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Infestation of *Diatraea saccharalis* (Fabr.) during Five Consecutive Cycles of Sugarcane Crop Succeeding Leguminous Crops

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Abstract

The area cultivated with sugarcane in Brazil is expanding, and increasingly using legumes cover crop in new deployed areas and in those which were reformed. Long-term trials were carried out in Piracicaba, São Paulo, Brazil, to evaluate the effect of leguminous green manure on the natural infestation of *Diatraea saccharalis* (Fabr.) during five cropping cycles of sugarcane "IAC 87-3396". This study was carried out from October 1999 to October 2005 in Piracicaba, São Paulo, Brazil, at coordinates 22˚42''S and 47˚38''W, 560 m above sea level, in soil classified as Typic Paleudult. Green manure crops were assigned to five treatments: peanuts (*Arachis hypogaea* L.) (cultivar "IAC-Tatu" and "IAC-Caiapó"), sunn hemp (*Crotalaria juncea* L.) (cultivar "IAC 1") and velvet-bean [*Mucuna aterrima* (Piper & Tracy) Holland] (cultivar "common"). A treatment without any green manure or weed was used as the control. The previous sugarcane crop was destroyed and the soil was prepared in a conventional way (using plow and harrow) before the leguminous crops were sowed. Thirty days after the sowing, weeds were removed and, 120 days later, the crops were cut and its biomass was deposited on the soil surface without incorporation. Experimental plots comprised five rows of sugarcane, each one measuring 10 m long and spaced 1.40 m apart. The sugarcane was harvested 18 months after biomass deposit, on October 25th, 2001 and its stalks were collected at intervals of approximately 12 months in: 07/09/2002, 08/01/2003, 11/07/2004 and 10/06/2005. At harvest, the masses were determined from a sample of sugarcane, cut from three rows (2 m long) in the center of the plot. The losses caused by the sugarcane borer were estimated by the intensity of the infestation by randomly observing and collecting sugarcane stems from

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each plot. A great reduction in the number of stalks and in the yield was noted proportionally to the intensity of the infestation of the borer in the sugarcane crop grown after the velvet-bean. The sugarcane-velvet-bean rotation should be regarded considering the intensity of sugarcane borer infestation. No influence of the other green manure crops was observed on the intensity of the infestations. However, the harvest seasons of the sugarcane seemed to influence the borer infestation.

Keywords

***Arachis hypogaea* L., *Crotalaria juncea* L., *Mucuna aterrima* (Piper & Tracy) Holland, *Saccharum* spp., Sugarcane Borer**

1. Introduction

The main species of sugarcane borer, *Diatraea saccharalis* (Fabr.) (Lepidoptera: Crambidae) [1]-[4], is widely distributed in all sugarcane fields of the country [5] [6]. It is the sugarcane's most important pest, especially in the Southeast Region of Brazil [7].

This pest may appear in up to four (rarely five) annual generations in São Paulo, depending on climatic conditions [8] [9]. The larvae cause direct losses such as killing the plant's apical bud, opening galleries through its interior, causing losses on its weight, shortening its internodes, breaking its stems and side shoots, and causing a symptom called "dead heart" in new reeds. There are also indirect damages, such as the entry of various micro-organisms, especially fungi of the genus *Fusarium* and *Colletotricum* that invade the galleries dug by the insect, causing red rot, reducing the quantity of sugar inside the stems by transforming the sucrose stored in the plant into glucose or fructose. The micro-organisms living in the stems may contaminate the juice, impairing industrial processes by inhibiting fermentation and hindering the quality of the sugar [5] [7] [10]-[12].

Chemical control has not yet been technically and economically feasible [9] [13], but the biological control by mass release of *Cotesia flavipes* (Cameron) is a technology effectively implemented, responsible for reducing the percentage of intensity of infestation from about 7% to around 2% in sugarcane areas in the state of São Paulo, Brazil, in assessments from 1977 to 1999 [7].

Studies on the effect of pre-cultivation of legumes on the control of pest populations, such as the sugarcane-borer, are still scarce. It was reported, in India [14], a reduction of infestation of stem borer *Chilo partellus* (Swinhoe), and increased productivity in grain sorghum (*Sorghum* sp.) intercropped legumes cowpea [*Vigna unguiculata* (L.) Walp.], and lablab [*Lab labpurpureus* (PRAIN) Kumari (sin. *Dolichus lablab* L.)], in Africa.

In Brazil, the control of nematodes through the pre-cultivation of green manure is very frequent. Ambrosano [15], found out that the population of *Pratylenchus* spp. was smallerin the treatments with the peanuts IAC-Tatu and IAC-Caiapó as green manures.

However, there has not been any study under field conditions on that topic, nor has it been reported any interference from pre-cultivation of green manure on the incidence of *D. sacharalis*. Thus the aim of this study was to evaluate and determine any possible effect of the pre-cultivation of some legumes on the intensity of natural infestation of the sugarcane borer at sugarcane fields for five consecutive harvesting seasons.

2. Material and Methods

The experiment was conducted from October 1999 to October 2005 in Piracicaba, SP, Brazil, at coordinates 22˚42"S, 47˚38"W and 560 m above sea level, in soil classified as Typic Paleudult, and cultivated with sugarcane for eight years.

After the destruction of the sugarcane, the soil was prepared in a conventional way (using plow and harrow). In December 1999, before the planting of sugarcane, five treatments were installed and arranged in a randomized block design scheme with five replications. The treatments consisted of four legumes crops: peanut (*Arachis hypogaea* L.) (cultivars "IAC-Tatu" and "IAC-Caiapó"), sunn hemp (*Crotalaria juncea* L.) "IAC 1" and velvet-bean [*Mucuna aterrima* (Piper & Tracy) Holland] "common", plus a control group kept fallow and clean. The experimental plots correspond to an area of five rows of sugarcane, each one measuring 10 m and spaced

1.40 m from one another.

Thirty days after the sowing, the weeds which grew around the green manure were removed, and after 120 days, in mid-April 2000, crops were cut and its biomass was deposited on the soil surface without incorporation. At this occasion, the levels of fertility of the soil were determined, whose chemical characteristics are listed in **Table 1**.

The green manure was conducted without correction or fertilization, aiming to find the natural potential of production of the studied legumes. These soil conditions were similar to those observed by Ambrosano [16].

After harvesting the green manures, the sugarcane cultivar "IAC 87-3396" was planted, using two canes per furrow to guarantee ideal stand of 18 gems of sugarcane per meter, with 1.40m between rows of plants. The sugarcane was fertilized with 500 kg·ha^{-1} of a 08-28-16 formulation (N, P_2O_5, K_2O) before planting. After each cut, it was applied 500 kg·ha^{-1} of a 20-5-20 formulation (N, P_2O_5, K_2O). Irrigation was not used, and weed control was performed after each harvesting of sugarcane, applying metribuzin-based herbicide (1.92 L·ha^{-1}).

The sugarcane was harvested after 18 months, on October 25th, 2001. The sugarcane stalks were collected at intervals of approximately 12 months in: 07/09/2002, 08/01/2003, 11/07/2004 and 10/06/2005. At harvest, the masses were determined from a sample of sugarcane collected from three segments of 2 m long in the center of the plot. From these masses, the yield of culms of sugarcane per hectare (TCH) was calculated, according to Ambrosano [16].

At each harvest season, the damages caused by the drill were estimated based on the intensity of the infestation [17] in ten stalks randomly collected from each plot. The percentage of internodes drilled or punched was calculated in relation to the total number of internodes examined in each plot.

Samples of ten stalks from adjacent plants were also harvested in each treatment [18] and referred to technological analysis of Brix%, sucrose%, by calculating the ton of sucrose per hectare (TSH) in order to estimate the total sugar production.

The temperature and rainfall data throughout the experimental period were obtained at the Integrated Center for Weather Information (CIIAGRO), from the Center for Ecophysiology and Biophysics from Agronomic Institute of Campinas (IAC).

Figure 1 shows a graphical analysis of the collected data. It relates sugarcane yield (TCH—tons of culms·ha^{-1}), on the Y axis, to the percentage of sugarcane borer infestation, on the X axis. The axes represent the averages of the variables, forming 4 quadrants. From these quadrants, it is possible to evaluate the variation on the yield and the sugarcane borer infestations and their dependence on the seasons. It was then performed an exploratory data analysis and the intensity of infestation was transformed into arcsine $\sqrt{x}$, in order to meet the assumptions of parametric analysis. It was used a mixed model for repeated measures by the PROC MIXED procedure through SAS statistical program. Multiple comparisons were performed by Tukey-Kramer. It was also performed the Pearson correlation analysis between the variable intensity of infestation, tons of sucrose per hectare (TSH) and tons of culms per hectare (TCH). In all analyzes the level of significance was considered 5%.

3. Results and Discussion

In **Figure 1**, the relationship between sugarcane yield and borer infestation can be evaluated for each cut season and for each green manure. The quadrant 1 represents low borer infestation and high sugarcane yield. All the treatments from cut season 1 were on this first quadrant. The second quadrant contains treatments with high stalk sugarcane yield, but high borer infestation. The only treatment within this classification is the peanut IAC-Caiapó from season 2. The third quadrant shows cases of low sugarcane yield and low borer infestation. In this classification we have some treatments from the cut season 3 and 5. The velvet-bean is contained in the

Table 1. Chemical characteristics of a Typic Paleudult grown for eight years with the culture of sugarcane, and after harvesting the biomass of legume green manures. Piracicaba, SP, Brazil, April 2000.

Depth	Organic matter	pH $CaCl_2$	Resin-P	K	Ca	Mg	H + Al	SB*	CEC	BS**
cm	g·dm^{-3}		mg·dm^{-3}			mmol$_c$·dm^{-3}				%
0 - 20	22.2	4.6	12.8	1.3	10.0	6.8	52.0	18.1	70.3	25.6
20 - 40	20.4	4.5	10.4	0.8	9.4	6.8	53.2	17.0	70.3	24.2

*SB = sum base; **BS = base saturation.

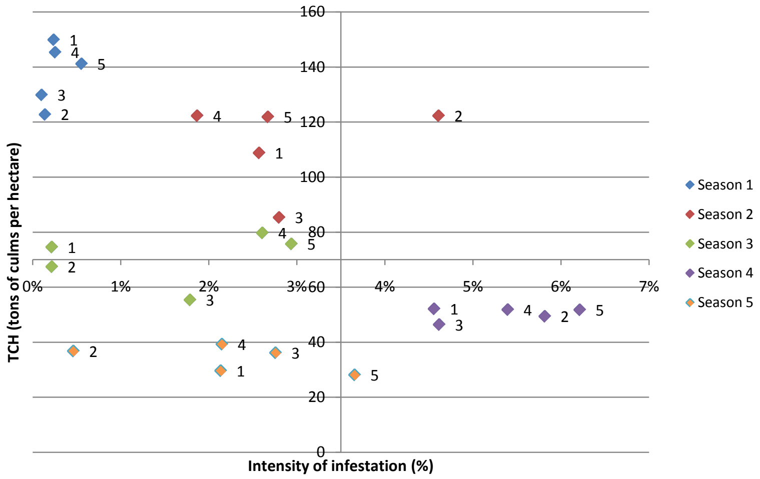

Figure 1. Quadrants with sugarcane yield values in tons of culms of sugarcane "IAC 87-3396" per hectare (TCH) on the vertical axis and the intensity of infestation with *Diatraea saccharalis* in sugar cane, in succession to legumes and according to five harvestings seasons on the horizontal axis. Piracicaba, SP, Brazil, 2001-2005.

fourth quadrant, which indicates a lower sugarcane yield and a higher infestation. In this quadrant there are all the treatments from cut season 4.That indicates this season as the worst time for production and the best for sugarcane borer attacks.

Except for cut season 2, the infestation by the sugarcane borer was always more intense in treatments with velvet-bean. At this season, there is a high productivity and a low level of intensity of infestation by borers for velvet-bean (**Figure 1**).

In numerous publications on the effects of green manure pre-cultivation practice in the agricultural productivity of sugarcane, particularly in the state of São Paulo, the most favorable results were determined after pre-cultivation of legumes: sunn hemp (*Crotalaria juncea* L.); velvet-bean [*Mucuna aterrima* (Piper & Tracy) Holland], pigeonpea [*Cajanus cajan* (L.) Millsp.], lablab (*Dolichos lab lab* L.) and soybean [*Glycine max* (L.) Merrill], [19]. In this line, Ambrosano [15] detected increments of 30% and 35% on the yields of sugarcane stalks and on sugar production, respectively, and a superior economic performance on sugarcane after the cultivation of Sunn hemp "IAC 1".

There was no difference in the intensity of borer infestation between the treatments ($p = 0.6487$) nor between the interaction treatment × season ($p = 0.6611$), but only between different cut seasons of sugarcane ($p < 0.0001$) (**Table 2**).

The factors which influence the population of this pest are quite variable between regions and even between properties. This fluctuation is dependent on the cultivar [10] [20], the season, the crop cycle, the age and the nutritional status of the sugarcane [21] and composition of the vegetation near the cane fields [22] [23].

The fourth harvesting season, held in November (11/07/2004), had moderate natural infestation (5.32%) (More intense losses on sugarcane are often reported during the period from December to April). Considering the cost/benefit ratio, the economic level of control is 3%. For higher levels of infestation, biological control agents should be released in order to control the borer. Furthermore, the precipitation may have contributed to increase in the intensity of infestation (**Figure 2**).

The results in **Table 2** and **Figure 2** are consistent with those published by several authors whom directly correlated fluctuation on the pest population to climatic factors, particularly temperature and humidity, as well as other factors, such as biological and edaphic [7]. Melo and Parra [8] determined also a positive correlation between the population and climatic factors (mainly temperature).

The results of the research on population fluctuation of certain pests and its relationship with climatic factors differs between different regions and, in many cases, factors which correlates significantly in a region are not important in another. Therefore, the population dynamics is specifically its location [7].

In several studies conducted within the State of São Paulo, Brazil, it was proven that climatic factors (the

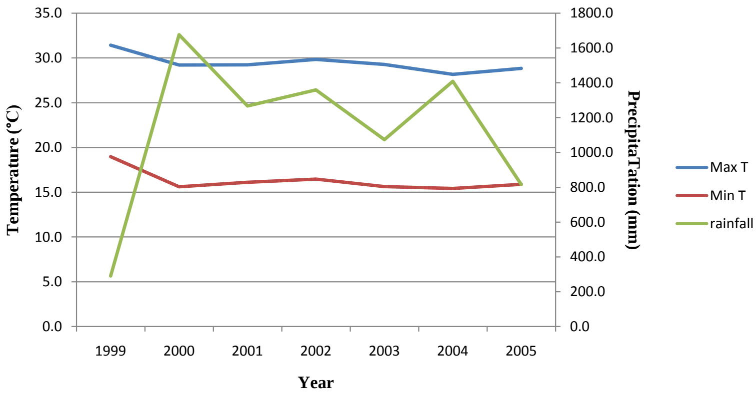

Figure 2. Maximum and minimum temperatures and rainfall in Piracicaba, SP, Brazil, for five cycles of growth of sugarcane "IAC 87-3396".

Table 2. Intensity of infestation of *Diatraea saccharalis* in sugarcane "IAC 87-3396", depending on the pre-cultivation of the legume and the harvesting season. Piracicaba, SP, Brazil, 2001-2005.

Treatment	October/2001	September/2002	August/2003	November /2004	October /2005	Average
			%			
Control[1]	0.10 ± 0.10[2]	2.80 ± 0.99	1.79 ± 1.12	4.62 ± 1.70	2.76 ± 1.33	2.41 ± 0.57a
Peanut "IAC-Tatu"	0.24 ± 0.10	2.57 ± 1.08	0.22 ± 0.22	4.56 ± 1.71	2.14 ± 0.53	1.95 ± 0.51a
Peanut "IAC-Caiapó"	0.14 ± 0.08	4.61 ± 0.88	0.22 ± 0.13	5.82 ± 2.26	0.46 ± 0.21	2.25 ± 0.67a
Sunn hemp "IAC-1"	0.25 ± 0.16	1.87 ± 0.61	2.61 ± 1.57	5.40 ± 1.69	2.15 ± 0.71	2.46 ± 0.57a
Velvet-bean	0.55 ± 0.37	2.67 ± 1.31	2.94 ± 1.97	6.21 ± 2.03	3.66 ± 1.03	3.21 ± 0.71a
Average	0.26 ± 0.09C	2.90 ± 0.45B	1.55 ± 0.56BC	5.32 ± 0.78A	2.23 ± 0.41BC	

Sunn hemp (*Crotalaria juncea*); Velvet-bean (*Mucuna aterrima*); Peanut (*Arachis hypogaea*). [1]Without pre-cropping with legumes; [2]Average ± standard error of the average. Average followed by the same uppercase horizontally and lowercase vertically are not statistically different ($p \leq 0.05$).

rainfall and the temperature were the most relevant) influence in about 40% on the dynamics of sugarcane borer population [7].

In Araras, SP, during a 14-year evaluation period, two peaks were noted on the male population of the sugarcane borer. The greatest peak was perceived during the month of September and the second greatest peak happened in February; smaller amounts of insects were seen in June, season which presents the lowest temperatures during winter of the state and of the region [24].

It was determined a significant negative correlation between the percentage of borer infestation and TSH and TCH in the treatment with velvet-bean (**Table 3**), which signifies the TSH and TCH values may be greatly reduced in the case of an increase in the intensity of infestations on the combination sugarcane borer and velvet-bean. Still, given this fact, more attention should be paid on sugarcane velvet-bean rotation in relation to the intensity of sugarcane borer infestation.

The fact that the correlations are significant, but weak, is an indicative of the possible influence of other factors, such as the presence of green manures, on the variation of TCH and TSH and in the intensity of borer infestation. The values in the control treatment, except for seasons two and four, have always been very close to the treatment with velvet-bean, which indicates a possible influence of the previous cultivations on the ranges of both TCH and TSH. Therefore, the green manure inhibits an abrupt reduction of these variables (**Figure 2**).

Ambrosano [16], in a study on green manure on sugarcane, determined an yield of 86 $t \cdot ha^{-1}$ and 61 $t \cdot ha^{-1}$ for the control groups on the first and second cuttings, respectively, and 92 $t \cdot ha^{-1}$ and 84 $t \cdot ha^{-1}$ on each cutting, respectively, for the treatments with sunn hemp. This reduction in yield throughout the cuttings, as evidenced by Ambrosano [16], is usual on the cultivation of sugarcane, but may be reduced or minimized by more sustainable practices, such as the use of green manure.

At season one, the productivity (TCH) was high and the intensity level of infestation by the sugarcane borer was low. Compared to the control group, it is worth observing the significant increase in the production of sugarcane stalks through five cuttings only after pre-cultivation of sunn hemp "IAC-1". Among the treatments with other legumes, there was no difference, as reported in [16]. The authors attributed this effect to the possibly higher productivity of dry matter by the sunn hemp and to the accumulation of nutrients, especially N and K by this legume.

There was a significant ($p = 0.0014$) weak negative correlation ($r = -0.2936$) between the intensity of infestation with the sugarcane borer and the TCH. For TSH there was also a significant ($p = 0.0011$) weak negative correlation ($r = -0.2998$) (**Table 4**). That is, there was a significant decrease ($p < 0.05$) in both TCH and the TSH with the increasing intensity of infestation by the sugarcane borer. These results confirm the negative effect of the intensity of infestation by the borer on agricultural yield and sugar production [11] [12] [17] [25].

In season three, the productivity of the sugarcane was considered average, compared to the 85 ton·ha^{-1} set for the harvest in 2009/2010 in São Paulo [26], with a reduced level of intensity of infestation by the borer, considering the level of economic control as 3% [17].

By the Gallo classification [17], during season five, along with the reduction of productivity of sugarcane, the intensity of infestation by the borer increased. These values are considered moderate for treatments with pre-cultivation of "common" velvet-beans, peanuts "IAC-Caiapó" and sunn hemp "IAC-1".

Various stalk-rotting fungi, particularly *Colletotrichum falcatum* Went. (aetiological agent of sugarcane red rot disease) as well as the sugarcane borer (SCB), *Diatraea saccharalis* (F.), are believed to have a major impact on

Table 3. Analysis of correlation between intensity of infestation of *Diatraea saccharalis* in the culture of sugarcane "IAC 87-3396" and tons of sucrose per hectare (TSH) and tons of cane per hectare (TCH) according to pre-cropping with legumes. Piracicaba, SP, Brazil, 2001-2005.

Treatment	Tons of sucrose ha^{-1} (TSH)		Tons of culms ha^{-1} (TCH)	
	*r	p-value	r	p-value
Control[1]	−0.33	0.1656	−0.32	0.1739
Peanut "IAC-Tatu"	−0.31	0.1350	−0.31	0.1318
Peanut "IAC-Caiapó"	−0.05	0.8073	−0.05	0.8180
Sunn hemp "IAC 1"	−0.37	0.07	−0.38	0.06
Velvet-beans	−0.48	0.0293	−0.48	0.0264
General	−0.2998	0.0011	−0.2936	0.0014

Sunn hemp (*Crotalaria juncea*); Velvet-bean (*Mucuna aterrima*); Peanut (*Arachis hypogaea*). r: Pearson correlation coefficient. [1]Without pre-cropping with legumes.

Table 4. Analysis of correlation between intensity of infestation of *Diatraea saccharalis* in the sugarcane crop "IAC 87-3396" and tons of sucrose per hectare (TSH) and tons of culms per hectare (TCH) in terms of five sugarcane harvesting season. Piracicaba, SP, Brazil, 2001-2005.

Sugarcane harvesting season	Tons of sucrose per hectare (TSH)		Tons of culms per hectare (TCH)	
	*r	p-value	r	p-value
1: October/2001	0.03	0.9044	0.11	0.9044
2: September/2002	−0.32	0.1287	−0.33	0.1166
3: August/2003	0.22	0.3239	0.22	0.3214
4: November/2004	−0.06	0.7802	−0.10	0.6544
5: October/2005	−0.36	0.0880	−0.3872	0.0679
Average	−0.2998	0.0011	−0.2936	0.0014

r: Pearson correlation coefficient.

the quality of sugar-cane stalks [5].

In future research, the sampling of sugarcane borer and its effects on the quality of juice produced should be better studied. Knowledge about the behavior of the sugarcane borer after the pre-cultivation of green manure will ensure its use, bringing benefits to farmers and the environment.

4. Conclusions

It was determined a great reduction in TSH and TCH values along with the increase on the intensity of sugarcane borer infestations on sugarcane crops grown over the soil pre-cultivated by "common" velvet-bean. More attention should be considered on sugarcane "common" velvet-bean rotation in relation to the intensity of sugarcane borer infestation.

For other combinations, there was no influence from the green manure pre-cultivation on the variation of the intensity of *Diatraea saccharalis* (Fabr.) infestation, but only from the cutting seasons.

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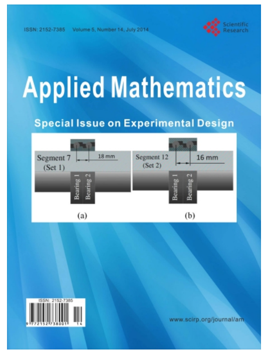
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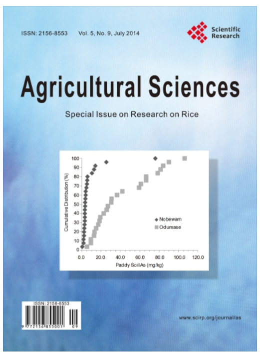
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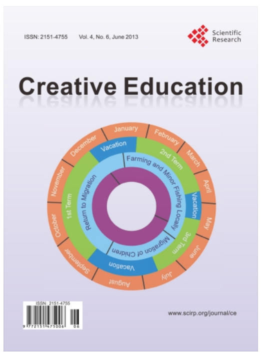
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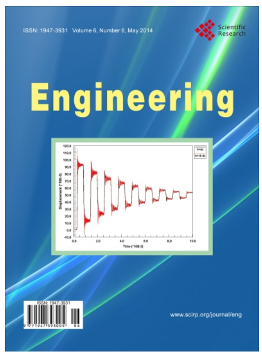
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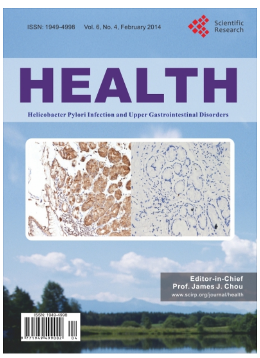
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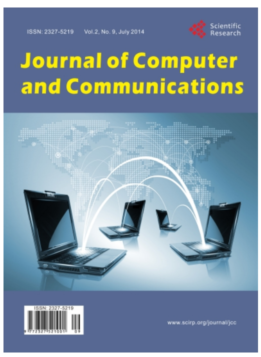
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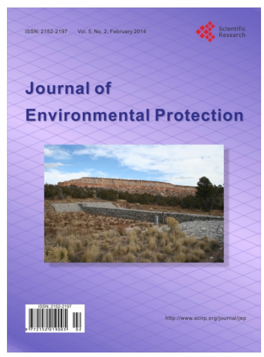
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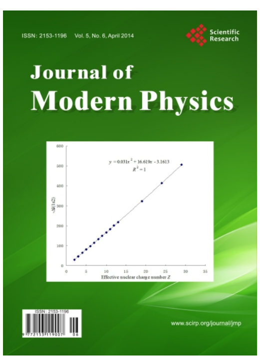
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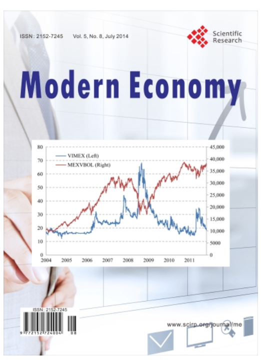
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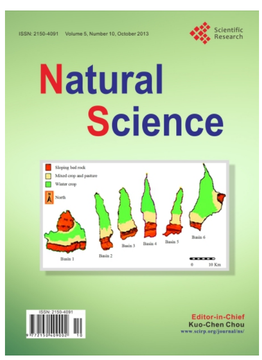
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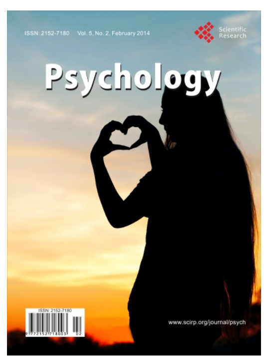
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