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# Responding to Late Blight Disease Pressure and Fungicide Resistance Using Multiple Fungicide Active Ingredients and Different Spraying Regimes in Uganda

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**Abstract:** Late blight (*Phytophthora infestans*) is one of the major diseases of economic importance limiting potato production in Uganda and causing yield losses of 40-60%. The emergence of more aggressive late blight pathotypes that are more difficult to control with ability to overcome host resistance or resist fungicide active ingredients has been noted in Uganda. Therefore, this study was carried out to identify suitable fungicides and spray regime for the effective management of late blight pathotypes on susceptible potato varieties in Uganda. Different fungicides that known to control late blight include Consento (Fenamidone 6.7% w/w + Propamocarb hydrochloride 93.6% w/w), Infinito (Propamocarb (55.3% w/w + Fluopicolide (5.53% w/w), Mancozeb (Dithiocarbamate 800g/kg), Agrolaxyl (Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP) were acquired from Bayer Crop Sciences and agro-inputs dealers in Uganda and tested for effective management of late blight on susceptible potato varieties in four different sites for two seasons (2015B and 2016A) using randomized complete block design (RCBD). Three (3) spraying regimes were tested and included; Bayer Crop Sciences recommended spray regime, current Uganda's recommended spray regime, Hybrid (blend of Uganda's recommended spray regime and Bayer recommendation) and no spray as control. Data on late blight disease severity was measured as percentage plant area affected (PLAA) and this was converted in to area under disease progress curve (AUDPC). The results showed that area under disease progress curve (AUDPC) ranged from 357-763 for the 3 different spray regimes while for the control (No spray), it ranged from 1895-2231. The late blight disease severity varied across sites and seasons, with Kalegyere site recording highest disease pressure in season 1 while Buginyanya had highest disease severity in season 2. Lowest disease pressure was registered with Bayer Crop Sciences based spray regime in season 1, while in season 2, hybrid spray regime registered lowest disease pressure. Use of multiple fungicide ingredients (Mancozeb (Dithiocarbamate 800g/kg), Consento (Fenamidone 6.7% w/w + Propamocarb hydrochloride 93.6% w/w); Infinito (Propamocarb (55.3% w/w + Fluopicolide (5.53% w/w) and Agrolaxyl (Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP) at different intervals has demonstrated the potential to suppress the disease to levels not causing serious economic damages by not allowing significant disease development on the leaves, hence has been recommended to be used for the management of late blight in Uganda.

**Keywords:** Late Blight, Spray Regimes, Disease Pressure, Fungicide, Disease Management

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## 1. Introduction

Late blight (*Phytophthora infestans* (Mont.) de Bary) is one of the major diseases of economic importance to potato production in Uganda and elsewhere in Sub-Saharan Africa [6]. World-wide losses due to late blight exceed several billion dollars annually [7]. In Uganda, the disease causes 40-60% [2]. This loss in production translates at average cost of 700 UGX per kg of potato to over 129 million dollars. The disease attacks leaves, stems and tubers and studies have shown that potato tubers stop growing when 75% of the plant canopy has been destroyed by blight [13]. There is an increasing pressure of Late blight disease on potatoes and this, is coupled with emergence of more aggressive late blight pathotypes that are more difficult to control with ability to overcome host resistance or resist fungicide active ingredients. The dominant late blight strain in Uganda in the past has been A1 mating type clonal lineage US-1 which has been displaced by a more virulent strain KE-1 [12]. This late blight pathogen population is noted to have high ability to change and evolve as evidenced by change in behavior of the newer populations of *P. infestans* which seem to vary geographically [5].

Most farmers in Uganda manage the late blight disease by spraying using fungicides [9, 11]. A number of potato varieties are very susceptible to late blight pathotypes and their production largely depends on fungicide application. Therefore this study was conducted to evaluate the different fungicide active ingredients and spray regimes that could be used to effectively manage the increasing late blight disease pressure on susceptible potato varieties in Uganda.

## 2. Materials and Methods

### 2.1. Effectiveness of Different Fungicides and Spray Regimes on Management of Late Blight Disease

Four late blight susceptible varieties were used in the study and these comprised of 3 Dutch potato varieties ('El-Mundo', 'Markies' and 'Sagitta') and local late blight susceptible check 'Victoria'. The varieties were planted in a randomized complete block design (RCBD) with two replicates at Kalegyere

(2450m/asl), Kachwekano (2225m/asl), Rwebitaba (1531m/asl) and Buginyanya (1887m/asl) at a spacing of 75X30cm with each plot separated by 1m distance. The experimental design was arranged in split-split-plots replicated 2 times. The main plots were fungicide spray regime; sub-plots were cultivars. The trials were established at these four sites because of high disease pressure of late blight in these areas in 2015B and 2016A seasons. The experimental treatment comprised of different potato varieties and fungicides that were applied based on 3 spray regimes (Bayer Crop Sciences recommended spray regime, current Uganda's recommended spray regime, Hybrid (blend of Uganda's recommended spray regime and Bayer recommendation) and no spray as control. (Table 1). The experimental trial was infected naturally under field conditions. The plants were monitored on weekly basis for late blight development and disease severity data was recorded as percentage leaf area affected due to the late blight disease following fungicide application [4].

### 2.2. Data Collection

Data on late blight disease severity was scored weekly starting at 30 days after planting using a scale developed by Landeo and Forbes [10] modified from Henfling [8]. Data was collected starting from when traces of Late blight were observed and continuing until physiological maturity. Disease severity data measured as percentage plant leaf area affected (PLAA) was then used to compute Area under disease progress curve (AUDPC) using procedure of Campbell and Madane [3]. Upon harvesting, yield data was also collected under different spray regimes and tubers were categorized into 3 groups; 1= small tubers (<30mm), 2= medium (45-60mm) and 3= large (>60mm).

*Statistical methods.* Analysis of variance was performed on the AUDPC values of potato varieties for the study; the percent foliar late blight infection values for each field study evaluations using Genstat computer package 11 edition. Mean comparisons were conducted using Fisher's Least Significant Difference (LSD $\approx$ 0.05). The sources of variability used in the statistical model were treatment (variety), Spray regime, the blocks (replicates) and the experimental error.

**Table 1.** Different fungicides and their spraying regimes for the management of late blight disease on potatoes in Uganda.

	1 <sup>ST</sup> WEEK	2 <sup>ND</sup> WEEK	3 <sup>RD</sup> WEEK	4 <sup>TH</sup> WEEK	5 <sup>TH</sup> WEEK
Bayer Crop Sciences recommended spray regime,	30ml Consentio (Fenamidone 6.7% w/w + Propamacarb hydrochloride 93.6% w/w) /15 litres of water		30ml Consentio (Fenamidone 6.7% w/w + Propamacarb hydrochloride 93.6% w/w) /15 litres of water		30ml Consentio (Fenamidone 6.7% w/w + Propamacarb hydrochloride 93.6% w/w) /15 litres of water
Current Uganda's recommended spray regime,	50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water	50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water	50g of Agrolaxyl (Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP)/15 litres of water		50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water
Hybrid (blend of Uganda's recommended spray regime and Bayer recommendation)	50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water	50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water	30ml Consentio (Fenamidone 6.7% w/w + Propamacarb hydrochloride 93.6% w/w) /15 litres of water		50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water
Control (No spray)	No spray	No spray	No spray	No spray	No spray

Table 1. Continued.

	6 <sup>TH</sup> WEEK	7 <sup>TH</sup> WEEK	8 <sup>TH</sup> WEEK	9 <sup>TH</sup> WEEK	10 <sup>TH</sup> WEEK	11 <sup>TH</sup> WEEK
Bayer Crop Sciences recommended spray regime,		27ml of Infinito (Propamacarb (55.3% w/w + Fluopicollide (5.53% w/w) /15 mls of water		27ml of Infinito (Propamacarb (55.3% w/w + Fluopicollide (5.53% w/w) /15 mls of water		27ml of Infinito (Propamacarb (55.3% w/w + Fluopicollide (5.53% w/w) /15 mls of water
Current Uganda's recommended spray regime,	50g of Agrolaxzyl (Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP)/15 litres of water	50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water)		50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water)		
Hybrid (blend of Uganda's recommended spray regime and Bayer recommendation)	27ml of Infinito (Propamacarb (55.3% w/w + Fluopicollide (5.53% w/w) /15 mls of water	50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water)	50g of Agrolaxzyl (Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP)/15 litres of water			
Control (No spray)	No spray	No spray	No spray	No spray	No spray	No spray

### 3. Results

#### *Effectiveness of Different Fungicide Active Ingredient and Spray Regimes on Management of Late Blight Disease Pressure on Susceptible Potato Varieties*

Following application of different fungicides, the results of the study indicated a significant difference ( $P < 0.005$ ) in severity of potato varieties in response to late blight infection. The study showed that amount of late blight disease on each of the varieties varied from 357-763 under different spray regime while where no fungicide was applied, the amount of disease was high (1895-2231) (Table 2). Variety El-mundo and Sagitta had higher disease severities compared to Markies and Victoria under different spray regimes. The proportion of the amount of disease in the field in comparison with control check was lower for Bayer crop sciences recommended fungicide spray regime (22.6%), followed by Hybrid spray regime (25.2%), current Uganda's recommended fungicide spray regime (35.1%). Disease severity was higher in season 2 than in season 1 (Figure 1 and Figure 2). This was mainly attributed to high disease pressure during the season 2 and stable rainfall and moderately lower temperatures during growing season that favored higher disease development. Season 1 was mainly characterized by higher temperatures and low rains which did not favor the build up the disease during the evaluation period (Weather data not shown). The highest plant area affected was noted to be 67% severity for no spray in season 1 while in season 2 was 85%. Bayer crop sciences

recommended fungicide spray regime was more effective in season 1 while hybrid regime was more effective in season 2. In terms of late blight disease control options, there was no significant difference between Bayer crop sciences recommended fungicide spray and hybrid. regime, however these two were significantly different from current Uganda's recommended spray regime neither of the spray regime was able to suppress the disease completely but were able to reduce the effects of disease on the foliage to levels that do not significantly affect yield. The average yield for the 3 spray regime ranged from 18.4-18.9 T/ha which was 65% higher than the control (No spray) (Table 3). Variety Markies and El-mundo performed relatively better than Victoria and Sagitta under the 3 spray regime with average marketable yield of 19-21 T/ha. The use of different fungicide active ingredient under hybrid spray regime is hence recommended for management of late blight as this would reduce on development of resistance to fungicide. This is in agreement with Brent and Hollomon [1] assertion that resistance to fungicides can be effectively managed using different active ingredients to minimize sudden and marked loss of effectiveness. Use of multiple fungicide ingredients (Hybrid spray regime) at different intervals has demonstrated the potential to suppress the disease to levels not causing serious economic damages by not allowing significant disease development on the leaves. This strategy would also minimize the chances of disease carryover to the tubers hence ensuring higher quality of tubers as well as minimizing development of resistance to fungicides

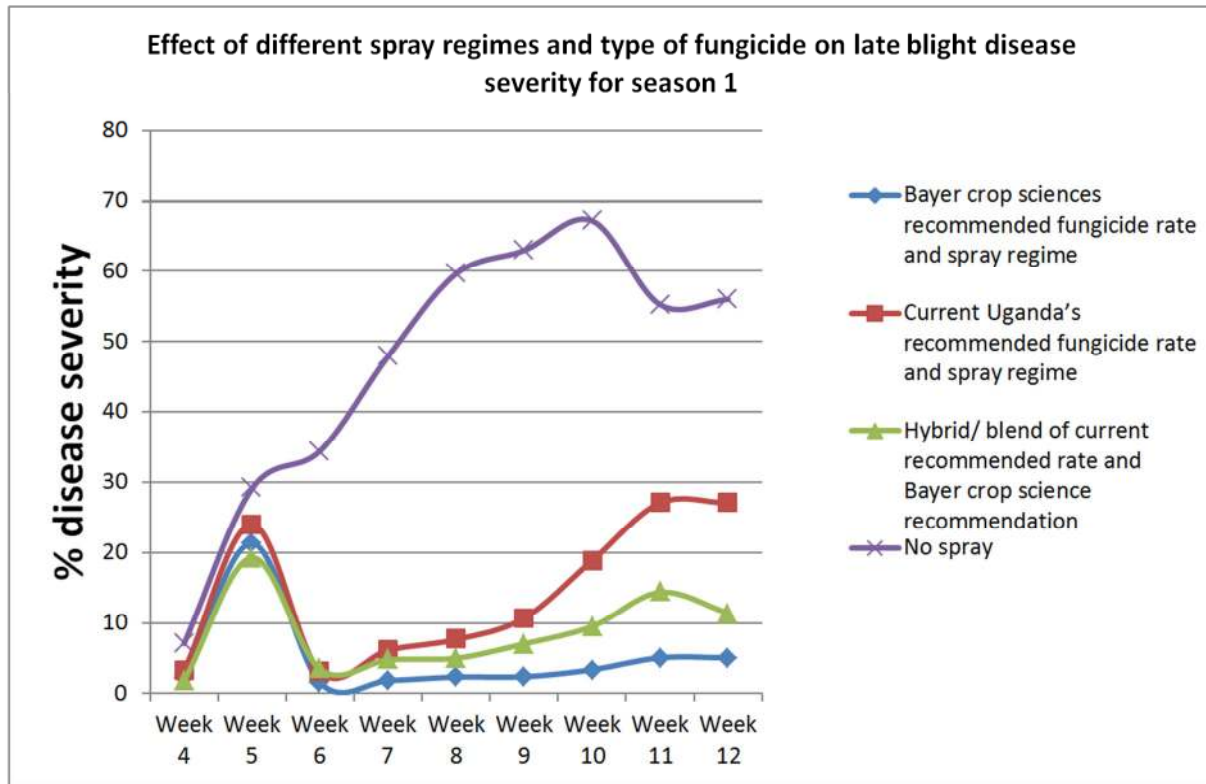


Figure 1. Effect of different spray regimes and type of fungicide on late blight disease severity for season 1.

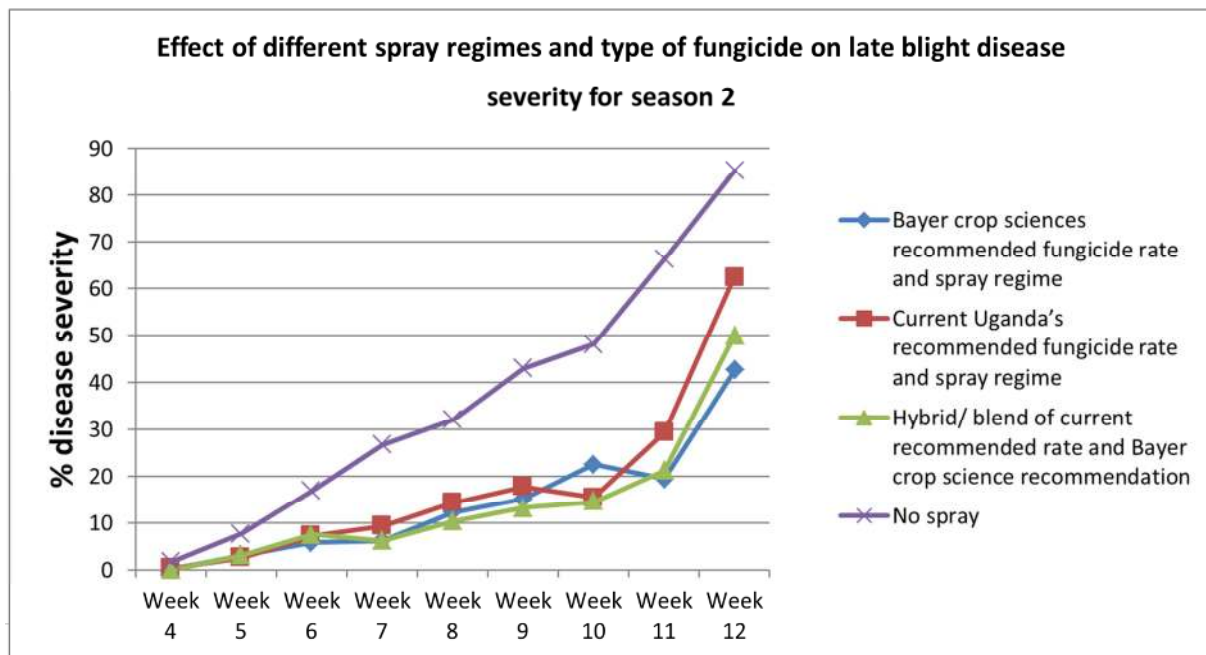


Figure 2. Effect of different spray regimes and type of fungicide on late blight disease severity for season 2.

Table 2. Effect of different spray regimes on a mount of late blight disease (Area under disease progress Curve (AUDPC) on four potato varieties.

Spray regime	Variety	Season 1			Season 1 mean
		Buginyanya	Kachwekano	Kalegyere	
Bayer Crop Sciences recommended spray regime,	Markies	337.9	214.5	504.0	352.1
	Victoria	213.5	177.1	491.4	294.0
	Sagitta	638.4	338.1	499.8	492.1
	El Mundo	212.1	195.0	504.0	303.7
Current Uganda's		287.7	147.7	520.8	318.7
		366.9	363.8	1697.3	849.7

Spray regime	Variety	Season 1			Season 1 mean
		Buginyanya	Kachwekano	Kalegyere	
recommended spray regime	Markies	431.9	102.2	1144.5	705.8
	Sagitta	138.6	395.5	1810.9	781.7
	Victoria	468.3	673.8	2047.5	1063.2
	El Mundo	461.3	153.0	1786.4	800.2
Hybrid (blend of Uganda's recommended spray regime and Bayer recommendation)	Markies	171.0	247.4	1250.4	529.6
	El Mundo	203.2	102.2	567.0	256.3
	Victoria	105.0	112.7	1134.0	450.6
	Sagitta	317.8	633.5	1598.1	849.8
		42.0	213.9	1702.4	652.8
Control (No spray)		457.6	3605.9	4473.2	2845.6
	Victoria	357.7	3577.0	4400.2	2778.3
	Markies	600.6	3214.8	4305.0	2706.8
	El Mundo	296.1	3927.0	4580.8	2934.6
	Sagitta	576.1	3704.8	4606.7	2962.5
F.pr					
LSD					

Spray regime	Variety	season 2				Season 2 mean
		Buginyanya	Kachwekano	Kalegyere	Rwebitaba	
Bayer Crop Sciences recommended spray regime,		1264.7	126.7	265.7	505.8	540.7
	Markies	959.7	99.4	186.2	374.5	405.0
	Victoria	653.1	67.2	186.2	318.5	306.3
	Sagitta	1720.3	223.3	186.2	766.5	724.1
	El Mundo	1725.9	116.9	504.0	563.5	727.6
Current Uganda's recommended spray regime,		737.1	247.1	693.7	801.5	619.9
	Markies	1006.6	216.3	186.2	822.5	557.9
	Sagitta	690.2	342.3	819.0	896.0	686.9
	Victoria	628.6	232.4	345.1	791.0	499.3
	El Mundo	623.0	197.4	1424.5	696.5	735.4
Hybrid (blend of Uganda's recommended spray regime and Bayer recommendation)		902.5	147.9	384.8	557.4	498.1
	Markies	838.6	92.4	186.2	556.5	418.4
	El Mundo	947.1	141.4	504.0	581.0	543.4
	Victoria	474.6	134.4	345.1	595.0	387.3
	Sagitta	1349.6	223.3	504.0	497.0	643.5
Control (No spray)		2874.7	838.8	672.7	1316.5	1425.7
	Victoria	2333.5	756.7	460.6	1382.5	1233.3
	Markies	2721.3	971.6	291.2	1164.1	1287.0
	El Mundo	2915.9	579.6	1260.0	1239.0	1498.6
	Sagitta	3528.4	1047.2	679.0	1480.5	1683.8
F.pr						
LSD						

Spray regime	Variety	Grand Mean	Proportion of the disease in the field against no spray (%)
Bayer Crop Sciences recommended spray regime,	Markies	459.9	22.6
	Victoria	357.4	
	Sagitta	385.9	
	El Mundo	543.9	
Current Uganda's recommended spray regime,		552.4	35.1
	Markies	713.5	
	Sagitta	607.2	
	Victoria	727.5	
	El Mundo	741.0	
Hybrid (blend of Uganda's recommended spray regime and Bayer recommendation)		763.2	25.2
	Markies	512.2	
	El Mundo	337.4	
	Victoria	503.6	
	Sagitta	585.5	
Control (No spray)		647.5	
	Victoria	2034.2	
	Markies	1895.5	
	El Mundo	1895.5	
	Sagitta	2114.1	
		2231.8	
F.pr		< 0.001	
LSD		341.3	

Table 3. Yield of the different potato varieties as influenced by different fungicide active ingredient and spray regimes.

Variety		Season 1							
		Buginyanya		Kachwekano		Kalegyere		Rwebitaba	
		Overall Yield T/Ha	Marketable Yield T/Ha	Overall Yield T/ Ha	Marketable Yield T/Ha	Overall Yield T/ Ha	Marketable Yield T/Ha	Overall Yield T/ Ha	Marketable Yield T/Ha
Bayer crop sciences recommended fungicide rate and spray regime	El mundo	22.4	18.4	47.2	42.2	33.5	28.9	17.9	15.0
	Markies	26.3	22.3	54.2	50.9	32.0	29.3	19.6	18.0
	sagitta	24.0	20.4	48.2	45.3	31.6	29.3	15.9	14.4
	Victoria	19.8	16.2	44.9	42.7	33.3	30.2	23.2	22.2
Current Uganda's recommended fungicide rate and spray regime	El mundo	19.6	14.7	41.3	30.0	37.1	26.9	12.9	5.4
	Markies	26.5	23.7	41.2	35.3	24.0	21.2	13.5	12.2
	sagitta	25.8	23.3	41.1	34.7	22.4	20.4	12.9	12.5
	Victoria	27.1	24.0	38.9	34.9	23.0	21.8	13.0	12.0
Hybrid/ blend of current recommended rate and Bayer crop science recommendation	El mundo	29.1	27.1	42.9	40.4	24.2	22.6	15.8	14.6
	Markies	24.0	20.4	41.8	31.1	26.4	19.8	12.3	9.8
	sagitta	25.4	20.9	45.5	40.0	25.4	20.3	12.9	11.0
	Victoria	29.3	27.3	47.8	44.7	24.0	19.1	12.1	11.1
No spray (Control)	El mundo	23.1	20.0	44.7	42.0	28.7	21.3	14.3	13.2
	Markies	22.2	19.3	46.4	43.3	20.9	17.8	13.9	12.5
	sagitta	27.1	16.9	43.1	30.0	28.0	23.1	11.5	6.9
	Victoria	23.3	19.6	9.7	6.5	0.7	0.2	4.0	3.7
	El mundo	23.8	20.4	7.3	4.7	0.0	0.0	8.9	8.2
	Markies	19.8	18.2	12.2	9.3	2.2	0.7	7.2	6.6
	sagitta	23.1	20.7	10.9	8.2	0.5	0.1	0.0	0.0
	Victoria	26.4	18.9	8.2	3.8	0.1	0.0	0.0	0.0

Variety		Season 2							
		Buginyanya		Kachwekano		Kalegyere		Rwebitaba	
		Overall Yield T/ Ha	Marketable Yield T/Ha	Overall Yield T/ Ha	Marketable Yield T/Ha	Overall Yield T/ Ha	Marketable Yield T/Ha	Overall Yield T/ Ha	Marketable Yield T/Ha
Bayer crop sciences recommended fungicide rate and spray regime	El mundo	10.2	8.0	13.3	11.7	6.0	5.5	23.9	21.3
	Markies	9.2	6.8	13.5	12.1	2.8	2.2	24.4	20.9
	sagitta	12.1	9.3	14.8	12.8	10.3	10.0	28.1	26.4
	Victoria	10.1	8.0	13.0	11.6	5.8	5.5	26.0	24.4
Current Uganda's recommended fungicide rate and spray regime	El mundo	9.6	7.9	12.0	10.1	5.2	4.2	17.1	13.5
	Markies	16.4	14.6	16.9	14.8	2.9	2.6	27.2	23.0
	sagitta	17.1	15.1	19.9	16.9	0.9	0.5	26.4	24.0
	Victoria	14.9	12.7	19.6	17.9	7.3	6.9	24.4	19.7
Hybrid/ blend of current recommended rate and Bayer crop science recommendation	El mundo	17.6	16.0	13.6	12.4	1.6	1.4	38.4	34.4
	Markies	16.1	14.7	14.4	11.9	1.6	1.5	19.6	13.8
	sagitta	18.7	14.6	15.8	14.1	4.9	4.5	30.4	22.8
	Victoria	17.7	13.9	18.6	16.8	2.2	1.7	27.9	23.7
No spray (Control)	El mundo	17.5	13.8	16.7	14.7	9.3	8.8	29.8	27.6
	Markies	28.5	21.1	16.3	14.7	4.0	3.7	46.5	27.0
	sagitta	10.9	9.7	11.9	10.2	4.0	3.6	17.5	12.8
	Victoria	6.5	5.6	6.7	4.9	1.4	1.2	10.0	8.6
	El mundo	6.8	5.6	8.8	7.4	3.0	2.7	12.2	11.1
	Markies	2.3	2.0	3.7	2.4	0.4	0.3	9.6	6.5
	sagitta	6.4	5.7	8.3	6.3	1.4	1.2	12.3	11.8
	Victoria	10.4	9.0	6.2	3.7	0.9	0.6	5.8	4.9

Variety		Grand mean Yield T/ Ha	Grand mean Marketable Yield T/Ha
Bayer crop sciences recommended fungicide rate and spray regime	El mundo	21.8	18.9
	Markies	22.7	20.3
	sagitta	23.1	21.0
	Victoria	22.0	20.1
Current Uganda's recommended fungicide rate and spray regime	El mundo	19.4	14.1
	Markies	21.1	18.4
	sagitta	20.8	18.4
	Victoria	21.0	18.7
Hybrid/ blend of current recommended rate and Bayer crop science recommendation	El mundo	22.9	21.1
	Markies	19.5	15.4
	sagitta	22.4	18.5
	Victoria	22.5	19.8
	Markies	23.0	20.2

	Variety	Grand mean Yield T/ Ha	Grand mean Marketable Yield T/Ha
No spray (Control)	sagitta	24.8	19.9
	Victoria	19.3	14.2
		7.8	6.3
	El mundo	8.9	7.5
	Markies	7.2	5.8
	sagitta	7.9	6.7
	Victoria	7.3	5.1

#### 4. Conclusion

The late blight disease pressure can effectively be managed by using a combination of different fungicide active ingredient and its application should follow the following regime; Application of 50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water) in 1<sup>st</sup> and 2<sup>nd</sup> week after emergence followed by 30ml Consento (Fenamidone 6.7% w/w + Propamacarb hydrochloride 93.6% w/w) /15 litres of water in the 3<sup>rd</sup> week after emergence, then 50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water) during the 5<sup>th</sup> week after emergence, followed by 27ml of Infinito (Propamacarb (55.3% w/w + Fluopicollide (5.53% w/w) /15 mls of water during 6<sup>th</sup> week, followed by 50g of Mancozeb (Dithiocarbamate 800g/kg) /15 litres of water) in the 7<sup>th</sup> weeks and last application to be done using 50g of Agrolaxzyl (Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP)/15 litres of water in the 8<sup>th</sup> week or 9<sup>th</sup> week. This regime would also reduces on likely chances of development of fungicide resistance by the late blight pathotype

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