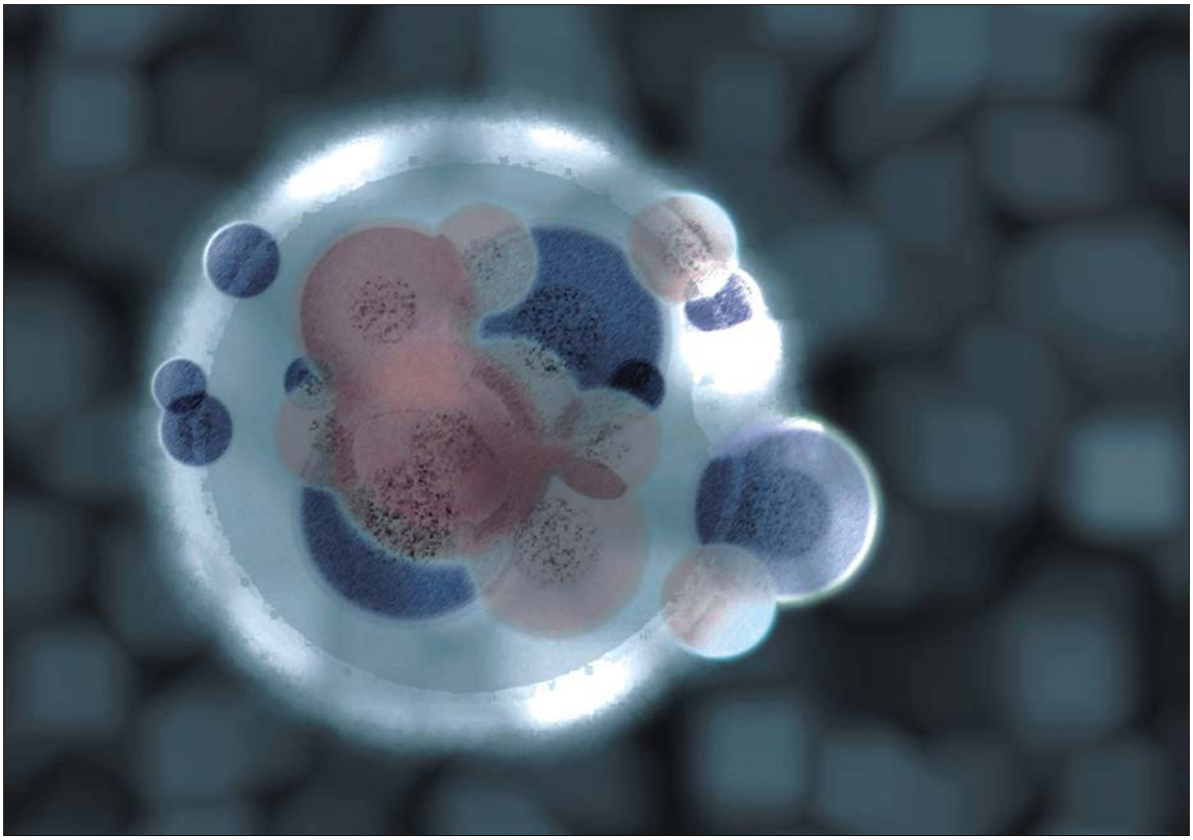

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Effect of Intercropping Bulb Onion and Vegetables on Purple Blotch and Downy Mildew

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Abstract: Field experiments were conducted over two growing seasons to determine the effectiveness of vegetable intercrops in the management of downy mildew (*Peronospora destrutor*) and purple blotch (*Alternaria porri*) of bulb onion. Vegetable intercrops evaluated, were carrot (*Daucus carota*), spider plant (*Cleome gynandra*) and French bean (*Phaseolus vulgaris*). The efficacy of the vegetable intercrops in reducing the foliar diseases was compared to a fungicide Tata Master™ (metalaxyl8%+mancozeb 64%). Each vegetable was intercropped with three onion varieties (Bombay Red, Red creole and Orient F1) and downy mildew and purple blotch development were determined until physiological maturity. Vegetable and bulb yields were also determined at harvest. The vegetable intercrops significantly reduced downy mildew and purple blotch severity but had no significant effect on disease incidence. Spider plant was the most effective vegetable intercrop in reducing downy mildew severity by up to 21% and purple blotch severity by 18%. Onion varieties Red creole and Bombay red had low disease levels compared to orient F1. Although intercropping onion with vegetables reduced bulb yield, it improved the gross return per unit area. The results showed that intercropping bulb onion with vegetables could be beneficial in reducing foliar diseases and improving gross return per unit area. However, further studies are necessary to determine the optimal spatial arrangements of onion and vegetable intercrops in foliar disease management.

Key words: Downy mildew, intercropping, onion, purple blotch, vegetables, yield

INTRODUCTION

Onion (*Allium cepa* L.), is the most important bulb crop grown for human consumption worldwide and it is among the most important horticultural crops (FAOSTAT, 2004; HCDA, 2008). In Kenya, onion is widely grown by both small-and large-scale farmers (HCDA, 2008). Onion contains a lachrymatic agent, a strong antibiotic in addition to fungicidal, bacterial, anti-cholestrol, anti-cancer and anti-oxidant components such as quercetin (Baghizadeh *et al*., 2009). In addition, it has been reported to be rich in phytochemicals especially flavonols which are medicinal (Javadzadeh *et al*., 2009). Onion production is limited by pests and diseases, erratic rainfall and declining soil fertility which result in yield reduction of about 15 tons ha^{-1}, against a potential of 45.5 tons ha^{-1} (Muendo and Tschirley, 2004). Downy mildew (*Peronospora destructor*) and purple blotch (*Alternaria porri)* are among the most important diseases of onion in Kenya, often causing total crop losses in favorable weather (Makelo, 2004; Jayakumar *et al*., 2008; Westcott, 2001; Schwartz, 2004). The diseases are primarily managed by application of chemical fungicides. However, success of chemical control mainly depends on high frequency of spraying (Abubakar and Ado, 2008a; Kucharek, 2004). In addition, increased frequency of chemical application leads to development of pathogen resistant strains and accumulation of residues in produce and environment resulting in risks to health, environment and non-target organisms (Burkett-Cadena *et al*., 2008). These concerns have led to regulation in the use of agrochemical thus providing an impetus to the search for alternative sustainable strategies.

Intercropping field vegetables with other crop species is increasingly gaining popularity as a potential alternative to the use of chemicals (Trdan *et al*., 2005a, b, 2006). Intercropping with commonly used vegetable crop fits into environmentally acceptable and sustainable crop production practices widely adopted by smallholder farmers. This concept entails growing two or more economic species together for at least a portion of their respective productive life cycle, planting them sufficiently close to each to allow for inter-specific competition (Kabura *et al*., 2008). Benefits of intercropping include, optimal use of resources, stabilization of yield, weed suppression, improved soil fertility conservation and higher economic returns (Blaser *et al*., 2007; Trdan *et al*., 2005a; Kabura *et al*., 2008). However, information on the

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role of intercropping on disease suppression is scanty. Therefore, the objective of this study was to evaluate the efficacy of intercropping bulb onion with other vegetables in the management of downy mildew and purple blotch.

MATERIALS AND METHODS

Experimental treatments design and lay out: Field experiments were carried over two growing seasons at the Faculty of Agriculture field station, University of Nairobi, between July 2008 and May 2009. The site is a hot spot for downy mildew and purple blotch of onion. The experimental design was randomized complete block design with split plot lay out. The three onion varieties (Bombay Red, Red creole and Orient F1) comprised the main plots of 4.5×6 m while the vegetable intercrops (carrot, spinder plant and French bean) comprised the subplots of 4.5×2 m. Two and a half month old onion seedlings were separately transplanted in the main plots at a spacing of 30×10 cm. Carrot (var. Nantes), spider plant and French bean (var. paulister) were separately intercropped with onion within the subplots such that one row of vegetable alternated four rows of onion. The intra-row spacing was 20 cm for French bean, 10 cm for carrot and 15 cm for spider plant. Control plots consisted of pure stand onion variety with and without fungicide Tata Master™. (metalaxyl 8%+ mancozeb 64%) applied at the rate of 3 kg ha^{-1} weekly. The vegetable intercrops were established before transplanting the onion. Guard rows of susceptible onion variety and volunteer plants infected with both downy mildew and purple blotch were allowed to grow around the experimental plots to provide inoculum. The plots were fertilized with di-ammonium phosphate at the rate of 80 kg N ha^{-1} at planting and top dressed with calcium ammonium nitrate (26% N) at the rate of 40 kg N ha^{-1}, 3 and 6 weeks after transplanting. Natural infection of onions by downy mildew and purple blotch was allowed to occur. Data collected included disease incidence and severity and yield of both onion and vegetables.

Downy mildew and purple blotch assessment: Recording of disease incidence and severity commenced at the onset of symptoms and was done weekly until physiological maturity of the crop. Downy mildew and purple blotch severity were assessed visually as the percentage leaf area diseased following assessment scales described by Ahmad and Khan (2002) and Kingiri (1993), respectively. Disease severity was evaluated on five alternate leaves of each of the ten plants picked at random from the inner rows of each plot making a total of 200 leaves from 40 plants per treatment. Disease incidence was determined by counting the number of diseased plants out of the total number of plants in each plot. The incidence data and severity was used to calculate the area under disease progress curve (AUDPC) according to Sparks *et al.* (2008).

$$\text{AUDPC} = \Sigma\, [\,(Y_{i+1} + Y_i)\,(0.5)\,(T_{i+1} - T_i)]$$

where, Y is disease incidence at time T and i are the time of the assessment.

Onion and vegetable yield assessment: Bending the necks cured the onion bulbs and the bulbs harvested when the foliage was dry. Bulbs from each plot were graded into marketable and non-marketable yield according to HCDA (1991) and each grade weighed separately. French bean pods and mature spider plant leaves were harvested weekly starting from 37 days and fourth week, respectively, after sowing. Carrot was harvested from 120 days after sowing and the total yield for each crop was extrapolated into kilograms per hectare. Gross return per hectare for each onion-vegetable intercrop or pure stand crop was determined by multiplying the average prevailing market price per kilogram and the respective yield per hectare as follows:

$$GR = (V_y \times V_p) + (B_y \times B_p)$$

Where:
GR = Gross return ha^{-1}
Vy = Vegetable yield (kg)
Vp = Vegetable price kg^{-1}
By = Onion bulb yield (kg)
Bp = Onion bulb price kg^{-1}

Data analysis: All data was subjected to analysis of variance (ANOVA) using Genstat computer software package (Lawes Agricultural Trust Rothamsted Experimental Station 2006, version 9). Means when significantly different were separated using the Fisher's protected LSD test at 5% probability level (Steel and Torrie, 1981).

RESULTS

Effect of vegetable intercrops on downy mildew: Intercropping onion with vegetables reduced downy mildew incidence and severity on all the three onion varieties (Table 1). However, only spider plant showed consistent and significant ($p \leq 0.05$) reduction of the disease incidence, severity and the area under disease progress curve (AUDPC) by up to 24.5% on all onion varieties (Table 2). Carrot and French bean significantly reduced downy mildew severity on Red creole and Orient

Table 1: Mean downy mildew incidence, severity and area under disease progress curve on three bulb onion varieties intercropped with different vegetables

	Downy mildew incidence (%)		
Treatment	Bombay red	Red creole	Orient F1
Pure stand alone	68.7	60.0	70.6
Pure stand+Fungicide	50.0	44.7	52.6
Onion+Carrot	67.6	56.7	65.4
Onion+French bean	65.9	55.1	66.4
Onion+Spider plant	51.8	45.0	53.6
$LSD_{Treatment}$ = 6.4			
$LSD_{Variety}$ = 1.3			
CV (%) = 3.6			
Pure stand alone	3.1	2.7	3.3
Pure stand+Fungicide	2.5	2.2	2.6
Onion+Carrot	2.8	2.7	3.0
Onion+French bean	2.9	2.5	3.1
Onion+Spider plant	2.7	2.4	3.0
$LSD_{Treatment}$ = 0.2			
$LSD_{Variety}$ = 0.1			
CV (%) = 1.6			
Pure stand alone	148.9	136.3	169.6
Pure stand+Fungicide	124.5	111.2	124.5
Onion+Carrot	143.9	137.4	155.9
Onion+French bean	147.8	124.3	159.2
Onion+Spider plant	138.0	123.7	154.7
$LSD_{Treatment}$ = 9.6			
$LSD_{Variety}$ = 8.6			
CV (%) = 7.7			

LSD: Least significant difference, CV: Coefficient of variation

Table 2: Mean percentage reduction in downy mildew and purple blotch on onion sprayed with fungicide or intercropped with vegetables

	Downy mildew			Purple blotch		
Vegetables	Incidence	Severity	AUDPC	Incidence	Severity	AUDPC
Fungicide	26.1	20.0	20.8	13.2	16.0	13.0
Carrot	4.8	6.7	3.9	-1.2	12.0	8.4
French bean	6.0	6.7	5.2	-0.5	12.0	9.8
Spinder plant	24.5	10.0	8.4	8.5	16.0	18.2

AUDPC: Area under disease progress curve

Table 3: Mean percentage incidence, severity and area under disease progress curve (AUDPC) of downy mildew and purple blotch on three onion varieties

	Downy mildew			Purple blotch		
Parameters	Bombay red	Red creole	Orient F1	Bombay red	Red creole	Orient F1
Incidence	60.8	52.3	61.7	83.8	79.5	83.8
Severity	2.8	2.5	3.0	2.2	2.2	2.3
AUDPC	140.6	126.6	152.8	91.0	92.1	98.3

AUDPC: Area under disease progress curve

F1. The AUDPC was significantly reduced on Orient F1 by all the vegetable intercrops but only French bean and spider plant had a significant effect on the AUDPC on variety Red creole (Table 1). The three onion varieties significantly differed in susceptibility to downy mildew, with Orient F1 showing the highest disease incidence, severity and the AUDPC (Table 1, 3). Variety Red creole was the least susceptible with up to 17% less disease compared to the Orient F1.

Table 4: Mean purple blotch incidence, severity and area under disease progress curve (AUDPC) on three bulb onion varieties intercropped with different vegetables

	Purple blotch incidence (%)		
Treatment	Bombay red	Red creole	Orient F1
Pure stand alone	87.1	82.0	87.6
Pure stand+fungicide	75.2	70.2	77.4
Onion+Carrot	88.0	85.4	86.5
Onion+French bean	89.3	81.5	87.2
Onion+Spider plant	79.4	78.4	80.1
$LSD_{Treatment}$ = 6.0			
$LSD_{Variety}$ = 1.2			
CV (%) = 1.3			
Pure stand alone	2.4	2.4	2.6
Pure stand+fungicide	2.2	2.0	2.2
Onion+Carrot	2.2	2.3	2.3
Onion+French bean	2.3	2.2	2.3
Onion+Spider plant	2.0	2.1	2.1
$LSD_{Treatment}$ = 0.1			
$LSD_{Variety}$ = 0.1			
CV (%) = 1.4			
Pure stand alone	99.7	104.1	108.4
Pure stand+fungicide	91.4	84.1	96.1
Onion+Carrot	92.0	96.2	97.8
Onion+French bean	95.3	87.7	98.8
Onion+Spider plant	76.8	88.3	90.4
$LSD_{Treatment}$ = 0.1			
$LSD_{Variety}$ = 0.1			
CV (%) = 1.4			

LSD: Least significant difference, CV: Coefficient of variation

Effect of vegetable intercrops on purple blotch: Only fungicide application and spider plant reduced purple blotch incidence compared to the untreated controls (Table 4). Among the three varieties, Bombay red and orient F1 had higher disease incidence compared to red Creole. Intercropping onion with vegetables significantly ($p \leq 0.05$) reduced purple blotch severity and AUDPC with spider plant having the highest reduction of up to 18% compared to the untreated controls (Table 3, 4). The three onion varieties differed in susceptibility to purple blotch, with Orient F1 showing significantly higher infection levels compared to Bombay red and Red creole.

Effect of vegetable intercrops on bulb onion yield: Bulb yield for all the three onion varieties was significantly ($p \leq 0.05$) reduced by intercropping with all the three vegetables (Table 5). Carrot showed the highest yield reduction of up to 60% followed by spider plant (47%) and French bean (29%) when compared to pure stand onion with fungicide application. Pure stand onion without fungicide application showed a reduction in bulb yield of up to 17%. A higher reduction in yield was observed in marketable bulbs compared to the total bulb yield. The reduction in bulb yield due to intercropping of onion with other vegetables was compensated by the additional yield from the vegetables resulting in higher gross return per hectare (Table 6).

Table 5: Total and marketable bulb yield (tons/ha) of three onion varieties intercropped with carrot, French bean and spinder plant as compared to pure stand and fungicide spray

	Total yield			Marketable yield		
Treatment	Bombay red	Red creole	Orient F1	Bombay red	Red creole	Orient F1
Pure stand alone	14.9	12.3	12.4	11.4	8.4	9.5
Pure stand+fungicide	15.9	12.6	13.5	13.4	9.2	11.0
Onion+Carrot	10.5	7.7	9.0	7.4	5.0	6.5
Onion+French bean	13.8	11.9	12.0	10.1	7.6	10.0
Onion+Spider plant	12.4	10.3	11.6	9.3	6.7	9.1
$LSD_{(p\leq 0.05)\ Treatment}$	3.4	3.4	3.4	3.2	3.2	3.2
$LSD_{(p\leq 0.05)\ Variety}$	1.1	1.1	1.1	1.3	1.3	1.3
CV (%)	14.6	14.6	14.6	25.0	25.0	25.0

LSD: Least significant difference, CV: Coefficient of variation

Table 6: Average return per hectare (KES) of bulb onion in pure stand or intercropped with other vegetables

Treatment	Intercrop	Bulb onion	Gross income
Pure stand alone	0	527,500	527,500
Pure stand+Fungicide	0	560,680	560,680
Onion+Carrot	265,632	207,160	472,792
Onion+French bean	254,735	301,480	556,215
Onion+Spider plant	247,000	282,200	529,200
$LSD_{(p\leq 0.05)}$	15,972.8	175,440.8	76,208.5
CV (%)	11.77	39.1	15.7

KES: Kenya Shillings, LSD: Least significant difference, CV: Coefficient of variation

DISCUSSION

This study has demonstrated that vegetable intercrops were effective in reducing downy mildew and purple blotch on onion. The results of the study agree with reports by Sahile *et al*. (2008) who demonstrated the suppression of chocolate spot (*Botrytis fabae)* on faba bean when intercropped with field pea, barley or maize. The reduction of downy mildew and purple blotch diseases on the onion crop may be attributed to reduction of the probability of fungal spores to encounter onion plants amongst the vegetable intercrops as indicated by Garrett and Mundt (1999). Studies by Ramert and Lennartsson (2002) have indicated that intercropping reduces the proportion of susceptible host tissues and, therefore, impacting on the production, amount and efficiency of the disease inoculum and, therefore, limiting spread and development of the disease. In addition, intercropping increases the space between the rows of onion crop, resulting in greater distance to be travelled by the disease inoculums. Further, the vegetable intercrops may have created a physical barrier that intercepted or filtered the fungal propagules, thus effectively limiting dissemination of the pathogen.

Among the intercrop species, spider plant showed the greatest suppression of both the downy mildew and purple blotch diseases on the onion crop. This is in agreement with Makelo (2004) who showed that spider plant possesses antifungal properties and its extracts inhibited the growth of *Alternaria porri*. The suppression of the diseases could also have been due to inherent allopathic effects in the spider plant (Maniania *et al*., 2002). Other factors that could have contributed to disease reduction include creation of unfavorable micro-climate that inhibited the foliar diseases on onion (Ramert and Lennartsson, 2002) and fungicidal properties in the spider plant (Makelo, 2004).

Onion variety Red creole was the least susceptible to both downy mildew and purple blotch diseases compared to varieties Bombay red and Orient F1. Similar genotypic variation between onion varieties has been reported by Abubakar and Ado (2008a, b), Malik *et al*. (2003) and Soumah and Keita (2004). The observed phenotypic variation among the onion varieties could be due to both genotypic and environment factors . Varietal differences have been shown to be due to inherent biochemical characteristics, such as quercetin levels, resulting to differences in bolting, marketable yields and disease susceptibility. Studies done in Uganda by Abubakar and Bakare (2008) showed genotypic variations among onion populations and indicated that Red creole was resistant to purple blotch.

Intercropping onion with the vegetables reduced both the total and marketable bulb yield. This is in agreement with findings by Trdan *et al*. (2006), Kabura *et al*. (2008) and Kucharczyk and Legutowska (2003), who reported that intercropping leek with carrot reduced yields. The reduction in yield could have been caused by the reduction in onion population and intercrop competition for nutrients, water and light (Ansari and Mamghani, 2008; Ofosu-Anim and Limbani, 2007). The reduction in bulb yield may be compensated by the yield from the vegetable intercrops and, therefore, no net loss to the farmer. In addition, the intercrop may act as buffer against total crop loss and diversifies the production. Therefore, the onion-vegetable intercrop would be suitable to small-scale farmers who do not have adequate resources for purchase of chemical fungicides. The system would also be very ideal for organic vegetable production, in which chemical application is not desirable. Apart from increasing total farm productivity, mixed species cropping can bring many important benefits such as improvement of soil fertility management and suppression of pests and/or diseases (Ramert and Lennartsson, 2002). Other benefits of intercrop system include erosion control, reduce leaching of nutrients, balanced distribution of labour and higher economic returns than sole cropping (Odo and Futuless, 2002; Blaser *et al*., 2007). In addition, the system would contribute to food and nutrition security for the small farmers by offering a continuous supply of vegetables during the growing season.

CONCLUSION

The study showed that intercropping bulb onion with spider plant would be beneficial in the management of downy mildew and purple blotch in small holder onion production systems. Although the intercrop would reduce onion bulb yield, the combined gross return per unit area would be comparable to that obtained in onion pure stand.

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