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Original Research Article

Efficacy of different irrigation methods in saving water and ameliorating pollution in paddy field: Take Pinghu as an example

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ABSTRACT

Objective: Improving water use efficiency and ameliorating pollution is a challenge facing agriculture, and this paper aims to present an experimental study on the efficacy of different irrigation methods in saving water and reducing pollution in paddy fields in an attempt to provide suitable management for paddy fields in plain regions. **Method:** We examined three irrigation methods: flooding irrigation, shallow-water irrigation, and rain-collecting irrigation in Pinghu, Zhejiang province. For each irrigation, we measured TN, TP, NH_4^+-H, NH_3-N, and COD in both irrigation water and drainage water. **Result:** Compared with flooding and shallow-water irrigation, rain-collecting irrigation reduced the amount of irrigation water by 67.4% and 43.4%, TN loss by 86.9% and 90.7%, emissions of NH_4^+-H by 96.7% and 98.3%, and COD emissions by 61.5% and 62.5%, respectively. The difference in change of TP and NH_3-N between all three irrigation methods was not significant. **Conclusion:** For the areas we studied, rain-collecting irrigation is most effective in saving water and reducing pollution.

Keywords: agroecology; traditional agriculture; resilience; adaptation; climate change

1. Introduction

Rice is the most important food crop in Pinghu City. In 2016, irrigation water consumption accounted for 47.6% of the city's total water consumption and 89.6% of the city's total agricultural water consumption[1]. Rice production is dominated by traditional inundation, which not only consumes a large amount of water but also causes large displacement and leakage in the field. Because it is located in the plain river network area, it is easy to produce non-point source pollution[2–4]. The implementation of water-saving irrigation modes for rice can not only save irrigation water[6–8] but also improve the utilization efficiency of water and fertilizer and reduce the emission of pollutants in rice fields[9–11]. After years of experimental research and practice, the water-saving irrigation modes are mainly shallow, wet, and sun irrigation, intermittent irrigation, wet irrigation, suitable rain irrigation, thin dew irrigation, controlled irrigation, and so on. According to the experimental results of Xiao et al.[12], the irrigation times and total irrigation amount of rice fields suitable for rain irrigation decreased by 60% and 81.9% compared with conventional irrigation, but the yield did not decrease significantly. Chi et al.[13] found that the water utilization rate of thin dew irrigation was 41.1% higher than that of submerged irrigation. Through a pit test, Jiang et al.[14] found that compared with conventional irrigation,

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intermittent irrigation, and wet irrigation reduced TN runoff loss by 52.01% and 38.24%, and leakage loss by 15.88% and 42.06% in the whole rice season. Although water-saving irrigation modes have achieved good water-saving and pollution reduction effects, they are often adapted to specific regions, climatic conditions, and soil types due to the different field water control standards of different water-saving irrigation modes. In most of the existing experiments, only a certain water-saving irrigation mode and conventional irrigation were compared. This research, in view of the basic situation of Pinghu, selected local rice cultivation in Pinghu irrigation experimental station in one of the most common conventional irrigations and popularized in Zhejiang Province, thin dew irrigation, and research in recent years, more comfortable rain irrigation, rice in the field experiment was carried out, the water-saving effect, and the study compared three kinds of irrigation mode for the rule of nitrogen, phosphorus, and other pollutants. To explore the water-saving irrigation mode of rice suitable for plain river network areas in order to provide some scientific basis for agricultural water management in Pinghu City.

2. Materials and methods

2.1. Overview of the study area

The rice field experiment was carried out in the Agricultural Drainage and Irrigation Technology Demonstration Base of Zhaojiaqiao Village, Huanggu Town, Pinghu City, Zhejiang Province, from June to December 2017. The geographical coordinates were 121°16' N, 30°36' E, and the altitude was 4.1 m. The experimental area has a subtropical monsoon climate, with an average annual temperature of 15.7 ℃ and an average annual rainfall of 1195.2 mm. The average annual sunshine time is 2075 h, and the average annual rainfall time is 140 days. The soil texture is silty clay, and the soil volume mass is 1.39 g/cm^3. There were 24 test plots in the experimental area, each of which was 6 m × 11 m in area. The water intake and drainage were all made of seamless steel pipes, and the water meter, filter, and control gate valve were installed. The ridge of the field was made of cement mortar bricks, about 20 cm above the soil surface. In 2017, the rainfall during the rice growing season was 681.7 mm, which was a wet year with more rainfall.

2.2. Experimental design

The experimental rice variety Xiushui No.12, a local japonica single-season late rice, was sown on June 29, 2017. The pure fertilization rate in the whole growth period was N: 241.5 kg/hm^2, P_2O_5: 150 kg/hm^2, and K_2O: 60 kg/hm^2. Phosphate fertilizer and potassium fertilizer were all applied to the base fertilizer, and nitrogen fertilizer was 5:3:2 base fertilizer, tillering fertilizer, and jointing fertilizer. There are three treatments in the experiment: conventional irrigation (W0 treatment), thin dew irrigation (W1 treatment), and suitable rain irrigation (W2 treatment). Each treatment has 3 replications, totaling 9 experimental plots, and each treatment is randomly arranged. According to the local farmers' irrigation habits, W0 treatment was used as a control. Except for thin water in the turning green period, sun-drying in the late tillering period, and natural drying in the yellow ripening period, the water layer of 20~40 mm was always kept in the fields in other growth stages, which could be properly stored in case of rainfall. The water management of W1 treatment in the late tillering stage and the yellow ripening stage is the same as that of W0 treatment, and the rest of the growth stages are irrigated with a thin water layer below 20 mm, dried in time, and drained in time after rain. The water management of W2 in the late tillering stage and yellow ripening stage is the same as that of W0 and W1. In other growth stages, rainfall is used to the maximum extent, water is stored in the field during rainfall, and irrigation quantity and times are reduced during rainless periods. See **Table 1** for the control standards of the field water layer in different growth stages of rice under different irrigation modes.

Table 1. Field water control standards of different irrigation modes.

Irrigation mode	Control standards	Green period	Tillering stage		Jointing and booting stage	Heading and flowering period	Milk stage	Yellow ripening stage
		0722–0802	Early 0803–0823	Late 0823–0831	0901–0917	0918–0926	0927–1009	1010–1204
W0 treatment	Upper limit	20 mm	40 mm	0 mm	40 mm	40 mm	40 mm	Natural drying
	Lower limit	5 mm	20 mm	80%θ_s	20 mm	20 mm	20 mm	
	Flooding depth	40 mm	80 mm	20 mm	80 mm	80 mm	80 mm	
W1 treatment	Upper limit	20 mm	20 mm	0 mm	20 mm	20 mm	20 mm	Natural drying
	Lower limit	5 mm	80%θ_s	80%θ_s	80%θs	80%θ_s	80%θ_s	
	Flooding depth	40 mm	40 mm	20 mm	40 mm	40 mm	40 mm	
W2 treatment	Upper limit	20 mm	20 mm	0 mm	20 mm	20 mm	20 mm	Natural drying
	Lower limit	5 mm	80%θ_s	80%θ_s	80%θs	80%θs	80%θs	
	Flooding depth	40 mm	200 mm	20 mm	200 mm	200 mm	200 mm	

The upper limit of irrigation is the height reached by each irrigation. If the height is lower than the lower limit of irrigation, irrigation is required. The flood tolerance depth is the maximum amount of water that can be stored in the field after rain. θ_s is the saturated moisture content of the rice root layer soil.

2.3. Test observation and water sample detection

During the rice growth period, the meteorological data were automatically obtained by the small meteorological station in the experimental station. The water level of the paddy field was read by the water ruler at a fixed position in the field at 08:00 every day, and measured before and after irrigation, rainfall, and drainage. When there was no water layer in the field, the soil moisture content of the rice root layer was measured by the drying method, and the soil moisture content was measured before and after irrigation, before and after rainfall, and during the transformation of the growth stage. Field layout bottoms, bottomless barrel, measuring water level change within 08:00 observation field measuring barrels a day, a bottom, bottomless barrel inside layer height measurement is 1 day before the difference between the amount of leakage, in addition to the drainage of field value minus leakage layer height change every day, is the transpiration and evaporation after a record, adjust the bucket of water level measurement to be consistent with the field. The collection of water samples mainly includes drainage water samples and leakage water samples. Sampling at each drainage: water samples of soil leakage were collected by vacuum pump once a week from the green stage to the milk ripe stage, and were measured before and after each fertilization. Water samples were mainly tested for TN, TP, $NH_4^+ - N$, $NO_3^- - N$ and COD.

2.4. Evaluation method

The actual yield of each treatment was collected separately and converted into yield per unit area. The analysis of the water-saving effect mainly includes the analysis of field water balance, rice water productivity, and effective utilization rate of irrigation water. The field water balance is mainly analyzed by the actual irrigation and drainage situation of each treatment. Water productivity, irrigation water productivity, and evapotranspiration water productivity can be calculated as follows:

$$\eta = \frac{G}{1 + P - O} \tag{1}$$

$$\eta_{\rm irr} = \frac{G}{I} \tag{2}$$

$$\eta_{\text{evp}} = \frac{G}{E} \tag{3}$$

where η is water productivity (kg/m^3); G is field yield (kg); I is irrigation water quantity (m^3); P is natural rainfall (m^3); O is displacement (m^3); η_{irr} is irrigation water productivity (kg/m^3). η_{evp} is evapotranspiration water productivity (kg/m^3). The calculation formula for the effective utilization rate of irrigation water and the effective utilization rate of field water is:

$$\varphi = \frac{ET_c}{I} \tag{4}$$

$$\varphi_e = \frac{ET_c}{I + P_e} \tag{5}$$

where: φ is the effective utilization rate of field irrigation water; ET_c is rice water requirement (mm); I is the amount of irrigation water entering the field (mm), φ_e is the field effective water utilization rate; P_e is the effective rainfall (mm) retained in the field. The pollution reduction effect is mainly calculated by the load of drainage pollutants and the load of leakage pollutants, which is calculated as the amount of discharge or leakage multiplied by the concentration of pollutants at each time.

3. Results and analysis

3.1. Output analysis

As can be seen from **Table 2**, the yield of rice under the three irrigation modes was basically the same. The actual yield of thin dew irrigation was the highest, followed by conventional irrigation, and suitable rain irrigation was the least, but the difference was not significant ($P > 0.05$). There is a certain difference in theoretical yield, which may be related to the large sampling randomness of spike number and solid grain number in each treatment. The actual yield of the three irrigation modes is within the normal range, and will not be reduced due to the different irrigation modes, which can meet the demand for normal rice growth.

Table 2. Rice yield under different irrigation modes.

Irrigation mode	Effective panicle number/(plant·hm^{-2})	Number of solid grains/20 ears	Empty abortive rate/%	Per thousand grains per gram	Theoretical yield (/kg·hm^{-2})	Actual output (/kg·hm^{-2})
W0 treatment	3,520,695a	113a	8.85a	22.47a	8962.5b	8094a
W1 treatment	3,716,220a	117a	7.93a	22.67a	9910.5a	8275.5a
W2 treatment	3,646,500a	113a	9.39a	22.43a	9298.5b	7987.5a

Note: Different letters after numbers in the same column indicate significant differences between treatments ($P < 0.05$), the same as below.

3.2. Analysis of water-saving effect

3.2.1. Field water balance analysis

The water distribution during the rice season in the experimental field is shown in **Table 3**. As can be seen from **Table 3**, the rainfall in the rice growing season in 2017 was more and more evenly distributed, especially abundant at the tillering stage, heading and booting stage, and flowering stage, which required a large amount of water for rice. Therefore, both irrigation times and irrigation amount were less than those in previous years on average. Compared with W0 treatment, W1 treatment and W2 treatment save water by 42.3% and 67.5%, respectively. Evapotranspiration accounted for 65.9%, 57.1%, and 49.8% of rice water consumption in W2, W0, and W1 treatments, respectively. Under the same climate conditions and similar rice growth conditions, there is little difference in rice transpiration, and the difference in evapotranspiration is mainly reflected in water surface evaporation. W0 treatment had the largest evaporation because of the high water layer in the field; W2 treatment stored more rainwater in the field, resulting in more evaporation of the water surface; while W1 treatment had the shallower water layer in the field, resulting in the least evaporation. The water discharge is W1 > W0 > W2, and the leakage is W0 > W2 > W1. This is because W1 only allows a small amount of water to remain in the field, so the water discharge after rainfall is large, but the daily leakage is small. Treatment W2 accumulated rainwater in the field, so the drainage was the least. However, due to the large amount of water in the field after the rain, the leakage water was increased to some extent. The water discharge of W0 treatment is between W2 treatment and W1 treatment, but the daily water level in the field is high, which leads to the largest water leakage. In 2017, artificial irrigation mainly occurred in the early growth period of rice, and drainage mainly occurred after heavy rainfall, and the amount of irrigated water was hardly discharged artificially. 0, W1 and W2 treatments accounted for 32.1%, 21.7%, and 13.5% of the total water consumption, respectively. Under the condition of more rainfall, W2 treatment has the lowest demand for irrigation and the best water-saving effect because it makes more use of rainfall.

Table 3. Water distribution of different irrigation modes in rice season.

Irrigation mode	Water inflow/mm		Water consumption/mm		
	Precipitation	Total irrigation amount	Water discharge	Leakage	Evapotranspiration
W0 treatment	681.7	262.8a	305.5b	45.8a	467.1a
W1 treatment	681.7	151.6b	326.6a	23.8c	347.6c
W2 treatment	681.7	85.8c	185.6c	31.7b	420.6b

3.2.2. Water productivity

The water productivity of each treatment in 2017 is shown in **Table 4**. It can be seen from **Table 4** that the water productivity of W1 treatment is the highest, reaching 1.60 kg/m^3, followed by W2 treatment, which is 1.34 kg/m^3, and W0 treatment is at least 1.25 kg/m^3. Although the amount of irrigation water in W2 treatment is the least, the water productivity in W1 treatment is the highest after deducting the amount of water discharged from W1 treatment. In terms of irrigation productivity, W2 treatment has the lowest irrigation amount, so the irrigation water productivity is the highest, reaching 9.29 kg/m^3, followed by W1 treatment, which is 5.34 kg/m^3, and W0 treatment has the lowest irrigation water productivity. In terms of evapotranspiration and water productivity, W1 treatment has the lowest evapotranspiration and the highest evapotranspiration and water productivity, reaching 2.24 kg/m^3, W2 treatment is next to 1.86 kg/m^3, and W0 treatment is the lowest, reaching 1.72 kg/m^3. It can be seen that the extra evapotranspiration of W2 and W0 treatments did not have a positive impact on the final yield of rice, and most of them were ineffective evapotranspiration.

Table 4. Water productivity of different irrigation modes.

Irrigation mode	Actual yield/(kg·hm^{-2})	Rainfall/m^3	Irrigation quantity/m^3	Displacement/m^3	Evapotranspiration /m^3	η/(kg·m^{-3})	$\eta_{irr/}$(kg·mm^{-3})	$\eta_{evp/}$(kg·mm^{-3})
W0 treatment	8 094.0a	454.7	174.5a	200b	312.9a	1.25c	3.08c	1.72c
W1 treatment	8 275.5a	454.7	102.5b	214.8a	243.9c	1.60a	5.34b	2.24a
W2 treatment	7 987.5a	454.7	57.2c	116.4c	286.3b	1.34b	9.29a	1.86b

3.2.3. Effective utilization rate of irrigation water

In 2017, the irrigation water utilization rate of each field in Pinghu Xiaotian is shown in **Table 5**. From **Table 5**, it can be seen that the effective utilization rate of irrigation water in the three modes is greater than 1, which shows that W2 treatment > W1 treatment > W0 treatment. After deducting the water discharge, the effective water utilization rate is W1 treatment > W2 treatment > W0 treatment. The utilization of irrigation water in W2 treatment was the highest, but it was lower than that in W1 treatment after deducting drainage. W1 treatment had less effective rainfall due to its larger displacement and stricter control standards for field water. W2 treatment not only makes efficient use of irrigation water but also makes more use of rainfall.

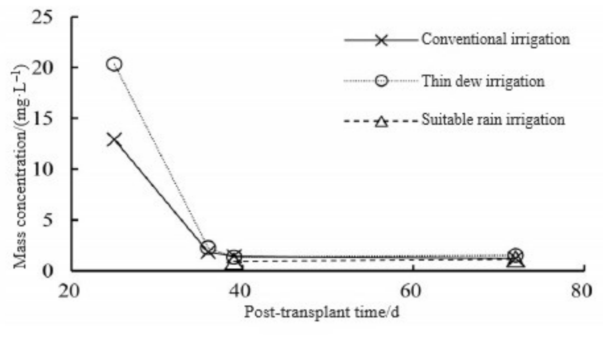
Table 5. Utilization rate of irrigation water in different irrigation modes

Irrigation mode	Irrigation water/m^3	Rainfall/m^3	Displacement/m^3	Effective total water volume/m^3	Crop water requirement/m^3	φ	φ_e
W0 treatment	174.5 a	454.7	200b	429.2 a	221.6	1.27 c	0.52 c
W1 treatment	102.5 b	454.7	214.8 a	342.4 c	221.6	2.16 b	0.65 a
W2 treatment	57.2 c	454.7	116.4 c	395.5 b	221.6	3.87 a	0.56 b

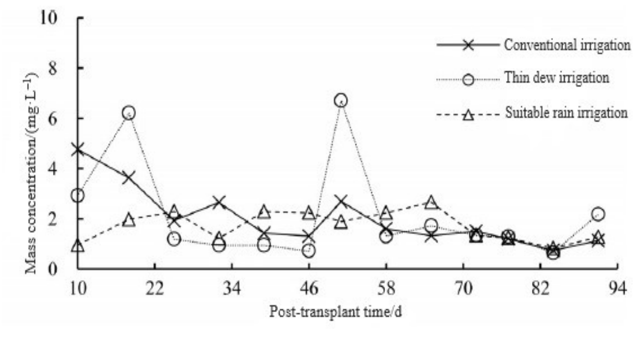
3.3. Analysis of pollution reduction effect

3.3.1. Pollutant load in drainage

During the whole rice season, the amount of sewage discharge was calculated by multiplying the mass concentration of pollutants in each drainage. **Figure 1** shows the variation in the mass concentration of pollutants in the drainage and leakage water samples for each treatment. It can be seen from **Figure 1(a)**, **4(c)**, **4(e)**, **4(g)** and **4(I)** that during the rice growing period, the concentration of drainage pollutants under different irrigation modes on the same date did not change much, but there was a big difference among different times. For example, the mass concentrations of TN, $NH_4^+ - N$ and COD in the drainage samples sampled on August 18 are significantly higher than those in the drainage samples on other dates. This is because a topdressing was conducted in the early stage, and heavy rainfall occurred shortly after fertilization, which increased the drainage. At this time, the fertilizer was not completely absorbed by the crops, and the mass concentration of pollutants was relatively high. There is no obvious regularity in the changes of TN and $NO_3^- - N$, because topdressing is mainly nitrogenous fertilizer, and the amount of TP is mainly related to the original amount of soil. Meanwhile, due to the great uncertainty of nitrification and denitrification, the amount of $NO_3^- - N$ is unstable.

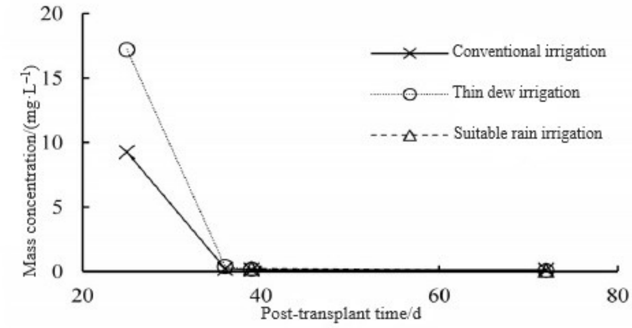


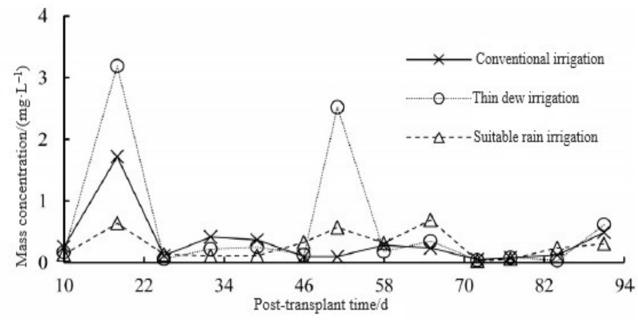
(a) TN mass concentration of each drainage



(b) Variation of TN mass concentration in leakage water

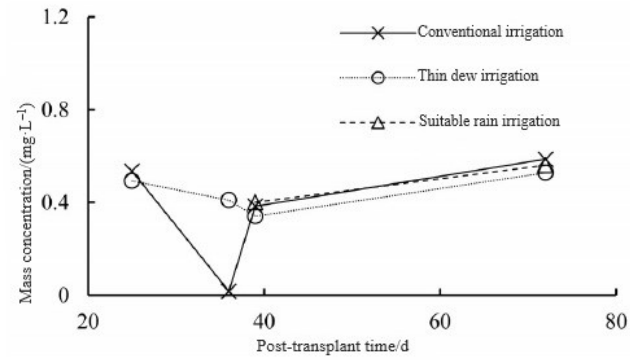
Figure 1. (*Continued*).

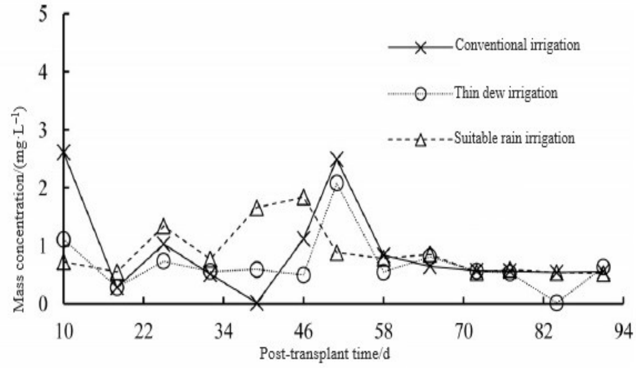




(c) $NH_4^+ - N$mass concentration of each drainage

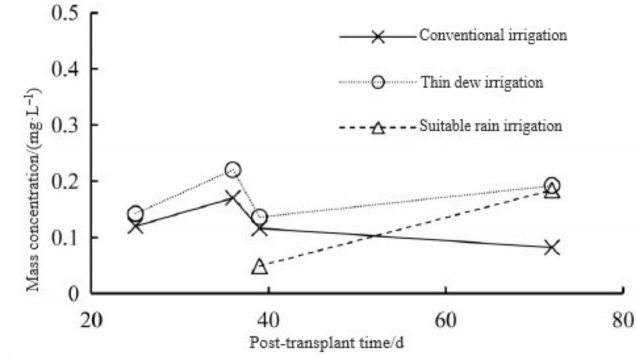
(d) Variation of $NH_4^+ - N$mass concentration in leakage water

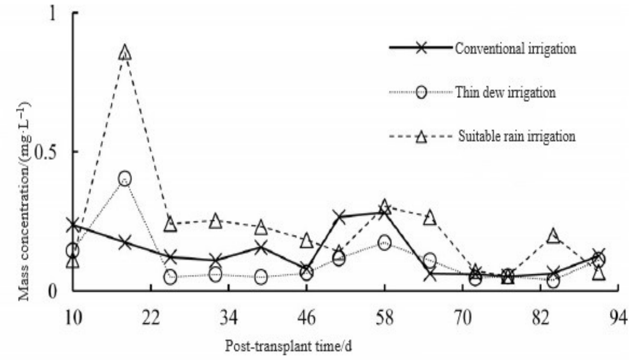




(e) $NO_3^- - N$mass concentration of each drainage

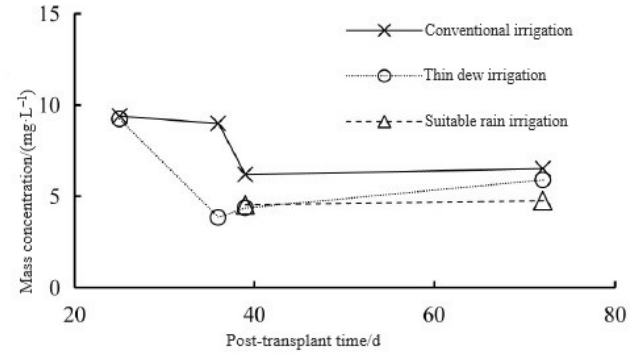
(f) Variation of $NO_3^- - N$mass concentration in leakage water

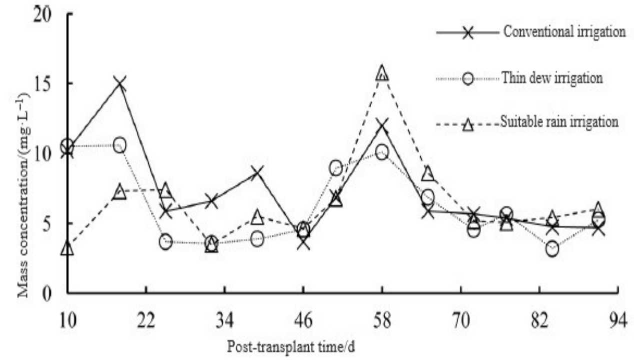




(g) TP mass concentration of each drainage

(h) Variation of TP mass concentration in leakage water





(i) CDO mass concentration of each drainage

(j) Variation of COD mass concentration in leakage water

Figure 1. Variation of drainage mass concentration and leakage mass concentration of each pollutant under different irrigation modes.

According to **Table 6**, from the perspective of different irrigation modes, TN and $NH_4^+ - N$ emissions of W2 treatment are much smaller than those of W1 treatment and W0 treatment, and W1 treatment has the largest pollutant load. The $NO_3^- - N$ emission is much smaller than TN and $NH_4^+ - N$. This is because there is less $NO_3^- - N$ in the rice field and the situation is unstable, so the amount of $NO_3^- - N$ taken away with the drainage of the rice field is also relatively small. The $NO_3^- - N$ emission is shown as W2 treatment. The total amount of TP emissions in paddy fields was small, and even though the displacements of W0 and W1 treatments were much larger than W2 treatments, there was not much difference between the different irrigation modes. The COD discharge of the paddy field was shown as W1 treatment >W0 treatment >W2 treatment, which was consistent with the result of water displacement. The COD load of the treatment with the most water displacement was also the largest.

Table 6. Pollutant emission (g/hm^2) of different irrigation modes.

Irrigation mode	TN quantity	$NH_4^+ - N$ quantity	$NO_3^- - N$ quantity	TP quantity	COD quantity
W0 treatment	18,330b	11,520b	1365b	360b	24,255b
W1 treatment	27,180a	20,610a	1500a	585a	29,310a
W2 treatment	1965c	240c	945c	255c	8700c

3.3.2. Pollutant leakage load

In addition to the drainage of rice fields, pollutants can also enter the plain river network through groundwater. Therefore, when considering non-point source pollution, it is also necessary to consider the pollutant load of leakage. During the experiment, leakage water samples were collected once a week for each treatment and measured before and after fertilization. From **Figure 1(b)**, **Figure 1(d–j)** can be seen that W0, W1, and W2 in the seepage treatment of TN and $NH_4^+ - N$ concentration after 2 times, according to the quality of all, have obvious growth, and with the passage of time, the mass concentration tends to be stable gradually, the quality of the COD, $NO_3^- - N$ concentrations change also appeared more obvious two peaks, reflecting the effect of fertilization. The mass concentration of TP remained stable in a small fluctuation range during the growing period of rice. Due to seepage of the pollutants concentration in addition to the larger changes after fertilization, other times are relatively stable, so the test data can represent that every time the weekly all data, measured data and after fertilization, measured using the measured data, measured using interpolation method to calculate gain, combined with the leakage of water a day, it is concluded that seepage pollutant load, as shown in **Table 7**.

Table 7. Pollutant leakage load (g/hm^2) under different irrigation modes.

Irrigation mode	TN quantity	$NH_4^+ - N$ quantity	$NO_3^- - N$ quantity	TP quantity	COD quantity
W0 treatment	1,318.5c	352.5c	442.5c	67.5c	4456.5c
W1 treatment	355.5b	27b	183b	22.5b	150b
W2 treatment	601.5a	120a	300a	132a	2344.5a

As can be seen from **Table 7**, the load of all pollutants in W1 treatment is the least, and the mass concentration of other pollutants in W2 treatment except TP is higher than that in W1 treatment but lower than that in W0 treatment. This is because the W1 basic does not retain water or water treatment field due to gravity by vertical seepage quantity minimum, so the W1 treatment of seepage water pollutant load is the smallest, and W2 processing after the rainwater is more, its subsistence, so W2 treatment to some amount of seepage leads to the leakage pollution load being bigger than W1 processing. In the growing stage of rice, W0 treatment kept water layers in the field except in the late tillering stage and the natural drying in the yellow ripening stage, so the leakage amount was the largest, and the leakage pollutant load of W0 treatment was the largest. The changing trend of TP is different from TN, COD, and $NH_4^+ - N$. Since there is no phosphate fertilizer in the late topdressing, the leakage load of TP is very low, and the regularity is not obvious.

4. Discussion

The experimental results show that there is little difference in yield between the three irrigation modes, and excessive water storage after rain may lead to a small reduction in yield, which is similar to the research results of Chen et al.[15] and Guo et al.[16], but contrary to the research results of Guo et al.[17,18], which may be caused by different rice varieties, different climates, and different soil types. At the same time, one year of trials may also be accidental, and many years of trial results are needed to verify.

In the rice growing season of Pinghu Experimental Station in 2017, the irrigation amount of thin dew irrigation and suitable rain irrigation was significantly reduced compared with that of conventional irrigation, which was similar to the results of previous studies[19–20]. Compared with conventional irrigation and thin dew irrigation, the irrigation amount decreased by 67.4% and 43.4%, respectively, due to more rainwater storage and utilization, and the water-saving effect was the most obvious.

In terms of pollution reduction, different water-saving irrigation modes perform differently. Due to abundant rainfall, the water layer in the fields irrigated by thin dew is lower, so the drainage volume is larger, resulting in the largest drainage pollution load, which is even slightly higher than conventional irrigation. Moderate rainwater irrigation stores more rainwater in the field, with the least drainage, which is reduced by 41.8% and 45.8%, respectively, compared to conventional irrigation and thin dew irrigation. Therefore, the drainage pollution load is significantly reduced compared to other irrigation modes. In terms of sewage discharge index, TN, $NH_4^+ - N$ and COD mass concentrations have a good response to fertilization. Compared with conventional irrigation, the TN load of suitable rain irrigation is reduced by 86.9%, and the COD load is reduced by 61.5%, which is consistent with previous research results[21–23]. The mass concentration of TP did not change regularly, which was slightly different from other research results[24–27]. The main reason was that only phosphorus fertilizer was applied as the base fertilizer in this experiment, and phosphorus was easily adsorbed by the soil. Therefore, nitrogen emissions were significantly reduced in the rain irrigation. Seepage law of pollutant load and drainage pollutant load, namely with a large amount of water pollutant load and maximum leakage, thin dew irrigation season due to the rice field water quantity is less, so the water seepage and leakage pollution load are minimal, optimal irrigation water due to the field after the rain, which resulted in increased seepage load after the rain leakage, than thin dew irrigation. However, conventional irrigation has the highest leakage pollution because of the high water layer during the rice growing period. In terms of the total pollution reduction effect, because the displacement is much greater than the leakage, it is integrated, and the decontamination effect of rainfall irrigation is the best. Due to the small area of the experimental community selected in this study, and the high level of manual management, there is still a gap in the application of the actual field, and it is necessary to further test it in the field. At the same time, how to change things requires many years of tracking tests.

5. Conclusion

1) Three kinds of irrigation models have maintained high yields. In terms of saving irrigation water, thin dew irrigation and rain irrigation are compared to traditional conventional irrigation, respectively. The least irrigation amount has the best water-saving effect.
2) Rain irrigation will store more rainwater in the field with the least displacement. Compared with conventional irrigation and thin exposure irrigation, 41.8% and 45.8%, the amount of drainage pollutants is also the least; the amount of water in the field of thin dew irrigation fields has been in a small state for a long time, the amount of water leakage is the least, and the load of the leakage pollutants is also the least.
3) Rain irrigation TN load is reduced by 86.9% compared with conventional irrigation, and COD load is

reduced by 61.5%. Due to the largest drainage load, thin dew irrigation has the least loading load, but the total pollutant load is the largest.

4) In a rich water year like 2017, it is more reasonable to choose rainfall irrigation models. Under the premise of ensuring production, it can save irrigation water and reduce the emissions of rice field pollutants.

Conflict of interest

The authors declare no conflict of interest.

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