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Prevalence of apple scab and powdery mildew infecting apples in Uganda and effectiveness of available fungicides for their management

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Apple scab caused by *Venturia inaequalis* (Cooke) wint, and apple powdery mildew, caused by *Podosphaera leucotricha* (Ell. and Ev.), are the most important diseases of apples in Uganda. Control of apple scab and powdery mildew require the application of fungicides in absence of resistant apple cultivars. This study was conducted to identify effective control fungicides and to document the status of these diseases in south western Uganda. The survey results of 2012 indicated that scab incidence was highest in districts of Kanungu (71.90%), followed by Kisoro (48.14%), Kabale (41.03%), Buhweju (29.23%), Mbarara (28.75%) and Rukungiri (17.80%). The severity of apple scab measured as percentage leaf area affected ranged from 20.12 to 76.19%. Powdery mildew incidence ranged from 30.00 to 70.00% with severity score ranging from 14.63 to 76.19%. Fungicides containing propineb (70% a.i), metalazyl (4% a.i) + macozeb (64% a.i), and bupirimate (25% a.i) were found to be effective at controlling apple scab with potential to reduce the disease severity by 61.11, 61.11 and 58.33%, respectively, while fungicides containing bupirimate (25% a.i), tebuconazole (43% a.i) and propineb (58% a.i) + cymoxanil (4.8% a.i) were more effective in the control of powdery mildew with potential to reduce the infection by 55.95, 39.12 and 20.84%, respectively.

Key words: Apple scab, powdery mildew and fungicides.

INTRODUCTION

Apple production is new agro enterprise that was established in Uganda since 2000 in South-western highlands mainly in Kabale district (ICRAF, 2003). 13 apple cultivars were introduced by NARO and ICRAF following farmers' demand for fruit trees. Two apple cultivars 'Anna and Golden Dorsett' were officially released in 2009 and are now widely grown in Uganda in the highlands of south western region as commercial varieties. The production of apples however is faced with a number of challenges among which diseases are one of the important constraints facing apple farmers. Apple scab and powdery mildew were identified as the most important diseases of apples in the country, with a potential to cause significant effects on the developing temperate fruit agro enterprise (Chemining et al., 2005). The apple scab pathogen *Venturia inaequalis* (Cooke) wint and the causal agent of powdery mildew (*Podosphaera leucotricha* (Ell. and Ev.) cause extensive crop losses in all apple production areas (Kerik, 2012; Brun et al., 2008). In the absence of proven diseases management technologies in Uganda, attempts to control these two diseases have been initiated through the use of fungicides and screening for tolerance among the introduced apple cultivars. However, no proper

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information is currently available regarding appropriate fungicides for the management of apple scab and powdery mildew. Therefore, this study was established to document the status of these diseases in the country and to evaluate the effectiveness of the available fungicides in the control of the diseases at Bungongi substation, in Kabale located at 1830 m a.s.l so that information on effective fungicides could be released and recommended for farmers to use.

MATERIALS AND METHODS

Prevalence of apple scab and powdery mildew in western district of Uganda

A survey was conducted in six district of the Western region of the country, where apples have been established since 2000. The survey districts consisted of Kabale, Kisoro, Kanungu, Rukungiri, Mbarara and Buhweju in western Uganda. Farmers with at least 5 year old apples were purposively selected and identified with help from the Agricultural extension officer. In each apple orchard, apple scab and powdery mildew disease incidence was estimated as percentage of apple tree leaves with visible symptoms. The disease severity was scored as percentage plant leaf area affected (PLAA) with scab according to a scale of 0 to 7 developed by Parisi et al. (1993), Croxall et al. (1952) 0 to 7 where 1 = 0% < percentage of scabbed leaf surface (sls)< 1%; 2 = 1%<sls<5 %; 3 = 5%<sls< 10%; 4 = 10< sls< 25%; 5 = 25%<sls<50%; 6 = 50%<sls<75%; 7 = 75%<sls while the severity of powdery mildew was evaluated visually on individual leaflets as percentage of infected area, using a 0 to 4 scale, where 0: no symptoms; 1: 1 to 5%; 2: 5.1 to 20%; 3: 20.1 to 40%; 4: 40.1 to 100% (Kim et al., 2004).

Screening fungicides to control powdery mildew and apple scab

Commercially available fungicides were evaluated in a nursery of apple rootstocks at Bugongi sub-station, for their efficacy in the control of apple scab and powdery mildew. The chemical fungicides were accessed from importers of Agricultural chemicals in Kampala. Among the fungicide evaluated, contact fungicides that inhibit fungal spore germination comprising of wettable suphur (80% a.i), Macozeb (80% a.i), and propineb (70% a.i), semi-systemic or systemic fungicides that retards spore movement and germination of sporangia that include propineb (58% a.i) + cymoxanil (4.8% a.i), Famoxadone (16.6% a.i) + cymoxanil (22.1% a.i) and Metalazyl (4% a.i) + Macozeb (64% a.i), Carbendazim (43% a.i), copper oxychloride (92% a.i), Tebuconazole (43% a.i) and Bupirimate (25% a.i) were used. For each fungicide, the industrial recommended concentration was applied to apple rootstocks grafted with “Anna and Golden Dorsett” that were infected with scab and powdery mildew.

Disease initiation for fungicide effectiveness in disease management

One-year-old apple seedlings varieties of ‘Anna’ and ‘dorsett’ grafted on rootstocks of “bidden fielder” cultivar were used in this experiment. One set of the experimental material was defoliated to 100%, while other was left intact. Both sets of seedlings were inoculated with spores of powdery mildew and apple scab, prepared from infected leaves as described. Infected leaves were collected and immersed in distilled water for four hours. The leaves were then removed, the inoculum filtered, through a 0.2 mm sieve. The suspensions were adjusted with distilled water and standardized to 1×10^3 conidia per ml using a hemacytometer and used as a fine mist spray on the seedlings until run off. Inoculation was done in the evening to encourage spore germination and penetration. 48 h after innoculation, seedlings were subjected to treatments of contact and systemic fungicides. To prevent interplot interference due to fungicide drift; a split plot design was adopted, where fungicides constituted the main plot and apple cultivars, the sub-plots. The main plots (fungicides) were separated from each other with polythene sheeting. For each combination cultivar by fungicide, three replicates were used.

Fungicide effectiveness in scab and powdery mildew management

Apple scab and powdery mildew incidence and severity were scored on the first ten leaves following inoculation, from 2009 to 2011. Data on the number of leaves with powdery leaf lesions and scab lesion were counted and used to calculate disease incidence, as a proportion of disease-infected leaves. The mean number of powdery mildew lesions and scab lesions per leaf was considered as the measure of disease severity that was used to compute the percentage leaf area affected (PLAA). Apple scab PLAA was estimated using a scale of 0 to 7, where; 1 =: 0% < percentage of scabbed leaf surface (sls)< 1%; 2 = 1%<sls<5 %; 3 = 5%<sls< 10%; 4 = 10< sls< 25%; 5 = 25%<sls<50%; 6 = 50%<sls<75%; 7 = 75%<sls (Parisi et al., 1993). Powdery mildew percentage of affected area was estimated visually on individual leaflets using a 0 to 4 scale, where 0: no symptoms; 1: 1 to 5%; 2: 5.1 to 20%; 3: 20.1 to 40%; 4: 40.1 to 100% (Kim et al., 2004). Data were recorded 10 days after fungicide sprays, and, every week subsequently for a period of 8 weeks per season. These data generated on the intensity of powdery mildew and scab was used to compute the area under disease progress curve (rAUDPC) using the procedure of Campbell and Madden (1990).

$$AUDPC=\sum_{i=1}^{n}[(x_i+x_{i-1})/2][t_i-t_{i-1}]$$

Where; x_i= present disease severity, x_{i-1}= previous disease severity, t_i-t_{i-1} = time difference between two consecutive disease severities

RESULTS AND DISCUSSION

Prevalence of apple scab and powdery mildew in Southwestern districts of Uganda

Apple scab and powdery mildew incidence and severity were significantly different (P=0.05). The results of the current work showed a high incidence of apple scab and powdery mildew in the majority of districts surveyed. Scab incidence was highest in Kanungu (71.90%), followed by Kisoro (48.14%), Kabale (41.03%), Buhweju (29.23%), Mbarara (28.75%) and Rukungiri (17.80%) (Table 1). The severity of apple scab was also high in all the districts surveyed, except for Rukungiri where the severity rates were of 20.12%, measured as percentage leaf area affected. Scab severity in Kanungu was 76.19%, in Kisoro, 45.00%, Kabale 44.29%, Buhweju 40.38%, Mbarara 33.45%, and Rukungiri, 20.12%. The most damaged plant part were the leaves, this is in

Table 1. Prevalence of apple scab in the two varieties grown in south western Uganda.

District	Cultivar Anna		Cultivar Golden Dorsett			
	Apple scab incidence (%)	Scab disease severity leaf area affected (PLAA) (%)	Apple scab incidence (%)	Scab disease severity leaf area affected (PLAA) (%)	Mean scab incidence	Mean scab disease severity leaf area affected (PLAA) (%)
Buhweju	23.33	41.67	34.29	39.29	29.23	40.38
Kabale	43.23	45.31	37.50	42.67	41.03	44.29
Kanungu	71.82	77.27	72.00	75.00	71.90	76.19
Kisoro	47.27	44.32	49.62	46.15	48.14	45.00
Mbarara	32.50	40.00	25.00	27.50	28.75	33.75
Rukugiri	18.24	19.12	17.50	20.83	17.80	20.12
Grand Mean	41.53	43.84	36.93	39.94	39.46	42.09
F.Pr					0.704	0.769
LSD (P=0.05)					12.78	11.89

agreement with work of Valiuskaite et al. (2009). Powdery mildew disease incidence was highest in Kanungu, at 70.00%, with severity score of 76.19%, followed by Kisoro district, with incidence of 38.00% and severity score 39.29%, in Kabale mildew incidence was 34.62% with severity of 41.47%, Buhweju 30.00% with 39.23% disease severity, while in Rukungiri incidence of mildew was at 12.93% with 14.63% disease severity.

The high incidence and severity of the diseases in most of the districts surveyed is attributed to the lack of proper management practices and lack of knowledge on the appropriate fungicides to be used for the management of these diseases. Developing cultivars resistant to both scab and powdery mildew and use of synthetic fungicides are important for scab and powdery mildew management. In this study it was noted that districts which experience lower temperatures and higher rainfall, scab was a major problem whereas powdery mildew was less important in areas where temperatures are higher and rainfall is lower, powdery mildew is a major problem, and scab is less important. This is supported by report of (Blazek and Hlusickova, 2003). The study also showed no significant difference in infectivity of apple scab and powdery mildew between the two common apple varieties 'Anna' and 'Golden Dorsett' in all the district surveyed (Tables 1 and 2). Cultivars Anna and Golden Dorsett were equally affected by apple scab and powdery mildew in the surveyed district.

Effectiveness of the fungicides for control of powdery mildew and apple scab

The results of the study indicate a significant difference (P=0.05) in the effectiveness of fungicides to control powdery mildew for three seasons of the study. Fungicides containing bupirimate (25% a.i), Tebuconazole (43% a.i) and Propineb (58% a.i) + cymoxanil (4.8% a.i)), were more effective in reducing apple disease severity and controlled the development of powdery mildew on leaves and young shoots of apple of grafted apple seedlings. Fungicides containing bupirimate (25% a.i) was able to reduce the severity of powdery mildew by 55%, followed by Tebuconazole (43% a.i) 30% and Propineb (58% a.i) + cymoxanil (4.8% a.i), 20%, Copper oxychloride (92% a.i) 19.54%, Macozeb (80% a.i) 19.45%, Famoxadone 22.1% (a.i)+ cymoxanil (30% a.i) 13.95%, Metalazyl (4% a.i) + Macozeb (64% a.i), 10%, Propineb (70% a.i) 7.79%, and Wettable suphur (80% a.i) 5.92% (Table 3). However, for fungicide *C*arbendazim *(*43% a.i)*,* the intensity of powdery mildew was the same as that of the control (No spray) implying that there was no effect in controlling the disease development

In order to control apple scab, fungicides containing Propineb (70% a.i), Metalazyl (4% a.i) + Macozeb (64% a.i), and bupirimate (25% a.i) were more effective in controlling apple scab with potential to reduce apple scab severity by 61, 61 and 58%, respectively (Table 4). Defoliated apple seedlings exhibit lower disease severity (rAUDPC) for scab across all fungicide sprays, ranging from 0.5 to 5.8% for defoliated apples, whereas for intact plants, it ranged from 5 .1 to 8.5%. This

Table 2. Prevalence of powdery mildew in the two apple varieties grown in Western Uganda.

District	Cultivar Anna		Cultivar Golden Dorsett			
	Powdery mildew incidence (%)	Powdery mildew disease severity leaf area affected (PLAA) (%)	Powdery mildew incidence (%)	Powdery mildew disease severity leaf area affected (PLAA) (%)	Mean powdery mildew incidence	Mean powdery mildew severityleaf area affected (PLAA) (%)
Buhweju	26.67	41.67	32.86	37.14	30.00	39.23
Kabale	35.31	42.08	33.50	40.50	34.62	41.47
Kanungu	69.09	75.00	71.00	77.50	70.00	76.19
Kisoro	40.00	39.77	34.62	38.46	38.00	39.29
Mbarara	20.00	43.75	12.50	25.00	16.25	34.38
Rukugiri	20.00	22.35	7.92	9.17	12.93	14.63
Grand Mean	36.25	41.90	29.94	34.89	33.42	38.75
F.pr					0.369	0.357
LSD (P=0.05)					11.57	12.98

Table 3. Average rAUDPC for powdery mildew and percentage reduction in severity for three seasons, as influenced by different fungicides in apple crops.

Fungicide trade name	Active ingredient	Application rate	Disease severity for powdery mildew, measured as rAUDPC	% reduction in powdery mildew disease severity
Nimrod	Bupirimate 25%	15 g/100 L	19.57	55.95
Orius	Tebuconazole 43%	35 ml/100 L	27.05	39.12
Milraz	Propineb 58% and cymoxanil 4.8%	200 g/100 L	35.17	20.84
Cobox	Copper oxychloride 92%	500 g/100 L	35.75	19.54
Agrozeb	Macozeb 80%	200 g/100 L	35.79	19.45
Equatin Pro	Famoxadone 22.1% + cymoxanil 30%)	50 g/ 100 L	38.23	13.95
Ridomil Gold	Metalazyl 4% +Macozeb 64%	250 g/100 L	39.98	10.02
Antracol	Propineb 70%	200 g/100 L	40.97	7.79
Thiovit	Wettable suphur 80%	200 g/100 L	41.8	5.92
Rodazim	Carbendazim 43%	30 g/100 L	47.35	-6.57
Control			44.43	
Grand Mean			37.58	
F.pr			0.036	
LSD (P=0.05)			13.77	

rAUDPC= relative area under disease progress curve, computed using the percentage of leaf area affected measured over a period of 8 weeks, for 2 consecutive experimental growing seasons.

Table 4. Average rAUDPC for apple scab and percentage reduction in the disease severity, for two seasons as influenced by different fungicides.

Fungicide trade name	Active ingredient	Application rate	Defoliated	Un defoliated	Grand mean	% reduction in scab severity
Antracol	Propineb 70%	200 g/100 L	0.5	5.1	2.8	61.11
Ridomil	Metalazyl 4% +Macozeb 64%	250 g/100 L	1	4.6	2.8	61.11
Nimrod	Bupirimate 25%	15 g/100 L	1.4	4.6	3.0	58.33
Equation Pro	Famoxadone 22.1% + cymoxanil 30%	50 g/ 100 L	1.2	4.9	3.1	56.94
Cobox	Copper oxychloride 92%	500 g/100 L	1	5.7	3.3	54.17
Milraz	Propineb 58% and cymoxanil 4.8%	200 g/100 L	2.6	5.2	3.9	45.83
Rodazim	Carbendazim 43%	30 g/100 L	2.5	5.2	3.9	45.83
Orius	Tebuconazole 43%	35 ml/100 L	0.8	9.0	4.9	31.94
Agrozeb	Macozeb 80%	200 g/100 L	2.1	9.1	5.6	22.22
Control			5.8	8.5	7.2	-
F.pr			<.001	<.001	0.001	
LSD (P=0.05)			0.98	0.98	2.19	

indicates that farmers should defoliate their apple orchards prior to fungicide spraying, as this cultural practice helps to reduce the disease innoculum, and subsequent disease severity. Therefore, it is recommended, for effective control of powdery mildew, that the plants are defoliated prior to spraying so that the product can reach newly formed leaves allowing an effective management of the spread of the disease.Based on the results of the current study, it is recommended that fungicide containing propineb (70% a.i), Metalazyl (4% a.i)+ Macozeb (64% a.i), and bupirimate (25% a.i) are used for effective management of apple scab, whereas Bupirimate (25%), Tebuconazole (43%) and Propineb (58%) + cymoxanil (4.8% a.i), are recommended for the control of powdery mildew in Uganda. The order of the recommendations correspond to the effectiveness of the products in our experimental conditions.

Conclusion

The interchangeable use of fungicides containing propineb (70%), Metalazyl 4% + Macozeb 64%),and bupirimate (25%) promotes the control of apple scab to levels below those causing economic damages. The products of Bupirimate (25%), Tebuconazole (43%) and Propineb (58%) + cymoxanil (4.8%) are recommended for the management powdery mildew. Incorporating cultural methods, such as defoliation and use of resistant varieties, could also help to reduce the severity of the investigated diseases.

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