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Integrated Disease Management against Wilt Disease of Pigeonpea Caused by *Fusarium oxysporum* f. sp. *udum*

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A B S T R A C T

Pigeonpea wilt caused by *Fusarium oxysporum* f. sp. *udum* is one of the most devastating soil-borne diseases of Pigeonpea. Concerned study conducted during *Kharif* 2016 and *Kharif* 2017 in Agricultural Research Station, Badnapur (M.S) aimed to find integrated disease management strategies to control *Fusarium oxysporum* f. sp. *udum* causing pigeonpea wilt disease. Result indicated that all 16 treatments during *Kharif* 2016 under normal soil and sick soil condition, soil application of (*T. viride* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. viride*) + soil drenching of azoxystrobin 23 EC showed minimum wilt incidence *i.e.* 3.33 % and 40.83 % with maximum yield compared to other treatments *i.e.* 1424.28 kg/ha and 513.05 kg/ha, respectively. During *Kharif* 2017 under normal soil and sick soil conditions, soil application of (*T. viride* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. viride*) + soil drenching of azoxystrobin 23 EC showed minimum wilt incidence *i.e.* 7.12 % and 45.42 % with maximum yield *i.e.* 1368.73 kg/ha and 458.38 kg/ha, respectively compared to other treatments.

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] is one of the most important pulse crops in the semi-arid tropics. It used as food as well as vegetable protein source and of fodder.

Endowed with excellent food and fodder qualities, these crops also restore soil fertility by scavenging atmospheric nitrogen, adding organic matter, enhancing phosphorus availability as well as improving physical, chemical and biological properties of the soil.The largest producer of pigeonpea in the world is India, where it is widely cultivated with minima1 input of nutrients and pest management measures. The main constraints in boosting the yield of the crop are susceptibility to diseases and insects.

The crop is attacked by more than 100 pathogens (Nene *et al.*, 1996) including fungi, bacteria, viruses, phytoplasma like organisms and nematodes. However, only a few of them cause economic losses (Kannaiyan *et al.*, 1984). The diseases of considerable economic importance at present are sterility mosaic, *Fusarium* wilt, *Phytophthora* blight,

Macrophomina root rot, stem canker and *Alternaria* blight. *Fusarium* wilt is the most important disease of pigeonpea in India resulting in yield losses up to 67 per cent at maturity and 100 per cent in case of infection at pre-pod stage (Kannaiyan and Nene, 1981). The *Fusarium* wilt in pigeonpea was first reported from Bihar by Butler (1910).

The pathogen is primarily a soil inhabitant; hence controlling the disease is very difficult. Application of carbendazim has been successful in controlling the disease, but to a limited extent and also it is not economical. Bio-control approaches have been initiated by using antagonistic microorganisms to combat the wilt disease in pigeonpea. Many control measures have been suggested but, cost-effective options for the management of this disease have not been developed. Keeping this in view, recent investigations were envisaged with the development of integrated management approaches for pigeonpea wilt disease.

Materials and Methods

The experiment was conducted at Agricultural Research Station, Badnapur VNMKV, Parbhani (M.S.) during *Kharif* 2016 and *Kharif* 2017. Based on *in vitro* (field) studies, the most effective five fungicides *viz.*, carbendazim, carbendazim + mancozeb (for seed treatment), propiconazole, thiophanate methyl and azoxystrobin (for soil drenching) were selected for concerned study.

One bio-agent *T. viride* (for both seed treatment and soil application) and two organic amendments *viz.*, neem seed cake and castor seed cake for (soil application) were selected and integrated alone as well as in combination to manage pigeonpea wilt (*F. udum*). The experiment was conducted for two consecutive years during *Kharif* 2015-16 and *Kharif* 2016-17.

The seed of susceptible pigeonpea cv. ICP 2376 were treated before sowing with the seed dressing fungicides and the bio-agent *viz.*, *T. viride*. The soil application of test organic amendments and the test fungicides was done at 30 DAS.

Fungicide and bio-agent treated seeds of pigeonpea cv. ICP-2376 were sown (90 cm x 20 cm) in randomized plots (Gross plot Size: 13 m x 85 m, Net plot Size: 12.8 m x 84 m, Block size per treatment: 3.6 m x 4 m with 4 rows and 20 plants / row on dated 12 June 2015 and 15 June 2016 for two *Kharif* seasons, respectively. The crop was grown by applying all recommended package of practices and irrigated as and when required.

Results and Discussion

Efficacy of various treatments integration against wilt (*F. udum*) incidence and seed yield during *Kharif* 2015-16

Under normal soil and sick soil conditions, T_{16} [soil application of (*T. viride* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. viride*) + soil drenching of azoxystrobin 23 EC] showed minimum wilt incidence *i.e.* 3.33 and 40.83 % with maximum yield compared to other treatments *i.e.* 1424.28 and 513.05 kg/ha, respectively.

Second best treatment was T_{15} [soil application of (*T. viride* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. v.*) + soil drenching of thiophanate methyl] showed 5 % wilt incidence with 1347.48 kg/ha in normal soil and under sick soil 43.93 % wilt incidence and 491.58 kg/ha yield were recorded. Maximum wilt incidences (43.92 and 100 %) were recorded in untreated control T_{17} with 582.33 kg/ha yield and without any yield in normal and sick soil (Table 1), respectively.

Table.1 Efficacy of various treatments integration against wilt (*F. udum*) incidence and seed yield in pigeonpea cv. ICP 2376 during *Kharif* 2015-16

Tr. No.	Treatments	Rate of application	Wilt incidence (%)		Reduction over control (%)		Yield (Kg / ha)	
			Normal soil	Sick soil	Normal soil	Sick soil	Normal soil	Sick soil
T_1	Carbendazim 50 % WP (ST)	1 g / kg seed	25.83 (30.48)	85.37 (67.64)	41.19	14.63	735.93	120.18
T_2	Carbendazim 25 % WP + mancozeb50 % WP (ST)	3 g / kg seed	23.43 (28.89)	82.50 (65.30)	46.65	17.50	757.18	143.42
T_3	*Trichoderma viride* (ST)	12 g / kg seed	27.50 (31.56)	87.08 (69.09)	37.39	12.92	710.04	100.04
T_4	Carbendazim 50 % WP (ST) +*Trichoderma viride* (ST)	1 g / kg seed +12 g / kg seed	22.92 (28.57)	80.21 (63.71)	47.81	19.79	766.48	151.17
T_5	(Carbendazim 25% WP + mancozeb 50 % WP) + *T. viride* (ST)	3 g / kg seed +12 g / kg seed	21.25 (27.39)	77.08 (61.38)	51.62	22.92	780.20	160.91
T_6	Neem seed cake (SA)	5 q / ha	23.75 (29.13)	80.00 (63.68)	45.92	20.00	761.39	154.49
T_7	Castor seed cake (SA)	5 q / ha	24.17 (29.40)	83.28 (65.95)	44.97	16.72	740.36	140.55
T_8	*Trichoderma viride* (SA)	20 kg / ha	21.25 (27.39)	78.33 (62.38)	51.62	21.67	793.04	171.09
T_9	*Trichoderma viride* (SA) + neem cake (SA)	20 kg / ha + 5 q / ha	17.50 (24.66)	71.09 (57.60)	60.15	28.91	912.11	223.10
T_{10}	*Trichoderma viride* (SA) + castor seed cake (SA)	20 kg / ha + 5 q / ha	19.25 (25.98)	76.25 (60.92)	56.17	23.75	832.21	187.69
T_{11}	*Trichoderma viride* (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST)	20 kg / ha + 3 g / kg seed	15.42 (23.00)	69.43 (56.79)	64.89	30.57	958.15	253.43
T_{12}	*T.v.* (SA) + neem seed cake (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST)	20 kg / ha + 5 q / ha + 3 g / kg seed +12 g / kg seed	12.50 (20.63)	62.50 (52.39)	71.54	37.50	1000.65	305.00
T_{13}	*T.v.* (SA)+ neem seed cake (SA) + [carbendazim + mancozeb] (ST) + *T.v.* (ST) + [carbendazim 25 % WP + mancozeb 50 % WP] (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g/ kg seed + @0.25 %	9.58 (17.88)	49.08 (44.46)	78.19	50.92	1109.10	426.29
T_{14}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + propiconazole (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	7.13 (15.18)	46.25 (42.82)	83.77	53.75	1175.94	457.27
T_{15}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + thiophanate methyl (SD)	20 kg / ha + 5 q / ha +3 g / kg seed + 12 g / kg seed + @ 0.1 %	5.00 (12.00)	43.93 (41.46)	88.62	56.07	1347.48	491.58
T_{16}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + azoxystrobin 23 EC (SD)	20 kg / ha + 5 q / ha +3 g / kg seed + 12 g / kg seed +@ 0.1 %	3.33 (8.33)	40.83 (39.67)	92.42	59.17	1424.28	513.05
T_{17}	Control	Untreated	43.92 (41.47)	100 (90.00)	00.00	00.00	582.33	0.00
S.E. ±			**2.00**	**2.89**	--	--	**66.12**	**36.25**
C.D.(P=0.05)			**5.81**	**8.38**	--	--	**191.35**	**104.91**
C.V.			**14.00**	**8.48**	--	--	**12.65**	**16.69**

T. viride soil application: 20 kg talc carrier based *T. viride* mixed with 500 kg well decomposed FYM / ha.
ST: Seed Treatment; SA: Soil Application; SD: Soil Drenching.
Figures in parentheses are angular transformed values.

Table.2 Efficacy of various treatments integration against wilt (*F. udum*) incidence and seed yield in pigeonpea cv. ICP 2376 during *Kharif* 2016-17

Tr. No.	Treatments	Rate of application	Wilt Incidence (%)		Reduction over control (%)		Yield (kg / ha)	
			Normal soil	Sick soil	Normal soil	Sick soil	Normal soil	Sick soil
T_1	Carbendazim 50 % WP (ST)	1 g / kg seed	28.33 (32.10)	89.17 (70.93)	41.89	10.83	685.91	57.33
T_2	Carbendazim 25 % WP + mancozeb 50 % WP (ST)	3 g / kg seed	27.62 (31.66)	87.39 (70.29)	43.34	12.61	717.78	80.34
T_3	*Trichoderma viride* (ST)	12 g / kg seed	29.17 (32.60)	91.25 (73.87)	40.16	08.75	662.23	44.93
T_4	Carbendazim 50 % WP (ST) +*Trichoderma viride* (ST)	1 g/kg seed + 12 g/ kg seed	26.25 (30.79)	84.17 (66.66)	46.15	15.83	734.83	102.48
T_5	(Carbendazim 25 % WP + Mancozeb 50 % WP) + *Trichoderma viride* (ST)	3 g / kg seed +12 g / kg seed	25.00 (29.93)	82.03 (65.02)	48.72	17.97	742.13	119.52
T_6	Neem seed cake (SA)	5 q / ha	26.25 (30.78)	84.17 (67.28)	46.15	15.83	721.10	99.38
T_7	Castor seed cake (SA)	5 q / ha	27.92 (31.87)	86.60 (69.85)	42.73	13.40	692.77	83.44
T_8	*Trichoderma viride* (SA)	20 kg / ha	24.26 (29.45)	83.75 (66.33)	50.24	16.25	756.96	121.95
T_9	*Trichoderma viride* (SA) + neem seed cake (SA)	20 kg / ha + 5 q / ha	21.67 (27.72)	75.25 (60.31)	55.55	24.75	853.68	168.66
T_{10}	*Trichoderma viride* (SA) + castor seed cake (SA)	20 kg / ha + 5 q / ha	22.31 (28.11)	80.00 (63.47)	54.24	20.00	710.04	146.97
T_{11}	*T. viride* (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST)	20 kg / ha +3 g / kg seed	19.25 (25.96)	73.33 (59.35)	60.51	26.67	920.75	206.50
T_{12}	*T.v.* (SA) + neem seed cake (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST) +*T.v.* (ST)	20 kg / ha +5 q / ha+ 3 g / kg seed +12 g / kg seed	16.31 (23.75)	66.55 (54.84)	66.54	33.45	969.22	258.30
T_{13}	*T.v.* (SA) + neem seed cake (SA) + [carbendazim + mancozeb] (ST) + *T.v.* (ST) + [carbendazim 25 % WP + mancozeb 50 % WP] (SD)	20 kg / ha +5 q / ha + 3 g / kg seed +12 g / kg seed + @ 0.25 %	12.92 (20.99)	53.33 (46.99)	73.50	46.67	1077.45	387.78
T_{14}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + propiconazole (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	10.47 (18.77)	51.20 (45.67)	78.52	48.80	1152.93	416.33
T_{15}	*T.v.* (SA) + Neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.*(ST) + thiophanate methyl (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	9.17 (17.56)	47.08 (43.30)	81.19	52.92	1336.85	443.77
T_{16}	*T.v.* (SA) + Neem seed cake (SA)+ [Carbendazim 25 % WP + Mancozeb 50 % WP] (ST) + *T.v.* (ST) + azoxystrobin 23 EC (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	7.12 (15.37)	45.42 (42.30)	85.39	54.58	1368.73	458.38
T_{17}	Control	Untreated	48.75 (44.26)	100 (90.00)	00.00	00.00	541.82	0.00
S.E. ±			**1.47**	**3.63**	--	--	**50.61**	**44.07**
C.D.(P=0.05)			**4.26**	**10.49**	--	-	**146.44**	**127.52**
C.V.			**09.19**	**10.11**	--	--	**10.17**	**20.46**

Figures in parentheses are angular transformed values
ST: Seed Treatment; SA: Soil Application; SD: Soil Drenching.

Table.3 Effect of various treatments integration on pooled mean (2015-16 and 2016-17) wilt incidence and seed yield in pigeonpea cv. ICP 2376

Tr. No.	Treatments	Rate of application	Normal Soil		Sick soil	
			Wilt incidence * (%)	Yield kg/ha	Wilt incidence *(%)	Yield kg/ha
T_1	Carbendazim 50 % WP (ST)	1 g / kg seed	27.08 (31.32)	710.92	87.27 (69.29)	88.75
T_2	Carbendazim 25 % WP + mancozeb 50 % WP (ST)	3 g / kg seed	25.52 (30.28)	737.48	84.95 (67.79)	111.88
T_3	*Trichoderma viride* (ST)	12 g / kg seed	28.33 (32.08)	686.13	89.17 (71.48)	72.49
T_4	Carbendazim 50 % WP (ST) + *Trichoderma viride* (ST)	1 g / kg seed + 12 g / kg seed	24.58 (29.71)	750.65	82.19 (65.19)	126.82
T_5	(Carbendazim 25 % WP + mancozeb 50 % WP) + *Trichoderma viride* (ST)	3 g / kg seed +12 g / kg seed	23.13 (28.66)	761.17	79.56 (63.20)	140.21
T_6	Neem seed cake (SA)	5 q / ha	25.00 (29.96)	741.25	82.08 (65.48)	126.93
T_7	Castor seed cake (SA)	5 q / ha	26.04 (30.64)	716.57	84.94 (67.90)	111.99
T_8	*Trichoderma viride* (SA)	20 kg / ha	22.76 (28.42)	775.00	81.04 (64.36)	146.52
T_9	*Trichoderma viride* (SA) + neem seed cake (SA)	20 kg / *ha* + 5 q / ha	19.58 (26.19)	882.90	73.17 (58.96)	195.88
T_{10}	*Trichoderma viride* (SA) + castor seed cake (SA)	20 kg / *ha* +5 q / ha	20.78 (27.04)	771.13	78.13 (62.20)	167.33
T_{11}	*Trichoderma viride* (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST)	20 kg / ha + 3 g / kg seed	17.33 (24.48)	939.45	71.38 (58.07)	229.97
T_{12}	*T.v.* (SA) + neem seed cake (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed	14.41 (22.19)	984.93	64.53 (53.62)	281.65
T_{13}	*T.v.* (SA) + Neem seed cake (SA) + [carbendazim + mancozeb] (ST) + *T.v.* (ST) + [carbendazim 25 % WP + mancozeb 50 % WP] (SD)	20 kg / ha + 5 q/ ha + 3 g/ kg seed +12 g/ kg seed + @ 0.25 %	11.25 (19.44)	1093.28	51.21 (45.73)	407.03
T_{14}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + propiconazole (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed +12 g / kg seed + @ 0.1 %	8.80 (16.98)	1164.43	48.72 (44.25)	436.80
T_{15}	*T.v.* (SA) + Neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + thiophanate methyl (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed +12 g / kg seed + @ 0.1 %	7.08 (14.78)	1342.17	45.51 (42.38)	467.68
T_{16}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + azoxystrobin 23 EC (SD)	20 kg / ha + 5 q / ha +3 g / kg seed +12 g / kg seed+ @ 0.1 %	5.23 (11.85)	1396.50	43.13 (40.99)	485.72
T_{17}	Control	Untreated	46.33 (42.87)	562.08	100.00 (90.00)	0.00
S.E. ±			**1.74**	**58.37**	**3.26**	**40.16**
C.D.(P=0.05)			**5.04**	**168.90**	**9.44**	**116.22**
C.V.			**11.59**	**11.41**	**9.29**	**18.58**
Factor (A=Year)	**S.E. ±**		**0.42**	**14.07**	**1.15**	**9.68**
	C.D.(P=0.05)		**1.19**	**39.82**	**3.24**	**27.39**
Factor (B=Treatment)	**S.E. ±**		**1.24**	**41.02**	**3.34**	**28.22**
	C.D.(P=0.05)		**3.49**	**116.08**	**9.44**	**79.86**
Factor (A X B)			**NS**	**NS**	**NS**	**NS**

*Figures in parentheses are angular transformed values

Table.4 Economics of integrated management practices imposed for *Fusarium* wilt disease of pigeonpea during *Kharif* 2015-16

Tr. No.	Treatments	Rate of application	PDI (%)	Seed yield* (kg/ ha)	Gross returns^ (Rs / ha)	Cost of cultivation (Rs/ha)	Cost plant protection (Rs / ha)		Total cost (Rs / ha)	Net profit	ICBR
							Treat-ments***	Labour Charges^^			
1	2	3	4	5	6	7	8	9	10	11	12
T_1	Carbendazim 50 % WP (ST)	1 g / kg seed	25.83 (30.48)	735.93	34036.76	21697	18.40	180	21895.40	12141.36	**1.55**
T_2	Carbendazim 25 % WP + mancozeb 50 % WP (ST)	3 g / kg seed	23.43 (28.89)	757.18	35019.58	21697	28.00	180	21905.00	13114.58	**1.60**
T_3	*Trichoderma viride* (ST)	12 g / kg seed	27.50 (31.56)	710.04	32839.35	21697	20.00	180	21897.00	10942.35	**1.50**
T_4	Carbendazim 50 % WP (ST) + *Trichoderma viride* (ST)	1 g / kg seed +12 g / kg seed	22.92 (28.57)	766.48	35449.7	21697	38.40	180	21915.40	13534.30	**1.62**
T_5	(Carbendazim 25 % WP + mancozeb 50 % WP) + *Trichoderma viride* (ST)	3 g / kg seed +12 g / kg seed	21.25 (27.39)	780.20	36084.25	21697	48.00	180	21925.00	14159.25	**1.65**
T_6	Neem seed cake (SA)	5 q / ha	23.75 (29.13)	761.39	35214.29	21697	4175	260	26132.00	9082.29	**1.35**
T_7	Castor seed cake (SA)	5 q / ha	24.17 (29.40)	740.36	34241.65	21697	4350	260	26307.00	7934.65	**1.30**
T_8	*Trichoderma viride* (SA)	20 kg / ha	21.25 (27.39)	793.04	36678.1	21697	687.50	180	22564.50	14113.60	**1.63**
T_9	*Trichoderma viride* (SA) + neem seed cake (SA)	20 kg / ha + 5 q / ha	17.50 (24.66)	912.11	42185.09	21697	4862.50	260	26819.50	15365.59	**1.57**
T_{10}	*Trichoderma viride* (SA) + castor seed cake (SA)	20 kg / ha +5 q / ha	19.25 (25.98)	832.21	38489.71	21697	5037.50	260	26994.50	11495.21	**1.43**
T_{11}	*Trichoderma viride* (SA) + [carbendazim 25 % WP + mancozeb 50 % WP](ST)	20 kg / ha + 3 g / kg seed	15.42 (23.00)	958.15	44314.44	21697	715.50	180	22592.50	21721.94	**1.96**
T_{12}	*T. v.* (SA) + neem seed cake (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T. v.* (ST)	20 kg / ha + 5 q / ha + 3 g / kg seed +12 g / kg seed	12.50 (20.63)	1000.65	46280.06	21697	4910.50	260	26867.50	19412.56	**1.72**
T_{13}	*T. v.* (SA) + neem seed cake (SA) + [carbendazim + Mancozeb] (ST) + *T. v.*(ST) + [carbendazim 25 % WP + mancozeb 50 % WP] (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed +12 g / kg seed + @ 0.25 %	9.58 (17.88)	1109.10	51295.88	21697	5078.50	540	27315.50	23980.38	**1.88**
T_{14}	*T. v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T. v.* (ST) + propiconazole (SD)	20 kg / ha +5 q / ha + 3 g / kg seed +12 g / kg seed + @ 0.1 %	7.13 (15.18)	1175.94	54387.23	21697	5217.70	540	27454.70	26932.53	**1.98**
T_{15}	*T. v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + thiophanate methyl (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed +12 g / kg seed + @ 0.1 %	5.00 (12.00)	1347.48	62320.95	21697	5042.50	540	27279.50	35041.45	**2.28**
T_{16}	*T. v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T. v.* (ST) + azoxystrobin 23 EC (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed +12 g / kg seed + @ 0.1 %	3.33 (8.33)	1424.28	65872.95	21697	5527.06	540	27764.06	38108.89	**2.37**
T_{17}	Control	Untreated	43.92 (41.47)	582.33	26932.76	21697	00.00	00.00	21697.00	5235.76	**1.24**
S.E. ±			**2.00**	**66.12**							
C.D.(P=0.05)			**5.81**	**191.35**							
C.V.			**14.00**	**12.65**							

*: Mean of three replications, ^: Selling rates of pigeonpea seed yield @ 4625/q, Labour Charges: 180 Rs / labour, **: As per Annexure III (A), ***: As per costs mentioned in the chapter III, ^^: Seed treatment and drenching charges @ Rs. 180/labour, ICBR: Incremental Cost Benefit Ratio, ST: Seed Treatment; SA: Soil Application; SD: Soil Drenching.

Figures in parentheses are angular transformed values

Table.5 Economics of integrated management practices imposed for *Fusarium* wilt disease of pigeonpea during *Kharif* 2016-17

Tr. No	Treatments	Rate of application	PDI (%)	Seed Yield* (kg / ha)	Gross Returns^ (Rs / ha)	Cost of Cultivation (Rs / ha)	Cost Plant Protection (Rs / ha)		Total Cost (Rs / ha)	Net Profit	ICBR
							Treat-mens ***	Labour Charges^^			
1	2	3	4	5	6	7	8	9	10	11	12
T_1	Carbendazim 50%WP (ST)	1 g / kg seed	28.33 (32.10)	685.91	34638.46	21697	18.40	180	21895.40	12743.06	**1.58**
T_2	Carbendazim 25 % WP + mancozeb 50 % WP (ST)	3 g / kg seed	27.62 (31.66)	717.78	36247.89	21697	28.00	180	21905.00	14342.89	**1.65**
T_3	*Trichoderma viride* (ST)	12 g / kg seed	29.17 (32.60)	662.23	33442.62	21697	20.00	180	21897.00	11545.62	**1.53**
T_4	Carbendazim 50 % WP (ST) + *Trichoderma viride* (ST)	1 g / kg seed + 12 g / kg seed	26.25 (30.79)	734.83	37108.92	21697	38.40	180	21915.40	15193.52	**1.69**
T_5	(Carbendazim 25 % WP + mancozeb 50 % WP)+*T.viride* (ST)	3 g / kg seed + 12 g / kg seed	25.00 (29.93)	742.13	37477.57	21697	48.00	180	21925.00	15552.57	**1.71**
T_6	Neem seed cake (SA)	5 q / ha	26.25 (30.78)	721.10	36415.55	21697	4175	260	26132.00	10283.55	**1.39**
T_7	Castor seed cake (SA)	5 q / ha	27.92 (31.87)	692.77	34984.89	21697	4350	260	26307.00	8677.89	**1.33**
T_8	*Trichoderma viride* (SA)	20 kg / ha	24.26 (29.45)	756.96	38226.48	21697	687.50	180	22564.50	15661.98	**1.69**
T_9	*Trichoderma viride* (SA) + neem seed cake (SA)	20 kg / ha + 5 q / ha	21.67 (27.72)	853.68	43110.84	21697	4862.50	260	26819.50	16291.34	**1.61**
T_{10}	*Trichoderma viride* (SA) + castor seed cake (SA)	20 kg / ha + 5 q / ha	22.31 (28.11)	710.04	35857.02	21697	5037.50	260	26994.50	8862.52	**1.33**
T_{11}	*Trichoderma viride* (SA) + [carbendazim 25 % WP + mancozeb 50 % WP] (ST)	20 kg / ha + 3 g / kg seed	19.25 (25.96)	920.75	46497.88	21697	715.50	180	22592.50	23905.38	**2.06**
T_{12}	*T. v.* (SA) + neem seed cake (SA) +[carbendazim 25% WP+ mancozeb 50 % WP] (ST) + *T. v.* (ST)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed	16.31 (23.75)	969.22	48945.61	21697	4910.50	260	26867.50	22078.11	**1.82**
T_{13}	*T. v.* (SA) + neem seed cake (SA) + [carbendazim + mancozeb] (ST) + *T. v.*(ST) + [carbendazim 25 % WP + mancozeb 50 % WP] (SD)	20 kg / ha + 5 q / ha + 3 g /kg seed +12 g / kg seed +@ 0.25 %	12.92 (20.99)	1077.45	54411.23	21697	5078.50	540	27315.50	27095.73	**1.99**
T_{14}	*T. v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP](ST) + *T. v.* (ST) + propiconazole (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	10.47 (18.77)	1152.93	58222.97	21697	5217.70	540	27454.70	30768.27	**2.12**
T_{15}	*T. v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T. v.* (ST) + thiophanate methyl (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	9.17 (17.56)	1336.85	67510.93	21697	5042.50	540	27279.50	40231.43	**2.47**
T_{16}	*T. v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP](ST) + *T. v.* (ST) + azoxystrobin 23 EC (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	7.12 (15.37)	1368.73	69120.87	21697	5527.06	540	27764.06	41356.81	**2.49**
T_{17}	Control	Untreated	48.75 (44.26)	541.82	27361.91	21697	00.00	00.00	21697.00	5664.91	**1.26**
S.E. ±			**1.47**	**50.61**							
C.D.(P=0.05)			**4.26**	**146.44**							
C.V.			**9.19**	**10.17**							

*: Mean of three replications, ^: Selling rates of pigeonpea seed yield @ 5050/q, Labour Charges: 180 Rs/labour, **: As per Annexure III (A), ***: As per costs mentioned in the chapter III, ^^: Seed treatment and drenching charges @ Rs. 180/labour,
ICBR: Incremental Cost Benefit Ratio; ST: Seed Treatment; SA: Soil Application; SD: Soil Drenching.
Figures in parentheses are angular transformed values

Table.6 Pooled mean of incremental Cost: Benefit ratio (*Kharif* 2015-16 and *Kharif* 2016-17)

Tr. No.	Treatments	Rate of application	ICBR		Pooled Mean
			2015-16	2016-17	
T_1	Carbendazim 50 % WP (ST)	1 g / kg seed	1.55	1.58	1.57
T_2	Carbendazim 25 % WP + mancozeb 50 % WP (ST)	3 g / kg seed	1.6	1.65	1.63
T_3	*Trichoderma viride* (ST)	12 g / kg seed	1.5	1.53	1.52
T_4	Carbendazim 50 % WP (ST) + *T. viride* (ST)	1 g / kg seed + 12 g / kg seed	1.62	1.69	1.66
T_5	(Carbendazim 25 % WP + mancozeb 50 % WP) + *T.viride* (ST)	3 g / kg seed + 12 g / kg seed	1.65	1.71	1.68
T_6	Neem seed cake (SA)	5 q / ha	1.35	1.39	1.37
T_7	castor seed cake (SA)	5 q / ha	1.3	1.33	1.32
T_8	*T. viride* (SA)	20 kg / ha	1.63	1.69	1.66
T_9	*T. viride* (SA) + neem seed cake (SA)	20 kg / ha + 5 q / ha	1.57	1.61	1.59
T_{10}	*T. viride* (SA) + castor seed cake (SA)	20 kg / ha + 5 q / ha	1.43	1.33	1.38
T_{11}	*T. viride* (SA) + [Carbendazim 25 % WP + mancozeb 50 % WP] (ST)	20 kg / ha + 3 g / kg seed	1.96	2.06	2.01
T_{12}	*T.v.* (SA) + neem seed cake (SA) + [Carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed	1.72	1.82	1.77
T_{13}	*T.v.* (SA) + neem seed cake (SA) + [Carbendazim + mancozeb] (ST) + *T.v.* (ST) + [carbendazim 25 % WP + mancozeb 50 % WP] (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.25 %	1.88	1.99	1.94
T_{14}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + propiconazole (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	1.98	2.12	2.05
T_{15}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + thiophanate methyl (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	2.28	2.47	2.38
T_{16}	*T.v.* (SA) + neem seed cake (SA)+ [carbendazim 25 % WP + mancozeb 50 % WP] (ST) + *T.v.* (ST) + azoxystrobin 23 EC (SD)	20 kg / ha + 5 q / ha + 3 g / kg seed + 12 g / kg seed + @ 0.1 %	2.37	2.49	2.43
T_{17}	Control	Untreated	1.24	1.26	1.25

ST: Seed Treatment; SA: Soil Application; SD: Soil Drenching

T_{16} treatment showed maximum per cent reduction of wilt (92.42 and 59.17 %) over control in normal as well as sick soil, respectively followed by treatment T_{15} (88.62 and 56.07 %). It was minimum in T_3: Seed treatment of *Trichoderma viride* 12 g/kg of seed (37.39 and 12.92 %) during *Kharif* 2015-16

Efficacy of various treatments integration against wilt (*F. udum*) incidence and seed yield during *Kharif* 2016-17

Under normal soil and sick soil conditions, T_{16} [soil application of (*T. v.* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. v.*) + soil drenching of azoxystrobin 23 EC] showed minimum wilt incidence *i.e.* 7.12 and 45.42 % with maximum yield *i.e.* 1368.73 and 458.38 kg/ha, respectively compared to other treatments.

Second best treatment was T_{15} [soil application of (*T. v.*+ neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. v.*) + soil drenching of thiophanate methyl] which showed 9.17 % wilt incidence with 1336.85 kg/ha yield in normal soil and in sick soil it was 47.08 % with 443.77 kg/ha yield. Maximum wilt incidences (48.75 and 100 %) were recorded in untreated control T_{17} with 541.82 kg/ha yield and without any yield in normal and sick soil, respectively (Table 2).

T_{16} treatment showed maximum per cent reduction of (85.39 and 54.58 %) over untreated control in normal and sick soil, respectively followed by treatment T_{15} (81.19 and 52.92 %). It was minimum in T_3: Seed treatment of *Trichoderma viride* 12 g/kg of seed (40.16 and 08.75 %) during *Kharif* 2016-17 (Table 2).

These results are in conformity with the findings of those reported earlier by several workers (Gade *et al.,* 2007; Dabbas *et al.,* 2008*;* Mahesh *et al.,* 2010; Karimi *et al.,* 2012; Prasad *et al.,* 2012; Chennakesavulu *et al.,* 2013; Pawar *et al.,* 2013; Kumar and Upadhayay 2015).

Pooled means of wilt incidence and seed yield (IDM)

The pooled results indicated that pooled mean of wilt incidence and seed yield (kg/ha) were significantly influenced with various treatments imposed to manage wilt incidence and 562.08 to 1396.50 kg/ha respectively, in normal soil, where as in sick soil wilt incidence was ranged from 43.13 (T_{16}) to 100 % and yield ranged from 0 to 485.72 kg/ha. Result of pooled analysis showed non-significant interaction of two years and seventeen treatments for both soil conditions but during *Kharif* 2015-16 and 2016-17 all the treatments were reduced the wilt incidence and increase the yield compare to untreated control under normal and sick soil conditions (Table 3).

Pooled mean of incremental Cost: Benefit ratio (under normal soil)

Results obtained during, *Kharif* 2015-16 and 2016-17 on economics / incremental cost: benefit (ICBR) in respect of the treatments integrated to manage pigeonpea wilt disease revealed that all the treatments significantly increased the seed yield, with maximum net profit and increased ICBR as compared to untreated control during both the years.

Among various treatments, [soil application of (*T. v.* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. v.*) + soil drenching of azoxystrobin 23 EC] was found most effective, with the highest gross return (Rs. 65872.95/- and 69120.87/-), highest net profit (Rs.38108.89/- and 41356.81/-) and highest ICBR (2.37 and 2.49) during *Kharif* 2015-16 and 2016-17, respectively (Table 5).

The second best treatment found was [soil application of (*T. v.* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. v.*) + soil drenching of thiophanate methyl] with second highest gross income (Rs.62320.95/- and 67510.93/-), net profit (Rs. 35041.45/- and 40231.43/-) and ICBR (2.28 and 2.47) during, *Kharif* 2015-16

and 2016-17, respectively. Results indicated that on the basis of two years (2015-16 and 2016-17) pooled mean data, the most economical treatment with highest mean ICBR (2.43) was [soil application of (*T. v.* + neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. v.*) + Soil drenching of azoxystrobin 23 EC] (Table 6) followed by the treatment T_{15} [soil application of (*T. v.*+ neem seed cake) + seed treatment of (carbendazim 25 % WP + mancozeb 50 % WP + *T. v.*) + soil drenching of thiophanate methyl] with the ICBR (2.38). The lowest ICBR (1.25) was recorded in treatment T_{17} (untreated control).

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