Journal of Pure and Applied Agriculture (2022) 7(1): 20-28
ISSN (Print) 2617-8672, ISSN (Online) 2617-8680
http://jpaa.aiou.edu.pk/

Evaluation of the chemical control of bacterial leaf blight (*Xanthomonas oryzae pv. oryzae*) of rice in transplanted rice (*Oryza sativa* L.) crop

Muhammad Asghar[1]*, Muzammal Hussian[1], Iftekhar Ahmad[1], Talfoor-ul Hasan[2], Mazhar Faid Iqbal[1], Muhammad Montazir Mahdi[3] and Muhammad Anjum Ali[4]

[1]Directorate of Farms Training & Adaptive Research, Gujranwala, Pakistan
[2]Pest warning and Quality Control of Pesticides, Gujranwala, Pakistan
[3]Pest warning and Quality Control of Pesticides, Hafizabad, Pakistan
[4]Directorate General Agriculture (Extension & Adaptive Research) Punjab, Lahore, Pakistan

*****Corresponding author: Muhammad Asghar (miang786@yahoo.com)

Abstract

Bacterial leaf blight of rice caused by *Xanthomonas oryzae* pv. *Oryzae* is considered a major threat to rice production worldwide including in Pakistan. Thus field trials were conducted to evaluate different commercially available antibacterial chemicals against this destructive disease on the rice cultivar Pk-386. For this purpose, comparative efficacy of bleaching powder, Kasumin 2SL (kasugamycin), Triseen 5SL (validamycin), Profile 50WP (kasugamycine+copperoxychloride), Coopix 50WP (copper oxychloride) Thrill 20WP (bismerthiazole) was studied as foliar spray applications against BLB at their recommended doses. The experiment was laid out in randomized complete block design with three replications. Among the tested chemicals the disease incidence (60.44%), Disease severity index (16.79%) were the lowest for Coopix 50WP with the highest yield (6.58 tonnes ha^{-1}) followed by Profile 50WP with 78.56%, 21.96%, and 6.44 tonnes ha^{-1} respectively. The performance of the control plot as compared to other treatments remained poor with the highest (98.08%) disease incidence, 58.01% (disease severity index) and lowest yield 50.67 tonnes ha^{-1}. The benefit to cost ratio in cases of Coopix 50WP and bleaching powder was same (1:13) but the incremental increase in income over the control with Coopix 50WP was highest (Rs. 30330) as compared to that of (Rs.16352) with the use of bleaching powder. Therefore on the basis of results copper oxychloride and kasugamycine+copper oxychloride could be recommended for the economic and efficient control of bacterial leaf blight of rice crops.

Keywords: Antibiotics, Bacterial leaf blight of rice, Chemical control, Kallar tract

To cite this article: Asghar, M., Hussian, M., Ahmad, I., Hasan, T., Iqbal, M. F., Mahdi, M. M., & Ali, M. A. (2022). Evaluation of the chemical control of bacterial leaf blight (*Xanthomonas oryzae pv. oryzae*) of rice in transplanted rice (*Oryza sativa* L.) crop. *Journal of Pure and Applied Agriculture, 7*(1), 20-28.

Introduction

Rice is the world's second most important cereal crop following the corn. In the last harvesting year about 482 million metric tons of husked rice was produced worldwide. Traditionally, Asian countries have the largest share in world rice production (Shahbandeh, 2021a, b). In Pakistan, rice is grown in all four provinces that includes Gujranwala, Hafizabad, Sialkot, Sheikhupura, Okara and Jhang districts in Punjab, Larkana, Jacobabad, Shikarpur, Badin, Thatta and Dadu districts in Sindh, Nasirabad, Jafferabad and Usta Mohammad districts of Balochistan and Swat & DI Khan areas in the province of Khyber Pakhtun khwa. Rice is an important food and cash crop for the people of Pakistan and is one of the most important exportable agricultural commodities. It accounts for 3.0 percent in value-added to agriculture and 0.6 percent in GDP. During 2019-20, rice was planted on an area of 3.034 million hectares with a production of 7.414 million metric tons (Government of Pakistan [GoP], 2020). In Pakistan, Basmati, coarse and fine rice varieties are grown mainly in special areas of Kallar Tract falling in Punjab. Basmati rice fetches a premium price in international market due to its distinct aroma and length. The national average yield of Pakistan is 3.5 ton ha^{-1} for Basmati and 5.0 ton ha^{-1} for coarse rice (Pakistan Agricultural Research Council [PARC], 2018), which is far below the yield, obtained in other rice growing countries of the world, due to a number of abiotic and biotic reasons (Ahmad et al., 2020).

The major biotic stresses that can cause significant reduction in rice yield include weeds, pest insects and diseases. Among biotic components the incidence of diseases is the foremost component of low yield in rice crop production system. Rice suffers from many diseases right from germination till maturity. These diseases may be caused by fungi, bacteria, viruses, nematodes, phytoplasma, and other non-parasitic disorders. Among the bacterial diseases, Bacterial leaf blight (BLB) is caused by *Xanthomonas oryzae* pv. *oryzae* (Xoo) (Ishiyama 1922) is the most devastating and a major threat to paddy production worldwide (Xu et al., 2010). This disease is found where ever rice is grown but it is particularly destructive in Asia. Moreover the weather conditions impact both the occurrence and gravity of this diseases. It is because of its destructiveness under favorable environmental conditions and wide spread distribution in irrigated and rain fed environments, it has become endemic on rice in many rice growing countries in Asia. It has capacity to cause considerable losses by damaging the crop on large scale and yield losses ranging from 30 to 50 % could be expected from its attack, especially in areas with new short stature high yielding rice varieties and under favorable environmental conditions (Mew, 1987; Swings et al., 1990; Patil et al., 2017).

All famous Basmati varieties of Pakistan are susceptible to BLB disease (Khan et al., 2000). In Pakistan the disease was recorded for the first time by Mew and Majid (1977), later on Ahmad and Majid (1980) reported it on rice varieties IR 6, Palman, Basmati-198 at Rice Research Institute (RRI), Kala Shah Kaku and farmer's field. This disease remains present throughout the growing season all over rice growing areas of the country but maximum incidence has been reported in Punjab (Akhtar et al., 2007).

Chemicals are the most important components of the Integrated Disease Management (IDM) for mitigating the plant diseases. The various chemicals, antagonists, botanicals and nutrient are recommended in different rice growing areas to manage BLB. Due to lack of knowledge or social reasons the farmers' community applies different chemicals haphazardly to combat this deadly disease. This practice not only damages the farmers economically but is also a major cause of environmental pollution. Keeping these views in mind, the present investigation was undertaken to reduce yield losses economically by managing the BLB of rice which ultimately will also helpful in reducing environmental pollution. The main objective of the present study however, was to check efficacy and economics of commercially available bactericides and other antibacterial chemicals against the BLB pathogen under natural field condition.

Materials and Methods

The experiments regarding chemical control of BLB (*Xanthomonas oryzae pv. oryzae*) of rice were conducted at farmer's fields in the village Chak Nizam (32° 11' 30" North, 74° 20' 25" East) located in traditional rice growing area i.e., the Kallar tract in Gujranwala, Punjab well known for Basmati and non-Basmati rice production all over the world (Asghar et al., 2015). For this purpose the nursery of rice cultivar Pk-386 was sown in the month of June. The land was prepared and puddled according to traditional agronomic practices of the area and 35 days old rice nursery was transplanted manually in well prepared soil. The plot size for each treatment was 6 m × 20 m with plant to plant and row to row distance of 23 cm. Nitrogenous (N), phosphatic (P) and potassium (K) fertilizer was applied @ 40, 80 and 62 Kg ha^{-1}, respectively. All P and K fertilizer was applied at the time of last puddling before transplanting rice nursery whereas N was applied 30 days after transplanting (DAT) and 60 DAT in two equal splits after transplanting the nursery in main filed. Weeds were controlled by Machete (butachlore) 60 EC @ 2 L ha^{-1} whereas Ferterra 4G (chlorantraniliprole) was used as insecticides @ 10.0 Kg ha^{-1} when the pest insects had reached at Economics Threshold Level (ETL). The irrigation and other agronomic practices were kept same for all the experimental units except the treatments under test. For this purpose commercially available bactericides and antibacterial chemicals were sprayed against BLB of rice in transplanted rice (Table 1).

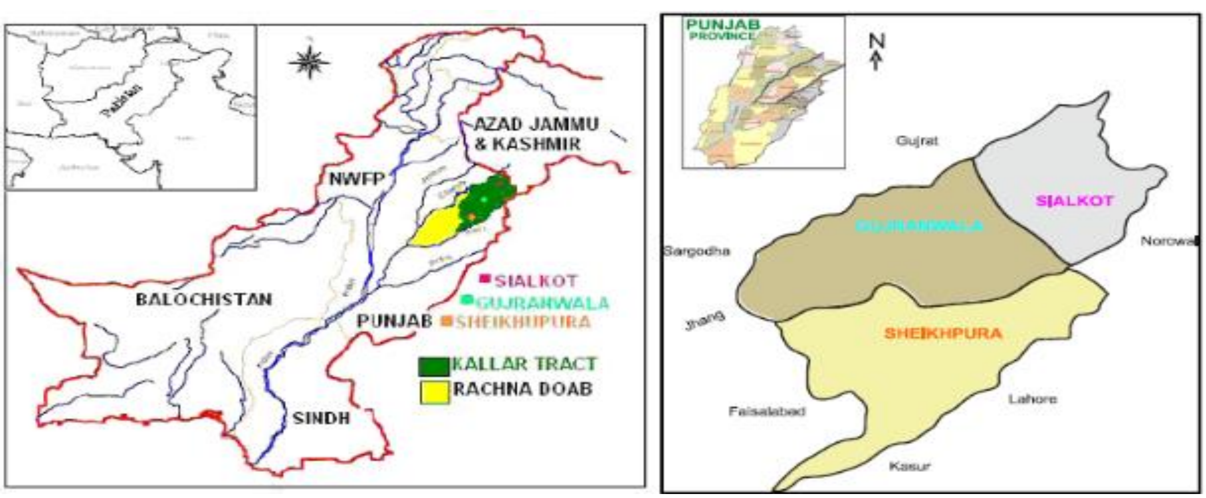

Fig. 1 Maps of research location in Kallar tract (Suhail et al., 2007; Asghar et al., 2013; Asghar et al., 2015)

Treatment details

There were eight treatments including the control. In control plot no bactericides or antibacterial chemical was applied but only fresh water was sprayed @ 250 L ha^{-1} (Qudsia et al., 2017). The field trials in both of the years were laid out by following Randomized Complete Block Design (RCBD) with three replications. The treatments comprising of bactericides and antibacterial chemicals (Table 1) were applied at their recommended doses after appearance of disease. In order to apply the treatments the required quantities of the bactericides/chemicals were weighed and suitably dissolved in a requisite quantity of fresh water to obtain desired concentrations as given in Table 1. The temporal data regarding disease was recorded before application of treatments and then after seven days and 14 days of their application using disease rating scales 0-9 (International Rice Research Institute [IRRI], 1996) (Table 2). In order to avoid the edge effect the experiment was laid out in such a way that there was 2 meter non experimental area all around the experimental field.

Table 1 Chemical treatments applied on rice crop against BLB

Treatments	Bactericide/ antibacterial chemical	Active ingredient	Manufacturer	Concentration in 100 L of water
T1	Control	-	-	-
T2	Bleaching powder	calcium hypochlorite		800 g
T3	Kasumin 2SL	kasugamycin	Arysta Life Sciences, Pakistan	600 ml
T4	Triseen 5SL	validamycin	Tara Group, Pakistan	100 ml
T5	Profile 50WP	kasugamycine+ copper oxychloride	Chem & Chem (Pvt.) Ltd. Pakistan	250 g
T6	Coopix 50WP	copper oxychloride	Tara Group, Pakistan	300 g
T7	Thrill 20 WP	bismerthiazole	FMC United (Pvt.) Ltd. Pakistan	250 g

Data collection

The observations for BLB incidence and severity were recorded from 15 leaves of 5 plants selected randomly from each repeat. These randomly selected plants were five paces apart from each other and distributed uniformly within each experimental unit. The randomly selected five plants were examined for disease incidence and severity. The percent disease incidence was calculated according to following formula described by Gnanamanickam et al. (1999).

$$\text{Disease Incidence (DI)\%} = \left(\frac{\text{Number of BLB infected leaves}}{\text{Totla number of leaves examined}}\right) \times 100 \ldots (Eq\ 1) \ldots$$

The severity of disease was recorded as percentage of leaf area infected out of total leaf area. For disease severity average lesion area of 15 leaves selected at random was measured according to Table 2 and according to equation 2 BLB severity index was calculated.

Table 2 Disease severity scale for evaluation of bacterial blight of rice in the field

Disease rating/Index value	Lesion size (% of leaf length)
0	0
1	>1-10
3	>11-30
5	>31-50
7	>51-75
9	>76-100

$$\text{Disease Severity Index (DSI)} = \left(\frac{\text{Sum of the scores or lesion size}}{\text{Number of observation X highest number in rating scale}}\right) \times 100 \ldots \ldots \text{(Eq 2)}$$

The data of yield and yield contributing attributes like number of productive tillers per m^2, 1000 grain weight (g), grains per panicle and paddy yield per m^2 in Kg was recorded. For this purpose all of the plots were harvested manually at maturity. A standardized quadrate measuring 1 m^2 was placed at three places randomly in each treatment plot. The rice plants inside of this quadrate were harvested. The number of tillers per plant per m^2 and number of grains per panicle were counted and then the grains were threshed manually. The grains from each plot were kept in labeled brown paper envelop separately and brought to laboratory for recording parameters to be used in further analysis. These samples at the end were sent to Pesticides Residues Research laboratory, Kala Shah Kaku (KSK) for analysis of residues of pesticides sprayed during the experiment.

Statistical analysis

The data recorded during the experiment for each treatment were statistically analyzed using the statistical software STATISTIX 8.1 (Analytical Software, 2006). Data of both of the years were pooled and subjected to analysis of variance (ANOVA) and the means were compared using least significant difference (LSD) at 5% significance level (Steel et al., 1997). In order to calculate the economics of chemical control for BLB the procedure laid out by Asghar et al. (2017) was followed. The net income of rice produce was obtained after deducting cost of chemical control from the value of the produce. The additional return was, however, calculated on the basis of additional income obtained from the particular treatment compared to that of untreated control. Benefit cost ratio (BCR) for each treatment was obtained by dividing additional returns by expenditure incurred for the cost of chemical control against BLB.

Results and Discussions

The experiment was carried out by using eight treatments to evaluate the efficacy of bactericides and antibacterial chemicals for the control of bacterial leaf blight of rice under natural field conditions. The results indicated that disease intensity in all the plots before the application of treatments was non-significant ranging from 64.45% to maximum of 80%. It is also depicted in Table 3 & Fig. 2. From Table 3 it is also clear that all the treatment plots before application of treatments were statistically at par with each other. It means that incidence of disease was almost uniform in all the experimental units at the start of experiment.

From Table 3, Fig.2 it is evident that after 7 days of application of treatments disease incidence ranged from 60% with Coopix followed by Profile (68.89 %) to the highest 86.67% within the control. The bleaching powder proved better in inhibiting the incidence of BLB as compared to Triseen and Thrill. From the results it became clear that Thrill remained completely unable to protect the crop from the attack of BLB. Whereas in case of Triseen the incidence of disease was the same as it was before spray but in case of bleaching powder the DI decreased and it protected the crop from further disease attack. Over all the incidence of disease in case of Coopix, Profile, bleaching powder and Kasumin decreased in order, whereas it increased in case of Thrill and control but remained unchanged in case of Triseen. This showed that Triseen had capacity to arrest the activity of bacteria to cause new infection. The results of the present study were in the lines of Chen et al. (2015) who found that zinc thiazole provided higher control efficacy than that of bismerthiazol and recommended zinc thiazole is an alternative tool for the management of BLB. The results of present research study were partially in agreement with those of Nasir et al. (2019). According to them among the tested chemicals, Flare 72WP (streptomycin sulphate) performed as the best with lowest DI (6.53%) followed by Castle 50WP (kasugamycin+copper oxychloride) with 10.33%, Cordate 4WP (kasugamycin) with 11.67%, Copper oxychloride 50WP (copper oxychloride) with 20.00%, Nativo 75WDG (tebuconazole+trifloxystrobin) with 26.67%, Gem Star Super 325SC (azoxystrobin+difenconazole) with 31.00% disease incidence over untreated control treatment. However, the mean disease incidence in the control treatment was 85.67% which was almost similar (86.67%) to the attack of BLB in the present study. The disease incidence was lowest in Coopix (66.02%) which was statistically at par with Profile (70.20%) and highest (96.08%) in control treatment which was in turn statistically at par with Triseen (93.86%) and Bleaching powder (91.63%). It was therefore, the Coopix followed by Profile 50WP and Kasumin which inhibited the incidence of BLB and protected the rice crop for longer period of 14 days. The results were quite in accordance with the findings of Khan et al. (2005); Khan (2013) who concluded that application of copper oxychloride at an interval of 10-15 days against BLB could be a good management strategy to control bacterial leaf blight. The results were also in line with those of Shahbaz et al. (2016) who observed that among the tested chemicals copper oxychloride controlled the disease efficiently (73%) over the other treatments. The results were also on the pattern of Shekhar and Kumar (2020) who evaluated that copper oxychloride in combination with streptocycline controlled the BLB of rice upto 15 days. The results were partially in accordance with those of Azher et al. (2013) who controlled BLB successfully (81.04%) by the use of Castle 50WP (kasugamycin+copper oxychloride).

Again there was significant difference among treatments 14 days after their application. On an average after 14 days of application of treatments the disease incidence over the control was lowest (37.64%) in case of Coopix followed by 19.52% with Profile. The results were completely in accordance with those of Shekhar and Kumar (2020) who depicted from the results that application of copper-based fungicides significantly reduced (38.78%) the impact of BLB disease in rice crop as compared to other treatments and untreated control. They concluded that the use of copper oxychloride could play an important role for the management of devastating BLB disease of rice. The result however, were quite in conformity with those of Shahbaz et al., (2016) who recorded a maximum (73%) decrease in damage to rice crop by BLB with the use of copper oxychloride followed by trifloxystrobin+tubeconazole (70%).

These results were partially in agreement with those of Nasir et al. (2019) who found that Flare 72WP (streptomycin sulphate) controlled the disease incidence upto 92.23% followed by Castle 50WP (kasugamycin+copper oxychloride) with (87.97%) and Copper oxychloride 50WP (copper oxychloride) with 76.48%. Figure 3 showed the temporal variation in disease incidence and it was evident that the DI increased in all the treatments after 14 days of their application. It means that none of the bactericide or antibacterial chemical was able to prevent the rice crop from further attack of BLB after 14 days of their application. However, the rate of progression of disease was highly arrested in case of Coopix (4%) followed by retarded progression of disease with Kasumin (1.05%) and Profile 50WP (5.23%). On the other hand the increase in rate of DI was significantly highest 31.63% in control followed by Triseen & Thrill (18.30%) and Bleaching powder (16.07%).

Table 3 BLB disease incidence before and after application of treatments

Antibiotics/ Antibacterial chemicals	DI % age before spray	DI % age 7 days after spray	DI % age 14 days after spray	DI % over control
T1-Control	64.45 a	86.67 a	96.08 a	0
T2-Bleaching Powder	75.55 a	71.11 cd	91.63 a	-6.57
T3-Kasumin 2SL	80.00 a	73.33 bc	81.04 bc	-17.37
T4-Triseen 5SL	75.56 a	75.56 abc	93.86 a	-4.30
T5-Profile 50WP	73.33 a	68.89 cd	78.56 c	-19.90
T6-Coopix 50WP	64.44 a	60.00 d	60.44 d	-38.37
T7-Thrill 20 WP	71.11 a	84.45 ab	89.41 ab	-8.84
LSD	27.164	11.906	10.267	
F	0.8374	5.61	14.51	
SE	12.468	5.4643	4.60	
P	0.8374	0.0056	0.0001	

LSD = Least significant difference at 5% level of significance; Means followed by the same letter in a column do not differ statistically (P = 0.05); All the values are the mean of two years

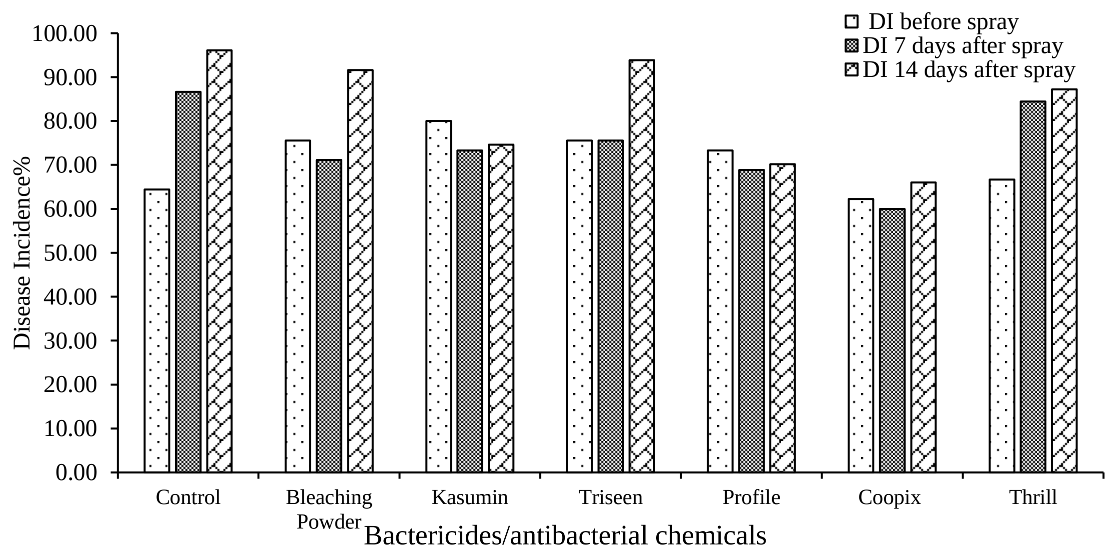

Fig. 2 DI (%) of BLB before and after application of treatments

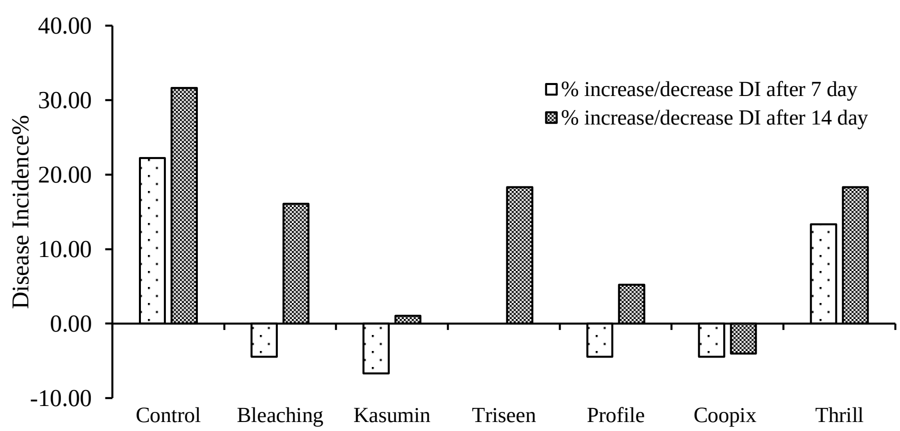

Fig. 3 Temporal variation percent increase or decrease of DI after 7, between 7-14 and after 14 days of treatments application

The results were on the line of Singh and Gupta (1982) who evaluated that the incidence and severity of leaf scald disease of rice caused by *Monographella albescens (Thüm)(Rhynchosporium oryzae* Hashioka & Yokogi) was significantly reduced by use of Blitox-50 (copper oxychloride), Difolatan (captafol) and Dithane M-45 (mancozeb) which were more effective for a longer period of time than the other pesticides used. Egel (2017) was also of the view that copper based products for bacterial diseases were more effective than against fungal diseases. As for as Disease Severity (DS) was concerned all the treatments were statistically at par with each other before application of treatments with non-significant differences among their means. After 7 days of application of treatments the difference among them was significant with highest (33%) in control followed by Thrill, Triseen and Bleaching powder. However the low DS was observed in case of Profile (18%), Kasumin (17%), Coopix (16%) and the lowest with Bleaching powder (15%). From the results mentioned in Table 3 it is evident that Bleaching powder has the ability to retard the spread of lesions of BLB upto 7 days of treatment. The Coopix proved the best followed by Profile (22%) and Kasumin (23%) these were however, statistically at par with each other.

The values for DSI after 14 days of treatments application as shown in Table 3 and demonstrated in Fig.4 were highest in control (58%) and lowest in Coopix (17%). The Bleaching powder which retarded the DS to excellent level after 7 days failed to perform after 14 days. It was clear that Bleaching powder can only prevent the BLB crop for first 7 days only. The results after 14 days of treatment application were significantly different from each other (Table 3). From Fig 4 it can also be observed that there is increasing trend of DS in case of control, Bleaching Powder, Triseen and Thrill.

Table 3 Variation in BLB disease severity indices before and after application of treatments

Antibiotics/antibacterial chemicals	DSI % age before spray	DSI % age 7 days after spray	DSI % age 14 days after spray
T1-Control	1.074 a	33.09 a	58.01 a
T2-Bleaching Powder	13.83 a	15.31 a	46.91 ab
T3-Kasumin 2SL	16.79 a	17.53 b	23.46 c
T4-Triseen 5SL	17.78 a	27.65a	44.44 b
T5-Profile 50WP	18.03 a	18.52 b	21.96 c
T6-Coopix 50WP	15.56 a	16.30 b	16.79 c
T7-Thrill 20WP	16.23 a	29.63 a	43.21 b
LSD	7.62	7.84	11.30
F	0.450	8.25	17.97
SE	3.50	3.60	5.19
P	0.831	0.0011	0.0000

LSD = Least significant difference at 5% level of significance; Means followed by the same letter in a column do not differ statistically (P = 0.05); All the values are the mean of two years

Therefore, in order to control and protect the rice crop from BLB for long duration multiple application of Bleaching powder but only two applications of Coopix, Profile or Kasumin are required. Actually multiple sprays in full grown rice crop are very difficult to apply but only two applications of Coopix etc. can assure the protection of rice crop from BLB for longer period of time (Chauhan, 1973; Singh and Gupta, 1982; Egel, 2017).

As for as the yield data was concerned it is shown in Table 4. From the table 4 it is clear that no of plants per m^2, no of tillers per plant and no. of tillers per m^2 were statistically at par with each other but with the highest values for Kasumin & Coopix, bleaching powder & Thrill and Kasumin & bleaching powder respectively. The spike lengths were statistically different from each other with longest 31.67 mm in profile and smallest in control treatment with 28.67mm. The plant height was maximum (126.15cm) in case of Coopix and was least (113.45cm) in case of control plot. As for as no. of grains per panicle were concerned those were highest (116.67) in plots treated with Coopix followed by Profile (106.67) and lowest with control treatments (93.33). Another important parameter regarding grain is the weight of 1000 grains weight which was highest (22.00g) in case of Coopix followed by Profile (21.60g) and lowest (18.91g) in control.

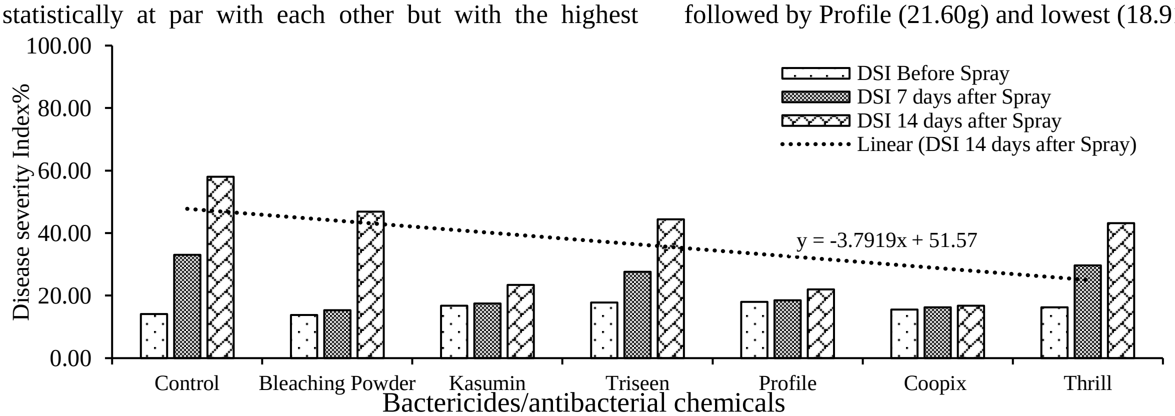

Fig. 4 Temporal variation in DSI %ages before spray and then after 7 and 14 days of treatments application

Consequently the observed grain yield followed the same previous pattern with the highest vales for Coopix (658.37g) followed by Profile (643.89g) and the yield remained lowest (506.72) in a control treatment. On % age basis the increase in yield as compared to untreated control was highest in case Coopix (23%) followed by Profile (22%), Kasumin (19%) bleaching powder (14%) and 7% both in cases of Thrill and Triseen. The similar results were recorded by Shekhar and Kumar (2020) who obtained maximum plant height (104.05cm), Number of tillers/plant (10.40), Panicle length (24.67cm), Straw yield (73.67q/ha), Grain yield per plot (7.37Kg/plot) with the treatments of Copper oxychloride+Streptocycline.

Table 4 Comparison of mean values of different yield components for chemical control of BLB of rice in transplanted rice

Bactericides/ Chemicals	No of plants/ m^2	No. of tillers/ plant	Tillers/ m^2	Panicle length (mm)	Plant height (cm)	No. of grains/ panicle	1000 grain wt (g)	Grain yield/m^2 (g)
Control	16.00a	17.33a	276.67a	28.67b	113.45d	93.33	18.91d	506.72e
Bleaching powder	16.33a	17.67a	288.33a	30.67ab	122.77abc	100.33	20.37bc	588.48c
Kasumin 2SL	17.00a	17.33a	294.33a	31.33a	124.46ab	101.67	21.29ab	624.39b
Triseen 5SL	16.67a	17.00a	283.67a	30.00ab	116.84cd	97.33	19.96cd	543.79d
Profile 50WP	16.67a	17.00a	283.33a	31.67a	125.31ab	106.67	21.60ab	643.89ab
Coopix 50WP	17.00a	16.33a	277.67a	32.33a	126.15a	116.67	22.07a	658.37a
Thrill 20WP	16.00a	17.67a	282.33a	31.00ab	118.53bcd	99.00	19.85cd	545.89d
LSD	2.22	1.68	42.71	2.33	2.72	42.90	1.24	30.95
F	0.35	0.73	0.19	2.51	4.65	0.30	7.77	32.60
SE	1.02	0.83	21.05	1.07	3.17	19.69	0.57	14.20
P	0.900	0.700	0.973	0.083	0.011	0.927	0.001	0.00

LSD = Least significant difference at 5% level of significance; Means followed by the same letter in a column do not differ statistically (P = 0.05); All the values are the mean of two years

Our results were similar to those of Khan et al. (2005) who obtained maximum plant height (cm), no. of fertile tillers m^{-2} , grains per panicle and 1000 grain weight (g) and ultimately highest paddy yield (4766.7 $kgha^{-1}$) in the plots treated with copper oxycholoride. The results were also similar to those of Singh and Gupta (1982) who obtained maximum rice yield by the use of Blitox-50 (copper oxychloride). The results were however, partially in agreement with those of Nasir et al. (2019) who obtained highest rice yield (89.66 kg) with Flare 72WP (streptomycin sulphate) followed by 89.20 kg with Castle 50WP (kasugamycin+copper oxychloride), 89.10 kg with Cordate 4WP (kasugamycin), 89.00kg with Bordeaux mixture (copper sulfate+lime+water), 88.90 kg with Copper oxychloride 50WP (copper oxychloride) and lowest (86.59 kg) with untreated control. The Anyhow, the results were against the finding of Qudsia et al. (2017) who obtained highest rice yield with Nativo 75WG (tebuconazole+trifloxystrobin) followed by Switch 80WDG (sulfur), Score 250EC (difenconazole), Dorazole 50EC (difenconazole+propiconazole), Copper oxychloride 50WP (copper Oxychloride). The economics of the chemical control of BLB of rice in transplanted rice (Table 5) was calculated on the basis of cost of the chemicals at the time of their use. The other factors that include cost of labor and rent for machinery were not included as those were same for all the treatments.

Table 5 Economics of different bactericides and chemicals used for chemical control of BLB of rice in transplanted rice

Bactericides/ Chemicals	Yield ($Kg\ ha^{-1}$)	Yield increase over check ($Kg\ ha^{-1}$)	Additional income over check ($Rs.\ ha^{-1}$)	Additional Expenditure over check ($Rs.\ ha^{-1}$)	Net Income (Pk-Rs.)	BCR
Control	5067.2	0	0	0	0	
Bleaching Powder	5884.8	817.6 (14%)	16352	1750	14602	13.00
Kasumin 2SL	6243.9	1176.7 (19%)	23534	4750	18784	6.43
Triseen 5SL	5437.9	370.7 (7%)	7414	3562	3852	2.12
Profile 50WP	6438.9	1371.7 (22%)	27434	3625	23809	10.35
Coopix 50WP	6583.7	1516.5 (23%)	30330	3250	27080	13.00
Thrill 20WP	5458.9	391.7 (7%)	7834	3000	4834	2.92

Anyhow on the basis of Cost Benefit ratio (BCR) Coopix yielded highest net income with highest BCR followed by Profile (Table 5). In case of bleaching powder the BCR was equal to that of Coopix but net income half as compared to

Coopix, and lower than Profile and Kasumin but higher than Triseen and Thrill bleaching powder. The results were partially in agreement with those of Singh et al. (1980) who evaluated a mixture of Agrimycin 100 + Fytolan (oxytetracycline+copper oxychloride) spray gave good control over the disease and an economic return.

Pesticides residual analysis

The paddy samples were submitted for residual analysis to Pesticides Residues Research laboratory, Kala Shah Kaku. They analyses the samples through GCMS-Agilent technique and reported that no residues of sprayed pesticides were found in rice paddy samples.

Conclusion

The attack of BLB in the present experiment remained low in two consecutive seasons. The variety Pk-386 was also moderately resistant to BLB. Even then the disease caused considerable damage to the yield of rice crop. The Coopix 50WP (copper oxychloride) followed by Profile 50WP (copper oxychloride+kasugamycin) performed excellently against the disease. The interesting finding was that the BCR in case of bleaching powder was equal to that of Coopix 50WP. Therefore it can be recommended that resource poor farmers can use it for the control of BLB on their rice crop for a week interval only.

Acknowledgements: The authors are highly acknowledge to the host farmer Mr. Muhammad Mushtaq Sandhu who offered his rice crop and other facilities to conduct the research study
Conflict of interests: The authors declare that they have no conflict of interests

References

Ahmad, H. M., Shahid, M. I., Ali, Q., Anjum, N. A., Ayyub, M., Ikram, A., Faisal, M., Ali, A., & Palwasha, A. (2020). Efficacy of different fungicides against rice blast under field condition in rice crop. Journal of Global Innovations in Agricultural and Social Sciences, *8*(1),15-18.

Ahmad, W., & Majid, A. (1980). Incidence of Bacterial Blight of rice in the Punjab (Pakistan). IRRN, 5, 5.

Akhtar, M.A., & Rafi, M. (2007). Virulence of *Xanthomonas oryzae* pv. *oryzae* isolates against rice cultivars. *Pakistan Journal of Phytopathology*, *19*, 19-22

Government of Pakistan [GoP]. (2020). Pakistan Economic Survey. Ministry of Food, Agriculture and Livestock. Federal Bureau of Statistics, Islamabad, Pakistan. Retrieved from https://www.finance.gov.pk/survey/chapters_21/02-Agriculture.pdf

Pakistan Agricultural Research Council [PARC]. (2018). *Rice research programme*. Retrieved from http://www.parc.gov.pk/index.php/en/rice

International Rice Research Institute [IRRI]. (1996). *Standard evaluation system for rice (SES)*. 4th edition, International Rice Research Institute, Philippines. Retrieved from http://www.knowledgebank.irri.org/images/docs/rice-standard-evaluation-system.pdf

Analytical Software. (2006). Statistix 8 user guide, version 1.0. Analytical Software, PO Box 12185, Tallahassee FL 32317 USA. Copyright © 2006 by Analytical Software.

Asghar, M., Afzal, M., Baig, M. M. Q., Arshad, M., Sabir, A. M., & Hussain, M. (2015). Farmers' perceptions and beliefs regarding future of rice crop in the Kallar tract of the Punjab, Pakistan. *International Journal of Agriculture Innovations and Research*, *3*(6), 2319-1473.

Asghar, M., Arshad, M., Fiaz, M. M., Suhail, A., & Sabir, A. M. (2013). A survey of rice farmers' farming practices posing threats to insect biodiversity of rice crop in the Punjab, Pakistan. *International Journal of Biodiversity and Conservation*, *5*(10), 647-654.

Asghar, M., Chauhdary, S. U., Afzal, M., Baig, M. M. Q., Waqar, M. Q., Gafoor, A., & Haider, S. Z. (2017). Evaluation of the effectiveness of different herbicides against a new weed Japanese brome (*Bromus japonicus* Houtt.) in wheat crop. *Azarian Journal of Agriculture*, *4*(3), 74-79

Azher, M., Yasin, S. I., Mahmood, S., Hannan, A., & Akhtar, M. (2013). Field evaluation of new fungicides against rice (*Oryza sativa*) diseases. *Pakistan Journal of Phytopathology*, *25*(2), 141-145.

Chand, T., Sing, N., Sing, H., & Thind, B. S. (1979). Field efficacy of stable bleaching powder to control bacterial blight of rice in rice. *International Rice Research Newsletters*, *4*(4), 12-13.

Chaudhary, R. C. (1996). Internationalization of elite germplasm for farmers: Collaborative mechanisms to enhance evaluation of rice genetic resources. In, *New Approaches for Improved Use of Plant Genetic Resources*, *4*, 221-243

Chauhan, H. L. (1973). Studies on bacterial leaf blight of paddy (*Oryza sativa* L.) caused by *Xanthomonas oryzae* (Uyeda & Ishiyama) Dowson. M.Sc. (Agri.) Thesis submitted to G.A.U., S.K. Nagar.

Chen, Y., Yang, X., Gu, C.Y., Zhang, A. F., Zhang, Y., Wang, W.X., Gao, T.C., Yao, J., & Yuan, S.K. (2015). Activity of a novel bactericide, zinc thiazole against *Xanthomonas oryzae* pv. oryzae in Anhui Province of China. *Annals of Applied Biology*, *166*, 129-135.

Egel, D. (2017). 10 useful rules for fungicide application. https://vegcropshotline.org/article/10-useful-rules-for-fungicide-application/. Accessed 22 Oct 2021.

Gnanamanickam, S. S., Priyadarisini, V. B., Narayanan, V., Vasudevan, P., & Kavitha, S. (1999). An overview of bacterial blight disease of rice and strategies for its management. Centre for advanced studies in botany, University of Madras, Guindy campus, Chennai, India. *Current Science*, *77*(11), 1435-1444.

Ishiyama, S. (1922). Studies of bacterial leaf blight of rice. *Report of Agricultural Experiment Station*, *45*, 233-261.

Khan, J. A., Jamil, F. F., & Gill, M. A. (2000). Screening of rice varieties/lines against bakanae and bacterial leaf blight (BLB). *Pakistan Journal of Phytopathology*, *12*(1), 6-11.

Khan, M. A. (2013). Annual Report of UAF Component of Project No 49. Control of bacterial leaf blight on rice through management and resistant varieties. http://uaf.edu.pk/uaf_research/prj_59.html. Accessed 17 Oct 2021.

Khan, T. Z., Yasin, S., Ayub, M., Shah, J. A., & Ahmad, M. (2005). Effect of different chemicals and antibiotics on bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*) of rice. *Mycopathology*, *3*(1&2), 57-59.

Mew, T. W., & Majid, A. (1977). Bacterial blight of rice in Pakistan. IRRN, *2*(1), 5.

Mew, T. W. (1987). Current status and future prospects of research on bacterial blight of rice. *Annual Review of Phytopathology*, *25*, 359-382.

Nasir, M., Iqbal, B., Hussain, M., Mustafa, A., & Ayub, M. (2019). Chemical management of bacterial leaf blight disease in rice. *Journal of Agricultural Research*, *57*(2), 93-98.

Patil, B., Jagadeesh, G. B., Karegowda, C., Naik, S., & Revathi, R. M. (2017). Management of bacterial leaf blight of rice caused by *Xanthomonas oryzae* pv. *oryzae* under field condition. Journal 0f Pharmacognosy and Phytochemistery, *6*(6), 244-246.

Qudsia, H., Akhter, M., Riaz, A., Haider, Z., & Mahmood, A. (2017). Comparative efficacy of different chemical treatments for paddy blast, brown leaf spot and bacterial leaf blight diseases in rice (*Oryza Sativa* L.). *Applied Microbiology*, *3*(3), 138. doi:10.4172/2471-9315.1000138.

Shahbandeh, M. (2021a). World rice acreage 2010-2019. https://www.statista.com/statistics/271969/world-rice-acreage-since-2008/. Accessed 18 Apr 2021.

Shahbandeh, M. (2021b). Rice-Statistics & Facts. https://www.statista.com/topics/1443/rice/. Accessed 18 Apr 2021.

Shahbaz, M., Ahmad, F., Muhammad, S., Javed, M. A., Waqar, M. Q., & Ali, M. A. (2016). Efficacy of different chemicals for the management of bacterial leaf light of rice (*Oryza sativa* L.) at various locations of adaptive research zone Sheikhupura. *Pakistan Journal of Phytopathology*, *28*(2), 223-230.

Sharma, P. N. (2011). Measurement of disease. http://www.hillagric.ac.in/edu/coa/ppath/lect/plpath111/Lect.%209.%20Pl%20Path%20111-20MEASUREMENT%20OF%20DI SEASE.pdf. Accessed 11 Sep 2021.

Shekhar, S., Kumar, A. (2020). Field evaluation of different chemicals against Bacterial leaf blight disease of rice caused by *Xanthomonas oryzae* pv. *oryzae*. *Journal of Pharmacognosy and Phytochemistry*, *9*(2), 707-712.

Singh, R., Das, B. K., Ahmed, K., & Pal, V. K. (1980). Chemical control of bacterial leaf blight of rice. *International Journal of Pest Management*, *26*, 21-25.

Singh, S. A., & Gupta, P. K. S. (1982). Efficacy of some fungicides against leaf scald disease of rice. *Tropical Pest Management*, *28*(4), 412-415.

Steel, R. D., Torrie, J. H., Dicky, D. A. (1997). Principles and procedures of statistics. A biometrical approach 3rd ed. McGraw Hill Book international Co., Singapur. 1997; pp.204-207.

Suhail, A., Asghar, M., & Arshad, M. (2007). Insect faunal biodiversity associated with rice in Pakistan, with particular reference to rice black bug. In: Ravindra, C.J., T.B. Alberto and S.S. Leocadio (eds.). Rice black bugs taxonomy, ecology, and management of invasive species. Philippine Rice Research Institute (PhilRice), pp.643-652.

Swings, J., Mooter, M. V. D., Vauterin, L., Hoste, B., Gillis, M., Mew, T. W., & Kersters, K. (1990). Reclassification of the causal agents of bacterial blight (*Xanthomonas campestris* pv. *oryzae*) and bacterial leaf streak (*Xanthomonas campestris* pv. *oryzicola*) of rice as pathovars of *Xanthomonas orzae* (ex Ishiyama 1922) sp. nov., nom. rev. *International Journal of Systematic Bacteriology*, *40*(3), 309-311.

Xu, Y., Zhu, X. F., Zhou, M. G., Kuang, J., Zhang, Y., Shang, Y., & Wang, J. X. (2010). Status of streptomycin resistance in *Xanthomonas oryzae* pv. *oryzae* and *Xanthomonas oryzae* pv. *oryzicola* in China and their resistance characters. *Journal of Phytopathology*, *158*(9), 601-608.