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Efficacy of different management modules against bacterial blight of clusterbean under epiphytotic conditions

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Abstract
Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] popularly known as "Guar" is an important leguminous crop of *kharif* season in arid and semi-arid region of the Indian subcontinent. In the present investigation efficacy of thirteen different treatments alone and with combination were tested against bacterial blight of clusterbean [*Xanthomonas axonopodis* pv. *cyamopsidis* (XAC)]. Among the treatments, lowest bacterial blight PDI (8.5, 7.5 and 5.83) were observed in treatment $T_{2;}$ (Streptocycline (250 ppm) + Blitox (0.2%) two sprayed at 15 days interval) followed by (11.0, 11.83 and 8.16 PDI) in treatment $T_{11;}$ (Streptocycline 150 ppm + Carbendazim 12% + Mancozeb 63% @ 0.2% two sprayed at 15 days interval). The seed yield, per cent disease reduction and per cent yield increase over control were also highest (1560 kgha^{-1}, 83.27 and 79.51% respectively) in the treatment (T_2) followed by in treatment (T_{11}) (1390 kg ha^{-1}, 76.37 and 59.95% respectively) which were the most effective as well as economically and beneficial treatments to manage the bacterial blight of clusterbean under epiphytotic conditions

Keywords: Bacterial blight, clusterbean, *Xanthomonas axonopodis* pv. *Cyamopsis* (xac), management

Introduction
Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub] popularly known as "Guar" is an important legumes crop of *kharif* season in arid and semi-arid region of the Indian subcontinent and to a small extent in Australia, Brazil, South Africa, Oklahoma and Texas in North America. In India, it is grown in the states of Rajasthan, Haryana, Gujarat and parts of Punjab and Uttar Pradesh under rain-fed conditions. It is grown for different purposes viz; vegetable, green fodder, green manure, production of seeds and extraction of gum. Clusterbean endosperm contains 19-43% galactomannan gum, which has tremendous industrial use such as an emulsifier, in cosmetics and pharmaceuticals industry. It is a very hardy and drought tolerant crop. Its deep penetrating root enables plant to utilize available moisture more efficiently, hence suitable for cultivation in arid and semi-arid region of Rajasthan. The crop survives best even at moderate salinity and alkalinity. The crop is valued as systems sustained components particularly in enhancing the soil fertility. Their role in propping up organic farming needs no emphasis.

Clusterbean suffers from a number of diseases caused by fungi, bacteria and virus. Bacterial blight (*Xanthomonas axonopodis* pv. *cyamopsidis*), Alternaria leaf spot (*Alternaria cyamopsidis*), Anthracnose (*Colletotrichum capsici* f.sp. *cyamopsidis*), Charcoal rot/Damping off (*Macrophomina phaseolina*), Dry root rot/ Leaf blight (*Fusarium solani* and Rhizoctonia *solani*) and wilt (*Fusarium caeruleum*) are important diseases of arid legume (Kumar, 2005) [8]. Among all the diseases, bacterial blight is the most devastating and limits clusterbean productivity in all growing regions especially in irrigated lands and dry upland environment where predisposing factors favours disease development to epidemic proportions. The pathogen is internally seed borne in nature and provides primary inoculums for secondary spread. This entails the need for designing effective disease management programme in order to save this economically important crop and regimens are, therefore, required to monitor persistence and distribution of this important pathogen.

Occurrence of bacterial blight and leaf spot of clusterbean caused by *Xanthomonas axonopodis* pv. *cyamopsidis* (XAC) has been reported from United States (Orellana *et al*., 1965) [12], Arizona (Mihail and Alcorn, 1985) [11], Madison (Undersander *et al*., 1991) [21] and Brazil (Almeida *et al*., 1992) [1]. In India, the disease has been reported from the states of Rajasthan (Patel *et al*., 1953) [14], as bacterial leaf spot and later as bacterial blight by Patel and Patel (1958) [13], Haryana (Gandhi and Chand, 1985) [5] and Karnataka (Patel and Patel, 1958) [13] caused by *Xanthomonas axonopodis* pv. *cyamopsidis* is a major impediment to clusterbean production in rain-fed and irrigated environments in India. Yield losses of as high as 68% have been reported (Gandhi and Chand, 1985) [5]. Due to severity of the disease, yield losses up to 32% have been reported in arid zone of Rajasthan (Lodha *et al*., 1986) [9].This seed-borne disease (on the seed coat or in the embryo) causes infestation of plants right from the seedling stage to till maturity (Srivastava and Rao, 1963) [19]. Principal symptoms include large angular necrotic lesions at the tips of leaves, yellow leaf spots, blighting, wilting which causes defoliation and in severe cases vascular necrosis, dieback and black streaking of the stem along with continuous oozing of exudates. Infected/contaminated seed or the propagating planting material is a major source of inoculum for most of the phytobacterial disease manifestation. Furthermore, the bacterium survives in tissue without causing discernable symptoms. The present study aims to evaluate the efficacy of fungicides, animal and plant by product and antibiotics as seed treatment alone or in combination with foliar spray for better management of bacterial blight disease of clusterbean.

Material and Methods

Field experiments were conducted in three cropping seasons of 2012-13, 2013-14 and 2014-2015 at the Research farm of Agricultural Research Sub Station, Hanumangarh (29.1547° N, 74.4995° E,) under Swami Keswananad Agricultural University (SKRAU), Bikaner. The soil of Hanumangarh is dominant in illitic clay, mostly acidic to neutral in reaction, low to medium in available N, medium to very high in available P, medium in K content. The experiments were carried out for three years on fixed sites in under arid agro climatic zones of Rajasthan. The experiments consist of thirteen treatments including a control (no application of fungicide) were laid out at fixed location in plot size of 5 x 3 m with 30 x 10 cm row and plant to plant spacing in randomized block design (RBD) with three replications using popular cultivar i.e. RGC-963 (*Cyamopsis tetragonoloba*) of clusterbean as the test variety. All the standard agronomic practices were followed to raise the clusterbean crop. Recommended dose of N: P: @ 20: 40 kg ha^{-1} were applied. The crop was sown during the first week of July. Two irrigations were applied at different crop stages (Seedling and pod formation) and weeding was done as and when required. One drenching of chlorpyriphose @ 2.4 litre /hectare was applied for termite control.

Treatments with different doses of fungicides, animal by product and antibiotics as mentioned in (table 1) were used for seed treatment and foliar application against bacterial blight disease of clusterbean. Seeds were treated with each fungicide, animal by product and antibiotic 12 h prior to sowing. The seeds were properly mixed in a separate glass beaker with each pesticide with their respective doses for 10-20 min to ensure uniform coating. Foliar application of all the fungicide, animal by product and antibiotic were applied at critical stages of (45 and 60 Day) of bacterial blight disease incidence. Epiphytotic condition of bacterial blight disease was created by uniformly sprayed of bacterial suspension with water in all the treatments at the time of vegetative growth of crop. The first foliar spray was applied at the time of appearance of bacterial blight in crop. In all the experimental plots, observation on per cent disease incidence of bacterial blight was recorded on plot basis up to maturity of crop. Per cent disease control was calculated by using the following formula

$$\text{PDC} = \frac{\text{PDI in control} - \text{PDI in treatment}}{\text{PDI in control}} \times 100$$

The severity of bacterial blight disease in all the experimental plots was assessed according to using 0-5 disease rating scale of Chester (1950) [4]. Ten plants were randomly selected from each plot at 7^{th} day after the foliar spray for estimating the per cent leaf area affected and PDI was calculated by using the following formula

$$\text{Disease severity (\%)} = \frac{\text{Sum of Numerical Ratings}}{\text{No. of plants scored} \times \text{Maximum disease rating scale}} \times 100$$

Data recorded on bacterial blight was subjected to arc sin transformation prior to statistical analysis. Single factor analysis of variance (ANOVA) test was used to determine significant difference ($p<0.05$) between the treatments. Economic parameters such as per cent increase in yield over control and benefit cost ratio (BCR) were calculated by considering the cost of all inputs and outputs. Benefit cost ratio was calculated by using following formula.

B: C ratio = [Income received (from the particular treatment) / Cost incurred (for the particular treatment)]

Results and Discussion

All the treatments were found effective in reducing the bacterial blight disease incidence over the control. In the present study the results depicted from (table 2) revealed that lowest bacterial blight PDI (8.5, 7.5 and 5.83) were observed in years 2012, 2013 and 2014 in treatment $T_{2;}$ (Streptocycline (250 ppm) + Blitox (0.2%) two spray at 15 days interval) followed by (11.0, 11.83 and 8.16 PDI) in treatment $T_{11;}$ (Streptocycline 150 ppm + Carbendazim 12% + Mancozeb 63% @ 0.2% two spray at 15 days interval). Similarly, the module consisting with treatment T_5; (Streptocycline 1gkg^{-1} seed (ST) + Streptocycline 150 ppm (FS) two spray at 15 days interval) significantly reduced the bacterial blight incidence (13.66, 12.83 and 10.00 PDI) over the untreated control (44.37, 46.33 and 40.50 PDI) respectively. The pooled mean results on bacterial blight showed that, lowest disease incidence (7.27 PDI) was recorded in treatment (T_2) followed by (T_{11}) (10.33 PDI) and (T_5) (12.16 PDI) as compared to control (43.73 PDI). The treatment $T_{10;}$ (Streptocycline 1gkg^{-1} seed (ST) + Blitox-50 @ 0.2% + Mancozeb @ 0.2% two spray at 15 days interval), $T_{12;}$ (Carbendazim 12% + Mancozeb 63% @ 0.2% two spray at 15 days interval) and T_8; (Copper hydroxide 0.2% (ST) + Copper hydroxide 0.2% three sprays at 15 days interval) have also been reduced the incidence of bacterial blight and significantly at par with each other. The pooled mean results revealed that all the treatment combinations of antibiotics, fungicides, plant extracts and cow dung significantly reduced the bacterial leaf blight incidence during 2012 to 2014 and the yield was also significantly higher than untreated control.

The pooled mean results indicated that all the treatments have been significantly reduced the bacterial blight disease incidence by seed treatment and foliar application over untreated control. The observations from (table 2) showed that the pooled mean of yield, per cent disease reduction and per cent yield increase over control in all the treatments were increased (958 to 1560 kgha^{-1}, 25.70 to 83.27% and 10.24 to 79.51% respectively) over the control and it was highest

(1560 $kgha^{-1}$, 83.27 and 79.51% respectively) in the treatment $T_{2;}$ (Streptocycline (250 ppm) + Blitox (0.2%) two spray at 15 days interval) followed by treatment $T_{11;}$ (Streptocycline 150 ppm + Carbendazim 12% + Mancozeb 63% @ 0.2% two spray at 15 days interval) (1390 $kgha^{-1}$, 76.37 and 59.95% respectively) as compared to untreated control. The trend of reduction in disease incidence was inversely related with an increase in seed yield. These findings are in confirmation with findings of Lodha (2001) [10] evaluated in a field experiment in Jodhpur, Rajasthan, India during the cropping season of 1991 and 1992 that seed treatment with Streptocycline + foliar spray of Streptocycline at 35 and 49 DAS reduced the bacterial blight and higher seed yield were recorded in the treatment received two spray of streptocycline. Rathore (2000) [16] observed that the treatment of clusterbean (*Cyamopsis tetragonoloba*) seeds with the antibiotic streptocycline, hot water, bavistin [carbendazim], captan, thiram and topsin M [thiophanate-methyl] was studied for the control of *Xanthomonas axonopodis* pv. *axonopodis*. Seed dip for 3 h in streptocycline aqueous solution (0.02%) was highly effective in reducing of bacterial blight of clusterbean. Similarly, Saini and Parashar (1981) [18] and Raju and Rao (1984) [15] were also found effective control of black rot on cauliflower and bacterial leaf spot on chilli with foliar spray of carbendazim and mancozeb, respectively. Evaluation of antibiotics and fungicides against bacterial blight of guar (*Cyamopsis tetragonoloba*) was carried out by Gupta (1977) [6]. The best control of the disease was obtained with streptocycline @ 100 to 250 ppm and agrimycin-100 @ 100 to 500 ppm. Ravikumar and Khan (1995) [17] reported that the seed treatment with streptomycin sulphate or streptocycline for 120 min at 300, 400 and 500 ppm eliminated the *X. campestris* pv. *vesicatoria* from tomato seeds. Yenjerappa *et al* (2004) [22] noticed the superior efficacy of streptocycline (0.05%) + copper oxychloride (2000 ppm) in checking the bacterial blight menace of pomegranate. Ashish *et al* (2016) [2] reported that Blitox (0.3%) + Streptocycline (250 ppm) proved most effective in reducing per cent disease index, per cent fruit cracking and providing maximum disease control. Maximum TSS, fruit weight, juice weight, pulp weight, 100 grain weight and total grain weight were observed in blitox (0.3%) + streptocycline (250 ppm) which corroborated to our study. Jagtap *et al* (2012) [7], reported that minimum disease severity of bacterial blight of cotton was found 8.35 per cent in treatment of carbendazim 0.1% + streptocycline 100 ppm, that combination was also found effective against bacterial blight of clusterbean.

The cost-benefit ratio (CBR) in the present investigation was also evaluated. Results presented in (table 2) revealed a positive return and highest CBR (1:3.69) in the module comprising of Streptocycline (250 ppm) + Blitox (0.2%) 2 spray at 15 days interval followed by the module comprising Streptocycline (150 ppm) + Carbendazim (12%) + Mancozeb (63%) @ 0.2% two spray at 15 days interval (1:3:31). Increased clusterbean seed yield and higher net return by Streptocycline (250 ppm) + Blitox (0.2%) 2 spray at 15 days interval in clusterbean was also reported by Yadav and Nath (2006) [21] and observed that three chemicals, viz. streptocycline, plantomycin and copper oxychloride, at different concentrations and their combinations were tested against the bacterial blight of clusterbean *in vitro* and *in vivo* and found that seed treatment and foliar application of streptocycline at 500 ppm showed minimum per cent of disease incidence and maximum seed yield of clusterbean. Bacterial blight infection could be significantly reduced by all three chemicals and its combinations at different concentrations as evidenced by the data of disease suppressing and increasing of yield. These findings are corroborated to our study.

Seed soaking of cow dung or vermin-compost in combination with spray of cow dung or vermin-compost was comparatively less effective in managing of disease in treatments (T_3, T_4, T_6 and T_7) but found significantly superior over control (T_{13}). Cow dung is comparatively more effective in reducing the disease because of some antibacterial properties present in cow dung that have ability to suppress the disease. Chaudhari *et al* (2016) [3] reported that cow dung was tested at 5, 10 and 15 per cent concentrations and screened by paper disc techniques *in vitro* to find out their efficacy against bacterial growth of *X. axonopodis* pv. *cyamopsidis*. All the treatments found significantly superior over check for bacterial growth of clusterbean pathogen. It is pertinent to mention here that combination of Streptocycline with Copper oxychloride (T_2) or Streptocycline in combination with Carbendazim 12% + Mancozeb 63% (T_{11}) is highly effective in reducing the disease and increasing the yield as compared to spray of combination of Blitox-50 + Mancozeb (T_{10}) or Carbendazim 12% + Mancozeb 63% (T_{12}) or seed soaking of streptocycline in combination with spray of streptocycline (T_5, T_9). It is clear from the results that antibiotic in combination with fungicide was more effective than the individual spray of streptocycline or fungicide. The efficacy of combined treatment of fungicide and streptocycline increased due to synergistic effect of fungicide and streptocycline.

Integrated disease management strategy should be formulated for poor farmers by generating locally specific techniques and solutions suitable for their particular farming systems and also by integrating the various control measures which are ecologically sound and readily available to them. Hence, it can be concluded from the results of the present investigation that module comprising streptocycline (250 ppm) + Blitox (0.2%) two spray at 15 days interval followed by module comprising streptocycline 150 ppm + Carbendazim 12% + Mancozeb 63% @ 0.2%, two spray at 15 days interval was the most effective as well as economically beneficial treatment to manage the bacterial blight of clusterbean under epiphytotic conditions.

Table 1: Details of different fungicides, organic product and antibiotics treatments

Treatment	Treatment details
T_1	Zink sulphate (0.25%) + Azadirachtin (1.5 ml^{-L}) two spray at 15 days interval
T_2	Streptocycline (250 ppm) + Blitox (0.2%) two spray at 15 days interval
T_3	Cow dung 20 g^{-L} water + Vermicompost 20 g^{-L} three sprays at 15 days interval
T_4	Cow dung 20 g^{-L} + Vermicompost 20 g^{-L} (Seed soaking +Foliar spray) two spray at 15 days interval
T_5	Streptocycline 1gkg^{-1} seed (ST) + Streptocycline 150 ppm (FS) two spray at 15 days interval
T_6	Cow dung 20 g^{-L} (ST) + Cow dung three sprays at 15 days interval
T_7	Vermi-compost 20 g^{-L} (ST) + Vermi-compost three sprays at 15 days interval
T_8	Copper hydroxide 0.2% (ST) + Copper hydroxide 0.2% three sprays at 15 days interval

T_9	Streptocycline 150 ppm (ST) + Streptocycline 150 ppm two spray at 15 days interval
T_{10}	Streptocycline 1gkg^{-1} seed (ST) + Blitox-50 @ 0.2% + Mancozeb @ 0.2% two spray at 15 days interval
T_{11}	Streptocycline 150 ppm + Carbendazim 12% + Mancozeb 63% @ 0.2% two spray at 15 days interval
T_{12}	Carbendazim 12% + Mancozeb 63% @ 0.2% two spray at 15 days interval
T_{13}	Control (with water treatment)

ST; Seed treatment; FS; Foliar spray

Table 2: Management of Bacterial Blight of Cluster bean under epiphytotic conditions

Treatments	2012		2013		2014		Pooled Mean		% Disease Reduction	% yield increase over control	B: C Ratio
	BB	Yield kgha^{-1}	BB	Yield kgha^{-1}	BB	Yield kgha^{-1}	BB	Yield kgha^{-1}			
T_1	27.83 (31.86)	967	29.16 (32.63)	1338	24.66 (29.75)	833	27.88 (31.41)	1046	36.24	20.36	1:2.86
T_2	8.5 (16.71)	1379	7.5 (15.6)	1975	5.83 (13.66)	1327	7.27 (15.32)	1560	83.27	79.51	1:3.69
T_3	30.5 (33.51)	947	30.0 (33.19)	1450	25.33 (26.56)	895	28.61 (31.08)	1097	34.57	26.33	1:2.79
T_4	22.33 (28.08)	1070	25.0 (29.92)	1481	20.33 (26.81)	926	22.55 (28.27)	1159	48.43	33.37	1:2.83
T_5	13.66 (21.49)	1111	12.83 (20.92)	1697	10.00 (18.21)	1049	12.16 (21.86)	1285	72.19	47.87	1:3.11
T_6	18.5 (25.38)	1009	20.16 (20.92)	1558	15.66 (23.17)	1003	18.10 (23.15)	1190	58.60	36.93	1:2.91
T_7	32.66 (34.84)	843	34.83 (36.16)	1234	30.0 (33.20)	802	32.49 (34.73)	960	25.70	10.43	1:2.34
T_8	19.33 (26.74)	762	19.16 (26.89)	1296	15.0 (22.01)	817	17.83 (25.21)	958	59.73	10.24	1:2.28
T_9	16.66 (24.06)	1090	15.33 (23.03)	1604	12.5 (20.35)	1080	14.83 (22.48)	1258	66.08	44.76	1:3.05
T_{10}	18.16 (25.14)	1132	19.33 (25.95)	1651	14.66 (22.35)	1018	17.38 (24.48)	1267	60.25	45.79	1:3.01
T_{11}	11.0 (19.37)	1240	11.83 (20.10)	1760	8.16 (16.39)	1172	10.33 (18.62)	1390	76.37	59.95	1:3.31
T_{12}	20.5 (26.92)	1000	19.36 (26.25)	1574	16.5 (23.80)	1030	17.78 (25.65)	1201	59.34	38.22	1:2.91
T_{13}	44.37 (42.06)	741	46.33 (42.9)	1111	40.5 (39.5)	756	43.73 (41.48)	869	-	-	1:2.17
GM = CV% = (P >0.05)	28.17 11.63 4.10	1004.4 18.00 225.0	27.7 10.37 3.6	1521.8 11.51 219.4	24.28 14.41 4.38	978 15.36 188.2	26.31 4.54 1.49	1172.5 4.62 67.87			

*Arc sine transformed values in parentheses; BB; Bacterial blight

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