Pak. J. Agri. Sci., Vol. 57(x),xxx-xxx ;2020
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/20.9746
http://www.pakjas.com.pk

IMPROVING RICE YIELD BY FREQUENTLY APPLYING HUMIC ACID LIQUID ORGANIC FERTILIZER AT LOW FERTILIZATION RATE

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Managing additional nitrogen fertilization properly in rice field is essential for improving nitrogen use efficiency and reducing its negative environmental impact. A field trial was conducted by introducing a humic acid organic liquid fertilizer (LoF) into a rice field and applied in more times at a lower dosage along with each irrigation event. Compared with traditional input of urea (278.9kg N ha^{-1}), LoF enhanced rice growth, yield, and nitrogen uptake at the pre-requisite that total N input was reduced by 12.5%. Rice yield was increased by 1.18 t ha^{-1} (14.6%); as a result, partial productivity of nitrogen fertilizer increased by 31.1%. Furthermore, total biomass production in LoF treatment was found 1.79 t ha^{-1} higher than that in UF treatment. It can be concluded that mixing the humic acid LoF into irrigation water at a low dosage and application in a frequent regime is an efficient and environmental friendly nitrogen management practice in the rice.

Keywords: Additional fertilization, liquid organic fertilizer, nitrogen use efficiency, rice.

INTRODUCTION

Nitrogen (N) fertilizer plays an important role in sustaining crop yields. In China, the application of chemical nitrogen is applied in high doses to achieve maximum rice yield. The high chemical N input resulted in large nitrogen loss and serious environmental problems (Ju *et al.,* 2009; Xu *et al.,* 2013; Zhang, 2017). To optimize nitrogen management in agricultural production, scientists tried to develop new nitrogen fertilizers, such as controlled released fertilizer (Timilsena *et al.,* 2015; Liu *et al.,* 2018) and organic fertilizer (Peng *et al.,* 2017; Chen *et al.,* 2018), or optimize the chemical N management by changing the amount and time for N application (Tedone *et al.,* 2018).

Recently, LoF, sometimes as the processed organic agricultural byproducts, were used in agricultural production. It has been used on different crops as a substitute of chemical nitrogen fertilizers (Dordas *et al.,* 2008; Deore and Laware, 2011; Kasim *et al.,* 2011; Canfora *et al.,* 2015; Huang et al. 2016; Ji *et al.,* 2017; Herawati *et al.,* 2017). Compared with chemical nitrogen fertilizer, liquid organic fertilizers can provide nutrients in a slower way and function in a longer period. It matches and synchronize crop demand much better, and help to maintain soil fertility and sustainability (Canfora *et al.,* 2015; Martinez-Alcantara *et al.,* 2016; Azevedo *et al.,* 2017; Ji *et al.,* 2017). It offers an opportunity to optimize the management of nitrogen topdressing in agricultural fields. Furthermore, it can be applied easily and uniformly together with irrigation inflow either by pipe irrigation or surface irrigation system.

In the rice field, which was irrigated more frequently and always fertilized with high nitrogen levels, urea is the most frequently used nitrogen fertilizer for topdressing. Generally, urea applied in two or three splits for topdressing during rice growth (Peng *et al.,* 2006). If the urea replaced by the LoF, it can be applied together with each irrigation event. That implied the LoF could be applied to the rice field at lower dosage regimes in a more frequent way, which could match the rice nitrogen requirement better and help to improve nitrogen use efficiency. However, there is no result of using LoF as topdressing nitrogen fertilizer in rice field.

A field trial was conducted by introducing a humic acid organic liquid fertilizer into the rice field. Further, the LoF was applied in more times at a lower dosage along with each irrigation event. The objectives of this research is to see the effect of organic liquid fertilizer on plant growth, nitrogen use efficiency and crop yield.

MATERIALS AND METHODS

Experiment treatment: The experiment carried out in 2017 rice season at Kunshan irrigation and drainage experiment station (31°15′15″N, 120°57′43″E) in East China. The study area has a subtropical monsoon climate, with an average annual air temperature of 15.5 °C, mean annual precipitation of 1,097.1 mm. Seasonal precipitation in 2017 rice season was 420 mm. The soil is dark-yellow hydromorphic paddy soil. The soil texture in the plowed layer is clay, with an organic matter of 30.3 g kg^{-1}, total nitrogen of 1.79 g kg^{-1}, total phosphorus of 1.4 g kg^{-1}, total potassium of 20.86 g kg^{-1}, and pH of 7.4 (soil/water, 1:2.5). The variety of rice was Japonica Rice Nanjing 46, one of the prevailing varieties in this region, which was transplanted with 16.7 cm × 26.7 cm hill spacing on July 7 and harvested on 30 October 2017.

There were two fertilizer treatments for additional nitrogen fertilizer, namely liquid organic fertilizer (LF) and urea (UF). Both treatments were replicated three times and set in 6 plots (15 m×10 m). The ridges were constructed with concrete about 100 cm buried in soil, to isolate different plots and avoid hydraulic exchange between adjacent plots. For UF treatment, basal fertilizer was applied according to local farmer's practice, 525 kg ha^{-1} compound fertilizer and 150 kg ha^{-1} of urea was applied. However, for LF treatment, urea was canceled in basal fertilizer and was replace by LoF applied in the following irrigations. For additional fertilization, urea was applied three times in UF treatment, and LoF was applied seven times in LF treatment. Detailed information on fertilization is shown in Table 1.

The LoF used in LF treatment is humic acid, LoF supplied by Inner Mongolia Wofeng agricultural development company, and it was produced from the waste of Monosodium glutamate. The humic acid, amino acid and organic matter contents in LoF were 50 g L^{-1}, 20 g L^{-1} and 180 g L^{-1}, N, P_2O_5, and K_2O contents were 80 g L^{-1}, 70 g L^{-1} and 100 g L^{-1}.

CF is compound fertilizer (N, P_2O_5 and K_2O contents are 16%, 12%, and 17%). U is urea (N content is 46.2%). LoF is liquid organic fertilizer (N contents is 80 g L^{-1}). For each fertilization, fields were irrigated to maintain flooding water of about 50 mm.

Field measurement and sampling**:** Twenty hills of rice plants were designated in each treatment, plant height and tiller numbers were measured every 5 days until it was constant in October. Leaf SPAD has measured over ten leaves in each treatment every 10 days by a SPAD-502 (Japan) chlorophyll meter, to reflect the leaf nitrogen status. At harvesting, three plants were sampled from each treatment and were divided into root, stem, leaf, sheath, and panicle. Then it was oven-dried before the weight of each part was measured by a precision balance. The oven-dried samples were first ground and the N concentrations were then determined by the Kjeldahl procedure. Plant nitrogen uptake was calculated by compiling biomass weights with corresponding N concentration. Partial productivity of nitrogen fertilizer was calculated as the ratio between rice yield and total nitrogen inputs.

Statistical Analysis**:** Least significant difference (LSD) test was used to compare the difference in biomass production, rice yield and its components, nitrogen uptake and productivity of nitrogen fertilizer between LF and UF treatments at the significant level of p=0.05. All statistical analysis was performed using SPSS19.0 (SPSS Inc., Chicago, USA).

RESULTS AND DISCUSSION

Plant height and tiller dynamics**:** Plant height increased with time during 60 days after transplanting (Figure 1A). Humic acid liquid organic fertilizer, which was applied to the

Table 1. Fertilization records in UF and LF treatments (kg ha^{-1} for urea, L ha^{-1} forr LoF).

Treatment	Base fertilizer	Tillering fertilizer	Strong seedling fertilizer	Panicle fertilizer	Total nitrogen
UF	525CF+150U	75U	150U	45U	278.9
	7 July	27 July	7 Aug	29 Aug	---
	Basal	Top dressing	Top dressing	Top dressing	
LF	525CF	436LoF, 436LoF	218LoF, 436LoF, 218LoF	130LoF, 130LoF	245.3
	7 July	23 July, 31 July	7 Aug, 16 Aug, 27 Aug	4 Sept, 10 Sept	---
	Basal	Mixing	Mixing	Mixing	

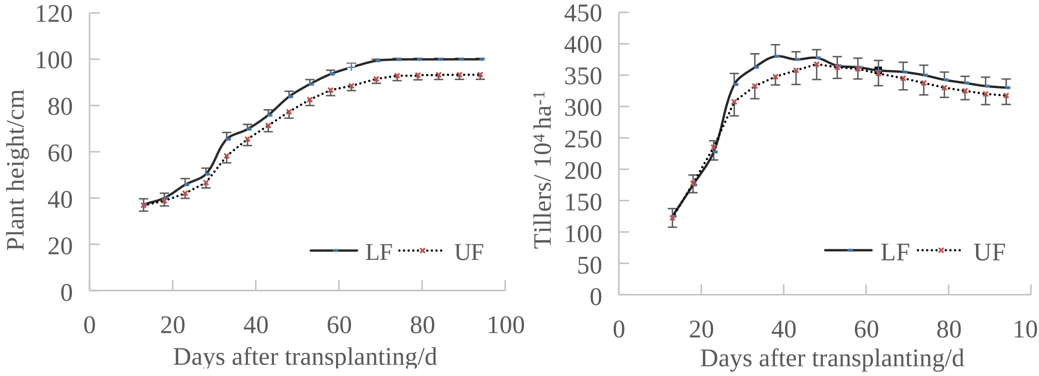

Figure 1. Plant height (A) and tiller dynamics (B) of rice fertilized with humic acid liquid organic fertilizer (LF) and urea (UF).

rice field along with each irrigation event seven times, relatively at a low dosage for each application, resulted in higher rice plant height than a traditional top dressing of urea. The difference in plant height between LF and UF treatments was as low as 0.3 cm at the initial of rice season and then increased gradually along with rice growth to about 8.0 cm at 69 days after transplanting. Then the difference in plant height was constant to harvest, with the final value of about 6.7cm. The difference in plant height between LF and UF treatments were most significant at p=0.05 level except for the first four observations.

Tiller numbers increased rapidly and reached the maximum in the middle, then reduced in the later period of the rice season (Figure 1B). In the LF field, it got the maximum tillers of 3.80 million per hectare at 38 days after transplanting. It was 0.33 million per hectare higher, and about ten days earlier than in UF paddies. The difference in tiller numbers between LF and UF treatments was found to be significant on DAT of 33d and 38d. At harvesting, the final effective tillers in LF were 3.30 million per hectare; it was 0.12 million per hectare higher than in UF field. Thus, the LF treatment resulted in higher tillers both in the maximum and effective tillers. The percentage of earring-tillers was calculated as 86.84% in LF field, almost the same as that in UF treatment (86.39%).

Replacing the topdressing of urea to humic acid liquid organic fertilizer, and dividing the top dressing of fertilizer into more splits can meet the nitrogen requirement of rice plants better, and result in increased plant height, maximum and effective tillers.

***Leaf SPAD value*:** Leaf SPAD, which was used to reflect leaf nitrogen status, for functional rice leaves were measured during rice season. Leaf SPAD was high in the vegetative growth stage and reduced gradually in reproductive growth stage (Figure 2).

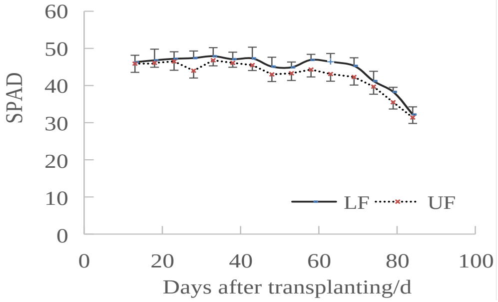

Figure 2. SPAD of functional leaf for rice in LF and UF treatment.

In the LF field, leaf SPAD was 0.4-3.4 (averaged in 1.79) higher than that in UF. It was generally higher in LF field than in UF field, although the difference was not significant. We believe it was the direct evidence that LF treatment meet the rice nitrogen requirement better than UF.

***Biomass and nitrogen uptakes*:** Biomass and nitrogen uptakes were measured at harvesting (Table 2). Due to enhanced rice growth in LF treatment, rice biomass accumulation in different organs was slightly higher than that in UF. As a result, total biomass production in LF treatment was found 1.79 t ha^{-1} higher than that in UF treatment. Since the UF meet with rice nitrogen requirements better (as listed in Figure 2), nitrogen contents in different rice organs were increased. Total nitrogen uptakes in rice plants were calculated as 175.60 kg N ha^{-1} in the LF field. It was 27.01 kg N ha^{-1} higher than in UF treatment.

***Yield and its components*:** As a result of increased maximum tillers and percentage of earring-tillers, the effective panicles in LF treatment was slightly higher than in UF treatment. Due to high nitrogen contents in both leaf and other organs, grains per panicle and thousand-grain weight were also slightly higher. As a result, rice yield in the LF field, which was estimated as 9.21 t ha^{-1}, was significantly higher than the yield in UF treatment. Meanwhile, seasonal N input in the LF field was reduced by 12.5%; the partial productivity of nitrogen fertilizer increased greatly by 31.1%.

The basal application of nitrogen in the form of compound fertilizer was much lower in LF fields, and topdressing of N in forms of humic acid liquid organic fertilizer was much higher than in UF fields. In UF fields, urea was top-dressed in three times (34.8, 69.6, 20.88 kg N ha^{-1}) in tillering and jointing stages. In addition, in LF field, the type of topdressing fertilizer is humic acid liquid organic fertilizer, which was top-dressed in seven splits during the rice season. The dosage of each application was 34.9, 17.4 and 10.4 kg N ha^{-1}, it was lower than that in UF treatment. The nitrogen element in humic acid liquid organic fertilizer is mostly in forms of organic nitrogen (i.e. humic acid, amino acid). That helps reduce the risk of nitrogen loss in forms of ammonia volatilization and leaching, which accounted for a large proportion of nitrogen input in rice fields (Xu *et al.*, 2012; Zhang, 2017). Thus, replacing the topdressing of urea with humic acid liquid organic fertilizer, and dividing it into more splits resulted in higher rice yield and nitrogen use efficiency.

***Soil TN at harvesting*:** Soil total nitrogen at harvesting were almost the same in LF soil with that in UF soil at 0-10cm

Table 2. Biomass production and nitrogen uptakes for rice with LF and UF fertilization.

Treatments		Root	Stem	Leaf	Sheath	Panicle	Total
Biomass	LF	1.69±0.08*	2.40±0.17	2.41±0.25	2.39±0.44	10.43±1.24*	19.33±0.32*
(t ha^{-1})	UF	1.44±0.18	2.23±0.16	2.36±0.13	2.32±0.15	9.18±0.99	17.54±1.60
Nitrogen uptakes	LF	16.30±0.74*	14.89±1.02	23.14±2.44	14.79±2.72	106.45±14.71	175.60±1.85*
(kg N ha^{-1})	UF	12.83±1.62	12.96±0.92	19.37±1.02	13.48±0.89	89.95±10.29	148.59±6.06

* indicated the data in LF treatment is significantly higher than that in UF treatment.

depth (Figure 3). But for soils at 10-20cm and 20-40cmm, soil TN contents were slightly lower in LF than those in UF treatment. Nitrogen in LoF is mostly in forms of organic nitrogen (i.e. humic acid, amino acid) that was immobilized by soil microorganism in the mineralization process and has a lower chance of moving downward along with deep percolation in the rice field. We can deduce that the leaching losses of nitrogen will reduce in the rice field if the UF was replaced by LoF.

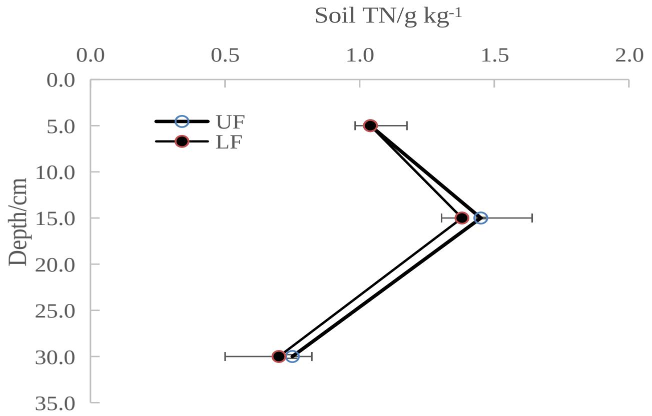

Figure 3. Soil TN contents in UF and LF soil

Implications on nitrogen management in rice fields**:** The humic acid organic liquid fertilizer was introduced into the rice field and applied as additional fertilizer in a more frequent low dosage regime. It illustrated that the LoF enhanced rice growth and nitrogen uptakes; even the total N input was reduced by 12.5% compared with traditional UF treatment. As a result, the nitrogen use efficiency and partial productivity of nitrogen fertilizer increased greatly. LoF was reported to be efficient in increasing plant growth or production on different plants at the same dosage to chemical fertilizer (Dordas *et al.*, 2008; Kasim *et al.*, 2011; Herawati *et al.,* 2017), or at even lower dosage (Ji *et al.,* 2017; Canfora *et al.,* 2015). Our research indicated that LoF, as the topdressing fertilizer, increased rice yields significantly at a 12.5% lower application rate.

Furthermore, we changed the application habit of topdressing nitrogen fertilizer in rice field. The basal application of urea was canceled and replaced by the topdressing of LoF at a low dosage seven times in the rice season. The increment in both crop growth (Figure 1 and 2), nitrogen uptakes (Table 2), yield and component of rice (Table 3) confirmed that topdressing LoF in a frequent and low-dosage regime meet rice nitrogen need well.

In the view of field nitrogen balance, the high nitrogen use efficiency and high soil residual nitrogen at harvesting indicated there must be fewer nitrogen losses (in forms of ammonia volatilization, leaching, runoff, and denitrification) in LF rice field than UF field. It was a general conclusion that nitrogen ingredients (nitrate or ammonium) in nitrogen fertilizer resulted in different pattern in nitrogen losses from rice field (Cai *et al.*, 1986； Xu *et al.*, 2012； Chen *et al.*, 2015; Peng *et al.,* 2015; Huang *et al.,* 2016; Li *et al.,* 2017; Liu *et al.,* 2018). Topdressing of ammonium nitrogen fertilizer (including urea) general following with a high ammonia volatilization, which accounted for a large proportion of nitrogen loss immediately after topdressing of nitrogen (Xu *et al.,* 2012; Xue et al. 2014; Li et al. 2017; Zhang et al. 2017; Wang *et al.,* 2018). In LoF, other than ammonium nitrogen, nitrogen was mostly in form of dissolved organic matter (Deore and Laware, 2011). The ammonia volatilization loss should be lower because organic nitrogen generally resulted in less ammonia volatilization loss following top dressing in the rice field than urea (Huang *et al.,* 2016; Liu *et al.,* 2018). And both ammonium nitrogen and organic nitrogen are easy to be bound with soil matrix, which reduced the leaching risk (as supported by results in Figure 3). In current research, LoF was applied in a frequent and low-dosage regime, that also helps to reduce the peak pulse in ammonia volatilization loss and leaching (Lin *et al.*, 2012; Xue et al. 2014; Huang *et al.,* 2016; Li et al. 2017; Xia *et al.,* 2017). The high plant uptakes (in Table 2) also suggested that LoF should be helpful in improving crop uptakes and reducing nitrogen loss to the ambient environment. Thus, LoF should be an environmentally friendly fertilizer in the rice field. Further research should investigate the environmental impact of LoF application in rice fields.

Seasonal precipitation was 440 mm in 2017 rice season (p = 87% among 50 years). There were more irrigation events during the rice season than the normal year or wet year. As a result, the LoF was divided into seven splits, and the application rates were ranged from 10.4-34.6 kg N ha^{-1} (in Table 1). If there were more precipitation, that will provide more water for crop water demand, and irrigation events will be reduced. It implies that LoF should be applied into rice field in less splits, and the application rate for each application

Table 3. Yield and its component of rice and the partial productivity of nitrogen fertilizer (PFPN).

Treatment	**Nitrogen inputs** kg N ha^{-1}	**Yield** (t ha^{-1})	**Effective panicles** (×10^{5} ha^{-1})	**Grains / panicle**	**Thousand grain weight** (g)	**PFPN** kg kg^{-1}N
LF	84.0+160.1	9.21±0.11*	30.7±0.95	117.0±3.0	28.65±0.14*	36.37±2.41*
UF	153.6+125.3	8.03±0.10	29.2±0.63	114±2.0	27.86±0.11	28.78±0.35

For nitrogen inputs, the data at both sides of + is the basal and additional nitrogen input.
* indicated the data in LF treatment is significantly higher than that in UF treatment.

should increase to a certain degree. That will result in high nitrogen loss in short period after fertilization. So, the performance of LoF in rice field should be tested in different hydrological years. Since rice can be irrigated more frequently (Bouman and Tuong, 2011; Mao, 2012; Hassan *et al.,* 2015). We believe it worth trying to set more levels of LoF fertilization rate and to divide LoF into more little-dosage-splits, to find a suitable LoF application regime (including dosage and splits regime) that can meet with rice plant nitrogen requirement appropriately.

***Conclusions*:** The humic acid organic liquid fertilizer resulted in marvelous results in the rice field, which enhanced rice growth, yield, and nitrogen uptakes in prerequisite that total N input was reduced by 12.5% compared with traditional urea. The nitrogen use efficiency and partial productivity of nitrogen fertilizer increased greatly**.** It means the humic acid organic liquid fertilizer, which was mixing into irrigation water at a low dosage and frequently regime, is an efficient and environmentally friendly management practice for additional nitrogen management in the rice field. It is worth investigating it with more regimes with detailed different splits and frequency to find the best management practice for rice additional fertilization management.

***Acknowledgment*:** This research was financially supported by National Key Research and Development Plan (No.2016YFC0400103), Jiangsu Province Water Conservancy Science and Technology Project (No.2018065), Fundamental Research Funds for the Central Universities (NO.2019B17914).

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