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Original Research Article

Effects of fertilizer, irrigation level and spider presence on abundance of herbivore and carnivore in rice cultivation in Yogyakarta

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Abstract

Cultivation techniques that are usually followed in rice cultivation is believed to greatly affect the interaction between arthropods in form of bottom-up and top-down ways, which in turn, affects their diversity and abundance. Beside of that, the spider is generalist predator that has a great potential as a biological pest control agent. This research aimed to determine the effects of spider presence, fertilizer and irrigation level on abundance of herbivore and carnivore in rice cultivation in Yogyakarta, Indonesia (Wates – Kulon Progo). It was done in factorial design using three factors: fertilizers (organic, inorganic, and without fertilizer), irrigation levels (less water = 2 cm, conventional >10 cm), and spider presence (with and without spider). Each combination treatment had three replications. The results showed that the interaction between fertilizer and irrigation level affected soil PH and total N of rice plant but not to total N of soil. Organic fertilizer with less irrigation decreased the abundance of carnivore but it did not affect the abundance of herbivore. Meanwhile, interaction between spider presence and irrigation level affected carnivore abundance, but not to herbivore generally. The spider presence decreased Delphacidae abundance but did not affect the abundance of Alydidae dan Staphylinidae.

Keywords: Ecological effect, Natural enemies, Parasitoid, Predator, System of rice intensification

Introduction

About 75% of rice cultivation methods around the world are implemented conventionally (Bouman and Tuong, 2001) which are at least characterized by applying synthetic input and flooded irrigation. Unfortunately, the expected increase in production is not proportional to the cost. Population outbreak of pest was happened by synthetic fertilizer (Heong et al., 1995; Heong, 2004; Hepperly et al., 2009) and gave a negative impact on soil, water, animals and humans (Peng and Cassman, 1994). Furthermore, flooded irrigation prevented rice crop of achieving optimal growth, increasing vulnerability to pest attacks (Baehaki, 1985; Kirk and Bouldin, 1991; Kirk and Solivas, 1997) and enlarging water conflicts interest (Gleick, 1993; Peng et al., 2009). One of the rice cultivation techniques that considered eligible to answer that problem is the cultivation of organic rice with less irrigation as like as System of Rice Intensification (SRI).

SRI cultivation uses organic fertilizer which is known as healthy and environmentally friendly and able to increase rice production (Hepperly et al., 2009). SRI cultivation minimizes the use of water to the optimum limit (Zhang et al., 2012), improves the efficiency of nutrient and water use (Zhao et al. 2011), increases the population of useful soil biota (Anas et al., 2012), enhances plant resistance to biotic and abiotic stress (Thakur et al., 2011), and reduces loss fertilizer by leaching (Turmel et al., 2011).

As one system, giving certain treatment to rice plant also affect the herbivore and carnivore population that associated with it. Several studies related to multitrophy interaction (Price et al., 1980; Hamback et al., 2007; Tscharntke and Hawkins, 2008) showed that the diversity and abundance of herbivore was essentially influenced by the quality of the plant as a source of feed and carnivore as its natural enemy. There is a common perception that the SRI cultivation can suppress the presence of herbivore and maintain the abundance of carnivore (Padmavathi et al., 2007; Mukerji, 2009), but other studies showed varying results.

A research that conducted by David et al. (2005) in India showed that SRI cultivation was able to suppress the abundance of *Hydrellia* sp, *Thrips* sp, and *Nilaparvata lugens*, but it was not able to suppress the abundance of *Tryporiza incertulas* and *Cnaphalocrocis medinalis*. Chapagain et al. (2011) conducted a study in Chiba Japan and reported that the abundance of insects was more influenced by the level of standing water than fertilizer. SRI Cultivation given 1.5 cm irrigation level was able to suppress the abundance of insect, especially *C. medinalis*. In contrast, a multi-year study (2008-2011) conducted by Karthikeyan et al. (2014) in Kerala India ensured that rice applied with synthetic fertilizer and alternate wetting and drying irrigation effectively suppressed the abundance of *T. incertulas* and *Hydrellia* sp but was not effective against *C. medinalis*.

Besides of that, spiders are predatory arthropods commonly found in lowland rice ecosystems in high diversity and abundance. They are classified as generalist predator (Foelix, 1982; Reissig et al., 1985) and time generalist (Suana, 1999), which could potentially affect the arthropods in rice ecosystems. Rypstra (1997) stated that the combination of several species of spiders were more effective in reducing herbivores density.

Denno et al. (2002) examined the complex interactions between salt-water cordgrass (*Spartina alterniflora*), different synthetic fertilizer levels (high nitrogen and low nitrogen), two species of leafhoppers (*Prokelisia dolus* and *P. marginata*) and one spider (*Pardosa littoralis*). The results showed that the spider pressure against leafhoppers was effective in Spartina with low nitrogen. Subsequently, Denno et al. (2003) explored more complex interaction between *S. alterniflora* and six species of leafhoppers and *P. littoralis*. The results showed that the abundance of herbivores increased with the nitrogen content of *S. alterniflora*.

On the other hand, the spiders were able to suppress the abundance of two Prokelisia leafhoppers due to their poor ability to escape from predation. Eldred (2006) tested the effect of irrigation level on the abundance of arthropods on riparian plant (*Mimulus guttatus*) and found high abundance of leafhopper in water standing land while of grasshoppers in light irrigated land. The research aimed to study the effect of fertilizer, irrigation level and spider presence as a community on the abundance of herbivore and carnivore in Yogyakarta – Indonesia.

Material and Methods

The research was conducted in Desa Ngestiharjo Kecamatan Wates Kabupaten Kulon Progo Provinsi Yogyakarta (Vertisols, altitude 50 m above sea level), from April to July 2014. Mekongga rice varieties was planted in conventional rice cultivation field, using SRI method (system of rice intensification) (Thiyagarajan and Gujja 2013) except fertilizer and irrigation level rules. The elements of SRI that were used: Planting young seed (15 days after planting), single seedling, spacing 25 x 25 cm, and mechanical weeder. No pesticides were applied during the study.

The research was arranged in a completely randomized block design with three replications. Treatments were factorially arranged as combination of fertilizers (organic, inorganic, without fertilizer), irrigation levels (2 cm, and > 10 cm) and spider presence (with spider and without spider). There were 12 treatments combination those were applied in three replications, so that there were 36 experimental plots entirely, each plot sized 6 x 5 m. The organic fertilizer was cow manure as much as 5 ton/ha (48.5 kg N/ ha), while synthetic fertilizers applied containing 99 kg N/ha (150 kg/ha urea, 200 kg/ha compound fertilizer (15% N, 15% P_2O_5, 15% K_2O, 10% S) and 100 kg/ha SP-36 (36% P_2O_5). The treatment without fertilizer meant no fertilizer. All organic fertilizer was applied at the beginning of planting, but synthetic fertilizer was given twice, at 15 days and 35 days after planting. Level of irrigation to all treatments is increased gradually from minimum to maximum, it was distinguished by maximum water level only. The minimum water level (0 cm) was given at the beginning of planting until 15 days after planting in both of irrigation levels. The maximum water level (less water = 2 cm, conventional >10 cm) was given when the panicles emerged until milk grain stage. After that stage, the two irrigation levels returned to a minimum water level.

Meanwhile, the without spider treatment meant all spiders were hindered entering the plots but other arthropods were allowed, whereas the with spider treatment meant all arthropods were allowed entering the fields, including spiders. To achieve that purpose, each plot without spider treatment was bordered of transparent plastic with a thickness of 2 mm, as high as 60 cm and immersed into the soil as deep as 5 cm. Every two weeks, the plastic was smeared with vaseline albumin to lubricate it so that it could not be climbed by spider. Meanwhile, a plot with spider treatment was left open without border.

Herbivore and carnivore collections were started from the third week after planting until one day before harvesting (6 times). They were collected by using D-vac vacuum modified from 10 samples of rice, randomly selected in each plot. The collections were saved in a plastic container containing 95% chloroform, subsequently transferred to collection bottle containing 70% alcohol. Then, the collection were carried to a laboratory and identified. The process of identification, counting, and grouping used several references: Chu (1949), Kalshoven (1981), Reissig et al., 1985), Wilson and Claridge (1991), CSIRO Australia (1991a), CSIRO Australia (1991b), Goulet and Huber (1993), Heinrichs (1994), Barrion and Litsinger (1995), Amir (2002) and Triplehorn and Johnson (2005). The identification of arthropods was carried out in the Basic Entomology Laboratory Faculty of Agriculture, University of Gadjah Mada, from August to December, 2014.

Laboratory analysis was conducted on soil pH (pH meter), total N of soil (Barkley and Blade method), and total N of rice plant (wet digestion method) (Eviati and Sulaeman 2009). All data, including herbivore and carnivore abundance, were statistically analyzed applying the techniques of analysis of variance and the significance of different sources of variations was tested under Factorial RBD design at probability level 0.05% by using statistic 8 software (Thomas and Maurice).

Results and Discussion

Soil pH, total N of soil and total N of plant

There was interaction between fertilizer and irrigation level (F=5.10, P=0.0143). Applying organic or inorganic fertilizers in less irrigation level and applying organic fertilizer in conventional irrigation did not affect the soil but application of inorganic fertilizer in conventional irrigation reduced the soil pH (Table 1). According to Winarso (2005), organic fertilizer relatively contained little nitrogen fertilizer and slow release so that able to maintain the soil pH neutrality. Neutral soil pH conditions caused the availability of macro and micro elements become more balanced. On the other hand, application of high doses of $NH4^+$ as like as synthetic fertilizers, could decreased one level of soil pH for 3-4 weeks because of $NH4^+$ converted to NO_3^- and released H^+ so that the land be likely to acid. Furthermore, Rosmarkam and Yuwono (2002) stated that the conventional irrigation could increase soil pH in acid soil and decrease the soil pH in alkaline.

Furthermore, there was no interaction between fertilizer, irrigation level and spider presence on the total N of soil (F=1.16, P=0.3318). Fertilizer, irrigation level and spider presence singly did not affect the total N of soil (Table 2). There was no interaction between fertilizer, irrigation level and spider presence on the total N of rice plant (F=0.09, P=0.9145), but there was interaction between fertilizer and irrigation level (F=3.75, P=0.0383). Applying organic fertilizer did not increase the total N of rice plant but applying inorganic fertilizer increased the total N when applied to less irrigation level but not to conventional irrigation (Table 3).

Yardim and Edwards (2003) reported that organic fertilizer plays an important role in maintaining the balance of plant nutrients, but the high rate of N application from inorganic fertilizer causes the plant to absorb more nutrients, indicated by the higher total N of plant. Setyorini et al. (2006) found that 40% of the total N was absorbed by plant comes from fertilizer which was applied. Then, N elements are used by plants to synthesize proteins, amino acids and chlorophyll of plant (Uchida 2000). Staley et al. (2011) reported that application of inorganic fertilizer increased the total N of plant, but organic fertilizer increased the formation of plant defense compounds.

Different irrigation estimated to affect nutrient loss due to leaching, and leaching more noticeable in conventional than less water irrigation. Rosmarkam and Yuwono (2002) and Irawati et al. (2003) stated, not all the fertilizer applied to plant can be absorbed by plants, largely evaporated, immobilization and leached those are affected by temperature, soil fertility and irrigation. Sudewi (2010) reported that rice cultivation with water standing during the cultivation caused a high loss of N due to denitrification. Instead, according Zhao et al. (2011) and Turmel et al. (2011), the less water increased the efficiency of use of nutrients and water and reduced fertilizer loss due to leaching.

Herbivore and carnivore abundance

The outbreak population of *Leptocorisa oratorius* was happened during the course of our research. The incident was also reported by BPTP Yogyakarta (2015). There were 23 species of herbivores found on all treatments, which were grouped into nine families. Two highest herbivores were Alydidae (*L. oratorius*) and Delphacidae (*Nilaparvata lugens* and *Sogatella furcifera*). Alydidae abundance was higher than Delphacidae.

There was no interaction between fertilizer, irrigation level and spider presence on herbivore abundance (F=1.51, P=0.2416). Fertilizer, irrigation level and spider present also did not cause difference on abundance of herbivore singly (Table 4), including Alydidae (Table 5), but spider presence tended to affect them.

Spider presence in the field that was applied by organic fertilizer with less irrigation did not affect the herbivore, but spider presence was able to increase herbivore abundance in conventional irrigation (Figure 1). Otherwise, spider presence in the field that was applied by organic fertilizer and less irrigation level increased the presence of Alydidae abundance significantly (Figure 2).

There was no interaction between fertilizer, irrigation level and spider presence on Delphacidae abundance (F=0.10, P=0.9062), but spider presence decreased Delphacidae abundance significantly (F=5.72, P=0.0249) (Table 6). The pressure of spider on Delphacidae abundance happened overall except in field of organic fertilizer with conventional irrigation in the field of the increasing abundance of Alydidae (Figure 3).

We estimated that the outbreak population of *L. oratorius* caused the fertilizer and irrigation level did not significantly affect the herbivores abundance in general. The incident increased intra and interspecies competition to get resources and space, so herbivores that lost competition utilize other available sources to survive, as described in theory of interaction among organisms (Stamp 1996; Kaplan and Denno 2007). Furthermore, spider was not natural enemies of Alydidae. According Rothschild (1970), spider does not have a prey preference to insects that secrete chemical compounds for self-defense. Foelix (1982) also stated that the spider does not like the insects that use chemical compounds for self-defense. On the other hand, *L. oratorius* known as herbivore that highly produce such chemical compounds (Gunawardena and Bandumathe 1993, Gunawardena 1994). Therefore, the presence of spider did not significantly affect the abundance of *L. oratorius*.

Conversely, spider presence had an impact on the decrease of Delphacidae abundance, considering that spiders are primary predator of Delphacidae as reported by some scientist (Laba 2001, Maloney et al. 2003, Suana and Haryanto 2013). Therefore, the spider presence increased the pressure on Delphacidae abundance, and the spider absence decreased pressure on it (Figure 3).

There were 21 families of carnivores found on all treatments, which were grouped into five orders. Carnivores with the highest abundance in all treatments belonged to family Staphylinidae (Coleoptera).

There was no interaction between fertilizer, irrigation level and spider presence on carnivore abundance (F=1.48, P=0.2480), but there was interaction between irrigation level and spider presence on carnivore abundance (F=4.25, P=0.0478). Spider presence in less irrigation decreased the abundance of carnivore (Table 4). Meanwhile, spider presence in the field that was applied by organic fertilizer with less irrigation tend to decrease Staphylinidae abundance (Figure 4).

The carnivores, especially predator, generally have many prey, not depend on one prey and easy to switch to other resources if the primary prey is not available (Chattopadhyay et al., 2014; Vallina et al., 2014). Some families of spider were found more active at low water level to make the movement and displacement easier. The spider presence basically does not endanger the existence of other carnivores but increased interspecific competition among predators to get resources. Therefore, it would be easy for carnivore which have a high mobility to move about if the necessary resources were also available in other places, including conventional irrigation. Staphylinidae is reported as a scavenger and predator (Nasir, 2012). Coccinellidae prey on aphids, mites, larvae, and other little soft-bodied insects (Amir, 2002; Lubis, 2005; Karindah, 2011). On the other hand, according to Gardiner (2015), Carabidae feed on larvae, snails and weed seeds.

Through bottom up mechanism, interaction between fertilizer and irrigation level affected soil PH and total N of rice plant. But, the organic fertilizer singly did not increase the soil pH, total N of soil and total N of rice plant. Organic fertilizer with less irrigation, as like as SRI method, decreased the abundance of carnivore but it did not affect the abundance of herbivore. The two highest herbivores were Alydidae and Delphacidae, while the highest carnivore was Staphylinidae. Meanwhile, through top down mechanism, interaction between spider presence and irrigation level affected carnivore abundance, but not to herbivore generally. The spider presence decreased Delphacidae abundance but not to affect the abundance of Alydidae dan Staphylinidae (Figure 5).

Table 1. The soil pH in factorial treatment (fertilizer and irrigation level)

Fertilizer	Irrigation		Mean of fertilizer
	Less water	Conventional	
Organic	6.81 c	7.19 a	7.00
Inorganic	6.85 c	6.83 c	6.84
Without fertilizer	6.91 bc	7.07 ab	6.99
Mean of irrigation	6.86	7.03	(+)

Note: The number is followed by different letter, shows significantly differences between the treatment or combination of treatments according the LSD test at 5% significance level

(+) there is interaction between fertilizer and irrigation level

Table 2. Total N of soil (%) in factorial treatment (fertilizer, irrigation level and spider presence)

Fertilizer	Irrigation	Spider presence		Mean of fertilizer	Mean of irrigation
		With	Without		
Organic	Less water	0.21	0.20	0.20 a	0.19 a
	Conventional	0.20	0.19		0.20 a
Inorganic	Less water	0.20	0.18	0.20 a	
	Conventional	0.20	0.21		
Without fertilizer	Less water	0.17	0.19	0.19 a	
	Conventional	0.20	0.20		
Mean of spider presence		0.20 a	0.20 a	(-)	(-)

Note: The number is followed by different letter, shows significantly differences between the treatment or combination of treatments according the LSD test at 5% significance level

(-) there is no interaction between fertilizer, irrigation and spider presence

Table 3. Total N of rice plant (%) in rice cultivation with factorial treatment (fertilizer, irrigation level and spider presence)

Fertilizer	Irrigation		Mean of fertilizer	Mean of spider presence	
	Less water	Conventional			
Organic	0.82 b	0.96 b	0.89	With	0.94
Inorganic	1.35 a	0.96 b	1.16	Without	1.02
Without fertilizer	0.78 b	1.03 ab	0.91		
Mean of irrigation	0.98	0.98	(+)		(-)

Note: The number is followed by different letter, shows significantly differences between the treatment or combination of treatments according the LSD test at 5% significance level

(+) there is interaction between fertilizer and irrigation

(-) there is no interaction between fertilizer and spider presence

Table 4. The abundance of herbivore (individual/hill) on rice cultivation with factorial treatment (fertilizer, irrigation level and spider presence)

fertilizer	water level	Spider presence		mean of fertilizer	mean of irrigation
		with	without		
organic	less water	6.07	5.95	5.36 a	6.09 a
	conventional	5.82	3.61		5.40 a
inorganic	less water	5.82	7.19	6.65 a	
	conventional	7.00	6.57		
without fertilizer	less water	6.05	5.44	5.22 a	
	conventional	5.28	4.12		
mean of spider presence		6.01 a	5.48 a	(-)	(-)

Note: The number is followed by different letter, shows significantly differences between the treatment or combination of treatments according the LSD test at 5% significance level
(-) there is no interaction between fertilizer, irrigation and spider presence

Table 5. The abundance of Alydidae (individual/hill) on rice cultivation with factorial treatment (fertilizers, irrigation and spider presence)

fertilizer	water level	Spider presence		mean of fertilizer	mean of irrigation
		with	without		
organic	less water	4.57	2.19	4.02 a	4.23 a
	conventional	4.65	4.65		4.47 a
inorganic	less water	4.55	5.39	5.24 a	
	conventional	6.07	4.94		
without fertilizer	less water	4.68	3.97	3.79 a	
	conventional	3.80	2.70		
mean of spider presence		4.72 a	3.97 a	(-)	(-)

Note: The number is followed by different letter, shows significantly differences between the treatment or combination of treatments according the LSD test at 5% significance level
(-) there is no interaction between fertilizer, irrigation and spider presence

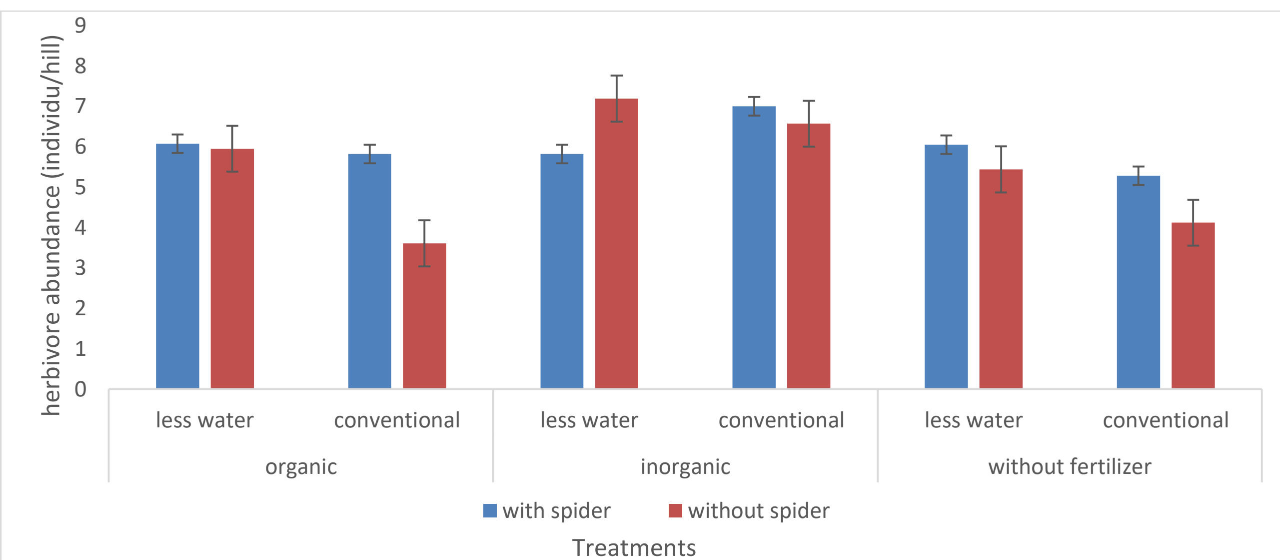

Figure 1. Effect of spider presence on abundance of herbivore (individual/hill) on rice cultivation with factorial treatment (fertilizer, irrigation level and spider presence).

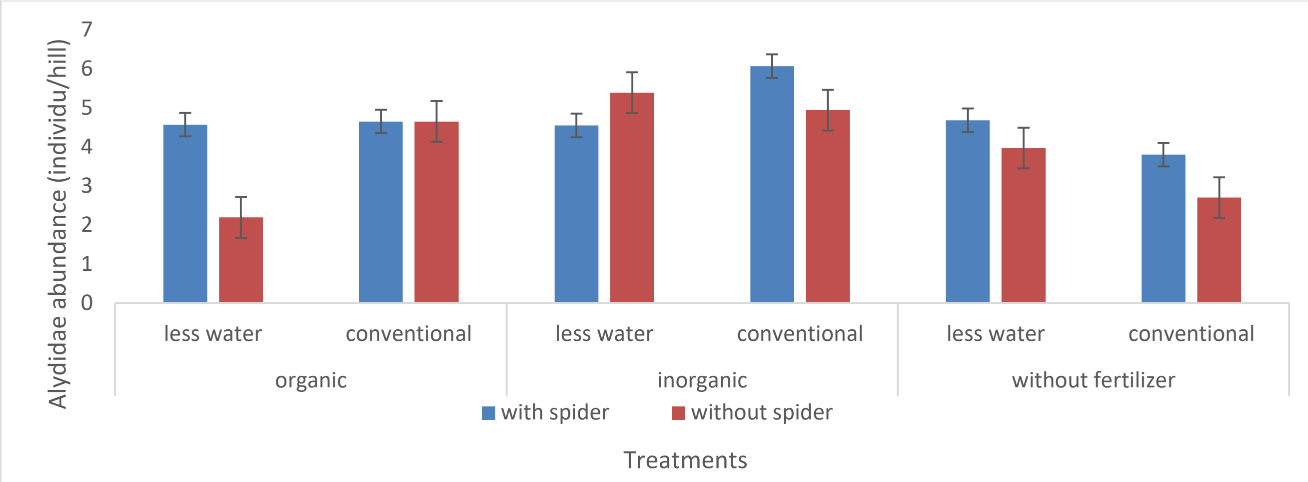

Figure 2. The abundance of Alydidae (individual/hill) on rice cultivation with factorial treatment (fertilizer, irrigation level and spider presence)

Table 6. The abundance of Delphacidae (individual/hill) on rice cultivation with factorial treatment (fertilizers, irrigation and spider presence)

fertilizer	water level	Spider presence		mean of fertilizer	mean of irrigation
		with	without		
organic	less water	0.65	1.07	0.88 a	0.94 a
	conventional	0.87	0.94		0.91 a
inorganic	less water	0.74	1.32	0.94 a	
	conventional	0.67	1.03		
without fertilizer	less water	0.75	1.13	0.96 a	
	conventional	0.80	1.17		
mean of spider presence		0.75 b	1.11 a	(-)	(-)

Note: The number is followed by different letter, shows significantly differences between the treatment or combination of treatments according the LSD test at 5% significance level
(-) there is no interaction between fertilizer, irrigation and spider presence

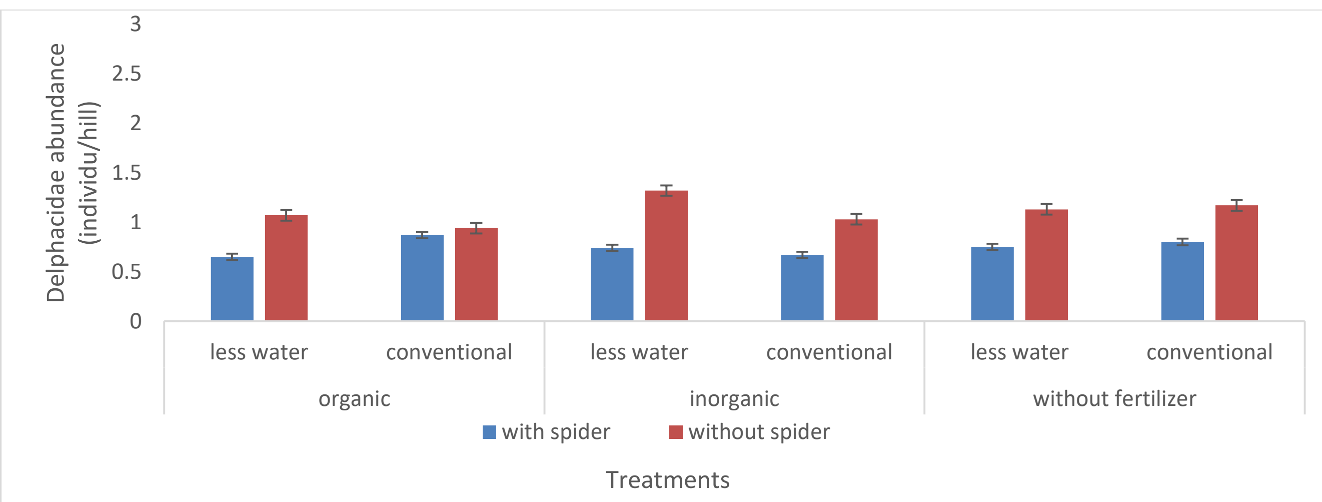

Figure 3. The abundance of Delphacidae (individual/hill) on rice cultivation with factorial treatment (fertilizers, irrigation level and spider presence)

Table 4. The abundance of carnivore (individual/hill) on rice cultivation with factorial treatment (fertilizer, irrigation level and spider presence)

Irrigation	spider presence		mean of irrigation	mean of fertilizer	
	with	without			
less water	3.05 b	3.29 b	3.16	organic	3.42
conventional	4.16 a	3.31 b	3.78	synthetic	3.80
mean of spider presence	3.65	3.30	(+)	without fertilizer	3.14 (-)

Note: The number is followed by different letter, shows significantly differences between the treatment or combination of treatments according the LSD test at 5% significance level
(+) there is interaction between fertilizer and spider presence
(-) there is no interaction between fertilizer, irrigation and spider presence

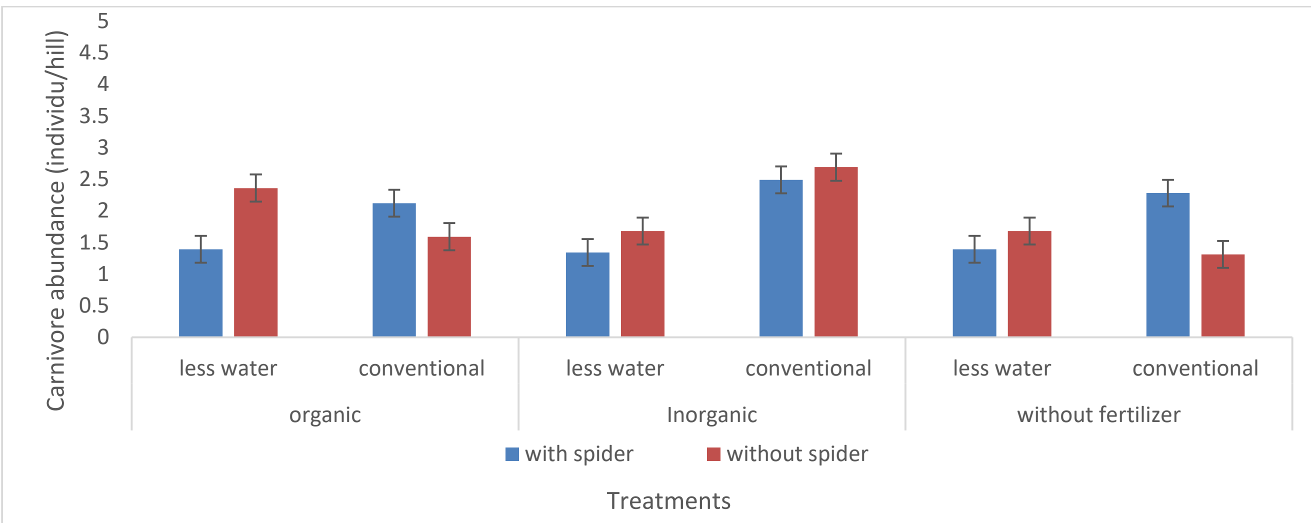

Figure 4. The abundance of Staphylinidae (individual/hill) on rice cultivation with factorial treatment (fertilizer, irrigation level and spider presence)

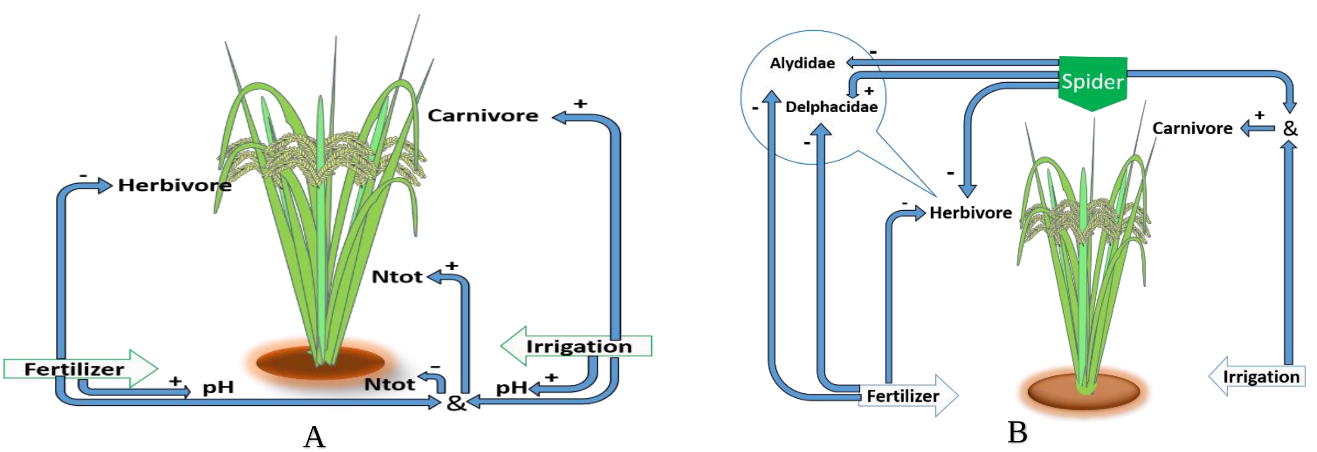

Figure 5. Effect of fertilizer, irrigation level and spider presence on herbivore and carnivore abundance through bottom-up (A) and top-down (B) mechanisms.
Notes: + = significantly different, - = no significantly different, & = interaction, Ntot = total N, pH = soil pH

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