Research Article

Effectiveness of Seed Treatment with Recommended Fungicides on Seed, Soil Borne Diseases and Productivity of Cotton

D Monga[1], SK Sain[1*], S Nakkeeran[2], SL Bhattiprolu[3], VV Rajani[4], V Kulkarni[5] and MSL Rao[5]

[1]ICAR-Central Institute for Cotton Research- Regional Station, Sirsa (Haryana), India; [2]Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu), India; [3]Regional Agricultural Research Station, Lam, Guntur (Andhra Pradesh), India; [4]Cotton Research Station, Junagadh Agricultural University, Junagadh (Gujarat), India; [5]Agricultural Research Station, University of Agricultural Sciences, Dharwad (Karnataka), India; Email: sain.skumar@gmail.com

Abstract

Seed and soil borne diseases of cotton collectively refer to a group of diseases that affect the germination of cotton seed, emergence, survival and plant stand in the field. The damage caused by these pathogens ultimately reduces the cotton productivity and production worldwide. Sometimes, chemical fungicides recommended for management of these fungal pathogens are not performing up to the mark in the field. The one of the reason may be due to increased resistance of seed and soil borne pathogens against recommended fungicides. Hence, the study was conducted to reexamine the effectiveness of age old recommended commercial fungicides for cotton seed treatments. The field experiments were conducted during three consecutive years from 2012-13 to 2014-15 using seed treatment fungicides namely carboxin, thiram and carboxin + thiram at four different locations in four states of India including Andhra Pradesh, Karnataka, Gujarat and Tamil Nadu. The fungicides (carboxin, thiram and carboxin + thiram) with three doses each (recommended dose, one above and one below) were evaluated as seed treatment and found to be effective in managing the seedling mortality, alternaria blight and bacterial leaf blight diseases. However, the highest disease management was recorded with the doses above the recommended dose of carboxin + thiram (4.5 g Kg^{-1}) followed by carboxin + thiram (3.5 g Kg^{-1}) and thiram (4 g Kg^{-1}) and these treatments also enhanced the yield by 40.7, 37.3 and 29.4 per cent, respectively irrespective of locations, varieties and pathogens. This study is indicating that the fungicides employed and or recommended to control these diseases in cotton are still effective and the higher doses than their recommended doses were found to be better than the recommended dose at all the location within the country. Thus, the dose above the recommended dose of CIB & RC may be used for effective management of these diseases and enhancing the cotton productivity. However, environmental studies should be conducted prior to any recommendations.

Key words: Cotton, disease management, productivity, recommended fungicides, seed treatment

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Cotton (*Gossypium* spp) known as "White Gold" is worlds one of the most important commercial and natural textile fiber crops and a significant contributor of oilseeds. More than 90 per cent of the natural fiber is obtained from cotton crop alone. India is a country where all the four cotton species namely Desi (diploid) cotton *G. arboreum*, & *G. herbaceum* and American cotton (tetraploid) *G. hirsutum* & Egyptian cotton *G. barbadense* are grown commercially. However, most commercially cultivated cotton varieties and hybrids in North West India are derived from two species *G. arboreum* and *G. hirsutum.* It occupies 12.2 million ha area in India including 7.5 per cent of India's arable land and 36.8 per cent of the global cotton area. Indian cotton contributes to 23.5 per cent of the global production (AICRP on Cotton, 2017-18).

Various seed and soil borne diseases occur on cotton in India, including bacterial blight (*Xanthomonas citri* 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 oxysposum* f sp *vasinfectum, Verticillium dahlia* are the major constraints for productivity. These diseases are mostly soil and seed borne in nature and occur in almost all cotton growing regions in India with mild to severe incidence. The most of cotton cultivars are susceptible to these diseases. The severity of these diseases is reported to be from 20 to 32 per cent with an extent of damage to seed cotton yield is upto 29.2 per cent (Monga et al 2013). Increasing the productivity, production and the fiber quality are the main goal of almost all cotton production and protection programs. More than 40 fungi have been isolated from diseased cotton seedling, although only some of these have been shown to be as seed mycoflora (Hillocks 1992). A number of soil borne and seed borne fungi can infect cotton seedling individually or in association as disease complex (Hillocks and Waller 1997). Seed borne fungi may effect on uniform emergence, vigorous and uniform stand of healthy seedling. If the fungi have been virulent in the seed and at seedling stage, germination can be delayed or may not occur and seedling may die before emergence (Arndt 1953; Lima et al 1988; Roncadori et al 1971 and Smith 1950). In the field, the most obvious symptoms of cotton seed and soil borne diseases are skipped in the rows resulting from rotted seed or dead seedlings. In addition to losses in plant stand, seed and soil borne diseases may delay crop growth, resulting in additional management problems, such as timing of pesticide applications and harvest. In severe disease condition, replanting may be required which may not be as yielding as it happens with the initial sowing.

To achieve the yield targets, obtaining good germination and establishing good plant stand is the prime requirement for cotton acreage. The diseases are primarily managed by host plant resistance breeding programs. But high pathogenic variability and mutability limits the sustainability and effectiveness of any naturally selected resistance against the pathogen. However, seed priming is a widely used common technique to overcome germination and biotic and abiotic problems in different crops. Thus, the purpose of seed priming with chemicals should be to eradicate the seed borne pathogens and/or protect them against soil pathogens, mainly at germination time. Various seed treatment options such as bioagents, hormones, PGRs, fungicides and insecticides are commonly used however, only two fungicides and their combination namely Carboxin 75% WP, Thiram 75% WS, Carboxin 37.5% + Thiram 37.5% DS are registered and recommended by Central Insecticide Board & Registration Committee (CIB&RC) for cotton seed treatment among a total of seven fungicides which are recommended for use in cotton crop in India (as on 30.06.2016) (CIB & RC, 2017). The pesticides were recommended long back and there is no such study available which has indicated any resistance or effectiveness of these chemicals. Thus, this study was carried out for three consecutive years at identified hot spot areas to prove the efficacy of the recommended fungicides in managing the seed and soil borne diseases in various parts of India.

Materials and Methods

Fungicides. The treatment fungicides recommended for use in cotton were selected from the CIB & RC registration list namely Carboxin 75% WP, Thiram 75% WS, Carboxin 37.5% + Thiram 37.5% DS. The selected three are registered fungicides for use in cotton as seed treatment (CIB & RC 2017). The concentration (gram of active ingredients (a.i.) per kilogram of fungicides) of the fungicides and their doses evaluated are presented in table format. The untreated seeds were used as control.

Seed treatment. Acid-delinted neutralized seed of *Gossypium hirsutum* L. were primed with two chemical fungicides and a combination with three doses *i.e.* one recommended dose by CIB&RC and two doses *i.e.* one below and one above the

	Name	Active ingredients (a.i.)	Dose (g) per kg of seed
1	Thiram	75% WS	2.0
2	Thiram	75% WS	3.0
3	Thiram	75% WS	4.0
4	Carboxin	37.5% WP	1.0
5	Carboxin	37.5% WP	2.0
6	Carboxin	37.5% WP	3.0
7	Carboxin + Thiram	37.5% WP	2.5
8	Carboxin + Thiram	37.5% WP	3.5
9	Carboxin + Thiram	37.5% WP	4.5
10	Untreated control		

recommended dose (Table 1). Seeds of each cotton cultivar were soaked in normal drinking water for 2-3 hours and the moist seeds were coated with the chemical fungicides and their combinations, separately. Coated seeds were air dried for 2-3 hours under shade prior to sowing in the field. The control was maintained as untreated soaked seeds.

Experimental sites and period. To study the effect of different seed dressing chemicals against seed borne, soil borne and foliar diseases, field experiments were conducted for the three consecutive year from 2012-13 to 2014-15 at four selected sites (disease hot spots) under All India Coordinated Research Programme on Cotton (AICRP on cotton) namely Acharya N G Ranga Agricultural University, Regional Agricultural Research Station, Lam, Guntur (Andhra Pradesh), University of Agricultural Sciences, Dharwad (Karnataka), Cotton Research Station, Junagadh Agricultural University, Junagadh (Gujarat), and Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu). These sites are chosen based on the disease severity recorded in the past under AICRP on cotton. The cotton varieties and Bt hybrids susceptible to the respective disease were selected for the experiments. These cultivars were from the recommended varieties by the Government of the respective states namely G.cot-18 in Junagadh (Gujarat); Genotype Abhadita in Dharwad**;** NA 1325 in Guntur, and MCU13 in Coimbatore.

As the root rot disease and bacterial blight was more severe at Coimbatore and Dharwad, respectively, the trials were continued only at these locations. Similarly, the Alternaria leaf spot/blight was not much severe at Junagadh, hence the trial data were not included in the paper.

Experimental design. The field experiments were laid out in complete randomized block design (CRBD) with three replications at all the locations. In each replication the gross field plot size 6.3 × 4.8=30.2 m^2 (Net plot area: 5.4 × 2.4=12.96 m^2) were maintained at each location. Each plot consisted of five rows. The row to row and plant to plant spacing were maintained at each experimental trial as per the package-of-practices recommended by the respective State Agriculture Department/ University *i.e.* Coimbatore-100 × 60 cm; Dharwad-120 × 45 cm; Junagadh- 120 × 45 cm; Gunture-105 x 60 cm. The experimental cotton crops were cultivated as per the package of practices recommended by the respective State Agricultural Department/ University neither seed nor any foliar treatments were applied for disease management except the treatments applied for the planned experimental trial.

Observation and data collection. Data on different parameters were collected as field emergence (germination %) for estimating the per cent mortality of the plants in each treatment. Final observations were taken as total plant stand/ plant population in each treatment. The root rot severity was recorded based on the plants infected with root rot disease in each plot. All observations for Alternaria leaf spot or blight was taken on 10 leaves per plant following the 0-4 disease ratings (Raj, 1988). Where, 0 = Plants completely free from infection; 1 = Leaf area covered< 5%; 2 = Leaf area covered 6-20%; 3 = Leaf area covered 21-40; 4 = Leaf area covered >40%. Similarly, the observations for bacterial leaf blight were also taken on 10 leaves per plant following the 0-4 disease ratings (Raj 1988). Where, 0 = Plants completely free from infection; 1 = Spots few scattered; 2 = Leaf area covered upto 10%; 3 = Leaf area covered from 11-20%; 4 = Leaf area covered >20%. The overall data were presented as per cent disease index (PDI) following the formula of Raj (1988): Per cent Disease Index = [(Sum of numerical ratings) / (Total no. of leaves recorded x Maximum disease grade)] x 100.

Data were analyzed statistically and treatment effects were compared by least significant difference test (LSD) at 0.05 per cent with the help of computer program OP Stats (Sheoran et al 1998).

Results and Discussion

Effect of chemical seed treatment on seedling mortality. Seed and soil borne pathogens like *Alternaria alternata*, *A. macrospora*, *Fusarium* sp, *Rhizoctonia* sp, *Sclerotium* sp, *Aspergillus* sp and *Xanthomonas axonopodis* pv *malvacearum* have been found to be associated with the seedling mortality in cotton. The three year experimental data showed that the highest seedling mortality was recorded during 2012-13 at Coimbatore (53.2%) followed by Dharwad (32.2%). Overall severity of seedling mortality was higher at Coimbatore and Dharwad during all the three years. The results of the seed treatment experiments conducted at four different locations having different agro climatic condition revealed that all the chemicals are effective in minimizing the seedling mortality irrespective of the years, concentration and locations (Table 1). Increased doses of chemicals either individually or in combination further decreased the seedling mortality. When compared to the seed treatment fungicides and their concentrations, seed treatment with thiram+ carboxin @ 4.5 g Kg^{-1} recorded the minimum seedling mortality at all the four locations. The lowest seedling mortality was recorded in seed treatment with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} (3.8%) compared to the control (14.1%) at Guntur. Similarly, at Coimbatore where the highest average seedling mortality was recorded (53.2%), the seed treatment with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} was found effective in reducing the mortality per cent with the average minimum seedling mortality (6.5%) compared to other treatments and control (35.1%). This was followed by Carboxin 75%WP@3 g Kg^{-1} (9.3%) and Carboxin 37.5 %WP+Thiram 37.5% DS 3.5 g Kg^{-1} (10.5%) were found next best to decrease seedling mortality. Overall, seed treatment with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} was found effective in reducing the mortality per cent with the average minimum seedling mortality (9.1%) compared to other treatments and control (24%). This treatments was followed by Carboxin 75%WP@3 g Kg^{-1} (11.2%) and Carboxin 37.5 %WP 3.5 g Kg^{-1} (12%) and Thiram 75 WS @4 g Kg^{-1} (12.2%) were found next best to decrease seedling mortality (Fig.1). In general from above finding it can be concluded that highest reduction in seedling mortality was also recorded with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} (62%) followed by Carboxin 75%WP@3 g Kg^{-1} (53.3%) and Carboxin 37.5 %WP 3.5 g Kg^{-1} (50%) and Thiram 75 WS @4 g Kg^{-1} (49.2%) (Fig 1). There was positive trend between the increase in the concentration and decrease in the seedling mortality. The increased dose of each chemicals further enhance the level of disease control. Similarly, Montenegro (2015) has reported that the increase dose of Carboxin + Thiram from 0.2 to 0.6 per cent resulted in better control of seed borne fungi like *Alternaria* spp *Fusarium* spp, *Penicellium* spp *Aspergillus* spp and *Rhizopus* spp in broccoli.

Effect of seed treatment chemicals on bacterial blight incidence. The three year experimental trial carried out for bacterial blight management at Dharwad showed that the highest bacterial blight was recorded during 2014-15 (37.9%) (Table 2). As, overall severity of bacterial blight was higher at Dharwad during all the three years compared to the other centres, hence, the trial was continued only at Dharwad station. The results of the seed treatment experiments conducted during three consecutive years revealed that all the chemicals are effective in

Table 1. Effect of seed dressing chemicals against seedling mortality caused by seed and soil borne diseases of cotton

Treatment	Seedling mortality (%)*															
	Junagadh				Dharwad				Guntur				Coimbatore			
	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean
Thiram 75 WS	14.6	13.0	12.2	13.3	25.0	26.1	26.2	27.8	18.0	8.3	7.5	11.3	21.3	10.0	12.0	14.4
@2g Kg^{-1}	(22.5)	(21.1)	(20.4)		(29.9)	(30.8)	(30.6)		(25.1)	(16.88)	(15.9)		(27.5)	(18.4)	(20.3)	
Thiram 75 WS	12.1	11.8	10.7	11.5	21.3	24.3	24.3	23.3	12.7	5.8	5.33	7.9	15.9	8.0	11.0	11.6
@3g Kg^{-1}	(20.4)	(20.1)	(19.1)		(27.5)	(29.5)	(29.5)		(20.88)	(14.0)	(13.3)		(23.5)	(14.4)	(19.4)	
Thiram 75 WS	9.3	8.9	10.7	09.6	21.7	24.7	24.8	23.7	6.7	2.5	4.0	4.4	16.6	7.6	9.0	11.1
@4g Kg^{-1}	(17.8)	(17.4)	(19.1)		(27.8)	(29.9)	(29.9)		(15.0)	(9.1)	(11.5)		(24.0)	(16.0)	(17.5)	
Carboxin 75%	15.4	10.7	11.1	12.4	26.9	27.4	27.4	27.2	26.7	9.2	5.83	13.9	20.2	11.0	12.0	14.4
WP@1g Kg^{-1}	(23.1)	(19.1)	(19.5)		(31.3)	(31.6)	(31.55)		(31.1)	(17.6)	(14.0)		(26.7)	(19.4)	(20.3)	
Carboxin 75%	12.3	13.5	10.30	12.1	22.3	24.6	24.6	23.8	20.0	5.8	5.0	10.3	16.6	10.3	10.5	12.5
WP@2g Kg^{-1}	(20.5)	(21.6)	(18.7)		(28.2)	(29.7)	(29.7)		(25.6)	(14.0)	(12.9)		(24.0)	(18.7)	(18.9)	
Carboxin 75%	9.5	11.8	10.1	10.5	24.6	25.0	22.2	23.9	6.7	1.7	4.67	4.4	9.3	9.5	9.0	9.3
WP@3g Kg^{-1}	(18.0)	(20.1)	(18.5)		(29.7)	(29.9)	(28.1)		(15.0)	(7.4)	(12.5)		(17.8)	(18.0)	(17.5)	
Carboxin 37.5%	8.4	9.4	9.4	09.1	21.0	21.0	21.0	21.0	10.7	7.5	5.67	7.9	20.8	8.6	10.0	13.1
WP+Thiram	(16.6)	(17.9)	(17.9)		(27.3)	(27.2)	(27.2)		(19.1)	(15.9)	(13.8)		(21.1)	(17.1)	(18.4)	
37.5% DS2.5g Kg^{-1}																
Carboxin 37.5%	7.7	8.3	5.2	07.1	20.4	22.20	20.0	20.9	9.3	5.0	4.83	6.4	14.6	8.0	9.0	10.5
WP+Thiram	(16.1)	(16.7)	(13.2)		(26.8)	(28.1)	(26.6)		(17.8)	(12.9)	(12.7)		(22.5)	(16.4)	(17.5)	
37.5% DS 3.5g Kg^{-1}																
Carboxin 37.5 %	6.6	5.8	4.7	05.7	20.7	20.0	20.7	20.5	6.0	1.7	3.5	3.8	3.7	7.3	8.5	6.5
WP+Thiram	(14.9)	(13.9)	(12.5)		(27.1)	(26.6)	(27.1)		(14.2)	(7.4)	(10.8)		(11.1)	(15.7)	(17.0)	
37.5% DS 4.5g Kg^{-1}																
Untreated	19.9	17.19	16.05	17.71	32.3	27.7	27.7	29.2	17.3	15.8	9.17	14.1	53.2	27.0	25.0	35.1
Control	(26.5)	(24.5)	(23.6)		(34.7)	(31.8)	(31.8)		(24.6)	(23.4)	(17.6)		(46.8)	(31.3)	(30.0)	
LSD (0.05%)	3.6	4.4	5.2	4.2	3.14	0.84	7.11	4.52	11.331	8.4	6.3	7.82	10.4	8.6	3.4	8.4

*Figures in parentheses are arcsine transformed values

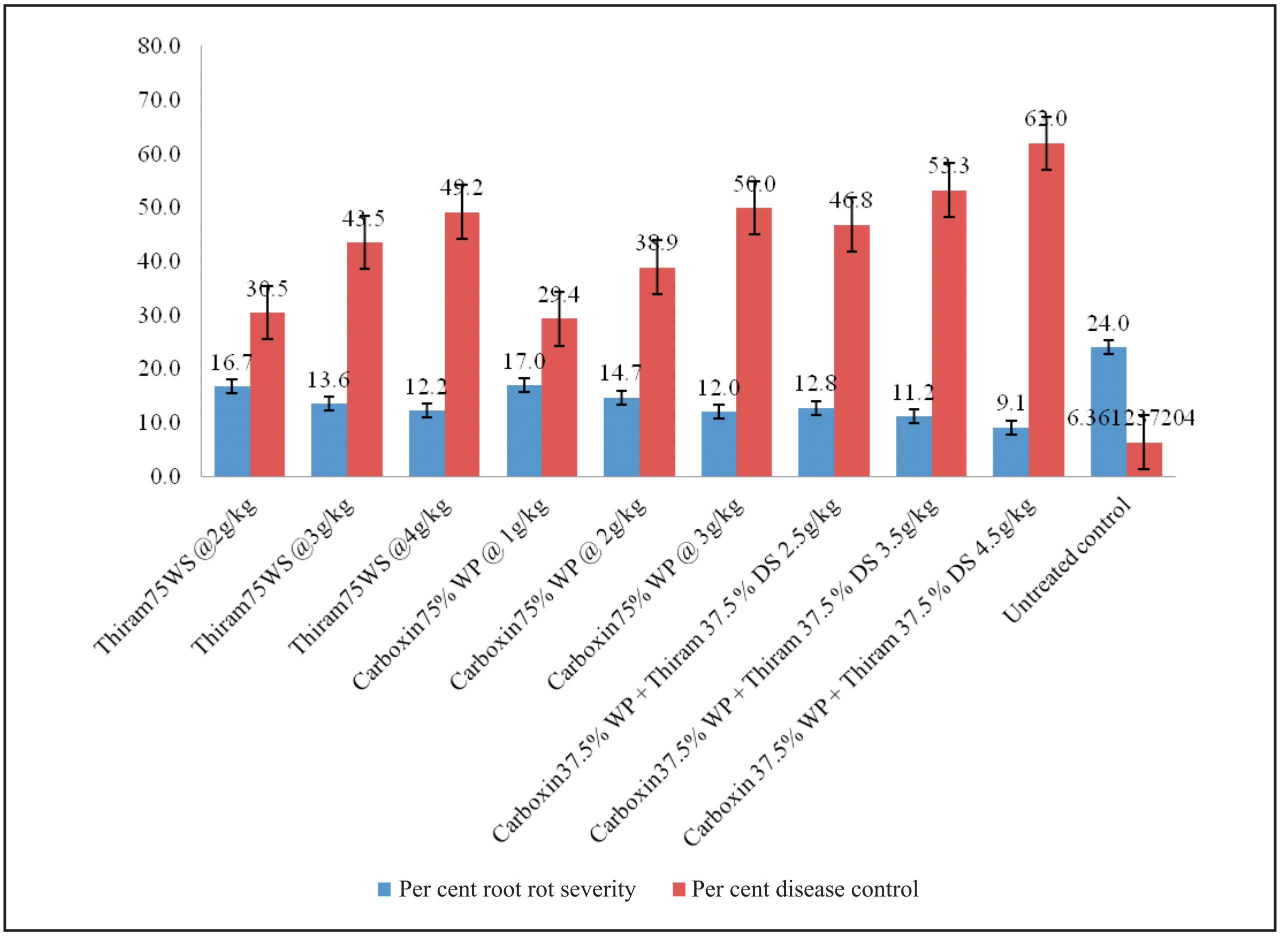

Figure 1. Overall effect of seed treatment chemicals on per cent disease incidence (Sd± 4.17) and reduction of seedling mortality (Sd± 6.36) over control. Bars represent standard deviation of means

Table 2. Effect of seed dressing chemicals against seed and soil borne bacterial blight diseases of cotton at Dharwad

Treatment	Per cent severity of bacterial blight*			
	2012-13	2013-14	2014-15	Pooled mean
Thiram75WS @2 g Kg^{-1}	07.7 (16.1)	9.9 (18.3)	29.7 (33.0)	15.8
Thiram75WS @3 g Kg^{-1}	06.6 (14.9)	7.8 (16.3)	32.4 (34.7)	15.6
Thiram75WS @4 g Kg^{-1}	07.8 (16.2)	10.00 (18.5)	26.3 (30.9)	14.7
Carboxin75% WP @ 1 g Kg^{-1}	07.0 (15.3)	9.1 (17.5)	31.9 (34.4)	16.0
Carboxin75% WP @ 2 g Kg^{-1}	08.9 (16.4)	8.7 (17.2)	29.9 (33.1)	15.8
Carboxin75% WP @ 3 g Kg^{-1}	08.0 (16.5)	9.6 (18.0)	30.2 (33.3)	15.9
Carboxin37.5% WP + Thiram 37.5 % DS 2.5 g Kg^{-1}	07.2 (15.6)	9.4 (17.9)	32.6 (34.8)	16.4
Carboxin37.5% WP + Thiram 37.5 % DS 3.5 g Kg^{-1}	07.2 (15.5)	8.5 (16.9)	35.2 (36.4)	16.9
Carboxin 37.5% WP + Thiram 37.5 % DS 4.5 g Kg^{-1}	08.6 (17.0)	8.8 (17.2)	30.3 (33.4)	15.9
Untreated control	15.2 (22.9)	11.5 (19.8)	37.9 (38.0)	21.5
LSD (0.05%)	8.242	3.487	5.853	4.32

*Figures in parentheses are arcsine transformed values

minimizing the bacterial blight irrespective of the years, concentration. When compared to the seed treatment fungicides and their concentrations, seed treatment with Thiram75WS @4 g Kg^{-1} followed by Carboxin75% WP @ 2 g Kg^{-1}, Carboxin75% WP @ 3 g Kg^{-1} and Carboxin + Thiram @ 4.5 g Kg^{-1}, recorded the minimum bacterial blight. However, there was no uniformity in the reduction of bacterial blight in respect with chemical seed treatment and their doses during the three years. On the whole, from above finding and the pooled data, it can be concluded that highest reduction in bacterial blight was recorded with Thiram 37.5% DS 4 g Kg^{-1} (31.6%) followed by Thiram 37.5 % DS 2 g Kg^{-1} and Carboxin 75%WP@ 2 g Kg^{-1} (26.5%) (Fig 2). Carboxin 37.5% WP + Thiram 37.5 % DS 4.5 g Kg^{-1} and Carboxin75% WP @ 3 g Kg^{-1} gave the similar reduction in bacterial blight severity (26%). Germination percentage, seedling length, seedling dry weight, seedling vigour indices were reported to be high in cotton seed treated with Polymer @ 7ml + thiram @ 2 g Kg^{-1} of seeds as compared to thiram @ 2 g Kg^{-1} alone and with different Polymer concentrations (Vijaya Mahantesh et al 2017).

Effect of seed treatment chemicals on Alternaria blight incidence. The glance of data of three consecutive years experimental trials presented in Table 3 showed that the highest alterneria leaf blight severity was recorded during 2014-15 at Dharwad (40.5%). Overall severity of alterneria leaf spot was higher at Dharwad during all the three years. All the chemicals were found effective in minimizing the alterneria leaf blight irrespective of the years, concentration, and locations (Table 3.). When compared to the seed treatment fungicides

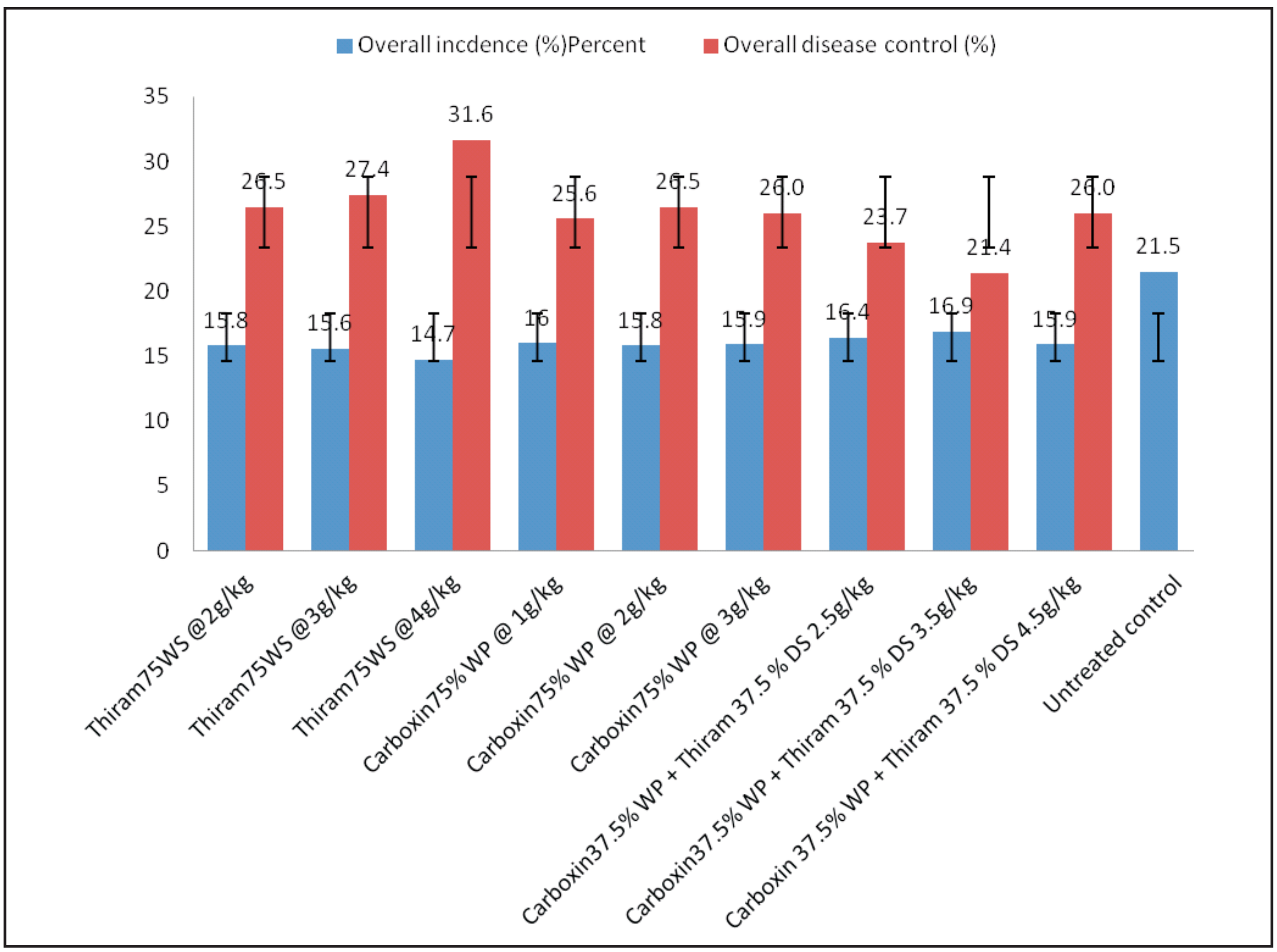

Figure 2. Overall effect of seed treatment chemicals on per cent disease incidence (Sd± 1.86) and reduction of bacterial blight (Sd± 2.75) over control.

Table 3. Effect of seed dressing chemicals against seed and soil borne foliar diseases (ALB/ALS) of cotton

Treatment	Per cent severity of Alternaria leaf blight*											
	Dharwad				Guntur				Coimbatore			
	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean
Thiram75WS @2 g Kg^{-1}	33.5 (35.4)	29.5 (32.9)	33.8 (35.5)	32.3	4.9 (12.9)	9.0 (17.4)	7.67 (16.1)	7.19	12.5 (20.7)	11.6 (19.9)	11.6 (19.9)	11.9
Thiram75WS @3 g Kg^{-1}	32.7 (34.9)	28.2 (32.1)	33.8 (35.5)	31.6	4.8 (12.7)	8.3 (16.7)	6.3 (14.5)	6.49	10.0 (18.4)	12.0 (20.3)	12.0 (20.3)	11.3
Thiram75WS @4g Kg^{-1}	33.9 (35.6)	30.6 (33.6)	32.4 (34.7)	32.3	4.0 (11.5)	7.7 (16.6)	4.7 (12.5)	6.17	9.8 (18.2)	11.6 (19.9)	11.6 (19.9)	11.0
Carboxin75% WP @ 1g Kg^{-1}	30.3 (33.4)	28.3 (32.2)	33.6 (35.4)	30.7	5.2 (13.2)	8.3 (16.7)	6.3 (14.5)	6.62	13.5 (21.6)	12.8 (21.0)	12.8 (21.0)	13.0
Carboxin75% WP @ 2g Kg^{-1}	31.1 (33.9)	28.5 32.3)	34.3 (35.8)	31.3	4.5 (12.3)	7.7 (16.6)	5.0 (12.9)	5.72	9.8 (18.2)	12.0 (20.3)	12.0 (20.3)	11.3
Carboxin75% WP @ 3g Kg^{-1}	30.0 (33.2)	28.3 (32.2)	34.6 (36.0)	31.0	2.8 (9.6)	6.7 (14.9)	4.0 (11.5)	4.49	4.7 (4.3)	11.0 (19.4)	11.0 (19.4)	8.9
Carboxin37.5% WP + Thiram 37.5 % DS 2.5g Kg^{-1}	29.2 (32.7)	27.7 (32.4)	33.1 (35.1)	30.0	4.2 (11.3)	7.7 (16.6)	5.7 (13.7)	5.85	12.0 (20.3)	12.0 (20.3)	12.0 (20.3)	12.0
Carboxin37.5% WP + Thiram 37.5 % DS 3.5g Kg^{-1}	27.0 (31.3)	17.1 (24.4)	34.8 (36.1)	26.3	3.3 (10.5)	6.7 (14.9)	4.3 (12.0)	4.77	10.0 (18.4)	11.0 (19.4)	11.0 (19.4)	10.7
Carboxin 37.5% WP + Thiram 37.5 % DS 4.5g Kg^{-1}	27.9 (31.9)	17.2 (24.5)	32.2 (34.6)	25.8	2.5 (9.1)	6.0 (14.2)	3.7 (11.0)	3.09	4.8 (12.7)	11.6 (19.9)	11.6 (19.9)	9.3
Untreated control	35.8 (36.8)	31.3 (34.0)	40.5 (39.5)	35.9	13.3 (21.4)	23.0 (28.6)	15.33 (23.03)	13.30	19.7 (26.3)	12.6 (20.8)	12.6 (20.8)	15.0
CD at 5%	1.772	0.79	2.32	1.55	1.609	3.1	1.98	1.23	9.7	NS	NS	NS

*Figures in parentheses are arcsine transformed values

and their concentrations, seed treatment with thiram+ carboxin @ 4.5 g Kg^{-1} recorded the minimum alterneria leaf blight severity at all the three locations. Increased doses of chemicals either individually or in combination further decreased the alterneria leaf blight severity. The lowest alterneria leaf blight severity was recorded in seed treatment with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} (3.09%) compared to the control (13.3 %) at Guntur. However, at the Dharwad where the highest average alterneria leaf blight severity was recorded (35.9%), the seed treatment with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} was found effective in reducing the disease with the average minimum alterneria leaf blight severity (25.8%) compared to other treatments and control (35.9%). The treatments *viz*, Carboxin 37.5 %WP+Thiram 37.5% DS 3.5 g Kg^{-1} (26.3%) and Carboxin 37.5 %WP+Thiram 37.5% DS 2.5 g Kg^{-1} (30.0%) were found next best to decrease alternaria leaf blight. Overall when the data of all the locations were pooled together, seed treatment with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} was found effective in reducing the alterneria leaf blight severity with the average alterneria leaf blight severity (12.7 %) compared to other treatments and control (21.4%). This was followed by Carboxin 37.5% WP + Thiram 37.5 % DS 3.5 g Kg^{-1} (13.9%) and Carboxin 75%WP@ 3 g Kg^{-1} (14.8%) were found next best to decrease seedling mortality (Fig. 5). If data taken as whole from above findings it can be concluded that highest reduction in alterneria leaf blight severity was also recorded with Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} (40.5%) followed by Carboxin 37.5% WP + Thiram 37.5 % DS 3.5 g Kg^{-1} (34.9%) and

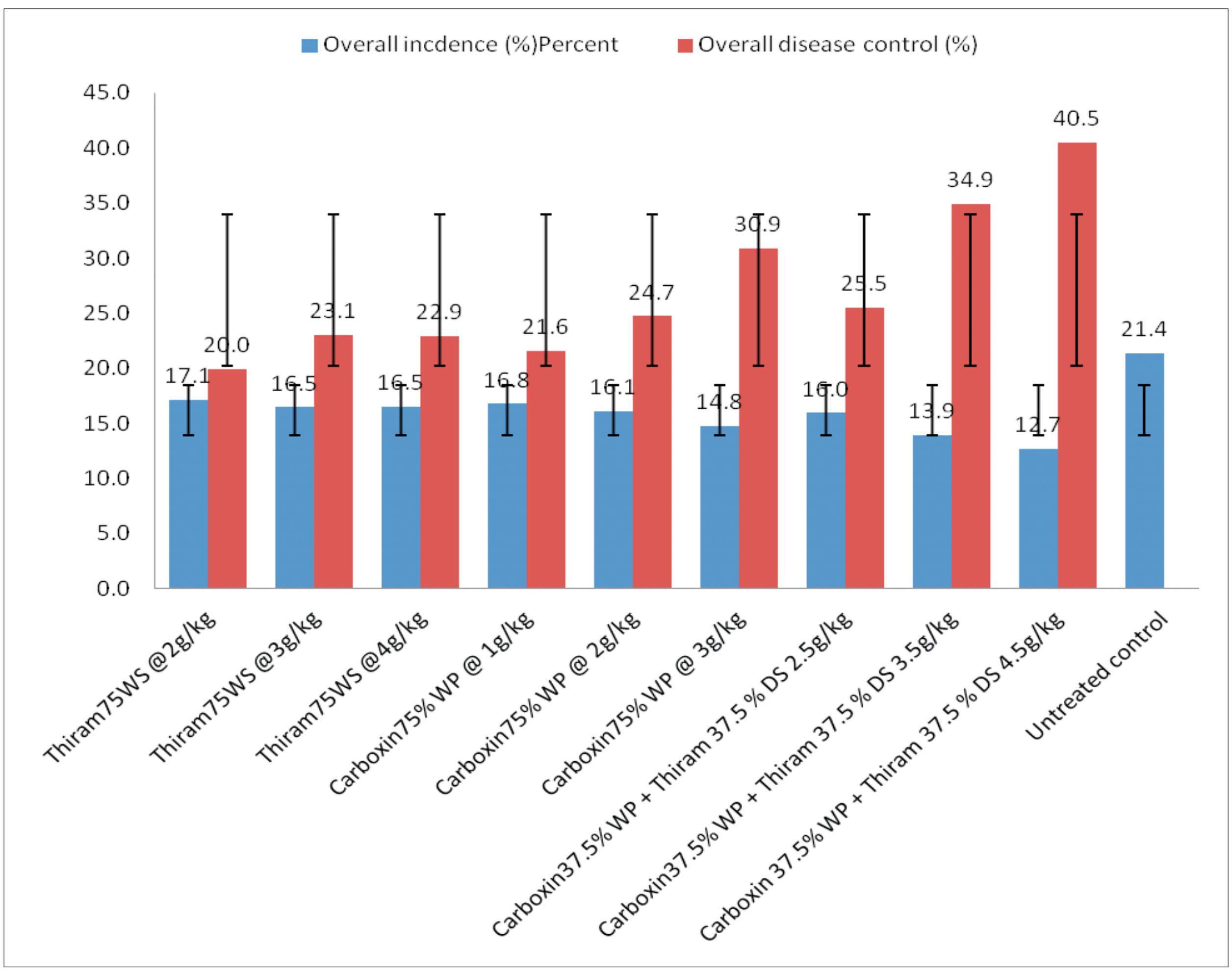

Figure 3. Overall effect of seed treatment chemicals on per cent disease incidence (Sd± 2.30) and reduction of Alterneria leaf blight (Sd± 6.90) over control

Carboxin 37.5 %WP 3 g Kg^{-1} (30.9%) (Fig. 3).

Effect of seed treatment chemicals on seed cotton yield. The data presented in Table 4 showed that the highest seed cotton yield was recorded during 2013-14 and 2012-13 at Dharwad (22.5 q ha^{-1}) and Junagadh (22.4 q ha^{-1}), respectively in the seed treatment with Carboxin 37.5% WP + Thiram 37.5 % DS 4.5 g Kg^{-1}. When compared to pooled mean of all three years data, the seed treatment fungicides and their concentrations, seed treatment with carboxin + thiram @ 4.5 g Kg^{-1}, Carboxin 37.5% WP + Thiram 37.5 % DS 3.5 g Kg^{-1}, and Thiram 75WS @4 g Kg^{-1} recorded the maximum seed cotton yield at all the four locations. Increased doses of chemicals either individually or in combination further increased the yield significantly. However, there was clear cut uniformity in yield increase trend that increase of seed yield was recorded with increase in dose of chemical seed treatment. On the whole, from above finding it can be concluded that highest increase in seed cotton yield was recorded with Carboxin 37.5% + Thiram 37.5% % DS 4.5 g Kg^{-1} (40.5%) followed by Carboxin 37.5% + Thiram 37.5% DS 3.5 g Kg^{-1} (37.1%), Thiram 75WS @4 g Kg^{-1} (29.3%) (Fig 4).

It can be concluded from the research experiments conducted at four different locations during three consecutive years that all the fungicides recommended for seed treatment in cotton are effective against seed and soil borne disease management in cotton. However, the increased dose from the recommended dose had the better efficacy in providing the better results. When compared to the two chemicals and their combination the Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1} followed by Carboxin 37.5% + Thiram 37.5% DS 3.5 g Kg^{-1} and Thiram 75WS @4 g Kg^{-1} were found to be the best treatments for managing the diseases and increasing the yield significantly in cotton at various tested locations.

Seedling diseases of cotton collectively refer to a group of diseases that affect the germination of cotton seed, emergence, survival, development of seedlings as well as establishing plant stand and ultimately reduce cotton production worldwide (DeVay 2001; Melero-Vara and Jimenaz-Diaz 1990; Ogle et al 1993). Seed quality is a very important factor in establishing a good cotton plant stand and thus producing good crop (Brid 1986). Varying seed lots of varying quality and variety may all show varying level of germination and disease incidence in varying soil depending on the level of inoculum of seed and soil borne disease pathogens. Good quality cotton seeds may escape, or show a good deal of resistance to seedling disease as demonstrated by the results of this study with good and poor quality seed lots. These differences in disease susceptibility exhibited by good and poor quality seed lots most likely reflect differences in the kinds or amounts of pathogen germination stimulants that are released to the soil by the germinating seeds and or availability of pathogens inoculum in the soil (Ayers and Lumsden 1975; Howell 2002, 2007).

Thus, the purpose of treating seeds chemically is to eradicate their pathogens and/or protect them against soil pathogens, mainly by germination time. Since 1993, a historic standard fungicide treatment, Carboxin + PCNB + metalaxyl, in Arizona and Carboxin, Thiram and their cominations were included as seed treatment fungicides (Rothrock et al 2012; CIB&RC 2017). The AICRP on cotton has evaluated cotton seedling survival for commercially available and recommended fungicide seed treatment combinations over diverse environmental conditions in India as part of the activities AICRP. In addition, selective fungicide treatments and their increased doses were used to aid in determining the importance of seed and soil borne diseases. The objectives of this study were to examine the importance of seedling diseases on cotton, the role of specific pathogens, and the validity of the recommended fungicides and their doses in cotton disease management in various environments.

Although all of the fungicides used in this study inhibited the activities of the pathogens *in vivo*, much of the systemic chemical was likely absorbed by the germinating seedling. Similarly, Carboxin (2g/kg seed) has been reported to be comparatively good in controlling seed borne fungal pathogens (66-87%) *Myrothecium roridum, Aspergillus niger, Curvularia lunata* in cotton (Tomar et al 2002). In addition, Baniani et al (2016) have found that Thiodicarb

Table 4. Effect of seed dressing chemicals on seed cotton yield of cotton

Treatment	Yield quintal per ha															
	Junagadh				Dharwad				Guntur				Coimbatore			
	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean	2012-13	2013-14	2014-15	Pooled mean
Thiram 75WS @2 g Kg^{-1}	19.4	17.5	8.4	15.1	4.2	20.5	13.1	12.6	6.6	7.1	10.1	7.9	3.2	8.0	8.5	6.6
Thiram 75WS @3 g Kg^{-1}	19.6	17.6	9.0	15.4	4.0	21.1	13.4	12.8	7.1	7.6	10.3	8.3	3.8	8.2	9.6	7.2
Thiram 75WS @4 g Kg^{-1}	21.1	19.2	9.5	16.6	4.3	21.4	13.5	13.1	7.3	8.2	11.9	9.1	3.7	8.3	10.0	7.3
Carboxin 75% WP @ 1 g Kg^{-1}	19.5	17.8	8.6	15.2	4.2	20.6	13.0	12.6	6.7	7.3	10.2	8.1	3.6	7.2	7.7	6.2
Carboxin 75% WP @ 2 g Kg^{-1}	20.8	18.0	8.9	15.9	4.2	20.8	13.0	12.7	6.9	8.5	12.3	9.2	3.7	7.0	8.5	6.4
Carboxin 75% WP @ 3 g Kg^{-1}	20.4	18.4	9.7	16.1	4.5	21.8	13.0	13.1	7.2	8.8	12.4	9.5	3.7	7.3	8.8	6.6
Carboxin 37.5% WP + Thiram 37.5 % DS 2.5 g Kg^{-1}	20.5	18.4	9.1	16.0	4.9	21.0	13.8	13.2	6.9	7.8	10.4	8.4	3.6	8.0	9.5	7.0
Carboxin 37.5% WP + Thiram 37.5 % DS 3.5 g Kg^{-1}	22.2	19.4	9.9	17.1	5.6	22.3	16.1	14.7	7.3	8.7	12.6	9.5	3.9	8.7	10.2	7.6
Carboxin 37.5% WP + Thiram 37.5 % DS 4.5 g Kg^{-1}	22.4	19.7	10.4	17.5	5.8	22.5	16.2	14.8	7.6	9.2	12.9	9.9	4.3	8.8	10.5	7.9
Untreated control	15.8	13.6	6.83	12.06	3.5	20.1	12.7	12.1	6.0	6.5	8.5	7.0	2.1	5.4	6.0	4.5
CD at 5%	3.47	3.25	1.84	3.21	0.36	0.17	2.35	2.14	NS	1.25	1.21	1.13	0.86	0.43	0.32	0.35

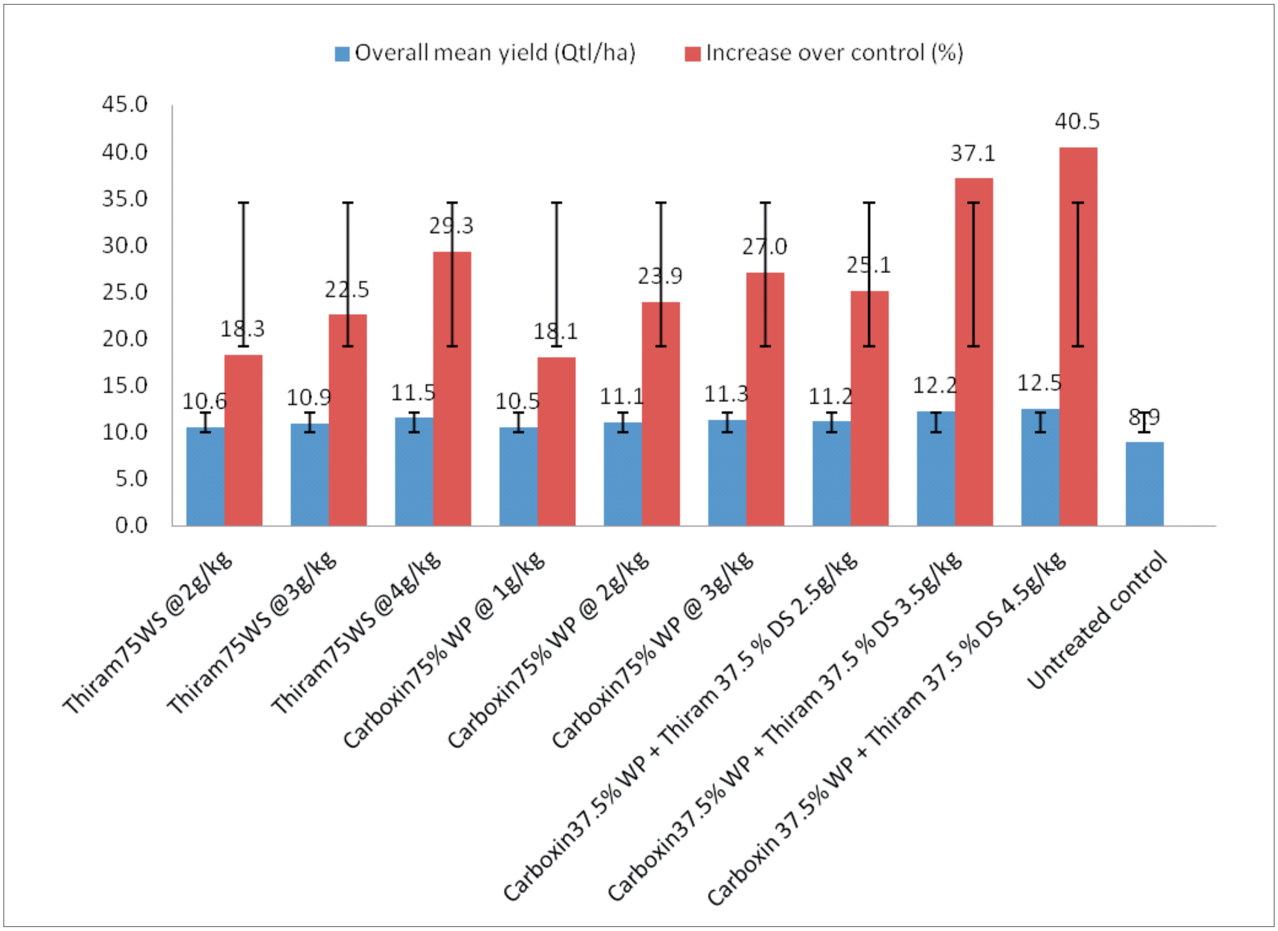

Figure 4. Overall effect of seed treatment chemicals on seed cotton yield (Sd± 0.998) and per cent increase (Sd± 7.73) over control

insecticide and Imidacloprid with rate of 7 per thousand and Carboxin + thiram with the rate of 4 to 6 per thousand alone or in combination are best for cotton seed treatment for disinfection compared to other chemicals.

Conclusion

Optimum disease control in soil containing both pre- and post emergence and foliar pathogens was achieved with a combination of Carboxin 37.5% + Thiram 37.5% DS 4.5 g Kg^{-1}. Carboxin 37.5% + Thiram 37.5% DS 3.5 g Kg^{-1} and Thiram 75WS @4 g Kg^{-1} were the next best in controlling the disease and enhancing the yield irrespective of locations, varieties and pathogens indicating that the fungicides employed and or recommended to control these diseases in cotton are still effective and the enhanced doses of these chemicals from the recommended doses can give better results within the country.

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