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Integrated management of *Cercospora* leaf spots of groundnut (*Arachis hypogaea* L.) through host resistance and fungicides in Eastern Ethiopia

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***Cercospora* leaf spots caused by *Cercospora arachidicola* and *Cercosporidium personatum* are the most widespread diseases of groundnut that result in severe yield losses in Ethiopia. Field trials were conducted at Babile and Dire Dawa to evaluate the effect of integrated use of host resistance and fungicides on the temporal epidemics of leaf spots and yield of groundnut. The experiments were conducted during the 2010 main cropping season using three groundnut varieties and six fungicide treatments. The experiment was laid out as RCBD in a factorial arrangement with three replications. Severity, disease progress rate, area under disease progress curve (AUDPC) and yield of groundnut were used to evaluate the effects of treatments. High levels of disease control were achieved by weekly application of chlorothalonil at both locations. Up to 25 and 65% severity levels were recorded on sprayed and unsprayed plots of the varieties, respectively. Fungicide applications also significantly reduced disease progress rate and AUDPC value on the susceptible variety. Seed yield harvested from fungicide sprayed plots was consistently greater than the yield harvested from unsprayed plots.**

Key words: *Arachis hypogaea* L., *Cercospora* leaf spots, disease progress rate, disease severity and integrated disease management.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), also known as peanut, is an important leguminous oilseed crop belonging to the family Fabaceae (Mali and Bodhankar, 2009). It is one of the most popular and universal crops cultivated in over 100 countries in six continents but mainly Asia, Africa and America with a world production of 37.1 million metric tons from an area of 23.1 million hectares (FAO, 2007). Its cultivation is mostly confined to countries ranging from 40° N to 40° S. Major groundnut producing countries are China, India, Nigeria, U.S.A and Indonesia, respectively. Groundnut is very important cash crop for small scale farmers of developing countries. In Ethiopia, it is grown over an area of 41,761 ha, with an annual production of 46,887 t (MoARD, 2009).

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Groundnut is one of the three economically important oilseed crops consisting of nigerseed/noug and sesame in Ethiopia. It serves as a source of cash income for many small-scale farmers and the country also obtains foreign currency by exporting the crop (Geleta et al., 2007). However, eastern Ethiopia holds primary position in producing and supplying for both domestic and export markets as compared to other parts of the country. Groundnut is commonly cultivated by farmers under rain-fed conditions. Particularly in East Hararghe Zone, the crop ranked third next to maize and sorghum in area coverage and seed production.

Despite its importance, the average national yield of groundnut in Ethiopia is very low. This might be due to a number of biotic and abiotic constraints. Among the biotic constraints, fungal diseases are one of the major factors affecting the production and productivity as well as the quality of the crop. Amongst the fungal diseases, *Cercospora* leaf spots, caused by *Cercospora arachidicola* (early leaf spot) and *Cercosporidium personatum* (syn. *Phaeoisariopsis personata*) (late leaf spot) are the major destructive diseases of groundnuts worldwide including Ethiopia (Backman and Crawford, 1984; Smith et al., 1992). The damages done by these diseases generally ranged from defoliation to reduction in pod, seed and haulm yield (Brenneman and Culbreath, 2000). Yield losses due to *Cercospora* leaf spots are as high as 50% in the USA (Shokes and Culbreath, 1997; Hagan et al., 2006).

Cercospora leaf spots are widespread and economically important diseases of groundnut in Ethiopia, and they can cause about 65% yield losses in high diseases pressure areas of the country (Teklemariam et al., 1985). The study on leaf spot and rust resistance, which was conducted at Babile and Bisidimo, showed that most of the genotypes tested suffered a high disease severity and yield was not obtained from most plots due to heavy defoliation of leaves in different years depending on weather conditions (Abraham, 2009). Although, the diseases are highly destructive in the areas, farmers do not apply any control measures like fungicides applications and selection of improved varieties. Therefore, it is necessary to develop suitable disease management practices for groundnut crop in Ethiopia.

As indicated by different studies in different countries, effective control of *Cercospora* leaf spot can be achieved by applying recommended fungicides. Significant yield improvement (up to 75%) was observed with fungicide applications (Naab et al., 2005). Synthetic fungicides that combat phytopathogenic fungi can increase crop yields and provide stability of crop production and market quality (Kishore et al., 2007). Chemical method still plays a vital role in the management of plant diseases. However, repeated application of fungicides could lead to reduced efficacy, greater production costs and environmental pollution. It can also kill or negatively affect beneficial microorganisms used as bioagents and nitrogen fixer in the soil. In addition, farmers in the arid and semi-arid areas of Africa in general including Ethiopia are resource poor and so most of them cannot afford the cost of chemical control measure as the sole method of disease management. Plant disease can be effectively managed by a combination of fungicides and host plant resistance (Pande et al., 2001).

The use of resistant varieties to a particular disease is one of the main methods of disease management. Therefore, the planting of moderately resistant cultivars will reduce the use of fungicides and associated expenses and increase economic gain. Thus farmers will benefit economically from planting resistant varieties (Johnson and Beute, 1986). Therefore, development of integrated disease management programs could be effective in decreasing the production costs and improving productivity and quality as well as reducing the detrimental effects of chemicals on the ecosystem. So, this study was conducted to determine the effect of integrated use of host resistance and fungicides spray intervals on the epidemics of *Cercospora* leaf spots and yield of groundnut.

MATERIALS AND METHODS

Experimental sites

Field experiments were conducted at Babile and Dire Dawa research stations of the Haramaya University during the main cropping season in 2010. The sites are located in a semi-arid and arid agroclimatic zone in the country and they differ mainly in their altitude, temperature, and annual total rainfall. Babile is situated in Oromia Regional State at 30 km East of Harar at 9° 08' 40" N latitude, 42° 21' 30" E longitudes and at altitude of 1650 m.a.s.l. The district is characterized by weather conditions conducive for leaf spots epidemic development. It receives annual rainfall of over 600 mm (Mitiku, 1989; Tadele and Tana, 2002). Mean annual maximum and minimum temperatures are 28.05 and 15.52°C, respectively. The type of the soil at Babile research field is a well drained sandy loam with pH of 7.0 (Mitiku, 1989). While Dire Dawa is located at 40 km North of Haramaya University at 9° 31' N latitude, 41° 51' E longitudes and at altitude of 1160 m.a.s.l. It receives annual rainfall of 520 mm, and has mean maximum and minimum temperatures ranging from 28.1-34.6 and 14.5-21.6°C, respectively. The dominant soil type is well-drained loamy sand with a pH of 8 (Tana et al., 2002).

Experimental materials and treatments

Three groundnut varieties currently under production and differing in their resistance level to leaf spots were used. The varieties were: Oldhale (local variety), Betisedi (ICG-273) and Werer-962 (ICGV-86928). The varieties Betisedi and Werer-962 were released in Ethiopia in 1993 and 2004 by Werer Agricultural Research Center, respectively. Werer-962 is a late maturing variety and resistant to leaf spots. Different severity levels of leaf spots were created by varying intervals of application of chlorothalonil (Odeon 825 WDG) and carbendazim (Bavistin 50% DF) at the rate of 1.4 and 0.5 kg ha^{-1}, respectively. Chlorothalonil was sprayed at intervals of 7, 14 and 21-days on each variety while carbendazim was sprayed at intervals of 14 and 28-days. Foliar spray with the fungicides was started after the appearance of the symptoms of the disease using a manual Knapsack sprayer. Unsprayed plots were left as a control to allow maximum leaf spots development on each variety. At Babile, eight sprays were made on the most frequently sprayed plots (7-days interval), three sprays were made on the plots that received chlorothalonil every 21-days and carbendazim every 28 days and five sprays were made on the plots that received chlorothalonil and carbendazim every 14-days.

Experimental design and management

A randomized complete block design in a factorial arrangement was used with three replications at both locations. The total treatment combination of 18 (three varieties × six fungicide treatments) were used. 10 and 60 cm spacing between plants and rows were used, respectively. Spacing between blocks and adjacent plots were 1 m. Each plot had a size of 2.4 × 4 m and consisted of four rows (with two harvestable central rows) of the groundnut plants. Planting of the crop was done on 30 April at Babile and 8 May in 2010 at Dire Dawa. Seeding was done at the rate of two seeds per hill and seedlings were thinned to one plant per hill two weeks after emergence. Leaf spot was allowed to develop naturally on each cultivar without any artificial inoculation at Babile. Specifically, the experimental field at Dire Dawa is not known to be planted with groundnut in previous years. Due to this reason, equal amount of infected groundnut residues were applied on each plot at the time of planting to enhance the development of *Cercospora* leaf spot. All agronomic practices, including N and P fertilizers, were done for all treatments as required at both locations.

Disease assessment

The disease severity was assessed at weekly intervals by estimating the percentage of leaf area affected using a 1-to-9 scale of Subrahmanyam et al. (1995) on all leaves of 10 randomly selected and tagged plants in each plot beginning from the disease appearance, where 1 = no disease, all leaves healthy and 9 = almost all leaves defoliated; leaving bare stems; some leaflets may remain; but show severe leaf spots; 81-100% leaf area damaged by the disease. Disease scoring was done for both *Cercospora* leaf spots (early and late) together and separate data for the two leaf spots was not presented because the chemicals control both diseases equally. In all assessments, disease severity was averaged for the 10 plants in each plot. The severity grades were converted into percentage severity index (PSI) for analysis using the formula of Weeler (1969).

$$\mathrm{PSI} = \frac{\text{Sum of numerical ratings}}{\text{No. of plants scored x maximum disease score on scale}} \times 100$$

The area under the disease progress curve (AUDPC) from PSI was calculated for each plot using the formula of Shaner and Finnery (1977):

$$\mathrm{AUDPC} = \sum_{i=1}^{n-1} 0.5[(x_i + x_{i+1})(t_{i+1} - t_i)]$$

Where, n = total number assessment times, t_i = time of the i^{th} assessment in days from the first assessment date, x_i = percentage of disease severity at i^{th} assessment. AUDPC was expressed in percent-days because severity(x) will be expressed in percent and time (t) in days. AUDPC values were used in the analysis of variance to compare amount of disease among plots with different treatments. Disease progression from each treatment was calculated by transforming the percent disease severity values to the logistic model as ln(y/1-y), where y is leaf spot severity in proportion (Van der Plank, 1963). The transformed data were then regressed over time (as DAP) so as to get the disease progress rate, which is the coefficient of the regression line.

Assessment of seed yield

Seed yield data were recorded from each plot at harvest. Yield data were recorded from the central two rows of each plot by leaving the border two rows to avoid border effects. The yields were presented on per ha basis.

Statistical analysis

Data of disease severity from each assessment date, AUDPC values, disease progress rates, and seed yield were subjected to analysis of variance (ANOVA) to determine the effects of treatments. The two locations were considered as different environment because of the significant variation in weather conditions during the experiments. Due to this reason, data were not combined for analysis. Analyses of variances (ANOVA) were performed using SAS computer software (SAS System 9). Comparison of treatment means was made using least significance difference (LSD) test at 5% level of significance.

RESULTS AND DISCUSSION

Disease severity

Varieties by spray interval interactions showed very highly significant ($P < 0.001$) difference at final date of assessment at Babile and Dire Dawa. This might indicate a differential cultivar effect on *Cercospora* leaf spot development at different spraying intervals. Almost complete control was achieved by application of chlorothalonil at 7-day intervals on all varieties at both locations. At Babile, the highest leaf spot severity (65.3%) was observed on unsprayed plots of the susceptible variety "Betisedi" while the lowest (24.6%) was observed on plots sprayed chlorothalonil at 7-days interval of the moderately resistant variety "Werer-962" at assessment of 106 DAP (Figure 1B and C). Carbendazim spray at 28-days interval reduced the disease severity significantly as compared to unsprayed plots of each cultivar. Disease severities of plots sprayed fungicide at 14- and 21-days intervals were not significantly different from each other on the moderately resistant variety "Werer-962". This study is in agreement with that of Culbreath et al. (1992) who reported that the application of chlorothalonil, or alternating applications of chlorothalonil and tebuconazole or azoxystrobin at 21-days or longer intervals, can provide good control of early and late leaf spot when

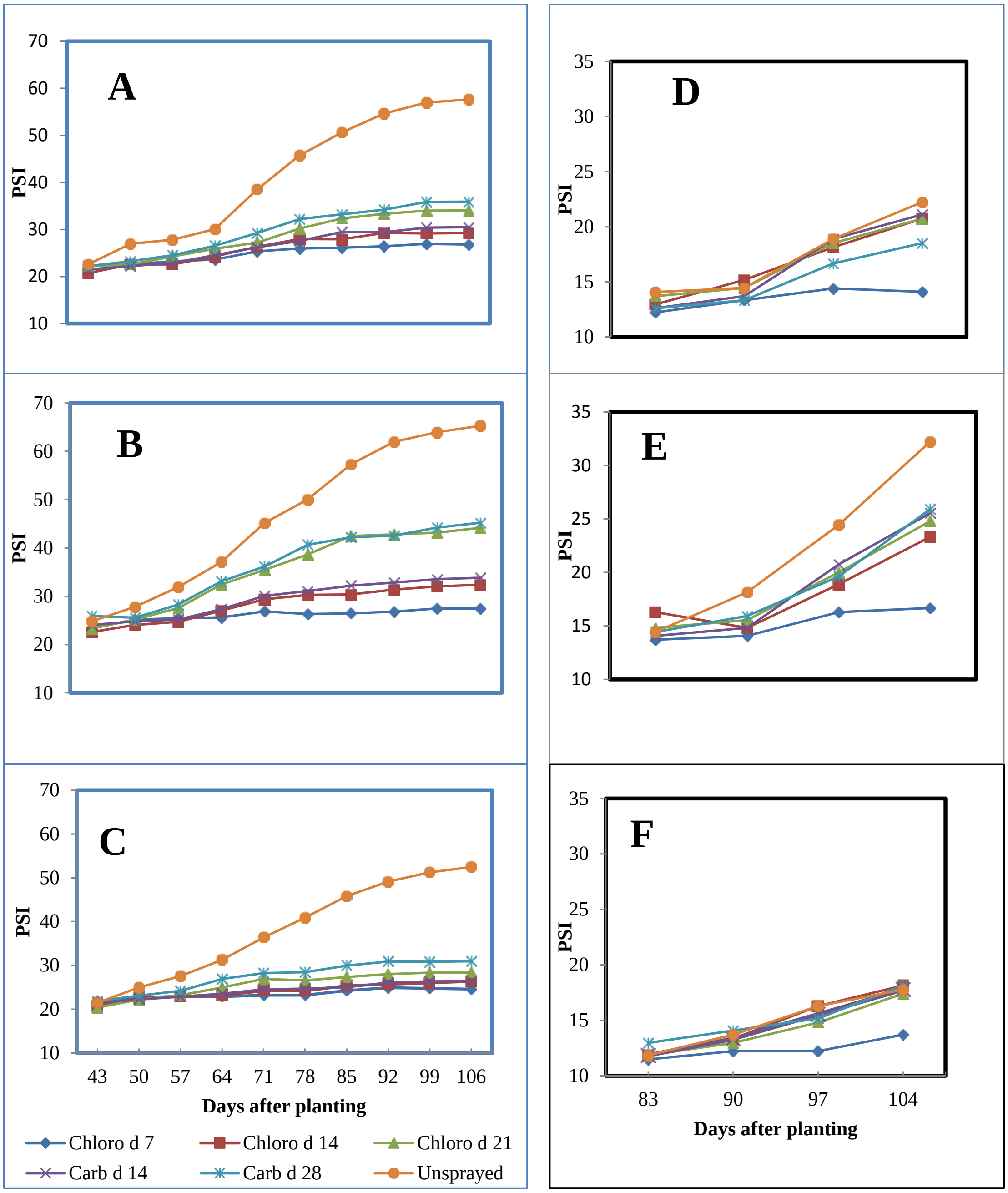

Figure 1. *Cercospora* leaf spot progress curves under different fungicides spray intervals on three groundnut varieties (A) Oldhale, (B) Betisedi and (C) Werer-962 at Babile and (D) Oldhale, (E) Betisedi and (F) Werer-962 at Dire Dawa in 2010 main cropping season. Disease severity was assessed every 7-days starting from 43 DAP at Babile and starting from 83 DAP at Dire Dawa.

combined with a cultivar possessing moderate levels of resistance to those pathogens. The ultimate value of partial resistance to control of groundnut leaf spot was a means to reduce fungicide use (Gorbet et al., 1982).

At Dire Dawa, the highest PSI value (32.2%) was also observed on unsprayed plots of the variety "Betisedi" while the lowest (13.7%) on plots sprayed chlorothalonil at 7-days interval of the variety "Werer-962" at 104 DAP (Figure 1E and F). In plots sprayed with chlorothalonil at 7-days interval (a total of two sprays), mean leaf spot severity ranged from 13-16% on all varieties. Except chlorothalonil at 7-days intervals, disease severities of all fungicides treatments were not significantly different from the unsprayed plots on the moderately resistant variety.

Table 1. AUDPC of *Cercospora* leaf spot on three groundnut varieties sprayed with chlorothalonil and carbendazim at Babile and Dire Dawa in 2010 main cropping season.

Cultivars	Fungicides Treatments (Spray Intervals)	AUDPC (%-days)	
		Babile	Dire Dawa
Oldhale	Chl 7-days	188.0	99.7
	Chl 14-days	204.6	136.1
	Chl 21-days	238.2	137.4
	Carb 14-days	213.1	140.0
	Carb 28-days	251.2	123.1
	No spray	401.3	143.9
	Mean	249.4	130.0
Betisedi	Chl 7-days	192.3	115.4
	Chl 14-days	225.4	147.8
	Chl 21-days	305.5	156.9
	Carb 14-days	235.8	162.0
	Carb 28-days	313.1	159.4
	No spray	452.4	198.3
	Mean	287.4	156.6
Werer-962	Chl 7-days	172.7	90.7
	Chl 14-days	183.4	120.6
	Chl 21-days	198.5	112.8
	Carb 14-days	184.7	116.7
	Carb 28-days	216.2	116.7
	No spray	363.1	119.3
	Mean	219.8	112.8
Site Mean		252.20	133.15
LSD (0.05)		22.96	8.53
CV (%)		5.49	3.86

Chl = chlorothalonil and Carb = carbendazim.

In general, *Cercospora* leaf spot was less severe on the varieties at Dire Dawa. This might be due to the prevailing weather conditions of the area. Dire Dawa is characterized by severe drought (arid) conditions and during the experiment, the mean minimum and maximum temperatures were higher as compared to the previous year and RH of the area was also low. On the other hand, for *Cercospora* leaf spot, prolonged periods of humidity and leaf wetness, as well as a late rainy season favor sporulation which results in greater disease (Smith et al., 1992; Butler et al., 1994; Nutter and Shokes, 1995).

Area under the disease progress curve (AUDPC)

The AUDPC is a very convenient summary of plant disease epidemics that incorporates initial intensity, the rate parameter and the duration of the epidemic which determines final disease intensity (Madden et al., 2008). Varieties by fungicides spray interval interactions showed very highly significant (P < 0.001) difference in terms of AUDPC values both at Babile and Dire Dawa. At Babile, the highest AUDPC value (452.4%-days) was calculated from unsprayed plots of the variety "Betisedi" while the lowest AUDPC value (172.7%-days) was from plots sprayed chlorothalonil at 7-days interval of the variety "Werer-962" (Table 1). AUDPC values of 401.3%-days and 452.4%-days were calculated from unsprayed plots of the varieties Oldhale and Betisedi, respectively, which had the highest disease severity at Babile. The AUDPC value of unsprayed plots of the variety Werer-962 was lower by 38 and 89%-days as compared to unsprayed plots of the varieties Oldhale and Betisedi, respectively. At Dire Dawa, the lowest AUDPC value (90.7%-days) was also calculated from plots sprayed chlorothalonil at 7-days interval of the variety "Werer-962" while the highest AUDPC value (198.3%-days) was from unsprayed plots of the variety "Betisedi" (Table 1). Our finding is in agreement with that of Mukankusi et al. (1999) who stated that weekly applications of fungicides resulted in the lowest *Cercospora* AUDPC and the highest yields. Shokes et al. (1982) also reported that earlier initiation of fungicide applications on a calendar schedule reduced severity and defoliation, and resulted in higher yield.

Disease progress rate

Disease progress rate showed significant difference among the varieties and fungicide treatments both at Babile and Dire Dawa. The varieties by spray intervals interactions effect were not significant at the 5% probability level. Therefore, the main effects (varieties and spray intervals) were used for comparison of the rates (Table 2). Leaf spot developed at different rates on the varieties. At Babile, the fastest leaf spot progress (0.042 units per day) occurred on the variety Betisedi while the slowest progress was from the variety Werer-962 (0.033 units per day). The varieties Betisedi and Oldhale were not significantly different from each other in terms of disease development rate. At Dire Dawa, the rate of disease development was relatively slower. Leaf spot increased by 0.030, 0.029 and 0.017 units each day on the cultivar Betisedi, Oldhale and Werer-962, respectively. The moderately resistant variety Werer-962 reduced the rate of disease development consistently over the locations. Johnson and Beute (1986) reported that reduced infection rates may delay the onset of defoliation beyond some critical point in host development and yield accumulation. The ultimate value of partial resistance to control of groundnut leaf spot was as a means to reduce fungicide use (Gorbet et al., 1982).

The fungicides spray intervals also created very significantly variable (P<0.001) rates of leaf spot development. The fastest disease progress was observed on unsprayed plots than on sprayed plots as shown by the results at

Table 2. Disease progress rate of *Cercospora* leaf spot on three groundnut varieties sprayed with chlorothalonil and carbendazim at Babile and Dire Dawa in 2010 main cropping season.

Treatment	**Disease progress rate (units/day)**	
Cultivars	**Babile**	**Dire Dawa**
Oldhale	0.040	0.029
Betisedi	0.042	0.030
Werer-962	0.033	0.017
Mean	0.038	0.026
LSD (0.05)	0.005	0.007
Spray Interval		
Chl 7-days	0.015	0.010
Chl 14-days	0.031	0.028
Chl 21-days	0.043	0.027
Carb 14-days	0.028	0.035
Carb 28-days	0.041	0.022
No spray	0.072	0.031
Mean	0.038	0.026
LSD (0.05)	0.007	0.010

Chl = chlorothalonil and Carb = carbendazim

both locations. At Babile, leaf spot epidemics developed at 0.072 units per day on unsprayed plots (Table 2). This rate is about five times faster than the rate on plots sprayed chlorothalonil every 7-days interval (0.015 units per day). This indicated that leaf spot development was at much higher rate on unsprayed check plots as compared to other spray intervals. At Dire Dawa also, the lowest disease progress rate was obtained from plots sprayed fungicides and from the variety Werer- 962 (Table 2). The finding of this study is in agreement with that of Beard et al. (2004) who reported that application of fungicide can retard the rate of disease progress. Application of fungicides consistently resulted in greater groundnut yields and biomass as compared to untreated control (Nutsugah et al., 2007).

Seed yield

Interactions between effects of varieties and foliar spray intervals showed very highly significant ($P < 0.001$) differences in terms of seed yield at Babile but not at Dire Dawa. At Babile, the highest yield (1750.8 kg/ha) was obtained from plots sprayed chlorothalonil at 7-days interval of the variety "Werer-962" while the lowest yield (687.9 kg/ha) was from unsprayed plots of the variety "Betisedi" (Table 3). Fungicides spray at different intervals also significantly varied seed yield harvested from the variety "Betisedi". This result indicates the yield of susceptible variety "Betisedi" decreased as the intervals between sprays increased. However, the yields obtained from different spray treatments of the moderately resistance variety Werer-962 were not significantly different from each other except yield of unsprayed plots. This means all fungicides intervals increased yields of this variety almost in the same amounts. Our finding also agree with that of Gorbet et al. (1990) who reported that moderate resistance cultivars gave little or no additional yield response when the fungicide schedule was intensified from 20 to 10-days. Gorbet et al. (1982) also stated that there is no difference in yields between applications of chlorothalonil at 14 and 20-days intervals. The ability to use pyraclostrobin at 21-days intervals and maintain control of early leaf spot similar to that of application of currently available fungicides at 14-day intervals represents potential savings in time, fuel, labor and equipment costs (Culbreath et al., 2002).

At Dire Dawa, however, *Cercospora* leaf spot appeared at the end of the season (about 75 DAP) on all disease resistant and susceptible varieties and it did not cause serious leaf defoliation up to the time of harvest. Due to these reasons, significant differences were not detected in yield among fungicide treatments. However, the varieties significantly differed in their seed yield and, this might be due to their differences in genetic makeup level. The highest seed yield (1108.8 kg/ha) was obtained from the variety "Werer-962" while the lowest seed yield (895.4 kg/ha) was obtained from Betisedi. The yield obtained from Werer-962 was not significantly different from the yield of Oldhale. The yield losses caused by leaf spot are mainly because of decrease in photosynthetic leaf area caused by necrotic spots and defoliation (Boote et al., 1980; Bourgeois and Boote, 1992; Naab et al., 2005). The time of leaf spot diseases occurrence depends on the weather conditions and the field cropping history (Virginie, 1999).

In general, seed yield harvested from fungicide sprayed plots was consistently greater than the yield harvested from unsprayed plots. The highest yield was obtained from fungicide sprayed plots of moderately resistant variety when compared with the yield of susceptible varieties. Therefore, integrated use of host resistance and foliar applications of fungicides are recommended to reduce the epidemic level of *Cercospora* leaf spots and to achieve optimum yield of groundnut.

Conflict of interest

The authors did not declare any conflict of interest.

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Table 3. The effect of integrated use of host resistance and fungicide treatments on the yield of groundnut at Babile and Dire Dawa in 2010 main cropping season.

Treatment		Seed yield (kg/ha)	Treatments	Seed Yield (kg/ha)
Cultivars	Spray Intervals	Babile	Cultivars	Dire Dawa
Oldhale	Chl 7-days	1658.3	Oldhale	1049.9
	Chl 14-days	1590.1	Betisedi	895.4
	Chl 21-days	1475.1	Werer-962	1108.8
	Carb 14-days	1430.9	Mean	1018.0
	Carb 28-days	1413.4	LSD (0.05)	130.2
	No spray	974.1	Spray Intervals	
Betisedi	Chl 7-days	1504.0	Chl 7-days	1030.6
	Chl 14-days	1476.1	Chl 14-days	1019.0
	Chl 21-days	993.7	Chl 21-days	1017.9
	Carb 14-days	1324.1	Carb 14-days	1014.0
	Carb 28-days	1054.2	Carb 28-days	1020.6
	No spray	687.9	No spray	1006.2
Werer-962	Chl 7-days	1750.8	Mean	1018.0
	Chl 14-days	1700.4	LSD (0.05)	184.18
	Chl 21-days	1685.4	CV (%)	18.9
	Carb 14-days	1681.7		
	Carb 28-days	1631.4		
	No spray	1167.9		
Site Mean		1400.0		
LSD (0.05)		131.54		
CV (%)		5.7		

Chl = Chlorothalonil and Carb = Carbendazim.

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REFERENCES

Abraham T (2009). Increasing Crop Production through Improved Plant Protection-Volume II. Plant Protection Society of Ethiopia (PPSE). PPSE and EIAR, Addis Ababa, Ethiopia. 263p.

Backman PA, Crawford MA (1984). Relationships between yield loss and severity of early and late leaf spot disease of peanut. Phytopathol. 74:1101-1103.

Beard C, Jayasena K, Thomas G, Loughman R (2004). Managing Stem Rust of Wheat. Plant Pathology, Department of Agriculture, Western Australia.

Boote KJ, Jones JW, Smerage GH, Barfield CS, Berger RD (1980). Photosynthesis of peanut canopies as affected by leaf spot and artificial defoliation. J. Agron. 72:247-252.

Bourgeois G, Boote KJ (1992). Leaflet and canopy photosynthesis of peanut affected by late leaf spot. Agron. J. 84:359-366.

Brenneman TB, Culbreath AK (2000). Peanut disease control. Pp. 96-97. In: "2000 Ga. Pest Control Handbook" (Guillebeau, P. ed.). Univ. Ga. Coop. Ext. Serv. Special Bull. 28. 20p.

Butler DR, Wadia KDR, Jadhav DR (1994). Effects of leaf wetness and temperature on late leaf spot infection of groundnut. Plant Pathol. 43:112-120.

Culbreath AK, Stevenson KL, Brenneman TB (2002). Management of late leaf spot of peanut with benomyl and chlorothalonil: A study in preserving fungicide utility. Plant Dis. 86:349-355.

Culbreath AK, Brenneman TB, Kvien CK (1992). Use of a resistant peanut cultivar with copper fungicides and reduced fungicide applications for control of late leaf spot. Crop Prot. 11:361-365.

FAO (2007). Food and Agricultural Organization of the United Nation, FAO Statistical Database http://faostat.fao.org/faostat/collections?subset=agriculture.

Geleta T, Sakhuja PK, Swart WJ, Tana T (2007). Integrated management of groundnut root rot using seed quality and fungicide seed treatment. Inter. J. Pest Manag. 53(1):53-57.

Gorbet DW, Knauft DA, Shokes FM (1990). Response of peanut genotypes with different levels of leaf spot resistance to fungicide treatments. Crop Sci. 30:539-533.

Gorbet DW, Shokes FM, Jackson LF (1982). Control of peanut leaf spot with a combination of resistance and fungicide treatment. Peanut Sci. 9:87-90.

Hagan AK, Campbell HL, Bowen KL, Pegues M (2006). Evaluation of calendar and AU-Pnuts fungicide schedules for the control of late leaf spot and rust on peanut in southern Alabama. Alabama Agric. Exp. Stn. Bull. 663. 15 p.

Johnson CS, Beute MK (1986). The role of partial resistance in the management of *Cercospora* leaf spot of peanut in North Carolina. Phytopathol. 76:468-472.

Kishore GK, Pande S, Harish S (2007). Evaluation of essential oils and their components for broad-spectrum antifungal activity and control of late leaf spot and crown rot diseases in peanut. Plant Dis. 91:375-379.

Madden LV, Hughes G, Van den Bosch F (2008). The Study of Plant Disease Epidemics. The Am. Phytopathol. Soc. St. Paul, Minnesota, USA.

Mali GV, Bodhankar MG (2009). Antifungal and phytohormone production potential of Azotobacter chroococcum isolates from groundnut (*Arachis hypogaea* L.) Rhizosphere. Asian J. Exper. Sci. 23(1):293-297.

Mitiku H (1989). Description of selected physio-chemical properties of the soil at Babile. Soil Section Research Progress Report, Alemaya

University of Agriculture, Ethiopia.
MoARD (Ministry of Agriculture and Rural Development) (2009). Animal and Plant Health Regulatory Directorate. Crop Variety Register Issue No. 12. June, 2009, Addis Ababa, Ethiopia. 123p.
Mukankusi C, Adipala E, Kyamanywa S, Epieru G, Warren H, Wilson HR, Odeke V (1999). Efficacy and economic benefit of different chemical spray regimes on the management of the major pests and diseases of groundnut in eastern Uganda. Afr. J. Plant Prot. 9:69-81.
Naab JB, Tsigbey FK, Prasad PVV, Boote KJ, Bailey JE, Brandenburg RL (2005). Effects of sowing date and fungicide application on yield of early and late maturing peanut cultivars grown under rain fed conditions in Ghana. Crop Prot. 24:325-332.
Nutsugah SK, Abudulai M, Oti-Boateng C, Brandenburg RL, Jordan DL (2007). Management of Leaf Spot Diseases of Peanut with Fungicides and Local Detergents in Ghana. Plant Pathol. J. 6(3):248-253.
Nutter FW, Shokes FM (1995). Management of foliar diseases caused by fungi. In: Peanut Health Management. Hasan A, Melouk HA, Shokes FM (eds.), pp. 65-73. Am. Phytopathol. Soc. St. Paul, Minnesota.
Pande S, Narayana RJ, Upadhyaya HD, Lenne JM (2001). Farmers participatory integrated management of foliar diseases of groundnut. Inter. J. Pest Manag. 47:121-126.
Shaner E, Finney RE (1977). The effect of nitrogen fertilization on the expression of slow mildewing resistance in Knox wheat. Phytopathol. 67:1051-1056.
Shokes FM, Culbreath AK (1997). Early and Late Leaf Spots. In: Compendium of Peanut Diseases, Kokalis-Burelle N, Porter DM, Rodriguez-Kabana R, Smith DH, Subrahmanyam P (Eds.), 2nd Ed. Am. Phytopathol. Soc., St. Paul, MN, USA, pp. 17-20.
Shokes FM, Gorbet DW, Sanden GE (1982). Effect of planting date and date of spray initiation on control of peanut leaf spot in Florida. Plant Dis. 66:574-575.
Smith DH, Pauer GDC, Shokes FM (1992). Plant disease of international importance. Diseases of Vegetables and Oil seed. 232p.
Subrahmanyam P, McDonald D, Waliyar F, Reddy LJ, Nigam SN, Gibbons RW, Rao VR, Singh AK, Pande S, Reddy PM, Subba-Rao PV (1995). Screening methods and sources of resistance to rust and late leaf spot of groundnut. ICRISAT Information Bull. no. 47.
Tadele T, Tana T (2002). Agronomic performance of sorghum and groundnut cultivars in sole and intercrop cultivation under semiarid conditions. J. Agron. Crop Sci. 188:212-218.
Tana T, Schutz W, Milberg P (2002). Germination ecology of the weed *Parthenium hysterophorus* in eastern Ethiopia. Annal Appl. Biol. 140:263-270.
Teklemariam W, Asfaw T, Mesfin T (1985). Review of Research on oil crop disease in Ethiopia. Pp. 292-312. In: Tsedeke A. (ed.). A review of Crop Protection Research in Ethiopia, proceedings of the first Ethiopian crop protection system, 4-7 February 1985, IAR, Addis Ababa, Ethiopia.
Van der plank JE (1963). Plant diseases: Epidemics and control. New York. Academic press, 334p.
Virginie MA (1999). Use of Weather-based Modeling for Disease Management of Early Leaf Spot of Peanut and Glume Blotch of Wheat. M.Sc. Thesis, North Carolina State: North Carolina State University.
Weeler JB (1969). An introduction to plant diseases. Wiley, London, 347p.