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Effects of fertilizer and fungicide application rates on late blight disease and growth of Irish potato (*Solanum tuberosum* L.)

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Abstract

Late blight disease of Irish potato is caused by an Oomycete *Phytophthora infestans* is one of the severe crop diseases worldwide that leads to poor production of Irish potatoes. The knowledge in management of the pathogen in terms of variation of nutrition and fungicide in the cultivation of potato remain limited. This study was conducted to determine the effects of nutrition and fungicide variation in relation to potato variety in management of *P. infestans* in potato crop. The experiment was conducted at Egerton University and Tumaini sites in a randomized complete block design - a split -split plot arrangement with *Kenya sherekea* and *Dutch robjin* potato varieties with treatments rates of N-P-K 17:17:17 fertilizer at 0, 90, 135 kg ha^{-1} and fungicide, Acrobat, 0, 2.5, 3.5 g/L. There was significant ($p \leq 0.05$) difference in among the varieties, sites, fertilizer and fungicide levels for disease severity and incidence in the management of late blight in potato crop thus a potential in reduced cost of production and increased yield.

Keywords: *Phytopthora infestans, potato, variety, fertilizer, fungicide*

1. Introduction

Irish potato (*Solanum tuberosum* L.) is globally considered as a significant non-grain crop grown for human consumption and the fourth important food crop after maize (*Zea mays* L.), rice (*Oryza sativa* L.), and wheat (*Triticum aestivum* L.) (Cunnington, 2008). Universally, the total yield is at least 300 million metric tons cultivated in over 120 countries, food securing a minimum of a billion population (Ghimire *et al*., 2020). In developing countries, potato is a significant crop whose production has almost doubled in the recent decades with a corresponding increase in consumption (Mengui *et al*., 2019). In Kenya, potato is the second after maize in terms of staple food crops and plays a key role in food security (Muthoni and Nyamongo, 2009). It is highly affected by drought stress because of its shallow root system (Ghimire *et al*., 2020). However, the production is influenced by biotic stresses of disease causing pathogens (Rosana *et al*., 2017). Its susceptibility to an Oomycete, *P. infestans* (Mont.) De Bary that causes late blight disease that attacks all vegetative and reproductive parts of plants is one of the most severe diseases of potatoes that reduces yield (Agrios, 2005; Ghorbani *et al*., 2004; and Lontsi *et al*., 2020).

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Phytophthora infestans is a widespread and destructive pathogen on both potato and tomato. In the recent decades, major changes in the population and emergence of new strains of this pathogen have been recorded universally (Fry, 2008). It is unclear whether late blight pressure is associated with variation in pathogen population aggressiveness that are often linked with the mutation of new variants (Shimelash and Dessie, 2020). It is known that the pathogen has shown to overcome the resistance to improved varieties, which has led to development of resistance to some fungicides in providing effective protection of the disease (Kassa & Beyene, 2001). These changes influenced the management of this severe foliar disease on potato crop. The disease causes substantial damage and yield losses on potatoes and tomatoes particularly in highlands agro-ecological areas where climate is favourable to the pathogen. Management measures involve the use of many homologated chemical fungicides (Fontem *et al*., 2005). Globally, late blight disease is probably the major biotic stress in potato crop production that leads yield reduction and increased cost of production (Savary *et al*., 2012). The late blight disease resulted in yield losses that caused a great famine in Ireland, 1845 (Fernández-Northcote *et al*., 1998). Irish potato production was mainly practiced in areas with cool climatic conditions, which are conducive environment for proliferation of late blight pathogen. It has a short life cycle that causes crop defoliation within a week, requiring multiple fungicide application with short interval regime (Jackson *et al*., 2021).

Management of the disease requires an integrated approach such use of cultural methods, scouting a blended host plant resistance with an application of homologated chemical fungicides (Kirk *et al*., 2005). In third world countries, many of the potato cultivars grown are susceptible to *P. infestans* thus fungicides are crucial in potato production (Oyarzún *et al*., 2005). Cultivation of resistant varieties to the pathogen is an essential tool in integrated disease management systems (IPM) as it has economic, environmental benefits especially to small holder farmers therefore reduces chances of mutation in the races of *P. infestans* thus reduction in fungicide resistance by the fungus (Mukalazi *et al*., 2001). An adaptive management approach to the disease in Irish potatoes is location specific as well as use of resistant varieties, which could informative on level of relative resistance of each variety (Kromann *et al*., 2009) thus reduction in fungicide need in cultivation of potatoes among smallholder farmers . In the recent decade, there is insufficient research in quantifying resistance *to P. infestans* which could be beneficial in tropics in potato cultivation (Yuen and Forbes, 2009). Extreme use of inorganic fertilizers like nitrogen often promote vegetative growth that are succulent, which may enhance susceptibility of Irish potatoes to *P. infestans*. The use of soil organic amendments than the inorganic fertilizers to suppress the disease has been recognized (Mosota Rosana *et al*., 2017). This study was conducted to determine the effects of mineral nutrition and fungicide application rates on *P. infestans* in potato crop production. The findings beneficial for an integrated late blight disease management in potatoes by smallholder farmers thus contributing to food security and their livelihoods.

2. Materials and methods

2.1. Sites description

The experiments were conducted at Tumaini (0°12'S, 35°41'E), Molo Sub-County and Egerton University (0° 23´ S, 35° 35´ E) Njoro Sub-County, Kenya during the season of July-September, 2014. Egerton University is at agro-ecological zone III, has mollic andosols loam soils with an elevation of 2,238 m above sea level (m a.s.l.), an annual mean precipitation is 1,000 mm and annual mean temperature is 15.9° C (Jaetzold and Schmidt, 1983). Tumaini site is at agro-ecological zone III, the soils are acidic, well drained, deep, dark reddish brown with a mollic A horizon, thus mollic Andosols (Rosana *et al*., 2017) with an elevation of 2,200 m a.s.l., mean annual rainfall of Tumaini, Molo is 1,200 mm and mean temperatures of 13.75°C (Jaetzold and Schmidt, 1983).

2.2. Identification and preparation of **Phytophthora infestans** *inocula*

The *P. infestans* isolate in this study was isolated from infected potato leaves and tubers obtained from the field (Fontem *et al*., 2004) and was morphologically characterized in the laboratory (Bukar *et al*., 2010; Fatima *et al*., 2009; and Fawole and Oso, 1988) using fungi identification keys of the fungal isolates based on their taxonomic keys (Barnett and Hunter, 1972; Howard, 2002; Larone, 2002; Moubasher, 1993; and Robinson, 2011). The inocula were collected directly from a two weeks old pure cultures grown on V8 media amended with antibiotics (rifampicin 20 mg. mL^{-1}, ampicillin 200 mg. mL^{-1}) (in 90 mm diameter petri dishes) stored at 18°C (in the dark) by adding 10 ml of sterile distilled water then scrapped the surface lightly with a sterile platinum loop then were shaken in a vortex to dislodge the sporangia and filtered in a double layer of cheese cloth. The inocula concentration was diluted to 2×10^4 sporangia / mL (Fontem *et al.*, 2005) and incubated at 4°C for 2 h to induce the release of zoospores preceding the use in inoculation (Jie, 2001).

Plants were inoculated at 37 days after emergence (DAE) with inocula concentration (2.0×10^4 spore / ml) of the pathogen after sprinkle irrigation to enhance disease development. Fertilizer (N. P. K) treatment application was done during planting using three levels of fertilizer which was sufficient for crop growth. Fungicide application started 10 days after inoculation and repeated in intervals of seven days up to 61 Days After Planting (DAP).

2.3. Experimental treatment applications

The Egerton University and Tumaini experimental sites were ploughed and harrowed to a fine soil tilth. The experiment was laid out in a randomized complete block design, split – split plot arrangement with 18 treatments replicated thrice. The 16 certified clean sprouted medium sized (50 g) potato tubers of *Kenya Sherekea* (KS)- (tolerant) and *Dutch Robjin* (DR) (susceptible) varieties sourced from Agricultural development cooperation, Tumaini were planted at a spacing of 0.75 m × 0.30 m in a plot measuring 3×1.2 m, thus four rows in each plot on July, 4th and 5th, 2014 at Tumaini and Egerton University sites, respectively. The three rates of N. P. K 17:17:17 complete fertilizer at 0, 90, 135 kg / ha were applied in two equal splits (at planting and five weeks later after planting). The cultural practices such as manual weeding and molding were carried out on need basis. The insect pests were controlled when at least 50% emergence of the crop had been attained and pest population had reached economic threshold by spraying using Actara (Thiamethoxam). The plants were inoculated at 37 DAP with spores suspension (2.0×10^4 spore / ml) of *P. infestans* pathogen after a sprinkle irrigation. Acrobat fungicide was sprayed to the crop at the rates of 0, 2.5, 3.5g / l, thrice with an interval of seven days starting from 10 days after inoculation with the pathogen up to 61 DAP.

3. Data collection and analysis

The plant morphological features that were measured at different plant growth stages to determine the response to the treatments applied included the followings: plant height, the number of haulms and leaves at 47, 54 and 61 DAP. At 120 DAP harvesting was done, yield was measured by quantifying tuber numbers from each plot and expressed in tons per hectare (t / ha) for subsequent analysis. The data collected on late blight disease severity was collected as described by (Rosana *et al.*, 2017), potato growth parameters and yield were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS Institute, 2001) software. Correlation ($p \leq 0.05$) among variables and parameters measured were analyzed using the correlations analysis. The strength of the linear relationship among various parameters measured was also assessed. Treatment means were separated using Least Significant Difference (LSD) at ($p \leq 0.05$).

4. Results

The results on effect of site, Egerton and Tumaini on late blight severity and incidence (Tables 1 and 2). The precipitation during the cropping season was high and relative humidity was sufficient for the infection and development of late blight disease on Irish potato crop.

Table 1: Effects of experimental sites on *P. infestans* severity on potatoes crop

Percentage disease severity index			
Site	**47 DAP**	**54 DAP**	**61 DAP**
Egerton	10.51^a	16.35^a	18.95^a
Tumaini	12.01^b	18.96^b	30.40^b

Note: Means followed by the same letter in each column are not significantly different at ($p \leq 0.05$); DAP= Days After Planting.

Table 2: Effects of experimental sites on *P. infestans* incidence on potatoes crop

Percentage disease incidence			
Site	**47 DAP**	**54 DAP**	**61 DAP**
Egerton	41.20[a]	43.98[a]	44.91[a]
Tumaini	49.53[b]	54.17[a]	53.24[b]

Note: Means followed by the same letter in each column are not significantly different at ($p \leq 0.05$); DAP= Days After Planting.

There was a significant ($p \leq 0.05$) difference in the rate of disease development with time between the two experimental sites. The disease incidence and severity were significantly ($p \leq 0.05$) higher in Tumaini than Egerton site at DAP (Tables 1 and 2). Disease incidence provided significant difference at 54 DAP (Table 1) which was not significant (Table 2). At 61 DAP, the disease severity was high in Tumaini site (30.40%) compared to Egerton University (18.95%) (Table 1) and disease incidence was high at Tumaini site (53.24%) as compared to Egerton University site (44.91%) (Table 2). Disease development at Tumaini was high than Egerton University due to the favorable weather conditions which favored high inocula load. The potato debris in the surrounding farms may have also served as a source of inocula in addition to the artificially inoculated pathogen load. On the contrary, the experiment plot at Egerton University had previously had maize and sorghum prior to our experiment. The inocula load may have been low with limited possibility of external sources of pathogen transfer to the field other than the artificially inoculated load.

4.1. Effect of fertilizer and fungicide application on potato growth

The application of N: P: K fertilizer treatments to the potato crop were found to have effects on potato growth variables but their level depended on the application of Acrobat fungicide. At both sites, Egerton and Tumaini, application of fertilizer and fungicide on potatoes resulted to a significant change in height. The application of both fertilizer and fungicides was significantly ($p \leq 0.05$) effective on increase of potato height (Table 3).

Table 3: Effects of fertilizer and fungicide rates on height of potatoes crop

		Height					
	Fertilizer kg/ha	**Egerton**			**Tumaini**		
	Fungicide g/l	**0**	**90**	**135**	**0**	**90**	**135**
47 DAE	0	20.11[a]	22.76[a]	25.7[a]	22.11[a]	23.76[a]	26.70[a]
	2.5	22.64[b]	25.60[bc]	25.80[ab]	25.14[ab]	28.60[ab]	28.30[bc]
	3.5	22.77[b]	23.88[c]	24.95[b]	26.27[b]	27.28[b]	28.05[c]
54 DAE	0	37.50[a]	42.22[a]	43.37[a]	39.5[a]	44.20[a]	45.37[a]
	2.5	36.45[a]	40.60[ab]	42.80[bc]	38.95[ab]	42.60[bc]	45.30[a]
	3.5	38.20[b]	39.33[b]	41.31[c]	41.7[c]	42.8[c]	44.80[a]
61DAE	0	44.86[a]	47.25[a]	47.65[a]	46.86[a]	49.20[a]	49.70[a]
	2.5	43.28[a]	44.99[bc]	46.77[b]	45.78[ab]	47.09[a]	49.27[a]
	3.5	47.97[b]	45.67[c]	48.80[a]	50.47[c]	48.17[a]	50.0[a]

Note: Means followed by the same letter in each column are not significantly different at ($p \leq 0.05$); DAP= Days After Planting.

At both sites, timing was highly significant at ($p < 0.05$) at 47, 54 and 61 days after emergence. The interaction between fungicide and fertilizer application rates were not significant ($p > 0.05$) but stem height increased with the time. The treatments of 135 kg / ha fertilizer rate at planting time and 3.5 g / l of fungicides was the tallest while the treatments 0 Kg / ha of the total fertilizer rate and 0 g / l of fungicide rate the crop plants haulms were shortest (Table 3).

The application of fertilizer and fungicide treatments resulted in a significant change in the number of haulms in potatoes ($p \leq 0.05$) in the two sites (Table 4). The effects of fertilizer and fungicide combinations were effective at 47 DAE for 90 kg / ha and 3.5 g / l. Further effects were witnessed at 54 DAE and 61 DAE when fertilizer and fungicide were combined. The highest number of haulms (10.5) were recorded at Tumaini for 2.5 g / l of fungicide and 135 kg / ha of fertilizer. The lowest number of haulms were recorded at application rates of 0 kg / ha for fertilizer and 0 g / l fungicide across all the days (Table 4).

Table 4: The number of haulms as influenced by the interaction of fertilizer and fungicide

	Fertilizer kg/ha	Haulms (no)					
		Egerton			Tumaini		
	Fungicide Rates	0	90	135	0	90	135
47 DAE	0	3.25[a]	5.08[a]	5.8[c]	4.6[a]	6.07[a]	6.85[a]
	2.5	3.75a	5.25[ab]	6.25[ab]	4.65[a]	6.30[a]	7.0[ab]
	3.5	3.58a	6[b]	6.4[a]	4.58[a]	7.0[b]	7.20[b]
54 DAE	0	3.4[a]	6.88[a]	6.58[a]	4.4[a]	7.81[a]	7.68[ab]
	2.5	5.58[b]	6.58[ab]	7.5[a]	7.20[b]	8.58[ab]	9.59[a]
	3.5	5.08[bc]	6.75[b]	7.25[b]	7.08[bc]	8.65[b]	9.30[ab]
61 DAE	0	3.8[a]	6.25[a]	7.41[ab]	5.50[a]	8.30[a]	9.50[ab]
	2.5	7.5[b]	7.66[b]	8.25[a]	6.50[b]	9.90[ab]	10.50[a]
	3.5	5.75[b]	7.33[bc]	7.83[ab]	7.75[c]	9.20[ab]	9.80[ab]

Note: Means followed by the same letter in each column are not significantly different at ($p \leq 0.05$); DAP= Days After Planting.

Interaction of fertilizer and fungicides rates had effects on leaves development across the sites with Tumaini site recording highest leaf number (17.40). The latter was the highest mean number recorded at 135 kg / ha of fertilizer and 3.5 g / l fungicide application rates. Application of N:P:K fertilizer treatments was found to have effects on the number of leaves per plant but the level depended on the application of fungicide to control late blight to avoid defoliation of the leaves. The untreated plots recorded the lowest number of leaves per plant the two experimental sites at 8.75and 9.50 respectively (Table 5).

The tuber yield in tons per hectare differed significantly ($p \leq 0.05$) between fertilizer and fungicides-treated and untreated, the control since it ranged between 11.0 and 22.7 at Egerton University site compared to 13.3 and 32.2 at Tumaini site. The highest yield was awarded to the treatment of fungicide and fertilizer rates of 3.5 g / l and 135 kg / ha respectively at both experimental sites. Although mineral fertilizer consistently proved to have a significant role on yield, it exposed the potatoes to late blight due to the effect on succulence of the whole plant. High tuber yield was obtained from plants that were treated with fungicide which had Dimethomorph 90 g / kg + Mancozeb 600 g / kg mixtures that were systemic and protective in nature. The results on yield indicate that use of fertilizers increased yields as the rates of fertilizers increased between 0 and 135 kg / ha (Table 6).

Table 5: The effects of fertilizer and fungicides interaction on the number of leaves on potato crop

	Fertilizer kg/ha	Leaves (No)					
		Egerton			Tumaini		
	Fungicide Rates	0	90	135	0	90	135
47 DAE	0	8.75[a]	11.25[a]	11.58[ab]	9.50[a]	12.0[a]	12.56[ab]
	2.5	8.33[a]	10.33[b]	12.33[a]	10.32[b]	12.31[bc]	14.32[a]
	3.5	8.66[a]	9.91[c]	12.41[a]	11.61[c]	12.80[c]	15.40[a]
54 DAE	0	10.41[a]	12.33[a]	12.50[ab]	11.40[a]	13.45[a]	13.60[a]
	2.5	10.83[b]	11.58[ab]	13.58[a]	13.70[b]	14.56[ab]	16.50[b]
	3.5	10.66[b]	11.66[ab]	13.41[a]	14.66[c]	15.36[c]	17.40[c]
61 DAE	0	11.83[a]	13.75[a]	14[ab]	13.80[a]	15.61[a]	17.21[a]
	2.5	12.58[b]	13.25[ab]	15[a]	14.58[bc]	15.30[ab]	17.11[a]
	3.5	12.25[bc]	13.50[ab]	15[a]	14.21[bc]	15.30[ab]	17.40[a]

Note: Means followed by the same letter in each column are not significantly different at ($p \leq 0.05$); DAP= Days After Planting.

Table 6: Effects of fertilizer and fungicide interactions on the potato yield

Yield kg/ha at 120 DAP			
Fungicide g/l			
Fertilizer (kg/ha) /	0	2.5	3.5
Egerton			
0	11.0[a]	17.5[a]	21.2[b]
90	10.0[b]	14.0[b]	20.5[ab]
135	10.5[ab]	19.3[c]	22.7[a]
Tumaini			
0	13.3[a]	18.2[a]	19.4[a]
90	20.3[b]	24.5[b]	26.5[b]
135	20.0[c]	30.1[c]	32.2[c]

Note: Means followed by the same letter in each column are not significantly different at ($p \leq 0.05$); DAP= Days After Planting.

The results presented exhibit that total yield had significant (p = 0.01) and positive correlation with site (r = 0.61**), plant height (r = 0.40**), fungicide (r = 0.49**) and fertilizer (r = 0.39**). These results indicate that total yield of potato depends on the site, the plant height, the number of leaves, fungicide and fertilizer (Table 7).

Table 7: Correlation analysis for the site, height, number of leaves, number of haulms, fungicide, fertilizer and yield of potatoes

	Site	Height	Number of leaves	Number of haulms	Fungicide	Fertilizer	Yield
Site	1						
Height	0.45**	1					
Number of leaves	-0.42	0.4	1				
Number of haulms	0.53**	0.31	0.24	1			
Fungicide	0.55**	-0.41	0.53*	-0.47	1		
Fertilizer	0.38	0.31*	-0.32	0.54**	-0.47**	1	
Yield	0.61**	0.51**	0.40**	-0.33	0.49**	0.39**	1

Note: *, ** represent differences at 0.05 and 0.01 level of significance, respectively.

5. Discussion

The cultivation and yield of Irish potato crop has been limited mainly by late blight disease with a potential of causing 100% yield loss thus food insecurity. The effort in developing and use of integrated disease management has been directed in minimizing the usage of excessive fungicides which include but not limited to a combination of nutrition with fungicides (Rosana *et al*., 2017), biological management (Köhl *et al*., 2019). The introduction of phytoalexins and glycoalkaloids secondary metabolites through breeding to the potato crop may offer host some defence against *P. infestans* (Majeed *et al*., 2017). The use of plant extracts and natural products are likely to achieve a suitable sustainable management of late blight thus less residual elements to the environment than the risks associated with fungicide-resistant strains of *P. infestans* (Majeed *et al*., 2015). The use of clean seed materials (Jackson Mutuku *et al*., 2021) worldwide for production of clean seed and cultivation of potato crop to reduce *P. infestans* in potato field thus reduction in usage of pesticides. However, limited or none of the strategies established or a combination mainly have resulted in additional costs or low adoption by farmers (Rosana *et al*., 2017). Reduction of the effects of abiotic and biotic stresses would be an approach in promoting food security with the resources at the disposal of the farmer (Lobell *et al*., 2009). However, there is no potato cultivar that has resistance to *P. infestans* thus a potential of an integrated management of the disease in the crop could be more (Jackson Mutuku *et al*., 2021). The main approach used in the control of late blight disease is the application of fungicides which are formulations of inorganic and organic materials with the potential of growth inhibition, killing of the zoospores and mycelium of the causative organism (Majeed *et al*., 2017).

In the recent decade, strains of *P. infestans* show resistance to fungicides that have metalaxy as an active ingredient (Gisi and Sierotzki, 2008). Though, metalaxyl containing fungicides show good results against *P. infestans* (Gisi and Cohen, 1996) its continuous applications has resulted in development resistance to the disease (Clayton and Shattock, 2006) and a sizable share of metalaxyl-insensitive genotypes of *P. infestans* has been documented globally. On field grown potatoes in Ireland, Netherlands and Switzerland where phenylamide resistant isolates of *P. infestans* were detected which were associated with a decline in the disease management in crop (Majeed *et al*., 2017). However, other fungicides which exhibited suppressive effects against Oomycete pathogen have also lost their affectivity. The high disease severity could be attributed to irregular climatic conditions of low and high humidity which seem to favour disease development which concurs with what was reported by (Waals *et al*., 2001). The lower disease incidences at some locations could be attributed to balanced fertilizer and fungicide application rates. The host developmental phase has got some effects on the incidence of *P. infestans* with older crop exhibiting an increased severity than younger plants which concurs with the findings of (Agrios, 2005).

The use of fungicide or host resistance alone cannot manage late blight thus a need to an integrated disease management approach (Fry and Shtienberg, 1990). In an evaluation of the cultivars in response to inorganic fertilizers, there was a general increase in late blight disease incidence, severity and thus susceptibility with an increase in fertilizer (Nfor *et al*., 2011) but in contrast with the findings that, plants with optimum nutrition have the maximum disease resistance (Marschner, 1986). Susceptible varieties require more fungicide application rates than resistant cultivars (Nærstad *et al*., 2007) and they are integral part in management of late blight disease in potato crop (Mosota Rosana *et al*., 2017). The increase in yield was linked with the decreasing foliar late blight disease severity (Fontem *et al*., 2004).

The classes of fungicides used in the management of late blight disease in potato crop include protectant and systemic. Fungicide mode of activity their capacity to disrupt target parasite cell membranes, activation of catalytic enzymes of the host tissues that inhibits the growth of the pathogen through the pathotoxic activity through prevention of zoospores to encyst, cause their bursting and prevent the protoplast regeneration of Oomycete pathogen (Cohen *et al*., 2007). Late blight is effectively managed when fungicide applications to the potato crop is made prior to infection as most fungicides have protectant effects and they may lose their efficacy after *P. infestans* has established itself in host tissues (Ingram and Williams, 1991). The properties of protectant fungicide tend to protect host tissues by inhibiting or killing the propagating structures of the pathogen before it establishes itself with successive interval applications (Mosota Rosana *et al*., 2017) and they doesn't persist for a long duration as the active ingredient can be washed down by the rain (Deahl *et al*., 2008). The fungicides are effective against the disease when they are applied in wet conditions and at higher frequency rate (Majeed *et al*., 2017), however, under wet conditions and heavy rain falls, they may be less effective due to rain erosion and difficulty in spraying (Kankwatsa *et al*., 2003). The systemic fungicides are more persistent than the protectant fungicides and may be used in management of the late blight disease, they penetrate deeply into the host tissues and they remain active longer period, they are applied approximately two months after planting with at least 2 applications at an interval of 8-10days (Mantecón, 2007). In addition, the local and acropetal penetrants are also used which have some protective barriers on and with the penetration to host tissues (Majeed *et al*., 2017).

Late blight disease in potato during the cropping season was due to the presence of inocula and favorable conditions for disease development on the crop. This is in agreement with the studies on environmental conditions in highlands of East Africa highlands of Uganda and Kenya that favored occurrence and development late blight disease (Olanya *et al*., 2001; and Olanya *et al*., 2002) and in the highland tropics with high disease pressure making the susceptible potato varieties require frequent systemic or trans - laminar fungicide applications for the management of the disease (Kromann *et al*., 2009). The symptoms of late blight disease were observed from establishment of Irish potato crop, harvesting to tuber bulking phase thus signifying the disease infect potatoes at various developmental stage of the crop which was in concurrence with Tadesse results (Mekonen and Tadesse, 2018). Previous study has shown that symptoms of late blight disease initially occur in 10 -15 days after emergence of the crop which could lead to severe epidemics resulting in at least 80 % foliage damage while the mild or / and late infections leads in less severe epidemics and thus less yield loss (Olanya *et al*., 2002).

The *P. infestans* challenges the host tissue by proliferation with its mycelia, the haustoria that establishes intercellular connection within the host tissues by disrupting host cell wall for nutrient absorption (Whisson *et al*., 2016). The profuse intercellular growth and development of mycelium and haustoria result in host cellular damage with an appearance which is greenish brown or yellowish spots which turn blackish with progress of disease development, and in moist condition that favour the pathogen growth results in wilting of the plant (Majeed *et al*., 2017). In moist climatic conditions the sporangiophores forms sporulation of the sporangia and the visibility of mycelium, at lower surface of leaves (Schumann and D'arcy, 2000). The sporangia are then disseminated over long distance by air from infection areas to regions with healthy potatoes and / or tomatoes. The sporangial germination occurs either directly by protruding germ tube or by producing motile zoospores within hours of coming into contact with host's leaves in the presence of moisture thus initiate disease symptoms (Fry and Shtienberg, 1990). A successful infection and establishment of *P. infestans* is a complex process that involves interaction between host and the pathogen with influence of the environmental factors such as availability of moisture, prevailing temperature, pathogen's virulence and host's plant level of resistance (Majeed *et al*., 2017).

The differences in infection of crops across various sites could be due to differences between temperatures during the day and night thus a delay in growth and development, this is in concurrence with the positive effects, on fertilizer use efficiency in potato crop growth and yield (Rosana *et al*., 2017) and the role of nitrogen in branching- tillering through cytokinin production by roots (Assuero and Tognetti, 2010). The application of mineral fertilizer and fungicide had better values on plant physical growth as the rates of application of the treatments increased. This is in agreement with the use of mineral fertilizers that supply nutrients to crops for development (Moyin-Jesu, 2007). The timing and application of nitrogenous fertilizer is an important factor that determines the rate of vegetative growth, leaves and branching as well as canopy cover and structure (Mosota Rosana *et al*., 2017). Plant growth and development depends on the establishment of a vigorous and well developed rooting system that is strong and well-shaped branching achieved through adequate fertilizer, water supply and solar radiation (Gathungu *et al*., 2000).

The positive relationship between number of leaves stem height and yield observed in this study stressed the significance of these parameters in the growth and the development of the crop as well as the degree of interdependence that exists between them. This relationship could be associated with the elevation of the amount of the fertilizer applied signifying the importance of nutrients N, P and K for plant growth and development thus increase in dry matter composition in plant and hence in leaf area. This is concurrence with the study on found that the tuber yield per hectare that was significant and positively correlated with plant height, foliage coverage, and number of stems per hill sized tuber (Getachew *et al*., 2012).

6. Conclusion

The *P. infestans* that causes late blight disease of potato is primarily managed in most of the agro-systems by continuous usage of fungicides. The integrated management of disease in using nutrition-fungicide rates approach in the potato crop exhibited significant deterrent effects on development of pathogen, positive potato growth characteristics, yield and thus food security.

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Competing Interests

The authors have declared that no any conflicting interests exist

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