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Compatibility of seed dressing fungicides with imidacloprid seed treatment in BT cotton

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Abstract
Compatibility of certain seed dressing fungicides with imidacloprid seed treatment in Bt cotton hybrid was investigated at Regional Agricultural Research Station, Lam, Guntur during 2015-2017. Jaadoo BG II cotton seed, treated with imidacloprid against early sucking pests was retreated with eight test fungicides. Seed dressing fungicides *viz*., thiram @ 3g/kg, carbendazim @ 2g/kg, streptocyclin @100ppm, trifloxystrobin @ 1ml/kg, captan @ 3g/kg, carboxin @ 2g/kg, mancozeb @ 3g/kg and penflufen @ 2 ml/kg seed were compatible with imidacloprid treatment of Bt cotton seed in terms of germination, seedling vigour without phytotoxicity and reduced seed borne infections along with sucking pest control up to 28days. Hence cotton seed treatment with imidacloprid followed by fungicide is recommended to manage sucking pests as well as soil and/or seed borne diseases for healthy crop stand to reap higher yields.

Keywords: cotton, compatibility, seed treatment, imidacloprid, fungicides

Introduction
Cotton is an important commercial crop in India with a production of 377 lakh bales of 170 kg lint in 2017-2018 from an area of 122.35 lakh ha with a productivity of 524 kg/ha, which is far behind the leading countries. Andhra Pradesh stood 7th in area (5.44 lakh ha) but 5th in production (22.0 lakh bales) and 3rd in productivity (688 kg/ha) during 2017-2018 (Anonymous, 2018) [1]. Seed and/or soil borne diseases of cotton affect the seed germination and emergence, survival, and development of seedlings as well as establishing plant stand. Several pathogens including bacterial blight (*Xanthomonas axonopodis* pv *malvacearum*), fungal leaf spots caused by *Alternaria macrospora*, *A. alternata*, *Myrothecium roridum*, *Colletotrichum capsici* are seed borne while *Rhizoctonia solani*, *R. bataticola* (*Macrophomina bataticola*), *Fusarium oxysporum* f. sp. *vasinfectum*; *Verticillium dahlia* are mainly soil borne in cotton. In Andhra Pradesh Alternaria leaf spot is the most commonly occurring disease starting from the germination and causes economic losses under congenial conditions (Bhattiprolu and Prasada Rao, 2009) [2]. Importance of seed treatments in sustainable agriculture was reviewed by Sharma *et al* (2015) [3]. Seed treatment with thiram @ 3g or carboxin @ 2g or captan @ 3g or carbendazim @ 2g was recommended to manage seed/soil borne diseases in cotton (Bhattiprolu, 2017) [4]. Bt cotton is being sold with pretreatment using imidacloprid against sucking pests during early growth stage. Therefore the recommended seed dressing fungicides should be compatible with imidacloprid seed treatment in Bt cotton. An experiment was conducted at Regional Agricultural Research Station, Lam to verify the compatibility of seed dressing fungicides with imidacloprid seed treatment in Bt cotton.

Materials and Methods
Field studies were carried out to investigate the compatibility of seed dressing fungicides with imidacloprid seed treatment in Bt cotton hybrid Jaadoo BG II during *kharif* 2015-2017, at RARS, Lam, Guntur. Insecticide treated seed of Bt cotton hybrid, Jaadoo BG II was sown on 03.08.15, 02.08.16 and 28.07.17 in plots of 31.5 sq. m adopting a spacing of 105 x 60 cm. Ten treatments *viz*., T_1 - Seed treatment (ST) with thiram @ 3g/kg seed; T_2 - ST with carboxin @ 2g/kg seed; T_3 - ST with captan @ 3g/kg seed; T_4 - ST with mancozeb @ 3g/kg seed; T_5 - ST with carbendazim @ 2g/kg; T_6 - ST with streptocyclin @ 100ppm; T_7 - ST with penflufen @ 2ml/kg; T_8 - ST with trifloxystrobin @ 1ml/kg; T_9 - Insecticide treated seed and T_{10} - Untreated control were imposed at the time of sowing in randomized block design with three replications.

Data on germination and seedling vigour was recorded at 14 days after sowing (DAS) and 30DAS. Number of leaves showing phytotoxicity symptoms along with total number of leaves, on 10 randomly selected plants was recorded. Phytotoxicity percentage was calculated and treatments were graded on 1-10 scale i.e.

Table: Scale and phytotoxicity (%)

S. No.	Scale	Phytotoxicity (%)
1	0 Scale	No phytotoxicity
2	1 Scale	1 – 10% phytotoxicity
3	2 Scale	11 – 20% phytotoxicity
4	3 Scale	21 – 30% phytotoxicity
5	4 Scale	31 – 40% phytotoxicity
6	5 Scale	41 – 50% phytotoxicity
7	6 Scale	51 – 60% phytotoxicity
8	7 Scale	61 – 70% phytotoxicity
9	8 Scale	71 – 80% phytotoxicity
10	9 Scale	71 – 90% phytotoxicity
11	10 Scale	81 – 100% phytotoxicity

Data on seed borne diseases was collected up to 45days of sowing by adopting 0-4scale (Sheo Raj, 1988) [5] where 0 = No disease; 1 = <5% leaf area infected; 2 = 6-20% leaf area infected; 3 = 20-40% leaf area infected and 4 = >40% leaf area are infected and expressed as Percent Disease Index (PDI) using Wheeler's formula (1969) [6]:

$$PDI = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves scored x maximum rating}} \text{ X } 100$$

Percent disease control in each treatment was calculated. Observations on the incidence of sucking pests at 28DAS were recorded followed by recommended protection measures against insect pests on need basis. Yield data from three replications of each treatment was recorded. Decrease / increase in the disease / yield over control were calculated using the formula:

$$\frac{T - C}{C} \text{ X } 100 \text{ where}$$

T = PDI or yield (q/ha) of respective treatment
C = PDI or yield of control
Treatment wise Benefit Cost Ratio (BCR) was calculated by dividing gross returns with gross expenditure.

Results and Discussion

Germination was significantly superior in streptocyclin, thiram, carbendazim, mancozeb, trifloxystrobin and penflufen whereas numerically higher in carboxin and captan at 14 DAS, during 2015-16. Seedling vigour was non-significant at 28DAS but numerically higher in captan, carbendazim, streptocyclin, thiram and mancozeb. During 2016-17 germination was significantly superior in all fungicidal treatments (carbendazim, trifloxystrobin, thiram, captan, mancozeb, penflufen, streptocyclin, carbendazim and carboxin, respectively) at 14 DAS. Seedling vigour was significant at 28DAS in all the fungicidal treatments. At 14 DAS germination was significantly superior in all fungicidal treatments (carboxin, streptocyclin, thiram, carbendazim, captan, mancozeb, trifloxystrobin and penflufen, respectively). Seedling vigour was significant at 28DAS in all fungicidal treatments in 2017-18 (Table 1). Tomer *et al.*, (2012) [7] obtained 63.96% to 68.77% germination by protecting against seed borne *Myrothecium roridum*, *Aspergillus niger* and *Curvularia lunata* in J 4 cotton cultivar.

All fungicides effectively reduced Alternaria leaf spot at seedling stage. Further, the test fungicides did not cause any phytotoxicity symptoms during three years of study. There was no sucking pest incidence up to 28days. Maximum yield of 21.78q/ha was recorded with captan as against 15.34q/ha in control plots. Carbendazim and thiram were statistically on par with captan while streptocyclin, penflufen, trifloxystrobin, mancozeb and carboxin were at par during 2015-16. Maximum yield of 19.08q/ha was recorded with captan as against 12.75q/ha in untreated control plots during 2016-17. Maximum yield of 25.58q/ha was obtained with mancozeb as against 18.52q/ha from untreated control plots during 2017-18 (Table 2).

Seed treatment with insecticides and fungicides along with *Rhizobium* or biocontrol agents or biofertilizers was found compatible in different crops (Harpreet Kaur Cheema *et al*., 2009 [8]; Mehta *et al*., 2011 [9]; Yara Cristiane Buhl Gomes *et al*., 2017 [10]). Seed dressing fungicides, Sixer (mancozeb + carboxin) and Vitavax Power (carboxin + thiram) were compatible with seed dressing insecticide, Gaucho against leaf spot fungus *Myrothecium roridum* (Anonymous, 2006) [11]. Ebadollah Baniani *et al.* (2015) [12] recommended Goucho and carboxin-thiram, Larvin and carboxin-thiram for seed disinfection cotton. Asghar Heydari (2015) [13] observed that delinting with 98% acid was more effective against *Rhizoctonia solani* causing seed decay (rot) and seedling damping-off in cotton varieties.

Seed delinting with 80 and 60% acid and seed treatment with carboxin-thiram fungicide also significantly reduced the disease incidence in comparison with linted seeds. Diafenthiuron in combination with carbendazim and copper oxychloride were found to be more effective in reducing the sucking pest population and foliar diseases incidence, without phytotoxicity and safer to natural enemies in Bt cotton (Bontha Rajasekhar and Mallapur, 2017) [14]. Imidacloprid insecticide, applied as seed treatment, singly or in combination with carboxin-thiram, triadimenol-captan, and tebuconazole-thiram, protected wheat and barley from aphid infestation for 27-85 days after planting in greenhouse and field (Pike *et al*., 1993) [15]. Imidacloprid + tebuconazole and thiomethoxam + tebuconazole combinations as a seed treatment allowed easy application of pesticides, reduced early aphid infestation in wheat and found to be safer to non-target organisms compared to the foliar application of pesticides (Baber Hassan *et al*., 2017) [16].

Pooled data (2015-17) showed that at 14 days after sowing germination was significantly superior in all fungicidal treatments (thiram, carbendazim, streptocyclin, trifloxystrobin, captan, carboxin, mancozeb and penflufen). Seedling vigour was significant at 28DAS in all fungicidal treatments (Table 1). All fungicides effectively reduced Alternaria leaf spot at seedling stage (Table 2). Further, the test fungicides did not cause any phytotoxicity symptoms. There was no sucking pest incidence up to 28days. Maximum reduction in disease was obtained with carboxin (60.67%) followed by Streptocycline (56.22%), Thiram (56.12%) and mancozeb (55.11%). Maximum yield of 21.10q/ha was recorded with captan as against 15.54q/ha in untreated control plots (Table 3). Maximum increase in yield was obtained with captan (35.78%) followed by thiram (32.43%) and mancozeb (32.24%). Highest gross returns of Rs 87354/- were recorded with captan followed by Thiram (Rs 85201/-) and mancozeb

(Rs 85207/-). Benefit cost ratio (BCR) of different seed treatments varied between 1.02 and 1.27 as against 0.94 in untreated control (Table 3). Highest benefit cost ratio was also obtained with captan (1.27) followed by thiram (1.24) and mancozeb (1.24).

Table 1: Compatibility of seed dressing fungicides with imidacloprid seed treatment in Bt cotton

Treatment		Germination (%)				Seedling vigour				Phytotoxicity
		2015-16	2016-17	2017-18	Mean	2015-16	2016-17	2017-18	Mean	
T_1	Insecticide treated seed plus thiram @3g/kg	97.45[a]	97.0[a]	96.7[a]	97.04[a]	4721.98	10129.33[a]	1816.6[a]	5555.97[a]	Nil
T_2	Insecticide treated seed plus carboxin @2g/kg	90.00[b]	92.33[a]	98.0[a]	93.45[a]	4047.88	9877.77[a]	1912.3[a]	5279.2[a]	Nil
T_3	Insecticide treated seed plus captan @3g/kg	89.39[b]	96.0[a]	96.3[a]	93.91[a]	5054.13	10295.60[a]	1853.3[a]	5734.35[a]	Nil
T_4	Insecticide treated seed plus mancozeb @3g/kg	95.45[a]	94.33[a]	95.3[a]	93.37[a]	4672.90	10205.50[a]	1783.5[a]	5553.96[a]	Nil
T_5	Insecticide treated seed plus carbendazim @2g/kg	95.50[a]	98.0[a]	96.7[a]	96.72[a]	4945.40	9911.53[a]	1737.7[b]	5531.55[a]	Nil
T_6	Insecticide treated seed plus streptocyclin 100ppm	98.18[a]	93.0[a]	97.0[a]	96.06[a]	4908.78	9479.67[a]	1769.8[a]	5386.10[a]	Nil
T_7	Insecticide treated seed plus penflufen @2ml/kg	91.15[a]	93.67[a]	94.7[a]	93.16[a]	4053.43	9624.47[a]	1813.5[a]	5163.80[a]	Nil
T_8	Insecticide treated seed plus trifloxystrobin @1ml/kg	91.76[a]	97.33[a]	95.0[a]	94.7[a]	4073.83	9646.40[a]	1725.5[b]	5148.58[a]	Nil
T_9	Insecticide treated seed	88.65[b]	87.0[b]	87.3[b]	87.66[b]	4392.87	7712.1b	1535.4[c]	4546.78[b]	Nil
T_{10}	Untreated control	85.89[b]	81.67[b]	84.0[b]	83.85[b]	3549.37	7523.53b	1476.7[c]	4183.2[b]	Nil
	CD (p=0.05)	7.13	6.90	6.24	6.62	NS	1721.89	150.1	688.52	
	CV%	4.5	4.3	3.9	4.2	13.2	10.6	5.0	7.7	

*The figures indicated with same alphabet are not significantly different

Table 2: Effect of seed treatment with seed dressing fungicides and imidacloprid in Bt cotton

Treatment		Alternaria leaf spot (PDI)*				Seed Cotton Yield (q/ha)			
		2015-16	2016-17	2017-18	Mean	2015-16	2016-17	2017-18	Mean
T_1	Insecticide treated seed plus thiram @3g/kg	06.67 (14.95) [a]	3.33 (10.47)[a]	3.0 (9.98)[a]	4.34 (11.97)[a]	20.45[a]	17.42[a]	23.87[a]	2058[a]
T_2	Insecticide treated seed plus carboxin @2g/kg	06.33 (14.54) [a]	2.67 (9.37)[a]	2.67 (9.46)[a]	3.89 (11.39)[a]	17.64[b]	17.58[a]	22.05[b]	1909[b]
T_3	Insecticide treated seed plus captan @3g/kg	08.33 (16.74) [a]	3.67 (11.02)[a]	2.67 (9.46)[a]	4.89 (12.79)[a]	21.78[a]	19.08[a]	22.42[a]	2110[a]
T_4	Insecticide treated seed plus mancozeb @3g/kg	07.00 (15.34) [a]	3.0 (9.98)[a]	3.33 (10.47)[a]	4.44 (12.11)[a]	17.73[b]	18.35[a]	25.58[a]	2055[a]
T_5	Insecticide treated seed plus carbendazim @2g/kg	08.33 (16.74)[a]	2.67 (9.37)[a]	3.67 (11.09)[a]	4.89 (12.79)[a]	20.10[a]	17.08[a]	21.04[b]	1941[b]
T_6	Insecticide treated seed plus streptocyclin 100ppm	07.67 (16.56) [a]	2.67 (9.37)[a]	2.67 (9.46)[a]	4.33 (11.97)[a]	19.40[b]	17.27[a]	21.23[b]	1930[b]
T_7	Insecticide treated seed plus penflufen @2ml/kg	08.00 (16.43) [a]	3.0 (9.98)[a]	3.67 (11.09)[a]	4.89 (12.79)[a]	18.87[b]	17.33[a]	21.35[b]	1919[b]
T_8	Insecticide treated seed plus trifloxystrobin @1ml/kg	08.00 (16.43)[a]	4.0 (11.54)[a]	3.0 (9.98)[a]	5.00 (12.92)[b]	18.34[b]	16.97[a]	22.04[b]	1912[b]
T_9	Insecticide treated seed	09.00 (17.46) [b]	6.0 (14.18)[b]	7.67 (16.11)[b]	7.56 (16.00)[c]	16.75[c]	14.33[b]	19.40[c]	1683[c]
T_{10}	Untreated control	12.33 (20.53) [b]	9.0 (17.46)[c]	8.33 (16.74)[b]	9.89 (17.36)[d]	15.34[c]	12.75[c]	18.52[c]	1554[c]
	CD (p=0.05)	2.61	1.34	1.33	1.02	1.86	2.18	2.27	141.7
	CV %	18.6	19.5	19.1	11.0	5.8	7.6	6.1	4.3

*Figures in parentheses are transformed values. The figures indicated with same alphabet are not significantly different

Table 3: Economics of seed treatment with seed dressing fungicides and imidacloprid in Bt cotton (Pooled data 2015-2017)

Treatment		Control of Alternaria leaf spot (%)	Increase in yield (%)	Gross expenditure	Gross returns	Net Profit	Benefit cost ratio (BCR)
T_1	Insecticide treated seed plus thiram @3g/kg	56.12	32.43	68647	85201	16554	1.24
T_2	Insecticide treated seed plus carboxin @2g/kg	60.67	22.84	68648	79033	10385	1.15
T_3	Insecticide treated seed plus captan @3g/kg	50.56	35.78	68647	87354	18707	1.27
T_4	Insecticide treated seed plus mancozeb @3g/kg	55.11	32.24	68648	85077	16429	1.24
T_5	Insecticide treated seed plus carbendazim @2g/kg	50.56	24.90	68647	80357	11710	1.17
T_6	Insecticide treated seed plus streptocyclin 100ppm	56.22	24.20	68647	79902	11255	1.16
T_7	Insecticide treated seed plus penflufen @2ml/kg	50.56	23.49	68652	79447	10795	1.16
T_8	Insecticide treated seed plus trifloxystrobin @1ml/kg	49.44	23.04	68655	79157	10502	1.15
T_9	Insecticide treated seed	23.56	8.30	68646	69676	1030	1.02
T_{10}	Untreated control			68625	64335	-4290	0.94

Conclusion

Seed dressing fungicides *viz*., thiram, carbendazim, streptocyclin, trifloxystrobin, captan, carboxin, mancozeb and penflufen were compatible with imidacloprid treatment of Bt cotton seed in terms of germination, seedling vigour without phytotoxicity, reduced seed borne infections besides sucking pest control up to 28days. Thus cotton seed treatment with imidacloprid followed by an effective fungicide like captan or thiram or mancozeb is recommended to manage sucking pests and soil and/or seed borne diseases for healthy crop stand for reaping higher yields.

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