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Eco friendly management of pearl millet downy mildew (*Sclerospora graminicola*) by using organic compounds

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Abstract
Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an important cereal and forage crop of arid and subtropical regions of the Indian subcontinent as well as several African regions. Downy mildew (DM) or 'green ear' disease caused by *Sclerospora graminicola* (Sacc.) Schroet. occurs most destructively in Asia and Africa. The first epidemic of downy mildew occurred in 1971 on the first popular pearl millet hybrid, HB 3, resulting in severe grain loss of about 4.6 million metric tonnes. Eco friendly management components were evaluated at Main Pearl Millet Research Station, JAU, Jamnagar (Gujarat) during *kharif* 2021 and *kharif* 2022 for minimize downy mildew disease incidence. Total five seed treatments [(*Trichoderma harzianum (JAU* @ 8 g/kg), PSB formulation (PSB 8 g/kg), neem oil (3%) and metalaxyl (6 g/kg)] including check were tested. Minimum percent downy mildew incidence recorded in standard check Metalaxyl (11.79%) which was at par with *T. harzianum* (12.58%) and PSB formulation (13.12%). Same trends observed in grain yield, maximum grain yield found in standard check Metalaxyl (2051 kg/ha) which was at par with *T. harzianum* (1966 kg/ha) and PSB formulation (1941 kg/ha). While maximum fodder yield recorded in Metalaxyl (39.02 q/ha) which was at par with *T. harzianum* (38.75 q/ha), PSB formulation (35.84 q/ha) and neem oil (34.64 q/ha).

Keywords: Downy mildew, pearl millet, *Trichoderma harzianum*, Metalaxyl

Introduction
Pear millet (*Pennisetum glaucum* (L.) R. Br.), a crop of international importance, is indigenous to areas in North Africa (D' Andrea *et al.*, 2001) [2]. Pearl millet is a cereal crop that thrives in the arid and semi-arid tropical regions of Asia and Africa. This highly nutritious crop is a staple food for poor farming communities. It is a short day C4 type warm weather crop and is the most drought tolerant warm season cereal grown in the harsh, arid and dry-semi-arid tropical environments of South Asia and sub-Saharan Africa. It is more tolerant to high temperatures than any other cereals. The best temperature for the germination of pearl millet seed is from 23 to 32 °C. The optimum rainfall requirement of pearl millet ranges between 400-800 mm and it can also be successfully grown in areas that receive less than 400 mm of annual rainfall. In Gujarat it is an important food and fodder crop as it is fourth in terms of area after rice, wheat and maize and third after wheat, rice and maize in terms of production. It is an important staple food for the people of arid and semi-arid regions of the state *viz*, North Gujarat, Kutch and Saurashtra. It is cultivated by Gujarat farmers in 3 different seasons' *viz*., *kharif*, semi-rabi and summer. Realizing the importance of Bajra as an important food crop, Government of Gujarat initiated "Bajra Research Scheme" in the year 1962 identifying Jamnagar as the main research station. Jamnagar has the ideal environment for raising Pearl Millet crop thrice in a year which is a boon for enhancing the breeding cycle in the crop improvement research. Many diseases of pearl millet have been described worldwide (Wilson, 2000) [9], however, catastrophic fungal diseases had not been known before Indian pandemic caused by downy mildew in 1985. The disease was known in most of the pearl millet growing areas but it remained sporadic until introduction of high yielding hybrids with susceptible parent line (Singh, 1995) [5]. The causative agent *Sclerospora graminicola* (Sacc.) Schroet. originally described from Europe (Schroeter, 1879) [4], was probably introduced into new areas in infected seeds various weeds contaminating grains (Weston, 1928) [7]. Pearl millet downy mildew recently is distributed worldwide and one of the most important diseases causing losses up to 60% of grain yield (Nene and Singh, 1976) [3]. *Sclerospora graminicola* (Sacc.) Schroet, incitant of downy mildew of pearl millet, is an obligate parasite, belonging to family Peronosporaceae, orders Peronosporales. Downy mildew of pearl millet was first reported by Butler in India and described it the disease of ill-drained lands where it developed into epidemics of severity (Butler, 1907) [1].

The disease was considered with minor importance till 1970, as its incidence was sporadic on local cultivars. The first epidemic of downy mildew occurred in 1971 on the popular pearl millet hybrid HB-3, resulting in severe grain loss of about 4.6 million metric tonnes (Singh, 1995) [5]. Genetically uniform single-cross F1 hybrid cultivars generally become susceptible more rapidly than heterogeneous open-pollinated varieties (Thakur *et al.*, 2006) [6] leading to heavy production losses. Downy mildew severity reached epidemic levels in India during the mid-1970s to 1980s when only a few single cross hybrids were cultivated on a large scale. Like other oomycetes, *Sclerospora graminicola* has a complex disease cycle where developmental forms differ in physiology and anatomy along with different impacts on host-parasite interactions, survival and distribution in space and time. The disease can efficiently be managed with the systemic fungicide metalaxyl. However, looking to the acquired tolerance to metalaxyl in recent past a need to search for new organic compounds which was remain parallel or best effective managed downy mildew incidence. *i.e.* seed treatment with organic agent to take care of external seed borne inoculum. The present study was carried out to evaluate different orgnic compounds as an alternative substitute to metalaxyl for the management of pearl millet downy mildew.

Material and Methods

Field experiments were conducted during *kharif* 2021-22 and *kharif* 2022-23 at Pearl Millet Research Station, JAU, Jamnagar to find out the effective organic compounds for minimize downy mildew disease incidence. Experiment conducted in sick plot with randomized block design (RBD) each having four replications. The plot size was 4.2 m × 2.4 m and distance between row to row and plant to plant was 60 cm and 10 cm respectively. Four line were maintained in each treatment (plot). Total five treatments [(*Trichoderma harzianum* (*JAU* @ 8 g/kg), PSB formulation (PSB 8g/kg), neem oil (3%) and metalaxyl (6g/kg)] including control was used as seed treatment. Seed treatment was carried out for management of pearl millet downy mildew. Seed treatment was given at the time of sowing. The observations on total number of plants and plants infected with downy mildew were recorded at 60 DAS.

Percent disease incidence (PDI) will be calculated by using the following formula (Wheeler, 1969) [8].

$$\text{Disease incidence (\%)} = \frac{\text{No. of diseased plants}}{\text{Total number of plants}} \times 100$$

Results and Discussion

Different organic compounds *i.e. Trichoderma harzianum* (*JAU* @ 8 g/kg), PSB formulation (PSB 8 g/kg) and neem oil (3%) including chemical fungicide metalaxyl (6g/kg) and control were evaluated for management of downy mildew. Downy mildew incidence at 60 days after sowing, grain yield (kg/ha) and fodder yield (kg/ha) were recorded in both season *kharif*-2021 and *kharif*-2022. Amongst different treatments, minimum downy mildew incidence at 60 DAS was recorded in metalaxyl 35 SD (10.91%) which was near to seed treatment of PSB formulation (11.08%) and *Trichoderma harzianum* (12.83%) in *kharif* 2021. While in *kharif* 2022 minimum downy mildew incidence recorded in same as previous in metalaxyl 35 SD (12.67%) which was at par with *T. harzianum* (12.33%) and PSB formulation (15.16%). Significant difference observed in both years polled data, minimum downy mildew incidence recorded in metalaxyl 35 SD (11.79%) which was at par with *T. harzianum* (12.58%) and PSB formulation (13.12%). Maximum (18.09%) downy mildew incidence recorded in control (Table 1 and Fig. 1).

For grain yield, significant difference observed among the treatments in both years individual as well as pooled data. In *kharif* 2021 maximum grain yield recorded in metalaxyl 35 SD (2177 kg/ha) which was at par with *T. harzianum* (1995 kg/ha) and PSB formulation (1981 kg/ha). In *kharif* 2022 maximum grain yield recorded in *T. harzianum* (1937 kg/ha), which was at par with all treatment, metalaxyl 35 SD (1925 kg/ha), PSB formulation (1901 kg/ha) and neem oil (1812 kg/ha). Control treatment recorded minimum grain yield (1274 kg/ha). In relation to pooled data, maximum maximum grain yield recorded in metalaxyl 35 SD (2051 kg/ha) which was at par with *T. harzianum* (1966 kg/ha) and PSB formulation (1941 kg/ha). Control treatment recorded minimum grain yield (1317 kg/ha) (Table 2 and Fig. 2).

In fodder yield pooled data, maximum fodder yield recorded in metalaxyl 35 SD (39.02 q/ha), which was at par with *T. harzianum* (38.75 q/ha), PSB formulation (35.84 q/ha) and neem oil (34.64 q/ha). Control recorded minimum (31.60 q/ha) fodder yield (Table 3 and Fig. 3).

Table 1: Effect of organic compounds on downy mildew disease incidence (%) at 60 DAS of pearl millet

Sr. No.	Treatments		Disease incidence (%)		Pooled mean
			2021-22	2022-23	
1	*Trichoderma harzianum* (*JAU* @ 8 g/kg)		20.99** (12.83)*	20.55** (12.33)*	20.77** (12.58)*
2	PSB formulation (PSB @ 8 g/kg)		19.45 (11.08)	22.91 (15.16)	21.18 (13.12)
3	Neem Oil (3%)		21.54 (13.48)	24.17 (16.76)	22.86 (15.12)
4	Metalaxyl 35 SD (6 g/kg)		19.28 (10.91)	20.85 (12.67)	20.07 (11.79)
5	Control (Untreated)		23.66 (16.11)	26.61 (20.06)	25.14 (18.09)
	Y	S.Em. ±			0.47
		CD at 5%			1.38
	T	S.Em. ±	0.99	1.12	0.75
		CD at 5%	NS	3.44	2.18
		CV%	9.46	9.71	9.61
	Y × T	S.Em. ±	-	-	0.16
		CD at 5%	-	-	NS

**Data were transformed (Arcsine) prior to analysis, *Data given in parentheses are retransformed values, Y = Year, T = Treatment,

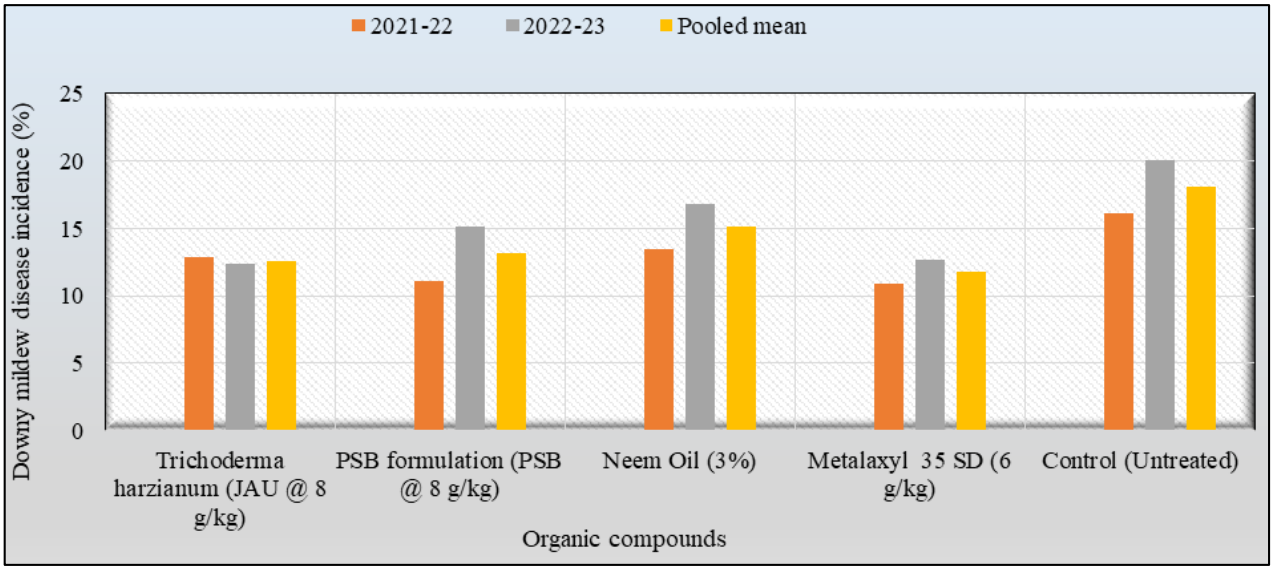

Fig 1: Downy mildew disease incidence at 60 DAS

Table 2: Effect of organic compounds on grain yield of pearl millet at maturity

Sr. No.	Treatments		Grain yield (kg/ha)		Pooled mean
			2021-22	2022-23	
1	*Trichoderma harzianum* (*JAU* @ 8 g/kg)		1995	1937	1966
2	PSB formulation (PSB @ 8 g/kg)		1981	1901	1941
3	Neem Oil (3%)		1540	1812	1676
4	Metalaxyl 35 SD (6 g/kg)		2177	1925	2051
5	Control (Untreated)		1361	1274	1317
	Y	S.Em. ±			40.60
		CD at 5%			NS
	T	S.Em. ±	68.36	108.67	16.19
		CD at 5%	210.67	334.88	187.38
		CV%	7.55	12.28	10.14
	Y × T	S.Em. ±	-	-	90.78
		CD at 5%	-	-	NS

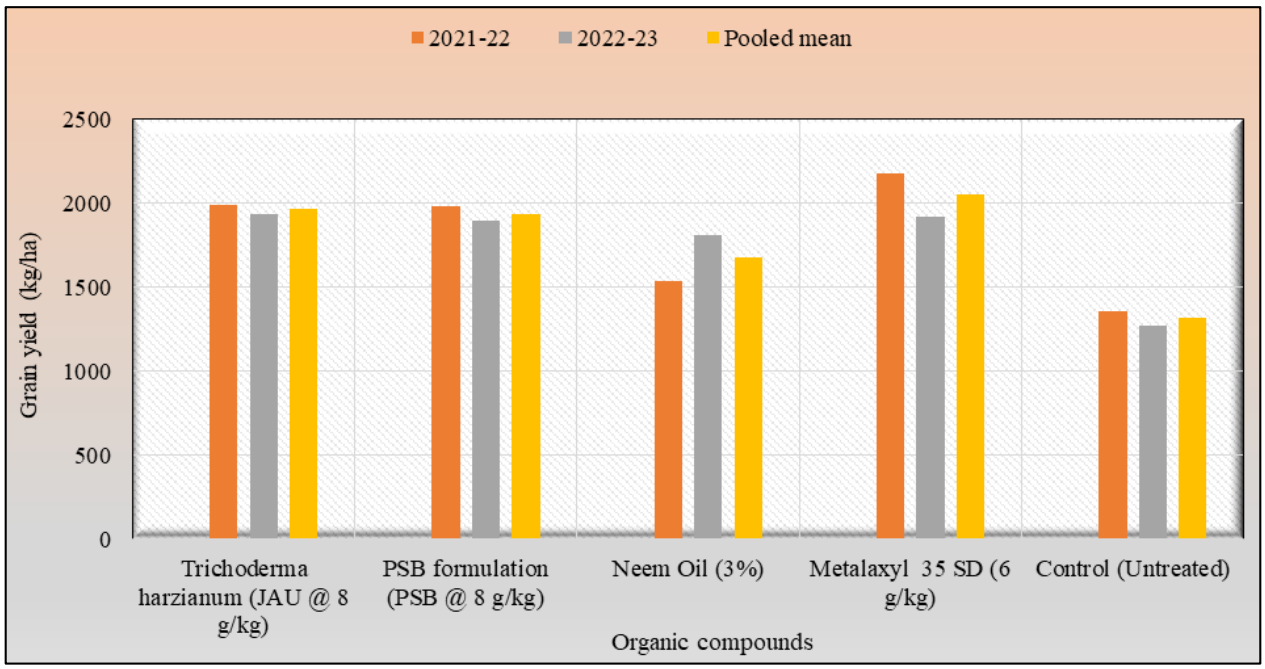

Fig 2: Effect of organic compounds on grain yield

Table 3: Effect of organic compounds on fodder yield of pearl millet at maturity

Sr. No.	Treatments		Fodder yield (kg/ha)		Pooled mean
			2021-22	2022-23	
1	*Trichoderma harzianum* (*JAU* @ 8 g/kg)		34.19	43.31	38.75
2	PSB formulation (PSB @ 8 g/kg)		34.96	36.72	35.84
3	Neem Oil (3%)		32.01	37.27	34.64
4	Metalaxyl 35 SD (6 g/kg)		37.69	40.34	39.02
5	Control (Untreated)		26.98	36.22	31.60
	Y	S.Em. ±			1.02
		CD at 5%			2.97
	T	S.Em. ±	1.40	2.89	1.61
		CD at 5%	4.31	NS	4.69
		CV%	8.43	14.93	12.64
	Y × T	S.Em. ±			2.27
		CD at 5%			NS

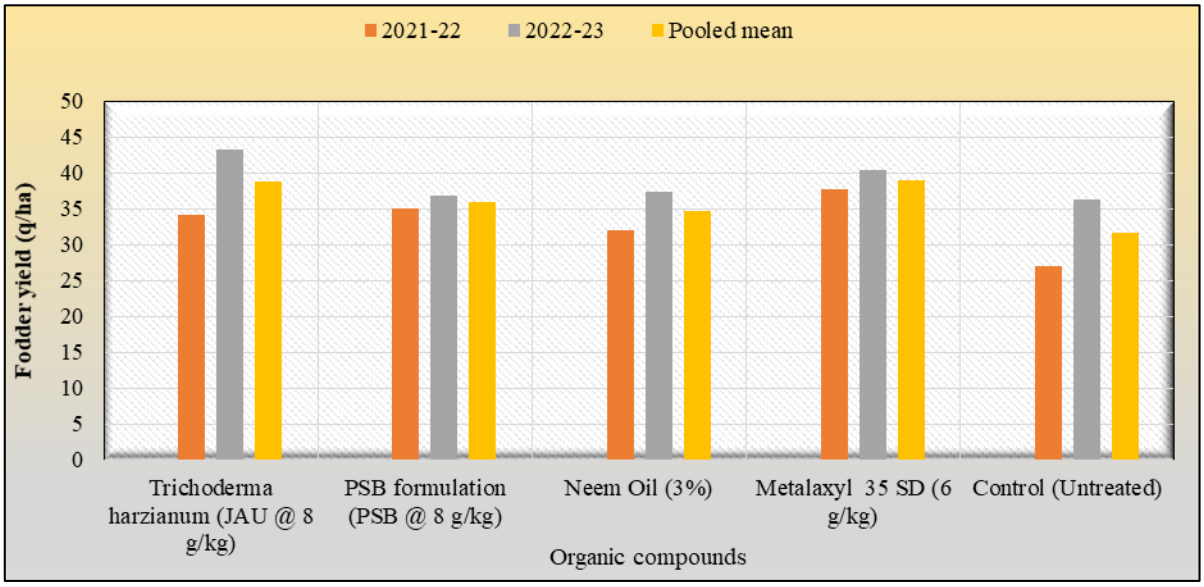

Fig 3: Effect of organic compounds on foddern yield

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