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Full Paper

Detection of downy mildew [*Peronosclerospora philippinensis* (W. Weston) C.G. Shaw] resistance in sugarcane (*Saccharum officinarum* L.) based on chlorophyll content and biomass

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Abstract

Peronosclerospora philippinensis (Weston) C.G. Shaw is the most virulent downy mildew in the Philippines and one of the major diseases that reduce the yield of sugarcane. Sixty sugarcane genotypes consisting of 49 hybrids and 11 varieties were screened in the greenhouse for downy mildew resistance. Chlorophyll reading and visual rating of the incidence of disease were performed for ten weeks, commencing one month after planting. T10-535 showed the lowest disease incidence among the hybrids and VMC-87599 showed the lowest disease incidence among the varieties. Other hybrids which showed the lowest disease incidence were E5-531 F, A50-530 M, and 150-530. Results of chlorophyll reading shows that VMC-87599 had the highest soil-plant analysis development (SPAD) value over the ten-week period. There was a significant correlation between disease rating and disease incidence, and a moderate correlation between chlorophyll content and disease incidence. No correlation was observed between disease incidence and roots, stalk and leaf biomass. The correlation in disease incidence and severity to roots, stalk and leaf biomass could be further checked throughout the growth phase of sugarcane to evaluate physiological parameters such as chlorophyll content and biomass partitioning.

Keywords - disease incidence, disease responses, resistance, severity, susceptibility

Introduction

Sugarcane (*Saccharum officinarum* L.) belongs to the family Poaceae and is cultivated massively for its sugar content. Around 80% of the world's sugar is extracted from sugarcane while the remaining 20% is from sugar beet. According to World Data Atlas, Philippines ranked 13th in world sugarcane production with a total harvest of 2,100 thousand metric tons (TMT). Aside from sugar, sugarcane can also produce byproducts for bioethanol and power co-generation (Martin, 2015). In the last decade, sugar produced in the Philippines has been almost completely for domestic consumption and importation to the United States ruled by tariff-rate quotas (US quota). To provide sugar supply not only domestically but also to neighbouring countries is a big task and opportunity for the Philippines. Unfortunately, sugarcane production area declined to 415,000 ha from 418,000 ha in crop year 2017-2018. Moreover, there was a significant decrease in farm productivity, with an average of 58 tons per hectare in year 2017-2018, compared to the record high 66 tons per hectare from previous year (Sugar Regulatory Administration, 2018). It is still far from the average farm productivity of Thailand which is 65-70 tons per hectare (Athipanyakul et al., 2020).

Downy mildew is one of the most important diseases of sugarcane in the Philippines. The most common species are *Peronosclerospora philippinensis* (Weston) C.G. Shaw and *P. sacchari* (T. Miyake). These two species have no significant difference in the number of nuclei per spore (Pawar,

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1986), and their DNA banding patterns when analysed through Southern blot are almost identical (Yao et al., 1991). A lack of uniqueness between *P. philippinensis* and *P. sacchari* is shown after looking at their genomes using simple sequence repeats as markers (Perumal et al., 2008). However, COX-1 primers showed differences between the two species and the defining difference is the size of the oospores which may have been overlooked in some of the molecular biology studies (Thompson et al., 2013). The invasion of pathogens in the sugarcane plant is via young leaf tissue at the base of the leaf spindle in young shoots and via conidia landing on young buds.

Sugarcane has long growth duration therefore it is extremely vulnerable to insect pests and diseases. Indeed, biotic stresses as well as planters' productivity are of special concern in sugarcane breeding programs because they may cause great economical impact with susceptible cultivars. Downy mildew contributes significantly to cane yield reduction in the Philippines (Egan, 1984), with 21.7% reported infection in a moderately susceptible variety and 46.5% in a very susceptible variety (Lee, 1952). In 1962, a serious outbreak of downy mildew was reported by Rivera (1962) with an infection rate as high as 75% among hybrids of *Saccharum spontaneum* L. parentage. Losses due to stunting can reach 40% or more. The stunting in susceptible varieties is associated with systemic infection (Rauka et al., 2005; Suma & Pais, 1996). Philippine downy mildew in maize shares similar symptoms with other hosts such as sorghum and sugarcane although the former has been studied most for its economic significance. Ricaud et al.'s (1989) review of sugarcane diseases emphasized that information on the susceptibility or resistance of all new varieties and hybrids can help prevent downy mildew disease from becoming a serious threat to sugarcane production. Baer and Lalusin (2013) identified sugarcane hybrids that are resistant to downy mildew using molecular markers associated with downy mildew. The latter study focused on identifying sugarcane hybrids using molecular markers but did not investigate the correlation of downy mildew infection and severity to chlorophyll content and to roots, stalk and leaf biomass. An investigation of the effect of infection on biomass is warranted because studies consistently show that there is greater proportional allocation of biomass to roots than leaves in plants growing in optimal conditions (Hunt & Lloyd, 1987; Hunt & Nicholls, 1986; Hunt et al.,1987; Shipley & Peters, 1990). Infected stem mustard with turnip mosaic virus showed decreased plant weight, leaf area and significantly reduced chlorophyll content after two weeks (Guo et. al, 2005). In addition, there is a significantly reduced total biomass of beech infected with *Phytophthora citricola* and *P. cambivora* when compared with uninfected plants (Fleischmann et al., 2004).

Another contribution of this study to the literature was to determine resistant varieties of sugarcane against downy mildew. We identified the varieties and hybrids with putative resistance to downy mildew using phenotypic screening by determining disease rating, disease incidence, chlorophyll content and biomass coefficients.

Materials and Methods

Phenotyping

Six-month-old cane points of 11 varieties and 49 hybrids from the Institute of Plant Breeding (IPB), University of the Philippines Los Baños (UPLB), College, Laguna were planted in polybags (19"x19") filled with 5 kg soil mix with coconut coir dust. Three sets or seed pieces were planted in each polybag. The experiment was arranged in randomized complete block design with three replications and three subsamples per treatment. The seedlings were maintained in the Feed and Industrial Crops Division IPB-UPLB greenhouse for three months. Spreader rows which have been previously infected naturally with downy mildew were already planted two months ahead in the greenhouse to induce disease pressure. There were 82 sugarcane spreader rows per replication. Inoculation was also done by creating a spore suspension in water from an infected sugarcane leaf. The suspension was sprayed twice in the plants with weekly interval and was done early dawn.

Determination of disease rating and incidence commenced a month after planting. Observations were recorded weekly for ten weeks to determine infection percentage on the downy mildew disease response. The method used in the determination of disease rating and disease incidence was through phenotypic screening. Rating of downy mildew disease was scored based on the rating scale of the International Society of Sugarcane Technologists (ISSCT) in Table 1 (Baer & Lalusin, 2013). Disease incidence was scored by noting the percentage of

Table 1.Standard evaluation score (SES) of downy mildew rating in sugarcane (International Society of Sugarcane Technologists [ISST])

Rating	Incidence	Response	Significance in Plant Breeding
1	1.0 - 4.9	Very Highly Resistant	Useful (1-3)
2	5.0 -8.9	Highly Resistant	
3	9.0 - 12.9	Resistant	
4	13.0 - 16.9	Moderately Resistant	Intermediate
5	17.0 - 20.9	Intermediate	(4-6)
6	21.0 - 24.9	Moderately Susceptible	
7	25.0 - 28.9	Susceptible	Not Useful
8	29.0 - 32.9	Highly Susceptible	(7-9)
9	33.0 – 100	Very Highly Susceptible	

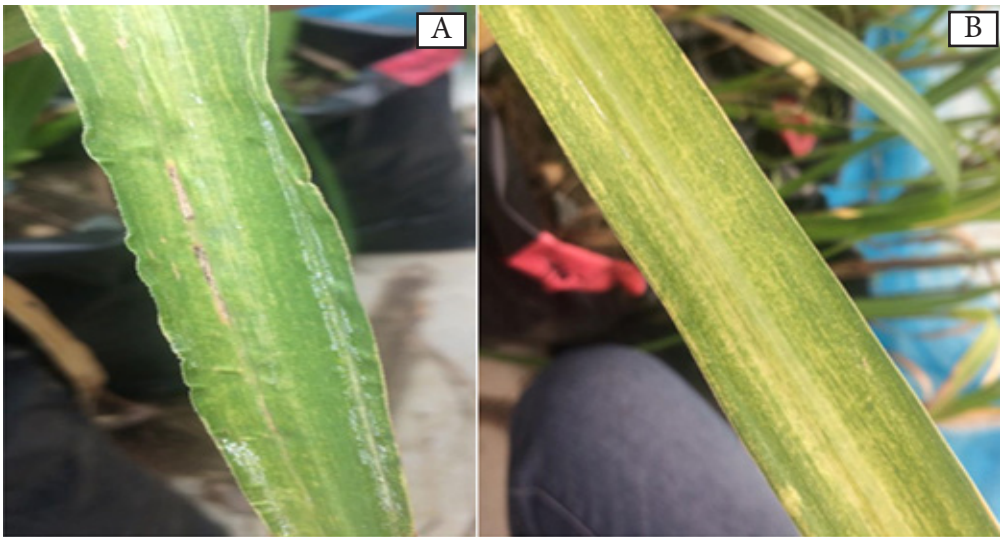

Figure 1. Appearance of downy mildew leaf streak in susceptible sugarcane leaf after 3 months (A. VMC 74530) (B. VMC 86550).

the leaf with downy mildew disease. Leaves that have a large presence of yellow or withered portions (Figure 1) are indicative of high disease incidence while leaves that have little coloration change (Figure 2) are indicative of low disease incidence or high resistance. The morphology of the causal pathogen observed during inoculation agrees with the description of Hughes and Robinson (1961). This study was limited only in one population of downy mildew originally isolated from one area.

Determination of Chlorophyll and Biomass Measurement

Immediately after downy mildew scoring, chlorophyll content was determined using soil-plant analysis development (SPAD) (Minolta SPAD-502 [Konica-Minolta Inc., Japan]) at the midpoint of the third leaf from the base. All measurements were obtained from the three replications. Measurements commenced one month after planting and were recorded weekly for 10 weeks. Three leaves were measured per polybag/replication and an average value was obtained. Biomass partitioning was determined at harvest. When the sugarcane plants were three months old, the above and below-ground biomass were harvested. The root parts were carefully washed to remove the soil adhering to the roots. The leaves, stems and roots were air-dried for five days then oven-dried at 64 °C for seven days. The leaves for the biomass partitioning comprised of senesced leaves, leaf blade and the sheath.

Figure 2. Appearance of resistant sugarcane leaf for downy mildew (*Peronosclerospora philippinensis)* after 3 months (VMC-87599).

Statistical Analysis

The gathered data was analyzed using Analysis of Variance (ANOVA) through the free software Statistical Tool for Agricultural Research (STAR) [International Rice Research Institute (IRRI)]. If a significant difference was found between treatments, Tukey's Pairwise Mean Comparison was used as post hoc analysis. Correlation analysis was performed in the scoring of disease rating to disease incidence, to chloropyll content and to biomass partition (leaf, stalk and root).

Results and Discussion

Development and Reaction of the Test Entries to Downy Mildew

Table 2 shows the disease rating, disease incidence and the measurements of chlorophyll and biomass for each genotype, averaged across the three leaves and across the ten weekly observations. The disease rating of sugarcane (column 2 of Table 2) ranged from 2.17-8.45, with the lowest rating indicative of highest resistance based on the Standard evaluation score (SES) of downy mildew rating in sugarcane (Table 1). The hybrid T10-535 C showed the lowest rating of 2.17 while VMC 86550 displayed the highest rating of 8.45. Percentage disease incidence for ten weeks ranged from 7.89% to 65.89%, as shown in column 3 of Table 2. Hybrid T10-535 C also displayed the lowest percentage of disease incidence which means that it was the most resistant while variety VMC 86550 manifested the highest percentage of disease incidence, indicating that it was the most susceptible. The 11 varieties and 49 hybrids differed significantly in disease rating and disease incidence during the 10 weeks of the screening trial (Table 2). It was observed that some of the hybrids, particularly E14 627 F, were already infected one month after planting, while others produced symptoms only after three weeks more. The highest percentage of downy mildew infection at week 10 was observed in variety VMC 86550 (65.89%) and hybrid A35-530 M (41.33%). All other populations had percentage infections ranging from 20% to 40%.

Based on the ten-week average, among the 11 varieties, VMC 86550 was considered the most susceptible followed by entries VMC 74530 and PHIL 8477 as shown in column 2, Table 2. Their disease ratings were 8.45, 7.89, and 7.50, respectively. Moreover, among the 49 hybrids, H31-627F (disease rating = 8.22) and A35 530 M (disease rating = 7.89) were found most susceptible followed by Thailand, E14-627 F, J47, D35-530 M, Queensland, M13-528 C, H34, G1-530 M, K19-530 C, E23-531 F, T44-535 C and C29-531 M (disease rating ≥ 7.00). It was observed that hybrid E14-627 F displayed earlier onset of the disease and also exhibited one of the highest disease incidences (41.28%). Variety VMC 86550 which had the highest disease rating (8.45) and highest percentage of disease incidence (65.89%) already started to get infected at week five, showing the disparity in terms of virulence and disease aggressiveness in the population set-up under screen house conditions. This result was also observed in the study of Baer and Lalusin (2013).

As shown in column 3 of Table 2; T10-535 C showed the lowest disease incidence (7.89%) among the hybrids and VMC-87599 showed the lowest disease incidence (12.22%) among the varieties. Other hybrids which showed the lowest disease incidence were E5-531 F, A50-530 M and 150-530. Notably, the genotypes with the lowest disease incidence were also resistant. Based on the rating scale in Table 1, T10-535 (incidence = 7.89%) was highly resistant; variety VMC-87599 (incidence = 12.22%) was resistant while hybrids E5-531 F (incidence = 13.00%), A50-530 M (incidence = 14.22%) and 150-530 (incidence = 16.72%) demonstrated moderate resistance. The identification of entries with resistant and susceptible genotypes was based on the correlation analysis between disease rating and disease incidence of the 11 varieties and 49 hybrids selected for downy mildew resistance at different time intervals. In addition, Pearson correlation analysis for weekly

Table 2. Summary table for disease rating, incidence, chlorophyll content and partitioning coefficient of biomass of the 60 varieties/hybrids of sugarcane infected with downy mildew.

Genotype	Disease Rating	Disease Incidence (%)	Chlorophyll Content	Partitioning Coefficients^{ns}		
				Leaf Biomass/ Total Biomass	Stalk Biomass/ Total Biomass	Root Biomass/ Total Biomass
Hybrids						
01-537 F	5.67^{a-e}	25.89	29.60^{a-e}	0.70	0.27	0.04
150-530	4.72^{a-d}	16.72	41.77^{a-d}	0.79	0.16	0.06
A35-530 M	7.89^{a-e}	41.33	35.37^{a-e}	0.59	0.33	0.08
A36-530 M	5.56^{a-e}	26.56	33.19^{a-e}	0.63	0.31	0.06
A37- 530	5.39^{abc}	28.37	37.49^{abc}	0.55	0.37	0.08
A50-530 M	3.44^{cde}	14.22	46.84^{cde}	0.56	0.35	0.09
C29-531 M	7.00^{abc}	31.17	32.88^{abc}	0.54	0.38	0.08
C5-531 M	5.22^{a-e}	22.89	33.57^{a-e}	0.55	0.38	0.08
D19-531 F	4.61^{a}	19.83	35.32^{a}	0.78	0.16	0.06
D35-530 M	7.56^{a-e}	33.44	34.80^{a-e}	0.90	0.00	0.10
D47-531 F	6.11^{a-e}	28.50	33.54^{a-e}	0.41	0.46	0.12
E13-627 F	6.67^{a-e}	29.83	34.92^{a-e}	0.66	0.27	0.07
E14 627 F	7.67^{a-e}	41.28	23.69^{a-e}	0.69	0.24	0.07
E23-531 F	7.11^{abc}	31.28	31.06^{abc}	0.40	0.57	0.03
E26-628 C	6.00^{a-e}	26.89	30.16^{a-e}	0.65	0.30	0.05
E5-531 F	3.22^{a-e}	13.00	31.74^{a-e}	0.72	0.25	0.03
F3-530 C	5.78^{a-d}	25.56	30.45^{a-d}	0.42	0.51	0.07
G1-530 M	7.11^{a-e}	32.11	27.48^{a-e}	0.60	0.33	0.07
G2-530 M	4.33^{a-e}	17.28	30.53^{a-e}	0.42	0.53	0.04
G50-638 M	6.94^{a-e}	29.39	28.51^{a-e}	0.48	0.47	0.05
G6-638	5.11^{a-e}	20.11	44.34^{a-e}	0.83	0.11	0.07
H23-627 F	5.44^{a-d}	19.28	36.89^{a-d}	0.65	0.28	0.07
H27-627 F	4.22^{a-e}	19.89	33.43^{a-e}	0.67	0.25	0.07
H30 627 F	6.39^{a-e}	25.89	31.98^{a-e}	0.53	0.39	0.09
H31-627 F	8.22^{a-d}	41.11	32.48^{a-d}	0.57	0.35	0.08
H34	7.17^{a-e}	30.22	33.61^{a-e}	0.82	0.11	0.07
H34-627 F	6.22^{a-e}	36.56	38.79^{a-e}	0.65	0.25	0.10
H39-627 F	6.55^{abc}	26.44	31.42^{abc}	0.33	0.60	0.08
H608521	6.05^{a-e}	27.61	32.49^{a-e}	0.49	0.39	0.12
H6-531 F	6.72^{cde}	28.00	32.51^{cde}	0.39	0.57	0.03
INDONESIA	6.06^{e}	24.72	32.14^{e}	0.76	0.12	0.12
J39-530 M	5.45^{a-e}	21.00	41.70^{a-e}	0.64	0.14	0.23
J47	7.67^{a-e}	40.11	33.47^{a-e}	0.80	0.12	0.08
J5-638 C	5.61^{ab}	25.11	29.58^{ab}	0.55	0.41	0.04
K19-530 C	7.11^{a-e}	29.56	33.54^{a-e}	0.76	0.16	0.08
L8-531 F	6.89^{a-e}	36.66	41.49^{a-e}	0.79	0.17	0.05
M13-528 C	7.22^{a-e}	34.67	33.13^{a-e}	0.80	0.09	0.11
N51-531 F	4.56^{abc}	18.00	37.30^{abc}	0.81	0.12	0.07
PORAC	4.83^{a-e}	22.28	36.65^{a-e}	0.43	0.51	0.06

Table 2. Continued...

Genotype	Disease Rating	Disease Incidence (%)	Chlorophyll Content	Partitioning Coefficients^{ns}		
				Leaf Biomass/ Total Biomass	Stalk Biomass/ Total Biomass	Root Biomass/ Total Biomass
Hybrids						
PSGM	6.78^{a-e}	30.17	35.09^{a-e}	0.70	0.23	0.06
Q2B 535 M	6.22^{a-e}	27.56	34.54^{a-e}	0.89	0.03	0.08
Queensland	7.45^{a-e}	31.45	27.69^{a-e}	0.69	0.26	0.05
R5 530 C	6.72^{a-e}	34.56	34.86^{a-e}	0.61	0.25	0.14
R9-530 F	5.61^{a}	22.44	38.06^{a}	0.61	0.30	0.10
S35-535 M	5.11^{a-e}	24.61	37.21^{a-e}	0.59	0.36	0.05
T10-535 C	2.17^{a-e}	7.89	37.57^{a-e}	0.71	0.23	0.07
T44-535 C	7.06^{abc}	31.22	36.44^{abc}	0.80	0.05	0.15
Thailand	7.67^{a-e}	38.83	35.10^{a-e}	0.56	0.38	0.06
U3 537 F	4.28^{a-e}	17.56	36.36^{a-e}	0.66	0.27	0.07
Varieties						
PHIL 7270	5.00^{a-d}	19.67	35.22^{a-d}	0.75	0.16	0.09
PHIL 7544	6.33^{a-e}	24.56	35.35^{a-e}	0.58	0.37	0.05
PHIL 8477	7.50^{a-e}	32.17	31.55^{a-e}	0.40	0.54	0.05
VMC 67315	5.89^{a-e}	25.72	31.11^{a-e}	0.62	0.35	0.03
VMC 7139	5.56^{de}	21.67	32.98^{de}	0.63	0.31	0.06
VMC 7244	7.39^{a-e}	29.39	35.48^{a-e}	0.54	0.42	0.05
VMC 74364	6.06^{b-e}	24.67	30.78^{b-e}	0.51	0.44	0.05
VMC 74530	7.89^{a-e}	34.44	33.59^{a-e}	0.66	0.09	0.24
VMC 84549	6.50^{a-e}	29.44	29.15^{a-e}	0.68	0.22	0.10
VMC 86550	8.45^{a-e}	65.89	37.78^{a-e}	0.67	0.18	0.15
VMC-87599	3.22^{a-e}	12.22	51.45^{a-e}	0.59	0.36	0.04

Note: Values in the same column with the same letter superscript are not significantly different at the 5% level (Tukey's Test)

data showed that disease rating had a moderate to strong positive relationship with disease incidence, and was observed across all ten weeks (Figure 3).

Resistance to disease can be divided generally into qualitative and quantitative resistance. From the perspective of an epidemiologist, qualitative resistance act against some races (race specific, vertical), whereas quantitative resistance is similarly effective against all races of a pathogen (non-race-specific, horizontal) (Van der Plank, 1968). Sugarcane can have a qualitative or quantitative resistance. It is possible that the resistance observed in this study is specific only to *P. philippinensis* (qualitative resistance), but future studies can investigate if the resistance observed is also for species *P. sacchari* (quantitative resistance). Breeders can easily handle qualitative resistance since it can often be evaluated at the seedling stage but are likely to lose their effectiveness by fast changes in pathogen populations (Miedaner & Korzun, 2012). In the case of quantitative resistance, the pathogen infected all the hosts, but more resistant ones were less affected. There is lower pathogen virulence in qualitative resistance and higher pathogen virulence in quantitative resistance (Frank, 1992). Although this study was conducted under a controlled environment, the results showed significant differences among the hybrids and varieties. Hence it is possible to select varieties or hybrids resistant to downy mildew.

Chlorophyll Content Measurement

The chlorophyll content was measured to determine its relation to the downy mildew disease rating. The chlorophyll content of the 60 genotypes ranged from 23.69 to 51.45 SPAD value as shown in

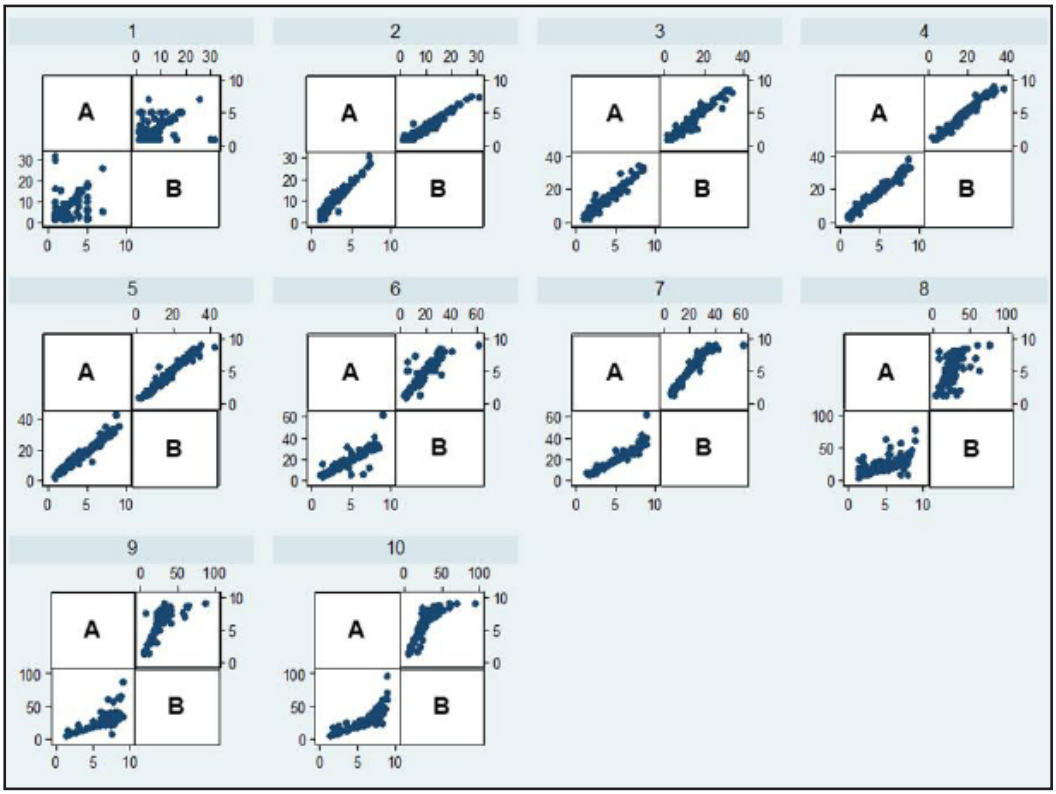

Figure 3. Weekly correlation graph between disease rating (A) and disease incidence (B).

column 4 of Table 2. The 11 varieties and 49 hybrids differed significantly in chlorophyll content. Of the 11 varieties, VMC-87599 and VMC 86550 had the highest 10-week averaged SPAD values (51.45 and 37.78, respectively). Among the 49 hybrids, A50-530 M, G6-638, 150-530, J39-530 M, L8-531 F, H34-627 F, R9-530 F, T10-535 C, A37-530, N51-531 F and S35-535 M had the highest 10-week averaged SPAD value which ranged from 37.21-46.84 (Table 2). It can be observed that genotypes with high SPAD values (such as VMC-87599, A50-530 M and 150-530) were resistant to downy mildew, and that hybrids with low SPAD values (such as E14 627 and Queensland) were identified as susceptible, where resistance and susceptibility were inferred based on the disease scoring in Table 1. However, there were also genotypes with high chlorophyll content (such as VMC 86550) that showed higher disease incidence over the ten weeks. There is moderate correlation (r = -.4238) between SPAD value and infection rating (Table 3) (p =0.001).

Chlorophyll and disease incidence are related possibly because fungal infection such as downy mildew and other viral infections are depicted by a total destruction of the cellular integrity of the impacted tissues leading to cell expiration and degradation of chlorophyll. It is accompanied by a transient increase in transpiration, followed by tissue desiccation (Bauriegel et al., 2011). However, the relationship is not very strong, possibly because not all plant pathogens for downy mildew bring about chlorophyll breakdown. The decline in host photosynthesis is restricted to the affected portions and adjacent regions only (Scholes & Rolfe 1995; Moriondo et al. 2005). Further, there might be 'green islands' immediately around the sites of infection where chlorophyll concentrations and photosynthesis are retained (Scholes & Farrar, 1986). In sugar beet infected with powdery mildew, Magyarosy and Malkin (1978) found evidence of impaired chloroplast electron transport and decreased rates of CO_2 assimilation, yet were unable to show any loss of chlorophyll.

Biomass Partitioning

There were significant differences among the 11 varieties and 49 hybrids in terms of leaf, stalk and root biomass partitioning coefficients (Table 2). The leaf biomass partitioning coefficients in column 5 ranged from 0.33 to 0.90. The highest value was

Table 3. Pearson product-moment correlation analysis of the relationship between disease rating to disease incidence, chlorophyll content and biomass of the 60 varieties/hybrids of sugarcane injected with downy mildew.

	Disease Incidence	Chlorophyll Content	Leaf Biomass	Stalk Biomass	Root Biomass
r	0.8773	-0.4238	-0.0217	-0.0497	0.2373
p-value	<0.001	0.001	0.869	0.706	0.068
Interpretation	Highly significant	Highly significant	Insignificant	Insignificant	Insignificant

observed in genotype D35-530 M while the lowest value was observed in genotype E23-531 F. Column 6 shows the stalk biomass partition which ranged from 0 (D35-530 M) to 0.60 (H39-627 F). The root biomass partitioning coefficient in column 7 displays values ranging from 0.03 (hybrids E23-531 F, E5-531 F, H6-531 F, and variety VMC 67315) to 0.24 (VMC 74530). However, biomass (leaf, stalk and roots) generally was not significantly correlated with the degree of downy mildew disease incidence as shown in Table 3.

Previous studies on sugarcane infections did not investigate the effect of downy mildew on the biomass of three-month old sugarcane since most studies were concerned on the yield loss during cane harvesting. This study has found no evidence of a relationship between disease incidence and the biomass of three-month old sugarcane. Possibly, this may be because during the tillering stage, plants produce more shoots and roots. Moreover, most of the roots that were gathered in the three-month old sugarcane plants were from sett roots. Future studies with a larger sample or longer time period, or focusing only on particular genotypes, can provide more information. Nevertheless, the data obtained from this study show that there are genetic differences as to the degree at which sugarcane genotypes can accumulate biomass.

Conclusions

Based on the results of the ten-week scoring in downy mildew, hybrid T10-535 C showed high degree of resistance while hybrids E5-531 F, A50-530 M and 150-530 showed moderate resistance. Variety VMC-87599 showed resistance for the three-month screen trial to the disease. The varieties and hybrids showed significant differences in chlorophyll content based on SPAD reading for 10 weeks. Moderate correlation was observed between chlorophyll content and disease rating. Correlation could be further checked by performing longer time period studies on sugarcane to cover the growth phase needed to evaluate physiological parameters such as chlorophyll content and biomass partitioning. With these results, it can be recommended that sugarcane planters can plant VMC-87599 for the management and control of downy mildew.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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