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Effects of Fertilizer and Fungicide Application Rates on the Incidence and Severity of Late Blight (*Phytophthora infestans*) on Irish Potatoes (*Solanum tuberosum* L)

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Abstract The effects of fertilizer and fungicide application rates have been demonstrated in the field on potato production. However, the fertilizer rates have not been tested fully to ascertain its effects on incidence and severity of late blight (*Phytophthora infestans*) on irish potatoes (*Solanum tuberosum* L). The objective of this study was to determine effects of N-P-K 17:17:17 fertilizer and Acrobat fungicide (Dimethomorph 90g/Kg + Mancozeb 600g/Kg) application rates on the incidence and severity of late blight on Irish potatoes. The experiment was conducted at Egerton University Field seven and Tumaini farm, in Molo Sub County. This was done in a randomized complete block design in a split split plot arrangement with Kenya sherekea and Dutch robjin potato varieties being used. The pathogen was isolated from infected leaves and tubers and identified in the laboratory. It was then used for in inoculation in the field. The treatments rates were N-P-K 17:17:17 fertilizer at 0, 90, 135Kg ha^{-1} and fungicide, Acrobat (Dimethomorph 90g/Kg + Mancozeb 600g/Kg) at rates of 0, 2.5, 3.5g/L. Each potato variety was sprayed with the fungicide three times in intervals of seven days at 47DAP, 54DAP and 61DAP. Fertilizer application was done at planting and 35 days later after emergence at equal splits. Data was collected on percent disease index (PDI) and disease severity index (DSI). Analysis of variance (ANOVA) was conducted and means separated using Tukey's test whenever ANOVA showed significant treatment differences. There was significant ($P \leq 0.05$) difference among the varieties, sites, fertilizer and fungicide levels for disease severity and incidence. The results showed that fertilizer and fungicide application rates had some effects on late blight development under field conditions depending on variety. Therefore fertilizers and fungicides should be used cautiously to reduce incidence and severity of potatoes to late blight.

Keywords: *fertilizer, phytophthora infestans, solanum tuberosum, fungicide*

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1. Introduction

Potato (*Solanum tuberosum* L) is the world's most important non-grain food commodity as its production increases each year with Asia and Europe producing about 80 % [5]. It is an important food and cash crop for many poor people and is often considered an important mechanism for poverty alleviation and food security in developing countries [26]. Considering the number of hectares harvested and metric tons produced, potato is considered one of the fastest growing food crops in the subtropics and tropics [6]. One of the potential factors limiting growing this crop commercially can be partially attributed to its susceptibility to diseases, of which late blight caused by the oomycete *Phytophthora infestans* is considered the most important [11].

Historically, the disease has often resulted in destructive consequences and the most documented event is the great famine caused by this disease in Ireland (1845) when almost half of the potato crop was destroyed [8]. Worldwide, *P. infestans* causes enormous economic damage amounting to an estimated $5 billion annually, between control and actual production [14]. Management of late blight requires aggressive measures that include combined use of cultural, scouting, sanitation, and most importantly the combination of host plant resistance with application of fungicides [15]. In most parts of the developing world, the most widely grown potato genotypes are susceptible to late blight therefore fungicides are a necessity for potato production [25]. Utilization of host resistance to late blight has a lot of significance in integrated late blight management due to its long-term economic benefits for small-scale farmers. It also minimizes changes in the population structure of

P. infestans hence decreasing the likelihood of resistance to fungicide [20].

Management of potato late blight can be highly location specific and optimal use of new, resistant cultivars will probably require some degree of adaptive research [16]. Such research could be facilitated by information on the relative level of resistance of each candidate cultivar and the value of this resistance in reducing fungicide needs. Frequently this information is lacking and until recently, there was no system for quantifying resistance in potato to *P. infestans*, which could be applied in tropical and sub-tropical locations [32]. Excessive use of chemical fertilizers especially nitrogen can often promote succulence and excessive vegetative growth that may increase the susceptibility of the crop to the disease pathogen. The potential of organic amendments over synthetic inorganic fertilizers in suppression of disease incidence has long been recognized. Evidence of suppression of disease attack by different forms of organic amendments has been reported by various researchers [3]. This study was therefore conducted to determine the effects of fungicide and fertilizer application rates on the management of late blight on potatoes in the field conditions. The findings of this study were expected to provide the basis for integrating fertilizer and fungicide in disease management (DM) of late blight by smallholder potato farmers.

2. Materials and Methods

2.1. Sites Description

The experiments were conducted at Egerton University field seven in Njoro Sub County and Tumaini farm in Molo sub county, Kenya in July – October, 2014. Egerton University lies at latitude 0° 23´ S, longitude 35° 35´ E and at an altitude of 2238 m above sea level. The annual mean precipitation is 1000 mm and the annual mean temperature is 15.9°C. The site is situated in the agro-ecological zone III and has mollic andosols loam soils [13]. The site has relatively high altitude as well as high annual rainfall which are suitable for potato production and also late blight development and spread . Tumaini farm in Molo lies at latitude 0°12´S, Longitude 35°41´E and at altitude of 2200 m above sea level. The mean annual rainfall of Molo is 1200 mm and mean temperatures of 13.75°C [13]. The soils of Molo are acidic, well drained, deep, dark reddish brown with a mollic A horizon, and classified as mollic Andosols [7].

2.2. Preparation of (*P. infestans*) Inoculum

The *Phytophthora infestans* isolate that was used in all trials was isolated from infected potato leaves obtained from the field as described by [9] and identified in the laboratory. Cultures of *P. infestans* were grown on V8 medium amended with 150 ppm ampicillin and 100 ppm rifamycin, in 90 mm diameter Petri dishes for 10 – 14 days at 18°C in the dark. The inocula were collected with a fine brush into 10 mL of sterile distilled water (SDW). The suspensions were shaken in a vortex to dislodge sporangia and then filtered through a double layer of cheese - cloth to remove mycelial fragments. The sporangial suspension was transferred to another flask and the inoculum concentration was diluted to 2×10^4 sporangia/mL with the aid of a hemocytometer. The suspension was incubated at 8°C for 1 hour to promote zoospore release prior to use.

2.3. Experimental Procedures

The field was ploughed and harrowed to attain a fine soil tilth. The experiment was laid out in a split – split plot arrangement of randomized complete block design (RCBD) with eighteen treatments replicated three times. The plot size measuring 3×1.2 m with a spacing of 75 cm × 30 cm (75 cm between the rows and 30 cm between the plants) resulting in 4 rows per plot. A clean sprouted certified potato seed of medium size (50g) of varieties Kenya Sherekea and Dutch Robjin sourced from Agricultural development cooperation (ADC), Molo were sown per hole at an appropriate depth. Sowing was done on 4th and 5th July, 2014 at Molo and Egerton University respectively. Insect pests were controlled by spraying the plots when 50% emergence had been attained and when the pest population had reached economic threshold using Actara (Thiamethoxam). Other cultural practices such as weeding were carried out regularly when there was need. The three rates of N. P. K 17:17:17 fertilizer (0, 90, 135 Kg/ha) were applied in two equal splits at planting and 35 days later after planting (August 8, 2014). Plants were inoculated at 37 days after planting (August 10, 2014) with spore suspension (2.0×10^4 spore/ml) of the pathogen after sprinkle irrigation to enhance disease development. Acrobat (Dimethomorph 90g/Kg + Mancozeb 600g/Kg) fungicide was sprayed three times at 7 days interval starting 10 days later after inoculation at rates of (0, 2.5, 3.5g/l).

2.4. Data Collection

Disease onset (DO) in each cultivar was recorded in days after planting. Starting with the appearance of the first late blight symptoms, each plant within two middle rows in each plot was visually evaluated for percent foliar infection at seven-day intervals starting at 47 DAP , 54 DAP and at 61 DAP . Harvesting was done at 120 days after planting. Evaluations continued until untreated plots of the susceptible variety no longer increased in disease severity. Disease incidence and severity per plot were converted to percentages according to [29] as shown in Equations below.

$$\text{PDI}(\%) = \frac{\text{NDP}}{\text{TNPP}} \times 100$$

Where; PDI = Percent disease index per plot, NDP = number of diseased plants, TNPP = Total number of plants per plot. Disease severity per plot in both experiments was visually assessed on a scale of 0 – 9 as shown 0: No disease; 1: Small lesion on the inoculated point with the lesion area less than 10% of the whole leaflet; 3: Lesion area between 10 and 20% of whole leaflet;5: Lesion area between 20 and 30% of whole leaflet, the waterish area less than 50% of the whole leaflet; 7: Lesion area between 30 and 60%; 9: Lesion area over 60% of the whole leaflet . Where 0 means (immune) no disease was observed and 9 mean all leaves and stems drying and dead due to disease (highly susceptible).

The disease severity were converted to disease severity index using the equation

$$DSI(\%) = \sum \frac{DSL \times NLSL}{TNL \times HSR} \times 100$$

Where; DSI = Percent disease severity index, NLSL = No of leaflets with the same level TNL = Total number of leaflets HSR = Highest severity rating. Total tuber yield (TTY) of each experimental unit (plot) was determined by harvesting the two inner rows of each plot at exactly 120 days (October 31, 2014) after planting. Tubers were sorted as unmarketable (blighted, rotten and deformed) and marketable from the total tuber yields and the components were measured. All measures were given in T/ha, which was derived by extrapolation from the yield per plot.

2.5. Statistical Analysis

The data collected on late blight severity, incidence and yield were subjected to analysis of variance (ANOVA) using Statistical Analysis System [27] software. Treatment means were separated using Least Significant Difference (LSD) at (P≤0.05 whenever ANOVA showed significant treatment effects.

3. Results and Discussions

3.1. Effects of Potato Variety on Incidence and Severity of Late Blight (*P. infestans*) in the Field Conditions

The two varieties exhibited differences in susceptibility to the development of late blight (Table 1 and Table 2). There was a significant (P≤0.05) differences in the severity and incidence of Late blight in the Kenya sherekea and Dutch robjin varieties.

Table 1. Influence of potato variety on severity of late blight (*P. infestans*) in the field conditions July - October 2014

	Percentage (%) Disease severity index (DSI)					
	Egerton			Molo		
Variety	47DAP	54DAP	61DAP	47DAP	54DAP	61DAP
Dutch robjin	13.65^a	18.96^a	31.96^a	15.87^a	25.63^a	37.75^a
Kenya sherekea	8.86^b	16.35^b	17.39^b	8.90^b	18.95^b	27.12^b

Means followed by the same letter in each column are not significantly different at (*P*≤0.05). DAP= Days after planting.

Table 2. Influence of potato variety on the percentage disease incidence of (*P. infestans*) in the field conditions July - October 2014

	Percentage (%) Disease incidence (PDI)					
	Egerton			Molo		
Variety/DAI	47DAP	54DAP	61DAP	47DAP	54DAP	61DAP
Kenya sherekea	24.07^b	37.50^b	51.85^a	33.33^b	45.01^b	52.11^b
Dutch robjin	46.30^a	60.65^a	66.6^a	57.27^a	58.33^a	75.0^a

Means followed by the same letter in each column are not significantly different at (*P*≤0.05). DAP= Days after planting.

Comparing the two varieties, Dutch robjin recorded highest severity index of 31.96 and 37.75 at Egerton and Molo respectively as compared to Kenya sherekea with 17.39 and 27.12 at Egerton and Molo respectively which was significantly (*P*≤0.05) different. Disease incidence among the two varieties was significant (*P*≤0.05) with Dutch robjin variety exhibiting unstable resistance to *P. infestans* as compared to Kenya sherekea in the field conditions (Table 2). The percentage disease incidence increased progressively after inoculation due to high inoculum load. Kenya sherekea variety proved to be resistant to late blight disease with mean values of 24.07 to 52.11 as compared to Dutch robjin variety 46.30 to 75 on disease incidence (Table 1 and Table 2). Dutch robjin variety was more affected at both sites but epidemic was high at Molo site as compared to Kenya sherekea. Comparison of the two varieties therefore indicated the Kenya sherekea varietywas more resistant to late blight as compared to Dutch robjin which was susceptible to late blight. This indicates how resistance can be exploited to minimize on application of fungicides and other inputs for increased yield in potato production. The field at Molo had high inocula load and high humidity which favoured pathogen development. Over seasoning potato debris also served as a source of inoculum in addition to the artificially inoculated pathogen load. On the contrary, the experiment plot at Egerton University was at an isolated area where only cereals (sorghum and maize) had been planted prior to the experiment. The inoculum load was therefore low with limited possibility of external pathogen transfer to the field apart from the artificially inoculated load. Although late blight occurrence was detected in both sites during the cropping season, the presence of inoculum and favourable conditions facilitated disease development at the two sites. Environmental conditions at both sites of the experiment might have contributed late blight occurrence and development. This was in agreement with research findings by [24] on environmental conditions in East Africa highlands of Uganda and Kenya favourable for late blight occurrence and development throughout the year. Consequently, in areas of high disease pressure, such as the highland tropics, susceptible varieties require frequent fungicide applications and the disease is difficult to manage without the use of expensive systemic or trans - laminar fungicides [16].

3.2. Interaction Effects of Fertilizer and Fungicide Application Rates on (*P. infestans*) Severity on Potatoes under Field Condition

The interaction effects for fertilizer and fungicide application rates on *P. infestans* severity on potatoes at Egerton University and Molo sites are presented in Table 3 below. The results indicate that the effect of time on disease severity was significantly worse later in the season at 61DAP.

Effects of fertilizer and fungicides interactions between Egerton and Molo sites indicated that severity was slightly high in Molo at 37.75 as compared to Egerton at 26.94. The results showed little significant differences as shown in (Table 3). Untreated plots had recorded high severity indexes as shown in (Table 3). High rates of fungicide seemed to be effective for management of late blight at both sites but it depended on the levels of fertilizers applied. Disease pressure was low at 47 DAP and it kept increasing slightly up to 61DAP where high severity indexes was recorded. High disease severity at Molo can be attributed to alternating low and high humidity conditions which seem to favour disease development which was similar to what [31] reported. Lower disease at some locations could be attributed to balanced dose of fertilizers and fungicides. Host developmental stage has got some effects on late blight development with older plants recording increased severity rates than younger plants as shown in (Table 3) which is in agreement with the findings of [1].

In general, late blight incidence varied between mineral fertilizer schemes but the effect depended on disease pressure and fungicide rates. The two sites showed differences in efficacy of fungicide spray for both incidence and severity (Table 3 and Table 4). The relatively disease control obtained with fungicide mixtures under moderate to severe late blight conditions suggests that fungicide mixtures can provide effective late blight management in established epidemics compared with the use of a protectant or systemic alone as it was reported by [18].

The disease severity and incidence was high in the control plot at 61DAP where neither fertilizer nor fungicide was applied. The highest rate of increase of late blight severity was recorded between 54 and 61DAP and the progress declines when the fungicide rates were increased (Table 3). The incidence was lower at 0kg/ha of fertilizer than 90kg/ha and 130kg/ha which corresponds with reduction of the disease at 2.5g/l and 3.5g/l of fungicide (Table 4). Disease incidence results indicate a significant difference on days after planting between the two sites. Combining fertilizer and fungicides application rates, both had effects on severity though it was not significant. Application of fertilizer at 135kg/ha lead to slightly high infection rates as compared to other rates of fertilizer application. The disease was more severe at 61DAP for fertilizer and fungicide applied. Application of fertilizer at 0kg/ha and fungicide at 3.5g/l produced significant effects at 47 DA P and 61 DAP. The results on disease incidence showed significant ($P \leq 0.05$) differences at the three growth stages (Table 4). The incidence increased as fertilizer rates increased and decreased as the level of fungicide rates as shown in (Table 4). Late blight severity and incidence results from (Table 3 and Table 4) showed that the disease can occur at any time during the growing season which was in agreement to [2].

Table 3. Interaction effects of fertilizer and fungicide application rates on (*P. infestans*) severity on potatoes under field conditions at Egerton University and Molo July – October 2014

(DSI) Disease severity index (%)							
		Egerton			Molo		
	Fertilizer (kg/ha)	0	90	135	0	90	135
	Fungicide (g/l)						
	0	11.85^{a}	12.44^{a}	12.38^{a}	15.87^{a}	16.42^{a}	16.01^{a}
47 DAP	2.5	11.01^{a}	10.96^{a}	11.55^{a}	14.31^{a}	12.9^{a}	13.96^{a}
	3.5	7.26^{b}	11.78^{a}	12.10^{a}	11.89^{b}	14.65^{a}	15.79^{a}
	0	17.60^{a}	19.36^{a}	18.23^{a}	25.63^{a}	26.43^{a}	25.61^{a}
54 DAP	2.5	16.82^{a}	17.04^{a}	18.57^{a}	24.51^{a}	22.83^{a}	23.99^{a}
	3.5	14.08^{a}	18.23^{a}	19^{a}	21.89^{b}	24.94^{a}	25.78^{a}
	0	26.5^{a}	26.41^{a}	26.94^{a}	37.75^{a}	36.42^{a}	35.6^{a}
61 DAP	2.5	23.74^{a}	24.93^{a}	26.53^{a}	33.03^{a}	31.35^{a}	33.58^{a}
	3.5	15.74^{b}	24.92^{a}	26.25^{a}	30.08^{b}	35.14^{a}	33.98^{a}

Means followed by the same letter in each column are not significantly different at ($P \leq 0.05$). DAP= Days after planting.

Table 4. Interaction effects of fertilizer and fungicide application rates on (*P. infestans)* incidence on potatoes under field conditions at Egerton University and Molo July – October 2014

Percentage (%) disease incidence (PDI)							
		Egerton			Molo		
	Fertilizer (Kg/ha)	0	90	135	0	90	135
Days After Planting	Fungicide (g/l)						
	0	54.17^{a}	50.0^{a}	50.0^{a}	75^{a}	69.02^{a}	58.33^{ab}
47 DAP	2.5	37.30^{ab}	54.17^{a}	52.08^{a}	66.67^{ab}	60.66^{a}	52.08^{b}
	3.5	20.83^{b}	41.67^{b}	47.92^{a}	33.33^{ab}	50^{a}	69.02^{a}
	0	43.75^{a}	58.33^{a}	47.92^{a}	58.33^{a}	66.67^{ab}	75.5^{ab}
54 DAP	2.5	52.08^{a}	47.92^{a}	50.0^{a}	52.02^{ab}	50^{b}	66^{ab}
	3.5	41.67^{a}	50.0^{a}	50.0^{a}	50^{a}	41.67^{ab}	51^{a}
	0	64.58^{a}	56.25^{ab}	58.33^{ab}	68.33^{a}	66.67^{a}	58.33^{ab}
61 DAP	2.5	31.25^{b}	47.92^{ab}	56.25^{ab}	50^{ab}	66.7^{a}	75^{a}
	3.5	33.33^{ab}	45.83^{ab}	47.92^{ab}	50a	41.57^{ab}	58.33^{a}

Means followed by the same letter in each column are not significantly different at ($P \leq 0.05$). DAP= Days after planting.

Table 5. Effect of different potato growth stages on severity of late blight under field condition at Molo and Egerton University

(DSI) Disease severity index (%)					
		Egerton		Molo	
	Variety	Kenya sherekea	Dutch robjin	Kenya sherekea	Dutch robjin
	Fungicide(g/l)				
47 DAP (Growth stage 1)	0	9.51^{c}	14.93^{a}	10.01^{c}	13.93^{a}
	2.5	9.55^{c}	12.80^{b}	11.51^{c}	14.8^{b}
	3.5	7.5^{d}	13.23^{ab}	9.0^{d}	13.47^{ab}
54 DAP (Growth stage 2)	0	17.22^{a}	19.57^{a}	19.21^{a}	20.22^{a}
	2.5	15.07^{a}	19.89^{a}	16.07^{a}	19.21^{a}
	3.5	16.79^{a}	17.43^{a}	15.07^{a}	18.4^{a}
61 DAP (Growth stage 3)	0	19.27^{b}	33.98^{a}	20.27^{a}	32.54^{a}
	2.5	18.99^{bc}	31.14^{a}	20.9^{b}	32.02^{a}
	35	13.92^{c}	30.75^{a}	15.05^{c}	33.75^{a}

Means followed by the same letter in each column are not significantly different at ($P\leq0.05$). DAP= Days after planting.

Table 6. Interaction effects of variety and fungicide application on late blight incidence on Potatoes at different growth stages at Egerton University and Molo

Percentage (%) disease incidence (PDI)					
		Egerton		Molo	
	Varieties	Kenya sherekea	Dutch robjin	Kenya sherekea	Dutch robjin
	Fungicide (g/l)				
47 DAP (Growth stage 1)	0	31.94^{b}	70.83^{a}	50.01^{b}	80.93^{a}
	2.5	23.61^{b}	72.22^{a}	30.94^{a}	75.21^{b}
	3.5	16.67^{b}	56.94^{a}	17.08^{c}	58.97^{b}
54 DAP (Growth stage 2)	0	55.56^{a}	44.44^{a}	55.5^{a}	60.21^{b}
	2.5	48.61^{a}	51.39^{a}	49.09^{a}	50.22^{a}
	3.5	51.39^{a}	43.06^{a}	49.01^{a}	53.52^{a}
61 DAP (Growth stage 3)	0	54.17^{ab}	65.28^{a}	51.01^{b}	42.17^{a}
	2.5	26.39^{c}	63.89^{a}	48^{b}	52.97^{a}
	3.5	31.94^{b}	52.78^{ab}	29.94^{b}	58.78^{a}

Means followed by the same letter in each column are not significantly different at ($P\leq0.05$). DAP= Days after planting.

3.3. Interaction Effects of Variety and Fungicide Application on (*P. infestans*) Severity on Potatoes at Different Growth Stages

Resistance of potato varieties together with use of fungicides can slow down the development of late blight. A variety with field resistance to late blight in tubers and a medium to high resistance to foliage blight can help in reducing the use of fungicides (Table 5 and Table 6). This is a clear indication that use of host density as a tool f o r management of late blight can been used for control late blight. Growth and development of host plants influence development of late blight. Young plants are slightly susceptible to blight while plants of intermediate age are more resistant than the young or old plants depending on the levels of fungicide used (Table 5 and Table 6).

Analysis of variance showed significant ($P\leq0.05$) differences among the varieties and fungicide rates treatments (Table 5 and Table 6). In general the results of combined analysis showed that the interaction of varieties and fungicides was significant ($P\leq0.05$) for disease severity at 47 and 61 DAP (Table 5 and Table 6). Further analysis showed significant ($P\leq0.05$) differences between Kenya sherekea and Dutch robjin varieties for late blight severity and incidence. Dutch robjin variety recorded the highest disease incidence (72.22%) and (80.93%) in control experiments (no sprays) at both sites compared to Kenya sherekea variety (55.56%) (Table 5 and Table 6). Application of fungicides was effective in reducing development and progress of late blight disease on resistant variety Kenya sherekea compared to susceptible variety Dutch robjin. The results of the study therefore indicate that fungicide use alone or host resistance alone cannot control potato late blight fully which requires use of integrated approaches. This is therefore in agreement with the research conducted in sub-tropical environments which documented that optimum management of late blight requires an integrated approach [10].

The results indicate that fertilizer application had significant effects on the severity of late blight for the two sites and cultivars (Table 7). The recorded increase in severity from 41DAP to 61 DAP was observed at both sites and for the two cultivars. The Kenya sherekea variety recorded lower severity indexes than Dutch robjin at the two sites (Table 7).

Data on disease incidence revealed that there was significant ($P\leq0.05$) differences among the treatments at different stages of growth apart from 54 DAP (Table 8). Evaluation of the cultivars on their response to inorganic fertilizer amendment showed that there was general increase in late blight severity with increase in fertilizer rate. The increase in late blight severity was higher for Dutch robjin than Kenya sherekea (Table 7). Varieties exhibited different levels severity and incidence with Dutch robjin recording highest percentages compared to Kenya sherekea (Table 7 and Table 8). Results indicated that fertilizing potatoes increased its susceptibility to late blight. Just like disease severity, increased fertilization lead to increased disease incidence. Increasing fungicide rates reduced disease incidence when interacted with resistant cultivars (Kenya sherekea) as compared to susceptible cultivars (Dutch robjin) unlike increasing fertilizer rates that increased disease incidences. Lack of consistency in disease levels that was recorded across the sites could be attributed to environmental variations among the sites. In some cases the occurrence of the disease before initiation of spray program resulted to inadequate disease control confounding effects on treatment. This could require adjustment of fungicide application rates to improve general resistance of susceptible varieties. When the cultivars were evaluated for their response to inorganic fertilizer amendments, there was a general increase in late blight disease severity and incidence with increase in fertilizer rates among the varieties .This could be due to the effects of mineral fertilizer which encouraged rapid growth and development of new tissues that leads to favourable microenvironment for disease development [30]. Increase in late blight severity and incidence was higher for in Dutch robjin variety as compared to Kenya sherekea variety (Table 7 and Table 8). Results further indicated that fertilizing potato increased its susceptibility to late blight, which also required adjustment of rates of fungicide application. Therefore the findings did not agree to earlier findings of [17], that plants with optimum nutrition have the maximum disease resistance. Therefore small scale farmers should exercise caution in fertilizer application rates based on the host resistance to late blight. Dutch robjin proved to be more susceptible to late blight hence required higher rates of fungicide sprays depending on disease pressure than Kenya sherekea (Table 7 and Table 8). This research demonstrated consistency to other findings that susceptible varieties require more fungicides than resistant varieties [21]. Unsprayed plots resulted to high disease development and progress rate than the sprayed plots which could result in losses (Table 7 and Table 8). These results confirmed the findings of [23] that fungicides must be used in control of late blight and [12] that fungicides application is an integral part of potato late blight management.

Table 7. Interaction effects of variety and fertilizer application rates on (*P. infestans*) severity on Potatoes at different growth stages

	(DSI) Disease severity index (%)				
		Egerton		Molo	
	Varieties	Kenya sherekea	Dutch robjin	Kenya sherekea	Dutch robjin
	Fertilizer (Kg/ha)				
41 DAP (Growth stage 1)	**0**	6.99^{c}	13.09^{a}	12.99^{b}	17.01^{a}
	90	9.69^{b}	13.77^{a}	14.09^{b}	17.28^{a}
	135	9.91^{b}	14.11^{a}	15.27^{c}	30.06^{b}
54 DAP (Growth stage 2)	**0**	15.16^{a}	17.16^{a}	17.16^{b}	30.11^{a}
	90	16.91^{a}	19.91^{a}	19.01^{b}	23.09^{a}
	135	17.39^{a}	19.80^{a}	20.12^{b}	38.11^{a}
61 DAP (Growth stage 3)	**0**	13.23^{c}	30.84^{a}	21.23^{b}	28.2^{a}
	90	18.92^{b}	31.92^{a}	24.07^{b}	29.41^{a}
	135	20.03^{b}	33.12^{a}	24.29^{b}	30.97^{a}

Means followed by the same letter in each column are not significantly different at ($P \leq 0.05$). DAP= Days after planting.

Table 8. Interaction effects of variety and fertilizer application on (*P. infestans*) incidence on Potatoes at different growth stages

	Percentage (%) disease incidence (PDI)				
		Egerton		Molo	
	Varieties	Kenya sherekea	Dutch robjin	Kenya sherekea	Dutch robjin
	Fertilizer (Kg/ha)				
47 DAP (Growth stage 1)	**0**	16.67^{b}	58.33^{a}	27.09^{b}	68.27^{a}
	90	25.0^{b}	72.22^{a}	28^{b}	70.11^{a}
	135	30.56^{b}	69.44^{a}	38.76^{b}	75^{a}
54 DAP (Growth stage 2)	**0**	40.08^{a}	47.22^{a}	40.02^{b}	69.09^{a}
	90	44.44^{a}	63.87^{a}	42^{b}	70^{a}
	135	47.22^{a}	51.37^{a}	50.22^{b}	79.09^{a}
61 DAP (Growth stage 3)	**0**	30.56^{c}	55.56^{ab}	40.05^{c}	72^{ab}
	90	43.06^{bc}	69.44^{ab}	42.09^{bc}	75^{ab}
	135	38.89^{bc}	56.94^{a}	45.1^{bc}	89^{a}

Means followed by the same letter in each column are not significantly different at ($P \leq 0.05$). DAP= Days after planting.

Table 9. Effects of fertilizer and fungicide interactions on the potato yield at Egeton University and Molo July- October 2014.

Yield Kg/Ha at 120 DAP			
	Fungicide g/l		
Fertilizer(Kg/Ha) /	0	2.5	3.5
Egerton			
0	10.0^{de}	16.8^{b}	19.3^{b}
90	9.1^{e}	13.1^{cd}	19.7^{ab}
135	10.0^{e}	20.5^{bc}	23.3^{a}
Molo			
0	11.2^{de}	17.8^{b}	18.3^{b}
90	19.1^{e}	23.4^{cd}	25.7^{ab}
135	19.0^{de}	29.2^{bc}	30.0^{a}

Means followed by the same letter in each column are not significantly different at ($P \leq 0.05$)
DAP= Days after planting.

Higher benefits of tolerant cultivar Kenya sherekea sprayed only thrice on different rates of fungicide demonstrated the importance of cultivar host resistance on amount of fungicide concentrations to use in management of late blight. Whereas susceptible cultivar like Dutch robjin results in using increased rates and frequency of spray of fungicides which results to high production costs. Resistant cultivars therefore provide an opportunity for reduced amounts of fungicide to control potato late blight which in agreement with the findings of [4]. Low levels of disease in Kenya sherekea (16.67 and 6.99) could be due to relatively high levels of horizontal resistance compared to Dutch robjin (Table 7 and Table 8). This could be a very important aspect in integrated disease management in potatoes by farmers in an attempt to minimize fungicide usage in production. Documented research results in low input farming systems of the tropical highlands of Africa have shown that high frequency of fungicide use and associated costs have resulted in enormous economic losses to small scale farmers [22]. Integration of host resistance in late blight management system could help small scale farmers reduce high rates of fungicide application hence significant economic benefits for resource constrained farmers in Kenya.

Final tuber yield as tons per hectare as shown in (Table 9) differed significantly ($P \leq 0.05$) between fertilizer and fungicides-treated and untreated (control). It ranged between 9.1 and 23.3 tons at Egerton University compared to 11.2 to 30.0 tons at Molo. The highest yield was awarded to the treatment of fungicide and fertilizer rates of 3.5g/l and 135Kg/ha respectively at both experimental sites. Although mineral fertilizer consistently proved to have a significant role on yield, it subjected the potatoes to late blight due to effect on succulence of the whole plant. Results on yield indicate that fertilizers increased yields as the rates of application increased between 0 and 135 Kg/ha (Table 9). This was dependent on better nutrient balance and varietal response to fertilizers hence in agreement with what [28] reported on organic manures and inorganic fertilizers in potato production. Yield gains per unit of fertilizer added were high provided that fungicides rates were also increased. This can be explained by the fact that on fungicide application, tuber sizes were improved, therefore reducing the proportion of non-marketable yield. The two fungicides application rates (2.5 and 3.5g/l) gave the best control of the late blight disease. It was clear that increase in yield was correlated with decreasing in foliar late blight severity which was in agreement with findings of [19]. Potato tuber yield was higher in the resistant variety than the susceptible variety. Although fertilizers seemed to increase infection from late blight, it greatly increased yields which would probably compensate for the cost application of both fertilizers and fungicides. This study shows that fungicides and fertilizers have potential for increased growth and development which depends on host resistance and application rates. This study suggests that in order to realize good returns and management of late blight variety of potato becomes a key factor.

4. Conclusion and Recommendations

The response of Dutch robjin variety to fertilizer and fungicide application rates in the management of late blight under field conditions revealed that it was more susceptible to late blight than Kenya sherekea variety. However the Kenya sherekea demonstrated less susceptibility to late blight compared to Dutch robjin at high fertilizer application rates. This could be considered as a result of adjusting or application of slightly high rates of fungicides to reduce infection rates. The two varieties were susceptible to late blight in favourable environments but the degree of susceptibility differed with the level of resistance, site and fertilizer rate. Protective and systemic fungicides should be adopted by farmers due to their significant deterrent effects on the development of late blight in some potato production areas. Fungicide application also requires adjustment to neutralize the effect of fertilizer input on disease development in favourable environments and for susceptible varieties like Dutch robjin.

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Competing Interests

The author has declared that no any conflicting interests exist.

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