EFFECTS OF DIFFERENT WATER MANAGEMENT METHODS ON SEEDING RATE, PHENOLOGICAL AND YIELDING PROPERTIES OF DIFFERENT RICE CULTIVARS (*ORYZA SATIVA* L.)

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(Received 25th Dec 2018; accepted 8th Feb 2019)

Abstract. Flooding management is an effective and environmental-friendly way to reduce weed populations in paddy fields. However, flooding would also cause waterlogging in direct seeding rice production. The present study was conducted to explore the effect of different water management methods at the germination stage on rice growth and yield, with six rice varieties as materials. 0, 1, 2, and 3 cm water layer treatments at germination stage were set and named as I0, I1, I2 and I3, respectively. The result showed that I1 and I2 treatments significantly reduced seedling rate and seedling quality compared to I0. The highest yield was recorded during I0, while the yield in the case of I3 treatment was lower than the former but higher than I1 and I2. Similar trends were also recorded in dry matter weight at heading stage and maturity stage.
Keywords: *rice, water condition, seedling rate, seedling quality, yield, dry matter accumulation*

Introduction

Rice (*Oryza sativa* L.), as one of the main stable food crops, feeds more than half of the world's population (Ashraf et al., 2017). Pan et al. (2016) demonstrated that more than 60% of the population live on rice in China while rice makes up 40% of the country's total grain. It is very important to maintain the rice productivity and improved the yield potential of rice in China.

In Chinese history, transplanted rice production system has been the main rice production modern for a very long time (CabangonTuong and Abdullah, 2002). Traditionally, rice seedlings were transplanted in puddling condition. However, with the severe labor scarcity and low efficiency due to laborious nature of work and lower net returns, transplanted rice production system is becoming more and more unsuitable for Chinese agriculture (Tao et al., 2016). Direct-seeded rice, as a substitutive rice growing technique, has the benefit to reduced production costs, labor and extra efforts for nursery raising, seedling uprooting and transplanting (Liu et al., 2015). Pan et al. (2017) indicated that this new rice production system not only favors earlier crop establishments, but also provides an opportunity to make better use of early season rainfall, and finally leading

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer1702_42694279

towards increase the grain yield. Nevertheless, direct-seeded rice production system still has many parts no perfect enough.

Water management is an important part in rice production which could greatly affect rice yield and quality. The study of Kong et al. (2017) revealed that short term water management at filling stage was able to improve antioxidant enzyme activity and alleviate the damage from heat stress to rice. Ren et al. (2017) also demonstrated that feebly arid conditions (water potential of - (15 ± 5) kPa) at booting stage could increase 2-acetyl-1-pyrroline content in fragrant rice grains significantly. Normally, pre-germinated seeds would be hill-seeded in paddy filed in direct-seeded rice production system. The water management during the germination stage would be important for seedling growth and development. The research of Luo et al. (2018) showed that water layer higher than 4.5 cm would significantly inhibit the germination and seedling growth and decreased the antioxidant enzyme activity. However, there was no much report about the water management during the germination stage in direct-seeded rice production.

Therefore, present study was conducted in Experimental Research Farm, College of Agriculture, Yangtze University in order to investigate the effect of different water conditions at germination stage on rice growth and development.

Materials and methods

Seed materials

Seeds from six rice cultivars, *Wandao107*, *Liangyou168*, *Fengliangyouxiang-1*, *Fengliangyou-2*, *Guofeng-1*, *Quanyou801* were used as the experimental materials in this pot experiment. Those rice varieties were all widely grown in Middle China.

Treatment description and growth conditions

Before sowing, the seeds were soaked in water for 24 h, germinated in manual climatic boxes for another 10 h (33 °C), then shade-dried. Then, seeds were direct-seeded into soil containing plastic pots (30 cm in height and 450 cm^2 in surface area) and 50 seeds for each pot in triplicate. The different water managements were applied after the sowing and sustained for 25 days. The water layer treatment description is as below:

I0: Maintenance of 0 cm water layer at soil surface throughout day and night.

I1: Maintenance of 1 cm water layer at soil surface throughout day and night.

I2: Maintenance of 2 cm water layer at soil surface throughout day and night.

I3: Maintenance of 3 cm water layer at soil surface throughout day and night.

15 days after the sowing, the seedling rate was recorded and at 25 days after the sowing, twenty seedlings were collected randomly from each pot for the estimation of dry matter, seedling length, leaf surface area and chlorophyll content. Chlorophyll content was determined by using the SPAD meter ‘SPAD-502’ (Konica Minolta, Japan). Leaf area of all green leaf blades was measured with Li-Cor area meter (Li-Cor Model 3100, Lincoln, NE). Then, ten seedlings were retained for each pot and every pot in the experiment was remained at 3 cm water layer at soil surface until harvest. The experiment soil was sandy loam consisting 23.78 g/kg organic matter, 1.61 g/kg total nitrogen, 78.66 mg/kg available nitrogen, 0.87 g/kg total phosphorus, 21.79 mg/kg available phosphorus, 17.64 mg/kg total potassium, 151.09 mg/kg available potassium and 6.48 soil pH. The environment of climatic box were set as: 33 °C days and 27 °C nights, under 1200X yellow light intensity and 75% humidity.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer1702_42694279

Estimation of dry matter accumulation transportation

At heading stage and maturity, ten rice plants were collected for the determination of dry matter weight. The leaves, stem-sheaths and grains were separated from the plants and dried under the condition of 80 °C respectively in order to get the estimation of dry matter. Some parameters were calculated as below:

$$\text{Transportation rate in leaf} = \frac{\text{leaf weight at heading stage} - \text{leaf weight at maturity stage}}{\text{leaf weight at heading stage}}$$

$$\text{Transportation rate in stem} - \text{sheath} = \frac{\text{stem} - \text{sheath weight at heading stage} - \text{stem} - \text{sheath weight at maturity stage}}{\text{grain weight at maturity stage}}$$

$$\text{Contribution rate in leaf} = \frac{\text{leaf weight at heading stage} - \text{leaf weight at maturity stage}}{\text{grain weight at heading stage} - \text{grain weight at maturity stage}}$$

$$\text{Contribution rate in stem} - \text{sheath} = \frac{\text{stem} - \text{sheath weight at heading stage} - \text{stem} - \text{sheath weight at maturity stage}}{\text{grain weight at heading stage} - \text{grain weight at maturity stage}}$$

Determination of yield and yield related attributes

At maturity, twenty random rice plants were harvested and threshed manually and sun dried (adjusted to ~14% moisture contents) to get the grain yield per pot and expressed in grams per plant (g plant^{-1}). Grains were separated manually from each panicle to count total number of grains and number of filled grains per panicle. To record 1000-grain weight, six random samples from filled grains were counted, weighed and averaged. Panicle number per pot was measured by counting the panicle numbers of each plant in three pots in each treatment and averaged.

Statistical analysis

This study was managed as a randomized complete block design with three replicates (n = 3). Data were analyzed on Statistix 8.1 (Analytical Software, Tallahassee, FL, USA) at the probability level of 5% ($P < 0.05$). Differences among means were separated by using least significant difference (LSD) test.

Results

Seedling rate

As shown in *Table 1*, different water management affected seedling rate of different rice varieties differently. The highest seedling rate was recorded in I3 condition. Compared to other rice varieties, *Wandao107* had the highest seedling rate which was 67.50%. The lowest seedling rate was recorded in I1 treatment while the seedling rate in *Liangyou168* was lower than other rice varieties.

Seedling quality

There were some differences in seedling quality of different varieties under different water managements (*Table 2*). Compared to I0, I1 treatment significantly reduced leaf area and SPAD values while there was no remarkable difference among I0, I2 and I3 in leaf area and SPAD values. The highest plant height and shoot dry weight were both

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer1702_42694279

recorded in I3 and the lowest plant height, root length, shoot dry weight and root dry weight were all recorded in I1.

Dry matter accumulation

As shown in *Table 3*, different water managements at germination stage affected dry matter accumulation differently. At heading stage, the trend of leaf dry weight at heading stage was recorded as I0 > I3 > I2 > I1. Similar conditions were also observed in stem-sheath weight and grain weight. At maturity, the highest dry weight of leaf, stem-sheath and grain were all recorded in I0. There was no significant difference between I2 and I3 in stem-sheath dry weight and total dry weight. Moreover, the lowest dry matter weight was recorded in I1 at both heading stage and maturity.

Table 1. *Differences in survival rates of different varieties under different water layers*

Treatment	Variety	Seedling rate (%)
I0	*Fengliangyou-2*	26.67c
	Fengliangyouxiang-1	35.00b
	Liangyou168	26.67c
	Wandao107	60.00a
	Guofeng-1	45.83a
	Quanyou801	35.83b
	Mean	**36.95**
I1	*Fengliangyou-2*	32.50a
	Fengliangyouxiang-1	39.17a
	Liangyou168	18.33b
	Wandao107	66.67a
	Guofeng-1	38.33a
	Quanyou801	22.50b
	Mean	**31.39**
I2	*Fengliangyou-2*	34.17bc
	Fengliangyouxiang-1	43.33ab
	Liangyou168	27.50c
	Wandao107	40.83ab
	Guofeng-1	49.17a
	Quanyou801	33.33bc
	Mean	**38.06**
I3	*Fengliangyou-2*	40.83bc
	Fengliangyouxiang-1	48.33b
	Liangyou168	33.33c
	Wandao107	67.50a
	Guofeng-1	45.83b
	Quanyou801	20.83d
	Mean	**42.78**

Means in the same column followed by different lower case letters for the same variety differ significantly at $P < 0.05$ by T-test, the same as below

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer1702_42694279

Table 2. *Differences in seedling quality of different varieties under different water layers*

Treatment	Variety	Plant height	Root length	Leaf area	SPAD value	Shoot dry weight	Root dry weight
I0	*Fengliangyou-2*	32.66ab	13.89b	19.43ab	35.95b	0.239b	0.081bc
	Fengliangyouxiang-1	36.73ab	14.99ab	18.15ab	39.84a	0.266b	0.099bc
	Liangyou168	28.70b	14.38b	13.05b	39.23ab	0.204b	0.073c
	Wandao107	37.20a	18.17ab	19.47ab	39.26ab	0.311ab	0.099bc
	Guofeng-1	39.62a	20.28a	18.39ab	37.76ab	0.394ab	0.124ab
	Quanyou801	40.40a	15.12ab	22.56a	39.23ab	0.462a	0.147a
	Mean	**35.89b**	**16.14a**	**18.51a**	**38.54a**	**0.313b**	**0.104a**
I1	*Fengliangyou-2*	19.23c	8.14a	7.60c	31.98a	0.067c	0.021b
	Fengliangyouxiang-1	19.81c	7.59a	7.46c	32.64a	0.076c	0.019b
	Liangyou168	19.26c	6.84a	3.48d	32.57a	0.054c	0.012b
	Wandao107	35.12ab	12.61b	11.5b	36.95a	0.234ab	0.051b
	Guofeng-1	39.66a	13.87b	16.87a	34.18a	0.320a	0.100a
	Quanyou801	26.74bc	12.51b	10.59bc	32.57a	0.170bc	0.047b
	Mean	**26.64c**	**10.26c**	**9.58b**	**33.48b**	**0.153c**	**0.042c**
I2	*Fengliangyou-2*	40.16a	13.54ab	21.70a	38.3a	0.443a	0.091a
	Fengliangyouxiang-1	38.84a	10.47b	18.83ab	36.94a	0.286a	0.062a
	Liangyou168	32.78a	11.5ab	14.31b	35.71a	0.252a	0.056a
	Wandao107	39.09a	13.4ab	17.03ab	38.82a	0.320a	0.067a
	Guofeng-1	38.97a	16.04a	17.28ab	35.72a	0.334a	0.091a
	Quanyou801	41.24a	14.16ab	21.93a	35.71a	0.484a	0.108a
	Mean	**38.51ab**	**13.18b**	**18.51a**	**36.87a**	**0.353a**	**0.079b**
I3	*Fengliangyou-2*	40.13a	13.76a	19.11ab	39.22a	0.439a	0.076a
	Fengliangyouxiang-1	42.99a	14.86a	24.41a	36.94ab	0.437a	0.076a
	Liangyou168	36.06a	13.01a	20.28ab	39.75a	0.342a	0.060a
	Wandao107	44.61a	16a	23.83a	37.07ab	0.497a	0.098a
	Guofeng-1	35.36a	15.44a	14.10b	32.33b	0.317a	0.069a
	Quanyou801	44.82a	15.31a	22.4ab	39.75a	0.473a	0.097a
	Mean	**40.66a**	**14.73ab**	**20.69a**	**37.51a**	**0.418a**	**0.079ab**

Matter transportation and contribution during the filling stage

As shown in *Table 4*, different water managements during the germination stage affected the matter transportation during the filling stage differently. The leaf transportation rate in I0 was significantly higher than I2 and I3 which were 0.394, 0.374 and 0.372 while there was no significant difference among I0, I1, I2 and I3 in leaf contrition. The lowest stem-sheath transportation rate was recorded in I1 and there was no significant difference among I0, I2 and I3. Furthermore, the highest photosynthesis contribution rate was recorded in I1 and the lowest was recorded in I0.

Yield and related attributes

Different water management during the germination stage affected rice yield by regulating the yield related attributes (*Table 5*). The highest yield was recorded in I0 treatment as well as panicle number, grain number, seed-setting rate and grain weight.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer1702_42694279

There was no significant difference between I2 and I3 in yield, 1000-grain weight, seed-setting rate and grain number. Furthermore, I1 treatment had the lowest yield due to the lowest panicle number, grain number and 1000-grain weight.

Table 3. *Differences in dry matter accumulation of different varieties under different water layers*

Treatment	Variety	Heading stage				Maturity			
		Leaf dry weight	**Stem-sheath dry weight**	**Grain dry weight**	**Total dry weight**	**Leaf dry weight**	**Stem-sheath dry weight**	**Grain dry weight**	**Total dry weight**
I0	*Fengliangyou-2*	1.023d	1.830e	0.750e	3.603e	0.633cd	1.723d	2.140c	4.497e
	Fengliangyouxiang-1	1.112c	1.937d	0.770d	3.819d	0.667c	1.820c	2.203bc	4.690d
	Liangyou168	0.826e	1.743f	0.677d	3.246f	0.517e	1.620e	2.013d	4.150f
	Wandao107	1.124c	2.127c	0.813c	4.064c	0.620d	2.003b	2.303b	4.927c
	Guofeng-1	1.203b	2.237b	0.920b	4.360b	0.740b	2.080ab	2.407ab	5.227b
	Quanyou801	1.324a	2.330a	1.097a	4.751a	0.830a	2.140a	2.500a	5.470a
	Mean	**1.102a**	**2.034a**	**0.838a**	**3.974a**	**0.668a**	**1.898a**	**2.261a**	**4.827a**
I1	*Fengliangyou-2*	0.626e	1.243d	0.517d	2.386d	0.387d	1.223d	1.523bc	3.133d
	Fengliangyouxiang-1	0.631e	1.147e	0.413e	2.191e	0.393d	1.100e	1.393c	2.887e
	Liangyou168	0.670d	1.107e	0.400e	2.177e	0.347e	1.047e	1.407c	2.800e
	Wandao107	0.832b	1.677b	0.620b	3.129b	0.533b	1.567b	1.593b	3.693b
	Guofeng-1	1.246a	2.080a	0.850a	4.176a	0.767a	2.050a	2.093a	4.910a
	Quanyou801	0.725c	1.530c	0.590c	2.845c	0.487c	1.473c	1.507bc	3.467c
	Mean	**0.788d**	**1.464d**	**0.565d**	**2.817c**	**0.486d**	**1.410c**	**1.586d**	**3.482c**
I2	*Fengliangyou-2*	0.942c	1.777b	0.727ab	3.446b	0.623a	1.650ab	2.107a	4.380ab
	Fengliangyouxiang-1	1.172a	1.327f	0.577c	3.075d	0.613a	1.280c	1.703d	3.597c
	Liangyou168	0.758e	1.473c	0.627c	2.858f	0.510c	1.407c	1.803cd	3.720c
	Wandao107	0.726e	1.523d	0.690b	2.939e	0.500c	1.433bc	1.903bc	3.837c
	Guofeng-1	0.879d	1.637c	0.700b	3.216c	0.570b	1.537b	2.003ab	4.110bc
	Quanyou801	1.136b	1.890a	0.787a	3.812a	0.637a	1.747a	2.107a	4.490a
	Mean	**0.936c**	**1.604c**	**0.684b**	**3.224b**	**0.576b**	**1.509b**	**1.938b**	**4.022b**
I3	*Fengliangyou-2*	0.940d	1.520b	0.610b	3.070d	0.603b	1.463b	1.800b	3.867
	Fengliangyouxiang-1	1.325a	1.420b	0.560c	3.305c	0.743a	1.387b	1.750b	3.88
	Liangyou168	0.744e	1.307c	0.530c	2.581f	0.503c	1.223c	1.703b	3.43
	Wandao107	1.123b	1.807a	0.753a	3.683a	0.657b	1.777a	2.103a	4.537
	Guofeng-1	0.737e	1.500b	0.603b	2.840e	0.503c	1.400b	1.787b	3.69
	Quanyou801	1.024c	1.790a	0.760a	3.574b	0.637b	1.713a	2.117a	4.467
	Mean	**0.982b**	**1.557b**	**0.636c**	**3.175b**	**0.608c**	**1.494b**	**1.877c**	**3.978b**

Table 4. *Differences in matter transportation of different varieties under different water layers*

Treatment	Variety	Transportation rate in leaf	Contribution rate in leaf	Transportation rate in stem-sheath	Contribution rate in stem-sheath	Contribution rate of photosynthesis
I0	*Fengliangyou-2*	0.381b	0.280b	0.058a	0.076b	0.643ab
	Fengliangyouxiang-1	0.401b	0.312ab	0.060a	0.082ab	0.606ab
	Liangyou168	0.375b	0.232c	0.071a	0.092ab	0.676a
	Wandao107	0.448a	0.338a	0.058a	0.082ab	0.579bc
	Guofeng-1	0.384b	0.311ab	0.070a	0.105ab	0.584b
	Quanyou801	0.373b	0.352a	0.082a	0.135a	0.512c
	Mean	**0.394a**	**0.304a**	**0.067a**	**0.095a**	**0.600b**

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DOI: http://dx.doi.org/10.15666/aeer1702_42694279

I1	*Fengliangyou-2*	0.382b	0.240b	0.016a	0.019b	0.742a
	Fengliangyouxiang-1	0.377b	0.244b	0.041a	0.050ab	0.707a
	Liangyou168	0.483a	0.322a	0.054a	0.061ab	0.618b
	Wandao107	0.359bc	0.307bc	0.066a	0.113a	0.580b
	Guofeng-1	0.385b	0.385b	0.014a	0.025b	0.589b
	Quanyou801	0.329c	0.263c	0.037a	0.066ab	0.671ab
	Mean	**0.386ab**	**0.294a**	**0.038b**	**0.055b**	**0.651a**
I2	*Fengliangyou-2*	0.338bc	0.231c	0.071a	0.092a	0.677b
	Fengliangyouxiang-1	0.477a	0.500a	0.035a	0.041a	0.459a
	Liangyou168	0.327bc	0.211c	0.046a	0.056a	0.733a
	Wandao107	0.311c	0.186c	0.059a	0.074a	0.740a
	Guofeng-1	0.352b	0.238c	0.061a	0.083a	0.679a
	Quanyou801	0.439a	0.383b	0.076a	0.114a	0.503b
	Mean	**0.374b**	**0.292a**	**0.058ab**	**0.077ab**	**0.632ab**
I3	*Fengliangyou-2*	0.358cd	0.283c	0.037a	0.048a	0.670a
	Fengliangyouxiang-1	0.439a	0.489a	0.024a	0.028a	0.484b
	Liangyou168	0.324d	0.208d	0.064a	0.073a	0.720a
	Wandao107	0.415ab	0.347b	0.017a	0.023a	0.630a
	Guofeng-1	0.317d	0.199d	0.066a	0.089a	0.712a
	Quanyou801	0.378bc	0.287c	0.041a	0.064a	0.649a
	Mean	**0.372b**	**0.302a**	**0.041ab**	**0.054b**	**0.644ab**

Table 5. *Differences in yield and related attributes of different varieties under different water layers*

Treatment	Variety	Panicle number per plant	Grains number per panicle	Seed-setting rate (%)	1000-grain weight (g)	Yield (g plant^{-1})
I0	*Fengliangyou-2*	15.30ab	298.55a	0.93a	26.61c	32.50c
	Fengliangyouxiang-1	11.20b	172.19b	0.90a	25.59d	24.65f
	Liangyou168	13.50ab	225.05b	0.92a	27.13b	27.17d
	Wandao107	17.40a	195.43b	0.93a	27.11b	40.12a
	Guofeng-1	11.10b	204.41b	0.91a	26.46c	26.67e
	Quanyou801	14.10ab	190.78b	0.91a	27.61a	35.13a
	Mean	**13.80a**	**214.40a**	**0.92a**	**26.7506a**	**31.04a**
I1	*Fengliangyou-2*	6.90a	221.11a	0.92ab	26.24c	12.32d
	Fengliangyouxiang-1	8.00a	117.74d	0.92ab	25.49d	14.36bc
	Liangyou168	8.20a	145.29c	0.84c	26.67b	13.98c
	Wandao107	8.80a	158.46bc	0.88bc	26.63b	18.46a
	Guofeng-1	7.00a	172.74b	0.9ab	25.98c	12.70d
	Quanyou801	7.20a	177.78b	0.93a	27.57a	15.15b
	Mean	**7.70c**	**165.52c**	**0.9ab**	**26.4317c**	**14.50c**
I2	*Fengliangyou-2*	7.30a	250.54a	0.9a	26.20c	15.8967a
	Fengliangyouxiang-1	7.80a	139.59c	0.84a	25.89d	13.20d
	Liangyou168	7.40a	147.11bc	0.88a	26.94b	13.39d
	Wandao107	8.00a	160.45bc	0.85a	26.78b	15.22b
	Guofeng-1	7.10a	186.85b	0.89a	26.26c	14.15c
	Quanyou801	7.70a	180.85bc	0.86a	27.39a	16.11a
	Mean	**7.60c**	**177.57bc**	**0.87b**	**26.5772b**	**14.66b**

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer1702_42694279

I3	*Fengliangyou-2*	13.30a	269a	0.84a	26.43c	22.65a
	Fengliangyouxiang-1	9.90ab	192.15b	0.86a	25.29d	15.82d
	Liangyou168	9.90ab	147.09cd	0.88a	26.93b	15.79d
	Wandao107	8.20b	127.7d	0.89a	26.93b	14.80e
	Guofeng-1	8.70b	180.22bc	0.91a	26.25c	19.91c
	Quanyou801	12.50ab	182.39bc	0.85a	27.73a	21.25b
	Mean	**10.40b**	**183.09b**	**0.87b**	**26.5928b**	**18.37b**

Correlation analysis

As showed in *Table 6*, the rice yield had significant positive correlation with root length, leaf area, SPAD value and root dry weight of seedling. There also exited a significant positive correlation between panicle number and SPAD value of seedling. Furthermore, the dry matter weight of leaf, stem-sheath and grain at both heading stage and maturity had significant positive correlation with seedling quality (height, root length, leaf area, SPAD value, shoot dry weight and root dry weight).

Table 6. *Relationship among seedling quality, yield and dry matter weight*

		Height	Root length	Leaf area	SPAD value	Shoot dry weight	Root dry weight
Panicle number per plant		0.155	0.281*	0.260*	0.371**	0.132	0.220
Grains number per panicle		0.107	0.210	0.205	0.164	0.172	0.218
Seed-setting rate (%)		-0.218	0.110	-0.121	-0.162	-0.118	0.066
1000-grain weight (g)		0.060	0.141	0.077	0.141	0.125	0.153
Yield (g plant^{-1})		0.148	0.453**	0.259*	0.341**	0.152	0.412**
Heading stage	Leaf dry weight	0.616**	0.492**	0.658**	0.307**	0.529**	0.605**
	Stem dry weight	0.485**	0.6320**	0.482**	0.329**	0.440**	0.694**
	Grain dry weight	0.499**	0.592**	0.509**	0.331**	0.459**	0.685**
	Total dry weight	0.569**	0.623**	0.584**	0.347**	0.508**	0.715**
Maturity	Leaf dry weight	0.664**	0.558**	0.688**	0.357**	0.577**	0.659**
	Stem dry weight	0.476**	0.643**	0.462**	0.313**	0.427**	0.669**
	Grain dry weight	0.531**	0.635**	0.557**	0.417**	0.477**	0.663**
	Total dry weight	0.558**	0.658**	0.567**	0.383**	0.498**	0.699**

As shown in *Table 7*, there exited a significant positive correlation between seed-setting rate and stem-sheath dry weight. Both panicle number and yield had significant positive correlation with dry weight of leaf, stem and grain. Moreover, there was a significant positive correlation between grain number and stem-sheath dry weight.

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DOI: http://dx.doi.org/10.15666/aeer1702_42694279

Table 7. *Relationship between dry matter weight at heading stage and yield and yield related attributes*

	Panicle number per plant	**Grain number per panicle**	**Seed-setting rate (%)**	**1000-grain weight (g)**	**Yield (g plant^{-1})**
Leaf dry weight	0.311**	0.137	-0.043	-0.056	0.396**
Stem-sheath dry weight	0.416**	0.261*	0.233*	0.314**	0.657**
grain dry weight	0.361**	0.241*	0.156	0.354**	0.592**
Total dry weight	0.399**	0.234*	0.139	0.223	0.603**

Discussion

It is well known that water condition is one of the most important factors affecting the seed germination. Ismail et al. (2009) demonstrated water layer at 10 cm would greatly inhibit the germination and early seedling growth of rice. The study of Prakash et al. (2016) had evidenced that flooding treatments not only could significantly influenced the survival rate of rice seedling, but also was able to affect all the parameters of seedling quality such as shoot, root and total dry matter production. Present study also showed the similar conditions. Compared to I0, I1 treatment reduced the seedling rate significantly whilst there was no remarkable difference I0 and I3 in seedling rate. The possible reason might be the flooding stress at I3 level could stimulate the mechanisms which were associated with tolerance to flooding for some rice varieties (Zhang et al., 2017). For example, the lowest seedling rates of both *Wandao107* and *Fengliangyouxiang-1* were recorded in I2 while there was no significant difference between I0 and I3. Furthermore, we noticed that there was no much significant difference between I0 and I3 in seedling quality. Some parameters (seedling height and shoot dry weight) in I3 were even higher than I0. It might because the 3 cm water layer conditions would also be suitable for early seedling growth. Similar discovery was reported by Fan et al. (2017) who demonstrated shallow water irrigation during the seedling stage could significant improved seedling quality of fragrant rice.

Seedling quality is one of the factors which could greatly affect the rice yield. Previous study had shown that different seedling age significantly affected yield and economics of hybrid rice by influencing the growth and chlorophyll content (Pramanik and Bera, 2013). The study of Xia et al. (2000) revealed that magnetic treatment was able to up-regulate the rice yield by improving the seedling growth. Normally, it is generally recognized that good quality of rice seedling would be the base for high yield. Our study emphasized this point by showing the significant positive correlation between seedling quality and dry matter accumulation at heading stage and maturity while there exited a significant positive correlation between dry matter production and rice yield. Our founding was also consistent with previous study (Farooq et al., 2006) which stated that seedling establishment is a key part in rice production and good seedling quality could improve the potential of rice yield.

Furthermore, the highest yield was recorded in I0 and the yield in I3 treatment was lower than I0 but higher than I1 and I2. Luo et al. (2018) demonstrated that water layer higher than 3 cm would inhibit germination and growth of weed and volunteer rice. Thus, 3 cm water irrigation might be a management which is able to reduce the weed and volunteer without causing a great yield loss.

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Conclusion

Compared to I0, I1 and I2 treatments significantly reduced seedling rate, seedling quality and the grain yield. I3 treatment was lower than I0 but higher than I1 and I2. Similar trends were also recorded in dry matter weight at heading stage and maturity stage. Therefore, the 3 cm water irrigation might be considered as a management which is able to reduce the weed and volunteer without causing a great yield loss. More studies should be conducted at the field trials or at molecular level before the real application.

Acknowledgements. This study was supported by Innovation and Application of Key Technologies for Light Simplified Direct Sowing of Rice in the North of the Middle and Lower Reaches of the Yangtze River (2017YFD0301403-06), Research and Demonstration on the Common Key Technologies of Changing Rice into Japonica in Jianghan Plain (2015Z20007) and Key Technological Tackling of Common Characters in Japonica Rice (2015Z20021).

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