INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
18F–029/201x/00–0–000–000
DOI: 10.17957/IJAB/15.0769
http://www.fspublishers.org

***Full Length Article***

# Effects of Different Tillage Modes for Ammonia Volatilization Emissions from Flue-cured Tobacco Fields

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## Abstract

Ammonia ($NH_3$) is one of the important greenhouse gases which could affect the climate change, to reduce the number of farmland ecosystem of $NH_3$ emissions, using the intermittent airtight ventilation method, studied the impact of rotation and long-term plant crude opium cultivation conditions above emission regularity of $NH_3$ volatilization and dynamic growth. The results show that compared with the crop rotation treatment, continuous cropping treatment can significantly increase the emissions of $NH_3$ volatilization rate and vega cumulants, stage and basal fertilizer than vega emissions of $NH_3$ volatilization rate is high, the soil is 0.46 kg.hm$^{-2}$·d$^{-1}$; In stage basic fertilizer and fertilizer, continuous cropping treatment and rotation of $NH_3$ volatilization cumulants are in line with the Logistic growth curve, and the measured values and calculated a highly positive correlation between simulation value; Throughout the vega fertilizing period, continuous cropping treatment of $NH_3$ volatilization cumulant than 0.055 kg/hm$^2$, rotation and continuous cropping treatment and rotation NH3 volatilization loss rate of 1.58 times. Crop rotation system can reduce the $NH_3$ volatilization rate, and can reduce the $NH_3$volatilization cumulative loss, and thus can reduce the $NH_3$ volatilization loss rate. © 2018 Friends Science Publishers

**Keywords:** Long-term test; Flue-cured tobacco; $NH_3$ volatilization; Continuous cropping; Crop rotation

## Introduction

As one of the important greenhouse gases that affect climate change, $NH_3$ is also the main component of acid rain's catalytic substances and ozone emissions (Adrie *et al*., 2002). With global warming, the issue of greenhouse gas emissions has drawn great attention from scientists and governments all over the world. By introducing the mathematical model of dynamic simulation analysis was carried out on the test, and using the characteristic parameters of quantitative simulation is deduced. The logistic dynamic simulation analysis is more practical. Farmland ecosystems are important source of greenhouse gas emissions (USEPA, 2007), and up to 90% of total ammonia emissions from agricultural activities are released into the atmosphere (Misselbrook *et al.*, 2000; Boyer *et al*., 2002). $NH_3$ that dissipates into atmosphere reacts with atmospheric acids to form aerosols, or return to the ground in the form of sediments and cause acidification of the soil. However, ammonia volatilization has brought many negative effects on the environment (Van der Eerden *et al*., 1998; Huckaby *et al*., 2012). Currently, in order to reduce the emission of $NH_3$ from farmland ecosystems, many scholars have published many relevant research reports. Someone studied the soil ammonia volatilization under different fertilization methods, including turning over after broadcasting, earthing after banding and irrigation after broadcasting (Li *et al*., 2008). The results indicated that there is a certain difference between the various treatments, and the treatment of turning over after broadcasting and earthing after banding could help to reduce the ammonia volatilization emissions. Someone conducted studies on the ammonia volatilization of continuous cropping wheat field under long-term fertilization via airtight ventilation. They found that the volatilization flux of ammonia volatilization in wheat field increased with the growth and development of wheat, and reached the highest value of 20.91±3.28 g.hm$^{-2}$·d$^{-1}$ within mature period. By studying the effects of different crop rotation patterns on ammonia volatilization in paddy fields in Taihu Lake Region (Wang *et al.*, 2006). Someone pointed out that the amount of N volatilized from ammonia volatilization in paddy fields was the lowest at a nitrogen application rate of 240 kg.hm$^{-2}$ during the Chinese milk vetch -rice rotation period, which was lower than the ammonia nitrogen loss during fallow-rice rotation at 9.7 kg.hm$^{-2}$ (Hu *et al.*, 2013). Some scholars also pointed out that the ammonia volatilization rate reached the highest in alfalfa grassland during the later growing stage (flowering stage) under continuous cropping and highest during the budding stage



**To cite this paper:** Yuzhou, J., L. Qingli, Z. Yungui, L. Zhihong, Z. Yan, Z. Jingwei, S. Junxiong and W. Peng, 201x. Effects of different tillage modes for ammonia volatilization emissions from flue-cured tobacco fields. *Int. J. Agric. Biol*., 00: 000–000

under crop rotation. Moreover, the rate of ammonia volatilization in continuous cropping is higher than that in crop rotation (Xugang and Mingde, 2005). Although studies have been conducted on $NH_3$ emissions from farmland for different tillage types, different types of fertilizers and fertilization rates, the studies have mainly focused on grain crops such as corn, rice and wheat (Li *et al.*, 2008; Ma *et al.*, 2012; Wang *et al.*, 2012; Wu *et al.*, 2012) [11-14]. There is little research on ammonia volatilization in flue-cured tobacco. Therefore, in this experiment, closed intermittent aeration method was adopted to study the law of ammonia volatilization under different tillage modes in flue-cured tobacco soil by long-term positioning, and the logistic dynamic simulation analysis, and linear regression analysis was conducted in order to understand the nitrogen balance process of tobacco planting soil in different tillage modes and eco-environmental effects.

## Materials and Methods

### Overview on Test Area

The experiment was conducted in Longgang Long-term Nutrient Research Station in Guizhou Province in April to September of 2016, featuring geological location at E107°06'40.8", N26°52'24.8", elevation of 1,130 meters, frost-free period for 240-265 days, annual average temperature of 13.5°C to 14.6°C, annual sunshine duration for 948.2-1,084.8 h and average rainfall of 1,129.9-1,205.9 mm. The test area was established at the tobacco and flue-cured tobacco wheel as locating points for experiment since 2008. In addition, K326 flue-cured tobacco variety was selected for experiment in yellow soils with fertility status from 0 to 20 cm featuring total nitrogen 1.6 $g.kg^{-1}$, total phosphorus 0.7 $g.kg^{-1}$, organic matter 40.0 g. $kg^{-1}$, alkali-hydrolyzable nitrogen 121.8 $mg.kg^{-1}$, available phosphorus 12.4 $mg.kg^{-1}$, rapidly-available potassium 137.3 $mg.kg^{-1}$ and pH7.3.

### Test Design and Management

The experiment was designed with three treatment processes, No fertilizer + Crop rotation for comparison (CK); inorganic fertilizer + Crop rotation (CR); inorganic fertilizer + Continuous cropping (CC) with specific fertilizer rate shown in Table 1. The basic fertilizer used during flue-cured tobacco experiment was composed of compound fertilizer (N 10%; $P_2O_5$ 10%; $K_2O$ 25%), calcium superphosphate ($P_2O_5$ 14%) and potassium sulfate ($K_2O$ 51%). In addition, the phosphate fertilizer shall be applied in the basic fertilizer at one time. After application, the ammonium nitrate (N: 35%) and potassium sulfate ($K_2O$ 51%) can be used for the additional fertilization.

First, dig out a 10 cm wide field ditch in field, apply basic fertilizer in the ditch and after earthed coated. Dig out a 10 cm wide field ditch i transplant the flue-cured tobacco seedlings n ridge; at last, apply additional fertilizer on the soil dig out a ditch at 5 cm away from tobacco plants. Other management measures shall be implemented in accordance with the management and cultivation system of local tobacco fields. Moreover, the flue-cured tobacco seedlings were applied with basic fertilizer in April 27$^{th}$ and transplanted in April 29$^{th}$ based on the planting distance of 100 cm, row spacing of 60 cm and cultivated density of 16667 plants per $hm^{-2}$. Since there were 30 plants in each row and 8 rows in each community, there totals 240 plants in each community. The first additional fertilizer shall be applied in June 1$^{st}$, The first harvest shall be applied in July 8$^{st}$.

### Sample Collection and Analysis

Airtight chamber intermittent ventilation method was adopted for in situ determination of ammonia volatilization (Wang *et al.*, 2002; Wang *et al.*, 2004). The principle is that the ammonia (NH3) volatilized from the soil in the cover is evacuated by means of a vacuum pump to be absorbed by the gas scrubbing cylinder with 2% boric acid and the ammonia absorbed by the boric acid is titrated with 0.01 mol/L $H_2SO_4$. The chamber used was composed of a plexiglass enclosure (diameter of 20 cm, height of 15 cm), a PVC tube, a white latex tube, a gas scrubber with capacity of 250 mL and a 1300 W vacuum pump (Fig. 1). The measurement was started on the second day after fertilization and was measured on the 1$^{st}$, 2$^{nd}$, 3$^{rd}$, 4$^{th}$, 5$^{th}$, 7$^{th}$, 9$^{th}$, 13$^{th}$, 14$^{th}$ and 15$^{th}$ day after the start of the test. The test was carried out daily 8: 00-10: 00 and 15: 00-17: 00, and all treatments were required to pump for 1 h before the test. In the determination, the cover was clamped into the soil surface 10 cm deep, and the soil coverings were clamped to the two adjacent fertilizing lines after banding, and the sites of three replications within each treatment was selected in the correspondingly-treated area.

### Calculation Method and Data Analysis

The ammonia volatilization rate of soil is calculated by the following formula:

$$f = \frac{\Delta M}{A \times \Delta t} = h \times \frac{\Delta C}{\Delta t} \times \frac{M \times 273}{22.41 \times (273 + \frac{T1 + T2}{2})} \times 60$$

Where: f is the gas discharge flux, $\mu g \cdot m^{-2} \cdot h^{-1}$; m is the mass of N in the gas, μg; A is the cross-sectional area of the sampling box, $m^2$; h is the height of the sampling box, m; $\Delta C/\Delta t$ is the concentration variation of gas sample per unit time, $\times 10^{-9}$ $min^{-1}$; M is the molar mass of N corresponding to 1 mol $N_2O$, $g \cdot mol^{-1}$; 273/[273 + (T1 + T2/2)] is the temperature correction factor; T1 and T2 refer to gas temperature within the cover when taking the first and last sample respectively, ℃.

Ammonia volatilization loss (%) = (Ammonia volatilization in nitrogen treatment - Ammonia volatilization in nitrogen-free treatment)/Nitrogen application rate×100.

**Table 1:** Fertilizer rate of different treatment process ($kg.hm^{-2}$)

| | Fertilizer application rates ($kg.hm^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| | Tobacco field | | | | | |
| | Basal fertilizer | | | Top fertilizer | | |
| Treatment | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| CK | 0 | 0 | 0 | 0 | 0 | 0 |
| CR | 45 | 75 | 90 | 30 | 0 | 60 |
| CC | 45 | 75 | 90 | 30 | 0 | 60 |

Note: Basal fertilizer is an application of phosphate fertilizer at a time, top fertilizer is applied according to conventional methods and time

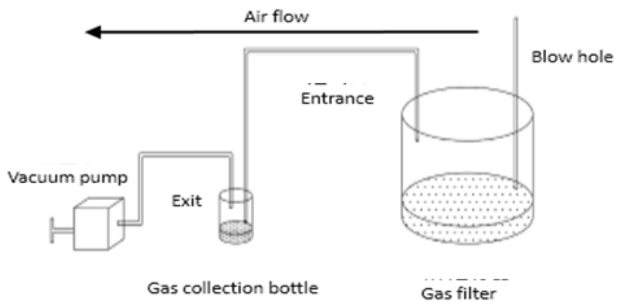


**Fig. 1:** Sketch of $NH_3$ absorption equipment in the field plots

The test data can be arranged into a diagram via EXCEL 2010 and analyzed with SPSS 11.5 and SigmaPlot 12.0 software. Moreover, the significance test shall be analyzed with Duncan method.

## Results

### Laws of Ammonia Volatilization in Tobacco Fields after Base Fertilizer

The ammonia volatilization flux of 15 days after base fertilizer in tobacco field is shown in Fig. 2a. The ammonia volatilization flux of each treatment shows a bimodal curve. In the first 2 days after basal application, the ammonia volatilization rate of CK treatment was the lowest, while that of K1 treatment was higher than that of K2 treatment. The first peak of each treatment occurred from the second day to the fourth day after basal fertilizer application. The amount of treatments of ammonia volatilization flux were K2＞K1＞CK, respectively of 0.46,0.36 and 0.18 $kg.hm^{-2}\cdot d^{-1}$, and reaching the highest value of ammonia volatilization flux. This indicated that the peak of ammonia volatilization after basal fertilizer begins at this stage, especially in the early stage of fertilization. Ammonia volatilization rate of K1 was higher than that of K2 treatment 0.09 $kg.hm^{-2}\cdot d^{-1}$ in the two days after the base fertilizer. After the second day, ammonia volatilization rate of K2 treatment was higher than that of K1 treatment and CK treatment respectively. The average of amount of treatments of ammonia volatilization flux were K2＞K1＞CK. The results showed that during the basal period, the continuous cropping pattern of flue-cured tobacco could result in higher ammonia volatilization rate than the rotation pattern.

As shown in Fig. 2b, the cumulative loss of ammonia volatilization under different tillage treatments on tobacco fields was positively correlated with time, all increasing with time. In addition, CK treatment was always lower than K1 treatment and K2 treatment at this stage. The first four days after application of base fertilizer, K1 showed highest ammonia volatilization cumulative loss; after 4 days, cumulative loss of ammonia volatilization of K2 has been maintained at the highest value, and the ammonia cumulative loss during base fertilizer of K2 treatment was higher than that of K1 treatment and CK treatment by 14.36% and 51.79%, respectively. Therefore, continuous cropping in flue-cured tobacco fields can produce a higher cumulative loss of ammonia volatilization during the basal period.

As shown in Fig. 2b, the curve-fitting of the cumulative loss of ammonia volatilization during the 15 days after basal application of tobacco field showed that the cumulative loss of ammonia volatilization (y) and the number of days after basal fertilizer (t) were completely consistent with Logistic Growth function, [$y = a/(1 + x / x_0)^{-b}$]. Further correlation analysis showed that there was a highly positive correlation between the measured values of ammonia volatilization cumulative loss of CK, K1 and K2 after 15 days and the simulated values calculated by Logistic equation with the correlation coefficients of 0.9858 ** and 0.9954 ** and 0.9801 **, all reached a significant level.

### Laws of Ammonia Volatilization in Tobacco Fields after Top Dressing

The ammonia volatilization flux of 15 days after topdressing in tobacco field is shown in Fig. 3a. The amount of treatments of ammonia volatilization flux were K2＞K1＞CK, respectively of 0.31, 0.27 and 0.14 $kg.hm^{-2}\cdot d^{-1}$, and reaching the highest value of ammonia volatilization flux during the period of 4-5 days after topdressing. The first 13 days after topdressing, K2 treatment showed the highest ammonia volatilization flux and CK treatment showed the lowest. After the 13th day, the ammonia volatilization flux of each treatment tended to be equal at 0.1368 $kg.hm^{-2}\cdot d^{-1}$. The the average of amount of treatments of ammonia volatilization flux were K2＞K1＞CK. Studies have shown that continuous cropping in the top-dressing is conducive to the increase of ammonia volatilization rate in tobacco field.

During the 15 days after topdressing, the cumulative loss of ammonia volatilization of each treatment increased with time, as shown in Fig. 3b. There was no significant difference among the treatments in the first 3 days after topdressing. After 3 days, the differences between the treatments became significant, and the cumulative loss of ammonia volatilization was similar to that in basal fertilizer stage, of which K2 treatment showed the most cumulative loss of ammonia volatilization. The cumulative losses of ammonia volatilization during topdressing of K2 were higher than that of K1 and CK by 20.41% and 38.78%, respectively, which indicated that continuous cropping mode adopted in tobacco field will increase the cumulative amount of ammonia volatilization.

As shown in Fig. 3b, the cumulative losses of ammonia volatilization during the 15 days after topdressing in tobacco field were fitted by curve fitting. It proved that, except that the K0 showed linear relationship, the cumulative ammonia volatilization loss (y) and days after topdressing (t) was in full compliance with the Logistic growth function, [$y = a / (1 + x / x_0)^{-b}$]. Further correlation analysis showed that there was a highly positive correlation between the measured values of ammonia volatilization cumulative loss of K1 and K2 15 days after topdressing and the simulated values calculated by Logistic equation with the correlation coefficients of 0.9670 ** and 0.9944 **, both reached a significant level.

### Ammonia Volatilization Cumulative Amount and Loss Rate in Tobacco Field

As shown in Table 2, the effects of different tillage treatments on cumulative ammonia volatilization and loss rate of tobacco field after fertilization are different. In terms of cumulative volatilization and loss rate of ammonia during basal fertilizer and topdressing in tobacco fields, that of K2 treatment was higher than other treatments, and significant differences were showed among all treatments. However, cumulative ammonia volatilization and losses during topdressing were higher than that in the base fertilizer period. During 30 days of the fertilization period, ammonia volatilization accumulation of tobacco field in K2 treatment was higher than that of CK and K1 treatment by 0.150 and 0.055 kg·hm$^{-2}$, respectively, while the ammonia volatilization loss rate of K2 treatment was 1.58 times that of K1 treatment. The results showed that the cumulative amount and the loss rate of ammonia volatilization were high during the topdressing period; and the continuous cropping pattern was more capable of promoting the accumulation of ammonia volatilization and the loss rate after fertilization than the continuous cropping method.

## Discussion

In the process of agricultural production, the past one-time fertilization cannot meet the law of crop nutrient demand, which eventually resulted in low utilization of fertilizer,

**Table 2:** Effect of Different Fertilization Strategies on Ammonia Volatilization and Losses in Tobacco Field after Fertilization

| Treatment | 15 days after the basal fertilizer | | 15 days after top fertilizer | | Total | |
|---|---|---|---|---|---|---|
| | Cumulants/kg.hm$^{-2}$ | Loss rate/% | Cumulants/kg.hm$^{-2}$ | Loss rate/% | Cumulants/kg.hm$^{-2}$ | Loss rate/% |
| CK | 0.089 c | - | 0.085 c | - | 0.175 c | - |
| K1 | 0.159 b | 0.069 | 0.111 b | 0.026 | 0.270 b | 0.095 |
| K2 | 0.185 a | 0.096 | 0.140 a | 0.054 | 0.325 a | 0.150 |

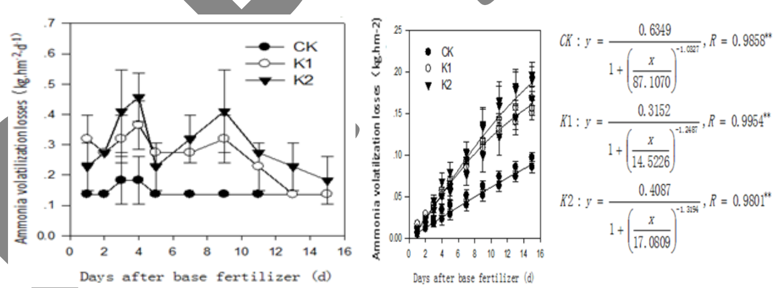


**Fig. 2**: Effect of different fertilization strategies on ammonia volatilization in post-base tobacco fields
a. Ammonia volatilization rate after base fertilizer
b. Ammonia volatilization cumulative loss after base fertilizer

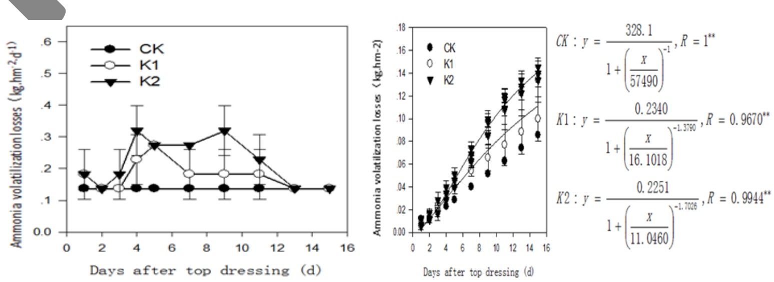


**Fig. 3:** Effect of different fertilization strategies on ammonia volatilization in tobacco field after topdressing
a. Ammonia volatilization flux after topdressing
b. Ammonia volatilization cumulative loss after topdressing

and later were changed to fertilization mode of basal and top dressing. As a result of a series of reactions of nitrogen fertilizer applied to farmland, ammonia volatilization will occur, which gradually results in the loss of nitrogen fertilizer and environmental hazards (Chien *et al.*, 2009). Watering are needed to dissolve nitrogen fertilizers after basal and topdressing in the yellow-colored tobacco area of Guizhou, which will increase the soil water content, resulting in rapid hydrolysis of urea applied to the soil and generating ammonium nitrogen. The more the ammonium nitrogen accumulates, the greater the ammonia volatilization flux, and finally reaching the peak of ammonia volatilization. The results showed that the peak of ammonia volatilization rate occurs in the first 3-5 days after fertilization, and then drops rapidly, which is in line with the soil ammonia volatilization studies in north China farmland (Dong *et al.*, 2006). However, the peak occurred again in this study in 8-10 days after topdressing, and then into the low-volatility stage. The phenomenon occurs because of residual fertilizer in the tobacco field hydrolyzed and produced ammonium nitrogen, which accumulated once again in the soil and contributed to a second peak of ammonia volatilization. In the first 2 days after basal application, the ammonia volatilization rate of CK treatment was the lowest, while that of K1 treatment was higher than that of K2 treatment. The results indicated that continuous cropping resulted in soil compaction and hindered soil respiration, affecting the ammonia volatilization rate. The the average of amount of treatments of ammonia volatilization flux were K2＞K1＞CK. The continuous cropping patterns might affect physical and chemical properties of the soil, and then plant roots are affected, so that it cannot fully absorb nitrogen in the base fertilizer, which resulted in increase of ammonia volatilization rate.

With the increase of time, the soil fertilizer is gradually absorbed by the plant. Due to decrease of raw material for nitrification process in soil, accumulation of ammonium nitrogen reduced and resulting in gradually decrease of ammonia volatilization rate. It has been reported that the accumulative amount of ammonia volatilization showed a growth curve of "S type" (Fei and Changyan, 2011). In this experiment, the accumulative amount of ammonia volatilization in the yellow-colored area of Guizhou showed a growth curve of "S type", which accorded with Logistic growth curve. There was a highly positive correlation between the measured values and calculated simulated values, except that the cumulative ammonia volatilization with no-fertilization treatment in the topdressing stage of tobacco showed a linear growth curve, whose mechanism needs to be further studied.

From the results of the experiment, the cumulative ammonia volatilization and loss rate during the top-dressing period are higher than the base fertilizer stage. This indicated that residual fertilizers in the soil during the basal fertilizer together with fertilizers of topdressing increased the cumulative amount of fertilizer remaining in the tobacco field, resulting in a higher cumulative amount of ammonia volatilization during the top-dressing period. Whether it is basal or topdressing, continuous cropping could result in higher cumulative amount of ammonia volatilization in tobacco field than that of crop rotation. The reason might be that the continuous cropping pattern could change physical and chemical properties as well as microenvironment of the soil, and then root absorption of nutrients is affected. Due to uncomplete absorption of soil fertilizers, the fertilizer residues in the soil increased, resulting in a higher ammonia volatilization rate. However, this phenomenon needs further verification.

## Conclusion

1). Compared with crop rotation, continuous cropping could significantly increase the ammonia volatilization rate and cumulative amount in tobacco field. The highest ammonia volatilization rate under continuous cropping treatment reached 0.46 kg.hm$^{-2}$·d$^{-1}$ at base fertilizer stage and 0.32 kg.hm$^{-2}$·d$^{-1}$ at topdressing stage.
2). Cumulative ammonia volatilization under continuous cropping and crop rotation showed a similar "S type" growth curve, which were in line with the Logistic growth curve, and the measured values and calculated values were in highly positive correlation.
3). During the 30 days after fertilization, the accumulative amount of ammonia volatilization of tobacco fields in continuous cropping were higher than that of rotation cropping and no-fertilization treatment by 0.055 kg·hm$^{-2}$ and 0.15 kg·hm$^{-2}$, respectively. The ammonia volatilization loss rete with continuous cropping treatment was 1.58 times of that with crop rotation treatment.

Therefore, the crop rotation system could reduce the volatile ammonia emission rate and reduce the cumulative loss of ammonia volatilization, which could reduce the loss rate of ammonia volatilization.

## Acknowledgements

This work is supported by Fund Program: "Evaluation on Carbon-nitrogen Circulation and Ecological Value of Tobacco-soil System" (110201402015), a science and technology program of China National Tobacco Corporation. I also would like to express my gratitude to all those who have helped me during the writing of this thesis. I gratefully acknowledge the help of my supervisor Professor Zhang Yungui. I do appreciate her patience, encouragement, and professional instructions during my thesis writing.

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**(Received 26 February 2018; Accepted 11 May 2018)**