Journal of Plant Sciences and Crop Protection
Volume 3 | Issue 1
ISSN: 2639-3336

Research Article Open Access

Efficacy of Chemical and Organic Fungicides against Spot Blotch Management of Wheat

Gupt SK*[1], Basnet R[1], Pant KJ[1], Wagle P[2] and Bhatta M[3]

[1]National Wheat Research Program, Bhairahawa, Nepal Agricultural Research Council, Nepal
[2]National Oilseed Research Program, Nawalpur, Sarlahi, Nepal Agricultural Research Council, Nepal
[3]Department of Agronomy, University of Wisconsin-Madison, Madison, WI 53706, USA

***Corresponding author:** Gupt SK, National Wheat Research Program, Bhairahawa, Nepal Agricultural Research Council, Nepal, Tel: +9779867534411, E-mail: shivaratnagupt@gmail.com

Citation: Gupt SK, Basnet R, Pant KJ, Wagle P, Bhatta M (2020) Efficacy of Chemical and Organic Fungicides against Spot Blotch Management of Wheat. J Plant Sci Crop Protec 3(1): 101

Received Date: February 15, 2020 **Accepted Date:** December 19, 2020 **Published Date:** December 22, 2020

Abstract

Spot blotch of wheat caused by *Bipolaris sorokiniana* is a problematic biotic constraint that causes 15-80% yield abatement in the Indian subcontinent and other parts of the world. The most effective means of managing crop diseases is to develop resistant varieties against crop diseases. In spite of enormous effort to forage resistant varieties or donor parents to develop resistant varieties against spot blotch, variety with satisfactory resistance level has yet to be identified. To manage spot blotch, at favorable environmental conditions for this disease, we evaluated four chemical fungicides *viz.* Tilt (Propiconazole 25 EC) @ 1.5 mL/L, Amistar (Azoxystrobin 23 SC) @ 1.5mL/L, Kasugamycin and Diathane M-45 @ 2g/L and two organic fungicides *viz.* Chadani and Flute @ 3g/L. These fungicides were sprayed on eleven commercial wheat varieties and one check variety *i.e.* sonalika and evaluated for two consecutive years. Statistical analysis indicated that Tilt and Chadani significantly reduced the average disease severity (AUDPC) from 485 to 294 (Tilt) and 297 (Chadani), was found effective among others. Furthermore, Tilt and Chadani significantly increased the average fifty spikes yield 97.7g and 95.8g respectively over control 87g.

Keywords: Chemical Fungicides; Organic Fungicides; Spot Blotch; AUDPC; Grain Yield; Management; Wheat

Abbreviations: AUDPC: Area Under Disease Progress Curve; TKW: Thousand Kernel Weight; 50 SY: Fifty Spikes Yield; YPS: Yield Per Spike, PE: Peduncle Extrusion, SL: Spike Length, PH: Plant Height, DH: Days to Heading; DM: Days to Maturity

Introduction

Wheat is one of the major cereals, which is largely produced and consumed and imparts about 20% of total energy and protein to world population [1]. Spot blotch [incited by *Cochliobolus sativus* (Ito & Kurib) Drechslera ex Dastur; *Biploaris sorokiniana* Sacc.] is one of the major diseases of wheat. It affects around 23% (9 million ha) of wheat producing areas of South East Asia including countries like India, Bangladesh, and Nepal [2]. Grain yield loss due to spot blotch ranged between 15 to 25% [3] whereas under severe epidemic condition it may reach up to 80% [4]. Due to lack of resistant wheat genotypes, spot blotch occurs in the warmer region of Nepal in moderate to severe intensity and causes an average yield loss 23-40% [5]. Around 23% of wheat areas featuring warmer region in South East Asia endure biotic stress i.e. spot blotch and abiotic stress i.e. heat stress, which are the major constraints for wheat production [6]. This disease circumvents when there is intermittent rainfall and temperature > 26 °C and requires effective control measure for wheat production [7]. Combined effect of spot blotch and heat stress at crucial stage of wheat crop *i.e.* grain filling stage causes remarkable yield abatement and threaten the livelihood of millions of wheat farmers [3,8]. Heat stress, intermittent rainfall, dew deposition of leaves during the period of anthesis to grain filling stage accelerate the spot blotch severity and has been predicted to increase in future [7,9,10]. Due to lack of adequate resistant variety against this disease, judicial way of chemical control measures for spot blotch is necessary to increase yield of staple crop i.e. wheat to ensure food security [7].

Genetic resistance is one of most effective method of controlling diseases therefore; researchers have made tremendous efforts in identifying spot blotch resistance genetic resources [11]. For instance, resistance cultivars such as BH1146, Yangmai 6, Ning 8201, and Chirya 3 have been successfully used as donor parents in many breeding programs to develop desirable resistant cultivars [9,12]. Furthermore, some major QTLs such as *Sb1, Sb2 Sb3 and 5AL* have been identified [13-16]. Despite several efforts, wheat cultivars grown in South East Asia regions still have limited genetic resistance against spot blotch [2,6,17]. This further gets complicated with the chances of evolving new races of pathogen [18-20].

Several management strategies such as crop rotation, planting time, and chemical control have been adopted for mitigating the disease response. Among these, use of chemical fungicide is on of the most common approach [7,21,22]. The chemical fungicides belongings to strobilurins, triazoles and dithiocarbamates are most efficient to manage crop diseases [19,23-25]. The strobilurin and triazole fungicides have antioxidant properties with different mode of action, economical and safe to environment [7,24,26,27]. Furthermore even alternative to chemical fungicides, many researchers have studied the effect of different formulation of plant extract and organic fungicides to protect crop diseases [28,29]. Plant extract from different species has been used to control spot blotch of wheat [30,31]. Plant extracts used as fungicide contain secondary metabolites which encourage lignification in host cell wall, reduce penetration of pathogen and enhance wound healing in hosts [32].

The first objective of this study was to evaluate the efficiency of the modern chemical and organic fungicides to reduce spot blotch severity at epiphytotic environmental conditions. The second objective was to study the effect of modern chemical and organic fungicides on traits associated with spot blotch of wheat and wheat yield.

Materials and Methods

Plant Materials

Twelve bread wheat genotypes comprising eleven commercial cultivars of *viz.* Bhrikuti (CMT/COC75/3/PLO//FURY/ANA75), Gautam (SIDDHARTHA/NING8319/NL297), Aditya (GS348/NL746//NL748), NL-971 (MRNG/BUC//BLO/PVN/3/PJB81), Vijaya (NL748/NL837+UG99Resistant), Tilottama (WAXING*2/VIVITSI+UG99Resisitant), Danphe (KIRITATI//2*PBW65/2*SERI-1B+UG99 Resistant), Banganga (XIA-984-10 YAAS KUNMING/BL1868), Sworgdwari (XIA-984-10 YAAS KUNMING/BL1868), Wk-1204 (SW89-3064/STAR "S"), 'Dhaulagiri (BL1961/NL867) and a susceptible check cultivar Sonalika/RR 21(1154-388/AN/3/YT54/NIOB/RL64) were collected from National Wheat Research Program, Bhairahawa , Nepal. These cultivars are commercially grown in Terai region of Nepal viz. 'Bhrikuti', 'Gautam', 'Aditya', 'NL-971', 'Vijaya', 'Tilottama', 'Banganga', 'Sonalika' (RR 21) and hill region of Nepal *viz*. 'Sworgdwari', 'Wk-1204', 'Dhaulagiri' and 'Danphe' . These wheat cultivars were released and recommended by National Wheat Research Program, Bhairahawa, Nepal. Two years (2016-17 and 2017-18) field experiments were conducted at the experimental field at latitude 27^0 32' and longitude 83^0 28' of Plant pathology unit of the National Wheat Research Program, Bhairahawa, Nepal.

Experimental Setup

The field was fertilized with N:P:K @ 120:60:40 Kg/ha where half dose of nitrogen as applied at basal dose and the reminder at active tillering (GS 35 to 39) stage. Twenty-one strips were made, each strip consisting twelve plots of 2m length ×1m width with 50 cm plot to plot and strip to strip distance. Twelve bread wheat genotypes were sown in a strip in a randomized complete block design with three replicates for six treatments (four chemical fungicides and two organic fungicides) and one control. Each bread wheat genotype was sown in a single plot of a strip. Sowing was accomplished in second week of December so that post-anthesis stage is subjected to warm and humid temperature conducive for spot blotch development. Each plot had four 2m rows at 25cm apart. Each bread wheat genotype was sown in a single plot of a strip in continuous seed sowing method in rod rows at seeding rate of 120 Kg/ha. A weedicide, Pendimethalin 30 EC, manufactured by Hindustan Agrochemicals, Ahmedabad, Gujarat was sprayed @ 2 ml/L one day after sowing to inhibit weed germination followed by manual weeding at 30 days after sowing. An insecticide, Rogor (Dimethoate 30 EC) manufactured by Plant remedies Pvt. Ltd, India was applied twice @ 1 ml/L at the active tillering stage and booting stage to control insect infestation. Three irrigations were supplied, first at CRI stage (21 days after sowing, DAS) second at booting stage (GS 45) and third at milking stage (GS 73).

Pathogen and Inoculation

The wheat leaves with spot blotch symptoms were collected from wheat field at the National Wheat Research Program, Bhairahawa, Nepal. The fungus *B. sorokiniana* was isolated from collected infected wheat leaves and pure culture was maintained on 2% potato dextrose agar (PDA). Large numbers of spores were generated by inoculating 5 mm mycelium plugs on processed sorghum grains as described by Chand *et al.* 2013 [33]. Inoculated sorghum grains were kept in BOD incubator (FAITHFUL SPX-150B III) at 25±2 ^{o}C for 15 days to accelerate substantial sporulation. The sporulated sorghum grains were filtered with muslin cloth in distilled water to harvest spores of *B. sorokiniana* and to prepare aqueous solution which was adjusted to spore density 104 mL^{-1}. The experimental wheat field was uniformly inoculated twice at the evening time with spore's suspension when wheat crop had reached booting stage GS 45 and at complete heading stage GS 59 [34].

Chemical and Organic Fungicide Treatments

The efficacy of four chemical fungicides viz. Tilt (Propiconazole 25 EC), Amistar (Azoxystrobin 23 SC), Kasugamycin 50% WP, and DM-45 75% WP; and two organic fungicides viz. Flute 50% W/W and Chadani were evaluated against spot blotch of wheat. These organic fungicides has not been studied for spot blotch management yet. Both chemical and organic fungicides were applied twice: first at heading stage i.e. GS 55 (seven days after inoculation) and second at anthesis stage i.e. GS 69 (seven days after inoculation). The chemical fungicides Tilt and Amistar were sprayed @ 1.5 mL/L whereas Kasugamycin and DM-45 were sprayed @ 2 g/L water. The organic fungicides viz. Flute and Chadani were applied @ 3 g/L water. Flute consist vegetable extract 18%, biological activator 1% and organic matter 31% (Coinage exim Pvt. Ltd Devachi, Uruli, Pune, India) whereas Chadani consists natural alkaloid and organic catalysts to activate plant enzyme system (Grace Bio-care PVT. LTD. Vadodara, Gujrat). Each chemical and organic fungicide was treated in three replicates in a randomized fashion comprising 18 strip plots (fungicide treated) and 3 strip plots were used as control out of total 21 strip plots.

Assessment of Agronomical and Physiological Traits

Ten plants of similar growth stages were selected for each genotype, per plot, per strip and were tagged with black wool and used for assessment of agronomical and physiological traits. Agronomical and physiological traits viz. days to heading, days to maturity, peduncle length, spike length, plant height were recorded, averaged and analyzed. Furthermore, thousand grain weight (TKW), fifty spike weight per plot, average weight per spike were also assessed and analyzed. Days to heading was recorded by counting the number of days between day of sowing to days at which ear emerged in 50% plants of a plot [35]. Plant height was assessed by measuring the height of tagged plants from base to tip of spike excluding awn at GS 87 [34] whereas days to maturity were recorded by counting the number of days from day of sowing to day until the grains become completely hard [35]. Spike length of tagged plants was measured from the base of the first spikelet to tip of top spikelet excluding awn [36]. Peduncle length of tagged plants was measured from the auricle of flag leaves to base of lowest spikelet of a spike. Thousand unbroken wheat grains per genotype per plot per strip were randomly counted and weighed. Similarly fifty spikes per genotype per plot per strip were randomly selected, harvested, threshed, cleaned and weighed. The average weight per spike was assessed by dividing the weight of fifty spikes by 50 of each genotype of each plot for each strip.

Disease Scoring

The disease was recorded thrice, first at GS 55 (50% heading) one day prior to first spray of fungicides, second at GS 69 (anthesis completed) one day prior to second spay of fungicides and third at GS 77 i.e. late milk stage [34]. The disease was scored on double-digit scale i.e. 00-99 basis [37]. The first digit (D1) of a score indicates vertical progress of disease on plants from ground whereas second digit (D2) indicates diseased area of leaves. The percentage of each score was computed using the formula:

% Severity = D1/9*D2/9*100

Progress of the disease *i.e.* AUDPC was computed by using the percent severity of corresponding disease rating in the formula [38]:

$$AUDPC = \sum_{i=1}^{n} [\{(Y_i + Y_{i+1}) / 2\} * (t_{i+1} - t_i)]$$

Where Y_i = disease level at time t_i
($t_{i+1} - t_i$) = days between two disease scores
n = number of readings.

Statistical Analysis

Analysis of variance, combined over the year was estimated using the PROC MIXED in SAS v9.4 (SAS Institute, 2018). The phenotypic correlation was calculated in R (R Development Core Team), broad-sense heritability was calculated by using the formula $H^2 = \sigma_g^2 / (\sigma_g^2 + \sigma_{g*y}^2 / y + \sigma_e^2 / ry$ for multiple years; in which stands for genetic variance, σ_{g*y}^2 for genotype-by-year interaction, σ_e^2 for error variance, y for the number of years, and r for the number of replications.

Results

ANOVA

Analysis of variance tested over two years for traits *viz.* AUDPC, TKW, 50 SY, PE, YPS, PH, SL, DH, and DM revealed significant genetic and genotype variance except for peduncle extrusion and plant height as shown in Table 1. Variance in traits considering year and genotype interaction showed significant variation for all traits under this study as shown in Table 1. Similarly analysis of variance in traits due to effect of fungicides assessed in this experiment indicated significant variation except PE, PH, SL, DH, and DM analyzed for two years as shown in Table 1. Moreover the variance due to the effect of year and fungicides on traits showed significant variation except PE, DH, and DM. Furthermore the variance of traits such as AUDPC, TKW and SL showed significant variation due to interaction of genotypes and fungicides sprayed in this experiment as shown in Table 1. However only variance of AUDPC was significant due to interaction of year*genotypes*fungicides out of nine traits studied as shown in Table 1. Individual year analysis of variance for traits revealed that genotypes were significant for all traits under study in the first growing season as shown in Table 2. The variance on traits *viz.* AUDPC, TKW, 50 SY, YPS, and PH were significant due to effect of fungicides as shown in Table 2. However due to interaction of genotypes* fungicides variance for AUDPC, TKW and PH were significant as shown in Table 2. In second growing seasons analysis of variance resulted that genotypes were significant only for AUDPC, TKW, 50 SY, YPS, SL, and DM whereas not significant for PE, PH, and DH as shown in Table 3. The variance of AUDPC, TKW, and Sl was significant due to effect of fungicides in second growing season as shown in Table 3. The traits AUDPC and SL showed significant variation due to interaction of genotypes*fungicides in second year of study as shown in Table 3. Analysis of variance either for both year or for individual year indicated that the effect of fungicides over AUDPC is significantly different.

Source	DF	AUDPC		TKW		50 SY		PE		YPS		PH		SL		DH		DM	
		Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value
Year	1	5758904	0.0001	400	0.018	5174.40	0.0466	**an**	0.0686	2.07	0.0457	920.97	0.1446	54.28	0.0003	1817.16	<.0001	196.87	<.0001
Error a= rep (year)	4	28524	<.0001	26.68	0.025	638.52	0.0008	**±S**	<.0001	0.25	0.0009	281.20	<.0001	0.42	0.9037	1.08	0.8804	0.006	0.5601
Genotype	11	428489	<.0001	12666.05	<.0001	6473.28	<.0001	**EM**	<.0001	2.6	<.0001	571.51	<.0001	15.18	<.0001	73.87	<.0001	74.97	<.0001
Year* Genotype	11	116925	<.0001	88.05	<.0001	590.81	<.0001	117.8	<.0001	0.23	<.0001	368.95	<.0001	11.21	<.0001	71.7	<.0001	40.33	<.0001
Fungicide	6	312896	<.0001	393.22	<.0001	1039	<.0001	11.6	0.2544	0.4	<.0001	77.92	0.0547	2.82	0.1137	0.6	0.9865	0.005	0.745
Year* Fungicide	6	63594	<.0001	133.05	<.0001	447.9	0.0028	11.6	0.2544	0.17	0.0029	166.80	0.0002	6.34	0.0009	0.6	0.9865	0.005	0.745
Genotype* Fungicide	66	8860	<.0001	17.65	0.0002	110	0.8095	6.85	0.9047	0.04	0.8186	48.86	0.0687	3.75	<.0001	3.37	0.6589	0.008	0.4121
Year* Genotype* Fungicide	66	6595	0.0061	12.42	0.0643	107	0.845	6.85	0.9047	0.04	0.8464	42	0.2547	2.90	0.0006	3.371	0.6589	0.008	0.4121
Error b=Residual	332	4213		9.44		131.58		8.94		0.05		37.39		1.63		3.67		0.008	
Broad sense heritability		0.64		0.86		0.8		0		0.8		0.25		0.14		0.02		0.46	

**P<0.0001*, AUDPC: Area under Disease Progress Curve, TKW: Thousand Kernel Weight, 50 SY: Fifty Spikes Yield, YPS: Yield Per Spike, PE: Peduncle Extrusion, SL: Spike Length, PH: Plant Height, DH: Days to Heading, DM: Days to Maturity

Table 1: Analysis of variance for traits in response to different fungicides applied against spot blotch in wheat genotypes across two growing seasons

Source	DF	AUDPC		TKW		50 SY		PE		YPS		PH		SL		DH		DM	
		Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value	Mean±SEM	P Value
Replication	2	7997	0.2375	16.33	0.0869	145.17	0.2038	67.6	<.0001	0.05	0.2031	103.44	0.0128	0.48	0.7851	0	1	0	1
Genotypes	11	478744	<.0001	678.8	<.0001	4796.07	<.0001	209.6	<.0001	1.91	<.0001	853.91	<.0001	22.22	<.0001	137.45	<.0001	104.8	<.0001
Fungicide	6	318681	<.0001	437.07	<.0001	1371.65	<.0001	**0**	1	0.54	<.0001	182.51	<.0001	1.52	0.6069	0	1	0	1
Genotype*Fungicide	66	11222	0.0001	15.88	<.0001	88.06	0.5386	0	1	0.03	0.5416	39.78	0.0029	2	0.5142	0	1	0	1
Residual	166	5514		6.58		90.4		3.2		0.04		23.11		2		0		0	

**P<0.0001*, AUDPC: Area under Disease Progress Curve, TKW: Thousand Kernel Weight, 50 SY: Fifty Spikes Yield, YPS: Yield Per Spike, PE: Peduncle Extrusion, SL: Spike Length, PH: Plant Height, DH: Days to Heading, DM: Days to Maturity

Table 2: Analysis of variance for traits in response to different fungicides applied against spot blotch in wheat genotypes for the first growing season

Source	DF	AUDPC		TKW		50 SY		PE		YPS		PH		SL		DH		DM	
		Mean ±SEM	P Value	Mean ±SEM	P Value	Mean ±SEM	P Value	Mean ±SEM	P Value	Mean ±SEM	P Value	Mean ±SEM	P Value	Mean ±SEM	P Value	Mean ±SEM	P Value	Mean ±SEM	P Value
Replication	2	49051	<.0001	37.04	0.052	1131.86	0.0018	61.09	0.0173	0.44	0.002	458.96	0.0002	0.36	0.7506	2.17	0.744	0.01	0.475
Genotypes	11	66670	<.0001	675.3	<.0001	2268.04	<.0001	9.83	0.766	0.91	<.0001	86.55	0.083	4.16	0.004	8.11	0.3618	10.47	<.0001
Fungicide	6	57809	<.0001	89.2	<.0001	115.27	0.6762	**23.33**	0.1536	0.05	0.6755	62.21	0.3067	7.65	<.0001	1.2	0.9863	0.01	0.7447
Genotype* Fungicide	66	4232.85	0.0296	14.2	0.2332	128.96	0.9126	13.7	0.6197	0.05	0.917	51.08	0.5105	4.67	<.0001	6.74	0.6518	0.016	0.4224
Residual	166	2912.5		12.3		172.76		14.7		0.07		51.67		1.25		7.35		0.015	

**P<0.0001*, AUDPC: Area under Disease Progress Curve, TKW: Thousand Kernel Weight, 50 SY: Fifty Spikes Yield, YPS: Yield per Spike, PE: Peduncle Extrusion, SL: Spike Length, PH: Plant Height, DH: Days to Heading, DM: Days to Maturity

Table 3: Analysis of variance for traits in response to different fungicides applied against spot blotch in wheat genotypes for the second growing season

Phenotypic Correlations among Traits

Correlation analysis revealed that AUDPC showed a strong negative correlation with TKW (-0.3), peduncle extrusion (-0.27), and significant correlation with 50 SY (-0.12), yield per spike (-0.12) but not significant with plant height (-0.06) at P<0.5 Table 4. Likewise, Correlation analysis revealed that AUDPC showed a strong negative correlation with TKW (-0.3), peduncle extrusion (-0.27), and significant correlation with 50 SY (-0.12), yield per spike (-0.12) but not significant with plant height (-0.06) at P<0.5 Table 4. Likewise, AUDPC showed strong positive correlation with days to heading (0.43) and days to maturity (0.21) and significant correlation with spike length (0.12) at P<0.05 Table 4. Similarly TKW showed strong positive correlation with 50 SY yield (0.38), yield per spike (0.38) and significant correlation with peduncle extrusion (0.09) at P<0.05 Table 4. Furthermore, TKW showed strong negative correlation with days to heading (-0.31), days to maturity (-0.32) and significant with spike length (-0.08) at P<0.05, but not significant with plant height (0.01) Table 4. Fifty spikes yield showed strong negative correlation with days to maturity (-0.23) but not significant with peduncle extrusion (0.02), plant height (0.04) and days to heading (0.04) at P<0.05) Table 4. Furthermore, 50 SY showed strong positive correlation with yield per spike (0.10) and spike length (0.17) Table 4. Moreover, peduncle extrusion showed strong negative and correlation with days to heading (-0.42) and days to maturity (-0.22) but strong positive with plant height (0.24) Table 4. Yield per spike showed strong negative correlation with days to maturity (-0.24) but strong positive with spike length (0.17) Table 4.

Traits	AUDPC	TKW	50 SY	PE	YPS	PH	SL	DH
TKW	-0.31**							
50 SY	-0.12*	0.38**						
PE	-0.27**	0.09*	-0.02					
YPS	-0.12*	0.38**	0.10**	-0.02				
PH	-0.06	-0.01	-0.04	0.24**	-0.04			
SL	0.12*	-0.08*	0.17**	-0.01	0.17**	0.04		
DH	0.43**	-0.31**	-0.04	-0.42**	-0.04	0.00004	0.05	
DM	0.21**	-0.32**	-0.23**	-0.22**	-0.24**	-0.17**	-0.06	0.40**

***P<0.0001* and *P<0.05 AUDPC: Area under Disease Progress Curve, TKW: Thousand Kernel Weight, 50 SY: Fifty Spikes Yield, YPS: Yield Per Spike, PE: Peduncle Extrusion, SL: Spike Length, PH: Plant Height, DH: Days to Heading, DM: Days to Maturity

Table 4: Phenotypic correlation among traits of wheat genotypes in response to various fungicides applied against spot blotch of wheat across two growing seasons.

Effects of Fungicides on Traits

Analysis of pairwise comparison of effects of fungicides on traits associated with spot blotch disease of wheat revealed that chemical fungicide *i.e*. Tilt (Propiconazole 25 EC) @ 1.5 ml/L and organic fungicide *i.e*. Chadani @ 3g/L were most effective and significant among other fungicides treated for reduction of AUDPC 293.86 and 297.22 respectively over control 493.8 in wheat genotypes (Table 5), (Figure 1, 2 and 3). Furthermore chemical fungicide *i.e*. Tilt (Propiconazole 25 EC) @ 1.5 ml/L and organic fungicide *i.e.* Chadani @ 3g/L significantly increased the 50 SY *i.e.* 97.74g and 95.81g respectively over control, and yield per spike *i.e.* 1.95g and 1.92g respectively over control 1.74 as well as compared to other fungicides treated. The effect of Tilt and Chadani on TKW was also good as compared to other fungicides treated. The fungicide Kasugamycin and Amistar ranked second in reducing AUDPC *i.e.* 335.47 and 329.74 respectively whereas DM-45 and Flute ranked third in reducing spot blotch severity *i.e.* AUDPC 384.16 and 379.25 respectively over control 483.8. The effect of Kasugamycin, Amistar, DM-45 and Flute on 50YS resulted 90.76g. 90.37g, 91.23 and 88.83g respectively over control 87g in wheat genotypes. Furthermore, the effect of Kasugamycin, Amistar, DM-45 and Flute on YPS resulted 1.91g, 1.8g, 1.82g and 1.77g respectively over control 1.74g in wheat genotypes under this study. Fungicides evaluated in this experiment didn't show significant superiority among them for PE, SL, PH, DH, and DM.

Traits	Tilt	Kasugamysin	Amistar	Chadani	Flute	DM-45	Control	LSD
AUDPC	293.86 (1)	335.47 (2)	329.74 (2)	297.22 (1)	379.25 (3)	384.16 (3)	483.8	21.52
TKW	46.24	43.72	45.9	45.2	43.78	45.65	39.49	1.00
50 SY	97.74 (1)	90.76 (2)	90.37 (2)	95.81 (1)	88.83 (2)	91.23 (2)	87	3.82
PE	17.15	17.16	17.7	17.18	17.63	17.67	18.25	0.97
YPS	1.95 (1)	1.91 (2)	1.8 (2)	1.92 (1)	1.77 (2)	1.82 (2)	1.74	0.076
SL	10.87	10.41	10.45	10.71	10.41	10.63	10.83	0.42
PH	88.34	85.62	86.15	86.89	85.62	87.03	88.03	2.05
DH	80.14	80.18	80	80.02	80.25	80.05	80.05	0.63
DM	114.79	114.79	114.79	114.77	114.80	114.79	114.79	0.03

() Parenthesis value represents the rank of respective traits corresponding to the fungicides

Table 5: Ranking based on T- test comparison of fungicides that affected traits associated with spot blotch disease of wheat genotypes, tested on two growing seasons

Figure 1: Effect of foliar spray of Tilt on the leaves of wheat genotypes against spot blotch A: Bhrikuti; B: Gautam; C: Gautam; D: NL-297; E: Vijaya; F: Tilottama; G: Danphe; H: Banganga; I: Sworgdwari; J: WK-1204; K: Dhaulagiri; L: RR-21

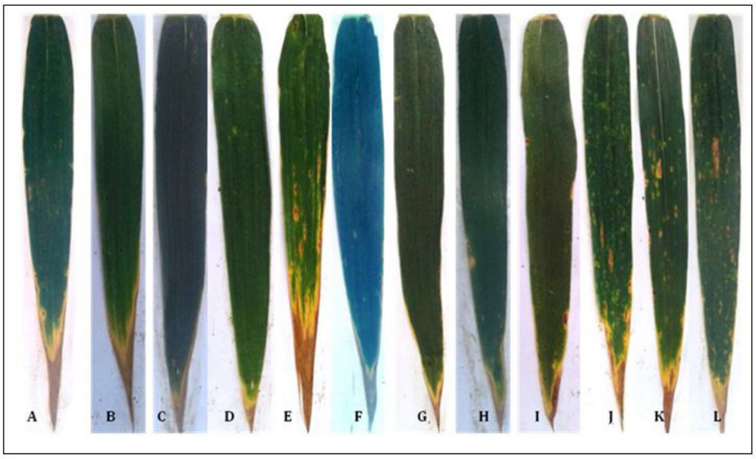

Figure 2: Effect of foliar spray of Chadani on the leaves of wheat genotypes against spot blotch A: Bhrikuti; B: Gautam; C: Gautam; D: NL-297; E: Vijaya; F: Tilottama; G: Danphe; H: Banganga; I: Sworgdwari; J: WK-1204; K: Dhaulagiri; L: RR-21

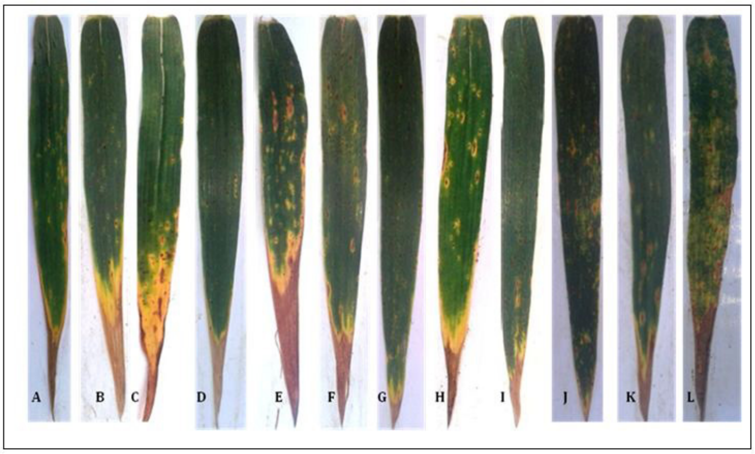

Figure 3: Spot blotch severity at GS 77 (milk dough stage) without spray of any fungicides on wheat genotypes A: Bhrikuti; B: Gautam; C: Gautam; D: NL-297; E: Vijaya; F: Tilottama; G: Danphe; H: Banganga; I: Sworgdwari; J: WK-1204; K: Dhaulagiri; L: RR-21

Discussion

Wheat crop cultivated in around 9 million hectares land of Eastern Gangetic Plains (EGP) of South Asia endure two major stress abiotic i.e. terminal heat stress and biotic *i.e.* spot blotch during its life cycle [17]. In Indian subcontinent including Nepal, wheat crop confronts with terminal heat stress and during the month of February, warm temperature and intermittent rains accelerate spot blotch severity causing additional stress [2]. It is necessity to evaluate foliar fungicides to reduce wheat yield losses caused by spot blotch at extremely favorable environment [7]. This experiment finds out that two foliar sprays first at heading stage (GS 55) and second at anthesis stage (GS 65) of chemical fungicides Tilt and organic fungicides Chadani is effective to reduce wheat yield losses caused by spot blotch under favorable environmental condition for this disease. A similar result for Tilt was found by Kalappanavar and Patil 1998 [43] and Yadav et al. 2015 [40]. Singh *et al.* 2016 [41] concluded his research findings that seed treated with vitavex and two sprays of Propiconazole 0.1% was best to reduce spot blotch severity and increased the wheat yield. The organic fungicide i.e. Chadani contains natural alkaloids and organic catalyst was effective to reduce the spot blotch severity. The natural alkaloids after absorbed by plants system activates the plant enzyme system and makes the plant healthy and enhance plant resistance mechanism to protect plant against broad group of fungi [42]. Naz *et al*. 2018 [30] also found plant extracts effective for reducing spot blotch of wheat. Alkaloids are secondary metabolites usually derived from plants and had basic nitrogen in a heterocyclic form e.g. pyrrole, quinolone, isoquinoline and indole [43]. These alkaloids affect the biological function at low concentration and many alkaloids have antimicrobial activity [44]. The effect of alkaloid e.g. allosecurinine on fungal spore germination of biotrophic and saprophytic fungi has been found by Singh *et al.* 2007 [45] and the effect of alkaloid ajoene (garlic extract) on fungal spore was found by Singh *et al.* 1990 [46]. Furthermore, two foliar sprays of Amistar (Azoxystrobin) at heading stage and booting stage were also found effective to reduce the spot blotch severity and increases wheat yield. Navathe *et al*. 2019 [7] also found that Amistar (Azoxystrobin) was effective for reducing spot blotch severity and increased the TKW, plot yield biomass, NDVI and delayed the senescence. Our research finding concluded that when there is warm temperature (>25 °C) and humidity >85% at heading to grain filling stage two spray of Propiconazole or Azoxystrobin @ 1.5 ml/L and Chadani (Containing natural alkaloids and organic catalyst) is effective to reduce the losses caused by spot blotch of wheat. We suggest users to apply these fungicides when the favorable environment prevails i.e. when there is an intermittent rains during heading to grain filling stage or high relative humidity and temperature is >25 °C.

Conclusion

This research concluded that chemical fungicide Tilt and organic fungicide Chadani (containing natural alkaloids and organic catalyst) reduce spot blotch severity and increase grain yield. These fungicides are found effective when environmental condition is favorable for spot blotch development at which condition wheat varieties are prone to this disease and losses yield. This research found that Tilt 25 EC @ 1.5 ml/L and Chadani @ when sprayed twice i.e. at GS 55(heading stage) and GS 65(anthesis stage) effectively reduce spot blotch severity and increase yield of wheat. The findings of this research will help wheat growers and small landholding farmers for managing spot blotch (devastating wheat disease) at favorable environmental conditions for the development of this disease. The findings of this research ultimately reduce the wheat yield losses caused by this disease and increase the net income of wheat growers.

Conflict of Interest

There is no conflict of interest.

Acknowledgement

We are thankful to the Nepal Agriculture Research Council of Nepal for providing fund to conduct this research experiment. Furthermore we are also thankful to National Wheat Research Program management for providing all kinds of support to accomplish this experiment.

References

1. Poudel R, Bhatta M (2017) Review of nutraceuticals and functional properties of whole wheat. J Nutr Food Sci 7: 571.

2. Joshi AK, Mishra B, Chatrath R, Ferrara GO, Singh RP (2007) Wheat improvement in India: present status, emerging challenges and future prospects. Euphytica 157: 431-46.

3. Dubin HJ, van Ginkel M (1991) The status of wheat diseases and disease research in warmer areas In: Wheat for the nontraditional warm areas: a proceedings of the International Conference, Foz do Iguaçu, Brazil.

4. Joshi AK, Chand R (2002) Variation and inheritance of leaf angle, and its association with spot blotch (Bipolaris sorokiniana) severity in wheat (Triticum aestivum). Euphytica 124: 283-91.

5. Sharma RC, Duveiller E (2006) Spot blotch continues to cause substantial grain yield reductions under resource-limited farming conditions. J Phytopathol 154: 482-8.

6. Singh PK, Zhang Y, He X, Singh RP, Chand R (2015) Development and characterization of the 4th CSISA-spot blotch nursery of bread wheat. Eur J Plant Pathol 143: 595-605.

7. Navathe S, Chand R, Mishra VK, Pandey SP, Kumar U, Joshi AK (2019) Management of Spot Blotch and Heat Stress in Spring Wheat through Azoxystrobin-Mediated Redox Balance. Agric Res 1-10.

8. Lobell DB, Sibley A, Ortiz-Monasterio JI (2012) Extreme heat effects on wheat senescence in India. Nat Clim Change 2: 186-9.

9. Gupta PK, Chand R, Vasistha NK, Pandey SP, Kumar U (2018) Spot blotch disease of wheat: the current status of research on genetics and breeding. Plant Pathol 67: 508-31.

10. Joshi AK, Ortiz-Ferrara G, Crossa J, Singh G, Sharma RC (2007) Combining superior agronomic performance and terminal heat tolerance with resistance to spot blotch (Bipolaris sorokiniana) of wheat in the warm humid Gangetic Plains of South Asia. Field crops Res 103: 53-61.

11. Singh PK, Mergoum M, Ali S, Adhikari TB, Elias EM, et al. (2006) Identification of new sources of resistance to tan spot, Stagonospora nodorum blotch, and Septoria tritici blotch of wheat. Crop Sci 46: 2047-53.

12. Mujeeb-Kazi A, Rosas V, Roldan S (1996) Conservation of the genetic variation of Triticum tauschii (Coss.) Schmalh. (Aegilops squarrosa auct. non L.) in synthetic hexaploid wheats (T. turgidum L. s. lat. x T. tauschii; 2n= 6x= 42, AABBDD) and its potential utilization for wheat improvement. Genet Resour and Crop Evol 43: 129-34.

13. Lillemo M, Joshi AK, Prasad R, Chand R, Singh RP (2013) QTL for spot blotch resistance in bread wheat line Saar co-locate to the biotrophic disease resistance loci Lr34 and Lr46. Theoretical and applied genetics 126: 711-9.

14. Kumar S, Röder MS, Tripathi SB, Kumar S, Chand R, et al. (2015) Mendelization and fine mapping of a bread wheat spot blotch disease resistance QTL. Mol Breed 35: 218.

15. Lu P, Liang Y, Li D, Wang Z, Li W, et al. (2016) Fine genetic mapping of spot blotch resistance gene Sb3 in wheat (Triticum aestivum). Theor Appl Genet 129: 577-89.

16. Singh P, He X, Sansaloni C, Juliana P, Dreisigacker S, et al. (2018) Resistance to Spot Blotch in Two Mapping Populations of Common Wheat Is Controlled by Multiple QTL of Minor Effects. International journal of molecular sciences 19: 4054.

17. Kumar U, Joshi AK, Kumar S, Chand R, Röder MS (2010) Quantitative trait loci for resistance to spot blotch caused by Bipolaris sorokiniana in wheat (T. aestivum L.) lines 'Ning 8201'and 'Chirya 3'. Molecular Breeding 26: 477-91.

18. Bhatta M, Morgounov A, Belamkar V, Yorgancılar A, Baenziger PS (2018) Genome-wide association study reveals favorable alleles associated with common bunt resistance in synthetic hexaploid wheat. Euphytica 214: 200.

19. Bhatta M, Regassa T, Wegulo SN, Baenziger PS (2018) Foliar fungicide effects on disease severity, yield, and agronomic characteristics of modern winter wheat genotypes. Agron J 110: 602-10.

20. Bhatta M, Morgounov A, Belamkar V, Wegulo S N, Dababat AA, et al. (2019) Genome-wide association study for multiple biotic stress resistance in synthetic hexaploid wheat. Int J Mol Sci 20: 3667.

21. Dehne HW, Deising HB, Gisi U, Kuck KH, Russell PE, et al. (2008) Modern fungicides and antifungal compounds V: 15th International Reinhardsbrunn Symposium, Friedrichroda, Germany.

22. Thind TS (2011) Agricultural fungicides: present scenario and future needs. Plant Pathology in India: vision 2030: 206-11.

23. Lopez JA, Rojas K, Swart J (2015) The economics of foliar fungicide applications in winter wheat in Northeast Texas. Crop Protection 67: 35-42.

24. Zhang YJ, Zhang X, Chen CJ, Zhou MG, Wang HC (2010) Effects of fungicides JS399-19, azoxystrobin, tebuconazloe, and carbendazim on the physiological and biochemical indices and grain yield of winter wheat. Pesticide Biochemistry and Physiology 98: 151-7.

25. MacLean DE, Lobo JM, Coles K, Harding MW, May WE, et al (2018) Fungicide application at anthesis of wheat provides effective control of leaf spotting diseases in western Canada. Crop protection 112: 343-9.

26. Wu YX, von Tiedemann A (2002) Impact of fungicides on active oxygen species and antioxidant enzymes in spring barley (Hordeum vulgare L.) exposed to ozone. Environ Pollut 116: 37-47.

27. Li HX, Xiao CL (2008) Characterization of fludioxonil-resistant and pyrimethanil-resistant phenotypes of Penicillium expansum from apple. Phytopathology 98: 427-35.

28. Bdliya BS, Alkali G (2010) Efficacy of some plant extracts in the management of Cercospora leaf spot of groundnut in the Sudan Savanna of Nigeria. Archives of Phytopathology and Plant Protection 43: 507-18.

29. Koike ST, Gaskell M, Fouche C, Smith R, Michell J (2011) Plant disease management for organic crops. Publication 7252. University of California, USA.

30. Naz R, Nosheen A, Yasmin H, Bano A, Keyani R (2018) Botanical-chemical formulations enhanced yield and protection against Bipolaris sorokiniana in wheat by inducing the expression of pathogenesis-related proteins. PloS one, 13: 0196194.

31. Hossain MM, Hossain I, Khalequzzaman KM (2016) Biological control of leaf blight of wheat caused by Bipolaris sorokiniana. Bulletin of the Institute of Tropical Agriculture, Kyushu University 39: 43-51.

32. Soylu S (2008) Mechanisms of Disease Resistance in Plants against Phytopathogens. In: Biochemical Responses of Plants to Invaders, edn. Research Signpost, Kerala, India. 33-48.

33. Chand R, Yadav OP, Bashyal BM, Prasad LC, Joshi AK (2013) Technique for the maintenance of heterokaryotic isolates of Bipolaris sorokiniana. Indian Phytopathology 66: 61-5.

34. Zadoks JC, Chang TT, Konzak CF (1974) A decimal code for the growth stages of cereals. Weed res 14: 415-21.

35. Joshi AK, Chand R (2002) Variation and inheritance of leaf angle, and its association with spot blotch (Bipolaris sorokiniana) severity in wheat (Triticum aestivum). Euphytica 124: 283-91.

36. Ullah R, Mohammad Z, Khalil IH, Ullah A (2007) Heritability for heading, maturity, plant height, spike length and tillers production in winter wheat (Triticum aestivum L.). Pakistan J of Plant Sci 13: 65-72.

37. Saari EE, Prescott JM (1975) Scale for appraising the foliar intensity of wheat diseases. Plant Disease Report 59: 377-80.

38. Shaner G, Finney RE (1977) The effect of nitrogen fertilization on the expression of slow-mildewing resistance in Knox wheat. Phytopathology 67(8): 1051-6.

39. Kalappanavar IK, Patil NK (1997) Field evaluation of fungicides against leaf rust of wheat. Journal-Maharashtra Agricultural Universities 22: 335-335.

40. Yadav B, Singh R, Kumar A (2015) Management of spot blotch of wheat using Fungicides, Bio-agents and Botanicals. African Journal of Agricultural Research 10: 2494-500.

41. Singh CK, Singh C, Singh D, Singh RK, Chaudhary AK, et al. (2016) Effect of Chemicals and Bio-agent on Spot Blotch Disease of Wheat (Triticum aestivum L.). Int J of Bio-Re & Stress Management 7: p712-5.

42. Zhao Y, Wu Y, Wang M (2015) Bioactive Substances of Plant Origin 30. Handbook of food chem: 967-1008.

43. Achilonu MC, Umesiobi DO (2015). Bioactive phytochemicals: bioactivity, sources, preparations, and/or modifications via silver tetrafluoroborate mediation. J of Chem 2015: 22.

44. Singh UP, Sarma BK, Mishra PK, Ray AB (2000) Antifungal activity of venenatine, an indole alkaloid isolated from Alstonia venenata. Folia microbiol 45: 173-6.

45. Singh AK, Pandey MB, Singh UP (2007) Antifungal activity of an alkaloid allosecurinine against some fungi. Mycobiology 35: 62-4.

46. Singh UP, Pandey VN, Wagner KG, Singh KP (1990) Antifungal activity of ajoene, a constituent of garlic (Allium sativum). Canadian journal of botany 68: 1354-6.