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Research Article

BIOLOGICAL MANAGEMENT OF CHICKPEA (*Cicer arietinum* L.) WILT CAUSED BY *Fusarium oxysporum* f. sp. *ciceris*

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Abstract: Chickpea (*Cicer arietinum* L.) is grown on an average area of about 16401 ha in the Dangs district of South Gujarat per year. Severe incidence (10 to 40%) of wilt caused by *Fusarium oxysporum* f. sp. *ciceris* is one of the important constraints in the production of Chickpea in the Dangs. Since recent past The Dangs district of South Gujarat was declared as organic district and thus, afield experiment on biological management of chickpea wilt was formulated and conducted for three years. Two bio agents *viz., T. viride* 1.5% WP (2 x 10^6 cfu/g) (IIHR strain) and *P. fluorescence* 1.5% liquid form (1 x 10^8 cfu / ml) (NAU strain) were used as seed treatment and soil application. Among all the treatments, maximum disease control and grain production was reported in the seed treatment of *T.viride* @ 10g/kg of seeds + two soil applications of *T.viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering with minimum wilt incidence (5.46 %)and highest grain yield (2513 kg/ ha) followed by the seed treatment of *P. fluorescence* @ 10 ml / kg of seeds + two soil applications of *Pseudomonas fluorescence* @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering with the wilt incidence of (5.51 %) and highest grain yield (2471 kg / ha) over all the other treatment and control with positive effect on average plant height (cm), average numbers of branches/plant, average numbers of pods/plant, average numbers of root nodules/plant bio agent cfu /gm soil at harvest with high cost benefit ratio.

Keywords: *Chickpea, Wilt, Biological management*

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Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops of India. This crop is grown on an average area of about 16401 ha in Dangs of Gujarat [1]. Being one of the important *Rabi* crops of Dangs, there is a need to resolve the constraint of higher production of this crop. The increasing severity of wilt disease (*Fusarium oxysporum* f. sp. *ciceris*) (10 to 40%) is one of the important constraints in the production of Chickpea in Dangs [2]. Moreover, Dang area of South Gujarat is now considered as organic district. Thus, the present experiment on biological management of chickpea wilt was formulated and conducted at Hill Millet Research Station, N.A.U., Waghai, Dang, South Gujarat heavy rainfall zone - I and situation - I during *Rabi*-2017-18 to *Rabi*-2019-20 to find out suitable bioagent and its application method for the biological management of chickpea wilt.

Materials and methods

For conducting present experiment, the variety of gram used was GG-2. The treatment given was T_1: *T. viride* ST @ 10g/kg of seeds, T_2: *T. viride* ST @ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing, T_3: *T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering, T_4: *P. fluorescens* ST @ 10ml/kg of seeds, T_5: *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing, T_6: *P.fluorescens* ST @ 10ml/kg of seeds + two time SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering, T_7:Control where ST= Seed Treatment (Slurry method). SA= Soil Application. The bioagents *viz., Trichoderma viride* WP (2 X10^6 cfu/g) (IIHR Strain) and *P. fluorescens* (Liquid form) (1x10^8cfu/ ml) (NAU Strain) used here will be obtained from Dept. of Plant Pathology, NAU, Navsari. Plot size: Gross: 4.5 x 4.5 m (Ten rows), Net: 3.6 x 4.10 m (Eight rows)) Spacing: 45 cm x 10 cm). Three replication of each treatment was maintained with application of recommended dose of NPK-40:20:00 kg/ha. Observations on Per cent wilt incidence at 10 DAS and at maturity were recorded. Agronomic characters such as Plant height (cm), numbers of branches per plant, numbers of pod/plant, numbers of root nodules per plant were also recorded. CFU count of *T. viride* and *P. fluorescens* in treatment T_2, T_3, T_5 and T_6 was also calculated by following serial dilution method. Grain yield (kg /ha) and straw yield (kg/ha) was also recorded in all the three replications. Data thus obtained was analyzed by RBD design.

Results and Discussion

Total wilt incidence (%)

The pooled data presented in [Table-1] revealed that all the treatments significantly reduced the wilt disease incidence at seedling and at maturity as compared to the control.

At seedling stage (10 DAS)

The treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering was found significantly superior with minimum total wilt incidence at seedling stage (4.10%) which was found at par with treatment T_3:*T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering (4.17%) followed by treatment T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (4.44%), treatment T_2:

Table-1 Efficacy of bio agents as seed treatment as well as soil application for the management of chickpea wilt

Treatment	At seedling stage (10 DAS)				At maturity			
	2018	2019	2020	Pooled	2018	2019	2020	Pooled
T_1	14.87*(6.59)**	14.62*(6.37)**	13.25*(5.26)**	14.25*(6.07)**	18.30(9.93)	17.96(9.63)	16.97(8.52)	17.74(9.26)
T_2	13.20(5.26)	13.00(5.11)	12.04(4.37)	12.74(4.91)	16.03(7.78)	15.83(7.56)	16.44(8.22)	16.10(7.85)
T_3	12.04(4.37)	11.68(4.15)	11.46(4.00)	11.73(4.17)	13.89(5.78)	13.13(5.19)	13.44(5.41)	13.49(5.46)
T_4	12.85(4.96)	12.57(4.74)	15.21(6.89)	13.54(5.53)	16.73(8.30)	16.42(8.00)	17.11(8.67)	16.75(8.32)
T_5	11.52(4.00)	11.09(3.70)	13.63(5.63)	12.08(4.44)	15.71(7.33)	15.22(6.89)	17.03(8.59)	15.98(7.60)
T_6	11.52(4.00)	10.75(3.48)	12.65(4.81)	11.64(4.10)	12.88(4.96)	12.47(4.67)	15.18(6.89)	13.51(5.51)
T_7	21.77(13.78)	21.41(13.33)	21.53(13.48)	21.57(13.53)	35.79(34.22)	35.35(33.48)	36.24(34.96)	35.80(34.22)
SEm±	0.63	0.62	0.74	0.38	0.81	0.87	0.81	0.48
CD @ 5%	1.93	1.92	2.28	1.10	2.51	2.69	2.49	1.38
CV%	7.77	7.94	9.01	8.28	7.62	8.36	7.39	7.79
YxT				NS				NS

**Figures inside the parenthesis are original values while those outside are arc sine transformed values.*

Treatment details: T_1: T. viride ST @ 10g/kg of seeds: T_2: T. viride ST @ 10g/kg of seeds + SA of T. viride @ 2.5 kg /ha in 250 kg FYM at sowing; T_3: T. viride ST @ 10g/kg of seeds + two times SA of T. viride @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering T_4: P. fluorescens ST @ 10ml/kg of seeds: T_5: P. fluorescens ST @ 10ml/kg of seeds + SA of P. fluorescens @ 2.5 l /ha in 250 kg FYM at sowing; T_6: P. fluorescens ST @ 10ml/kg of seeds + two time SA of P. fluorescens @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering; T_7: Control

Table-2 Efficacy of bio agents as seed treatment as well as soil application on morphological characters of Chickpea and bioagent cfu over three years 2018-20

Treatment detail	Average plant height (cm)	Average numbers of branches/plant	Average numbers of pods/plant	Average numbers of root nodules/plant	Bio agent cfu / gm soil at harvest
T_1: *T. viride* ST @ 10g/kg of seeds	59.89	10.78	94.42	11.11	1 X 10^{3*}
T_2: *T. viride* ST @ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing	61.42	12.02	133.44	14.44	1 x 10^{7*}
T_3: *T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering	63.61	13.93	153.18	15.11	2 x 10^{10*}
T_4: *P. fluorescens* ST @ 10ml/kg of seeds	61.06	10.51	96.53	8.22	1 x 10^{5**}
T_5: *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing	63.16	11.80	133.13	7.44	1 x 10^{9**}
T_6: *P. fluorescens* ST @ 10ml/kg of seeds + two time SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering	66.43	14.44	148.09	7.00	>300 x 10^{10**}
T_7: Control	52.78	9.56	77.91	9.67	Tv = 2 x 10^{1*} PsF = 2 x 10^{2**}
S.Em±	1.14	0.57	2.84	0.55	
CD at 5%	3.28	1.65	8.16	1.57	
CV%	5.61	14.52	7.13	15.69	
YxT	NS	NS	NS	NS	

**PDA supplemented with rose bengal and streptocycline ** Pseudomonas agar (fluorescent base)*

Table-3 Efficacy of bio agents as seed treatment as well as soil application on Chickpea grain yield

Treatment	Grain yield (kg/ha)				Straw yield (kg/ha)			
	2018	2019	2020	Pooled	2018	2019	2020	Pooled
T_1: T. viride ST @ 10g/kg of seeds	2090	2199	1963	2084	2508	2423	2158	2363
T_2: *T. viride* ST @ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing	2198	2227	2208	2211	2637	2439	2319	2465
T_3: *T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering	2486	2559	2493	2513	2983	2818	2739	2847
T_4: *P. fluorescens* ST @ 10ml/kg of seeds	2108	2237	1925	2090	2529	2449	2131	2370
T_5: *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing	2306	2364	1953	2208	2767	2596	2133	2499
T_6: *P. fluorescens* ST @ 10ml/kg of seeds + two time SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering	2522	2605	2285	2471	3026	2862	2484	2791
T_7: Control	1648	1685	1411	1581	1978	1869	1522	1790
S.Em±	93.41	139.79	121.22	69.09	112.10	151.71	153.66	81.10
CD at 5%	287.86	430.78	373.55	198.33	345.43	467.51	473.50	232.80
CV%	7.37	10.68	10.32	9.57	7.37	10.54	12.03	9.95
YxT				NS				NS

Table-4 Economics of Biological seed treatment and soil application to control Chickpea wilt

Treatment	Bioagent quantity for Seed treatment/ha	Bioagent quantity for Soil application/ha	FYM quantitity soil application Kg/ha	Seed treatment cost (Rs./ha)	Bioagent cost Soil application (Rs./ha)	FYM cost /ha	Labour cost Seed treatment (Rs./ha)	Labour cost soil application (Rs./ha)	Total cost of cultivation	Yield (Kg/ha)		Income(Rs./ha)		Gross income (Rs./ha)	Net Income (Rs./ha)	Increase over control	CBR
										Grain	straw	Grain	straw				
T_1	600g	-	-	72	0	0	500	0	30072	2084	2363	104200	2363	106563	76491	25151	1: 2.54
T_2	600g	2.5kg/ha	250	72	300	375	500	250	30747	2211	2465	110550	2465	113015	82268	30928	1: 2.68
T_3	600g	5kg/ha	500	72	600	750	500	500	31422	2513	2847	125650	2847	128497	97075	45735	1: 3.09
T_4	600ml	-	-	42	0	0	500	0	30042	2090	2370	104500	2370	106870	76828	25488	1: 2.56
T_5	600ml	2.5L/ha	250	42	175	375	500	250	30592	2208	2499	110400	2499	112899	82307	30967	1: 2.69
T_6	600ml	5L/ha	500	42	350	750	500	500	31142	2471	2791	123550	2791	126341	95199	43859	1: 3.06
T_7	-	-	-	-	-	-	-	0	29500	1581	1790	79050	1790	80840	51340		1: 1.74

Treatment details: T_1: T. viride ST @ 10g/kg of seeds; T_2: T. viride ST @ 10g/kg of seeds + SA of T. viride @ 2.5 kg /ha in 250 kg FYM at sowing; T_3: T. viride ST @ 10g/kg of seeds + two times SA of T. viride @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering T_4: P. fluorescens ST @ 10ml/kg of seeds; T_5: P. fluorescens ST @ 10ml/kg of seeds + SA of P. fluorescens @ 2.5 l /ha in 250 kg FYM at sowing; T_6: P. fluorescens ST @ 10ml/kg of seeds + two time SA of P. fluorescens @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering; T_7: Control

Cost per item: 1. T. viride : Rs 120/kg, 2. P. fluorescens : Rs70/Lit, 3. Labour cost : Rs 250 /each, 4. FYM : Rs 1.25/ kg, 5. Grain cost : Rs 50/ kg, 6. Straw cost : Rs 1/ kg;

**The cost of bioagents and other items which were taken in consideration here are the university price and of the year in which experiment was undertaken*

T. viride ST@ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (4.91%), treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (5.53%) and treatment T_1: *T. viride* ST@ 10g/kg of seeds (6.07%) over the control.

At maturity stage

The treatment T_3: *T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering was found significantly superior with minimum total wilt incidence at maturity stage (5.46%) which was found at par with treatment T_6: *P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (5.51%) followed by the treatment T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (7.60%), treatment T_2:*T. viride* ST @ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (7.85%), treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (8.32%) and treatment T_1:*T. viride* ST @ 10g/kg of seeds (9.26%) over the control.

Morphological characters

The pooled data on morphological characters revealed that all the treatments significantly increased the average plant height, average numbers of branches per plant, average numbers of pods per plant at harvest as compared to the control.

Plant height

Among all the treatments, significantly higher plant height was recorded in treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (66.43 cm) which was found at par with treatment T_3:*T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering with recording higher plant height (63.61 cm) followed by treatment T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (63.16 cm), treatment T_2: *T. viride* ST@ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (61.42 cm), treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (61.06 cm) and treatment T_1: *T. viride* ST@ 10g/kg of seeds (59.89 cm) over the control (52.78 cm).

Numbers of branches per plant

Among all the treatments, significantly higher numbers of branches per plant were recorded in treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (14.44) which was found at par with treatment T_3:*T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering with recording higher plant height (13.93) followed by treatment T_2: *T. viride* ST@ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (12.02),treatment T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (11.80), treatment T_1: *T. viride* ST@ 10g/kg of seeds (10.78) and treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (10.51) over the control (9.56).

Numbers of pods per plant

Among all the treatments, significantly higher numbers of pods per plant were recorded in treatment T_3:*T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering (153.18) which was found at par with treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (148.09) followed by treatment T_2: *T. viride* ST@ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (133.44), T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (133.13), treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (96.53) and treatment T_1: *T. viride* ST@ 10g/kg of seeds (94.42) over the control (77.91).

Numbers of root nodules per plant

Among all the treatments, significantly higher numbers of root nodules per plant were recorded in treatment T_3:*T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering (15.11) which was found at par with treatment T_2:*T. viride* ST @ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (14.44) followed by treatment T_1: *T. viride* ST@ 10g/kg of seeds (11.11). Significant reduction of root nodules was observed in treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (7.00) which was found at par with treatment T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (7.44) followed by treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (8.22) over the control (9.67).

Bioagent cfu/g soil

The results obtained on cfu by using serial dilution technique in [Table-2] revealed that highest cfu of *P. fluorescens* (>300 x 10^{10}) was recorded in treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering followed by treatment T_5 and T_4at harvest. Whereas highest cfu of *T. viride* (2 x 10^{10}) was obtained in Treatment T_3:*T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering followed by T_2 and T_1 at harvest.

Grain yield (Kg /ha)

The results of grain yield presented in [Table-3] revealed that the effect of different treatments was found to be significant during all the individual years as well as in pooled also. All the treatments were recorded significantly higher yield as compared to the control.

Among all the treatments, significantly higher grain yield was recorded in treatment T_3: *T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering (2513 kg/ha) which was found at par with treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (2471 kg/ha) followed by treatment T_2: *T. viride* ST@ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (2211 kg/ha), T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (2208 kg/ha), , treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (2090 kg/ha) and treatment T_1: *T. viride* ST@ 10g/kg of seeds (2084 kg/ha) over the control (1581 kg/ha).

Straw yield (Kg/ha)

In case of straw yield [Table-3], higher straw yield was recorded in treatment T_3:*T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering (2847 kg/ha) which was found at par with treatment T_6:*P. fluorescens* ST@ 10ml/kg of seeds + two time SA of *P. fluorescens*@ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (2791 kg/ha) followed by treatment T_5 : *P. fluorescens* ST @ 10ml/kg of seeds + SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing (2499 kg/ha), T_2: *T. viride* ST@ 10g/kg of seeds + SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing (2465 kg/ha), treatment T_4: *P. fluorescens* ST @ 10g/kg of seeds (2370kg/ha) and treatment T_1: *T. viride* ST@ 10g/kg of seeds (2363 kg/ha) over the control (1790 kg/ha).

Economics

The economics was calculated by considering the net profit increase over control of different treatments [Table-4]. The treatment *T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering (T_3) recorded highest net return (Rs. 97075/ha) with CBR (1:3.09) followed by *P. fluorescens* ST @ 10ml/kg of seeds + two time SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering (T_6) with net return (Rs. 95199/ha) and CBR (1:3.06). Therefore, considering the yield and economics of the treatment T_3: *T. viride* ST @ 10g/kg of seeds + two times SA of *T. viride* @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering or treatment T_6: *P. fluorescens* ST @ 10ml/kg of seeds + two time SA of *P. fluorescens* @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering are recommended for the management of chickpea wilt and to obtain higher yield.

The research work carried out on biological management of chickpea wilt caused by *Fusarium oxysporum* f. sp. *ciceris*. is also more or less similar with the work carried out by earlier workers, Prasad, *et al*., (2002) [3] reported that soil application of *T. viride* and *T. harzianum* one week before sowing as more effective in reducing wilt and wet root rot of chickpea. The consortium (*T. viride* + *T. harzianum* + *T. hamatum*) found very effective for control of chickpea wilt due to synergistic effect. Rudresh, *et al*., (2005) [4] reported significant control of wet root rot and *Fusarium* wilt of chickpea by soil application of *T. harzianum* (PDBCTH) and *T. virens* (PDBCTV12), respectively. Nikam, *et al*., (2007) [5] revealed that soil and seed application of *T. viride* is found to be effective in controlling the chickpea wilt by 80.86% and 66.67% wilt incidence respectively moreover to this they have also reported that combined soil application of *T. viride* and ground nut cake followed by neem cake had given good control against chickpea wilt caused by *Fusarium oxysporum* f. sp. *ciceris*. According to Srivastava, *et al*., (2010) [6] the combination of fluorescent *Pseudomonas, Trichoderma* and arbuscular mycorrhiza provided much better control than uninoculated therapy in pot culture, reducing disease incidence by 74%. In comparison to treatment with a single bio-agent, Singh, *et al.,* (2013) [7] concluded that using a consortium of compatible bio-agents will improve plant development and biological control of phytopathogens. According to Dubey, *et al*., (2015) [8], combining *T. harzianum* and *P. fluorescens* with *Mesorhizobium* dramatically reduced the incidence of wilt.

According to Mahmood, *et al.,* (2015) [9] seed treatment with *Trichoderma harzanium* followed by chemical drenching was the most efficient, reducing disease by up to 93.75 percent. Pandey, *et al.,* (2017) [10] reported significantly lowest wilt incidence and root rot (8.59%) and highest seed germination (96.69 %), vigour index (2734) and grain yield (1535 kg/ha) in the treatment of seed biopriming for 10 hrs with suspension of talc based formulation ($2x10^8$ cfu/g) of *T. viride* @ 50 g in 250 ml of water/ kg of seed + soil application of *T. viride* enriched FYM (10 kg bioagent/ ton FYM) in furrow @ 1 ton/ ha. Deshmukh, *et al*., (2020) [11] have reviewed that seed bio-priming of *Pseudomonas fluorescence, Trichoderma viride* and *Trichoderma harzianum* in numbers of crops not only enhances crop seedling and plant growth but also induces disease resistance against numbers of major and minor diseases in variety of field, horticultural and forest crops. Seed treatment or soil application of *Trichoderma viride*. could be successfully used for management of fungal wilt in chick pea crop [12]. Joshi, *et al*., (2022) [13] revealed that seed treatment with a talc-based consortium of *Trichoderma asperellum* + *Pseudomonans fluorescens* at 10 g/kg seed resulted in a lower disease incidence (29.67%) when compared to soil application of an FYM-enriched formulation of *Trichoderma asperellum* + *Pseudomonans fluorescens* at 2.5 kg in 250 kg FYM (33.33%) with seed yields of 33.67 and 30.67.

Conclusion

Chick pea growing farmers of South Gujarat are recommended to treat seed with *Trichoderma viride* 1.5% WP (IIHR strain) (2 x 10^6 cfu/g) @ 10g/kg of seeds + two soil applications of *Trichoderma viride* 1.5% WP (IIHR strain) @ 2.5 kg /ha in 250 kg FYM at sowing and at 50% flowering or to treat seed with *Pseudomonas fluorescence* 1.5% liquid form (NAU strain) (1 x 10^8 cfu / ml) @ 10 ml / kg of seeds + two soil applications of *Pseudomonas fluorescence* 1.5% liquid form (NAU strain) @ 2.5 l /ha in 250 kg FYM at sowing and at 50% flowering for effective management of chickpea wilt.

Application of research: Study of biological management of Chickpea (*Cicer arietinum* L.) Wilt

Research Category: Plant pathology, Disease management

Abbreviations: cfu- colony forming unit, T_1 - Treatment 1 and so on
ST- seed treatment, SA- soil application, WP- Wettable powder, ha- hectare
FYM- Farm yard manure, CBR- Cost benefit ratio

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Study area / Sample Collection: Rajendrapur farm, Hill Millet Research Station, Waghai, 389151

Cultivar / Variety / Breed name: Chickpea (*Cicer arietinum* L.) - GG-2

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References

[1] Dobariya J.B., Thesiya N.M., Zinzala V.J. and Aklade S.A. (2016) *J. Krishi Vigyan*, 5(1), 19-22
[2] Pandya J.R. (2010) *PhD Thesis, Navsari Agricultural University, Navsari, 396450, Gujarat, India*.
[3] Prasad R.D., Rangeshwaran R., Anuroop C.P. and Rashni H.J. (2002) *Ann. Pl. Prot. Sci*., 10(1), 72-75.
[4] Rudresh D.I., Shivaprakash M.K. and Prasad D. (2005) *Biological Control,* 19(2), 157-166.
[5] Nikam P.S., Jagtap G.P. and Sontakke P.L. (2007) *African Journal of Agricultural Research*, 2(12), 692-697.
[6] Srivastava R., Abdul K., Singh U.S. and Sharma A.K. (2010) *Biological Control*, 53, 24-31.
[7] Singh S.P., Singh H.B. and Singh D.K. (2013) *The Bioscan*, 8(3), 801-804.
[8] Dubey S.C., Singh V. and Priyanka K. (2015) *Biocontrol*, 60, 413-424.
[9] Mahmood Y., Khan M.A., Javed N. and Arif M.J. (2015) *J. Anim. Plant Sci*., 25(4), 1063-1071.
[10] Pandey R.N. Gohel N.M. and Jaisani P. (2017) *Int. J. Curr. Microbiol. App. Sci*., 6(5), 2516-2522.
[11] Deshmukh A.J., Jaiman R.S., Bambharolia R.P. and Patil V.A. (2020) *International Journal of Economic Plants*, 7(1), 38-43.
[12] Bawane A.S., Zacharia S. and Kar S.R. (2022) *The Pharma Innovation Journal*, 11(3), 1284-1288.
[13] Joshi R., Sunkad G., Amaresh Y.S. and Kenganal M. (2022) *Biological Forum – An International Journal*, 14(2), 346-349.