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Yield and Biomass in Rice Interactions of Nitrogen, Phosphorous and Water Application

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Abstract: An investigation was made for yield and biomass in rice interactions of nitrogen and phosphorous fertilizer application under irrigated conditions. The objective of the experiment was to quantify nitrogen, phosphorous and water use and their combined effects on biomass and yield of rice. A routine management practice was performed in rice fields to maintain a water depth that would suppress weed growth during the growing season. Field experiments were conducted over the period of 1st week of July to 1st week of November, 2003 in Shuangqiao farm at northern part of Zhejiang province in southeast coastal area of China and Jia-9312 rice variety was used. Biomass and yield of rice were determined in comparison with the nitrogen and phosphorous fertilizer treatment and water use. The rice biomass increased rapidly during N_2 (180 kg N) treatments and then decreased. Also, positive effect on rice biomass for phosphorous application was observed. Both water and fertilizer (N and P) had a positive effect on yield, which increased from 5.8 to 7.8 t ha^{-1}. Grain yield increased on average by 2 t ha^{-1} by applying 180 and 40 kg P ha^{-1} fertilizer with sufficient water supply. Maximum dry weight of total paddy plant was observed in N_4P_2 treatment. From this experiment it was concluded that the yield of rice increased 50-60% in response to the application of N and P interaction with water.

Key words: Rice, biomass, yield, nitrogen, phosphorous

INTRODUCTION

Fertilizer and water management are crucial to high yields. Numerous studies on interaction among yield, fertilizer and irrigation has often revealed contradictory results[1,2]. It is controversial as to which component should be emphasized to further improve yield potential of current cultivars. When comparisons were made among modern cultivars, however, high yield was achieved by increasing biomass production[3-5]. For example, hybrid rice have approximately 15% greater yield than inbreeds mainly due to an increase in biomass production[6]. Yield also depends on water availability. Where water was limited, the maximum yield was rather low (300 to 400 g^{-2}) compared with the yields of about 600 to 1000 g^{-2} commonly achieved in several countries[7-10]. The application of fertilizer resulted in an increase in grain yield in both rain fed and irrigated conditions. Grain yield was increased, on average, by 50% with the application of 60 kg ha^{-1} N and 13 kg ha^{-1} P. It is likely that yield would have increased further in most of the experiments if higher rates of fertilizer have been used[11]. The very high yields were often reported as yield records in newspaper, agricultural bulletins or institute's annual reports[12,13]. Data on yield components, biomass production, fertilization and water application lacked in these reports. In a few cases, only yield components were presented. Limited information is available for yield and biomass of rice interaction of fertilizer and water use. Although there have been many studies of fertilizer application rate versus paddy yield in China, few of them have examined the effect of nitrogen, phosphorous and water for biomass and paddy yield separately. Therefore, there is a need to initiate studies on irrigation and fertilizer application practices for such situations. In this study, one such field experiment was conducted to determine the N, P and water use efficiencies for evaluating yield trends and biomass of paddy.

MATERIALS AND METHODS

Location, soil and climatic conditions of paddy fields: The experimental rice field is located in Shuangqiao farm of Zhejiang University at northern part of Zhejiang Province (120°40′E, 30°50′N), southeast coastal area of china. This region is characterized with a typical coastal climate, terrace and agriculture practice. The annual precipitation of the area was 1205.5 mm, of which 1006.7 mm occurred from April to August. The soil is coastal saline clay loam and blue soil with medium fertility. The soil in the plot trail contains 0.06-0.08% total N, 0.05-0.06% total P, 1.2-1.4% organic matter, 0.1-0.3% total salt, pH 7.6-7.8. The mean air temperature during the experimental period was 28.1°C and the average maximum temperature was 34°C.

Treatments, experimental design and cultural practices: The experimental field consists of 15 plots each having dimension of 4x5 m. A strip of 0.3 m land was left between the plots. The experiment was laid down in a Completely Randomized Block Design with three replicate. Factors were N and P fertilizer. Table 1 shows the nitrogen and phosphorous fertilizer application rate in each experimental plot at different form. Urea was applied as N fertilizer and P_2O_5 was added in the form of single super phosphate as P fertilizer. There were five treatments for nitrogen fertilizer(1) N_0; no N application (control)(2) N_1; 90 kg N ha^{-1} as urea (3) N_2; 180 kg N ha^{-1} as urea (4) N_3; 270 kg N ha^{-1} as urea and (5) N_4; 360 kg N ha^{-1} as urea. Also, there were three treatments for phosphorous fertilizer: (1) P_0; no P application (control); (2) P_1; 286 kg P ha^{-1} as super phosphate and 40 kg P ha^{-1} P_2O_5 (3) P_2; 429 kg P ha^{-1} as super phosphate and 60 Kg P ha^{-1} P_2O_5. The N fertilizer rates above concerned was applied, 60% as basal fertilizer and 40% as additional three times to the field plots. The total P was applied as basal dose. Each plot received same fertilizer treatment throughout the experiment, which were incorporated in the plough layer before flooding. The rice seedlings were transplanted on the day when basal fertilizer was applied. All fields were plowed with a tractor and harrowed three times in a dry condition to about 15 cm depth. All plots were irrigated to maintain a flooded condition continuously through out the active growth period of paddy.

Rice cultivation, harvest and yield: The 'one season' rice variety Jia-9312 was used because 'one season' rice (one summer rice crop in rotation one winter crop species each year) has become popular in Zhejiang province. For this reason this variety was selected. Rice seedlings were transplanted in early July and matured in late October and were harvested in early November, 2003. Three rainfalls occurred during the growing period of paddy. The total amount of rainfall during the duration of the experiment was 315 mm, most of which fell during July and August. Harvest dates were also close to physiological maturity of the rice crop and all micro-plots were harvested as physiological maturity. The paddy were separated from the straw, dried and weighed. Grain moisture was determined immediately after weighing and sub-samples were dried. Rice grain biomass and yield was determined based on random sampling in each sub-plot treatment (8 plants per plot) and was dried to 14% moisture. Moisture content in plant sample was determined after oven drying for 48 h at 70°C.

Data analysis: Paddy biomass and yield was compared for the situation between treatments against phosphorous and nitrogen fertilizer using MS Excel program. Same program was also used to prepare water application graph. The grain yields used in this analysis were minimum 20 m^2 harvested area in each replicate plot per treatment. We assumed that within each experiment procedures for measuring grain yield have maintained unchanged during the course of the experiment.

Table 1: Nitrogen and phosphorus fertilizer treatment

Nitrogen treatment	urea (kg ha^{-1})	Pure nitrogen (kg ha^{-1})	Phosphorus treatment	super phosphate (kg ha^{-1})	P_2O_5 (kg ha^{-1})
N_0	0	0	P_0	0	0
N_1	196	90	P_1	286	40
N_2	392	180	P_2	429	60
N_3	588	270			
N_4	784	360			

RESULTS

Field experiments on nitrogen, phosphorous fertilization and water application was gain importance to understand the yield and biomass characteristics of rice. This study deals with the effects of biomass, yield, fertilizer and water application in rice.

Nitrogen and phosphorous fertilizer application: Application of N up to 270 kg ha^{-1} and two forms of P (super phosphate 286 kg ha^{-1} and P_2O_5 40 kg ha^{-1}) increased paddy biomass significantly. Nitrogen dose above 270 kg ha^{-1} did not contribute significant improvement in the essential paddy biomass. In N_0P_2 treatment, the net effect of P fertilizer application on final biomass was small. The biomass reduced due to excess P fertilizer application. It indicates that excess fertilizer application has adverse effect on biomass (Fig. 2). However, the plots receiving N and P fertilizer produced the greatest yield. Nitrogen (360 kg ha^{-1}) and phosphorous (60 kg ha^{-1}) fertilizer application increased rice grain yield by 60% above control plot. Also, there was no apparent increase in yield for fertilization in N_2, N_3 and N_4 with all P treatments (Fig. 4). There were no significant increase in rice yield from 270 to 360 kg N ha^{-1} and 60 kg P ha^{-1}. Therefore, at the highest level of N and P fertilizer supply with sufficient water application was not helpful for rice yield.

Water application: The daily decrease of surface water after the first fertilizer application is shown in Fig. 1. Daily measurements of the depth of standing water in the plots were taken to measure the daily decrease of surface water after the first fertilizer application. Mean values were considered within 15 plots to prepare this bar diagram. Irrigation was applied a number of time during the dry spells. Application of irrigation water was made just a day

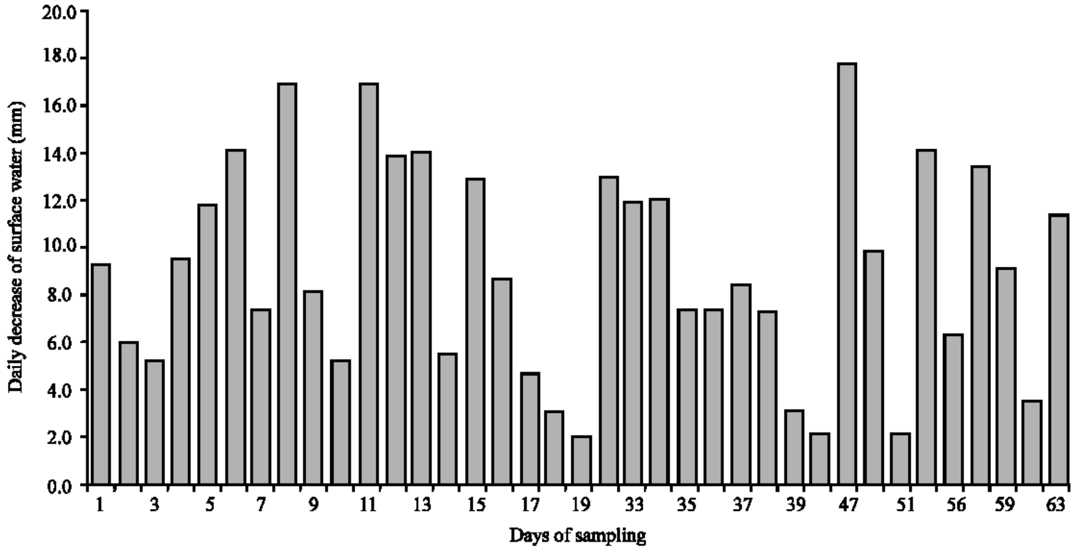

Fig. 1: Daily decrease of surface water after the first fertilizer application

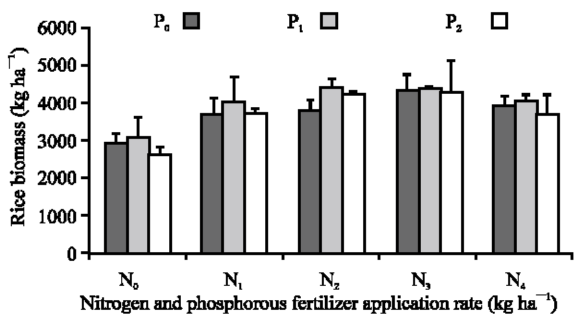

Fig. 2: Rice biomass w.r.t nitrogen and phosphorous fertilizer treatment

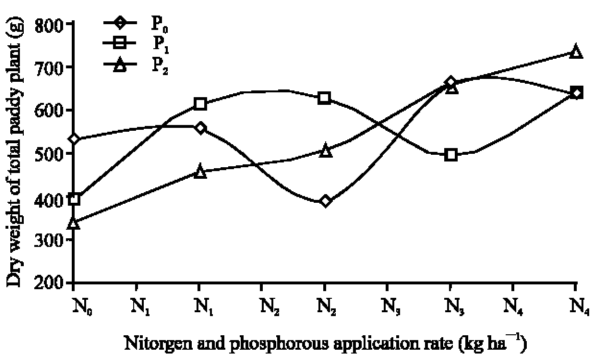

Fig. 3: Relationship between dry weight of total paddy plant w.r.t nitrogen and phosphorous fertilizer application rate

after the standing water had almost vanished from the field. The decreasing value was measured from water depth of paddy field. Normally 7 cm depth was maintained

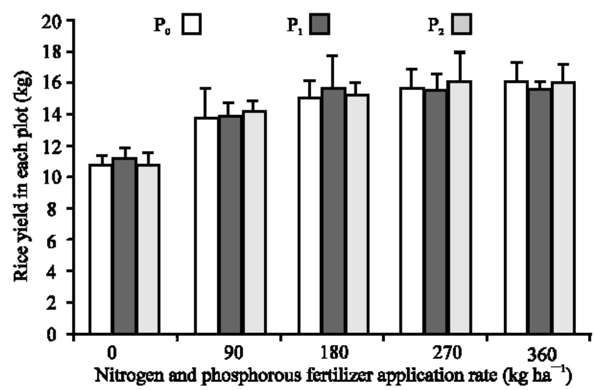

Fig. 4: Yield of rice w.r.t. nitrogen and phosphorous application

for flooding that was the benchmark. Then the water depth was monitored everyday and then irrigated up to 7 cm bench mark depth during the period of 7 days or more after each of fertilization. The difference between bench mark depth and measured water depth was the decreased amount of surface water. Maximum decreasing value of surface water was 17.5 mm after 47 days of planting and minimum was 2.5 mm after 40 days of planting. From planting to harvest, three rainfalls occurred in the paddy field. Generally, this routine work of water management practices was controlled weed and increased yield.

Rice biomass: A plot of nitrogen and phosphorous fertilizer treatment against the corresponding rice plant biomass is shown in Fig. 2. Addition of nitrogen and phosphorous fertilizer resulted in a significantly higher rice biomass plant compared to the controlled cases. At P_2N_2 treatment rice biomass was higher among all the treatments. In phosphorous treatment, addition of P at 286 and 429 kg ha^{-1} seemed have little effect on rice biomass in each treatment. Plant biomass for P_1 treatment (286 kg ha^{-1} super phosphate and 40 kg ha^{-1} P_2O_5) was greater from P_0 and P_2 treatment.

Maximum rice biomass was observed at 42x10^3 kg ha^{-1} in N_2P_1 treatment and minimum was observed at 42x10^3 kg ha^{-1} in N_0P_0 treatment. It means that the amount of rice biomass depends on nitrogen and phosphorous application. However there was little difference among phosphorous application for paddy biomass. In each treatment, paddy biomass gradually increased up to N_2 treatment and then decrease. P_1 treatment (286 kg ha^{-1}) showed the maximum rice biomass compared to P_0 and P_2 treatment. P_2 treatment was less to N_0, N_1, N_3 and N_4 treatment. The plant uptake of N and P from paddy field correlated with its biomass yield up to N treatment. In the present study, the rice biomass from P_2 treatment was not significantly different from the controlled case but was significantly lower than from P_1 in all N treatment.

Application of nitrogen, phosphorous and water had a profound effect on dry weight of total paddy plant in all treatment that was shown in Fig. 3. The dry weights of total paddy plant followed a similar trend among treatments as the grain yields. The highest dry matter yield of 780 g was obtained in N_4P_2 treatment. Lowest value of dry weight of total paddy plant was observed 320 g in N_0P_2 treatment. Among all the phosphorous treatment maximum dry weight of total paddy plant was 520 g in N_0P_0 treatment than 400 g in N_0P_1 treatment and rest was at 320 gm in N_0P_2 treatment. It was observed that the highest amount of phosphorous treatment application could not increase the plant growth without nitrogen application. A gradual increase of total dry weight of paddy plant was observed until N_4P_2 treatment, when a maximum value was reached. N_4P_2 treatment gave larger dry weight of total paddy plant than N_0P_1 and N_0P_2 treatment.

Yield performance: Compared with control, application of nitrogen fertilizers, either alone or combination with phosphorous significantly increased the yield of rice. Figure 4 showed the result of the experiments on yield of rice with respect to nitrogen and phosphorous fertilizer application rate including water application. There were no apparent differences among phosphorous treatment for yield of rice. Also, no more yield was observed in comparison of nitrogen application. In N_0P_0 and N_2P_1 treatment, yield was 5 and 8 t ha^{-1}, respectively. It means that the yield of rice increase 50-60 % due to nitrogen and phosphorous fertilizer application. There was no remarkable rice yield difference among N_2, N_3 and N_4 treatment with all P treatment. It depicted that the rice yield can be improved within the framework of nitrogen, phosphorous fertilizer and water application. As comparison to N_4P_2 and N_2P_1 treatment the yield gap was not great, but the fertilizer application difference was remarkable.

DISCUSSION

Yield responses to nitrogen and phosphorous fertilizer application and its residual effect: The grain yield of rice increased significantly with successive increase in N dose from 0 to 180 kg ha^{-1}. But, the differences in grain yield were not significant in N dose from 270 to 360 kg ha^{-1}. This could be due to the high losses of urea N as NH_3 volatilization under submerged conditions in treatments has higher N doses. Under submerged water irrigation high NH_3 volatilizations were losses about 40% of the total applied nitrogen[14]. Nutrient omissions trails conducted close by at both sides showed that the yield increasing effects for N and P applications caused a positive yield response[15]. Nitrogen and phosphorous application phenomena and its residual effect was verified also by other observation. An application of 17 kg ha^{-1} P increased grain yields of rice to about 2.5-3.0 t ha^{-1}. About 45% of applied P fertilizer was retained in the soils but was not recovered by crop uptake[16]. The important point to address is the effect of excess fertilizer application. So, we could not apply more fertilizer from certain level of fertilization rate. Different result verified this observation. The N nutrient uptake efficiency by plants was very limited[17]. In general the plants used only 24-41% of the N fertilizer. Most of the fertilizer was lost or remind in soil, resulting in direct economic loss to farmers and exerting a negative impact on the atmospheric environment and water quality[18]. Alternatively, rice yields decreased in response to high doses of fertilizer application[19].

Water use: The result suggested that for effective weed control, high rice yield and water use efficiency, the field must receive sufficient water use. Many researchers obtained same conclusion. Weed control has always been a major factor in rice production and was correlated with number of water use[20]. Bhagat *et al.*[21] and Williams *et al.*[13] whose observation were shallow water depth can effectively suppress weeds and continuous floods without herbicide treatments were increased rice yield[13,21]. Also, same agreement was observed by O'Toole *et al*. for water use to yield of rice[22].

Rice biomass and yield performance: Yield increase can be achieved by increasing biomass production that was verified our results on rice biomass[12]. Minor differences in rice fields were measured with phosphorous applications in N_1, N_2 and N_3 treatment. P fertilizer application did not have any positive effect on individual grain yield. The amount of N and P incorporation with water application increased rice yield by 3 t ha^{-1} over that of the unfertilized control. This conclusion was closely concerned with the observation of Lathovilayvong *et al.*[23], who stated that N and P are particularly important for rice yield and an initial application of 6.5-19 kg P ha^{-1} is required for high yield[23].

This study reviews the interactions of nitrogen, phosphorous and water application for paddy biomass and yield. From the experimental result it clearly indicated that the strongest increase in paddy biomass was obtained by the introduction of nitrogen and phosphorous at the reasonable amount. While the application of nitrogen and phosphorous fertilizer tend to increase yields, there was no apparent relationship between the rates of fertilizer applied and grain yield. Higher nitrogen levels resulted in greater biomass through out the growth period in all treatments, but effects were more pronounced under flooded conditions. These results suggest that the yield of rice is largely dependent on fertilization. There is an urgent need to develop fertilizer recommendation for immediate economic benefits to farmers in the ecologically harsh environments.

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