EFFICACY OF BASIL-CABBAGE INTERCROPPING TO CONTROL INSECT PESTS IN BENIN, WEST AFRICA

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SUMMARY

Cabbage (*Brassica oleracea* L.) is a common vegetable whose production is severely limited by insect pest pressure in Western Africa. This study was conducted during the dry and rainy season in south Benin to evaluate the potential of tropical basil (*Ocimum gratissimum* L.) for repelling cabbage pests (*Hellula undalis* Fabricius, *Plutella xylostella* L. and *Spodoptera littoralis* Boisduval). In a complete randomized block design with four replicates, the insect infestation was compared between three association modalities: (i) cabbage intercropped with tropical basil, (ii) cabbage plots surrounded by tropical basil and (iii) control (no basil in the cabbage area). The presence of tropical basil near cabbage plots significantly reduced insect pest abundance on cabbage. Damages were also less important on cabbage intercropped with tropical basil. Among both intercropping modalities, alternate rows showed the best results in terms of reducing pest populations and damages than compared to cabbage plots surrounded by tropical basil.

Key words: *Brassica oleracea,* intercropping system, Lepidopteran, *Ocimum gratissimum*, repellent plants, Sustainable pest management

INTRODUCTION

In West Africa, market gardening is one of the main sources of income for urban and periurban farmers (FAO, 2012). This sector plays an important role in food safety programs (De Bon *et al.,* 2010 *;* James *et al.,* 2010; Abdulkadir *et al.,* 2012) and contributes to the incomes of many families (Kanda *et al.,* 2009; Yolou *et al.,* 2015). Cabbage, *Brassica oleracea* L. (Brassicaceae) is one of the most cultivated vegetable crops in several West Africa countries (Asare-Bediako *et al.,* 2010 *;* De Bon *et al.,* 2010). In Benin, cabbage is produced in the entire national territory (Assogba Komlan *et al.,* 2012), but its production is heavily impacted by various pests among which Lepidopterans (*Hellula undalis* Fabricius, *Plutella xylostella* Linn. and *Spodoptera littoralis* Boisduval) are among the most damaging. Lepidopterans can reduce yields by 38 to 90% in absence of pest treatments (Asare-Bediako *et al.,* 2010). To counteract insect damages, farmers abusively use synthetic insecticides, leading to important health and environmental negative consequences (Kanda *et al.,* 2009 ; Ahouangninou *et al.,* 2012*;* Abou *et al.,* 2015). Pest resistance (Ninsin, 2015*;* Agboyi *et al.,* 2016), elimination of natural enemies (Ahmad *et al.,* 2011), pesticide residues in vegetables (Sæthre *et al.,* 2011*;* Atieno *et al.,* 2014*;* Biego *et al.,* 2015) are those many problems related to synthetic pesticides. Crop associations are among the possible alternatives that still remain to be improved. They have been shown in

some cases to reduce pest abundance by repelling pests or reducing their ability to locate appropriate host plants (Schader *et al.,* 2005*;* Björkman *et al.,* 2010*;* Zhang *et al.,* 2016).
Intercropping cabbage with other crops (*Cleomae gynandra* Linn., *Lycopersicum esculentum* Linn., *Coriandrum sativum* Linn., *Calendula officinalis* Promyk, *Tagetes patula nana* Kolombina) was previously suggested as efficient in reducing *P. xylostella* populations on cabbage (Ogol and Makatiani, 2007*;* Jankowska, 2010). Similar results were obtained for the management of other pests including *Brevicoryne brassicae* L. and *Zonocerus variegatus* L., *H. undalis* (Mochiah *et al*., 2011). Debra *et al.* (2014) reported that intercropping garlic or onion with cabbage reduced not only the pest prevalence but also minimized damages and improved yields. According to Tiroesele *et al.* (2015) intercropping *Ocimum basilicum* L. with cabbage has resulted in a significant decrease of aphid abundance in the intercropping plots. Other studies demonstrated that volatile organic compounds (VOCs) of various *Ocimum* species have a repellent effect on several pests (Kellouche *et al.,* 2010*;* Pugazhvendan *et al.,* 2012*;* Inbaneson *et al.,* 2012*;* Akono Ntonga *et al.*, 2014). *Ocimum* volatiles could also attract natural enemies of the target pest (Schader *et al.,* 2005*;* Mochiah *et al.,* 2011*;* Zhang *et al.,* 2016).
The objective of this study is to evaluate the potential of intercropping cabbage with tropical basil, *Ocimum gratissimum* L, to control populations of cabbage pests in Benin.

MATERIALS AND METHODS

Study site and chronogram

All experiments were carried out at the experimental site of the Vegetable Crop Program of the National Institute of Agricultural Research of Benin (6 ° 24 '35 "North, 2 ° 19' 55" East, South Benin). This site is characterized by a subequatorial climate with two rainy seasons (March to July and September to November) and two dry seasons (December to March and July to September). The day temperatures varied from 26°C to 31°C. The mean annual rainfall was 2007 mm during the period (INSAE, 2012).
Two experiments were carried out from April to August 2012 (rainy season) and from November 2012 to March 2013 (dry season). The main crop considered is cabbage (*Oxylus* variety). Tropical basil (tchayo in the local language "Fongbé" of southern Benin) is the companion plant associated with the cabbage.
In the first experiment (rainy season), one-month old tropical basil seedlings were first transplanted on the field plots. One month later, one-month old cabbage plants were transplanted. Three harvests of tropical basil were carried out before cabbage harvest. After each cut, poultry manure was applied to basil plants. After cabbage harvest, plots were cleaned, and tropical basil plants were kept in place for the second experiment (dry season). Subsequently, cabbage seedlings were transplanted under the same treatments on the same plots. The experiments were conducted in a randomized complete block design of three treatments and four replicates. Cabbage intercropped with tropical basil (CIT) and cabbage plots surrounded by tropical basil (CST) were compared to cabbage (SC) alone as control (Figure 1). Each treatment was installed on a primary plot of 10 m².
The observations were focused on three important cabbage pests: *H. undalis*, whose larvae gnaw the plants heart which leads to multi-heads cabbage without commercial value; *P. xylostella* and *S. littoralis*, whose larvae perforate the leaves and degrade the visual quality of cabbage. Larvae of these pests were counted weekly for 10 weeks. The counting was performed on eight plants per plot at each observation time. At harvest, the number of damaged cabbages (multi-heads, perforated and rotted) was evaluated for each treatment per plot.

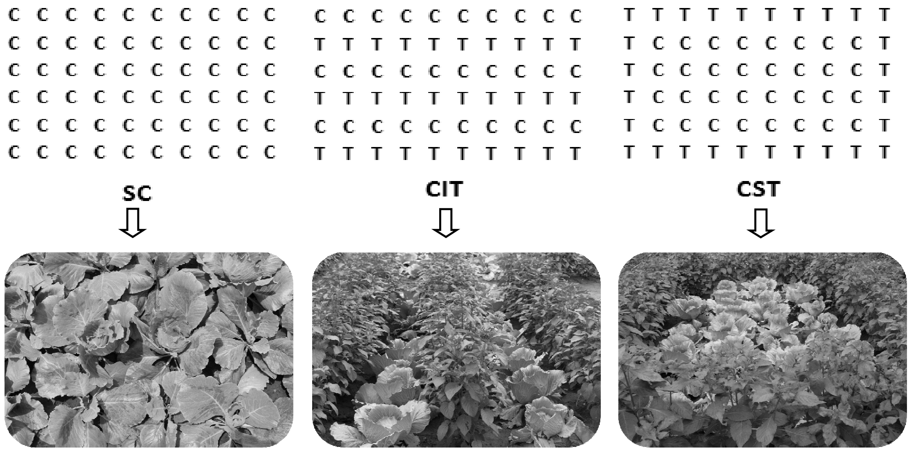

Figure 1. Schematic and picture illustration of the different treatments. C: cabbage, T: tropical basil, SC: sole cabbage, CIT: cabbage intercropped with tropical basil and CST: cabbage plots surrounded by tropical basil.

Statistical analysis

All statistical tests were performed using R software version 3.3.3 (R Core Team, 2017). Data were cumulated by season for each plot. The effects of intercropping on insect abundance (response variables: all pest pooled, and *H. undalis*, *S. littoralis*, *P. xylostella* individually) were assessed by fitting generalized linear mixed effect models ("glmer" function of the "lme4" package; Bates *et al.,* 2015) with Poisson error distribution (log-link function). Treatments were included as fixed variable and the plots as random effects, as measures were repeated on ten consecutive occasions in the same plots each season. Likelihood-ratio tests (drop1 function, "lme4" package; Bates *et al.,* 2015) at $p<0.05$, were used to test the effect of fixed variable in each model. The "glht" function ("multcomp" package; Hothorn *et al.,* 2008) were used for group comparisons. For cabbage harvested, the "fisher.test" and "fisher.multcomp" functions ("RVAideMemoire" package; Maxime, 2017) were used to compare the proportion of marketable and unmarketable cabbages and between groups respectively.

RESULTS

Pest abundance on cabbage

For each species, the number of counted larvae is around 1.5 to 3.0 times higher in control plots (sole cabbage) than in associated cabbage plots (Figure 2). A significant effect of the association was observed both in the rainy season (dl = 2, x^2 = 13.05, p = 0.001) and in the dry season (dl = 2, x^2=7.27, p = 0.026). The comparison between treatments for each season is presented in Table 1. During the rainy season (Figure 2a), a significant effect of the treatments was observed on the *H. undalis* (dl = 2, x^2 = 16.76, p <0.001) population, but not on the *S. littoralis* population (dl = 2, x^2 = 0.83, p = 0.659). No comparison could be done on *P. xylostella* due to the low number recorded during this rainy season. In the dry season, the *H. undalis* population was significantly affected by the treatments (d1 = 2, x^2 = 3.44, p <0.000). However, no effect was observed for *S. littoralis* (dl = 2, x^2 = 0.79, p = 0.671) and *P. xylostella* (dl = 2, x^2 = 1.19, p = 0.551). The comparison of means between treatments for each pest and season was presented (Table 2).

Table 1. Multiple comparisons of means between treatments according season on total pest population. SC: sole cabbage, CIT: cabbage intercropped with tropical basil, CST: cabbage plots surrounded by tropical basil. Estimate indicates the meaning of the difference between treatments compared. *p<0.5, **p<0.01 and ***p<0.001.

Seasons	Parameters	CIT-SC	CST-SC	CST-CIT
Rainy	Estimate	-	-	
	p-value	<0.001 ***	0.089	0.039 *
Dry	Estimate	-	-	
	p-value	0.006 **	0.118	0.493

Table 2. Multiple comparisons of means between treatments for each season on pest population. SC: sole cabbage, CIT: cabbage intercropped with tropical basil, CST: cabbage plots surrounded by tropical basil. Estimate indicates the meaning of the difference between treatments compared). *p<0.05, ***p<0.001; nc (not comparable).

Seasons	Pests	Parameters	CIT-SC	CST-SC	CST-CIT
Rainy	*H. undalis*	Estimate	-	-	
		p-value	<0.001 ***	0.094	0.040 *
	S. littoralis	Estimate	-	-	
		p-value	0.711	0.715	1
	P. xylostella		nc	nc	nc
Dry	*H. undalis*	Estimate	-	-	
		p-value	<0.001 ***	<0.001 ***	1
	S. littoralis	Estimate	-	-	
		p-value	0.709	1	0.709
	P. xylostella	Estimate	-	-	
		p-value	0.793	0.896	0.524

Pest damages on cabbage

Cabbages were categorized into unmarketable cabbages (bored, rot, and multi heads cabbages) and marketable cabbages (Figure 3). Significant differences were found between the proportion of unmarketable and marketable cabbages (rainy season, p < 0.001; dry season, p = 0.007). In the rainy season, unmarketable cabbages in intercropped plot with tropical basil was significantly low compared to the control (p < 0.001) and cabbage plots surrounded by tropical basil (p < 0.001). No difference was observed between sole cabbage plot and surrounded cabbage plot (p = 0.643). In the dry season, differences were found only between cabbage in intercropped plot with tropical basil and sole cabbage (p = 0.012).

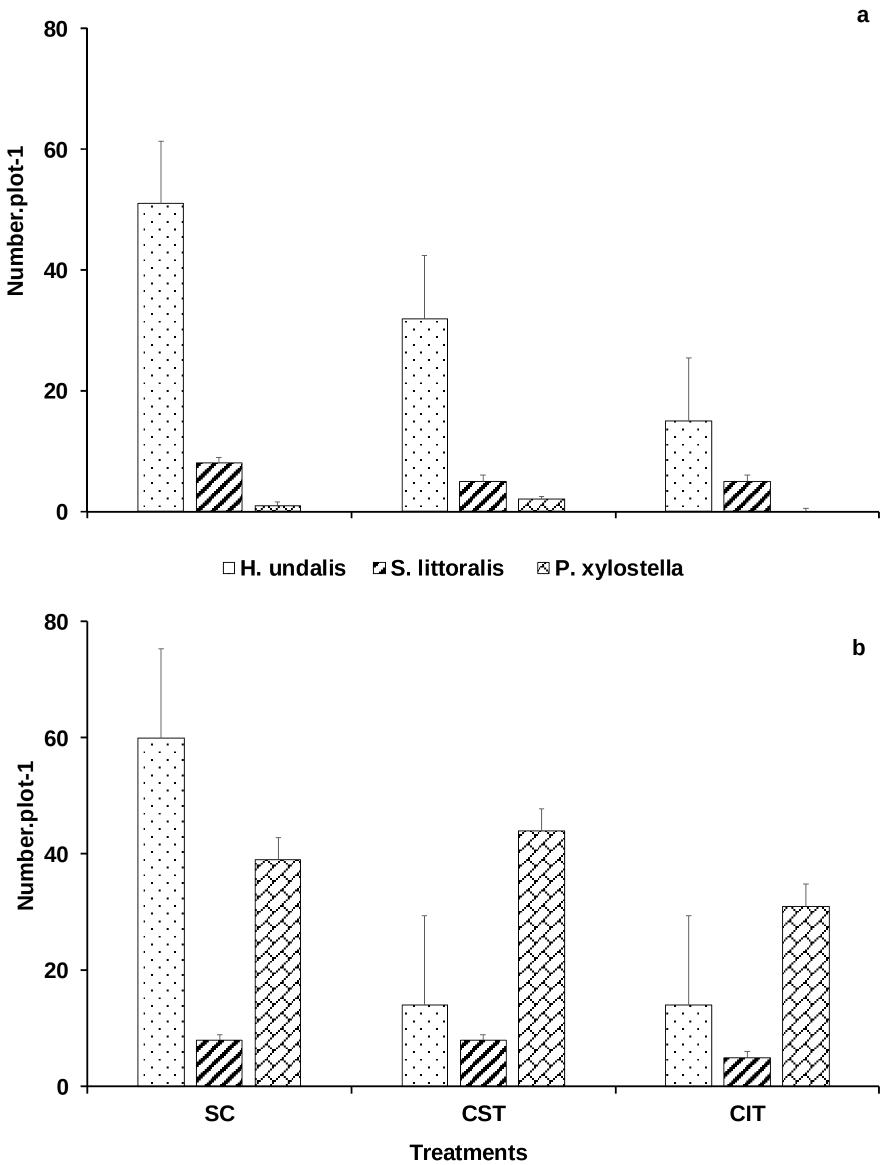

Figure 2. Average number of larvae counted on cabbage according the treatment for rainy (a) and dry (b) seasons. SC: sole cabbage, CIT: Cabbage intercropped with tropical basil, CST: cabbage plots surrounded by tropical basil.

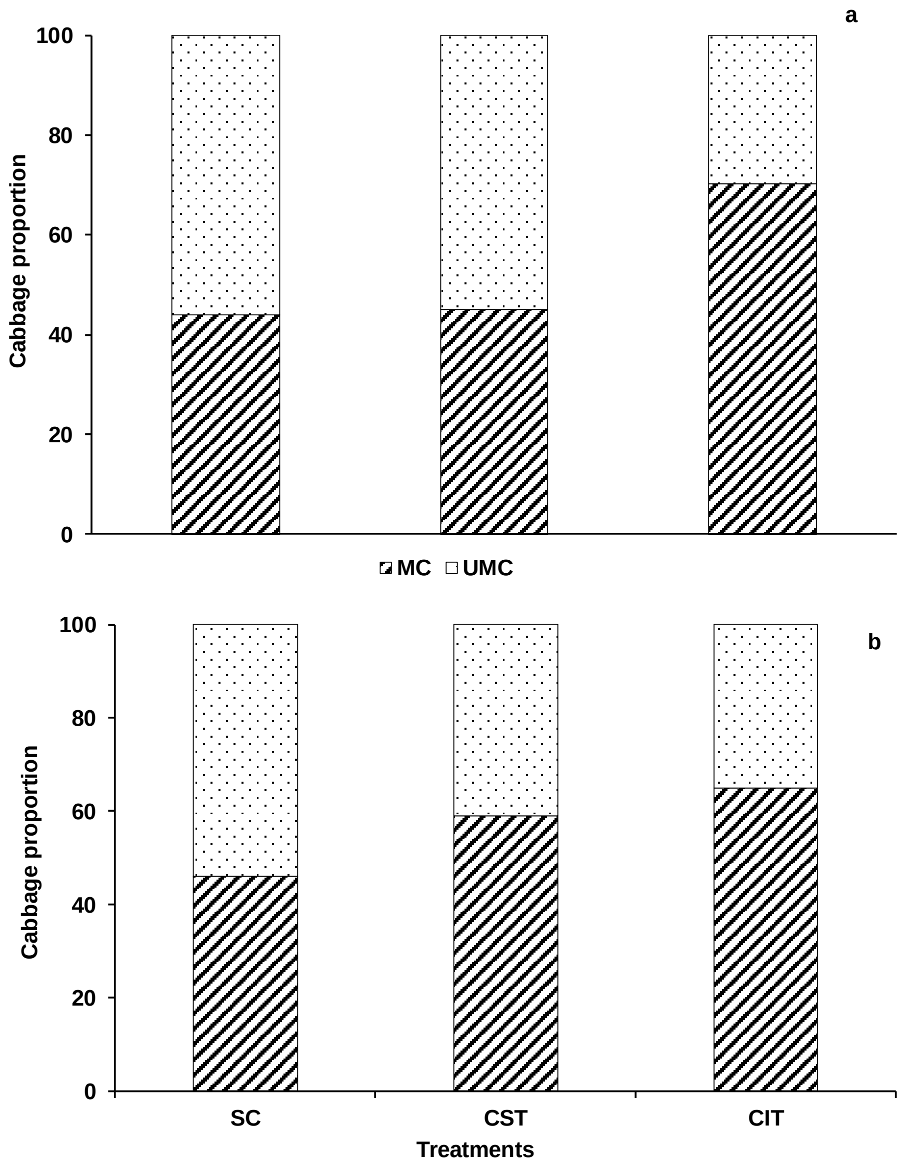

Figure 3. Proportion of unmarketable and marketable cabbages according to the treatments and following the seasons: a (rainy season), b (dry season). SC: sole cabbage, CIT: Cabbage intercropped with tropical basil, CST: cabbage plots surrounded by tropical basil.

DISCUSSION

The impact of tropical basil on three Lepidopteran cabbage pests was evaluated during this study. Regardless of the season, our results show that cabbage plots associated with tropical basil have attracted less pests compared to the control plots. Damages were also lower in associated plots. These results corroborate with other previous studies on the pest suppressive effect of intercropping with *Ocimum* plants. Kianmatee and Ranamukhaarachchi (2007) demonstrated that intercropping of *O. basilicum* or *O. sanctum* L. with *Brassica rapa* H. reduces pest populations (*H. undalis*, *Spodoptera litura* F., *Phyllotreta sinuate* F.), and damages in the intercropping plots than in control. Asare-Bediako *et al.* (2010) reported that the impact of *H. undalis* on cabbage was less important when cabbage was intercropped with pepper or onion. Similar studies have shown that the presence of *O. basilicum*, *Allium* spp, and *T. patula* on cabbage plots significantly reduce the damages of *B. brassicae* and as a result of yield increase compared to cabbage plots without these companions (Debra and Misheck, 2014; Tiroesele and Matshela, 2015).

The repulsive effect of companion plants on insects is generally attributed to their volatile organic compounds (VOCs). By associating cabbage with clover (live or dry), Finch and Kienegger (1997) concluded that the low oviposition of *P. xylostella* and *Pieris brassicae* L. observed on cabbage plants intercropped with live clover was more related to the presence of repellent compounds than to the physical appearance of the clover. Indeed, plant volatiles play an important role in the process of host plant localization by pests (Bruce *et al.,* 2005; Bruce and Pickett, 2011). *Ocimum* species are aromatic plants, whose repellent properties on various arthropods are demonstrated (Del Fabbro and Nazzi 2008; Oparaocha *et al.,* 2010; Kazembe and Chauruka, 2012). Thus, VOCs emitted from these tropical basil plants could have disrupted the recognition and oviposition behavior of lepidopterans on cabbage plants. This would explain the low populations of Lepidoptera larvae observed in the intercropping plots compared to the control. It could also be due to the activity of the natural enemies of these pests. Indeed, some VOCs can be attractive to natural enemies as demonstrated by Bender *et al.* (1999) on *B. oleracea* associated with *Brassica juncea* L., and Beizhou *et al*. (2011) on pear orchards associated with *O. basilicum*. It is, therefore, probable that tropical basil has attracted natural enemies of these lepidopterans that could have contributed to reduce their populations in cabbage intercropping plots. However, we cannot confirm these facts because the presence of natural enemies has not been evaluated in this study.

Single row-intercropping appeared to be the best arrangement of plants for reducing pest damage. This observation was supported by previous ones: single row-intercropping carrots with onions better control the attacks of *Delia brassicae* Bohé on carrots (Tukahirwa & Coaker, 1982). However, the two mix crops effect on each pest during both the seasons, did not significantly reduce the populations of *P. xylostella* and *S. littoralis* compared to the control as the results obtained by Kianmatee and Ranamukhaarachchi (2007). This would indicate that these two pests are not especially influenced by the presence of the tropical basil.

CONCLUSIONS

This study showed that tropical basil can reduce cabbage pests especially *H. undalis*. Association of cabbage and tropical basil in alternated row were more effective. In the context of the promotion of agro-ecological methods for crop pests management, especially vegetable crops, tropical basil could be used in the integrated pest management. Nevertheless, further studies are needed to perfect this technology in order to maximize the biocidal potential of this plant in the crop pest control. Used as a traditional vegetable in some West Africa countries and mainly in Benin, its adoption in intercropping systems by producers should be done without major constraints.

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