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Antifungal Bioefficacy of Organic Inputs Against Fungal Pathogens of Bell Pepper

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ABSTRACT

Five organic inputs namely panchgavya, vermiwash, biosol, cow urine and butter milk were evaluated against major pathogens of bell pepper namely Colletotrichum capsici, Phytophthora nicotianae, Sclerotium rolfsii, Fusarium solani, Fusarium oxysporum f.sp. capsici, Sclerotinia sclerotiorum and Rhizoctonia solani under in vitro and in vivo conditions. Under in vitro conditions, all inputs were tested at five concentrations ranging from 2.0 to 10.0 percent. Among these inputs, fermented cow urine showed maximum 100 and 99 percent inhibition in the mycelial growth of the test pathogens at 10 percent concentration followed by panchgavya exhibited complete mycelia inhibition of S. sclerotiorum and 99.0 percent inhibition in mycelia growth of S. rolfsii, F. solani and P. nicotianae. Similarly, vermiwash and biosol showed moe than 99.0 percent mycelia inhibition of all tested pathogens. Whereas, comparatively less inhibition was observed in case of fermented butter milk. Under in vivo conditions, all organic inputs were evaluated individually and in combinations against foliar pathogens and soilborne pathogens of bell pepper separately. Among all treatments, a combination of panchgavya (5%) + fermented cow urine (5%) caused maximum 87.02 percent control of phytophthora blight followed by anthracnose (85.22%) when applied as foliar spray at 15 days interval. Whereas, biosol (5%) + fermented cow urine (5%) showed 83.91 percent disease control of anthracnose. In case of soilborne diseases, drench with panchgavya (5%) + fermented cow urine (5%) exhibited maximum 88.04, 84.98 and 84.25 percent disease control of fusarium wilt, stem rot and root rot respectively.

KEYWORDS Bell pepper, organic inputs, fungal pathogens, microbes

INTRODUCTION

Bell pepper (Capsicum annuum L. var. grossum Sendt.), is one of the most important off-season vegetable of Himachal Pradesh (India) and offers potential for boosting economy of farmers of hilly regions. It is a warm season and chilling sensitive crop. It is affected by various diseases viz., anthracnose (Colletotrichum capsici (Synd.) Butler and Bisby), fruit rot (Phytophthora nicotianae Breda de Haan), powdery mildew (Leveillula taurica (Lev.) Arn.), stem rot (Sclerotium rolfsii Sacc.), wilt (Fusarium oxysporum (Schlect.) emend. Synd. and Hans. f.sp. capsici Riv.) and root rot (Rhizoctonia solani Kuhn) which affect the yield and quality of the produce, thereby reducing the profit margin of producers (Ochigbo & Harris, 1989). Anthracnose is one of the most important diseases of bell pepper causing yield losses upto 50 percent followed by phytophthora blight and fusarium wilt that also cause huge reduction in fruit yield (Erwin & Ribeiro, 1996; Pakdeevaraparn et al., 2005).

Although a large number of fungicides have been reported effective against these pathogens globally, but recurrent and inadequate use of specific chemicals over the years has led to the development of resistant strains, destruction of natural predators and parasites, appearance of new toxicant tolerant pathogen races (Corke, 1980), environmental contamination and health hazards (Okigbo & Ogbonnaya, 2006; Brimmer & Boland, 2003). On account of various hazardous effects, the alternate and environment friendly plant protection measures like use of organic inputs and animal products such as vermiwash, panchgavya, biosol, cow urine and fermented butter milk for cultivation of their crops. The use of traditional organic inputs is also described in Vedas, Arthashastra, Agnipuran, Surapalas Vrukshayurveda (Nene, 2003; Sadhale, 1996).

Various organic composts showed antifungal activity against soil borne and foliar pathogens. Aqueous extracts of vermicompost and organic compost inhibited the mycelial growth of Botrytis cinerea, Sclerotinia sclerotiorum, Sclerotium rolfsii, Rhizoctonia solani and Fusarium oxysporum f.sp. lycopersici in vitro (Nakasone et al., 1999).

Sugha (2005) evaluated the antifungal potential of panchgavya against R. solani, S. rolfsii, F. solani, S. sclerotiorum and Phytophthora colocasiae and advocated that the mycelial bits dipped for 6 h in panchgavya caused complete suppression of mycelial growth of R. solani and in other pathogens, the growth inhibition ranged between 88.1-92.3 per cent. Dogra (2006) observed the antifungal activity of panchgavya against major soil borne pathogens viz. F. solani f.sp. pisi, F. oxysporum f.sp. pisi, R. solani, S. solfsii and S. sclerotiorum. Mycelial bits dipped for 12 h in panchgavya caused more than 90 per cent inhibition of F. oxysporum f.sp. pisi and F. solani f.sp. pisi and 100 per cent inhibition of S. rolfsii, S. sclerotiorum and R. solani.

Basak and Lee (2005) conducted the experiment to study the efficacy and in vitro activities of cow urine and dung for controlling wilt caused by F. oxysporum f.sp. cucumerinum of cucumber and F. solani f.sp. cucurbitae. Cow dung solution showed 80-84 per cent inhibition of wilt pathogens and cow urine showed 100 per cent inhibition of wilt pathogens.

Fresh cow dung, urine, milk and cow dung based preparations namely cow dung slurry, dried powder and ash were evaluated against R. solani causing damping-off of okra and root rot of pea pathogens. Complete inhibition in mycelial growth was obtained by amending potato dextrose agar with cow dung and cow dung ash @ 5 g/100 ml medium followed by cow dung powder (0.5 mm radial mycelial growth) (Ashlesha et al., 2009). Out of twelve organic inputs tested, eight inputs viz. biosol, matka khad, agnihotra ash + cow urine, panchgavya, vermicompost, cow pat pit compost, NADEP compost and bio-

dynamic compost showed 60.2-100 per cent inhibition in mycelial growth of S. sclerotiorum without autoclaving (Shalika, 2009).

Sinha et al. (2010) studied the antifungal properties of vermicompost and vermiwash against soil borne pathogens (Pythium ultimum, R. solani and Fusarium sp.) and recorded 51-72 per cent inhibition in mycelial growth of pathogens. Sang et al. (2010) reported the reduction in mycelial growth of Phytophthora capsici and Colletotrichum coccodes in pepper and C. orbiculare in cucumber by water extracts of compost.

Joseph and Sankarganesh (2011) studied the antifungal activity of panchgavya and cow urine against soil borne pathogens. Sreenivasa and Naik (2011) observed 92.1 and 57.3 per cent inhibition in mycelial growth of Fusarium sp. at 15 and 20 per cent concentrations of cow urine in vitro.

Thus, the present study was planned to identify the antifungal properties of organic inputs against capsicum pathogens under in vitro and in vivo conditions.

MATERIALS AND METHODS

Isolation, purification and maintenance of test pathogens:
Pathogens of bell pepper viz., S. rolfsii, F. solani, F. oxysporum, C. capsici, P. nicotianae, S. sclerotiorum and R. solani were isolated from diseased plant parts using standard methodology on potato dextrose agar (PDA) medium. Small bits of infected tissues were surface sterilized by dipping in a solution of 0.1 per cent mercuric chloride for 10-15 seconds and washed thrice in sterilized water under laminar air flow. The bits were dried under two folds of sterilized filter papers and transferred to PDA slants. The tubes were incubated at 25 + 1°C for 7-8 days and purified by single spore/hyphal tip method. Pure cultures were maintained on PDA slants. Seven days old actively growing cultures of pathogens in Petri plates were used for studying antifungal properties.

Preparation of organic inputs:
Different organic inputs were prepared and evaluated at Model Organic Farm, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur.

Table 1: Different traditional organic inputs and method of praparation

Sr. No.	Organic Input	Ingredients used and their quantities	Method of Preparation	Photograph
1.	Vermiwash	Earthen pitcher = Three of 20 L capacity Cow dung = 12-15 kg Earthworms = 100-200 Nos Rubber pipe = 1mt long	In the first pitcher having a small hole at the base, put some dry grass at the bottom and then place a 15 - 20 cm layer of 2 - 3 weeks old cow dung on the dry grass. Put 100 - 200 earthworms on the cow dung and again covered with dry grass. The pitcher is hanged with some rope at suitable height under shade of a tree. In second pitcher full of water, a hole is made at the base and a small stick is inserted in such a way that water come out drop by drop. This pitcher is hanged over the first pitcher. The water coming from second pitcher fall drop by drop into the first pitcher and liquid substance coming from the first pitcher is collected with the help of a pipe in third pitcher placed at the ground level.	
2.	Panchgavya	Cow dung = 1kg (fresh) Cow dung slurry = 4 kg Cow urine = 3L Cow milk = 2L (fresh) Curd = 2kg Cow butter oil = 1kg (ghee)	It is a blend of 5 products obtained from cow mainly its dung, urine, milk, ghee and curd. For making Panchgavya, thoroughly mix the required quantities of the ingredients and allow to ferment for 7 days with twice stirring per day.	
3.	Biosol	Vermicompost=90kg Cow dung = 75kg Cow urine = 10L Agnihotra ash=250g Water = 200L Shri Yantra = 1	Dissolve 250g agnihotra ash in 200L water for 24 hours. Next day, take biodigester of 1000L capacity and add all ingredients except Shri yantra and mix well with wooden stick. Then hang the yantra at the top of container and air tight the lid. Allow it to ferment under anaerobic conditions for 65-60 days. For release of gases, keep one small outlet at the bottom of container.	
4.	Fermented cow urine	Cow urine = 10L Water = 20L	Mix fresh cow urine and water, allow it to ferment for 15 days and then use.	
5.	Fermented butter milk	Butter milk = 1L (Fresh) Water = 20L Cow urine = 500ml	Mix all the three ingredients in a pot and allow to ferment for 15 days.	

showed the standardized techniques of preparing the traditional organic inputs namely panchgavya, vermiwash, biosol, fermented cow urine and fermented butter milk.

In vitro evaluation of organic inputs: Organic inputs were tested by poisoned food technique (Falck, 1907) with and without auto-

claving at 2.0, 4.0, 6.0, 8.0 and 10.0 per cent concentrations. Desired concentrations of organic inputs were mixed with equal quantity of double strength sterilized PDA and poured aseptically in sterilized Petri plates. Medium mixed with equal quantities of distilled sterilized water without any treatment served as control. Seven days old mycelial bits (5 mm) of test pathogens were placed in centre of plates and incubated at 25 + 1°C. The experiment was repeated thrice and five replications per treatment were maintained. Data on mycelial growth were recorded when check plates were fully covered with mycelial growth test pathogens and per cent inhibition in mycelial growth was determined following McKinney (1923)

$$I = \frac{C - T}{C} \times 100$$

where, I = % inhibition
C = mycelial growth in check (cm)
T = mycelial growth in treatment (cm)

Evaluation of organic inputs under field conditions: Field trials were conducted at the experimental farm Department of Organic Agriculture during Kharif seasons of 2011 and 2012, to evaluate the role of various organic inputs and their combinations in the management of anthracnose (Colletotrichum capsici), fruit rot (Phytophthora nicotianae), stem rot (Sclerotium rolfsii), wilt (Fusarium oxysporum f.sp. capsici) and root rot (Rhizoctonia solani) of bell pepper with variety Bharat. Separate trials were conducted for foliar and soil borne pathogens with ten treatments. The experiments were laid out in randomized block design (RBD) and replicated thrice. Disease progress in time was studied by recording the disease severity from appearance of first disease symptoms at weekly intervals and average of two years was calculated.

Statistical analysis:
The data collected during the course of these investigations were subjected to appropriate statistical analysis, wherever necessary using standard procedure after using arc sine transformation (Gomez & Gomez, 1984). Transformed values of each treatment mean have been put in parentheses. The significance of difference was tested at five per cent level of probability and antifungal activity of pathogens was analyzed by analysis of variance (ANOVA).

RESULTS
In vitro evaluation of organic inputs: Results presented in

Table 2(a): Effect of vermiwash on mycelial growth of pathogens of bell pepper*

Conc. (%)	Rhizoctonia solani		Sclerotium rolfsii		Fusarium solani		Fusarium oxysporum f.sp. capsici		Colletotrichum capsici		Phytophthora nicotianae		Sclerotinia sclerotiorum	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
2	9.34	85.31	12.24	80.74	9.73	84.69	16.04	74.77	5.72	91.00	1.18	98.14	0.0	100.0
4	8.54	86.57	10.34	83.73	9.18	85.56	12.68	80.06	3.46	94.56	0.95	98.50	0.0	100.0
6	8.03	87.37	9.45	85.14	7.64	87.98	9.07	85.73	2.83	95.55	0.71	98.88	0.0	100.0
8	5.59	91.21	8.54	86.57	6.83	89.26	6.83	89.26	2.60	95.91	0.64	98.99	0.0	100.0
10	4.52	92.89	5.94	90.66	3.86	93.93	4.91	92.27	1.65	97.40	0.60	99.06	0.0	100.0
Check	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0
CD (p=0.05)	0.10	-	0.26	-	0.16	-	0.23	-	0.15	-	0.18	-	0.17	-

Table 2(b): Effect of panchgavya on mycelial growth of pathogens of bell pepper*

Conc. (%)	Rhizoctonia solani		Sclerotium rolfsii		Fusarium solani		Fusarium oxysporum f.sp. capsici		Colletotrichum capsici		Phytophthora nicotianae		Sclerotinia sclerotiorum	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
2	13.19	79.25	3.29	94.82	24.79	61.01	13.65	78.53	9.07	85.73	2.27	96.43	0.0	100.0
4	9.18	85.56	1.58	97.51	20.82	67.25	13.32	79.05	6.69	89.47	1.65	97.40	0.0	100.0
6	8.81	86.14	0.53	99.16	15.34	75.87	11.04	82.63	5.51	91.33	1.13	98.22	0.0	100.0
8	4.98	92.16	0.19	99.70	5.51	91.33	5.81	90.86	5.38	91.54	0.86	98.65	0.0	100.0
10	2.98	95.31	0.17	99.73	0.66	98.96	4.52	92.89	1.33	97.91	0.82	98.71	0.0	100.0
Check	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0
CD (p=0.05)	0.23	-	0.60	-	0.12	-	0.76	-	0.42	-	0.28	-	0.16	-

Table 2(c): Effect of biosol on mycelial growth of pathogens of bell pepper*

Conc. (%)	Rhizoctonia solani		Sclerotium rolfsii		Fusarium solani		Fusarium oxysporum f.sp. capsici		Colletotrichum capsici		Phytophthora nicotianae		Sclerotinia sclerotiorum	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
2	14.99	76.42	12.37	80.54	4.15	93.47	6.38	89.96	8.14	87.19	1.71	97.31	0.0	100.0
4	12.25	80.73	10.57	83.37	4.05	93.63	6.28	90.12	7.16	88.73	1.65	97.40	0.0	100.0
6	9.45	85.14	9.62	84.86	2.69	95.77	5.38	91.54	6.02	90.53	1.59	97.49	0.0	100.0
8	7.79	87.74	5.38	91.54	2.35	96.30	4.71	92.59	5.94	90.65	1.48	97.67	0.0	100.0
10	6.37	89.98	3.97	93.75	1.69	97.34	3.46	94.56	3.87	93.91	1.18	98.14	0.0	100.0
Check	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0
CD (p=0.05)	0.20	-	0.21	-	0.94	-	0.19	-	0.16	-	0.25	-	0.16	-

Table 2(d): Effect of fermented cow urine on mycelial growth of pathogens of bell pepper*

Conc. (%)	Rhizoctonia solani		Sclerotium rolfsii		Fusarium solani		Fusarium oxysporum f.sp. capsici		Colletotrichum capsici		Phytophthora nicotianae		Sclerotinia sclerotiorum	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
2	37.92	40.35	0.24	99.62	11.75	81.52	10.57	83.37	11.75	81.52	5.31	91.64	0.0	100.0
4	0.0	100.0	0.0	100.0	5.59	91.21	9.73	84.69	8.29	86.96	0.71	98.88	0.0	100.0
6	0.0	100.0	0.0	100.0	4.98	92.16	7.64	87.98	4.15	93.47	0.64	98.99	0.0	100.0
8	0.0	100.0	0.0	100.0	4.23	93.34	5.39	91.52	0.0	100.0	0.57	99.10	0.0	100.0
10	0.0	100.0	0.0	100.0	0.61	99.04	0.89	98.60	0.0	100.0	0.50	99.21	0.0	100.0
Check	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0
CD (p=0.05)	0.41	-	0.42	-	0.24	-	0.30	-	0.73	-	0.25	-	0.15	-

Table 2(e): Effect of fermented butter milk on mycelial growth of pathogens of bell pepper*

Conc. (%)	Rhizoctonia solani		Sclerotium rolfsii		Fusarium solani		Fusarium oxysporum f.sp. capsici		Colletotrichum capsici		Phytophthora nicotianae		Sclerotinia sclerotiorum	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
2	17.34	72.72	56.98	10.38	7.54	88.14	16.61	73.87	10.17	84.00	4.98	92.17	5.38	91.54
4	15.54	75.56	49.24	22.55	4.52	92.89	13.65	78.53	7.54	88.14	4.81	92.43	2.54	96.00
6	14.18	77.69	33.67	47.04	2.27	96.43	11.76	81.50	4.91	92.27	4.15	93.47	1.88	97.04
8	11.33	82.17	29.21	54.06	1.69	97.34	10.46	83.55	2.74	95.69	4.06	93.61	0.74	98.83
10	6.60	89.62	19.39	69.50	1.18	98.14	6.38	89.96	1.13	98.22	3.46	94.55	0.38	99.40
Check	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0	63.58	0.0
CD (p=0.05)	0.15	-	0.20	-	0.93	-	0.18	-	0.23	-	0.11	-	0.11	-

A- Mycelial growth (cm^2); B- Percent Inhibition
***Mean of three replications**

revealed that out of tested inputs, cow urine was found most effective against all test pathogens followed by panchgavya, vermiwash and biosol whereas fermented butter milk was least effective. Increase in inhibition was observed with the increase in concentration of organic inputs. Cow urine resulted in 100 per cent inhibition of R. solani, S. rolfsii and S. sclerotiorum at all the concentrations, while inhibition in mycelial growth of F. solani, F. oxysporum f.sp. capsici, C. capsici and P. nicotianae ranged between 81.52 to 99.21 per cent. Panchgavya was most effective against S. sclerotiorum with 100 per cent inhibition followed by S. rolfsii with 99.73 per cent inhibition and P. nicotianae (98.71%) at all the concentrations. It was also found equally effective against R. solani (95.31%), F. solani (98.96%), F. oxysporum f.sp. capsici (92.89%) and C. capsici (97.91%) at 10 per cent concentration. In rest of concentrations inhibition was 61.01 to 98.96 per cent.

Vermiwash caused maximum inhibition (100%) of S. sclerotiorum at all concentrations followed by P. nicotianae (99.06%) and C. capsici (97.40%). Mycelial inhibition of R. solani, S. rolfsii, F. solani and F. oxysporum f.sp. capsici was 90.66 to 93.93 per cent at highest concentration. Rest of the concentrations were comparatively less effective and provided inhibition to the tune of 74.77 to 98.88 per cent. Biosol at all concentrations provided complete control of S. sclerotiorum whereas 98.14 and 97.34 per cent inhibition was observed against P. nicotianae and F. solani respectively. S. rolfsii, C. capsici and R. solani were less sensitive to biosol with 93.75, 93.91 and 89.98 per cent inhibition at 10 per cent concentration. At 8 per cent and lower concentrations, inhibition ranged between 76.42 to 93.63 per cent. Fermented butter milk was comparatively less effective against all the test pathogens. It exhibited maximum (99.40%) inhibition of S. sclerotiorum followed by F. solani and C. capsici with 98.14 and 98.22 per cent mycelial inhibition at highest concentration. It was least effective against R. solani and S. rolfsii with 72.72 to 89.62 and 10.38 to 69.50 per cent inhibition in mycelial growth respectively. Mycelial inhibition of P. nicotianae, F. oxysporum f.sp. capsici and F. solani was 73.87 to 98.14 per cent.

In vivo evaluation of organic inputs:
Organic inputs were found most effective at 10 percent concentration under in vitro conditions, thus all inputs were tested at same concentration under in vivo conditions. Organic inputs were tested under field conditions for their antifungal activity against foliar (P. nicotianae and C. capsici) and soil borne pathogens (F. oxysporum f.sp. capsici, S. rolfsii and R. solani) when applied as spray /drench respectively at 15 days interval. Among various combinations, mixture of panchgavya + cow urine provided maximum control of Phytophthora blight (87.02%) and anthracnose (85.22%) followed by biosol + cow urine and vermiwash + cow urine against both the diseases with more than 82 per cent disease control.

Table 3(a): Effect of spray of different organic inputs against foliar pathogens of bell pepper under field conditions

Treatment (dose)	Anthracnose		Phytophthora blight	
	Disease Severity (%)*	Disease Control (%)	Disease Severity (%)*	Disease Control (%)
Vermiwash (10%)	24.84 (29.88)	63.45	19.67 (26.31)	68.72
Panchgavya (10%)	20.08 (26.61)	70.46	17.23 (24.52)	72.60
Biosol (10%)	21.11 (27.34)	68.94	19.22 (25.99)	69.44
Buttermilk (10%)	24.20 (29.45)	64.39	21.17 (27.38)	66.34
Cow urine (10%)	17.27 (24.54)	74.59	15.44 (23.13)	75.44
Vermiwash (5%) + Cow urine (5%)	12.04 (20.29)	82.28	7.04 (15.38)	84.04
Panchgavya (5%) + Cow urine (5%)	10.05 (18.47)	85.22	9.42 (17.86)	87.02
Biosol (5%) + Cow urine (5%)	10.93 (19.29)	83.91	8.24 (16.67)	80.83
Buttermilk (5%) + Cow urine (5%)	11.01 (19.36)	79.53	15.20 (22.93)	77.89
Control	67.97 (55.51)	-	62.89 (52.43)	-
CD (p=0.05)	0.99	-	2.64	-

***Mean of three replications**
Figures in parentheses are arc sine transformed values

Table 3(b): Effect of seedling drench after transplanting with different organic inputs against soil borne pathogens of bell pepper under field conditions

Treatment (dose)	Fusarium wilt		Stem rot		Root rot	
	Disease Severity (%)*	Disease Control (%)	Disease Severity (%)*	Disease Control (%)	Disease Severity (%)*	Disease Control (%)
Vermiwash (10%)	15.20 (22.93)	65.54	19.70 (26.33)	63.37	18.39 (25.37)	65.80
Panchgavya (10%)	15.15 (22.89)	70.99	19.53 (26.22)	70.14	12.44 (20.64)	69.15
Biosol (10%)	13.34 (21.41)	68.98	15.49 (23.16)	69.85	16.32 (23.81)	62.04
Buttermilk (10%)	24.23 (29.47)	54.93	17.69 (24.85)	58.87	17.10 (24.41)	58.81
Cow urine (10%)	12.29 (20.51)	72.13	15.41 (23.10)	71.34	15.15 (22.89)	70.99
Vermiwash (5%) + Cow urine (5%)	10.46 (18.85)	76.29	10.42 (18.82)	75.77	8.41 (16.84)	80.56
Panchgavya (5%) + Cow urine (5%)	5.28 (13.27)	88.04	6.46 (14.70)	84.98	6.35 (14.59)	84.25
Biosol (5%) + Cow urine (5%)	7.21 (15.56)	83.40	9.09 (17.54)	78.93	9.27 (17.71)	82.76
Buttermilk (5%) + Cow urine (5%)	13.57 (21.60)	74.76	11.51 (19.82)	73.39	9.07 (17.51)	77.52
Control	44.11 (41.60)	-	43.00 (40.95)	-	53.77 (47.14)	-
CD (p=0.05)	1.52	-	2.17	-	1.59	-

***Mean of three replications**
Figures in parentheses are arc sine transformed values

revealed that drench of panchgavya + cow urine at 15 days interval showed 88.04 per cent control of Fusarium wilt followed by stem rot (84.98%) and root rot (84.25%). Mixture of cow urine with biosol and vermiwash resulted in more than 80 per cent control of all the soil borne pathogens. Therefore, cow urine was found most inhibitory to all the test pathogens alone under in vitro conditions and in combination with other organic inputs under in vivo. Cow urine also enhanced the efficacy of organic inputs when applied in combinations.

DISCUSSION

All the five organic inputs namely cow urine, panchgavya, biosol, vermiwash and fermented butter milk in the present study showed more than 95 per cent inhibition in mycelial growth of all the test pathogens at 10 per cent concentration under in vitro conditions. Earlier workers reported the antifungal activity of cow urine (Basak & Lee, 2005) and dung (Ashlesha et al., 2009) against soil borne pathogens (F. oxysporum f.sp. cucumerinum, Fusarium solani, and Rhizoictonia solani). The strong fungitoxicity of panchgavya against different fungal pathogens viz., F. oxysporum, F. solani, Rhizopus oligosporus (Joseph & Sankarganesh, 2011), R. solani, S. rolfsii (Sugha, 2005; Dogra, 2006), Sclerotinia sclerotiorum (Shalika, 2009), Phytophthora capsici and Colletotrichum coccodes (Sinha et al., 2010) has been studied. These antifungal properties may be attributed to the presence of antimicrobial substances in cow dung such as patulodin like compound CK2108A and CK2108B produced by Eupenicillium bouifirmosum present in cow dung (Dorothy & Frisvad, 2002). The release of antimicrobial compounds may be due to the microorganisms (bacteria, fungi and actinomycetes) present in panchgavya (Swaminathan et al., 2007). Nakasone et al. (1999) studied the inhibitory effect of aqueous extracts of vermicompost and organic composts on mycelial growth of Botrytis cinerea, S. sclerotiorum, S. rolfsii, R. solani and F. oxysporum f.sp. lycopersici. Manandhar and Yami (2008) reported that the mycelial

growth of F. moniliforme was inhibited by vermicompost tea. They observed the increased peroxidase and catalase activity in vermiwash that stimulated natural defense mechanism in host plants. The antifungal activity of butter milk has been attributed to the number of lactic acid bacteria that produced antifungal metabolites such as proteinaceous compounds and fatty acids (Schniirer & Magnusson, 2005). Kurosaki et al. (2007) and Badadani et al. (2007) observed that the antimicrobial activity of cow urine may be attributed to the presence of inorganic phosphorus, dimethylamine, amino acids and peptides. It is inferred from these findings that the organic inputs (fermented cow urine, panchgavya and biosol) are most effective against all the pathogens of capsicum.

Results on the effectiveness of various organic inputs as foliar spray or drench or soil amendment has been reported earlier by Markakis et al. (2008), Yadav et al. (2010) and Madhavi and Bhattiprolu (2011) who reported the disease suppressiveness of FYM and vermicompost when applied in soil. Saadi et al. (2010) observed reduction in wilted plants (Fusarium oxysporum) with the application of organic composts containing cow manure. Addition of composts consisted of pruning wastes and coffee wastes reduced the incidence of Fusarium wilt in melon plants (Ros et al., 2005). Antagonistic microbial population (van Elsas et al., 2005), changes in microbial community (Janvier et al., 2007) and ammonia toxicity (Michel & Mew, 1998) were suggested as possible mechanisms of suppression.

Organic inputs are perceived as potential alternatives to synthetic chemical fungicides. Use of composts in disease management has been reported earlier. The suppression of Phytophthora nicotianae and P. cinnamomi with application of citrus waste compost has been studied by Heerden et al. (1995) and Khalil and Mughrabi (2007). The suppression appears to be due to the indigenous microbial antagonists in the compost. Chakravarty and Kalita (2011) found that the application of vermicompost and FYM in soil decreased the wilt incidence in brinjal due to presence of antagonistic species of Pseudomonas and Bacillus in greenhouse conditions. The mechanisms of action underlying the efficacy of organic composts to control plant pathogens have been reported as single or multiple mechanisms involving microbial antagonism (Mughrabi et al., 2008), an increase in peroxidase, polyphenol oxidase and phenylalanine ammonia lyase in okra plants (Siddiqui et al., 2009), siderophores (Lim & Kim, 2009) and an increase in peroxidase, β-1,3-glucanase and chitinase in tomato and onion plants (Haggag & Saber, 2007; Jung et al., 2007).

A new formulation - Orguard prepared during the present study was found effective against fruit rot/anthracnose of capsicum under polyhouse conditions. These findings have not been reported earlier by researchers. However, effectiveness of organic composts against pathogens studied by some workers (Yadessa et al., 2010; Chakravarty & Kalita, 2011). Gunaseeli and Maheswari (2009) reported that the soil application of compost tea decreased the incidence of Fusarium wilt because pathogen propagules such as chlamydospores and macroconidia are often subject after organic compost addition to rapid germination and subsequent lysis (Scheuerell et al., 2005). Similarly, Hurali and Patil (2009) found cow urine, butter milk and panchgavya highly effective against the soybean rust due to the increased peroxidase, catalase and polyphenol oxidase activity that stimulate the natural defense mechanism of host plant.

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REFERENCES

Ashlesha, Jandaik, S., & Sugha, S. K. (2009). Cow dung preparations in the management of Rhizoctonia solani. Plant Disease Research, 24, 30-33. | Badadani, M. S., Babu, S. V., & Shetty, K. T. (2007). Optimum conditions of autoclaving for hydrolysis of proteins and urinary peptides of prolyl and hydroxyprolyl residues and HPLC analysis. Journal of Chromatography Analytical Technology and Biomedical Life Sciences, 847, 267-274. | Basak, A. B., & Lee, M. W. (2005). Efficacy of cow dung in controlling root rot and Fusarium wilt of cucumber. Indian Journal of Plant Pathology, 23, 81-84. | Brimmer, T., & Boland, G. J. (2003). A review of the non-target effects of fungi used to biologically control plant diseases. Agric. Ecosyst. Environ., 100, 3-16. | Corke, A. T. K. (1980). Modern developments in the control of plant diseases : Biological Control Methods. Scientific Horticulture, 31, 54-59. | Dogra, S. (2006). Antifungal potential of panchgavya against some soil borne pathogens. M.Sc. Thesis, Department of Plant Pathology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India. | Dorothy, E. T., & Frisvad, J. C. (2002). Eupenicillium bovifimosum, a new species from dry cow manure in Wyoming. Mycologia, 94, 240–246. | Erwin, D. C., & Ribeiro, O. K. (1996). Phytophthora capsici. In: Erwin DC, Ribeiro OK (ed) Phytophthora diseases world-wide, pp. 262-268 . APS Press, St. Paul, NIN, USA. | Falck, R. (1907). Wachstumgesetze, Wachstm-taktorenund temperature Wertder helzerstevenden. Mycelien, 1,43-154. | Gomez, K. A., & Gomez, A. A. (1984). Statistical procedures for agricultural research. 2nd Ed. p 680. New York, Willey. | Joseph, B., & Sankarganesh, P. (2011). Antifungal efficacy of pangavya. International Journal of Pharm Tech Research, 3, 585-588. | Kurosaki, N., Yamato, O., Sasamato, Y., Mori, F., Imoto, S., Kojima, T., & Maede, Y. (2007). Clinico-pathological finding in peripartum dairy cows fed anions salts lowering the dietary cation- anion difference: involvement of serum inorganic phosphorus, chloride and plasma estrogen concentration in milk fever. Japanese Journal of Veterinary Research, 55, 3-12. | Manandhar, T., & Yami, K. D. (2008). Biological control of foot rot disease of rice using fermented products of compost and vermicompost. Scientific World, 6, 52-57. | McKinney, H. H. (1923). Influence of soil temperature and moisture on infection of wheat seedlings by Helminthosporium sativum. Journal of Agricultural Research, 26, 195-210. | Nakasone, A. K., Bettiole, W., & Souze, R. M. D. (1999). The effect of water extracts of organic matter on plant pathogens. Summa Phytopathologica, 25, 330-35. | Nene, Y. L. (2003). Crop Disease Management Practices in Ancient, Medieval, and Pre-Modern India. Asian Agri-History, 7, 185-201. | Ochigbo, A. A., & Harris, G. P. (1989). Effect of film plastic cover on the growth and yield of bush tomato grown in a bed system. Journal of Horticultural Sciences, 64, 300-302. | Okigbo, R. N., & Ogbonnaya, U. O. (2006). Antifungal effects of two tropical plant leaf extracts (Ocimum gratissimum and Aframomum melegueta) on postharvest yam (Dioscorea spp.) rot. African Journal of Biotechnology, 5, 727-731. | Pakdeevaraparn, P., Wasee, S., Taylor, P. W. J., & Mongkolporn, O. (2005). Inheritance of resistance to anthracnose caused by Colletotrichum capsici in capsicum. Plant Breeding, 124, 206-208. | Sadhale, N. (1996). Recommendation to incorporate earthworms in soil of pomegranate to obtain high quality fruits; In Vrikshayurveda, (The Science of Tree Growing) Verse 131 by Surpala, 10th Century A.D. Asian Agri-History Bulletin (No.1), India. | Schniirer, J., & Magnusson, J. (2005). Antifungal lactic acid bacteria as biopreservatives – review. Trends in Food Science & Technology, 16, 70-78. | Shalika. (2009). Non-chemical management of stalk rot of cauliflower caused by Sclerotinia sclerotiorum (Lib.) de Bary. M.Sc. Thesis. Department of Plant Pathology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India. | Sinha, R. K., Valani, D., Chauhan, K., & Agarwal, S. (2010). Embarking on a second green revolution for sustainable agriculture by vermiculture biotechnology using earthworms: Reviving the dreams of Sir Charles Darwin. Journal of Agricultural Biotechnology and Sustainable Development, 2, 113-128. | Sugha, S. K. (2005). Antifungal potential of panchgavya. Plant Disease Research, 20, 156-158. | Swaminathan, C., Swaminathan, V., & Vijay, Lakshmi, K. (2007). Panchgavya Boon to organic farming. International Book Distributing Co. Lucknow p. 332. |