EVALUATION OF TWO SOURCES OF SILICON DIOXIODE AND CULTIVAR FOR THE MANAGEMENT OF PEARL MILLET DOWNY MILDEW (*SCLEROSPORA GRAMINICOLA)* IN MAIDUGURI AND GOMBE, NIGERIA.

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SUMMARY

In a split plot design field experiment conducted at Maiduguri and Gombe, the efficacies of cultivar, Silicon dioxide (SiO_2) and Diatomaceous earth (DE) on the management of downy mildew (*Sclerospora graminicola* (Sacc.) Schroet) of pearl millet was evaluated. Three cultivars (SOSAT-C88, Ex-Borno and LCIC-7902) were the main plots while four seed treatment materials (SiO_2, DE, SiO_2 + DE, All Star 40DS (standard check)) and control were the sub plots and replicated four times. There was a significant difference among the treatments (P = 0.05). SOSAT-C88 had the lowest disease incidence (29.88%) and severity (21.64%). SOSAT-C88 and LCIC 7902 had the highest grain yield (1008.30 Kg/ha, 1061.20 Kg/ha respectively). Downy mildew incidence and severity were significantly lower in the treated crops compared to the control. However, All Star 40DS and SiO_2 + DE were statistically similar giving the lowest disease incidence (16.88% and 21.25% respectively), severity (12.67% and14.69% respectively), and highest grain yield (1190 and 1132.20 kg/ha respectively) while the control recorded the highest disease incidence (66.79%), severity (49.62%) and the lowest grain yield (711.90 kg/ha). SiO_2 + DE can therefore be used as an effective pearl millet downy mildew management option.

Keywords: Pearl millet, Downy mildew, Silicon dioxide, Diatomaceous Earth, Management

PEARL MILLET is one of the most important staple food crops for over 400 million people who live in the world's poorest and most food-unsecured regions in about 30 countries, particularly in India and Africa (35, 22). Downy mildew (*Sclerospora graminicola* (Sacc.) Schroet) is the most important and widespread disease of pearl millet in West Africa and India (32, 24), hampering its growth and productivity with continuing potential to cause catastrophic loss (27, 52). Substantial yield and quality losses of up to 54.6% due to pearl millet downy mildew at 0% seed treatment was reported in a three years study in Sudan savanna of Nigeria (25). Growing disease resistant varieties and hybrids have been reported as the most effective, eco-friendly and economic control method against downy mildew (54). However, the introduction and mass cultivation of genetically new pearl millet cultivars has led to the evolution of new pathotypes of *S. graminicola* (50, 53, 54). Pathogenic variations in populations of *S. graminicola*, have continually been reported in different major pearl millet growing countries such as India and Nigeria (8, 51, 26). The inability to find a millet cultivar that is resistant to all pathotypes of the *S. graminicola* (26) raised some concern about pearl millet production in Nigeria especially in the very dry areas, where it is the only crop that can be successfully grown. Hence, there is the need to search for other protective measures for pearl millet against downy mildew.

Although silicon (Si), which is the second most abundant element on the earth is not listed among the essential elements, it is known to be absorbed into plants and to confer plant resistance to both abiotic and biotic stresses (19, 36, 11, 31). There is a cumulative evidence linking the presence of Si with resistance of plants against fungal pathogens such as *Podosphaera xanthii* (*syn. Sphaerotheca fuliginea*) (37) and *Pythium* spp. (14) in cucumber; *Pyricularia grisea* in rice (16); and powdery mildews in barley (13) and wheat (10, 56). DE has also been reported to have anti-fungal and insecticidal properties on sugarcane and grape crops (36, 40). This study reports the results of the efficacy of silicon dioxide (SiO_2) and Diatomaceous Earth (DE) on the management of downy mildew (*Sclerospora graminicola*) of pearl millet.

MATERIALS AND METHODS

Multi-location field trials were conducted during the 2012 cropping season at the research farm of the University of Maiduguri (14^0N, 3^0E) and Gombe (10^0N, 11^0S), Nigeria. Two resistant SOSAT-C88 and Ex-Borno; and a susceptible pearl millet cultivar LCIC-7902 obtained from Lake Chad Research Institute, Maiduguri were seed treated with sole SiO_2, sole DE, SiO_2 + DE, All Star 40DS (standard check) and water (untreated control). Treated seeds were sown in a split plot design replicated four times with cultivars randomly assigned to the main plots while the five seed treatment materials were assigned randomly to the sub-plots measuring 96.25 m^2 and 15.75 m^2 (4.5 x 3.5m), respectively. Diatomaceous Earth (DE) (50.37% SiO_2) powder was from Bularafa, Yobe State while All Star 40DS (20% metalaxyl + 20% Imidacloprid and Silicon dioxide (SiO_2) were purchased from an agrochemical store and a laboratory reagents store in Gombe, respectively.

Seed treatment

The seeds of each cultivar were primed in SiO_2 (20mmol/L) aqueous solution and mechanically shaken for 6 hours as described by Johnson *et al.* (28) and Deepak *et al.* (17). All Star 40DS and DE were applied as seed dressing at rates of 10 and 50 g/ 3kg seeds, respectively as described by Smiley *et al.* (49). For SiO_2 + DE treatment, seeds were dressed with DE after being primed in SiO_2. Seeds primed in water served as untreated control.

Cultural practices and management

The sites were harrowed, broadcast fertilized with 30kg N, 30kg P_20_5 and 30kg K_2O/ha, marked out and sown at 70 and 50cm inter row and intra row spacing, respectively giving a plant population of 40 stands per plot. At three weeks after sowing (WAS), the crops were hoe - weeded, thinned to 2 plants/stand and spot-fertilized at 60kg, 30kg P_2O_5/ha and 30kg K_2O/ha rate (39). At 6 WAS, the second hoe weeding was carried out and Urea was spot-applied at 30kg N/ha. At maturity, the crops were harvested, dried, threshed, weighed and expressed in kg/ha as grain yield.

Downy mildew

Disease incidence was assessed on five randomly tagged plants at 15, 30, 45, 60 and 75 days after sowing (DAS) by expressing diseased plants as a percentage of total plants assessed. Disease severity assessment was done at 75 DAS, by scoring individual plants using a 1-5 rating scale where:

1. No disease
2. Disease on nodal tillers
3. Less than 50% of the basal tillers of plant infected
4. More than 50% of basal tillers of plant infected
5. Entire plant diseased or no productive panicle

The percent disease severity on five randomly tagged plants for each plot was calculated using the following formula (infection index) =

$$\frac{y\,(1-1)+\,y(2-1)+y(3-1)+y(4-1)+y(5-1)}{Nx\,(5-1)}\,x\;100$$

Where Y= Number of plants in each category and N= Total number of plants assessed

Data Analysis

Data obtained were subjected to statistical analysis of variance (ANOVA), using coupled Microsoft excel Analyzed-it® SPSS Version 18 (4). Variation of results were considered significant at P = 0.05.

RESULTS

Downy mildew incidence did not differ significantly in the tested cultivars in Maiduguri, Gombe, and the combined analysis at 15 and 30 DAS (Table 1). At 45, 60 and 75 DAS, there was no significant difference in the incidence of downy mildew among the cultivars in Maiduguri. SOSAT-C88 had significantly lower downy mildew incidence in comparison with Ex-Borno and LCIC-7902 that were statically similar in Gombe and the combined analysis.

All treated plots recorded significantly lower disease incidence than the untreated control except for All Star at 15 and 30 DAS in Maiduguri and Gombe respectively. The disease incidence recorded on All Star treated plots was significantly the lowest and statistically at par with the SiO_2 + DE treated plots in both locations and combined at 45, 60 and 75DAS (Table 1).

The results from Gombe at 15 DAS showed that significantly lower incidence of the disease was only observed in plots treated with DE (40.83%) and All Star (41.67%) while SiO_2 and SiO_2+ DE had higher disease incidence of 64.17% and 52.92% respectively, which were not significantly different from the control (59.58%). For the combined analysis, all the treatments had significantly lower incidence of downy mildew than the untreated control (55.63%) except for treatment with SiO_2 (57.50%). Crops treated with DE (34.38%) had significantly lower disease incidence than All Star 40DS (44.79%) (Table 1).

Incidences of downy mildew on all the treated plots were statistically at par but significantly lower compared to the untreated control plots at 30 DAS (Table 1). Significantly, lower downy mildew incidence was observed on SiO_2, DE, SiO_2+DE and All Star 40DS treated plots compared to untreated control in both location and the combined analysis. All Star 40DS and SiO_2 + DE treated plots recorded the lowest disease incidence followed by those treated with SiO_2 while the control had the highest downy mildew incidence at 45DAS (Table 1).

In Maiduguri, seed treatment with All Star 40DS had the lowest downy mildew incidence, which was not significantly different from those treated with SiO_2 + DE. This is followed by crops treated with SiO_2, while the untreated control crops recorded the highest incidence. In Gombe and combine analysis, results showed that treated crops significantly recorded lower disease incidence than the untreated control crops. There was no significant difference among crops treated with All Star 40DS, SiO_2 + DE and SiO_2, however, had significantly lower disease incidence than plots treated with DE at both 60 and 75 DAS. The interaction of cultivars and seed treatments on downy mildew incidence in the combined analysis was significant at 75 DAS (Table 1).

The untreated control had the highest disease incidence in all the varieties at 75 DAS in the combine analysis. The lowest downy mildew incidence was observed in SOSAT-C88 treated with All Star 40DS which was not significantly different from all other cultivars treated with All Star, SiO_2 +DE and SiO_2 (Table 2).

There was a significant difference ($P < 0.05$) among the cultivars on downy mildew severity in Gombe and combine analysis. The untreated crops had significantly ($P < 0.05$) the highest disease severity compared with the treated crops in both locations and combine analysis. SOSAT-C88 recorded the lowest downy mildew severity than Ex-Borno and LCIC-7902 that were statistically at par. Downy mildew severity was significantly higher in the control (40.52%) followed by crops treated with DE (24.65%) while the lowest downy mildew severity was recorded on crops treated with All Star 40DS (11.24%) which was not significantly different from crops treated with SiO_2 + DE (12.48%). A similar trend of results was observed in Gombe and the combined analysis (Table 3). There was a significant interaction between cultivars and seed treatments on the disease severity in Maiduguri, Gombe and the combined analysis (Tables 3). Irrespective of the cultivar, treatment with either All Star 40DS, SiO_2 + DE or SiO_2 alone significantly ($P = 0.05$) had the lowest downy mildew severity. This was followed by SOSAT-C88 treated with DE while untreated Ex-Borno and LCIC-7902 cultivars had the highest disease severity. Similar trend was observed for effect of interactions between cultivars and seed treatments on downy mildew severity in Gombe and the combined analysis (Table 4).

Results on grain yield differ significantly ($P < 0.05$) among cultivars in both locations and combine analysis. LCIC-7902 had the highest grain yield (1826.70 Kg) than those obtained from SOSAT-C88 (1630.00 kg) and Ex-Borno (1580.00Kg) in Maiduguri. In Gombe, SOSAT-C88 recorded the highest yield of 386.50Kg while Ex-Borno had the lowest yield of 225.33 kg. Yields obtained from SOSAT-C88 (1008.30kg) and LCIC-7902 (1061.20kg) were statistically at par but significantly ($P < 0.05$) higher compared with Ex-Borno (917.70kg) in the combined analysis (Table 3).Treated crops had a significantly P < 0.05) higher grain yield compared with the untreated control in both locations and combine analysis. The highest grain yield was recorded from crops treated with All Star 40DS, which was not significantly different from those treated with SiO_2+ DE in both locations and combine analysis. The interaction between cultivars and seed treatments was significantly different in both locations (Table 3).

In Maiduguri, yields obtained from LCIC-7902 treated with All Star 40DS and SiO_2 + DE were significantly higher than those obtained from the other treatment combination except for SOSAT-C88 treated with All Star 40DS. LCIC-7902 treated with All Star 40DS had the highest grain yields (Table 5). In Gombe, the highest yields were obtained from SOSAT C88 treated with All Star 40DS followed by LCIC-7102 and SOSAT-C88 treated SiO_2 + DE. The lowest yield of 95kg/ha was recorded in the control of LCIC-7902 (Table 5).

Table 1: Effects of cultivar and seed treatment on the incidence of downy mildew of pearl millet in Maiduguri and Gombe

	15 DAS			30 DAS			45 DAS			60 DAS			75 DAS		
Treatment	M/guri	Gombe	Com	M/guri	Gombe	Com	M/guri	Gombe	Com	M/guri	Gombe	Com	M/guri	Gombe	Com
Cultivar A															
SOSAT-C88	40.50^{a}	48.50^{a}	44.50^{a}	35.75^{a}	42.00^{a}	38.88^{a}	32.10^{a}	33.25^{b}	32.68^{b}	28.50^{a}	31.25^{b}	29.88^{b}	28.50^{a}	31.25^{b}	29.88^{b}
Ex-Borno	44.75^{a}	59.75^{a}	52.25^{a}	40.75^{a}	50.00^{a}	45.38^{a}	37.50^{a}	41.75^{a}	39.63^{a}	34.90^{a}	38.00^{a}	36.45^{a}	34.90^{a}	38.00^{a}	36.45^{a}
LCIC-7902	43.00^{a}	47.25^{a}	45.13^{a}	39.50^{a}	50.75^{a}	45.13^{a}	36.50^{a}	43.25^{a}	39.88^{a}	36.00^{a}	41.50^{a}	38.75^{a}	36.00^{a}	41.25^{a}	38.63^{a}
S.E(±)	4.192	6.787	4.528	3.089	3.389	2.574	2.451	2.759	1.700	3.257	2.595	2.201	3.257	2.654	2.120
Treatment(B)															
SiO_2	50.83^{a}	64.17^{a}	57.50^{a}	40.00^{b}	44.58^{b}	42.29^{b}	32.50b^{c}	32.08b^{c}	32.29^{c}	25.42^{c}	25.42^{c}	25.42^{c}	25.42^{c}	24.58^{c}	25.00^{c}
D.E	27.92^{c}	40.83^{b}	34.38^{c}	29.58^{b}	40.83^{b}	35.21^{b}	39.17^{b}	40.00^{b}	39.58^{b}	42.50^{b}	47.08^{b}	44.79^{b}	42.50^{b}	47.50^{b}	45.00^{b}
SiO_2 + DE	35.42^{bc}	52.92^{ab}	44.17^{bc}	32.08^{b}	42.92^{b}	37.50^{b}	26.42^{cd}	34.17^{bc}	30.29^{cd}	22.08^{cd}	20.42^{c}	21.25^{cd}	22.08^{cd}	20.42^{c}	21.25^{cd}
All Star 40DS	47.92^{ab}	41.67^{b}	44.79^{b}	37.92^{b}	48.75^{ab}	43.33^{b}	21.67^{d}	27.08^{c}	24.38^{d}	14.17^{d}	19.58^{c}	16.88^{d}	14.17^{d}	19.58^{c}	16.88^{d}
Control	51.67^{a}	59.58^{a}	55.63^{a}	53.75^{a}	60.83^{a}	57.29^{a}	57.08^{a}	63.75^{a}	60.42^{a}	61.50^{a}	72.08^{a}	66.79^{a}	61.50^{a}	72.08^{a}	66.79^{a}
S.E (±)	6.931	6.656	4.949	5.921	6.272	4.180	4.946	4.005	3.080	4.495	4.068	2.931	4.495	4.064	2.943
Interaction															
A×B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*

Means within column followed by similar letter(s) are not significantly different at P = 0.05 using Duncan Multiple Range Test (DMRT).
* = Significant at P=0.05, NS= Not Significant, Com= combined analysis, M/guri= Maiduguri

Table 2: Cultivar and seed treatment interaction on the downy mildew incidence of pearl millet at 75 DAS for combined locations

	Seed treatment				
Cultivar	SiO_2	DE	SiO_2 + DE	All Star 40DS	Control
SOSAT-C88	23.75^{de}	39.38^{c}	20.00^{de}	14.38^{e}	51.88^{b}
Ex-Borno	26.25^{d}	45.63^{bc}	20.00^{de}	16.25^{de}	74.13^{a}
LCIC-7902	25.00^{d}	50.00^{b}	23.75^{de}	20.00^{de}	74.34^{a}
S.E(±)			5.029		

Means followed by similar letter(s) are not significantly different at P = 0.05 using Duncan Multiple Range Test (DMRT).

Table 3: Effects of cultivar and seed treatment on pearl millet downy mildew severity and grain yield in Maiduguri and Gombe.

	Downy mildew severity (%) at:		
Treatment	Maiduguri	Gombe	Combined
Cultivar (A)			
SOSAT-C88	18.43^{a}	24.64^{b}	21.64^{b}
Ex-Borno	21.27^{a}	28.19^{a}	24.73^{a}
LCIC-7902	22.23^{a}	31.04^{a}	26.63^{a}
S.E(±)	1.326	1.228	0.828
Treatment (B)			
SiO_2	14.33^{c}	19.21^{c}	16.77^{c}
DE	24.65^{b}	30.87^{b}	27.76^{b}
SiO_2 + DE	12.48^{cd}	16.89^{cd}	14.69^{cd}
All Star 40DS	11.24^{d}	14.09^{d}	12.67^{d}
Control	40.52^{a}	58.72^{a}	49.62^{a}
S.E (±)	1.294	1.931	1.850
Interaction			
A×B	**	*	*
	Grain yield (kg/ha) at:		
Treatment	Maiduguri	Gombe	Combined
Cultivar (A)			
SOSAT-C88	1630.00^{b}	386.50^{a}	1008.30^{a}
Ex-Borno	1580.00^{b}	255.33^{c}	917.70^{b}
LCIC-7902	1826.70^{a}	295.67^{b}	1061.20^{a}
S.E (±)	67.969	15.783	35.941
Treatment (B)			
SiO_2	1761.10^{b}	338.61^{b}	1049.90^{ab}

DE	1533.30[c]	255.56[c]	894.40[b]
SiO_2+ DE	1866.70[ab]	397.78[a]	1132.20[a]
All Star 40DS	1966.70[a]	413.33[a]	1190.00[a]
Control	1266.70[d]	157.22[d]	711.90[b]
S.E(±)	55.175	20.259	224.890
Interaction			
A×B	*	***	NS

At each location, means followed by similar letter(s) are not significantly different at P = 0.05 and 0.001 using Duncan Multiple Range Test (DMRT). * =Significant at P = 0.05, ***= significant at P = 0.001

Table 4: Cultivar and seed treatment interaction on downy mildew severity of pearl millet in Maiduguri and Gombe.

Cultivar	Maiduguri				
	SiO_2	DE	SiO_2 + DE	All Star 40DS	Control
SOSAT-C88	14.29[e]	20. 31[d]	13.10[e]	11.57[e]	32.87[b]
Ex-Borno	13.33[e]	27. 01[c]	11.76[e]	10.89[e]	43.37[a]
LCIC-7902	15.36[de]	26.61[c]	12.59[e]	11.26[e]	45.30[a]
S.E (±)			2.404		
			Gombe		
Cultivar	SiO_2	DE	SiO_2 + DE	All Star 40DS	Control
SOSAT-C88	17.71[fg]	25.36[de]	16.33[fg]	14.43[fg]	49.39[b]
Ex-Borno	19.00[efg]	31.70[cd]	16.74[fg]	12.95[g]	60.55[a]
LCIC-7902	20.92[ef]	35.55[c]	17.60[fg]	14.90[fg]	60.22[a]
S.E (±)			3.233		
	Combined locations (Maiduguri and Gombe)				
Cultivar	SiO_2	DE	SiO_2 + DE	All Star 40DS	Control
SOSAT-C88	16.00[ef]	22.83[d]	14.71[ef]	13.00[ef]	41.13[b]
Ex-Borno	16.16[ef]	29.36[c]	14.25[ef]	11.92[f]	51.96[a]
LCIC-7902	18.14[e]	31.08[c]	15.10[ef]	13.08[ef]	55.76[a]
S.E (±)			2.983		

At each location, means followed by similar letter(s) are not significantly different at P = 0.05 using Duncan Multiple Range Test (DMRT).

Table 5: Cultivar and seed treatment interaction on pear millet grain yield in Maiduguri and Gombe

Cultivar	Maiduguri				
	SiO_2	DE	SiO_2 + DE	All Star 40DS	Control
SOSAT-C88	1716.70[de]	1433.30[fg]	1866.70[bcde]	1966.70[abc]	1166.70[h]
Ex-Borno	1716.70[de]	1416. 70[g]	1700.00[de]	1783.30[cde]	1350.00[gh]
LCIC-7902	1916.70[bcd]	1750.00[cde]	2033.30[ab]	2150.00[a]	1283.30[gh]
S.E (±)		109.210			
			Gombe		
Cultivar	SiO_2	DE	SiO_2 + DE	All Star 40DS	Control
SOSAT-C88	355.83[cd]	326.67[cde]	438.33[b]	566.66[a]	245.00[fg]
Ex-Borno	270.00[efg]	210.00[g]	315.00[def]	350.00[cd]	131.67[h]
LCIC-7902	390.00[bc]	230.00[g]	440.00[b]	323.33[cde]	95.00[h]
S.E(±)		35.089			

At each location, means followed by similar letter(s) are not significantly different at P = 0.05 using Duncan Multiple Range Test (DMRT).

DISCUSSION

This study has demonstrated the role of cultivar and silicon sources on the management of downy mildew in pearl millet. The lowest downy mildew incidence observed to be sustained by SOSAT-C88 cultivar throughout the season in Gombe and combine analysis has further validates its resistance against the pathogen (23). The susceptibility of Ex-Borno to downy mildew incidence throughout the season in both locations implies the breakdown of its resistance to *S. graminicola.* High pathogenic varying nature of *S. graminicola* that quickly overcomes the host resistance in pearl millet hybrids have been reported (8, 51, 26, 32). Downy mildew incidence was observed to progressively reduce on crops treated with SiO_2 alone throughout the season, which might suggest its ability to confer recovery resistance in the crops. Several studies have documented the ability of silicon to control and reduce the incidence and severity of fungal diseases in both cereals and legumes (19, 9, 12, 46). The prophylactic role of Si has been related to its accumulation in the leaves, which creates a physical barrier to pathogens (45) or may have a more active role by inducing the plant's own defense mechanisms (43, 41, 42, 20). Chemical resistance was reported to be the main form of resistance induced in crops by Si, which involves chemical defenses to pathogen attack through the enhanced production of defensive enzymes and the production of antifungal compounds such as phenolic metabolism products, phytoalexins and pathogenesis related proteins (55). The ability of Si to enhanced resistance to powdery mildew in cucumber (*Cucumis sativus*) by increasing antifungal activity in the plant has been demonstrated by Fawe *et al.* (21). It was similarly reported by Liang et al. (31) and Rodrigues et al. (42) that root application of Si enhances the activity of pathogenesis-related (PR) proteins thereby increasing resistance to pathogen attack on cucumber and rice (*Oryza sativa*) plants, respectively.

However, crops treated with sole DE had the lowest disease incidence only at first 15 DAS of plant growth. Application of Si to the soil mix or added to the nutrient solution was found to protected wheat (*Triticum aestivum*) from powdery mildew (10). Sole application of DE probably protected the crops against the initial inoculum of the pathogen but could not check subsequent infections due to secondary inoculum build-up. The solubility and availability of Si for plant absorption in soils occur at higher pH above 8.0 (29, 30) which was plausibly influenced by application of fertilizer and in turn affected the solubility of DE in the study.

Crops treated with All Star 40DS and combination of SiO_2 and DE (SiO_2 + DE) maintained the lowest disease incidence throughout the growth period of the plant in comparison to those treated with either SiO_2 or DE alone. It could be interpreted here that DE as a component of seed treatment protected the seed and seedlings from the initial inoculum of downy mildew pathogen while SiO_2 in turn checked subsequent infections of the plant by the pathogen as it developed. The combination of SiO_2 and DE as a single seed treatment gave a complementary protection thereby suppressing the disease incidence at all stages of plant’s growth and development. All Star 40DS showed both contact and systemic protection to crops against the disease pathogen, which was also confirmed by Anaso (5); Gwary *et al.* (25); Esptein, (18) and Ma and Yamaji (33). On a general note, the study indicatess that seed treatment with SiO_2, SiO_2 + DE and All Star 40DS showed a progressive reduction of downy mildew incidence with increase in plant growth while DE alone showed a decrease in plant disease incidence due probably to its inability to offer systemic protection to crops against the pathogen.

This study further indicated that downy mildew incidence was generally higher in Gombe than in Maiduguri. This could be attributed to higher rains in Gombe and possible variation in pathotype of the pathogen (26). Thakur *et al.* (54) have reported the variation in pathotypes of downy mildew in different locations.

The combined effect of each of the cultivar with any of SiO_2, SiO_2 + DE and All Star treatment influenced the suppression of downy mildew incidence superior to the control. This agrees with earlier work of Anon (7) who reported that integration of host plant resistance, seed treatments and good cultural practices favours effective control of downy mildew in pearl millet.

The finding of the present study also, indicates that application of All Star 40DS and SiO_2 + DE had the best suppression of downy mildew severity. The efficacy of SiO_2 and other silicon sources in suppressing downy mildew incidence and severity in crops have been reported (38, 17). Sadgrove, (44) reported that DE has the potential of combating both biotic and abiotic stresses in crops. Aliyu *et al.* (2) also confirmed the effectiveness of metalaxyl in suppressing the incidence and severity of downy mildew in pearl millet. Interaction between cultivar and seed treatment on downy mildew severity in Maiduguri showed that irrespective of the cultivar, the disease was less severe on crops treated with All Star 40DS, SiO_2 and SiO_2 + DE. Downy mildew being a polycyclic disease with the compound interest mode of infection (48) tends to have higher incidence and severity on the secondary (basal) tillers, which could have been suppressed by all the seed treatments compared to the control. The observed variation on grain yield between Ex-Borno and SOSAT-C88 in the two locations could probably be due to environmental (climatic and edaphic) factors (27, 1). From the study, efficacy of All Star 40DS, SiO_2, DE and their interactions with pearl millet cultivar was observed to increase crop yield due to their ability to suppress fungal diseases which have also been reported in cereal crops (15, 17, 3, 2). This indicates that when incidence and severity of downy mildew were suppressed, the yield of pearl millet increases.

CONCLUSION

It can be concluded that application of SiO_2 + DE and use of SOSAT-C88 cultivar have proven to be effective in suppressing the incidence and severity of downy mildew. SiO_2 + DE can therefore be used as an option for the management of downy mildew in pearl millet as they are cost-effective, available and eco-friendly.

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