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RESEARCH ARTICLE

EFFECT OF FUNGICIDE SPRAY SCHEDULE ON STEM RUST (*PUCCINIA GRAMINIS* F.SP.*TRITICI*) DEVELOPMENT AND GRAIN PHYSICAL QUALITY OF DURUM WHEAT IN ETHIOPIA

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ABSTRACT

Stem rust caused by *Puccinia graminis* f.sp. *tritici* is one of the major biotic constraints of wheat production. For controlling this pathogen fungicide application mandatory in Ethiopia but appropriate spray schedules is not well known and farmers were applying at least three times to control the stem rust disease. Hence the current research was designed with the objectives to evaluate the effect of fungicide spray schedule on stem rust development and grain physical quality of durum wheat. For this purpose, a factorial field experiment involving six durum wheat varieties (Denbi, Hitosa, Tob.66, Mukiye, Ude and Mengudo) with different level of resistance to stem rust, and three Tilt spray schedules of Tilt®250 E.C at 7, 14 and 21 days interval was conducted at Debre Zeit Agricultural Research Centre during the main and off seasons of 2016/17. The experiment was laid out in randomized complete block design with three replications and untreated checks were included for comparison purpose. Results revealed significant variations in disease parameters and crop performance among spray schedules, wheat varieties and their interactions. Stem rust severity was significantly reduced by the application of Tilt across all wheat varieties, and the highest decrease in disease level (8.9 and 15.2%) was achieved by Tilt sprays at seventh day interval during off and main seasons, respectively. By reducing the stem rust severity, it was possible to improve yield and grain physical quality of the produce. Current results demonstrate the need for effective and sustainable stem rust management to improve the grain physical quality of durum wheat in Ethiopia.

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INTRODUCTION

Wheat (*Triticum* spp.) is among the most important cereal crops in Ethiopia. Both bread and durum wheat is produced in Ethiopia. Eighty-one percent of the total land cultivated to grain crops in Ethiopia is covered by cereals out of which wheat accounts for 15.63% (CSA, 2016). Arsi and Bale highlands are regarded as highly suitable regions for wheat production in Ethiopia. Wheat is one of the major cereal crops grown in the Bale highlands of Ethiopia and this region is regarded as the largest wheat producer in Sub-Saharan Africa (Efrem *et al.,* 2000). Its density combined with its high protein content and gluten strength, amber color and superior cooking quality makes it the wheat of choice for producing pasta products.

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Nowadays, durum wheat is considered as potential crop by the government for food industry as import substitution and one means of income diversification for the farmers. With the increasing number of processing industries, the demand for durum wheat grains for pasta processing is growing in the country. In 2012 Ethiopia imported 472,147t of durum wheat, at a cost of 174.6 million dollars (Yetneberk, 2013). The same author also reported that 27 cooperatives and five unions in the districts of Agarfa, Goro, Ginir, Gololcha, Sinana and Dello Mena are the main beneficiaries and simultaneously actors of the economic growth and development endeavor in producing durum wheat for different pasta and macaroni factories. Hence, in spite of the large volume of local production, some processing industries prefer to import durum wheat grain for pasta production (Ayele *et al.,* 2009). Pasta producing firms in Ethiopia are about 10 in number (Yifru 2011). Ethiopian Revenue and Customs Authority indicated that in 2012 about 12,663.1 tons has been imported to the country.

In Ethiopia from time to time there is a problem of foliar diseases of bread and durum wheat that cause reduction in grain weight, grain size and yield. Particularly stem rust is the most important disease. Relationship between stripe rust (*Puccinia striiformis)* and grain quality of bread wheat has been studied in Ethiopia (Hailu *et al.,* 2007).For controlling this pathogen fungicide application is must in Ethiopia but appropriate spray schedules is not well known and farmers were applying at least three times to control the stem rust disease. However, there is still ample scope to study fungicide spray schedules with the interaction of durum wheat varietal response. Hence this study was initiated to evaluate the effect of fungicide spray schedule on stem rust development and physical quality of durum wheat.

MATERIALS AND METHODS

The experiment was carried out at Debre Zeit Agricultural Research Centre (DZARC) (8^o 44 'N, 39 ^{o} 02'E) during main (rain) and off-seasons (irrigation) of 2016/17. Debre Zeit is mid-highland (1900 m.a.s.l.) characterized by moderate rainfall (851mm total annual rainfall); average minimum temperature of 8.9^{o}C and mean maximum temperature of 28.3°C. The soil is characterized as pellic vertisol. Six durum wheat varieties were selected based on their response to stem rust:- Mukiye (MR), Mengudo (MS), Ude (MS), Denbi (S), Hitosa (S) and Tob-66 (MR). Tilt propiconazole (Tilt® 250 E.C.) applied at a rate of 0.5 l/ha at three different spray schedules. The first spray was made after the appearance of diseases symptoms on the hosts and when stem rust severity on the spreader rows reached 30%. Untreated plots were protected by plastic sheets during spraying of Tilt to minimize the Tilt drift. Treatments were arranged in randomized complete block design with three replications.

Each experimental plot was 2.5m long and 1.2m wide, with six rows each spaced 20cm apart, giving a plot area of 3m^2. The space between plots and blocks were 1m and 1.5m, respectively. Recommended seed rate and fertilizer were used for this experiment. Stem rust epidemic was initiated by inoculating spreader rows with the mixture of virulent stem rust races of TTKSK, JRCQC, TRTTF and TKTTF at equal proportions (0.6mg each). The spreader rows included Morocco, Digalu, Arendato and PBW343 and they were planted in a mixture of 25% each. Spreader was planted along the border of experimental plots (Jin *et al*., 2007) seven days before the test varieties were planted. A total of three inoculations were carried out to ensure enough disease pressure and inoculums source to the experimental field. The first two inoculations were done through injection at stem elongation growth stage (Zadoks *et al.,* 1974). Injection of the spreader rows was done at 0.5m intervals using 10ml syringe and 104 plants were inoculated for each single row spreader.
The stem rust severity scoring started when the infector rows attained about 30% susceptible responses based on modified Cobbs' scale; where 0% = immune and 100% = completely susceptible (Peterson *et al.,* 1948). Disease scoring started a week before the first spraying and continued for four times at 10 days interval.

The average coefficient of infection (ACI) for each variety was computed as follows.

$$\text{ACI} = \frac{\text{DS(\%)X Constant for response}}{\text{Total number of observations recorded}}$$

DS= Disease severity percentage

The AUDPC is calculated using the midpoint rule method (Campbell and Madden, 1990) as follows.

$$AUDPC = \sum_{i=1}^{n-1} (y_i + y_{i+1}) / 2 \times (t_{i+1} - t_i)$$

Where "y" is the percentage of affected tissue at each reading, "t" is time in days of each reading and "n" is the number of readings. The Area Under Disease Progress Curve (AUDPC) and terminal severity data was used to compare treatments.

$$\%\ \text{Ash} = \frac{\text{Weight of Residue}}{\text{Sample weight}} X\ 100$$

Data analysis

Data on terminal stem rust severity, AUDPC, average coefficient of infection, hectoliter weight, thousand kernel weight, grain protein content, grain gluten content, ash content, kernel size and yield were subjected to analysis of variance using GLM procedure of the System Analysis Software (SAS Institute, 2004).

RESULTS AND DISCUSSION

Terminal stem rust severity: During the main season, terminal stem rust severity on untreated plots was 63.3% on both susceptible varieties (Denbi and Hitosa), 30 to 66.7% on moderately susceptible varieties (Mengudo and Ude), and 14 to 26.8% on moderately resistant varieties (Mukiye and Tob-66) (Table 1). Terminal stem rust severity on treated plots during the main season varied between 16.7 and 20% on susceptible varieties, 4 and 30% on moderately susceptible varieties and 3 and 16.7 on moderately resistant varieties, suggesting a significant reduction in stem rust disease level as the result of fungicide sprays.During the off-season, terminal stem rust severity on untreated plots ranged from 26.7 to 30% on susceptible varieties, 18.3 to 25% on moderately susceptible varieties, and 10 to 13.3% on moderately resistant varieties and lower terminal stem rust were recorded on treated plots (Table 1).

The 7th day Tilt spray schedule was thus considered the most effective as it led to the lowest terminal stem rust severity (a mean value of 15.2 and 8.9% during the main and off-seasons, respectively) (Table 2). Stephen *et al.* (2009) also reported that application of Tilts effectively reduced disease severity. The highest mean values of terminal stem rust severity (46.2 and 20.6% during the main and off-season, respectively) were recorded on untreated plots.

Area under disease progress curve (AUDPC): During the main season, AUDPC values on untreated plots varied from 783 to 867 on susceptible varieties (Denbi and Hitosa), 200 to 992 on moderately susceptible varieties (Mengudo and Ude), and 150 to 450 on moderately resistant varieties (Tob-66 and Mukiye) (Table 1). AUDPC on treated plots ranged from 292 to 367 on susceptible varieties, 85 to 200 on moderately susceptible varieties and 47 to 267 on moderately resistant varieties. During the off-season, AUDPC on untreated plots ranged between 228 and 250 on susceptible varieties, 130 to 287 on moderately susceptible varieties, and 82 to 102 on moderately resistant varieties (Table 3).

Table 1. Terminal severity, average coefficient of infection, area under disease progress curve of different durum wheat varieties with different Tilt spray schedules

Varieties	Schedules	Main Season			Off-Season		
		Terminal severity	ACI	AUDPC	Terminal severity	ACI	AUDPC
	No spray	30	27.6	200	18.3	5.32	130
	7	5	3.9	65	7.3	1.95	46.7
Mengudo (MS)	14	4	9.2	58.3	8.2	3.07	80
	21	25	20.4	163.3	15	4.15	101.7
	No spray	66.7	143.3	991.7	25	13.05	286.7
	7	30	70.7	500	7.3	3.28	80
Ude(MS)	14	53.3	130.7	866.7	18.3	6.77	165
	21	60	138.7	933.3	18.3	8.02	181.7
	No spray	63.3	122.2	866.7	26.7	9.97	228.3
	7	20	49.5	366.7	12.3	5.82	135
Denbi (S)	14	50	120.8	808.3	20	7.43	173.3
	21	50	115.5	783.3	25.4	7.72	203.3
	No spray	14	11.7	150	13.3	4.15	86.7
	7	3.5	1.92	57.5	9.5	3.47	70
Mukiye (MR)	14	3.5	1.75	45.0	7.4	2.63	96.7
	21	8.3	10.8	125	11.3	3.9	101.7
Hitosa (S)	No spray	63.3	103.8	783.3	30	10.4	250
	7	16.7	40.7	291.7	8.3	3.88	86.6
	14	36.7	71.2	508.3	21.7	8.31	190
	21	56.7	95.5	716.7	26.7	8.73	215
Tob-66 (MR)	No spray	40	52.4	450	18	2.48	81.7
	7	26.7	48.9	358.3	6.6	2.27	68.3
	14	12.7	26	266.7	2.7	2.02	48.3
	21	36.7	78.8	558.3	16	2.64	68.3
Mean		32.3	62.3	455.4	15.6	5.47	132.29
CV (%)		25.2	20.1	27.8	52.7	26.12	24.47
LSD(0.05)		13.4	33.1	208.7	13.3	0.85	19.14

ACI=Average Coefficient of Infection; AUDPC=Area Under Disease Progress Curve; LSD (5%) =Least Significant Difference at P≤0.05

Table 2. Effect of Tilt spray schedules on stem rust disease parameters

	Main Season			Off-Season		
Schedules	Terminal severity	ACI	AUDPC	Terminal Severity	ACI	AUDPC
No spray	46.2	76.9	573.6	20.6	6.9	164.2
21	39.4	76.6	546.7	17.6	6.2	148.6
14	28.3	62.8	441.1	14	5.0	93.3
7	15.2	32.9	260.3	8.9	3.8	23.1
Mean	32.3	62.3	455.4	15.3	5.5	132.3
CV (%)	22.4	30.2	27.0	52.7	22.0	20.3
LSD (0.05)	4.9	12.8	83.7	4.8	1.9	43.2

A.C.I= Average Coefficient of Infection; AUDPC= Area Under Disease Progress Curve; CV= Coefficient of Variation %; LSD=Least Significant Difference at P≤0.05

Table 3. The effect of variety and Tilt spray schedules on yield and physical quality traits of durum wheat varieties during off and main seasons at Debre Zeit

Varieties	Schedule	Main season					Off-Season				
		Terminal severity (%)	Yield (t ha^{-1}).	HLW (Kg/hl)	TKW (g)	Seed Size (mm)	Terminal severity. (%)	Yield (t ha^{-1})	HLW (Kg/hl)	TKW (g)	Seed Size (mm)
Mengudo (MS)	No spray	30	5.7	73.0	43.5	3.2	18.3	5.0	72.1	54.2	3.2
	7	5	7.3	79.2	48.0	3.4	2.3	8.3	79.2	55	3.3
	14	4	6.3	79.2	46.6	3.3	4.2	7.3	78.7	55.5	3.4
	21	25	6.0	74.1	42.3	3.3	15	6.3	71.5	54.3	3.2
Ude (MS)	No spray	66.7	5.7	71.0	44.7	3.0	25	5.3	72.4	40.7	2.9
	7	30	7.0	77.1	51.7	3.4	7.3	7.7	79.1	52.3	3.2
	14	53.3	6.0	75.0	49.4	3.2	18.3	6.7	78.4	46.4	2.9
	21	60	5.3	72.3	46.0	3.1	18.3	6.0	74.5	43.9	2.8
Denbi (S)	No spray	63.3	4.7	72.0	36.4	2.9	26.7	6.3	72.5	35.7	2.7
	7	20	7.0	79.0	44.5	3.3	10.3	8.0	79.9	46.3	3.0
	14	50	6.0	79.1	41.4	3.1	20	7.7	78.3	40.0	2.8
	21	50	5.0	73.4	39.5	2.8	25.4	7.0	74.2	40.8	2.8
Mukiye (MR)	No spray	34	6.3	72.3	50.0	3.2	27.3	6.3	73.5	52.9	3.1
	7	3.5	7.0	75.7	52.4	3.3	9.5	7.3	78.9	53.2	3.2
	14	3.5	7.3	79.5	53	3.4	7.4	7.7	79.0	55.2	3.3
	21	25	6.3	73.1	52.	3.2	25.3	6.3	73.8	52.4	3.1
Hitosa(S)	No spray	63.3	4.7	73	38	2.9	23.3	5.3	73.6	37.7	2.8
	7	16.7	7.0	78.3	40.9	3.0	8.3	7.0	79.5	44.8	3.1
	14	36.7	6.7	77.7	38.8	2.8	21.7	7.0	79.7	40.5	3.0
	21	56.7	6.3	73.1	38.1	.9	26.7	5.7	73.7	41.4	2.9
Tob-66 (MR)	No spray	40	5.3	73.1	46.7	.0	18	5.7	72.6	49.7	3.1
	7	26.7	5.7	78.1	49.2	3.2	4.2	6.0	79.1	50.2	3.1
	14	16.7	6.0	79.1	50.0	.4	5.7	7.3	78.0	50.3	3.2
	21	36.7	5.3	74.0	45.9	.0	12	5.0	73.5	47.7	3.0
Mean		32.3	5.5	76.2	47.4	.1	15.6	6.0	75.3	44.2	3.1
CV%		52.7	16.5	1.5	5.5	.7	25.2	15.6	2.8	7.0	0.2
LSD(0.05)		13.3	1.5	3.8	5.5	0.03	13.4	0.55	1.3	1.8	0.01

HLW= Hectolitre Weight; TKW= Thousand Kernel Weight; g=gram; mm= millimetre; AUDPC= Area under disease progress curve; LSD = Least Significant Difference

Table 4. Effect of different spray schedules on yield and physical quality of durum wheat varieties during main and off-season at Debre Zeit in 2016/17

	Off-season					Main season				
Schedules	Terminal Severity	Yield (tha^{-1})	HLW	TKW	Seed size	Terminal severity	Yield (t/ha)	HLW	TKW	seed size
7	8.94	7.3	79.20	50.07	3.17	15.22	6.7	77.6	45.6	3.16
14	14	7.0	78.81	47.61	3.09	28.28	6.3	78.1	45.9	3.13
21	17.56	6.0	73.96	46.77	3.05	39.44	6.0	74.7	42.7	3.13
No spray	20.56	5.7	72.78	45.33	3.03	46.22	5.7	74.4	42.6	3.12
Mean	15.26	6.3	76.2	47.4	3.1	32.29	6.3	76.3	44.2	3.1
CV (%)	45.83	16.8	1.5	5.6	1.5	22.3	15.5	2.5	8.4	0.25
LSD (0.05)	4.76	0.7	0.8	1.8	0.1	4.92	0.6	1.3	2.5	0.1

HLW= Hectolitre Weight; TKW= Thousand Kernel Weight; LSD= Least Significant Different; CV= Coefficient of Variation

AUDPC on treated plots during the same season ranged from 87 to 135 on susceptible varieties, 47 to 80 on moderately susceptible varieties, and 48 to 70 moderately resistant varieties (Table 1). The lowest AUDPC was recorded at the 14th day Tilt spray schedule on moderately resistant varieties (Table 1). Taddese *et al. (*2010) also reported higher AUDPC values in untreated plots as compared to treated plots. The 7th day spray schedule was significantly different from other spray schedules having a mean value of area under disease progress curve (AUDPC) of 260 and 93 during main and off-seasons, respectively (Table 2). The highest mean value of area under disease progress curve (574 during the main) and (164 during the off-season) was recorded on untreated plots. According to the results of the current work, Tilt treatments at 7th and 14th days spray schedule were effective in markedly slowing down the progress of the disease. AUDPC is the result of all factors that influenced disease development such as environments, cultivars and population of the pathogen (Pandy *et al*., 1989).

Average coefficient of infection: Average coefficient of infection on untreated plots during the main season ranged from 103.8 to 122.2 on susceptible varieties (Denbi and Hitosa), 28 to 143.3 on moderately susceptible varieties (Mengudo and Ude), and 11.8 to 52.4 on moderately resistant varieties (Tob-66 and Mukiye) (Table 1). During the same season, average coefficient of infection on treated plots varied from 40.7 to 49.5 on susceptible varieties, 3.9 to 70.7 on moderately susceptible varieties and 1.8 to 26 on moderately resistant varieties. During the off-season, average coefficient of infection on untreated plots ranged between 9.9 and 10.4 on susceptible varieties, 5.3 to 13.1 on moderately susceptible varieties, and 2.5 and 4.2 on moderately resistant varieties (Table 1). Average coefficient of infection on treated plots during the same season ranged from 3.9 to 5.8 on susceptible varieties, 1.9 to 3.3 on moderately susceptible varieties, and 2.0 to 2.6 moderately resistant varieties (Table 1). The 7th day spray schedule was significantly different from other spray schedules having a mean value of average coefficient of infection 32.9 and 3.8 during main and off-season, respectively (Table 2). The highest mean value of average coefficient of infection was recorded for both seasons on untreated plots of durum wheat. The highest average coefficient of infection was calculated for untreated plots during the main and off-season with the mean values of 76.9 and 6.9, respectively. The highest average coefficient of infection were calculated on varieties Ude followed by Denbi (Table 1). While it was the lowest on variety Mukiye (11.8) during main season.

Yield and physical quality parameters: The Tilt sprays created significantly different levels of terminal stem rust severity across the durum wheat varieties that enabled to assess the effects of stem rust disease on durum wheat grain quality during both seasons. The physical characteristics of durum wheat, such as test weight, thousand kernel weight and kernel size have been known to influence the milling performance of durum wheat and also pasta quality directly or indirectly (Aalami *et al.,* 2007).

Grain Yield: During the main season, yield on untreated plots varied from 4.7 to 5.7 t ha^{-1} on susceptible varieties (Denbi and Hitosa), whereas, it was 5.7 t ha^{-1} on both moderately susceptible varieties (Mengudo and Ude), and 5.3 to 6.3 t ha^{-1} on moderately resistant varieties (Tob-66 and Mukiye) (Table 3). During the same season, a maximum yield of 7.0 t ha^{-1} was obtained from treated plots of susceptible varieties, whilst grain yields of 7.0 - 7.3 t ha^{-1} and 6.0 to 7.7 t ha^{-1} were obtained from fungicide treated of moderately susceptible varieties and moderately resistant varieties, respectively. Similarly Singh *et al.* (2008) and Pretorius *et al.* (2007) reported that stem rust reduced yield irrespective of the type and level of resistance possessed by the varieties.

Yield on untreated plots during the off-season ranged from 5.3 to 6.3 t ha^{-1}on susceptible varieties, 5.0 to 5.3 t ha^{-1} on moderately susceptible varieties, and 5.7 to 6.3 t ha^{-1} on moderately resistant varieties. Whereas, yield on treated plots during the off-season varied from 7.0 to 8.0 t ha^{-1} on susceptible varieties, 7.7 to 8.3 t ha^{-1} on moderately susceptible varieties, and 7.3 t ha^{-1} on both moderately resistant varieties (Table 3). There was significant ($P< 0.05$) increase in grain yield due to Tilt spraying at 7th and 14th day spray schedules during both seasons (Table 4). For varieties grouped under moderately susceptible and susceptible, the 7th day Tilt spray schedule significantly increased grain yield during both seasons (Table 4). Whereas, for moderately resistant varieties, the 14th day Tilt spray schedule was enough to improve grain yield over the untreated plots. Asmmawy *et al.* (2013) also reported that the Tilt-protected plots remained almost free from stem rust.

Hectoliter Weight: During the main season, hectolitre weight on untreated plots varied from 72.0 to 73.8$kghl^{-1}$ on susceptible varieties (Denbi and Hitosa), 71.0 to 73.0$kghl^{-1}$ on moderately susceptible varieties (Mengudo and Ude) and 72.3 to 73.1$kghl^{-1}$ on moderately resistant varieties (Tob-66 and Mukiye) (Table 3).

In the same season the hectolitre weight on treated plots ranged from 78.3 to 79.1 $kghl^{-1}$ on susceptible varieties, 77.1 to 79.2$kghl^{-1}$ on moderately susceptible varieties, and 79.1 to 79.5$kghl^{-1}$ moderately resistant varieties. Hectolitre weight on untreated plots during the off-season varied from 72.5 to 73.6$kghl^{-1}$ on susceptible varieties, 72.1 to 72.4$kghl^{-1}$ on moderately susceptible varieties, and 72.6 to 73.5kg hl^{-1} on moderately resistant varieties. During this season hectolitre weight on treated plots varied from 79.5 to 79.9$kghl^{-1}$ on susceptible varieties, 79.1 to 79.2$kghl^{-1}$ on moderately susceptible varieties and 79.1 to 79.5$kghl^{-1}$ on moderately resistant varieties. The Tilt spray schedules at 7th and 14th days were significantly different from other spray during main season (Table 6). The highest mean value of hectolitre weight was recorded for both seasons on treated plots of durum wheat (Table 4). Everts *et al.* (2001) suggested that shrivelling of wheat kernels reduces flour yield and the work of Obrien *et al.* (1990) indicated that stripe rust affected grains resulted in lower dough strength (the physical strength to resist extension), which in turn, could affect baking quality. The highest mean value of hectolitre weight (79.2$kghl^{-1}$ and 76.7$kghl^{-1}$) was obtained from the Tilt spray schedule of 7th day during off and main seasons, respectively. The lowest mean values were recorded for untreated plots of Mengudo followed, in increasing order by Ude, Denbi, Tob-66, Mukiye and Hitosa during off-season. The lowest varietal interaction with Tilt spray schedules in hectolitre weight were recorded on untreated plots Mengudo followed by Ude, Mukiye, Tob-66, Hitosa and Denbi during main season (Table 3). Moreover, the hectolitre weight of varieties categorized under moderately resistant were less affected by stem rust. Dereje *et al.* (2007) also reported that stripe rust has decreased hectolitre weight of grains harvested from unsprayed plots than frequently sprayed plots.

Thousand Kernel Weight: During the main season thousand kernel weight (TKW) on untreated plots ranged from 36.4 to 38g on susceptible varieties (Denbi and Hitosa), 43.5 to 44.8g on moderately susceptible varieties (Mengudo and Ude), and 46.7 to 50.0g on moderately resistant varieties (Tob-66 and Mukiye) (Table 3). Thousand kernel weight on treated plots during the main season varied from 40.9 to 44.5g on susceptible varieties, 48.0 to 51.7g on moderately susceptible varieties, and 50 to 53g moderately resistant varieties (Table 3). Thousand kernel weight on untreated plots during the off-season varied from 35.7 to 37.7g on susceptible varieties, 40.7 to 54.2g on moderately susceptible varieties, and 44.8 to 54.2g on moderately resistant varieties. During this season thousand kernel weight on treated plots ranged from 46.3 to 44.8g on susceptible varieties, 52.3 to 55.5g on moderately susceptible varieties and 50.3 to 53.2g on moderately resistant varieties (Table 3). The highest mean value for thousand kernel weights varied from 55.5g (Mukiye) to 51.7g (Ude) during off and main seasons for plots treated with at 7th and 14th day's interval, respectively. Similarly, Asmmawy *et al.* (2013) reported that the Tilt treated plots resulted high thousand kernel weight as compared to untreated controls. The highest mean value in TKW was recorded on fungicide treated variety Mengudo followed by Mukiye, Ude, Tob-66, Denbi and Hitosa (Table 3). Taddese *et al. (*2010) also reported significant increase in TKW as results of Tilt treatments. The kernels of the treated plots were not shrunk and hence had high thousand kernel weight as compared to untreated plots. Dexter and Matsuo (1981) reported that plump kernels tend to have high thousand kernel weights and yield more semolina. Cromey *et al.* (1992) also found that diseases such as stripe rust and root rots decrease the thousand kernel weight but also increase the protein levels in the grain.The lowest varietal interaction with Tilt spray schedules in thousand kernel weight were recorded on untreated plots of Denbi followed in decreasing order by Hitosa, Mengudo, Ude, Tob-66 and Mukiye during the main season (Table 3). Dill-Macky *et al.* (1990) reported up to 45% reduction in thousand kernel weight in Australia due to wheat stem rust.

Kernel Size: During the main season, the same kernel size (2.9mm) resulted on both susceptible varieties (Denbi and Hitosa) from untreated plots. On the other hand, kernel size varied from 3.0 to 3.2mm on moderately susceptible varieties (Mengudo and Ude), and 3.0 to 3.2mm on moderately resistant varieties (Tob-66 and Mukiye) for untreated plots. During this season the kernel size on treated plots varied 3.0 to 3.3mm on susceptible varieties, 3.2 to 3.4mm on moderately susceptible varieties, and also 3.4mm on both moderately resistant varieties. On the other hand, the kernel size on untreated plots during the off-season was 2.7 to 2.8mm on susceptible varieties, 2.9 to 3.2mm on moderately susceptible varieties, and 3.0 to 3.2mm on moderately resistant varieties.

During this season kernel size on treated plots varied from 3.0 to 3.1mm on susceptible varieties, 3.4mm on both moderately susceptible varieties and also 3.2 to 3.3mm on moderately resistant varieties (Table 3).Infection of wheat stem and leaf sheaths by wheat stem rust affects the transport of assimilates to the developing kernel and results in shrivelled kernel which affects yield and quality of wheat (Singh, 1998; Everts *et al.*, 2001). In this study significant reduction in kernel size is mainly attributable to the shrivelling of the kernels, which was brought about by stem rust disease. A uniform size distribution of kernels is desirable because the rolls on the mill used to extract semolina are set a certain distance apart according to the average kernel size (Pitz, 1992)..

Conclusion and Recommendation

Understanding the appropriate time of Tilt spray schedules based on the host response gives deeper insight in the management of stem rust development. Stem rust disease resulted in significant reduction in hectolitre weight (HLW), thousand kernel weight (TKW), kernel size and yield during main and off- seasons when left untreated. However, Tilt spray schedules significantly reduced terminal stem rust severity and other disease parameters there by significantly improved grain yield and grain physical quality of durum wheat.

Evaluation of the Tilt spray schedules based on the response of durum wheat variety confirmed that varieties having a moderately susceptible and susceptible reaction to stem rust disease development best performed, when treated with the fungicide Tilt at 7th day interval. On the other hand, stem rust was better controlled at 14th day Tilt spray schedule for varieties having moderately resistant (MR) reaction suggesting the possibility of reducing fungicide sprays in durum wheat varieties with relatively better level of resistance to the disease. Current results not only demonstrated the negative impact of stem rust on grain yield and physical quality parameters of durum wheat, but also the role fungicides and their combination with host resistance play in reducing stem rust pressure on durum wheat. By reducing the stem rust severity, it was possible to improve yield and grain quality of the produce.

In addition, the search for more stem rust control options should continue to come up with effective, sustainable and affordable disease management strategies.

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