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Assessment of a cabbage/pak choï crop association to manage aphid and parasitoid populations on cabbage crops in Senegal

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ABSTRACT

In Senegal, vegetable production is an important area within the agricultural sector and contributes to improve the local diet. Damage caused by aphids in particular puts heavy pressure on vegetables production. Crop associations play an important role in controlling insect pests in some countries. The aims of this study include investigations into the diversity of aphid and parasitoid populations, and an evaluation of the effects of crop associations between cabbage and pak choï. The experimental design used is a randomized block with four treatments and two controls, that is cabbage and pak choï , and two crop associations, that is pak choï between cabbage rows, and pak choï around cabbage beds. Two aphid species, *Myzus persicae,* and *Lipaphis pseudobrassicae* are identified. The Braconidae *Diaeretiella rapae* (Mac Intosh) (Hymenoptera: Braconidae) is the only parasitoid met during the study. *Myzus persicae* (Sulzer) is more abundant than *Lipaphis pseudobrassicae* (Davis). *Myzus persicae* and *L. pseudobrassicae* were not controlled by the cabbage / pak choï associations. Aphids populations decreased during the heading phase of the cabbage. This preliminary study contributes to a better understanding of the potential use of crop associations to manage cabbage aphid populations in Senegal.

Keywords: Crop associations, *Myzus persicae*, *Lipaphis pseudobrassicae*, *Diaeretiella rapae*, Brassicaceae, Senegal.

INTRODUCTION

The Brassicaceae has become one of the most widely cultivated crops with more than 37 million hectares grown worldwide (FAOSTAT, 2013). Its production has reached 152 million tons in 2013 (FAOSTAT, 2013). Now, they contribute to more than 26 billion US$ in the worldwide economy (FAOSTAT, 2013). Among cultivated species, the cabbage remains a very important crop providing income and nutrition and enabling small farms to remain financially viable (Grzywacz et al., 2010). In West Africa, the head cabbage is grown on 14 884 hectares with annual production of 292 342 tons (FAOSTAT, 2013). In Senegal, the statistical data in 2012 showed that the head cabbage ranked 5th position after the onion, the tomato, the industrial tomato, the cherry tomato, and the sweet potato accounting for just over 7% of

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national vegetable production. However, damage caused by insect pests, particularly aphids, is a major obstacle in increasing yields and quality of products (Sarfraz et al., 2005 ; Emden, 2007 ; Diatte et al., 2016 ; Labou et al., 2016). The aphids reproduce quickly and cause some important damages to the host plants (Dedryver, 2007 ; Giordanengo et al., 2010). Additionally, the honeydew produced by aphids and this accumulation on the host-plant leaves contribute to the fungi development as Fumagina which disturb the plant photosynthesis (Giordanengo et al., 2010). The aphids are known to be virus vectors and more than 50 species of aphids are noticed as vectors of virus (Varveri, 2000). In Senegal, few studies have been undertaken on aphid species and their natural enemies. Collingwood et al. (1981) reported the presence of *Myzus persicae* on Chilli pepper during insecticidal trials in Senegal. In Senegal, a census of aphids was carried out in 2012 and a list of 18 aphid species was established on different host plants, however, a study on aphid auxiliaries was not carried out (Coeur d'Acier, 2012).

Several control methods against these pests are used and principally the chemical control. The high use of insecticides affects the safety of food products but also biodiversity and regulating services of pest insects (natural enemies) (Macharia et al., 2005 ; Gomgnimbou et al., 2009).

Some alternative control methods have been developed among which are the concept of crop associations (Hooks and Johnson, 2003 ; Ponti et al., 2007 ; Bickerton and Hamilton, 2012). The argument more advised is the housing simplification and the single crop farming establishment favour the plots colonization by insect pests (Meehan et al., 2011). Pest management theories considering the trophic levels are behind two hypotheses proposed by Root (1973) to explain the importance of herbivore in monoculture compared with diversified cultures. In a diversified culture where the resources are less concentrated, herbivores found with difficulty their host plant, decreasing in the way their population importance; hypothesis of the resource concentration (Root, 1973). A complex housing favour the natural enemies action; hypothesis of natural enemies (Root, 1973). Beyond the cultural associations, the phenology of the plant can also control pests. The work of Sow et al., 2013 showed that *Plutella xylostella* populations decreased during the head of the cabbage.

The objectives of this study are : (i) to estimate the aphid and parasitoid populations abundance; (ii) to estimate the crop associations (cabbage head/pack choï) effects on the aphids and natural enemy species abundance; (iii) to determine the impact of cabbage age on the aphid and parasitoid populations abundance.

MATERIALS AND METHODS

Study site

This study is carried out on open fields between December 2013 and March 2014, in Malika, located in Dakar Niayes (14°47'552" N 17°19'818" W) at 189 m above sea level. This area is characterized by a long dry season from November to June with small variation of temperatures going 15 from 20 °C and a short rainy season from July to October. During the rainy season, temperature increases until 35 °C. Cumulative precipitations can reach 500 mm between August and September.

Experimental design

Two cabbage species were used: the head cabbage (*Brassica oleracea* L. var. *capitata* cv. Copenhagen Market) and the pak choï (*Brassica rapa* L. var. *chinensis* cv. "Pak choï white). Experiment were arranged in a randomized complete-block design with four treatments:

- Cabbage alone (CH),
- Pak choï alone (PC),

- Pak choï between cabbage rows (PCER),
- Pak choï around cabbage beds (PCA).

Each treatment was replicated six times. The head cabbage and the pak choï seeds were sown in plastic alveolus and the young plants transplanted 30 days later. Plants were watered early in the morning or in the evening by the farmer. The fertilizer (10 N, 10 P, 20 K) was applied according to the grower method. The experimental unit is a square of two side meters. No chemical treatment was applied during this test.

Sampling method

The weekly sampling started 38 days after the field transplanting. For each plot, five cabbages were randomly selected. To evaluate aphid abundance and associated parasitism, aphids were collected by cutting a piece of leaf on each sampled cabbage. The collected aphids were taken to laboratory where they were counted and identified. The mummies formed on the leaves were isolated individually in pill-boxes to monitor parasitoids emerged.

The identification of aphid adults was carried out using identification keys (Blackman et al., 1994) and sent to CBGP (CIRAD/Montpellier/France) to be confirmed by a specialist.

Statistical analyses

The data obtained were registered in Excel software and analyzed with the software XLSTAT version1. 1. 2012. Treatment effects on aphid abundance and parasitoid populations were determined by analysis of variance (ANOVA). Post hoc multiple comparisons of mean values were performed using the Newman–Keuls method (P < 0, 05) test. All data were transformed to normalize distributions using $\log_{10}$ (x+1). The relationships between cabbage age, aphid and parasitoid populations was assessed using Pearson correlation.

RESULTS

Aphid and parasitoid population abundance

During this study, 3 185 aphids were sampled in the different treatments. Two aphid species, *Myzus persicae* (Sulzer) and *Lipaphis pseudobrassicae* (Davis), (Hemiptera; Aphididae) and one species of parasitoid, *Diaeretiella rapae* (Mac Intosh) (Hymenoptera: Braconidae), were identified in the laboratory. *Myzus persicae* was mainly present with 80%, *L. pseudobrassicae* was less common with only 20% of sampled aphids (Figure 1). During the observations of the mummies in the laboratory, 274 *D. rapae* adults have emerged. *Diaeretiella rapae* species is a small parasitoid (3 mm) found worldwid numerous aphid species.

Crop association effects on the behavior of the aphid and parasitoid populations

Numbers of *M. persicae* sampled were statistically more important in the PCA association, where on average, 5.5 individuals were harvested. In the other treatments, 4.19, 3.94 and 3.39 individuals respectively have been harvested in the control CH, in the association PCER and in the control PC (F = 4.417; ddl = 3; p = 0.004) (Table 1). However, the number of *L. pseudobrassicae* individuals harvested was not significant with treatments (F = 1.285; ddl = 3; p = 0.279) (Table 1). For *D. rapae* adults, there are no significant differences between the treatments and the emerged adult numbers (F = 2.420; ddl = 3; p = 0.065) (Table 1).

Cabbage age effects on the Aphid populations

There was a significant negative correlation between the *M. persicae* populations and cabbage age (r = - 0.251; p < 0.0001). The *M. persicae* population increased between the first and the second weeks observation, however a population decrease was noticed in the third observation, simultaneous with the beginning of cabbage head formation (52[th] day after transplanting) (Figure 2).

The correlation between the *L. pseudobrassicae* population and cabbage age was significantly negative ($r = -0.275$; $p < 0.0001$). Like the *M. persicae* population, the *L. pseudobrassicae* population decreased during the observation period particularly in the third week of observation, simultaneous with the beginning of cabbage head formation (52[th] days after transplanting) (Figure 2).

Cabbage age effects on parasitoid populations

There was a significant correlation between *D. rapae* populations and cabbage age ($r = 0.286$; $p < 0.0001$). The parasitoid appeared in the third observation week, simultaneous with the beginning of the cabbage head formation (52[th] day after transplanting) (Figure 3). *Diaeretiella rapae* parasitism was zero during the two first observations. The number of aphids parasitized by *D. rapae* is highest in the third week followed by a weak increase of aphids parasitized by *D. rapae*.

Table 1: Comparison of aphid and parasitoid populations according to treatments.

Treatments	*M. persicae*	*L. pseudobrassicae*	*D. rapae*
PCA	5.50^a	1.20^a	0.46^a
PCER	3.94^b	1.01^a	0.51^a
CH	4.19^b	0.78^a	0.59^a
PC	3.39^b	1.23^a	0.27^a

Vertical averages with the same letter are not significantly different (Newman Keuls test 5%).
The data were transformed by log (x + 1).

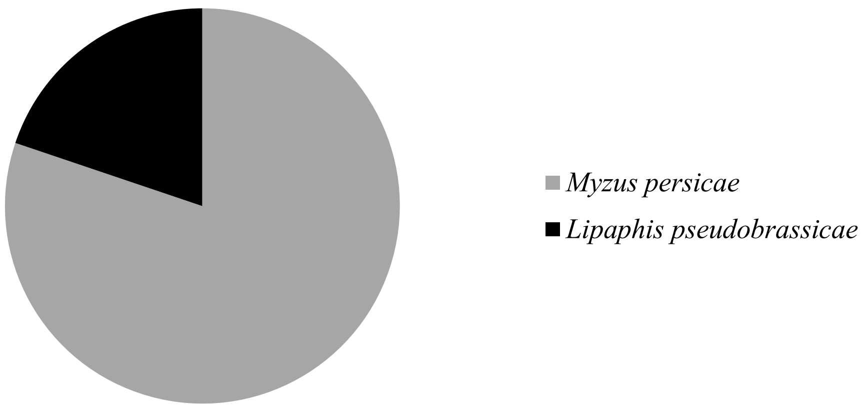

Figure 1: Abundance (%) of aphid populations sampled in Malika (Dakar).

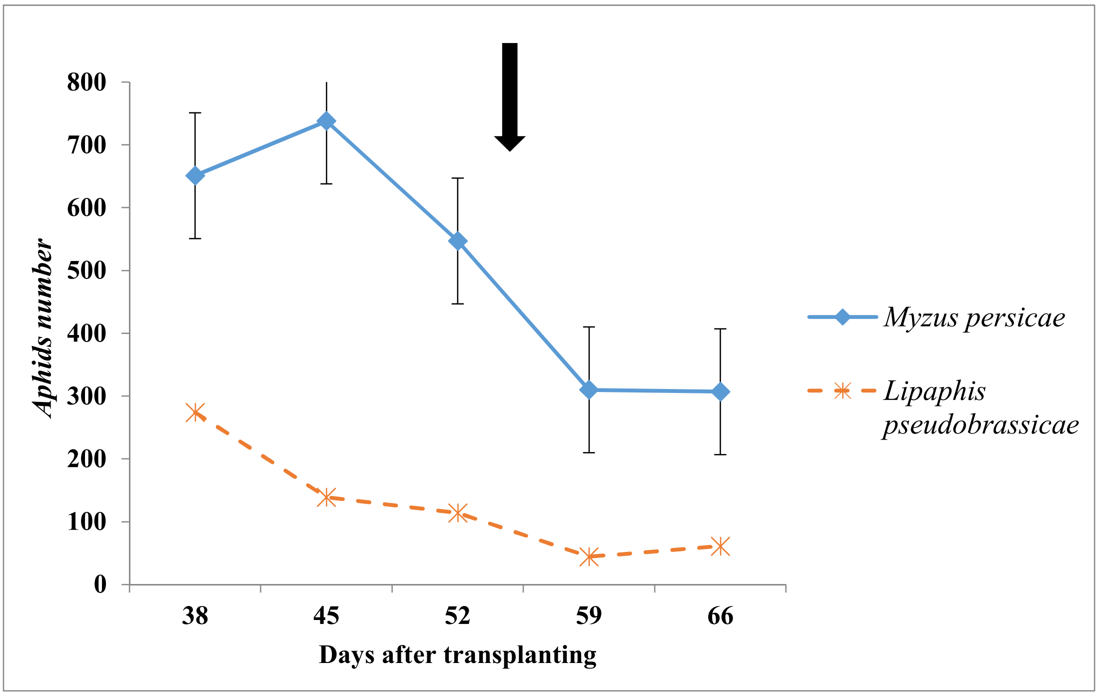

Figure 2: Development of aphid populations according to cabbage age. The black arrow shows start of cabbage head formation.

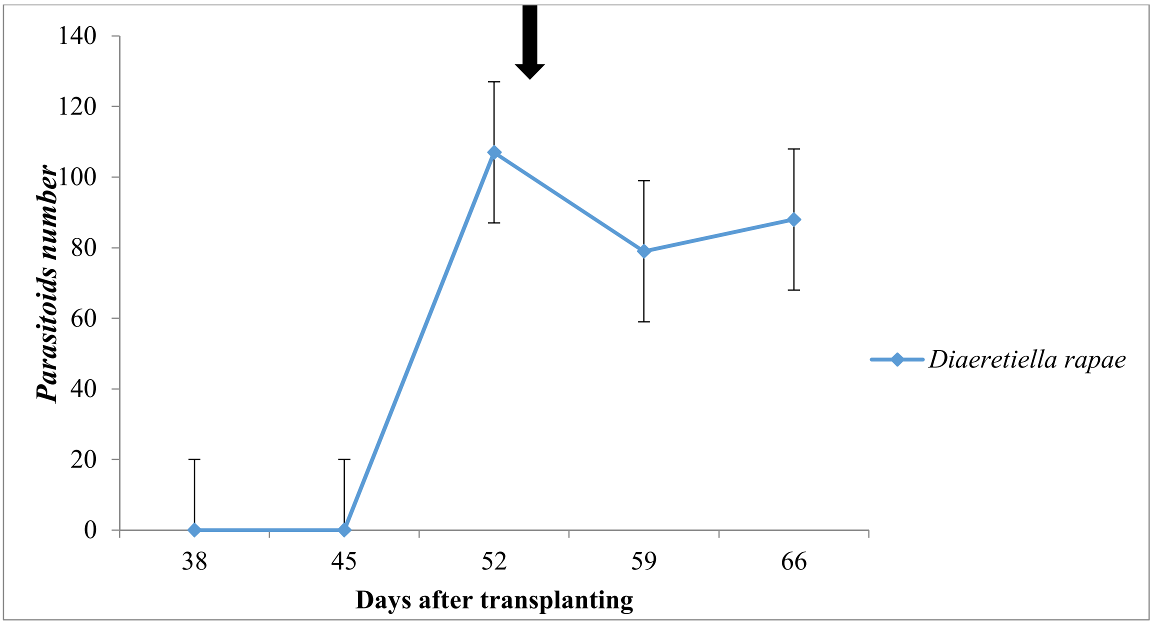

Figure 3: Development of parasitoid populations according to cabbage age. The black arrow shows start of cabbage head formation.

DISCUSSION

This study has allowed to identify two aphid species and one Braconid species. The *M. persicae* species is more common than *L. pseudobrassicae* (20%). This dominance can be explained by the inherent characters of each aphid species. *Myzus persicae* is a very widespread generalist species which attacks several host plants unlike *L. pseudobrassicae* a Brassicaceae specialist (Emden, 2007). The large number of *M. persicae* can be explained by the presence of a tomato crop near the cabbage cultures. This tomato crop would have kept *M. persicae* populations at a high level.

In fact, when the two aphid species are reared alone, their fecundity is greater than when they are reared together on the same host plant (Hu et al., 2003). Hu et al. (2003) have shown that *M. persicae* has a higher longevity and fecundity than *Lipaphis erysimi* (Kaltenbach) when they coexist on the same plant. These results are similar to ours which show the relative importance of *M. persicae* in relation to *L. pseudobrassicae*.

Our crop associations have not reduced the *M. persicae* and *L. pseudobrassicae* infestations. The lack of aphids control by the head cabbage / pak choï associations can be explained by the affiliation of these species to the same botanical family. According to Root (1973), the concentration of resource in a favourable habitat favours pest development. Our crop associations can be considered as a similar resource for the two aphid species which explains the level of attack in the associate plots with head cabbage and pak choï. However, in Asia, the pak choï is used with a lot of success as trap plant to control Diamondback moth, a major Lepidopteran pest on cabbage crops (Talekar et al., 1990). Our results are similar to those of Bosquée et al. (2014), where the crop associations have been more attacked by aphids than the controls. However, the results of some authors have shown that the association with plants from different botanical families increase the aphid infestation (Sarker et al., 2007 ; Bickerton and Hamilton, 2012 ; Chevalier Mendes Lopes et al., 2014).

The number of aphids parasitized by *D. rapae* is more important in cabbage control plots and in crop associations plots than in pak choï plots. This can be explained by the importance of the aphid populations in the cabbage controls and in the crop association. *Diaeretiella rapae* has a large affinity with Brassicaceae plants and parasitizes aphids connected with them, when aphids increase *D. rapae* females easily find host to attack (Ponti et al., 2007 ; Starỳ et al., 2007).

The *M. persicae* and *L. pseudobrassicae* populations were more important before head cabbage formation started. This could be explained by the feeding mode of the aphids which is a phloem diet and therefore the quality of the sap influences their feeding behavior (Dinant et al., 2010).

The correlation between cabbage age and *D. rapae* populations is positive, maximum parasitoid attack was in the third observation periods. Natural enemy populations depend on the host populations (Elliott et al., 2002). Aphid populations abundance during the first two observation weeks leads to a honeydew increase by aphids. This honeydew rich in sugar and in amino acid makes up a dietary source for numerous natural enemies but acts also as a volatile kairomone (Leroy et al., 2009). The volatile compounds from honeydew guide natural enemies towards a diet source, composed of preys or hosts, and increases behaviour such as search, localization and attacks (Leroy et al., 2009). The *D. rapae* populations decrease in the 4th observation week, and increase weakly in the last week, a result that can be explained by the aphid and the honeydew quality. Honeydew establishes a vital diet source for numerous natural enemies, especially *D. rapae* (Hogervorst et al., 2007).

COMPETING INTERESTS

We declare that there is no competing interest between the authors. The order of the authors at the level of the article and the content of the document has been validated unanimously.

AUTHORS ' CONTRIBUTIONS

AD is the lead investigator; DS-S and DB co-supervised the works and participated in the drafting of the manuscript; KD is the initiator of the project. He has defined the protocols and coordinated all activities.

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