



# The effect of mixed cropping practice of chili bird (*Capsicum frutescens* L.) on crop yield and pest and disease occurrence

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**Abstract.** Field experiments were performed to compare the effectiveness of four different mixed cropping in reducing pest and diseases incidence and to compare crop yield on chili bird. The four mixed cropping were chili bird – lettuce – cauliflower – tomato, chili bird – cauliflower – tomato, chili bird – tomato and sole chili bird as a control. The experiment was conducted at the Indonesian Vegetables Research Institute (IVERGRI) Lembang - West Java from September 2013 to April 2014. The experiment was arranged as a split plot complete randomized block design with three replications. Result of this experiment revealed that six pest and diseases were recorded such as thrips, mite, white fly, cercospora leaf spot, phytophthora blight and anthracnose. Although the population and/or plant damage due to these pest and diseases were lower in chili bird mixed-crop, however, there were no significant difference in plant damage between chili bird sole crop and mixed-crop except for whiteflies. Among the test treatments, the highest suppression of thrips, whiteflies and mite were observed at conventional system (farmers practice) followed by ATECU at 10 mL/L and IPM treatments. Applications of ATECU and spinetoram in IPM system reduced used of synthetic insecticide 42.86 %. Yield of chili bird varied with different mixed cropping practice. Significantly the highest yields were obtained in chili bird sole crop (5.06 t ha<sup>-1</sup>). Mixed cropping between chili-lettuce-cauliflower-tomato reduced marketable yield of chili more than 22.95% however provide additional net income compare to another treatment (Rp. 204.162.500,- per ha) and benefit cost ratio (B:C ratio) 2.53. The lowest net returns Rp. 88.772.500 and B:C ratio 2.01 were obtained in sole chilli. This obviously reflected the importance of mixed cropping to increase the productivity per unit area. Further, it also offers insurance against crop failure. This supports the point that mixed cropping may be an efficient ecological strategy to control pest and diseases and should be incorporated in sustainable agricultural management practices.

**Keys Words:** disease control, pest control, plant damage, sustainable agriculture, intercropping.

**Introduction.** Chili bird (*Capsicum frutescent* L.) is one of the important commercial vegetable crops and widely cultivated throughout the tropical and subtropical countries in the world. Demand for chili in the world is increasing every year. This crop is grown throughout the year in Indonesia and several cultivar/varieties are grown. In Indonesia, the chili bird is cultivated on about 134.882 ha with a total production of 800 t (BPS 2015). The average yields of *C. frutescent* is 5.93 t ha<sup>-1</sup>, which is low compared to the yield achieved by other chili bird growing countries of the world. Sometime the price of chili rises up due to less production of chili. Chili price has climbed to more than 100,000 rupiah (some 7.41 U.S. dollar) per kilogram from the normal price of over 30,000 rupiah (about 2.22 U.S. dollar). There are many factors responsible for the low yield of the chili bird, pest and diseases are one of them. Thrips (*Thrips parvispinus*), mite (*Polyphagotarsonemus latus*), fruit borer (*Helicoverpa armigera*), fruit fly (*Bactrocera* sp), anthracnose (*Colletotrichum* spp.), phytophthora blight (*Phytophthora capsici*) and bacterial wilt (*Ralstonia solanacearum*) are the most important pest and diseases on chili bird and climate change has exacerbated the high intensity of pest and disease attack which causing decreasing of chili production up to 25-100 % (Setiawati et al 2011b, 2013). Increased productivity of chili needs to be done in an effort to support the sustainable agricultural systems and also be directed to provide benefits and value - added and quality products with high competitiveness.

Several sustainable methods of control have been developed in recent years for reducing pest and diseases damage in field vegetable crops. There is a continual search for pesticides with reduced risk. This has helped to overcome some of the problems that occur when pest and diseases develop resistance to certain pesticides. One sustainable method of control is 'mixed cropping' (Hasyim et al 2015; Zehnder et al 2007), a system in which a plant species (the intercrop) is grown specifically to reduce pest and diseases damage on a main crop. Mixed cropping of chili with different crops offers greater scope to utilize the land and other resources to maximum extent. Besides, mixed cropping also acts as insurance as a resource for poor farmers if one crop fails, they get some yield of another crop (Setiawati & Asandhi 2003; Adiyoga et al 2004; Brintha & Seran 2012). There were two major reasons why farmers changed cropping pattern from monocropping into mixed cropping. First, farmers needed to meet the market demand for various kinds of vegetables. Because this demand could not be met by monocropping as it only produces one kind of vegetable, farmers diversified their farms by mixed cropping. On the other hand, vegetables were susceptible to pest and disease attacks. Diversification through mixed cropping reduces the risk of harvest failure by pest and disease attacks. If harvest failed because one vegetable was attacked, farmers could still earn income from other vegetables.

Increasing biodiversity by intercropping system had positive effects for species richness commonly observed among predator species may extend to pathogen communities as well, such that conserving pathogen biodiversity may carry additional benefits for biological control. However, there are also reasons that a mixed cropping system may be more susceptible to attack: 1) reduced cultivation and greater shading due to the presence of associated species, 2) associated crops serve as alternate hosts, and 3) crop residues from one crop may serve as a source of inoculum for the others.

Andow (1991) analyzed 209 studies involving 287 pest species. Compared with monocultures, the population of pest insects was lower in 52% and the population of natural enemies of the pests was higher in the intercrop in 53%. Boudreau (2013) reported that mixed cropping reduced disease in 73% of more than 200 studies.

Mixed cropping of chili bird and different crops is very popular traditional practice among the small holder Indonesian farmers. Chili bird is planted with wider row spacing (90 to 120 cm), the crop has initial slow growth and long harvest time, therefore, it provides excellent opportunities to taken up intercrops. Farmers usually use different forms of mixed cropping practices with different combinations of crops. Short duration crops like lettuce, cauliflower or tomato can also be raised as intercrops with chili bird. However, these crops owing to their root system, growth pattern, pest and diseases incidence, yielding ability and crop duration affect the performance of the cropping system. Interaction of intercrops with the main component crops of the cropping system viz., chili bird is considerably because of their differential root growth, growth pattern, yielding ability and crop duration. Such information is lacking. Hence, present experiment was undertaken with objective to study the effect of intercropping of chili bird on pest and diseases incidence and to asses the best system for resource management with respect to productivity, competition and economic parameters.

**Material and Method.** Field experiment was conducted at the experimental station of the IVEGRI in Lembang, province of West Java (1250 m above sea level) from September 2013 to April 2014. The soil type was Andisol with pH range of 5.0–6.0. The experiment was arranged as a split plot complete randomized block design with three replications.

Main plot (Planting system)

- A1. chili bird + lettuce + cauliflower + tomato (CB-L-CF-T)
- A2. chili bird + cauliflower + tomato (CB-CF-T)
- A3. chili bird + tomato (CB-T)
- A4. chili bird (monoculture) (sole chili bird)

Main plot : Control methods

- B1. Conventional system (Abamectin 18 EC + Azoxystrobin)
- B2. IPM (Spinoteram if population of Thrips reach action threshold + Azoxystrobin)

- B3. Biopesticide (ATECU + Azoxystrobin)

Note : ATECU is biopesticide which contain plant extracts as active components (*Azadirachta indica* + *Tephrosia vogelii*) in combination with cow urine.

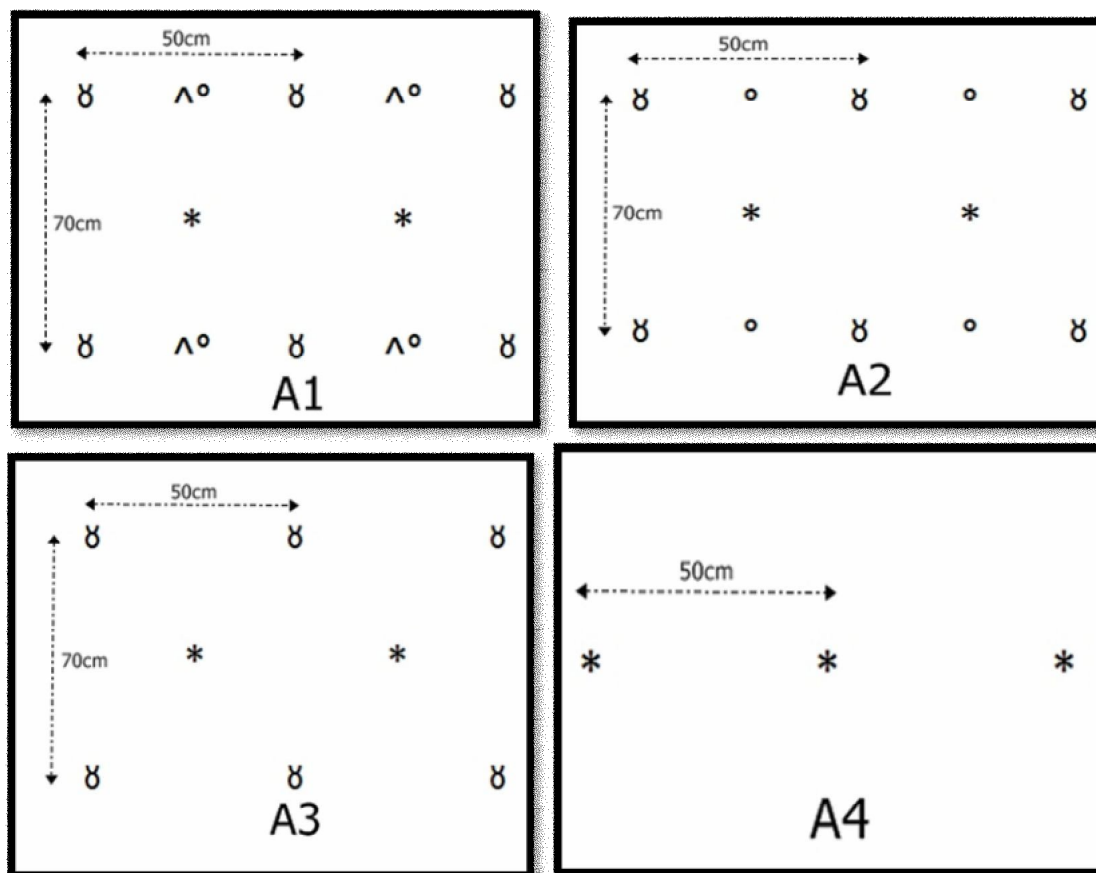


Figure 1. Treatments layout (\* - Chili bird plant density/ha: 11,000; ^ - Lettuce planted 15 days before chili bird, plant density/ha: 22,000; ° - Cauli flower planted 60 days after planting chili bird, plant density/ha: 22,000; ♂ - Tomato planted 45 days after planting chili bird, plant density/ha: 22,000).

Chili seedling was prepared previously at nursery protected using bio-agent and nylon net to minimize attack of pests and diseases at very early stages. Transplanting was conducted when the seedling was 4 weeks old.

Land preparation started with plugging and making beds. The size of bed is 1m by 4.5 m. Organic materials consisting of mature compost and manure were applied as basal fertilizer along with NPK composite fertilizers. The dose of organic materials and NPK was 30 t/ha and 1 t/ha respectively. The beds were covered with silvery plastic mulch.

Pests and diseases incidence and percentage of plant damage were counted from randomly selected 10 plants in each plot. Assessments were conducted throughout in the growing season recorded in weekly interval. At harvest time, chili pepper fruit per plot were weighed for each treatment. Data are presented as expected weight  $t\ ha^{-1}$ . Benefit cost analysis was performed considering the prevailing price of chili, lettuce, cauliflower and tomato at the harvesting period in the local market. For economic analysis, gross income, total operational cost, net returns and B:C ratio were used.

**Statistical analysis.** The data were subjected to one way ANOVA (SAS Program). Significantly different means ( $P < 0.05$ ) were separated using Duncan Multiple Range Test (DMRT) at 5% probability. Count data were  $\sqrt{x + 0.5}$  transformed and percentage data arcsine-square root transformed. In graphs and figure, the original data and their standard errors are presented.

## Results and Discussion

**Pests and diseases.** During the growth of the chili bird a number of pests and diseases were identified attacking the plant. These include thrips (*Thrips parvispinus*), mite (*Polypagotarsonemus latus*), whitefly (*Bemisia tabaci*), cercospora leaf spot (*Cercospora capsici*), phytophthora blight (*Phytophthora capsici*) and anthracnose (*Colletotrichum acutatum*). Sucking pests like thrips, whiteflies and mites population were relatively high and showed characteristic downward and upward curling symptoms on leaves. These pest and diseases attacked the plant at different growth stages of the plant. No correlation was found between planting system and control methods.

Thrips was observed on chili bird at 30 days after planting (DAP) and remained on the plant until harvest. At the time of the first assessment, most population of thrips was recorded in the sole chili plots. During this assessment, least population was recorded on the chili intercropped with L-CF-T. However, population dynamic of thrips during the experiment were similar between sole chili bird and mixed cropping. Number of thrips varied between 9.78 in CB-L-CF-T mixed cropping to 11.06 in control plots (Sole chili bird). The thrip population was low until 72 DAP and kept increasing between 79 and 100 DAP. From 107–121 DAP the thrips decreased regardless of treatments. However, population of thrips on the intercropped plots and the sole chili bird plots were not significantly different. Thus mixed cropping did not reduce the population of this pest on chili bird (Figure 2).

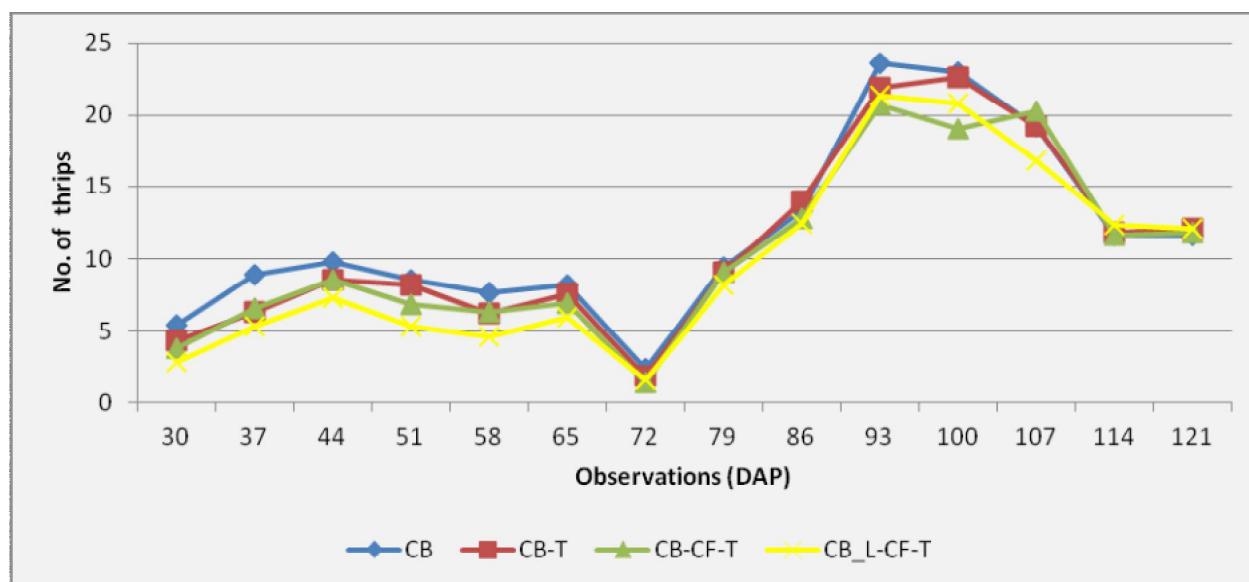


Figure 2. Effect of mixed cropping practices on population dynamic of thrips.

ATECU (10 mL/L) at 7 day interval provided excellent control of thrips in chili bird and performed as well as, or better than conventional and IPM treatments over the growing season (Figure 3). During the experiment ATECU and conventional system (Abamectin) were applied 14 times, while IPM system only 8 times. So that the use of IPM system could reduced the application of insecticides even with 42.86%.

The effect of different treatments against mite (*P. latus*) is presented in Table 1 and Figure 4. Plant damage by *P. latus* was lower at the first month growing of chili bird, and increasing in line as plant age increase. They were most abundant on the sole chili bird plots and IPM system (Figure 4) and the lowest was found in CB-L-CF-T and conventional system. However, plant damage due to mite on the intercropped plots and the sole chili bird plots were not significantly different.

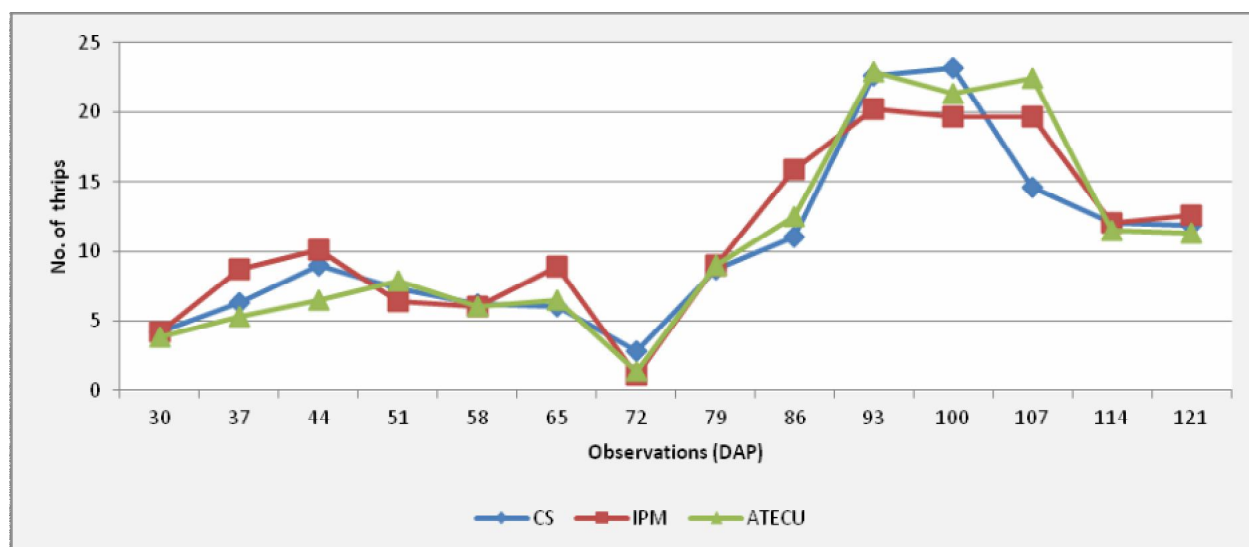


Figure 3. Effect of control methods on population dynamic of thrips.

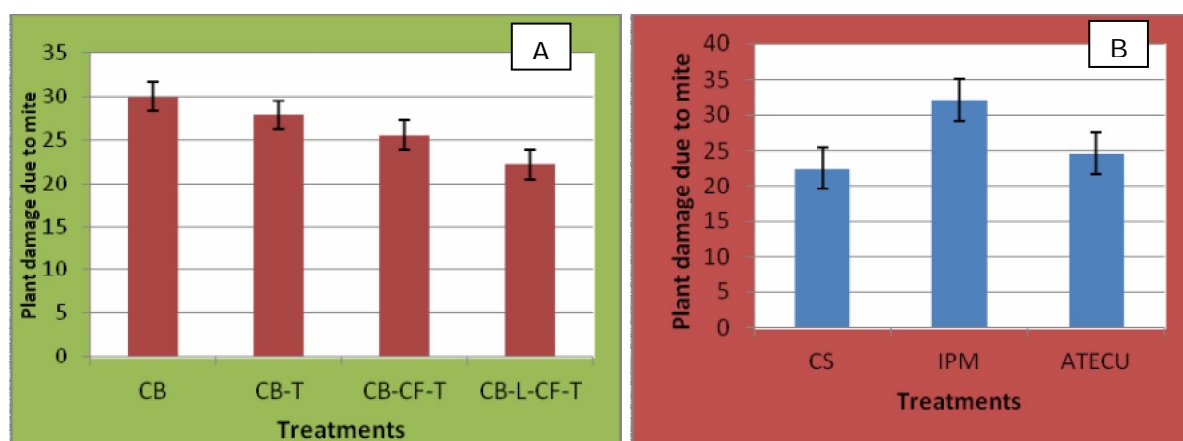


Figure 4. Plant damage due to mite on: A - planting system treatments, B – controls. The error bars represents the standard deviation.

Table 1

Effect of mixed cropping and control methods to plant damage due to mite

Planting system	Plant damage due to mite at.....DAP													
	30	37	44	51	58	65	72	79	86	93	100	107	114	121
CB	2.72 <sup>a</sup>	6.30 <sup>a</sup>	7.41 <sup>a</sup>	9.88 <sup>a</sup>	8.27 <sup>a</sup>	11.85 <sup>a</sup>	2.84 <sup>a</sup>	4.44 <sup>a</sup>	4.20 <sup>a</sup>	8.64 <sup>a</sup>	9.14 <sup>a</sup>	9.88 <sup>a</sup>	27.16 <sup>a</sup>	30.00 <sup>a</sup>
CB-T	3.83 <sup>a</sup>	6.91 <sup>a</sup>	6.17 <sup>a</sup>	9.75 <sup>a</sup>	10.99 <sup>a</sup>	10.25 <sup>a</sup>	2.96 <sup>a</sup>	4.94 <sup>a</sup>	4.57 <sup>a</sup>	10.62 <sup>a</sup>	10.37 <sup>a</sup>	10.49 <sup>a</sup>	26.79 <sup>a</sup>	27.90 <sup>a</sup>
CB-CF-T	3.70 <sup>a</sup>	9.01 <sup>a</sup>	9.14 <sup>a</sup>	9.88 <sup>a</sup>	10.00 <sup>a</sup>	12.22 <sup>a</sup>	2.47 <sup>a</sup>	4.57 <sup>a</sup>	3.33 <sup>a</sup>	9.38 <sup>a</sup>	10.74 <sup>a</sup>	10.00 <sup>a</sup>	23.58 <sup>a</sup>	25.56 <sup>a</sup>
CB-L-CF-T	2.22 <sup>a</sup>	4.94 <sup>a</sup>	5.06 <sup>a</sup>	7.41 <sup>a</sup>	8.15 <sup>a</sup>	10.12 <sup>a</sup>	3.09 <sup>a</sup>	6.05 <sup>a</sup>	3.70 <sup>a</sup>	9.51 <sup>a</sup>	9.88 <sup>a</sup>	10.74 <sup>a</sup>	20.49 <sup>a</sup>	22.22 <sup>a</sup>
LSD (5%)	2.57	6.09	4.32	5.67	5.10	4.26	0.91	2.42	4.18	8.86	8.51	7.29	27.11	28.61
Control methods														
CS	4.44 <sup>a</sup>	6.02 <sup>a</sup>	7.22 <sup>a</sup>	9.35 <sup>a</sup>	8.98 <sup>a</sup>	9.81 <sup>a</sup>	4.81 <sup>a</sup>	7.22 <sup>a</sup>	3.98 <sup>a</sup>	9.07 <sup>a</sup>	9.72 <sup>a</sup>	8.52 <sup>a</sup>	20.56 <sup>a</sup>	22.50 <sup>a</sup>
IPM	2.59 <sup>a</sup>	5.93 <sup>a</sup>	8.24 <sup>a</sup>	8.24 <sup>a</sup>	9.54 <sup>a</sup>	12.87 <sup>a</sup>	1.94 <sup>b</sup>	4.81 <sup>b</sup>	2.41 <sup>a</sup>	12.13 <sup>a</sup>	12.22 <sup>a</sup>	13.33 <sup>a</sup>	30.09 <sup>a</sup>	32.13 <sup>a</sup>
ATECU	2.31 <sup>a</sup>	8.43 <sup>a</sup>	5.37 <sup>a</sup>	10.09 <sup>a</sup>	9.54 <sup>a</sup>	10.65 <sup>a</sup>	1.76 <sup>b</sup>	2.96 <sup>b</sup>	5.46 <sup>a</sup>	7.41 <sup>a</sup>	8.15 <sup>a</sup>	8.98 <sup>a</sup>	22.87 <sup>a</sup>	24.63 <sup>a</sup>
LSD (5%)	2.22	5.28	3.74	4.91	4.42	3.69	0.79	2.10	3.62	7.68	7.37	6.32	23.48	24.78

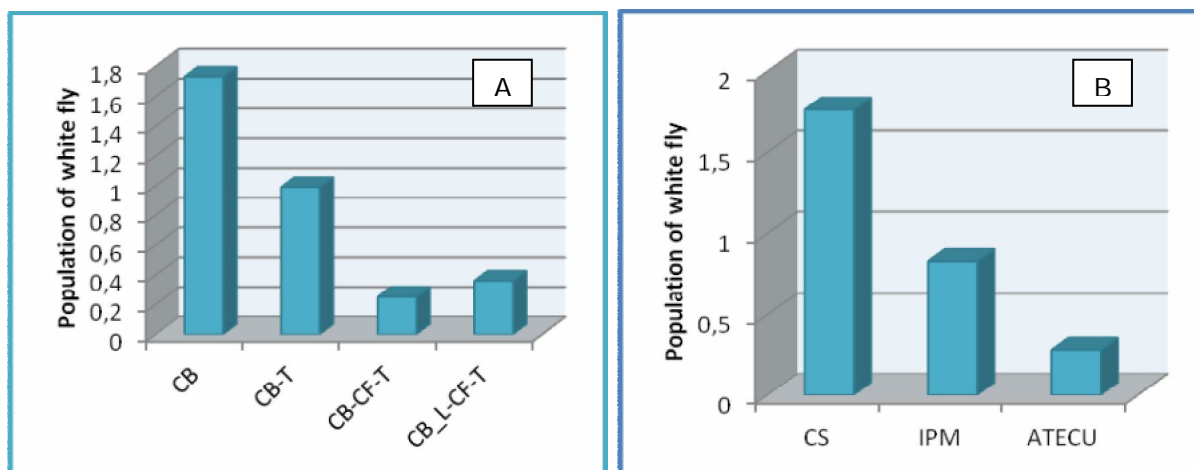


Figure 5. Population of white fly on: A - planting system treatments, B – controls.

The whiteflies observed on the plant at 6 WAT (week after treatment), with the largest number infesting the sole chili bird, while the CB-L-CF-T plots were least infested. The observed differences were significant between intercrop and sole chili bird. Setiawati et al (2011a) reported that mixed cropping between hot pepper-cabbage and hot pepper-tomato reduced population of *B. tabaci* at rate of 60.72 and 25.24%. Mixed cropping tomato with cucurbits or cruciferae can reduce the abundance of whiteflies and/or incidence of tomato yellow leaf curl virus in tomato (Al-Musa 1982; Schuster 2004; Setiawati et al 2011a), but the effect may depend on overall pest abundance (Castle 2006; Manandhar et al 2009). So that, one species serves as a trap crop or repellent protecting the other (Legaspi 2010). Application of ATECU was effective to control whiteflies on chili bird followed by IPM and conventional system (Figure 5).

Incidence of cercospora leaf spot had not significant variation as recorded in Table 2. Leaf infection by cercospora was lower at the first month growing of chili bird, and increasing in line with plant age. In these condition, intercrop were no significant differences at all observations in suppression of cercospora compared to the untreated control (sole chili), except 44 and 65 DAP. Percentage of the highest leaf infection at (20%) was found in intercrop CB-CF-T and CB-L-CF-F and the lowest infection (17.78%) were obtained from sole chili bird and intercrop CB-T. Close plant spacing enhances development of cercospora.

Phytophthora blight was found at 65 DAP. The result indicated that mixed cropping reduced the damage due to Phytophthora disease significantly over sole chili bird at 72 and 93 DAP. The rest of observations showed no significantly differences between intercrop and sole chili bird (Table 3).

The results show that the severity of anthracnose ranged from 14.07% to >14.29% (Figure 6). Mixed cropping is well documented and used for disease control and appears to be a more promising solution than pesticide application, but the underlying mechanisms are still unclear. Mixed cropping may be an efficient ecological strategy to control soil-borne plant disease and should be incorporated in sustainable agricultural management practices (Gao et al 2014). There were no significant differences between intercrop and sole chili bird. In general, there were no significant changes in the microclimatic situation in both chili sole and mixed cropping. Although Potts (1990) mentioned microclimate as one of the beneficial effect of mixed cropping, it should however be noted.

Studies have shown that mixed cropping has been advantageous in reducing insect pests and disease damage in some areas through diversifying the cropping system by introducing plant species that are non hosts for certain insects and diseases (Jones 2007). These are ecologically safe and culturally more acceptable among the chili bird farmers.

Table 2

Effect of mixed cropping and control methods to plant damage due to *Cercospora* leaf spot

<i>Planting system</i>	<i>Plant damage due to Cercospora sp. at.....DAP</i>													
	30	37	44	51	58	65	72	79	86	93	100	107	114	121
CB	17.56 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>	19.78 <sup>ab</sup>	20.67 <sup>a</sup>	19.78 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>	19.56 <sup>a</sup>	17.78 <sup>ab</sup>	22.22 <sup>a</sup>	8.89 <sup>a</sup>	13.33 <sup>a</sup>	17.78 <sup>a</sup>
CB-T	17.56 <sup>a</sup>	20.00 <sup>a</sup>	19.33 <sup>b</sup>	18.89 <sup>b</sup>	22.00 <sup>a</sup>	17.78 <sup>b</sup>	19.11 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>	13.33 <sup>b</sup>	20.89 <sup>a</sup>	13.33 <sup>a</sup>	13.33 <sup>a</sup>	17.78 <sup>a</sup>
CB-CF-T	18.44 <sup>a</sup>	19.56 <sup>a</sup>	19.78 <sup>ab</sup>	19.78 <sup>ab</sup>	22.22 <sup>a</sup>	18.44 <sup>b</sup>	19.33 <sup>a</sup>	20.89 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>	21.33 <sup>a</sup>	13.33 <sup>a</sup>	15.56 <sup>a</sup>	20.00 <sup>a</sup>
CB-L-CF-T	18.00 <sup>a</sup>	19.56 <sup>a</sup>	19.33 <sup>b</sup>	20.00 <sup>a</sup>	20.44 <sup>a</sup>	18.22 <sup>b</sup>	18.44 <sup>a</sup>	20.44 <sup>a</sup>	19.78 <sup>a</sup>	20.00 <sup>a</sup>	21.78 <sup>a</sup>	11.11 <sup>a</sup>	13.33 <sup>a</sup>	20.00 <sup>a</sup>
LSD (5%)	1.53	0.74	0.67	1.08	4.53	1.33	2.95	1.18	0.74	5.27	2.71	7.45	8.81	4.71
Control methods														
CS	18.33 <sup>a</sup>	19.67 <sup>a</sup>	19.33 <sup>a</sup>	19.83 <sup>a</sup>	20.83 <sup>a</sup>	17.67 <sup>b</sup>	18.50 <sup>a</sup>	20.00 <sup>b</sup>	20.00 <sup>a</sup>	15.00 <sup>b</sup>	22.67 <sup>a</sup>	18.33 <sup>a</sup>	13.33 <sup>ab</sup>	18.33 <sup>a</sup>
IPM	18.00 <sup>a</sup>	19.67 <sup>a</sup>	19.67 <sup>a</sup>	19.67 <sup>a</sup>	22.17 <sup>a</sup>	19.33 <sup>a</sup>	19.67 <sup>a</sup>	21.17 <sup>a</sup>	20.00 <sup>a</sup>	18.33 <sup>ab</sup>	20.67 <sup>a</sup>	11.67 <sup>b</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>
ATECU	17.33 <sup>a</sup>	20.00 <sup>a</sup>	19.83 <sup>a</sup>	19.33 <sup>a</sup>	21.00 <sup>a</sup>	18.67 <sup>ab</sup>	19.50 <sup>a</sup>	19.83 <sup>b</sup>	19.50 <sup>a</sup>	20.00 <sup>a</sup>	21.33 <sup>a</sup>	5.00 <sup>c</sup>	8.33 <sup>b</sup>	18.33 <sup>a</sup>
LSD (5%)	1.32	0.65	0.58	0.93	3.92	1.15	2.56	1.02	0.65	4.56	2.34	6.45	7.63	4.08

Table 3

Effect of mixed cropping and control methods to plant damage due to *Cercospora* leaf spot

Planting system	Plant damage due to <i>Phytophthora</i> blight at..... DAP								
	65	72	79	86	93	100	107	114	121
CB	0.67 <sup>a</sup>	21.11 <sup>a</sup>	19.33 <sup>a</sup>	1.56 <sup>a</sup>	6.22 <sup>ab</sup>	20.44 <sup>a</sup>	21.33 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>
CB-T	0.22 <sup>a</sup>	17.78 <sup>b</sup>	20.89 <sup>a</sup>	2.00 <sup>a</sup>	8.67 <sup>a</sup>	20.67 <sup>a</sup>	18.22 <sup>a</sup>	20.00 <sup>a</sup>	20.44 <sup>a</sup>
CB-CF-T	0.00 <sup>a</sup>	18.11 <sup>b</sup>	22.00 <sup>a</sup>	0.67 <sup>a</sup>	1.56 <sup>b</sup>	20.67 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>
CB-L-CF-T	0.67 <sup>a</sup>	18.00 <sup>b</sup>	21.78 <sup>a</sup>	1.11 <sup>a</sup>	1.56 <sup>b</sup>	20.89 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>
LSD (5%)	1.05	0.71	2.78	2.46	5.53	1.49	3.62	0.00	0.67
Control methods									
CS	0.67 <sup>a</sup>	12.17 <sup>c</sup>	21.33 <sup>ab</sup>	3.50 <sup>a</sup>	6.33 <sup>a</sup>	20.00 <sup>b</sup>	20.67 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>
IPM	0.50 <sup>a</sup>	21.17 <sup>b</sup>	22.67 <sup>a</sup>	0.50 <sup>b</sup>	4.33 <sup>a</sup>	21.33 <sup>a</sup>	18.33 <sup>a</sup>	20.00 <sup>a</sup>	20.33 <sup>a</sup>
ATECU	0.00 <sup>a</sup>	23.17 <sup>a</sup>	19.00 <sup>b</sup>	0.00 <sup>b</sup>	2.83 <sup>a</sup>	20.67 <sup>ab</sup>	20.67 <sup>a</sup>	20.00 <sup>a</sup>	20.00 <sup>a</sup>
LSD (5%)	0.91	0.61	2.40	2.13	4.79	1.29	3.13	0.00	0.58

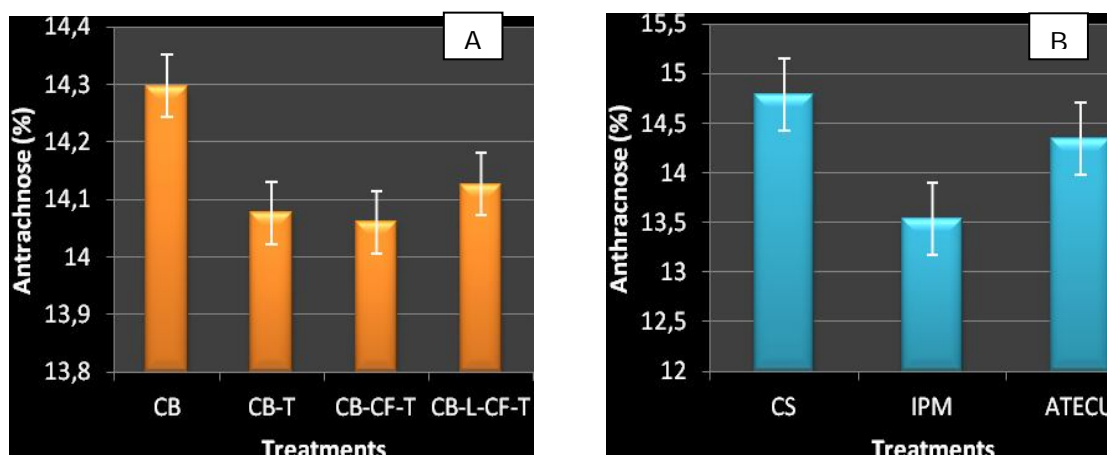


Figure 6. A - Plant damage due to *C. acutatum* on: A - planting system treatments, B - control method treatments. The error bars represents the standard deviation.

**Marketable yield.** Effect of different treatments on yield of chili bird was determined. Yield of chilli varied with different mixed cropping systems ranging between 3.9–5.06 t ha<sup>-1</sup>. The results showed that there were insignificant differences between mono and intercrops in fresh weight of marketable yield of chili bird. Fresh weight of chili bird was high in sole chili (5.06 t ha<sup>-1</sup>), followed by mixed cropping of CB-T (5.01 t ha<sup>-1</sup>), CB-CF-T (4.06 t ha<sup>-1</sup>) and the lowest yield was found in inter-cropping CB-L-CF-T (3.9 t ha<sup>-1</sup>). Both plants reduce considerably the yield of chili bird. Plots treated with conventional system (Abamectin 18 EC) produced highest yield (5.15 t ha<sup>-1</sup>) followed by ATECU 10 mL/L (4.72 t ha<sup>-1</sup>) and IPM (Spinetoram) (3.73 t ha<sup>-1</sup>) (Figure 7). The yield of tomato as intercropped was recorded 30.95, 31.42 and 32.41 t ha<sup>-1</sup>, respectively in CB-L-CF-T, CB-CF-T and CB-T. Cauliflower was recorded 17.67 t ha<sup>-1</sup> in CB-L-CF-T and 17.85 t ha<sup>-1</sup> in CB-CF-T and lettuce (9.13 t ha<sup>-1</sup>) in CB-L-CF-T. Some literature reported that a reduced yield was found in mixed cropping system compare to mono-cropping due to the competition between the two crops (Lotz et al 1997; Setiawati et al 2008; Brintha &

Seran 2012; Alom et al 2014). Greater productivity in mixed cropping system is commonly achieved by minimizing inter-specific competition and maximizing complementary use of growth resources (Islam et al 2006). It therefore means that non-host crop in a mixed cropping must be carefully selected in order not to compete with the main crop for essential nutrients.

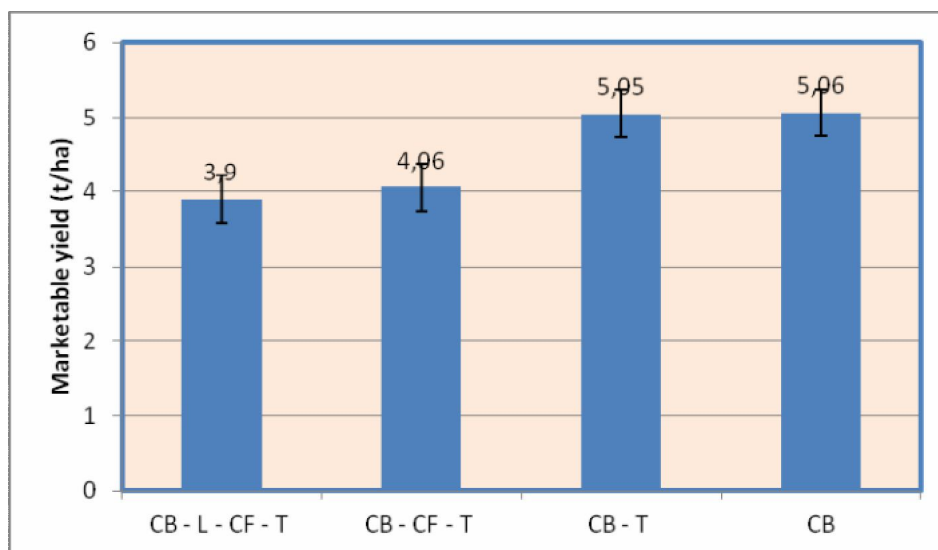


Figure 7. Marketable yield of chili bird in different mixed cropping system. The error bars represents the standard deviation.

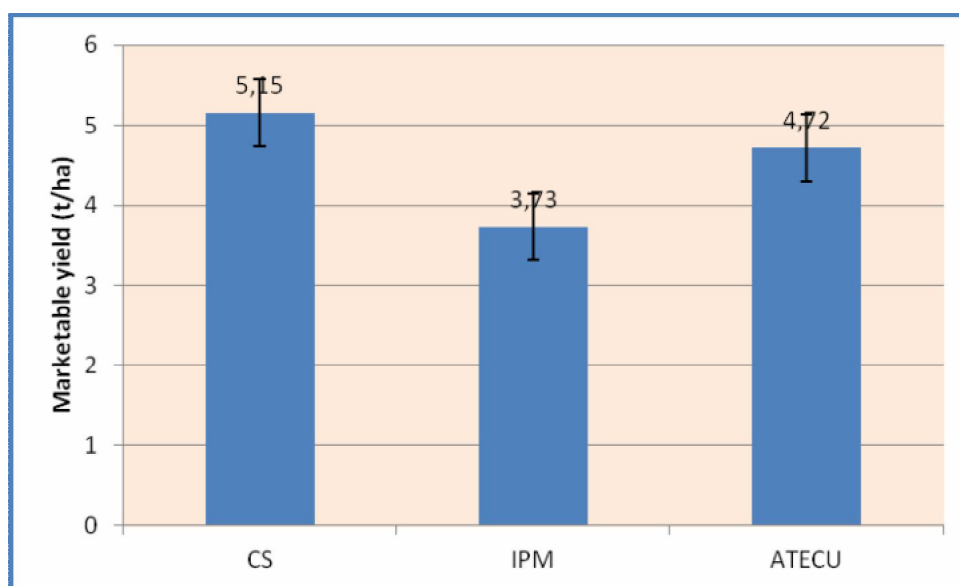


Figure 8. Marketable yield of chili bird recorded on control. The error bars represents the standard deviation.

Mixed cropping significantly reduced chili yield by 0.20 to 22.92% (Figure 9). CB-L-CF-T reduced marketable yield of chili up to 22.95%, CB-CF-T reduced marketable yield of chili up to 19.71%, while the minimum yield loss of chili was found in CB-T (0.20%). Begum et al (2015) reported that mixed cropping reduced chili yield by 3 to 48 %. The yield loss due to mixed cropping was also reported by Suresha et al (2007). The disadvantages of mixed cropping are that there is reduced yield of the component crops there may be competition for space, solar radiation, nutrients and water (Weber et al 1999; Begum et

al 2015); there may be allelopathic effects due to excretion of toxic substances by one or more crops.

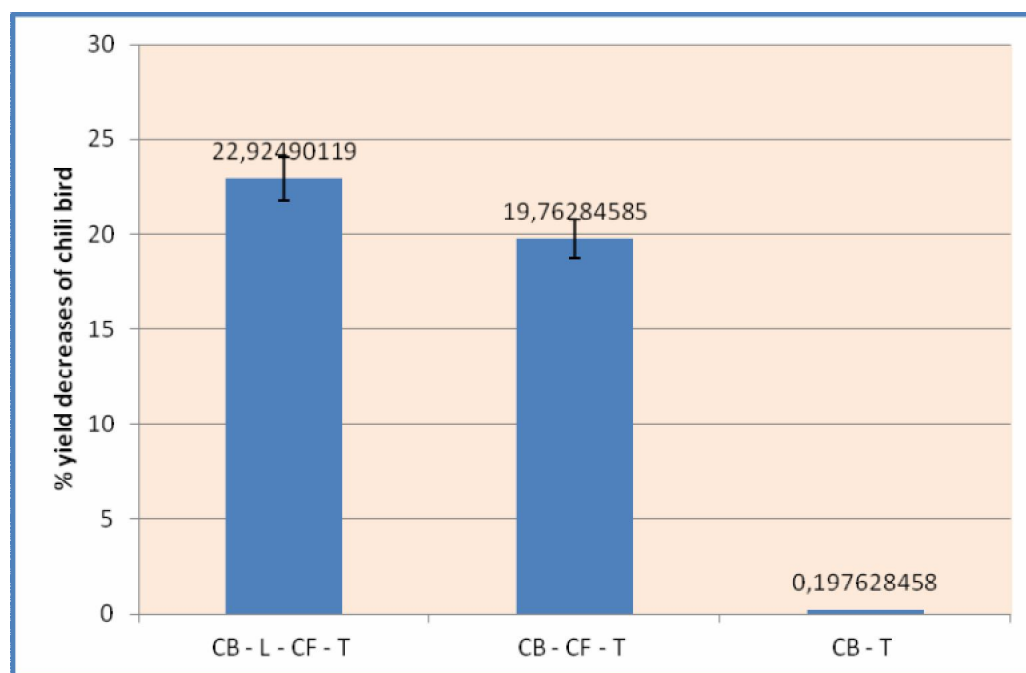


Figure 9. Percent yield decrease of intercropped chili bird over sole chili in different mixed cropping system. The error bars represents the standard deviation.

**Financial analysis of field trials.** The cost of cultivation was high in mixed cropping compared to mono-cropping. Net return represents the actual income received by the farmers. High net return was achieved from mixed cropping due to combined yield from both chili and another crop. Mixed cropping between CB-L-CF-T can provide additional net income (Rp. 204.162.500,- per ha) compare to another treatment. Yield advantages through mixed cropping have been reported by many workers (Molla & Sharaiha 2009). The lowest was found on chili bird monoculture (Rp. 88.772.500,-) (Table 5). Chili mixed cropping with L-CF-T recorded significantly higher B:C ratio of 2.53, followed by CB-CF-T (2.51), CB-T (2.31) compared to chili sole (2.01). It has been suggested can be that mixed cropping is more profitable than the sole cropping and risk of cultivation of one crop can be reduced by mixed cropping. Hence, mixed cropping could be suggested for the farmers if they invest financially for their cultivation.

Table 4  
Economics at different chili bird mixed cropping system per ha

Treatment	Gross returns (Rp./ha)	Cost of cultivation (Rp./ha)	Net return (Rp./ha)	B:C ratio
Chili – lettuce – cauliflower - tomato	337.220.000	133.057.500	204.162.500	2.53
Chili – cauliflower - tomato	330.985.000	131.297.500	199.687.500	2.52
Chili - tomato	274.330.000	118.612.500	155.717.500	2.31
Chili - monocrop	177.100.000	88.327.500	88.772.500	2.01

**Conclusions.** During the experiment six pest and diseases were recorded, namely thrips, white fly, mite, cercospora leaf spot, phytophthora blight and anthracnose. Although the population and/or plant damage due to these pests were lower in chili bird intercrop, however, there were no significant difference in plant damage between chili bird sole crop and intercrop except for whiteflies. Among the test treatments, the highest suppression

of thrips, whiteflies and mite were observed at conventional system (farmers practice) followed by ATECU at 10 mL/L and IPM treatments. Applications of ATECU and Spinetoram in IPM system reduced used of synthetic insecticide with 42.86%. Yield of chili bird varied with different mixed cropping systems. Significantly the highest yields were obtained in chili bird sole crop (5.06 t ha<sup>-1</sup>). Mixed cropping between CB-L-CF-T reduced marketable yield of chili more than 22.95% however provide additional net income compare to another treatment (Rp. 204.162.500,- per ha) and B:C ratio 2.53. The lowest net returns Rp. 88.772.500,- and B:C ratio 2.01 were obtained in sole chilli. This obviously reflected the importance of mixed cropping to increase the productivity per unit area. Further, it also offers insurance against crop failure. This supports the point that mixed cropping may be an efficient ecological strategy to control pest and diseases and should be incorporated in sustainable agricultural management practices.

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