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Economic Analysis of Parawilt Management in *Bt-Cotton* (*Gossypium hirsutum* L.) in Mansa District of South-western Punjab, India

Gurdeep Singh[1]*, Pritpal Singh[2], Kulwant Singh[3], Gurjinder Pal Singh Sodhi[4] and Bhallan Singh Sekhon[5]

[1,3,5]Krishi Vigyan Kendra, Mansa-151505, Punjab, India
[2]Farm Advisory Service Centre (FASC), Bathinda-151001, Punjab, India
[4]Directorate of Extension Education, P.A.U., Ludhiana-141001, Punjab, India
*Corresponding author email id: gurdeepsingh@pau.edu

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ABSTRACT

Parawilt characterized by a sudden drooping of leaves followed by death of plants within few hours after rainfall or heavy irrigation has been the major physiological disorder affecting productivity of Bt-Cotton (*Gossypium hirsutum* L.). We studied the effect of foliar application of cobalt chloride (@10 mg L^{-1} water) within 24-36 hours after appearance of symptoms on recovery rate, seed cotton yield and economics at farmers' fields in Mansa district of south-western Punjab. The results of front line demonstrations revealed that foliar application of cobalt chloride resulted in significantly (p<0.05) higher seed cotton yield by ~9.1 per cent, compared with the control (no-spray). The mean gross returns (MGRs) increased significantly by Rs. 9620/- ha^{-1} in the demonstration plots. The higher benefit-cost (B:C) ratio of 2.38 was observed for the demonstration plots, against 2.15 for the control (no-spray). The foliar application of cobalt chloride resulted in higher average production efficiency of 1.1 kg seed cotton yield ha^{-1} d^{-1} and average economic efficiency of Rs. 65.7 ha^{-1} d^{-1}, compared with the control. These results therefore, revealed that farmers can effectively manage parawilt in Bt-cotton using foliar application of cobalt chloride and may increase seed cotton yield and economic returns.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is globally the most important commercial fiber crop and is a commodity of international trade, is by 75 per cent of worlds' population for textile purpose (Agbenyegah, 2012; Yadav et al., 2018; Singh et al., 2021a). Its cultivation predominates in arid and semi-arid environments under rainfed and irrigated conditions (Roth et al., 2013; Kumar et al., 2021). Cotton has high temperature and radiation requirements (Constable and Bange, 2015), and is cultivated during summer season after wheat (*Triticum aestivum* L.) in an annual cotton-wheat cropping system (Singh et al., 2018a; Singh et al., 2021b). In south-western Punjab (India), cotton-wheat is the second largest cropping system only next to rice-wheat which is practiced mainly on light textured, low fertility soils and under poor quality under-ground irrigation water conditions (Singh et al., 2018a; Sharma et al., 2020). High temperature range of 45-48ºC particularly during early growing season limits potential yield of the cotton crop (Ahmad et al., 2014). Poor plant population due to high seedling mortality under prevailing high temperature conditions lead to a significant set-back on cotton productivity (Ahmad et al., 2014; Tariq et al., 2017). On the other side, rainfall particularly during flowering and bolting stage negatively impacts the cotton yields (Cetin and Basbag, 2010). Besides, severe attack of cotton whitefly (*Bemisia tabaci*) resulted in a drastic decline in *Bt*-cotton yield as was during the year 2015 (Singh and Sharma, 2016). Similarly, parawilt is another physiological disorder which affect seed cotton yield of *Bt*-cotton and thus, economic returns. The prolonged drought, high

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temperature and bright sun light followed by heavy irrigation or heavy rains favors the appearance of parawilt. This sudden wilting is characterized by drooping of leaves followed by collapse of plants within a few hours after rainfall (Hebbar and Mayee, 2011). Where parawilt occur near to crop maturity, bolls may open forcefully but do not ripen fully leading to poor and unmarketable cotton quality (Hebbar and Mayee, 2011). The incidence of parawilt in *Bt*-cotton was first reported in Punjab (India) in *kharif*-2004 in a research trial (Sarlach et al., 2008). Cotton plants could be saved from parawilt with timely foliar application of cobalt chloride (ethylene production inhibitor) at initial wilting stage. The foliar application of cobalt chloride is effective only at initial stage and the affected plants recover within a week of spray without any loss in seed cotton yield (Sarlach et al., 2008; Economic Times, 2011). Sarlach & Kaur (2013) observed that among different *Bt*-cotton cultivars, the incidence of parawilt varied from 0.5-8.5 per cent during 2009-10 with a recovery of ~80-97 per cent during 2009 and ~90-98 per cent during 2010 following timely foliar application of cobalt chloride (@ 10 mg L^{-1} water). In south-western Punjab, parawilt has been severely affecting the cotton crop following moderately to heavy rainfall after a long dry spell. Most of the farmers in the region are unaware about the parawilt symptoms and its management in *Bt*-cotton. Thus, the present study was conducted at farmers' fields to demonstrate the effect of foliar application of cobalt chloride (@ 10 mg L^{-1} water) on recovery rate of *Bt*-cotton crop against parawilt, seed cotton yield and economic impacts in Mansa district of south-western Punjab.

METHODOLOGY

The field treatments consisted of foliar application of cobalt chloride (@ 10 mg L^{-1} water) within 24-36 hours of appearance of symptoms of parawilt termed as demonstration plot vis-à-vis control (no-spray of cobalt chloride). The control (check) plots were kept small (~4 m^2) to minimize economic loss to the farmers. Demonstrations were conducted during two consecutive years (*kharif*-2018 and *kharif*-2019) at farmers' fields in different villages in Mansa. A total of 72 demonstrations (22 during 2018 and 50 during 2019) were conducted on an area of 40 ha. All other crop production and plant protection measures except for the foliar application of cobalt chloride were same at farmers' fields. The data about the percent recovery of crop against parawilt and the seed cotton yield harvested in the demonstration and the check plots were recorded from the farmers. The economic analysis viz. cost of cash inputs, gross returns, net returns and the benefit-cost ratio (B-C ratio) were based on data collected at farmers' fields in a structured schedule. The mean cost of cultivation (MCCs), mean gross returns (MGRs) and mean net returns (MNRs) were calculated separately for demonstration and check plots (Gupta et al., 2021). The mean cost of cash inputs (MCCIs) for cotton cultivation at different study sites were estimated as sum of expenditure incurred for the purchase of various inputs and human labor. The MGRs were calculated as a product of seed cotton yield and selling price using Eq. 1. The MNRs were calculated as the difference in MGRs and MCCIs.

$$\text{MGRs (Rs ha}^{-1}) = \text{Seed cotton yield x Selling price} \quad \ldots (1)$$

The B:C was calculated as a ratio of MGRs and MCCIs (Eq. 2).

$$\text{B-C ratio} = \text{MGRs / MCCs} \quad \ldots (2)$$

The production efficiency was estimated as a ratio of seed cotton yield (kg ha^{-1}) and the crop duration (days, d). Average crop duration of 165.8 days was considered for estimating the production efficiency of *Bt*-cotton (Eq. 3) (Singh et al., 2020).

$$\text{Production efficiency (kg ha}^{-1}\text{ d}^{-1}) = \frac{\text{Seed cotton yield (kg ha}^{-1})}{\text{Average crop duration (d}^{-1})} \quad \ldots (3)$$

The economic efficiency was determined from a ratio of MGRs and average crop duration (d) (Eq. 4).

$$\text{Economic efficiency (Rs. ha}^{-1}\text{ d}^{-1}) = \frac{\text{MNR (Rs. ha}^{-1})}{\text{Average crop duration (d)}} \quad \ldots (4)$$

The statistical analysis of seed cotton yield was carried out by analysis of variance in randomized block design (RBD). Mean separation for different treatments was performed using Duncan's Multiple Range Test (DMRT) test at $p<0.05$. Statistical analysis was performed with SPSS for Windows 16.0 (SPSS Inc., Chicago, USA).

RESULTS AND DISCUSSION

Seed cotton yield in demonstration and check plots

The highest seed cotton yield with foliar application of cobalt chloride varied between 23.0 and 24.5 q ha^{-1} at different farmers' fields during two years (Table 1). The lowest seed cotton yield in plots with foliar application of cobalt chloride application varied between 18.7 and 20.8 q ha^{-1}. However, average seed cotton yield in check (no-spray) varied between 19.5 and 21.2 q ha^{-1} during two years. These results showed that foliar application of cobalt chloride resulted in a significant ($p<0.05$) yield increase by ~10.4 per cent during *kharif*-2018, and ~7.7per cent yield increase during *kharif*-2018, compared with the control (no-spray). The pooled data for two years revealed that foliar application of cobalt chloride resulted in a significant yield increase of ~9.1 per cent at different farmer's fields, compared with the check (no-spray). The increase in seed cotton yield following foliar application of cobalt chloride could be ascribed to the recovery of cotton crop against parawilt.

Foliar application of cobalt chloride and recovery rate

The recovery rate of cotton crop against parawilt reported by farmers varied between 85 per cent and 95 per cent during *kharif*-2018 and between 75 per cent and 95 per cent during *kharif*-2019 (Table 2). Sarlach and Kaur (2013) also reported that recovery rate of cotton crop against parawilt varied between 80-98 per cent in parawilt affected plants, which recovered following application of cobalt chloride. The effect of foliar application of cobalt chloride was higher in the fields with moderate wilting and where the spray was done within 24 hours following appearance of dropping symptoms on top leaves. However, recovery rate declined in parawilt affected *Bt*-cotton fields, where application of cobalt chloride was delayed. The difference in recovery rate could be ascribed to varying tolerance of *Bt*-cotton hybrids for parawilt (Hebbar and Mayee, 2011).

Table 1. Cotton hybrids, farming situation and seed cotton yield under demonstration (foliar application of cobalt chloride) and check (no-spray) during different years (2018-19) at farmers' fields in Mansa, south-western Punjab (India)

Year	Hybrids	Farming situation/ Irrigation source/ Soil type	Seed cotton yield (q ha^{-1}) †				% Increase in seed cotton yield over demonstration average
			Demonstration plots			Check plots	
			Highest	Lowest	Average	Average	
2018	RCH 773, RCH 776, SP 7172, US 91	Irrigated/Canal and underground/ Sandy loam	24.5	20.8	23.4b	21.2a	10.4
2019	RCH 773, RCH 776, SP 7172, US-81	Irrigated/Canal and underground/ Sandy loam	23.0	18.7	21.0b	19.5a	7.7
Mean	-	-	23.8	19.8	22.2b	20.4a	9.1

†Mean values followed by different letters ate significantly different by Duncan's Multiple Range Test (DMRT) at p<0.05.

Table 2. Effect of foliar application of cobalt chloride on recovery rate against parawilt during different years (2018-19) at farmer's fields in Mansa, south-western Punjab (India)

Year	Cotton hybrids	No. of farmers responded	Per cent plant affected	Recovery rate (%)
2018	RCH 773, RCH 776, US 91	05	<3	85-90
		12	3-5	
		05	>5	
2019	RCH 773, RCH 776, SP 7172, US 81	15	<3	75-95
		28	3-5	
		07	>5	
Mean	—	—	—	92

Table 3. Economic analysis of *Bt*-cotton using cobalt chloride in Mansa, south-western Punjab

Economic parameter	2018	2019	Mean†
Demonstration plots (Rs. ha^{-1})			
Mean cost of cash inputs (MCCIs) (Rs. ha^{-1})	49400	47250	48325
Mean gross returns (MGRs) (Rs. ha^{-1})	121680	109200	115440b
Mean net returns (MNRs) (Rs. ha^{-1})	72280	61950	67115b
B:C	2.46	2.3	2.38b
Check plots (Rs. ha^{-1})			
MCCIs (Rs. ha^{-1})	50200	49000	49600
MGRs (Rs. ha^{-1})	110240	101400	105820a
MNRs (Rs. ha^{-1})	60040	52400	56220a
B:C	2.2	2.1	2.15a

†Mean values followed by different letters ate significantly different by Duncan's Multiple Range Test (DMRT) at p<0.05.

Economic analysis of foliar application of cobalt chloride vis-à-vis control

The MCCIs for demonstration plots with foliar application of cobalt chloride varied between Rs. 49400/- ha^{-1} and Rs. 47250/- ha^{-1} during *kharif*-2018 and *kharif*-2019 (Table 3). The pooled data for two study years revealed an average difference of Rs. 1275/- ha^{-1} in MCCIs leads to significant (p<0.05) difference of Rs. 9620/ - ha^{-1} in MGRs. The average MNRs were significantly increased by Rs. 10895/- ha^{-1} following foliar application of cobalt chloride, compared with the control (no-spray). The B-C ratio of 2.38 was observed for demonstration plots against 2.15 for the control (no-spray) plots.

Production and economic efficiency

The production efficiency of demonstration plots with foliar application of cobalt chloride and the control (no-spray) plots was 13.4 and 12.3 kg ha ^{1} d^{-1}, respectively (Figure 1a). Similarly, economic efficiency for cotton in demonstration plots with foliar application of cobalt chloride was Rs. 404.8 ha^{-1} d^{-1} compared to Rs. 339.1 ha^{-1} d^{-1} for the control (no-spray) plots (Figure 1b). Earlier, Singh et al., 2018b reported economic efficiency of Rs. 201 ha^{-1} d^{-1} for Bt-cotton. The effect of foliar application of cobalt chloride on the production and economic efficiency of cotton cultivation was similar with variable magnitude during the two study years. Thus, the data clearly indicates higher economic returns for cotton cultivation following management of parawilt with foliar application of cobalt chloride.

CONCLUSION

The drooping of cotton leaves (parawilt) and plant death after heavy rainfall or heavy irrigation particularly after a long dry spell has been a serious constraint in cultivation of *Bt*-cotton in south-western Punjab (India). Most often, farmers in the study region confuse this disorder with fungal diseases or pest attack and generally apply fungicide or insecticide for its management. It has been observed that in the fields where foliar application of cobalt chloride is delayed, the recovery rate of cotton crop against parawilt is reduced. These results of the study indicate that timely application of cobalt chloride against parawilt has been the most

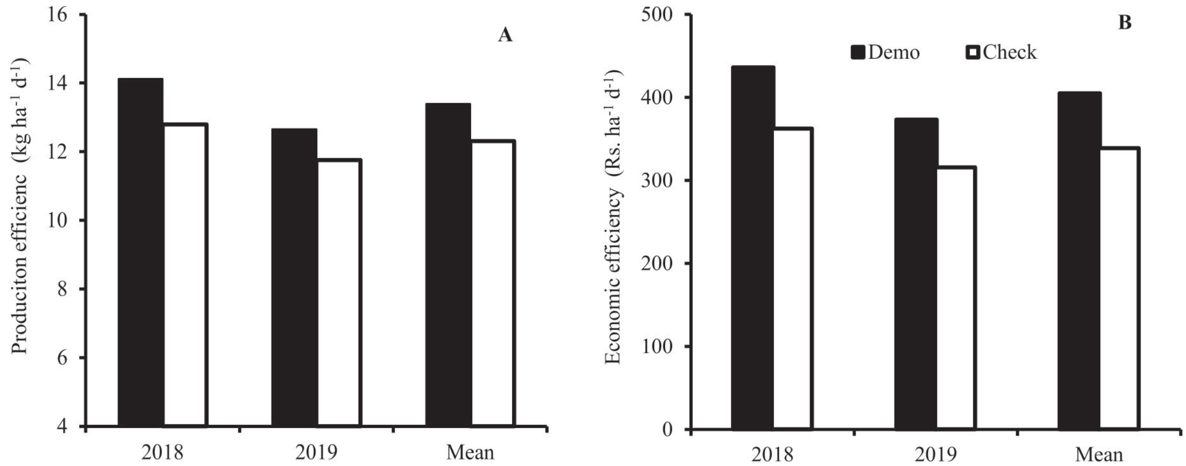

Figure 1. Production efficiency (a) and economic efficiency (b) of *Bt*-cotton following parawilt management using cobalt chloride in Mansa, south-western Punjab (India).

efficient management measure with high economic impact. The timely foliar application of cobalt chloride helped in getting higher seed cotton yield and higher economic returns due to increased production and economic efficiency.

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