found to be the best tomato variety followed by FA 593 for pest and disease adaption and productivity in Botswana.

Keywords: *Tomato productivity, Tomato variety evaluation, Adaptation, Yield performance, Disease and pest resistance, Nematode, Late blight*

1. Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most widely grown vegetable crops in the world, second to potato (FAO, 2005; Maerere et al., 2006). Tomatoes are used not only for fresh table food, but also for ketchup, puree, sauces and in many other ways. Tomatoes have been used as food by the inhabitants of Central and South Americas since prehistoric times (Choudhoury, 1967). It originally came from tropical area from

Mexico to Peru. All tomato varieties in Europe and Asia are said to be descendants of the seeds taken from Latin America to Europe and Asia by the Spanish and the Portuguese merchants during the 16th century. African tomatoes, on the other hand, were introduced by European merchants or colonizers. Thus, today, modern tomato cultivars and hybrid can be grown and can produce fruit in climates far different from the site of its origin. It has become one of the most popular vegetables in

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the tropics and other countries in Asia and the rest of the world (Villareal, 1979).

Tomato is a warm season crop and plants cannot stand severe frost. The crop does well under an average monthly temperature of 21°C to 23°C but commercially it may be grown at a temperature ranging from 18°C to 27°C. In most tropical countries, average yield ranges between 2 to 10 tons of fruit/ha, against yields of 20 tons in South Korea, 40 tons in the USA, 50 tons in Japan and over 130 tons in the Netherlands (Von Uexkull, 1979). It is obvious that the highest yields are found in the temperate countries. In Botswana, different tomato varieties yielded between 60 -100 tons per hectare (Department of Agricultural Research, 2006). On the other hand, tomato production in the hot, wet, lowland tropics is often hampered by diseases and pests (Yang, 1979). Growing tomato in the hot season needs heat-tolerant cultivars because of the period of high temperatures during summer. Furthermore, the cultivars to be used should be resistant to the major yield-reducing pests and diseases such as nematodes and late blight (Villareal & Lai, 1979). Botswana experiences very high temperatures in summer season which sometimes touches to 45°C and it becomes very difficult to grow vegetables including tomatoes which reduce tomato yield. The low productivity of tomato is attributed to a number of yield reducing factors which include low yielding varieties and pests and diseases attack. Under the prevailing climatic conditions in Botswana, horticultural crops are susceptible to a wide range of disease and insect attacks (Baliyan, 2012). The poor availability of inputs including varieties of vegetable crops and pest and disease problems in small scale horticulture farming in Botswana were ranked number one and three respectively (Baliyan and Kgathi, 2009). Nematode is a common pest attacking tomato plants, and climatic conditions in Botswana are very favorable because nematodes are more likely to develop in sandy soils and during warm conditions. The root-knot nematodes (*Meloidogyne* spp.) are the most important nematode affecting tomatoes. They attack roots causing galls to develop and reduce the size and efficiency of the root system. Stunting of plants, reduced fruit set and yield and poor quality result from infestation of nematodes. Among other tomato

diseases, fungal diseases reduce the yield significantly. The most important fungal disease is the late blight. The tomato late blight disease is caused by seed borne fungi *Phytophthora infestans*, which is a difficult disease to manage and causes significant reduction in yield (Jett, 2002). This disease influences the overall health and final crop stand (Bissdorf, 2005; Pandey et al., 2006).

A number of technologies exist and if adopted would improve yield of tomato. One of the key technological components in tomato production is the development of new varieties which are pest and disease resistant that would contribute to increased yield. Improved new varieties which can resist and tolerate the aforementioned unfavorable factors are among the technologies developed. Successful cultivation of tomato is based essentially upon the choice of suitable varieties for a particular location (Chaerani, 2006). The farmers choose tomato variety to grow depending on a number of factors which include production potential, market demand, regional adaptability, pest and disease resistance and the end use of the product (Orzolek et al., 2006). One of the key constraints in adapting tomato varieties are crop pests and diseases which may require integrated pest and disease management options (Raini et al., 2005). The availability of seeds and the cost of seeds affect the adoption of the varieties by the farmers. If the seeds are expensive and difficult to obtain, the farmers find other available cheaper varieties in the local market. Resistance in the host plant has been reported to be the most effective means of management (Yu et al., 1995; Blancard 1997). Other methods of managing the diseases and pests include removal of plant debris, removal of weeds, rotation, and the use of non-infested seed and seedlings (CAB International 2005). Farm chemicals have also been used, but these may not be effective where the weather is favorable for pest and disease development. In view of increasing concerns over the long term negative environmental impact of some chemicals (Stoll 1998), their rising costs, the search for effective options for managing the pests and diseases has recently focused on the development and evaluation of pest and disease varieties. Although several high yielding varieties and hybrids have been introduced during the last decades, there is a potential need for them to be evaluated in the agro-

climatic conditions of Botswana. Most vegetable cultivar trials, including tomato, focus on yield and quality attributes. However, pest and disease tolerance has not been routinely evaluated. Nematode and late blight are very serious pest and disease of tomato in Botswana which reduce tomato yield (Department of Agricultural Research, 2006).

Observing the importance of tomato crop and varieties, the on - station variety trials of sixteen varieties of tomato was started at Boro research station, Maun, Department of Agricultural Research, Ministry of Agriculture, Republic of Botswana. The purpose of the on - station variety evaluation trials was to provide up-to-date variety recommendations for the tomato growers. Before any final variety recommendation is made, it is extremely important to evaluate the varieties on farmer's field for their adaptation and productivity performance. Therefore, on - farm trials were conducted for evaluation of six promising varieties of tomato in Botswana. The six selected tomato varieties were the highest yielding varieties out of sixteen varieties under on-station trials and yielded between 60 -100 tons per hectare (Wiles, 2006; Department of Agricultural Research, 2006). Obviously, it was hypothesized that the selected six varieties will adapt and produce high yields in on-farm conditions. Therefore, it was important to evaluate the performance of these six varieties under the on – farm conditions. The on-farm trials were conducted for two consecutive years but this study presents the results of the second trial. The objective of the on-farm trials was to evaluate the yield performance and productivity and pest and disease resistance of promising varieties of tomato on farmer's fields in Botswana and also to obtain farmer perceptions on the varieties evaluated.

2. Materials and Methods

A Researcher Managed and Farmer Implemented (RMFI) tomato variety evaluation trial was conducted at farmer's field in Maun, Botswana (Southern Africa). A randomized complete block design with four replicates was used. Six varieties of tomatoes, namely FA 593, MFH 9343, MFH 9318, Six Pack, Heinz 1370 and Zeal were sown in seed trays. Prior to transplanting of four weeks old seedlings, 1000 kg/ha 2:3:2 (22) fertilizer was used

as basal dressing. The soil had good fertility and therefore only single topdressing of 100 Kg/ha Urea was applied at the flowering stage initiation. Plot size was 6 m × 2.4 m and each plot consisted of two 6 meter long rows. Row to row and plant to plant spacing was 1.2 m and 40 cm respectively. Guard rows were planted on each side of trial. The Parallel wire method was used for staking tomato plants. The trial was grown under sprinkler irrigation. Harvested fruits of tomato were graded into six categories of fruits: marketable, small, cracked, cat face, rotten and pest damaged, and were weighed and the yield (quantitative data) was recorded in data collection sheets. The quantitative data on yield was analyzed using a two-way analysis of variance, using the SPSS program version 19. Treatment means were separated using Fisher's Least Significant Difference (LSD) (Steel and Torrie, 1980). A related question of interest of study was to examine whether the two factors under consideration namely, varieties of tomato and experimental blockings had any impact on harvested tomato fruit categories such as (i) market weight of the total yield, (ii) small tomato weight, (iii) cracked tomato weight, (iv) cat face tomato weight and (v) percent market weight and (vi) weight of rotten tomatoes. To answer these questions, a two way analysis of variance was carried out by considering the two factors of interest (variety and replication) and the six categories of tomato weights as the dependant variables.

All the six varieties were also observed and rated for incidence of nematodes and late blight of tomato. After the final harvest, a sample of 100 plants of each variety was observed for seriousness of late blight attack. Thereafter, the same plants (which were observed for late blight) were pulled by roots and observed for seriousness of nematode attack. Average nematode and late blight resistance rating of tomato varieties was also observed by calculating the average percentage of tomato plants affected by nematode and late blight. The disease ratings (incidence and severity leaves, petioles and stems) were made by visually examining the sampled plants from all the plots from all the blocks and assigning each cultivar a descending number based on the severity of nematode and late blight infection. Pest or disease incidence can be defined as the proportion of plants (leaves, etc.) pest attacked or diseased, or

the number of pest attacked or diseased plants out of total plants observed; while pest or disease severity is the relative or absolute area of plant tissue affected by pest or disease (sometimes called “intensity”). The qualitative data (severity of nematode and late blight of tomato attack) were observed on a damage rating scale ranging 0–3 with 0= no damage (0%), 1= slight damage (0–25%), 2= moderate damage (25–50%) and 3= severe damage (50–100%). Using developed field data notebooks, data was collected and recorded on the incidences of nematodes and late blight.

In order to obtain farmers perceptions on the varieties under evaluation, focus group interviews were held with groups of horticultural farmers to enable a process of dialogic discussion and interaction between respondents and the researcher. The focus group is an established method of social inquiry (Greenbaum, 1993; Krueger, 1998) and a reliable and cost effective method to obtain the perception on any aspect. The horticultural farmers in Botswana are scattered and it was not possible for the researcher to reach to individual farmers because of the time and financial constraints. Therefore, a group of 30 farmers were invited to visit twice the trial site and were asked for their perceptions on the varieties of tomato under evaluation based on the specified criteria of yield, availability of seeds, storage durability, shape, size and colour of tomato fruits. The farmers were provided with a prepared tomato varieties rating sheet indicating these criteria and were asked to give their perception/preference by ranking the six tomato varieties.

3. Results

The results of two way variance analysis (Table 1) showed that yield produced by six tomato varieties were significant at 1% probability where the replication (block) effect of varieties were insignificant. Figure 1 shows the estimated marginal means of total tomato yield of six varieties over the four blocks. Total and marketable yield of tomato varieties are presented in Table 2 reflecting that Zeal gave the highest marketable yield (112.52 t/ha) and the lowest yield was produced by Six Pack (76.4 t/ha).

Table 1

Influence of Different Varieties (Treatments) of Tomatoes on the Yield of Tomatoes

Source	SS	df	MS	F	Sig
Replications	938.475	3	312.825	1.517	0.251
Treatments	3601.757	5	720.351	3.493	0.027
Error	3093.598	15	206.240		
Total	7633.830	23			

Table 2

Marketable and Total Yield (t/ha) and Percentage Marketable Yield

Variety	Marketable Yield	Total Yield	%Marketable
Zeal	112.52	130.83	86.05
FA 593	105.6	123.53	85.85
MFH 9343	103.85	117.05	89.12
Heinz 1370	90.30	112.18	80.42
MFH 9318	87.42	105.05	83.10
Six Pack	76.40	93.15	81.76

Table 3

Summary of ANOVA: Effect of Varieties and Blocks (Replications) on Harvested Tomato fruit category variables

Factors (Independent Variable)	Dependent Variables	p-value
Varieties	Market Weight	0.021*
Blocks		0.746
Varieties	Small Tomato Weight	0.003**
Blocks		0.177
Varieties	Cracked Weight	0.005**
Blocks		0.921
Varieties	Cat face Weight	< 0.001**
Blocks		0.461
Varieties	Rotten Weight	0.833
Blocks		0.022*
Varieties	Percent Market Weight	0.140
Blocks		0.144

Note: *, significant at 5% level, **, significant at 1% level

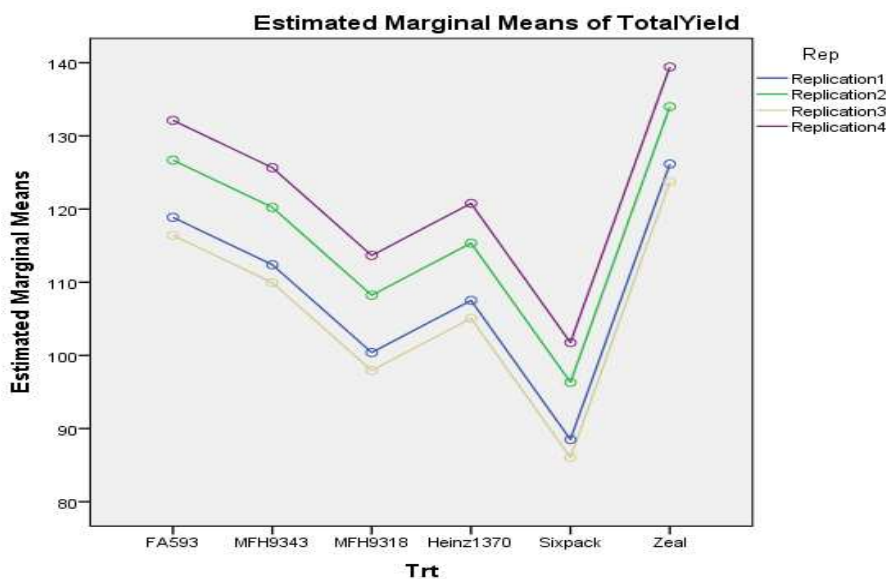


Figure 1: Estimated marginal means of total yield of six varieties over the four replications

Table 3 presents the partial output of a two way analysis of variance carried out to assess the significance of the two factors of interest (variety and replication) on the six harvested tomato fruit categories. It is revealed that tomato varieties do significantly affect the first four fruit categories listed in column two of Table 3, while the last two fruit categories are left unaffected.

Table 4

Nematode Pest Resistance Rating of Tomato Varieties (Percentage of tomato plants affected by nematode pest)

Variety\damage scale*	0	1	2	3	Rating
Heinz 1370	0	3	30	67	6
MFH 9318	1	5	36	58	5
FA 593	85	12	3	0	4
Zeal	88	10	2	0	3
MFH 9343	92	6	2	0	2
Sixpack	96	2	2	0	1

*0= no damage (0%); 1= slight damage (0–25%); 2= moderate damage (25–50%); 3= severe damage (50–100%)

The homogeneity of blocks in which six tomato varieties are replicated is confirmed (insignificant *p*-values) in the case of all six fruit categories

except the rotten weight fruit category. The nematode resistance rating of tomato varieties (percentage of tomato plants damaged by nematode pest) is presented in Table 4 indicating that none of the tomato varieties under evaluation was found nematode resistant. The percentage of tomato plants affected by late blight disease is presented in Table 5 indicating that FA 593 was the least affected whereas as Heinz 1370 was the worst affected by late blight.

Table 5

Late Blight Disease Resistance Rating of Tomato Varieties (Percentage of tomato plants affected by late blight disease)

Variety\damage scale*	0	1	2	3	Rating
Heinz 1370	0	20	36	44	6
Sixpack	48	17	23	12	5
MFH 9318	69	25	6	0	4
MFH 9343	80	16	4	0	3
Zeal	92	7	1	0	2
FA 593	98	2	0	0	1

*0= no damage (0%); 1= slight damage (0–25%); 2= moderate damage (25–50%); 3= severe damage (50–100%)

Table 6

Average Nematode and Late Blight Resistance Rating of Tomato Varieties (Percentage of tomato plants affected by nematode and late blight)

Variety/damage scale*	0	1	2	3	Rating
Heinz 1370	0.0	11.5	33.0	55.5	6
MFH 9318	35.0	15.0	21.0	29.0	5
Sixpack	77.0	9.5	12.5	6.0	4
MFH 9343	86.0	11.0	3.0	0.0	3
Zeal	90.0	8.5	1.5	0.0	2
FA 593	91.5	7.0	1.5	0.0	1

*0= no damage (0%); 1= slight damage (0–25%); 2= moderate damage (25–50%); 3= severe damage (50–100%)

Average nematode and late blight resistance rating of tomato varieties based on the percentage of tomato plants affected by nematode and late blight together are presented in Table 6 which reflects that FA593 has the highest resistance against nematode and late blight. The ranking of tomato varieties based on the perceptions of the farmers are presented in Table 7 which indicates that the farmers ranked variety Zeal as the most preferred tomato variety.

4. Discussion

4.1 Yield Performance of Tomato Varieties

The two way analysis of variance reveals that yields of six tomato varieties differ significantly ($p < 0.027$), while there are no significant block effects ($p < 0.257$) (Table 1). In other words, the six treatment combinations, namely, FA593, MFH9343, MFH9318, Heinz1370, Sixpack and Zeal contribute differently to the total yield of tomato. However, the total yield does not seem to be impacted by how the experimental fields are laid out in the study design. The multiple comparisons based on LSD principle reveal that the four combinations of varieties (FA593, Sixpack), (MFH9343, Sixpack), (MFH9318, Zeal), (Sixpack, Zeal) out of the $\binom{6}{2} = 15$ combinations

are significant at 5% level. Table 3 reflects that except the fruit category 'rotten weight' none of the fruit categories are affected by the design of the experimental plots. Further, six tomato varieties do exhibit adverse affect in terms of the quality of tomato produced. This finding is consistent with the finding in case of total tomato weight alluded to earlier as all the dependent variables under the two way ANOVA carried out here are related to the total yield weight.

Table 7

Ranking of Tomato Varieties Based on Farmers' Perceptions on Various Characters

Variety	Colour	Shape	Size	Storage durability	Availability of seeds	Yield Points	Total Points	Rating
MFH 9318	5	6	5	3	5	5	29	6
Heinz 1370	6	5	4	6	1	6	28	5
MFH 9343	4	4	6	4	4	4	26	4
Sixpack	1	3	3	5	3	3	18	3
FA 593	2	1	2	1	6	1	13	2
Zeal	3	2	1	2	2	2	12	1

Preference Scale 1 – 6 (Highest preference = 1 to Lowest preference = 6)

The treatment of variety Zeal emerges as the best tomato variety to be replicated in the blocks to maximize the tomato yield; followed by, FA593, MFH9343, Heinz1370 and MFH9318 (Fig 1). Zeal gave the highest marketable yield (112.52 t/ha) followed by FA 593 (105.6 t/ha). The percentage of marketable fruit (by weight) varied from 89.12% (MFH 9343) to 80.42% (Heinz 1370). The variety Sixpack produced the lowest total yield (93.15 t/ha) as well as the lowest marketable yield (76.40 t/ha) among the six varieties under evaluation. In The open pollinated variety Heinz 1370 performed well as it produced total yield of 112.18 t/ha but produced the lowest marketable percentage (80.42%) fruits (Table 2). The lowest marketable percentage fruits produced by Heinz 1370 can be attributed to very high susceptibility to the nematode pest and late blight disease and therefore, Heinz 1370 is not a good variety. The farmers in Botswana have been growing this variety only because of its easy availability and cheaper price of seeds. However, Zeal variety is also available at a reasonable price but there is need to disseminate information about this variety, which can be done by agricultural extension officials. Cost free seed kits can also be distributed to the potential tomato growers by the Ministry of Agriculture. The seeds of FA593 are very expensive, besides their non-availability in local market at all times.

4.2 Nematode Resistance Performance of Tomato Varieties

Tomato variety Heinz 1370 has the highest percentage (67%) of severely attacked plants by nematode and therefore ranked lowest (6th) followed by MFH 9318 having 58% plants attacked severely. The highest percentage of plants with no damage by nematodes (96%) was observed in Six Pack variety and therefore, Six Pack was found to be the least effected tomato variety. No severe damage (0%) was observed in FA 593, Zeal, MFH 9343 and Six Pack but a cumulative damage (slight and moderate damage) of 15%, 13%, 8% and 4% was observed in these varieties, respectively (Table 4). It can also be concluded that none of the six tomato varieties was found nematode resistant, which indicates, therefore, that there is a need to develop nematode resistant tomato variety.

4.3 Late Blight Resistance Performance of Tomato Varieties

Heinz 1370 has the highest percentage (44%) of severely attacked plants by late blight followed by Six Pack with 12% plants attacked severely and ranked the lowest (6th) against the late blight resistance. The highest percentage of plants with no damage by late blight disease (98%) was observed in FA 593 variety and therefore, it can be concluded that FA 593 is the least late blight affected tomato variety. No severe damage (0%) was observed in FA 593, Zeal, MFH 9343 and MFH 9318 but a cumulative damage (slight and moderate damage) of 2%, 8%, 20% and 31% was observed in these varieties, respectively. However, FA 593 followed by Zeal were the least affected varieties as only 98% and 92% plants were not attacked by late blight (Table 5). Therefore, it can be concluded that none of the six tomato varieties was found late blight resistant which indicates that there is a need to develop late blight resistant tomato variety. Development of disease resistant tomato genotypes is the most efficient and environmentally friendly way to control the diseases when sufficient genetic variation for resistance is available (Hulbert et al., 2001) and therefore plant breeders can upgrade the existing tomato varieties through cross breeding.

4.4. Average Nematode and Late Blight Resistance Performance of Tomato Varieties

For the purpose of easy and quick comparison of pest and disease resistance performance of tomato varieties, average nematode and late blight resistance rating of tomato varieties were calculated (Table 6). On an average, tomato variety Heinz 1370 has the highest percentage (55.5%) of severely attacked plants by nematode and late blight and therefore ranked lowest (6th) followed by MFH 9318 having 29% plants attacked severely by nematode and late blight. The highest percentage of plants with no damage by nematodes and late blight (91.5%) was observed in FA 593 variety and therefore, FA 593 was found to be the least effected tomato variety. No severe damage (0%) was observed in FA 593, Zeal and MFH 9343 but a cumulative damage (slight and moderate damage) of 8.5%, 10% and 14% was observed in these varieties, respectively (Table 6). It can also be concluded that none of the six

tomato varieties was found nematode and late blight resistant and therefore, there is a need to develop nematode and late blight resistant tomato variety as these pests and diseases reduce the productivity of tomato. The Department of Agriculture in the Ministry of Agriculture should initiate the development of such tomato varieties and evaluate those on-farm conditions for their adaptations in Botswana.

4.5 Farmer's Perception of the Preference of Tomato Varieties

The farmers appreciated and ranked the Zeal variety as number one, as this variety produced an almost equal size of healthy fruits of good firmness, attractive shape, colour, yield and availability of seeds. Overall, the farmers were of the view that Zeal followed by FA 593 are the best varieties of tomato as these varieties produced good yield, easy availability of seeds and its seeds are available at a cheaper price in the local market. However, on the other hand, farmers were not comfortable with the high price and non availability of the seeds of FA 593 variety in local market and therefore FA 593 was the least preferred variety (Table 7). It was observed that the high seed cost and non availability of high yielding varieties such as FA 593 is a constraint in the adoption of some varieties by farmers in Botswana but the seeds of Zeal are easily available at affordable price in Botswana.

5. Conclusion and Recommendations

The results of the experiment indicated that Zeal was the best yielding tomato variety followed by FA 593. Farmers also rated tomato variety Zeal the best variety followed by FA 593, as this variety produced good yield, easy availability of seeds and cheaper price of seeds in the local market. However, based on the high price and poor availability of the seeds in the local market, FA 593 was least preferred variety among the farmers. Hence the farmers had reservations and therefore did not adapt FA 593 because of the poor

availability and high price of seeds and therefore Zeal was the most preferred variety among the farmers. It was concluded that none of the six tomato varieties was either resistant to nematode or to late blight. Heinz 1370 was found to be the most severely attacked variety (67%) by nematode pest followed by MFH 9318 (58%). Heinz 1370 had the highest percentage (44%) of severely attacked plant population by late blight disease followed by Six Pack (12%). It was therefore recommended that farmers should not grow Heinz 1370 variety because this variety has been found to have the highest susceptibility to nematode pest and late blight disease resulting in the lowest marketable yield. Observing the yield, resistant to nematode, late blight and farmer's perception, it can be concluded that Zeal is the best tomato variety followed by FA 593 for pest and disease adaption and productivity in Botswana. So far, no tomato variety has been developed in Botswana but a number of tomato varieties are being developed every year in different parts of Africa, especially in South Africa and therefore, there is a need to develop and evaluate such new tomato varieties which are resistant to nematode and late blight and suitable for productivity in Botswana. The variety development and evaluation should be conducted by the Ministry of Agriculture in partnership with the potential tomato growers across the country.

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