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Effect of Intercropping on Potato Late Blight, *Phytophthora infestans* (Mont.) de Bary Development and Potato Tuber Yield in Ethiopia

Bekele Kassa[1] and Tharmmasak Sommartya[2]*

ABSTRACT

The study assessed the effect of intercropping on potato late blight, *Phytophthora infestans* disease epidemiology and potato tuber yield. The experiment was conducted at two locations in Ethiopia. Potato *Solanum tuberosum* (L) was intercropped with garlic, *Allium sativum* (L), at the ratios of 1:1; 1:2; 1:3; 2:1 and 3:1 plant population. These treatments were compared with fungicide (Dithane M-45) sprayed and unsprayed monoculture potato plant with respect to disease development and potato tuber yield. An improved potato variety (Wechecha), CIP-392640.513 clone and local susceptible variety were used for the study. The experiment was conducted in two factorial randomized complete block design with three replications. The results prevailed that, all potato-garlic ratios exhibited superior performance when compared to the fungicide unsprayed treatment. Among the proportions, 75 % garlic with 25 % potato (3:1) intercropped plots showed significantly ($p< 0.05$) low disease development and high tuber yield. Moreover, at 3:1 combination of garlic to potato the land equivalent ratio (LER) was greater than 1 and the monetary values were high at both testing sites. Significant ($p< 0.05$) differences were also observed among potato varieties with regards to the disease development and tuber yield. The study also demonstrated that fungicide treatment provided significant low ($p<0.05$) disease development and higher potato tuber yield when compared to the untreated monoculture control treatment. The findings of this study suggested garlic as a potential intercropping plant for the management of potato late blight disease under Ethiopian condition.

Key words: *Phytophthora infestans*, late blight, development intercropping, potato, *Solanum tuberosum* (L) garlic, *Allium sativum* (L), Ethiopia

INTRODUCTION

Late blight caused by *Phytophthora infestans* (Mont.) de Bary is the most widespread throughout the world and causes serious tuber losses globally (Erwin and Ribeiro, 1996; Fry and Goodwin, 1997; Garrett *et al*., 2001). In Ethiopia, the disease has been reported as the most destructive and economical disease on potato (Kassa and Hiskias, 1996). Though the effort made by researchers to reduce the effect of the disease on tuber yield is encouraging, still the loss is very tremendous (Tarekegne and Kassa, 1997). Because of many reasons as indicated by various

[1] Holetta Agricultural Research Center; Ethiopian Agricultural Research Organization (EARO) P.O.Box 2003, Addis Ababa, Ethiopia, E-mail: BEKELEKK@yahoo.com

[2] Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand.

* Corresponding author, e-mail: taam_ma_sak@yahoo.co.uk.

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researchers (Davidse *et al*., 1989; Schiessendoppler, 2003), researchers have been forced to seek other option which can exclude chemical fungicides in the management of the disease.

In the central highland of Ethiopia, potato is a garden crop and intercropping with brassica at a lower population being an ordinary practice (Amsal and Bekele, 1997) but crop like garlic is also grown as a sole crop in the same garden. Of the various options available in the high altitudes, cropping systems, other than so many advantages related to intercropping mentioned elsewhere (Okigbo, 1979), disease problems is low in an intercropping production systems compared to sole cropping production system (Batra, 1962; Nickel, 1973). For pathogens like P*hytophthora* which mostly disperse by wind and rain (Robinson, 1976; Neiderhauser, 1991), interrupting with none host crop for a disease may physically interfere and be able to entrap the spores, thereby reduce the available inoculum (Garret and Munndit, 2000). Skelsey *et al*. (2005) in his report also showed the influence of host diversity on the development of epidemic.

Mixture of potato with garlic could also reduce the spread of late blight through inoculum dilution and /or inhibitory effects of volatile compounds (Cizcova *et al*., 2002) that possibly could create an environment hostile to the development of late blight in potato. Hence, primarily, garlic is widely grown in the highland production system as a garden crop mainly for market; secondly, intercropping can help reduce the disease effect and probably the volatile oil which the crop emit can change the micro climate to be hostile to the pathogen. Therefore, this study assessed the effect of intercropping potato with garlic at different proportions on potato late blight epidemic factors and tuber yield under field conditions.

MATERIALS AND METHODS

Location and soil types

The study was conducted at two locations in Ethiopia. The first set of experiment was carried out at Holetta Agricultural Research Center located 44 km west of Addis Ababa and positioned at 38^0 32' N 9^0 3' E at an altitude of about 2,400m.a. s. l. The soil at the experimental site was red, Nitosol with a pH 4.83 and contained 1.61 % C, 1.65 % K and 33.49 ppm P_2O_5. The second site of experiment was conducted on farmer's field located in Dendi Wereda, Galessa, an altitude of about 3,000 meters above sea level (masl).

Rainfall temperature and relative humidity

The rain fall pattern is mostly consistent and characterized by bimodal type. At both sites, the long rain season stretched from the month of June to September and the short rain period is from February to March. The experiment at both locations was undertaken during the long, rain season. The rain fall amount received, the minimum and maximum temperatures as well as the relative humidity of the sites during the growing period were conducive to the growth and development of the pathogen (Figure 1: A and B).

Crop species and cultivars

Three potato varieties (Wechecha ,CIP – 392640. 513 and local) and one locally grown garlic variety were used in the study. However, local farmer's variety which was highly susceptible to the disease was planted as a satellite plot. Wechecha is an improved variety (population A) with vertical resistant to potato late blight while CIP – 392640. 513 is a clone in pipe line (population B) with polygenic resistant to the disease. These two varieties were obtained from the potato research program and considered to be 100-120 day potato variety. On the other hand, a 120-140 day local garlic variety (ready for planting) was purchased from the local market, Ginchi, Ethiopia.

Crop combinations and design

Five proportions of garlic with potato (1:1; 1:2; 1:3; 2:1 and 3:1), sole potato with and without fungicide treatments and sole garlic were involved in the experiment. The experiment was conducted in nested factorial within randomized complete block design with three replications. The plot size was 7.2 m × 4.8m for main plot and 3.6m × 4.8m for the sub plot. Spacing between rows and intra rows were 80 cm × 40 cm and 40cm × 10cm for potato and garlic, respectively. Only the middle two rows were harvested for determination of fresh tuber and bulb yield. Sole potato plots, the treated ones with Dithane M-45 at a rate of 3 kg/ha were used as positive control while fungicide untreated, sole potato plots were served as overall control treatment. At both experimental sites, potato and garlic were planted in June 2004. Garlic

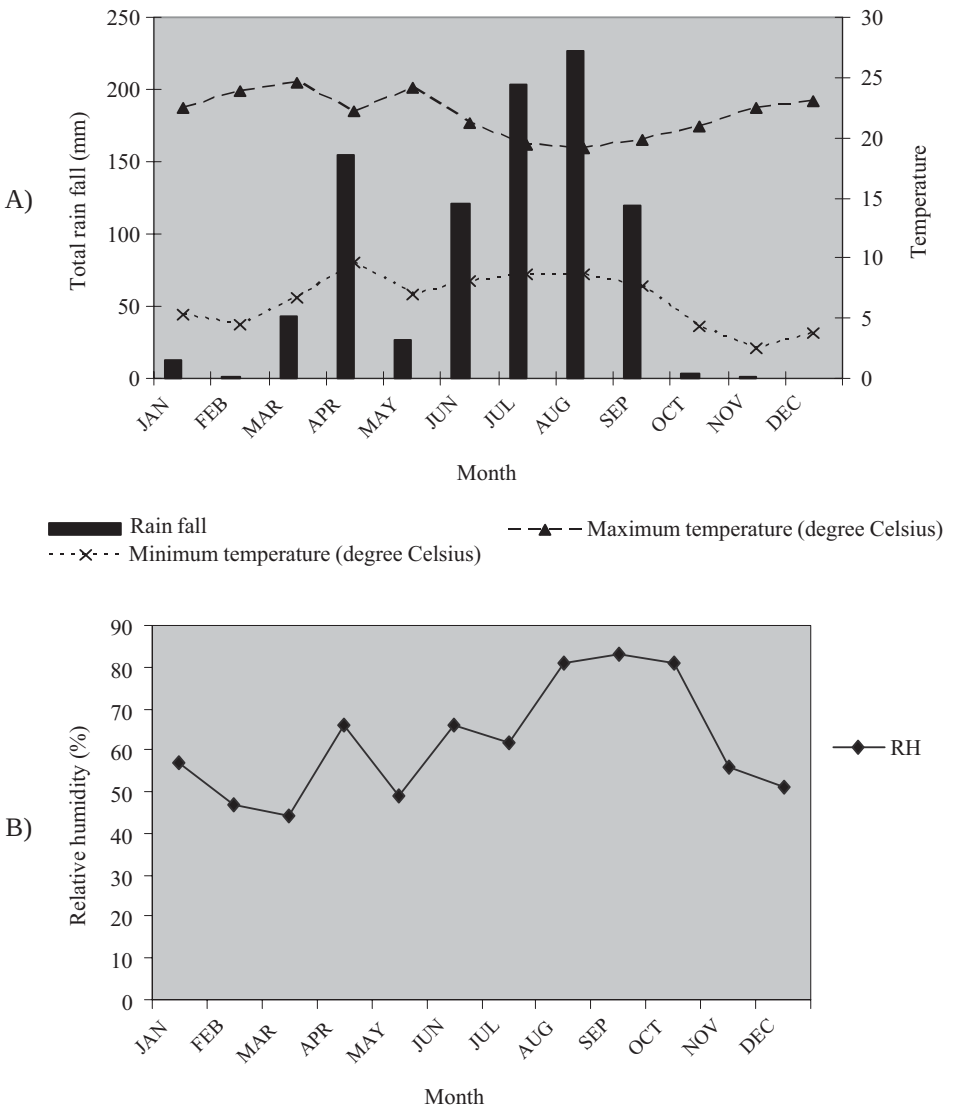

Figure 1 Environmental conditions during the experiment year: (A) monthly total rain fall and monthly average minimum and maximum temperature, (B) monthly average relative humidity.

fertilizer was side-dressed at a time of planting at the rate of 120 kg N/ha 113 kg N/ha and 89.7 kg P_20_5 /ha (Debre Zeit Agriculture Research Center, 1987) while for potato111 kg N/ha and 89.7 kg P_20_5 /ha (Holetta Agricultural Research Center, 1991) were derived from urea and DAP, respectively. Hilling and / harrowing were done 35 and 50 and 30, 50 and 80 days after planting for potato and garlic, respectively. To prevent the prevalence of rust disease on garlic crop at Holetta experimental site, fungicide (Tilt) was applied at a rate of 0.5 kg/ha product following the onset of the disease symptom (Getachew and Asfaw, 2000).

Disease assessment

Late blight was recorded based on percent leaf area infected at seven-day intervals starting from the onset of the first symptom for five times (Jan, 1987). In order to estimate the severity of the disease, disease data were integrated into area under the disease progress curve (AUDPC) as described by Shaner and Finney (1977). Some epidemiological indicators, such as lesion number and lesion size on five tagged plants from each plot, were collected when the disease progress reached maximum (53-61 days after emergence). Data on apparent infection rate (r) was generated and disease progress was plotted against time. Analysis of variance (ANOVA) was done with statistical package SAS (Little *et al.*, 1996). When appropriate, percent disease severity data were transformed following Gomez and Gomez (1994).

Economic analysis

Economic analysis was done using the workbook developed by CIMMYT (1998). Analysis of partial budget and marginal rates of return were done for each of the intercropping treatments to estimate the monetary value and relate with disease impact on the yield of potato. The costs of different inputs and cultural practices varied for each component crop were considered. The gross income was calculated based on the current price in the local markets. The exchange rate in 2004, which was US$1= Ethiopian Birr 8.62 was used.

Land equivalent ratio

Yield of component crops were harvested at the same time on November 5th at Holetta and November 20th at Galessa. The middle two rows from each plot were harvested and the fresh tuber and bulb weights were adjusted to ton per hectare. In order to measure the degree of which the potato with garlic proportion in the intercrops gave a higher return to land area than the pure stands, the land equivalent ratio (LER) and monitory value of the product was estimated following Mead and Willey (1980).

RESULTS

Late blight disease progress per treatment with time are shown in Figure 2A and B at Holetta and in Figure 3A and B at Galessa. At both sites, the local variety is highly susceptible to the disease, had significantly ($p<0.001$) highest disease severity compared to the remaining treatments (Figure 2A and B and Figure 3A and B). The local variety considered as satellite plot was totally distracted just two weeks after emergence because of the late blight disease pressure. Hence, it was excluded in the result and discussion part. Though up to the third disease assessment days, the disease progress on the fungicide unsprayed of sole potato treatments were not significantly faster in both varieties, then after, the progress of the disease was faster particularly on the polygenic resistant CIP-392640.513 clone compared to variety Wechecha. At Holetta at the end of the assessment day on unsprayed sole potato of CIP clone plot, the severity reached 75 %, whereas on Wechecha the maximum recorded was only 40 % severity. In general, potato with garlic intercropped treatments had lower disease progress compared

to the sole fungicide unsprayed treatment in both varieties and the 3:1 garlic with potato proportion treatment was comparable to the treatment with the fungicide control treatment. This reflected on the correlation coefficient of total tuber yield to the epidemic of the disease ($R^2 = 0.89$).

Data on potato late blight epidemic factors across the testing sites are presented in Table 1. The results obtained at Holetta experimental site showed significant difference ($p < 0.05$) between the varieties in terms of lesion number, AUDPC and r, however, the difference in lesion size were not significant (Table 1). The difference between potato with garlic proportion treatments and sole potato (with out fungicide control) treatment was significantly higher ($p < 0.05$) with respect to all parameters considered except lesion number. The ranges of lesion number were between 23.5 and 3.5 and were recorded in 1:3 and 1:0 (with fungicide control) garlic with potato proportions, respectively. The lowest lesion number, lesion size, AUDPC and r were recorded

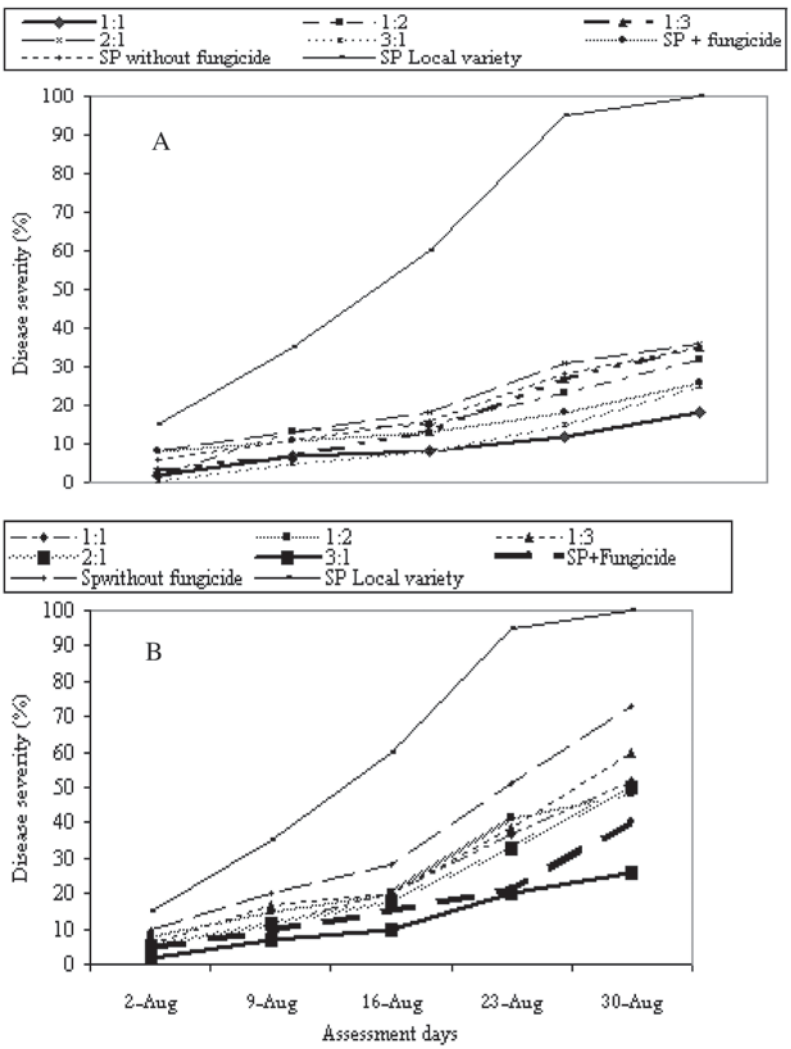

Figure 2 Late blight progress on (A) variety Wechecha (B) CIP-392640.513 clone and local susceptible variety as a check at Holetta.

in 1:0 sole potatoes control with fungicide treatment followed by 3:1 garlic potato proportion except the AUDPC. Potato-intercrops consisting of only 25 % potato provided significantly lower average lesion size when compared to the remaining potato with garlic proportions and sole potato without fungicide treatment except 1:1 proportion (Table 1). There was no difference in lesion number among treatments except 1:0 (with fungicide control) treatment that differed significantly.

Significantly higher tuber weight was obtained at 75 % garlic and 25 % potato intercrops (Table 2). The study also indicated differences between potato varieties with regard to disease development and marketable tuber weight. Improved potato variety (Wechcha) showed reduced disease development and higher tuber weight compared to the polygenic resistant clone. Moreover, the result revealed that the reduced fungicide use in field resistant variety of potato provided better control of the disease and higher

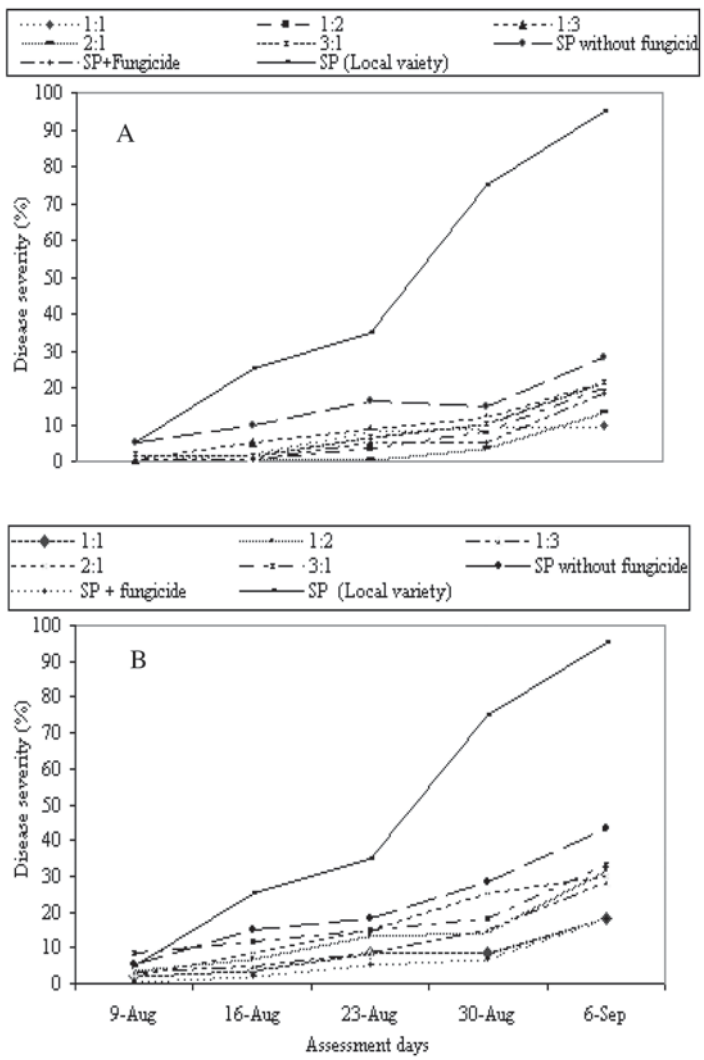

Figure 3 Late blight progress on (A) variety Wechecha (B) CIP-392640.513 clone and local susceptible variety as a check at Galessa.

tuber yield than the untreated control treatment.

The results of the on-farm experiment at Galessa, followed similar trend to the conditions reviled at Holetta. However, the disease pressure recoded particularly on the CIP clone was lower than expected (Table 1). Significantly ($p< 0.05$) low r on CIP clone was recorded compared to the improved variety, Wechecha but the difference in AUDPC between these two varieties was not significant. Regarding the local variety planted as a satellite plot for comparison, it could not withstand the disease pressure and was wiped out as early as 23 days after emergence. A significantly higher ($p< 0.05$) average AUDPC and r was observed in 1:0 (with fungicide) treatment compared to 1:0 (without fungicide) treatment. A significant ($p < 0.05$) increase in r was observed when the proportions of potato in the intercrop increased from 50 to 75 %, and 66 to 75% (Table 1). Similarly, the average disease severity expressed in AUDPC had slight increment at 75% potato intercrops; however, this increment was not significant. On the other hand, when the proportion of garlic increased in the intercropping from 50 to 75 % and 66 to 75 % r was significantly ($p < 0.05$) reduced at both sites.

Table 1 Mean lesion numbers, lesion sizes, areas under the disease progress curve (AUDPC) and apparent infection rates (r) at Holetta and Galessa (Ethiopia) for two varieties and seven component crop proportions as an alternate intercrop in the 2004 crop season.

Holetta	Variety	Lesion number	Lesion size	(AUDPC)	r
	Wechecha	13.1^{b}*	2.7^{a}	605.7^{b}	0.068^{b}
	CIP-392640.513	20.6^{a}	2.8^{a}	918.9^{a}	0.054^{a}
	Crop proportion				
	1:1**	16.3^{a}	2.6^{a}	760.4^{d}	0.070^{bc}
	1:2	16.3^{a}	3.1^{ab}	911.8^{ab}	0.061^{bc}
	1:3	23.5^{a}	3.3^{a}	790.0^{bc}	0.095^{ab}
	2:1	21.0^{a}	3.0^{ab}	685.7d^{ef}	0.077^{bc}
	3:1	15.8^{a}	2.0^{c}	706.4^{cde}	0.050^{bc}
	1:0 (WF)	5.3^{b}	1.7^{d}	588.7^{defg}	0.001^{d}
	1:0 (WOF)	19.5^{a}	3.1^{ab}	928.7$_{a}$	0.120^{a}
Galessa	Variety				
	Wechecha	-	-	161.0^{a}	0.079^{b}
	CIP-392640.513	-	-	284.4^{a}	0.0562^{a}
	Crop proportion	-	-		
	1:1	-	-	154.4^{a}	0.0743^{abc}
	1:2	-	-	244.8^{a}	0.0690^{bc}
	1:3	-	-	261.0^{a}	0.1121^{a}
	2:1	-	-	204.7^{a}	0.0815^{ab}
	3:1	-	-	258.0^{a}	0.0536^{cd}
	1:0 (WF)	-	-	105.9^{b}	0.0053^{e}
	1: 0 (WOF)	-	-	336.3^{a}	0.0834^{bcd}

* Means in the columns followed by the same letter are not significantly different at 5 % level in Duncan's multiple range tests. **1:1; 1:2; 1:3; 2:1; 3:1= the proportion of potato (*Solanum tuberosum* (L)) with Garlic (*Alium sativum* (L) [1] 1:0 (WOF) and 1:0 (WF) = Sole potato without fungicide spray and sole potato with fungicide, respectively. Dithane M-45 was applied at a rate 3 kg/ha ones.. The rate is the recommended rate to use in the integrated management of the disease.

Table 2 Mean tuber yields as influenced by variety and component crop proportion in intercrops at Holetta and Galessa (Ethiopia) in 2004 crop season.

Location		Tuber weight (gm)								Tuber yield t/ha							
Holetta	**Variety**	1:1	1:2	1:3	2:1	3:1	WOF	WF	Mean	1:1	1:2	1:3	2:1	3:1	WOF	WF	Mean
	Wech.*	36.4	33.8	45.0	50.7	153.4	27.2	20.1	49.2^{a}	3.9	4.0	8.5	4.1	3.4	9.3	5.1	5.5^{a}
	CIP	17.15	26.1	26.4	25.8	97.2	24.6	13.0	33.0^{a}	2.1	3.1	5.1	1.3	3.2	13.2	3.3	4.6^{b}
	Mean	26.3^{b}**	30.3^{b}	35.7^{b}	38.3^{b}	116.2^{a}	25.9^{b}	16.8^{b}	-	3.0^{c}	3.5^{c}	6.8^{b}	2.7^{c}	3.4^{c}	11.2^{a}	4.2^{bc}	-
	Variety																
Galessa	Wech.	40.3	54.8	29.4	23.6	31.5	32.7	33.8	35.2b	4.3	5.5	10.0	2.3	5.6	16.6	15.7	7.5^{b}
	CIP	53.3	72.1	75.4	54.3	78.8	61.4	82.1	68.2a	8.0	10.0	19.9	3.2	2.6	24.8	20.1	11.7^{a}
	Mean	46.8^{a}	63.4^{a}	52.4^{a}	38.9^{a}	55.1^{a}	47.0^{a}	57.9^{a}	-	6.0^{e}	7.6^{d}	14.9^{c}	2.8^{g}	4.1^{f}	20.3^{a}	17.9^{b}	-

**Wech. - To be specified as variety Wechcha and CIP for the clone CIP- 392640. 513

* Means in the rows and columns followed by the same letter are not significantly different at 5 % level in Duncan's multiple range tests. *1:1; 1:2; 1:3; 2:1; 3:1= the proportion of potato (*Solanum tuberosum* L) with garlic (*Alium sativum* L) [1] 1:0 (WOF) and 1:0 (WF) = monoculture potato without fungicide spray and monoculture potato with fungicide (Dithane M 45) at a rate 3 kg/ha ones respectively. The rate is the recommended rate to use in the integrated management of the disease.

Tuber weight and yield of potato in intercrops are presented in Table 2. The separate analysis of variance showed that there were highly significant ($p \leq 0.001$) differences between treatments (Table 3). The yield of potato increased with increasing proportion of the plant ratio in the intercrop. Similarly, fungicide treatment provided higher tuber yield when compared with the fungicide unsprayed treatments, both at Holetta and at Galessa sites.

At Holetta, higher tuber yield (5.5 t/ha) was obtained from Wechecha compared to CIP clone that gave significantly lower yield (4.6 t/ha) (Table 2). However, at Galessa the CIP clone gave significantly higher yield (11.2 t/ha) compared to Wechecha, which gave 7.5 t/ha. The total yield obtained from the intercropped plot of 1:3 garlic with potato proportions, was higher compared to the other proportions tested at both sites (Table 2). This yield advantage was also supported by land equivalent ratio (Table 3). However, at Holetta, tuber yield of the remaining treatments ranged from 2.7, to 3. 5 t/ha and there were no significant differences among these proportions, whereas at Galessa, differences among the various proportions were apparent.

The land equivalent ratio (LER) and monetary value are presented in Table 3. At both sites except 1: 2 garlic potato proportion the LER were ≥ 1 and gave higher monetary value (Table 3). At Holetta the LER was ranging from 0.884 to 1.520 whereas at Galessa the range was from 0.929 to 2.492. The lowest LER in this study probably related to the general low yield performance of garlic in the experiment. The monetary values obtained in the intercropping treatments were much higher compared to sole potato treatment at both sites. At Holetta, intercropping of potato with garlic gave in the ranges of 28 to 54 % monetary value over sole potato treatment. The same trend was also observed at Galeesa site and gave in the ranges of 17 % to 38 % over sole potato.

DISCUSSION

The result of the study showed that generally potato with garlic intercropped treatments had lower disease progress compared to the sole potato without fungicide control treatment in both varieties and at both sites. This finding agreed with the findings of Skelsey *et al*. (2005) who indicated that host diversity reduced the development of epidemic. These reflected in terms of narrow lesion that could generate a little amount of spores (intercropped treatments) compared to broad lesions as it happened in monoculture potato without fungicide protection. At both sites, when the proportion of garlic in the intercropping increased from 50 to 75 % and 66 to 75 %, r was significantly ($p < 0.05$) reduced. The explanation for this might be, when the proportion of none host crop (garlic) to the disease increased, the available inoculum could reduced, thereby the focal epidemics and through time, general epidemic would be restricted (Andrivon, 2003). The results of the on-farm experiment at Galessa, followed similar trend to the conditions reviled at Holetta.

The separate analysis of variance for potato and garlic tuber and bulb yields showed that there were highly significant ($p \leq 0.001$) differences between treatments. Probably the explanation for this could be related to population increment of none host plant to the pathogen and increment of concentrations of the volatile oils that come out from garlic plant in the field which probably hindered the growth of the pathogen. Similar results were the reports of Cizcova *et al*. (2002) which said to inhibit tuber sprouting and reduce the number of rotten tubers in potato by placing garlic extract at the corner of storage facilities.

The total yield obtained from the

Table 3 Intercropping effects on the LER and monetary values at Holetta and Galessa (Ethiopia) in 2004 crop season.

Treatment	Tuber yield (t/ha)	Garlic yield (t/ha)			LER	Monetary value (USD)
Crop proportion			Potato	Garlic	Total	
Holetta						
0:1 (Potato)	6.0	-	1.0	-	1.0	-
1:1	3.9	0.8	0.650	0.288	0.938	382.0
1:2	4.2	0.5	0.700	0.179	0.879	288.3
1:3	8.5	0.3	1.417	0.107	1.524	451.1
2:1	3.7	1.1	0.617	0.392	1.009	387.8
3:1	4.0	1.9	0.667	0.679	1.346	547.8
1:0(Garlic)*	-	2.8	-	1.0	1.0	-
Galessa						
0:1(Potato)	7.6	-	1.0	-	1.0	-
1:1	7.7	0.9	1.013	0.290	1.303	293.7
1:2	8.2	0.7	1.079	0.226	1.305	294.0
1:3	18.2	0.3	2.395	0.097	2.492	135.0
2:1	3.8	1.3	0.500	0.419	0.919	177.7
3:1	4.4	2.0	0.579	0.645	1.224	383.0
1:0 (Garlic)	-	3.1	-	1.0	1.0	-

* 1:1; 1:2; 1:3; 2:1; 3:1 = the proportion of Potato (*Solanum tuberosum* L.) with Garlic (*Alium sativum* L.)

intercropped plot of 1:3 garlic with potato proportions was higher compared to the other proportions tested at both sites. This yield advantage was also supported by land equivalent ratio. Generally, the LER were ≥ 1 and gave higher monitory value. However, at Holetta, the LER in 1:1 and 1:2 garlic with potato ratio and at Galessa 1:3 garlic with potato ratios were less than 1. These low LER were probably related to the general low yield performance of garlic in the experiment due to poor soil fertility. However, the monetary values indicated that intercropping of garlic with potato helped to achieve higher monetary value than to grow potato alone. The study demonstrated the effect of intercropping garlic and potato on potato late blight disease development and yield of potato.

CONCLUSION

Growing potato with garlic as an intercrop could reduce the late blight severity, development of the disease and r that supported to give the highest tuber yield, efficient LER and better monitory value. The findings of this study recommended garlic as a potential intercropping plant for the management of potato late blight disease under Ethiopian conditions.

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