Effect of intercropped cowpea on dampening population build-up of herbivorous mites in cassava plantations of the northern mountain region of Vietnam

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Abstract

Since 2013, cassava has become an one billion USD export crop of Vietnam, making it from a forgotten to a strategic crop in the country's agricultural sector. However, cassava production has gone through many obstacles over the last 4-5 years, such as price drops and climate-triggered harvest losses due to invasion of pest and diseases. High temperatures favour the increase in mite population, which can finally lead to outbreaks when evaporation exceeds precipitation for prolonged periods of time. This two year study investigated differences of mite population in cassava plots that with and without a leguminous cover crop (cowpea). The research was implemented in Cau Vai village in Mau Dong commune, Van Yen district, Yen Bai province of northern Vietnam. Ten cassava plots were selected in five pairs for different locations of upper, middle, foot slope and fluvial flood plain positions. Each pair contains a monocrop and an intercrop cassava plot. Three major results have been found, including: (i) significantly higher population of herbivorous mites in monocrop than in intercrop; (ii) highest herbivorous mite population on middle slopes; and (iii) significantly lower population of herbivorous mite in rainy months of July and August compared to the other months. Additional investigations also revealed that cassava yields are higher in intercrop plots and farmers can potentially double their income from planting cowpea with cassava. These findings, as part of a bigger unfinished study, leave a major conclusion that intercropping legume can help cassava become more resilient to heat stress, improve cassava yields and household incomes, and restore soil nutrients (not presented in this manuscript), i.e. increasing amounts of nitrogen in the topsoil. This conservation agriculture measure, if practiced in long terms, should play an crucial role as a *climate-smart* practice in restoring marginal and degraded lands, hence, making future agriculture more sustainable in mountain regions in Vietnam and around the world.

Key words: monocrop, leguminous intercrop, herbivorous mite, predatory mite, mite population, climate-smart

1. Introduction

Vietnam's great performance in agriculture in recent decades has been very impressive, i.e. achieved food security goal, and became the 2nd rice exporter and 1st coffee producer. However, the country did not pay enough attention to efficiency, farmer welfare, and product quality, which had finally led to environmental costs (World Bank, 2016). For example, input- and resources-based strategies to keep up with maximal yields rather than conservation and sustainability measures have resulted in soil nutrient depletion from intensification and erosion (Tuan, 2015), land degradation, uncontrolled forest invasion for agriculture (Trinh, 2007), and increased infectious diseases of plants and crops (Wyckhuys et al., 2017).

These problems persist in the Northern Mountain Region (NMR) of Vietnam, the country's poorest region. Due to the state's migration policy since the 1950's, farming practices had been gradually transformed from slash-and-burn and/or swiddening agriculture (Vien, 2003; Vien et al., 2004) into non-fallow, forest clearance, and intensification and market orientation to meet food demand of the growing population (Clemens et al., 2010). Unsustainable management practices, for instance intensive farming and monocropping on steep slopes, have been stated to be the main reasons for declined soil fertility and

crop yields. The study of Häring et al. (2010) in Son La indicated that soil chemical properties declined with soil organic matter by 66%, N_t by 67%, exchangeable Ca^{2+} by 91%, Mg^{2+} by 94%, K^+ by 73%, available P by 75%, pH values by 2.2 units, and cation exchange capacity by 56% since forest clearance. Häring et al. (2013) found a higher total SOC loss (6–32%), a lower decomposition (13–40%), and a lower SOC input (14–31%). These changes in SOC dynamics happened most in the plough layer (0–10cm). Tuan et al. (2014) estimated that the soil loss due to the monocropped maize system in Yen Chau (Son La) reached 174 t ha^{-1} a^{-1}.

Being one of the 6 countries that are most affected by global climate change impacts, Vietnam has been experiencing vast pest and disease desctructive effects on plants and crops. Kiritani (2013) stated that global warming has diversified population dynamics of insects. It leads to over-winter survival, population build-up, lengthened reproductive season, and biotic associations of species. Wyckhuys et al. (2017) found out that the performance of mealybug, an invasive pest found in cassava plantations in Laos, Cambodia and Vietnam, is highly species-specific and context dependent. Some species are favoured in low-soil fertility conditions and some are favoured in settings with high organic carbon and phosphorous contents. This means specific appropriate management practices can help dampen population build-up of different species. This relates to the work of Tuan et al. (2014), in which introduced conservation measures helped improve soil fertility as an resistance factor to pest invasion. Studies show that legume-based intercrop systems can significantly help not only reduce impact of invasive pests (Abdullah and Fouad, 2016; Singh et al., 2017) but also improve production of major crops (Patient et al.; 2019; Oso and Falade, 2010), improve farmers' livelihoods and promote sustainable agriculture (Singh et al., 2017), or at least increase land use efficiency (McIntyre et al., 2001)

This study aims at assessing a triple win of a cassva-cowpea intercrop system in terms of: (i) dampened population build-up of herbivorous (red spider) mites; (ii) improved soil quality and (iii) increased cassava yield and household income from cowpea. The study also looks at the angle that can makes the practice resilient to climate impacts, especially extreme heat. Within the scope of joint workshop, we only present findings of (i) and (iii) for their availability of data.

2. Materials and methods

2.1. Study area

The study was conducted in Cau Vai village (red circle on the map) within Mau Dong commune, Van Yen district, Yen Bai province of northwestern Vietnam. The village has elevation ranging from 42 to 156m a.s.l with most of its bounday embraced by the Red river that runs through Van Yen district downstream to the Red River Delta. Cau Vai village covers an area of 400 hectares and home to 899 inhabitants. The region is influenced by the tropical monsoon climate with an annual precipitation between 1,800 and 2,000 mm. The average annual temperature is between 23-24°C, with hot summers months from May to August and cold winter months between December and March. The study investigated five pairs of plots, each pair consisting of a monocroped and intercropped plot.

Agricultural production mainly relies on upland-based farming systems with small areas of irrigated paddy rice (*Oryza sativa*) in small valleys. On slopes, farming systems mainly go around cassava (*Manihot esculenta*), cinnamon (*Cinnamomum verum*), orange (*Citrus X sinensis*), and tree crops such as *eucalyptus* and *acacia Mangium*. Despite lowered market price in recent years and cassava area being shifted to cinnamon and orange, cassava (season between April and December) still remains the most important cash crop in Cau Vai village and Mau Dong commune. The study investigated five pairs of cassava plots with each pair consisting of a monocrop and intercrop plot locating at an identical position. These positions include: hill top, middle slope, lower slope, and fluvial plaint. The research team set up a field laboratory within a farmer's residence with a full-time junior researcher based in the field sites during two cassava seasons of 2017-2018.

2.2. Data collection

2.2.1. Soil sampling and soil parameters

We first made 3 soil profiles that cut across our sampling sites for cassava and composite soil samples to thoroughly understand what soil types are likely found in the village. The soil profiles (**Fig. 1b**) were dug down to the depth of 1.2–1.8 m, then field described and classified according to FAO (2006) and the IUSSWorking GroupWRB (2006). The description and sampling were made for every soil horizon like in Bui Le Vinh (2015).

We collected composite soil samples at the depth 0-30cm (the most effective rooting space for cassava) for all 10 investigated plots. Composite sampling approach was applied for an sampling area, in which four samples were collected at four corners and one samples was taken in the middle plot location. These samples were then mixed and 1,000 g of soil was taken for laboratory analysis. We sampled two parts of each plot, i.e. upper slope and lower slope positions based on the hypothesis that soil fertility levels differ at different slope positions (Bui, 2015; Bui et al., 2017; Wyckhuys et al., 2017) and, hence, lead to different performances of mites (herbivorous and predatory) and cassava plants. Soil parameters analyzed for the study include bulk density (BD), soil pH HCL, total nitrogel (N_t), and total organic matter (C_{org}). Within the scope of this manuscript and purpose of the workshop, we did not include soil analytic data into the findings, which will together be used later for a major international publication tentatively planned for submission in the 4th quarter of 2019.

2.2.2. Cassava leaf sampling and investigation of population densities

We sampled cassava leaf once every two weeks. Leaf sampling started one month after the plantation of cassava (in April), from May until November each year, making it 34 weeks in total and 17 sampling times. In each plot, we randomly selected five points and 5 plants around each point for leaf sampling. From each plant, we picked three full leaves, one from the upper part, one from the middle part and one from the lower part. Each leaf was then transferred into a small ziplock bag with an unique ID attached on before being put in a cooler box for transportation to the field laboratory.

At the field laboratory, the field researcher examined each leaf, using a stereoscope to count number of moving stages of herbivorous mites. Per leaf, abundance was also assessed for predatory mites (i.e., *Phytoseiidae*), coccinellid beetles or larvae, and other predators. Data were tabulated in Excel tables for further statistical analysis.

2.2.3. Soil humidity measurement

Leguminous cover crops are said to be beneficial to soil quality improvement, including increased soil moisture content and soil nutrients (Nouria et al., 2019). To evidently prove the hypothesis that improved soil moisture content from intercropped cowpea helps dampen population build-up of herbivorous (Singh et al., 2017; Patient et al., 2019; Bellotti et al., 2012; Poveda et al., 2008; and Oso and Falade, 2010), we measured soil moisture content in investigated monocrop and intercrop fields using a field device called EXTECH MO750. Measured data were tabulated in Excel for statistical analysis. Within the scope of this manuscript and purpose of the workshop, we did not include soil moisture data into the findings, which will together be used later for a major international publication tentatively planned for submission in the 4th quarter of 2019.

2.3.Recording cassava yields and additional income from cowpea for the investigated plots

The data of cassava yields were collected in two different ways: field measurement and farmer interview. At the end of each season, we randomly collected 25 cassava plants, measured weight of cassava roots of each plant, summed the total weight for 25 plants and took the everage weight value for one plant. We calculated the production of the plot by multiplying this average weight with the total number of cassava plants for that plot. Cassava yield was also computed for each of the investigated plots. This measurement was to cross-check with the information we got from the farmers. A farmer would relatively know how much his family got from each season when they sold their cassava to traders. This information was collected and tabulated. The two data sets were then used to comparatively derive the most reliable final

data set for statistical analysis. Information regarding production and yield of cowpea was collected the same way to reduce uncertainties for most accurate data analysis.

2.4. Statistics

We used a step-wise statistical approach to analyze the survey data

Step 1 – data cleaning using R-statistics. There was a large amount of time and energy put into collecting and preserving leaf samples, counting and recording mite population 17 times in 34 weeks earch year.

Step 2 – Descriptive statistical analysis. After cleaning the raw data, we used R-statistics to derive some descriptive figures of the data set for deeper analyses, such as mean and max values of herbivorous and predatory mites for seasons 2017 and 2018.

Step 3 – Non-parametric test was use to check the hypotheses of (i) greater population densities of herbivorous mites in the monocrop plots than in the intercrop plots and (ii) greater population densities of predatory mites in the intercrop plots than in the monocrop plots.

Step 4 – Anova statistical analysis was used to check if there would be any significant difference in mite population densities among four sampling positions.

Step 5 – Posthoc test was used, in case the Anova test was successful, to further examine which position would have highest/lowest densities of herbivorous/predatory mites, from which scientific evidence could be gathered to explain why.

3. Results and Discussions

3.1. Preliminary analytic results of soil profiles

We made three soil profiles at 03 different elevation points: higher (112m), middle (83m) and lower ground (50m) at three different positions, i.e. hill top, middle slope and fluvial plain, respectively. This sampling was to test the hypothesis that soil fertility and overall quality differ at different elevation points and locations. Soil analytic results show that soil profile 1 at the hill top position has the best quality in terms of soil nutrients (eg. total nitrogen and organic carbon) and soil bases (eg. clay content, base saturation, CEC). Soil profile 3 at the fluvial plain position has lowest content of bases, weaker structure, but not necessarily lower soil nutrients in the topsoil. Soil classification revealed that Acrisols are the major soil group of the research area. This soil group is characterized as one of the four clay soils with low base saturation (BS) and exchangeable cation capacity (CEC). These soils are not the most ideal soils for agriculture and need good management practices to improve soil fertility and overall quality (Bui Le Vinh, 2015; Bui et al., 2017).

3.2. Overall population comparison between red spider mite and predatory mite

Overall statiscal analysis shows higher population densities of herbivorous mites in the low value area in the intercrop than in the cassava monoculture, which means that there are more herbivorous mites in the monocrop plots. On the other hand, there are higher population densities of predatory mites in the low value area in the cassava monoculture than in the intercrop, which means that there are more predatory mites in the intercrop plots. Non-parametric test results shows a significantly higher average red spider mite density in the cassava monoculture and a significantly higher average predatory mite density in the intercrop with p-values of 9.52e-06 and 0.0002685, respectively. These findings are in agreement with many other similar studies such as Abdullah and Fouad, (2016); Singh et al. (2017); Patient et al. (2019); Oso and Falade (2010); Singh et al., (2017), which also found that legume-based intercrop systems significantly help reduce densities of invasive pests on major crops.

3.3. Population differences mong slope positions

We used Anova function to investigate any differences in population density of red spider mites across sampling positions. The analytic p-value of 2.74e-05 well proves the hypothesis of these differences. We

then used the Posthoc test to detail these differences. Results are presented in **Table 1**. There are clear differences between middle slope and lower slope positions and fluvial plain and middle slope positions with p-values of 0.0024365 and 0.0001306, respectively. This means that the middle slope position has the highest population density of red spider mite (**Fig. 1**). Wyckhuys et al. (2017) discussed the role of soil fertility and quality to plant health and resistance to pests and diseases. Although it is not certain that soil fertility and its overall quality has positive or negative influence on pest-disease resistance (Wardle etal., 2004; Zarnetske et al., 2013), a positive correlation has been found in this case study. According to some soil studies in northern Vietnam (Clemens et al, 2010; Bui Le Vinh, 2015; Bui et al., 2017), middle slope positions are normally the most eroded parts, for its highest steepness and inducing a high amount of erosive strength, with highest rich topsoil removal. In other words, soils at these locations are most depleted, i.e. low contents in nitrogent and organic carbon. Statistical analysis of collected soil data concretely proves this, however, is not presented in this manuscript.
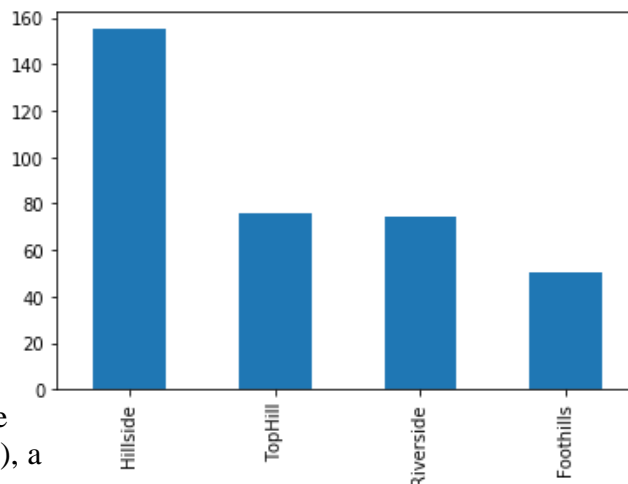
Fig. 1. Overall differences between population densities of red spider mites at various sampling positions

Table 1. Population densities among sampling positions

Sampling position	Difference	Lower	Upper	p
Middle slope - Lower slope	0.38565308	0.1054442	0.66586194	0.0024365
Fluvial plain - Lower slope	-0.01973835	-0.3351413	0.29566461	0.9984974
Hill top - Lower slope	0.17589008	-0.1378350	0.48961517	0.4707655
Fluvial plain - Middle slope	-0.40539143	-0.6488314	-0.16195150	0.0001306
Hill top - Middle slope	-0.20976300	-0.4510251	0.03149912	0.1134743
Hill top - Fluvial plain	0.19562843	-0.0857422	0.47699906	0.2775564

3.4. Differences of population density on the monthly basis

Fitting field results of red spider and predatory mites to the precipitation patterns during the sampling periods of 2017 and 2018 shows that population densities of red spider mites are higher in months of low rainfall and lower in months of higher rainfall. Red mites were dislodged by heavy rainfall, which made the population densities significantly low in high rainfall months of July (2017) and July and August (2018). This finding is well in agreement with Kachhawa and Rahman (2013). Comparatively on the monthly basis, monocrop plots have significantly higher densities of red spider mites than the intercrop plots. This finding well coincides wih those of Abdullah and Fouad, (2016); Singh et al. (2017); Patient et al. (2019); and Oso and Falade (2010).

3.5. Cassava yields and additional income from cowpea

Collected yield data reveal that the average cassava yield of the intercrop is 17% higher that that of the monocrop system with 21.11 and 18.02 tonnes/ha, respectively. This increase comes from improved soil fertility for increase nitrogen in the topsoil due to the biological nitrogen fixation mechanism of the cowpea legume and residue mulch that farmers leave on the soil survey after harvesting cowpea. This finding coincides with that of Abdullah and Fouad, (2016); Singh et al. (2017); Patient et al. (2019); Bellotti et al., 2012; Poveda et al., 2008; and Oso and Falade (2010).

Farmer interview data on cowpea yield and income reveal that one hectare of cassava-cowpea intercrop can produce 560kg of dried cowpea with a stable market price of 2.3 USD/dried kg of cowpea. This makes the total income additionally coming from cowpea per hectare 1,288 USD. This income is relatively equal to the income from cassava per hectare. This means that intercrop farmer can literally double their incomes. This finding is in strong agreement with that of Poveda et al., 2008.

4. Conclusions

Findings of the study leave us five main conclusions:

a) Population densities of red spider mites are higher in monocrop than intercrop fields. Although soil fertility and quality data are not presented in the manuscript to help explain this, the cover crop alledgedly reduces evapotraspiration and increases soil moisture content, which is the main reason why the intercrop system is better resilient to red spider mites.

b) Soils located on middle slope positions are more susceptible to more severe erosion and degradation and, therefore, less fertile. Population densities of red spider mites are likely higher at these locations.

c) Cassava yields are higher in the intercrop than the monocrop system which, together with additionaly income from cowpea, remarkably increase overall household income and help achieve food security and poor reduction goals for mountain provinces.

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