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Research Article

Evaluations of Different Seed-Dressing Fungicides with Chickpea Varieties for the Management of *Fusarium* Wilt in Eastern Amhara, Ethiopia

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The disease fusarium wilt is a serious and infectious year-round disease in chickpea-growing areas and causes huge chickpea yield losses. Thus, this research study was initiated with the objective of evaluating different seed-dressing fungicides with different chickpea varieties for the management of fusarium wilt (*Fusarium oxysporum* f.sp. *ciceris*) in Eastern Amhara, Ethiopia. Field experiment was conducted in hot spot areas of two locations using the material: two moderately resistant and one local (susceptible check) chickpea varieties with three commercially available seed-dressing fungicides (Apron Star, Noble, and Thiram). Treatments were arranged factorially in the RCB design with three replications. Results depicted that moderately resistant Mitk variety has significantly reduced disease pressure and gives better yield as compared to Arerti and local chickpea varieties. Even the disease pressure of fusarium wilt was lower in the Mitk variety followed by Arerti, and hence, its incidence and area under the disease progress curve reveal 6.23% and 292.1%-day, which was far apart by 17% and 873%-day, respectively, from Arerti. In case of the local chickpea variety, it was highly infected and its seed yield (0.4 t/ha) was lowered almost by half from the Mitk variety. Despite seed-dressing fungicides showed insignificant difference in both incidence and area under the disease progress curve, Thiram seed-dressing fungicides followed by apron star on Mitk variety indicates reasonable yield increment in both locations. Hence, integration of Mitk chickpea variety with the corresponding Thiram seed-dressing fungicides followed by Apron Star was advisable to manage fusarium wilt disease.

1. Introduction

Globally, chickpea (*Cicer arietinum* L.) is adapted to black soils in the cool semiarid areas of the tropics and subtropics as well as the temperate areas [1]. It is the third most important pulses gown in the world after dry bean and pea and constitutes 20% of the world's pulse production [2]. At present, it is produced in over 40 countries represented in all continents. However, the most important chickpea-producing countries are India, Turkey, Pakistan, Iran, Mexico, Australia, Ethiopia, Myanmar, and Canada. Chickpea is currently grown on about 10.7 million hectares worldwide with average annual production of 8.2 million tons. About 95% of chickpea cultivation and consumption is in the developing countries [1].

In Ethiopia, it is the second most important cool-season legume crop after faba bean [3]. Ethiopia also shares 4.5% of global chickpea market and more than 60% of Africa's global chickpea market [4]. Chickpea grows in diverse agro-ecological zones, which means it grows from 1500 to 2600 m above the mean sea level with rainfall of 700–1300 mm. Area coverage and productivity of chickpea were 242,703 ha and 20.58 q/ha, respectively, in Ethiopia. Here, the majority of productivity and area coverage are accounted in Amhara regional state, which produced 19 q/ha and 132,280 ha, respectively [5].

Regarding Waghimra Administration zone, chickpea is the fifth most important food legume crop next to faba bean, field bean, haricot bean red, and haricot bean white pulse crop. However, the average productivity of chickpea in Waghimra Administrative zone is much less (9.6 q/ha) as compared to the regional and national average production [5]. This was mainly due to various biotic and abiotic stresses. Among the biotic constraints were fusarium wilt, ascochyta blight, pod borer, and cut worm while abiotic constraints were drought, salinity, poor soil fertility, and limited management practice [6]. The disease fusarium wilt, which is caused by the saprophytic pathogen *Fusarium oxysporum* f.sp. *ciceris*, is one of the most economically important biotic stresses and the annual average yield loss has been estimated up to 10–90%. In higher relative humidity (>60%) and ambient temperature, it can cause 100% yield loss [6].

Epidemics of the pathogen are high when favored by moist soil, optimum temperature range (25–27.5°C), and pH values of 7.1–7.9. It is also highly contagious via infected seed, residue, soil, and contaminated materials [7]. *F. oxysporum* f. sp. *ciceris* is an asexually-reproducing root inhabiting (soil invader) fungus [8], which survive by being inactive in soil by means of chlamydospores free or embedded in plant tissues [7]. The pathogen load in the soil/seed can be minimized via various and integrated management strategies. Among these different cultural practices, seed treatment, appropriate planting date, removal of crop residue, and other mechanical and physical soil sanitation methods are the most importance practices to manage the disease. According to a report [9], the relatively resistant chickpea variety, i.e., Arerti, with fungicide seed treatment can reduce fusarium wilt incidence. Similarly, minimum disease incidence and disease progress rate were recorded on Shasho variety with Apron Star fungicide seed treatment [10]. Additionally, different scholars [4, 11] showed integrated management of fusarium wilt is the most effective and sustainable management strategies. However any management practice regarding fusarium wilt in Wag-Lasta areas have not previously practiced.

Therefore, this research proposal was initiated with the objective to evaluate different seed-dressing fungicides with different chickpea varieties for the management of fusarium wilt (*Fusarium oxysporum* f.sp. *ciceris*) disease in Eastern Amhara, Ethiopia.

2. Materials and Methods

Field experiment was conducted on two locations of naturally infected areas in Eastern Amhara, Ethiopia, i.e., at Sekota zuria district (woleh) trial site and Lalibella zuria district (kechin abeba on farm) in 2020 main cropping season (Figure 1). The experimental site of Sekota zuria district (woleh) was situated on latitude 39°03′19.85″N and longitude 12°32′03.76″E, and the Lalibella zuria experimental site was also geographically placed on 39°03′57.38″N and 11°57′32.15″E with altitude range of 2100 meter above sea level. The cropping season of Sekota zuria district (woleh) was characterized by its subhumid weather condition but in Lalibella, despite its typical humid and subhumid weather condition, the two-month weather (October and November) indicates somehow dry humid in the cropping year. The average annual rainfall in Sekota and Lalibella zuria districts was 807.3 and 1027.1 mm with mean minimum temperature of 13 and 13.6°C and mean maximum temperature of 27 and 24.6°C, respectively [12].

Three chickpea varieties (one from Cabuli, i.e., Arerti, the other from Deci, i.e., Mitk, and the last local) with three commercial fungicides (Apron Star, Thiram, and Noble) based on their market accessibility and efficacy were used (Table 1). Treatments were arranged factorially in a randomized complete block design with three replications. The fungicides Apron Star and Thiram were used as seed treatment, and the fungicide Noble was used as a seed treatment and supplemental basal spray after full emergence of chickpea. Basal spray was nothing but to support the effectiveness of Noble fungicide against fusarium wilt, and it was also an intracellularly curative fungicide; that is why it was added as a supplemental spray (personal observation). It was also applied 3 times with 10 days of interval.

Seeds of chickpea varieties were treated for 24 hours before sowing to be more effective. Doses of both seed dressing and foliar spray of Noble were used based on manufacturer recommendation, implying that Apron Star 2.5 g kg^{-1} of seed, Thiram 3 g kg^{-1} of seed, and Noble 3.75 g kg^{-1} of seed were used and the foliar spray Noble was applied in the afternoon 11–12 pm. Spacings that was used during field experiment were 1.5 m, 1 m, 0.4 m, and 0.1 m for block, plot, row, and between plant, respectively. The size of the field experiment and the plot size were 6.8×35 and 1.6×2 m, respectively. Management practices such as controlling untargeted disease and insect pest and agronomic practice (weeding, roughing out off type, and monitoring) were performed accordingly.

2.1. Disease Assessment and Data Collection. The disease fusarium wilt (*Fusarium oxysporum* f.sp. *ciceris*) was monitored regularly, and necessary data were recorded based on the data frame from germination to physiological maturity. Other untargeted diseases and insect pests such as ascochyta blight, p`od borer, and related pests were encountered and recorded. Biological data such as sowing date, stand count at harvest, plant height, flowering date, maturity date, seed per pod, biomass, and seed yield were collected at the field level. Disease incidence of fusarium wilt was recorded for six consecutive times in 10-days interval.

The disease incidence was computed as follows:

$$\text{incidence (\%)} = \frac{\text{Number of plant infected in a plot}}{\text{Total number of plant visited in a plot}} \times 100. \quad (1)$$

Area under the disease progress curve (AUDPC) was computed for each treatment from the assessment of disease incidence by using the following formula:

$$\text{AUDPC} = \sum_{i=1}^{n-1} \left(\frac{X_i + X_i + 1}{2} \right) (t_i + 1 - t_i), \quad (2)$$

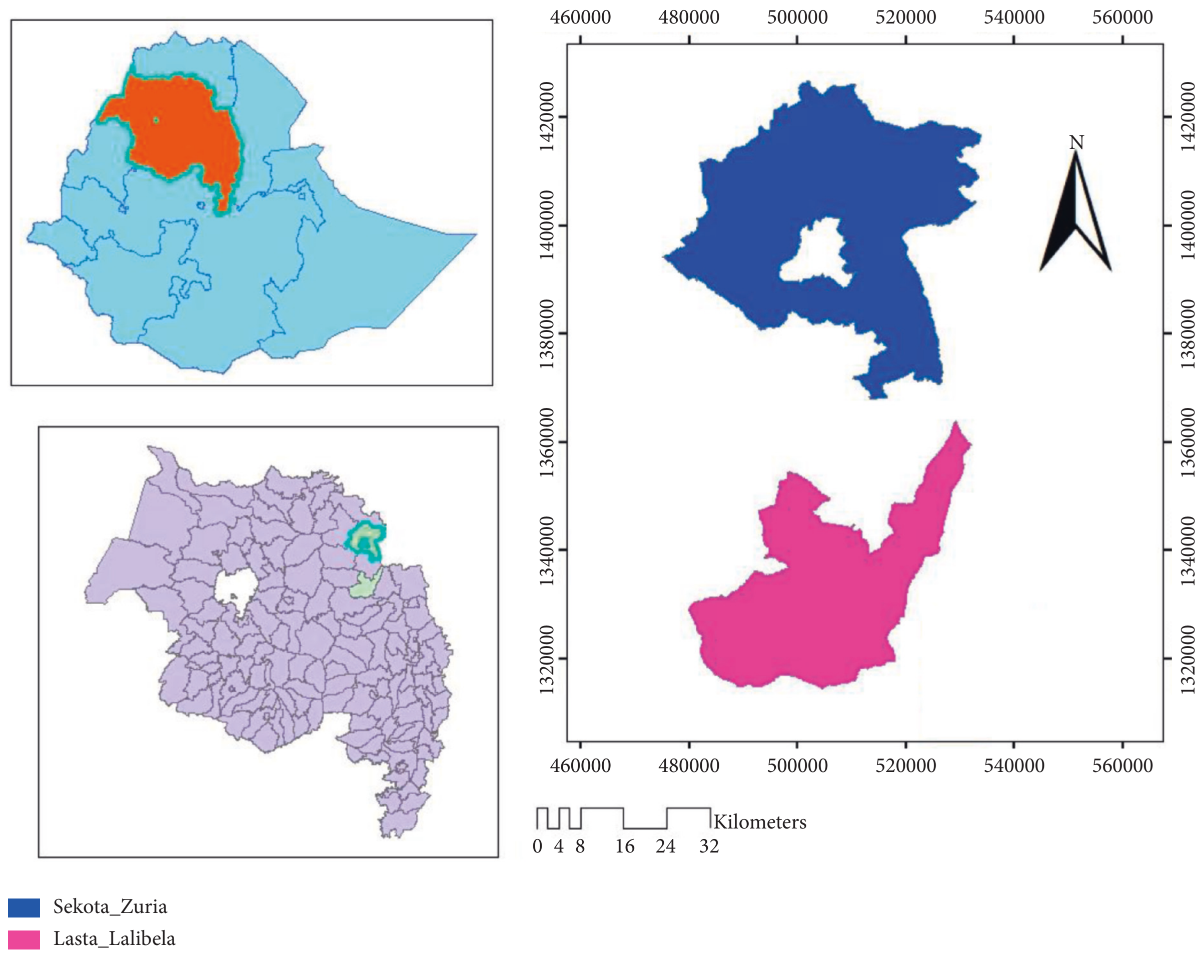

Figure 1: Maps of the study areas showing experimental districts in North Wollo (Lasta Lalibella district) and Waghimra zone (Sekota zuria district), Amhara, Ethiopia, during the 2020 cropping season.

Table 1: Treatments and the arrangement of chick pea varieties and different seed-dressing fungicides with foliar supplement of Noble.

S/N	Chick pea varieties	Fungicides	Treatment arrangement
1	Mitk	Apron Star	Mitk + Apron Star
2	Arerti	Thiram	Mitk + Noble + supplement with foliar spray
3	Local	Noble	Mitk + Thiram Mitk Arerti + Apron Star Arerti + Noble + supplement with foliar spray Arerti + Thiram Arerti Local + Apron Star Local + Noble + supplement with foliar spray Local + Thiram Local as control

where X_i is the disease incidence at the i^{th} assessment, t_i is the time of the i^{th} assessment in days from the first assessment date, and n is the total number of disease assessments.

2.2. Data Analysis. Disease incidence, AUDPC, growth parameters, seed yield, and related components were subjected to analysis of variance ANOVA to see the main effect (varieties and fungicides) plus interaction effects, which means chickpea varieties with seed-dressing fungicides against fusarium wilt disease. Least significant difference (LSD) value was used to separate difference among treatment means at 5% probability level.

3. Results and Discussion

Interaction effect of chickpea varieties × seed-dressing fungicides on seed yield and related components and on

Table 2: Interaction effect of seed-dressing fungicides and chickpea varieties on seed yield of chickpea at woleh trial site.

Varieties	Fungicides	SY (ton/hectare)
Mitk	Thiram	2.22
	Apron Star	1.87
	Noble	1.52
	Control	2.06
Arerti	Thiram	1.14
	Apron Star	1.58
	Noble	2.05
	Control	2.02
Local	Thiram	1.62
	Apron Star	1.59
	Noble	1.02
	Control	2.05
Mean		1.72
CV (%)		21.25
LSD (5%)		0.62

SY, seed yield; CV, coefficient of variation; LSD, least significant difference.

Table 3: Effect of seed-dressing fungicides and chickpea varieties on seed yield, growth parameters, and on fusarium wilt disease epidemics at Lalibella district.

Treatment	SC	PH	MD	PPP	SPP	BM	SY (t/ha)	INC %	AUDPC
Varieties									
Mitk	22.92	27.05	90.1	21.75	1.1	3.7	0.8	6.23	292.1
Arerti	22.66	26.72	100.7	21.97	1.07	5.6	0.6	23.5	1166.5
Local	12.66	25.29	92.5	26.04	1.54	2.5	0.4	43.6	2166.7
Mean	19.41	26.35	94.41	23.25	1.23	3.95	0.6	24.42	1208.4
LSD (0.05)	5.98	1.96	5.39	7.04	0.17	1.02	0.21	20.26	1021.7
Fungicides									
Apron star	20.3	27.14	92.2	24.03	1.13	3.8	0.62	24.3	1186
Noble	17.5	24.59	100.2	21.29	1.28	3.9	0.43	15.9	800
Thiram	20.0	26.9	90.8	27.95	1.30	3.6	0.72	18.7	1337
Control	19.7	26.7	94.3	19.7	1.23	4.2	0.60	28.7	1409
Mean	19.41	26.35	94.41	23.25	1.23	3.95	0.6	22.01	1183.4
CV %	36.5	2.67	6.78	35.9	16.53	30.51	41	98.4	100.3
LSD (0.05)	6.9	1.95	6.2	8.12	0.19	1.17	0.24	23.4	1179

SC, stand count; PH, plant height; MD, days to maturity; PPP, pod per plant; SPP, seed per pod; BM, biomass; SY, seed yield in ton per hectare; INC, incidence in percentage; AUDPC, area under disease progress curve in percent day; CV, coefficient of variation; LSD, least significant difference.

Figure 2: Thiram-treated Mitk variety and untreated local variety at Lalibella zuria district.

disease parameters were with nonsignificant ($p > 0.05$) difference. Hence, the main factor, i.e., chickpea varieties and seed-dressing fungicides were presented separately, but in woleh trial site, chickpea varieties and seed-dressing fungicides revealed the interaction effect on seed yield and Mitk chickpea variety depicted better seed yield (Table 2).

Results depicted that different chickpea varieties especially Mitk had good and significant response in combating fusarium wilt disease as compared to Arerti and local varieties at Lalibella district. The disease pressure of fusarium wilt was lower in Mitk variety followed by Arerti and hence, its incidence and area under disease progress curve reveals

Table 4: Effect of seed dressing fungicides and chickpea varieties on seed yield, growth parameters, and on fusarium wilt disease epidemics at Sekota zuria district (woleh).

Treatment	SC	PH	MD	PPP	SPP	BM	INC %	AUDPC
				Varieties				
Mitk	27.75	34.11	83.2	52.55	1.31	4.8	8.21	395
Arerti	28.66	38.55	103.4	46.52	1.17	5.8	6.42	328
Local	25.50	32.2	83.3	59.5	1.75	4.1	8.20	397
Mean	27.3	34.95	89.9	52.85	1.4	4.9	7.6	375.74
LSD (0.05)	4.87	3.14	1.19	19.01	0.22	1.21	3.43	177.9
				Fungicides				
Apron star	31.4	34.1	89.7	45.6	1.41	4.65	4.75	217.5
Noble	26.5	33.5	90.6	45.5	1.44	4.65	2.62	113.3
Thiram	23.4	35.9	89.7	55.9	1.36	4.86	10.4	526.4
Control	27.8	36.1	89.6	64.3	1.42	5.48	10.6	544.4
Mean	27.3	34.95	89.9	52.85	1.4	4.9	7.6	375.74
CV %	21.2	10.68	1.57	42.6	19.3	29.4	53.5	56.2
LSD (0.05)	5.6	3.6	1.37	21.95	0.26	1.40	3.96	205.42

SC, stand count; PH, plant height; MD, days to maturity; PPP, pod per plant; SPP, seed per pod; BM, biomass; INC, incidence in percentage; AUDPC, area under the disease progress curve in percent day; CV, coefficient of variation; LSD, least significant difference.

Table 5: Coefficient of correlation (r) between disease parameters and yield and some yield contributing components.

Parameters*	INC	AUDPC	DPR	Y.t/ha	SC	BM
INC	1.0000					
$P \leq$	0.0001					
AUDPC	0.9998	1.0000				
	0.0001	0.0001				
DPR	0.7621	0.7676	1.0000			
	0.0001	0.0001	0.0001			
Y. t/ha	−0.2748	−0.2706	−0.1789	1.0000		
	0.1047	0.1104	0.2964	0.0001		
SC	−0.3973	−0.3905	−0.3008	0.6947	1.0000	
	0.0164	0.0185	0.0746	0.0001	0.0001	
BM	−0.2961	−0.2935	−0.3483	0.2862	0.6911	1.0000
	0.0795	0.0823	0.0374	0.0907	0.0001	0.0001

INC, incidence; AUDPC, area under the disease progress curve; DPR, disease progress rate; Y. t/ha, yield in ton per hectare; SC, stand count; BM, biomass. The p value indicates the significant association of each parameter.

6.23% and 292.1%-day, which was far apart by 17% and 873%-day, respectively, from Arerti (Table 3). Regarding local variety, it was highly infected due fusarium wilt (Figure 2). Its stand count, seed yield, and other growth parameters were substantially reduced, and its seed yield was significantly ($p \leq 0.05$) lowered by half (0.4 t/ha) from the improved and relatively tolerant Mitk variety. However, in contradiction to these, few studies [6, 9] reported that Arerti and Shasho with protective seed-dressing fungicides revealed better seed yield than Mitk, respectively.

Seed-dressing fungicides did not affect ($p > 0.05$) fusarium wilt incidence and area under the disease progress curve as it was indicated in Table 3 while Thiram had significant advantage over Noble by its seed yield (0.72 t/ha) and revealed relatively better seed yield as compared to Apron Star and control (Table 2). Even plots, which were treated by Thiram, showed better pod number per plant comparing to other seed-dressing fungicides. However, growth parameters such as seed per pod, biomass, plant height, and stand count depicted nonsignificant difference ($p > 0.05$) (Table 3). In contrast, Mengist et al. [6] reported that apron star caused significant reduction in fusarium wilt incidence and it increases seed yield of chickpea. However, some scholars agree with this finding, which implies Thiram + carboxin followed by Apron Star offer good protection against fusarium wilt epidemic [13]. Minimum fusarium wilt incidence (3.78%) was recorded by dressing 2 g/kg of seed via Thiram + carboxin fungicides with the integration of other management practice [11].

In Sekota zuria district, at the woleh trial site, the epidemic of the disease was not as such as high as in Lalibella district in the 2020 cropping season. Hence, the impact of fusarium wilt on chickpea production was lower and significantly not highly affected (Table 4). Disease incidence and area under the disease progress curve on improved chickpea varieties (Mitk and Arerti) were statistically similar to the local variety. In case of phenological and growth parameters, pod per plant and stand count were statistically nonsignificant across the varieties while plant height (38.55 cm) and days to maturity (103.4) of Arerti was significantly higher than Mitk and local varieties, which means the variety was so late. However, seed per pod of the local variety was above the improved varieties, which means it was far by 0.44 and 0.58 from Mitk and Arerti, respectively (Table 4).

Regarding seed dressing and foliar supplementation of noble fungicides, since the disease pressure was scattered and almost stagnant at the flowering stage, most grow parameters such as stand count, plant height, pod per plant, seed per pod, and biomass were nonsignificant among seed-dressing fungicides and untreated plots. However, disease incidence and area under the disease progress curve of Noble- and Apron Star-treated plots were significantly lower than Thiram (Table 4).

Association of disease progress rate, incidence and area under disease progress curve were evaluated using correlation analysis. All disease parameters, i.e., incidence ($r = -0.2748$), AUDPC ($r = -0.2706$), and disease progress rate ($r = -0.1789$) were negatively and significantly ($p \leq 0.0001$) associated with seed yield of chickpea. In addition, biomass and stand count were negatively and significantly correlated with those disease parameters (Table 5). However, the disease parameter stated in the table such as AUDPC with incidence and disease progress rate and vice versa were highly and significantly associated ($p \leq 0.0001$) at correlation rate of 0.7676 to 0.999^{**} (Table 5). Thus, the disease fusarium wilt was the most predominant infectious disease that penalizes seed yield and growth parameters of chickpea.

4. Conclusion and Recommendation

The disease fusarium wilt is a common and alarmingly devastated disease in majority of chickpea growing areas of Eastern Amhara. Results revealed that local chickpea variety was highly infected and its seed yield was lowered almost by half from moderately resistant Mitk variety. In addition, the disease pressure on the local variety indicates very high as compared to the moderately resistant chickpea variety. However, seed-dressing fungicides showed insignificant difference in both incidence and area under the disease progress curve in Lalibella district. Besides, Thiram seed-dressing fungicides revealed better seed yield at Lalibella; even in Sekota zuria district, the interaction effect of the chickpea variety (Mitk) with seed-dressing Thiram fungicide followed by Apron Star indicated better yield. Hence, integration of moderately resistant chickpea variety with the corresponding Thiram seed-dressing fungicides followed by Apron Star were advisable to manage and reducing fusarium wilt disease. Moreover, further studies on integrated disease management strategies and resistant variety development should be deployed.

Data Availability

The data that support the findings of this study are available upon the request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors contributed in the fieldwork, data collection, data management, and follow-up. Zemenu Endalew conducted the data analysis and full write-up.

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