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Phytosynthetic bacteria (PSB) as a water quality improvement mechanism in saline-alkali wetland ponds

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Abstract: The efficiency of phytosynthetic bacteria (PSB) to improve the water quality in saline-alkali ponds was studied, the result showed that (1) PSB application could increase the content of DO, NO_3^--N and effective phosphorus (EP) in ponds; (2) the changes of COD were not evident, just effective in later period after PSB application; (3) PSB application could decrease the contents of NH_4^--N (NH_3-N), NO_2^--N; (4) PSB application could improve the structure of the effective nitrogen (EN) and EP, stimulate the growth of phytoplankton, and increase primary productivity, and finally increase the commercial profits of ponds because of the increase of EP and the decrease of EN contents; (5) the effect-exerting speed of PSB was slower, but the effect-sustaining time was longer; (6) the appropriate concentration of PSB application in saline-alkali wetland ponds was 10×10^{-6} mg/L, one-time effective period was more than 15 days. So PSB was an efficient water quality improver in saline-alkali ponds.

Keywords: phytosynthetic bacteria (PSB); saline-alkali wetland; fishpond; water quality improving

Introduction

There is a great amount of saline-alkali wetland, which has been exploited and gained certain profits, along Yellow River in China. Fish ponds have been built and fisheries has been developed, but because the water level in ponds changes with water table, in particular, in dry years, Yellow River's lacking water on the course of down streams in summer results in shortage of pond water even sometimes just tens of centimeters. In addition during high-temperature months (from July to September), wastes from feeding, fish excrements and aquatic organism cadavers easily make water quality degenerate, which is unfavorable to fisheries (Boyd, 1998). This makes it necessary to find a good improver for water quality in saline-alkali wetland fishponds in order to ensure good water quality.

The photosynthetic bacteria (PSB) application in aquaculture has been well studied. It has been demonstrated in the test of enclosures in which PSB was applied that the efficiency to improve water quality was high in saline-alkali wetland pond enclosures (Liu, 1999). We applied the PSB concentration of 10×10^{-6} mg/L which was determined according to the enclosure tests, in order to further the research of water quality improving efficiency of PSB in saline-alkali wetland ponds.

1 Materials and methods

1.1 Test pond

Test pond was situated at Xindian Research Base (Shandong Province), Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences. The test pond was No.4—1, area of which was about 3300 m^2, average depth about 1.5m, ratio of length to width 5:3, slope ratio 1:2.5. Carp (*Cyprinus carpio*) and Grass Carp (*Ctenopharyngodon idellus*) were mainly cultured. Color of pond water was poor, appearing black-brown. Fish often lacked oxygen and even some individuals died.

Water characters in pond were as follows: total alkalinity 4.557—4.808 mmol/L, total hardness 14.40—15.85°, mineralization degree 706.14—730.56 mg/L, pH 7.6—8.2. Water quality type was CCl_{II}^{Na}, which means the high mineralization, slight alkalinity and hardness of pond water.

1.2 PSB and test design

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PSB applied was made by Shanghai Haichang Real Development Co. Ltd., which was technically supervised by East China Sea Fisheries Research Institute and was concentrated as being mashed. The concentration of PSB applied was determined as 10×10^{-6} mg/L according to the literature(Liu, 1999).

The research continued from August 23rd to September 7th in 1999. It was drought resulting in low water level and lack of water resource to supply ponds. The base values of water quality characters were measured at 10 O'clock on August 23rd (recorded as 1d), after which PSB was applied, and then the related water quality characters were measured at 10 O'clock every day until the test ended. Water samples were taken at the depth of 0.5m under surface water. It dribbled from September 4th (13d) to afternoon September 5th (14d) with rest time sunny.

1.3 Water quality characters and their analysis

The water quality characters measured were dissolved oxygen (DO), pH, COD, total ammonia (NH_4^+-N (NH_3-N)), nitrite-nitrogen (NO_2^--N), nitrate-nitrogen (NO_3^--N), soluble reactive phosphorus (PO_4^{3-}-P), total phosphorus (TP).

pH was measured by pH meter, DO contents by iodometric method, COD values by acidic potassium permanganate method, NO_2^--N contents by phenolphthalein disulfonic acid colorimetry, total ammonia contents by Nessler's reagent colorimetry, PO_4^{3-}-P contents by ammonium molybdate colorimetry, and TP contents by potassium persulfate oxidation method. Measured samples for total ammonia, NO_2^--N and PO_4^{3-}-P contents were filtered by 0.45 μm filtering membrane (Michael, 1982).

2 Results and discussion

2.1 pH and water temperature

The changes of water temperature and pH values are listed in Table 1. The daily range of water temperature changed from 26.8℃—28.9℃ which was a physical factor in no relation to PSB application. pH values had obvious changes. After PSB application, pH values began to rise and the highest value occurred at 5d, after which it maintained around 7.9—8.1 until 13d when it declined. This was mainly caused by rain, because after weather became sunny, it returned to 8.0 at 16d, so the efficiency of PSB application on pH values can sustain more than 15 days.

Table 1 The changes of the water temperature and the pH value during the test

Time, d	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
pH	7.8	7.9	7.8	8.0	8.2	8.0	8.1	7.9	8.1	8.0	8.0	7.9	7.7	7.6	7.7	8.0
Water temperature, ℃	27.8	27.9	27.0	27.0	27.8	26.8	27.6	28.4	27.9	28.4	28.4	28.1	27.5	26.8	27.1	28.9

2.2 Dissolved oxygen (DO)

Researchers have reported that PSB could be applied to increase water DO contents(Cui, 1997; Si, 1995; Zhang, 1994). From Fig.1 it could be derived that from the second day after PSB application then on, DO contents began to increase with the first high value at 7d when the increasing range was 203.35%. At this time, DO contents transferred from lacking condition to satisfying condition(9.1 mg/L). Even at 13d, it was 3.3 mg/L because of rain, whereas it was still higher than that of 1d(3.0 mg/L), furthermore, after weather became fine, it increased rapidly with the second highest value at 16d. The average daily ascending speed of 1.97 mg/L compared with that of 1d during later period was higher than the previous-stage ascending speed of 1.02 mg/L during the later stage. During the whole test the average DO content increment, in contrast to DO content of 1d, was 3.57 mg/L, the increase range of which was 119.11%. When we evaluated the changing course, there was oscillations of DO contents although total trend of increase, which was, we think, because it needs time for PSB to transfer from dormant situation to active situation, finally to final performance. We can conclude that efficiency of PSB on DO content increase can continue more than 15 days, which is different from the result of enclosure tests in which one-time effect-sustaining time was about 6 days (Liu, 1999). Given the limit of water circulation in enclosures, this is natural, but we must notice the shortage of enclosure tests in aquaculture.

2.3 COD

The enclosure tests showed that effect of PSB on decreasing COD values was obvious (Liu, 1999). However, it could be observed from Fig. 1 that after PSB application COD values showed no decline but slight ascend, especially at 13d arriving the highest value, which possibly resulted from rain. It could be suggested that if it had not been for rain at 13d, causing the great range increase of COD values, COD values would have kept decreasing from 10d. It implicated that efficient of PSB application on COD decrease was slow in ponds compared with being rapid in enclosures.

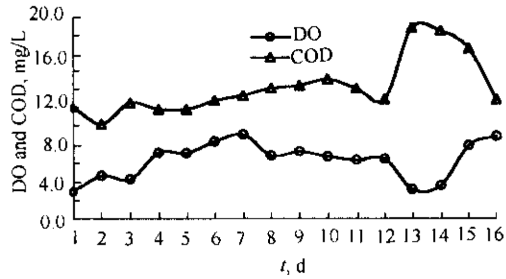

Fig. 1 Changes of the DO content and the COD value during the test

As a matter of fact, these differences of COD after PSB application were probably in relation to physical and chemical condition of pond water. In wet year of 1998, because pond water resource was sufficient ensuring good water quality, as a result DO contents were high, which led to the difficulty of water deoxidation situation, and finally high-decrease efficiency of COD by PSB. But in dry year of 1999, during culture period, especially during high-temperature months from July to September, along with water source lacking, water level rapidly decreased, water quality degenerated and water body lacked dissolved oxygen within a long-term period. All these factors comprehensively made many elements in deoxidation condition, which caused intensive oxygen consumption, even after PSB application, COD still remained at high points for a period of time, and then decreased which means phenomenal PSB efficiency. This result suggested that, in aquaculture, if water quality degenerates seriously, one-time PSB application concentration should be increased in order to improve water quality more quickly.

2.4 PO_4^{3-} - P

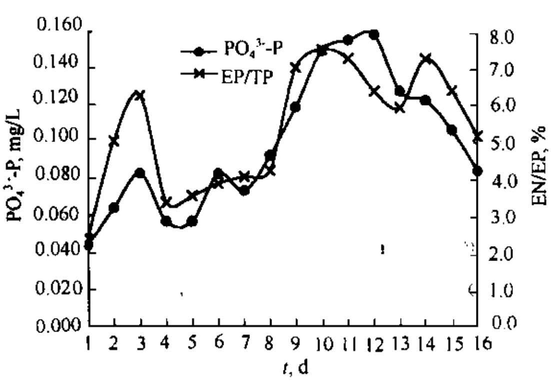

Fig.2 Changes of the phosphate and the ratio of the effective nitrogen (EN) and total phosphorus (TP) during the experiment

Soluble reactive phosphorus can be exploited directly by alga. In fish ponds phosphorus is always a limiting nutrient, so the nutritious condition in water body can be evaluated in terms of its content.

The changes of PO_4^{3-} -P are shown in Fig. 2. PO_4^{3-} -P increased after PSB application with fluctuations, it approached the highest content at 12d. Although PO_4^{3-} -P content decreased from 13d, it at 16d was still higher than that of 1d and still maintained at higher level. It could be derived that during test period average daily increment of PO_4^{3-} -P content was 1.02 mg/L, compared with base content at 1d, with increase range of 134%, and even the lowest content of 0.057 mg/L, increase range still approached 9.5%. In conclusion, PSB application could promote the phosphorus performance in addition to increase of DO contents, that is, beneficial circle of phosphorus was promoted, resulting in the increase of PO_4^{3-} -P contents in water photic layer.

Wang Wu *et al*. (Wang, 1992) have demonstrated that effective phosphorus content should be kept higher content as 0.030 mg/L in order to get high production in aquaculture by promoting phytoplankton growth. In this test, the base content of PO_4^{3-} – P was 0.044 mg/L, so this pond did not lack phosphorus. The simultaneous absolute value of effective phosphorus contents in 1998 were only 0.0010 mg/L or so, which implied that there was great difference for effective phosphorus contents between wet years and dry years, that is, it was lower in wet years. In order to promote phytoplankton, in turn, to increase production of filter-feeding fish in wet years, fertilizers containing phosphorus should be used to increase effective phosphorus level.

In conclusion, increase of effective phosphorus could maintain more than 15 days after PSB application.

2.5 Effective phosphorus(EP)/total phosphorus(TP)

The ratios of EP/TP are shown in Fig.2. The change course of the ratio was similar to that of effective phosphorus. A paper has reported effective phosphorus content was 0.2% of total phosphorus in pond water(Tan, 1990). In this pond, it was 2.4%, and after PSB application, the percent increased at 10d approaching the highest point of 7.6%, which also showed PSB could promote beneficial circle of phosphorus.

2.6 NH_4^+-N (NH_3-N)

NH_4^+-N contents and NH_3-N contents in water are affected by pH and water temperature(Michael, 1982). Table 1 indicated that pH values were 8.0 or so, resulting in slightly alkaline water, so inorganic nitrogen in saline-alkali wetland ponds occurred mainly in the forms of NH_4^+-N, NO_2^--N and NO_3^--N. If total ammonia concentration is unnaturally high, it will harm aquatic organisms, so NH_4^+-N(NH_3-N)-eliminating efficiency is one of keystones to evaluate the efficiency of water improvers.

The changes are represented in Fig.3. Although there were fluctuations, total trend was decrease. The average daily eliminating rate of NH_4^+-N(NH_3-N) was 0.394 mg/L with range of 88.9% in contrast to the base value, and even it declined in later period, the NH_4^+-N(NH_3-N) content was lower than that of 1d, so the eliminating efficiency of PSB application on NH_4^+-N(NH_3-N) was obvious. In conclusion, eliminating efficiency of PSB application to NH_4^+-N (NH_3-N) could sustain more than 15 days.

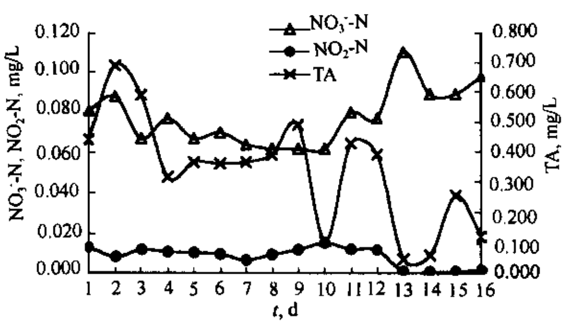

Fig.3 Changes of the NO_3^--N, NO_2^--N and the total ammonium (TA) during the test

2.7 NO_2^--N

NO_2^--N in water body is toxic to aquatic organisms especially fish (Scarano, 1985; Wang, 1997), so it is necessary to eliminate it in aquaculture. It is feasible to evaluate the degenerating degree of water quality according to its contents. Reports have demonstrated obvious efficiency of PSB as an improver to eliminate NO_2^--N from fishpond water(Liu, 1999).

The changes of NO_2^--N are shown in Fig. 3. It demonstrated that eliminating efficiency of NO_2^--N by PSB was obvious, average daily eliminating rate was 0.0048 mg/L with the eliminating range of 36.6% and maximum eliminating rate 0.0210 mg/L with the eliminating range of 91.6% in contrast to the base value at 1d. There were fluctuations of NO_2^--N content during the early period, but eliminating effect was efficient during the later period, showing the same regime as that of COD. This showed that eliminating effect of PSB to NO_2^--N was slow, as was possibly because NO_2^--N is the medium product between NO_3^--N and NH_4^+-N.

2.8 NO_3^--N

The changes of NO_3^--N contents are shown in Fig.3. These changes were not more obvious than those of NH_4^+-N (NH_3-N). NO_3^--N contents were gradually increasing during later period. Because NO_3^--N contents is low in saline-alkali wetland ponds, if measures are taken, nitrogen circles can become beneficial. After PSB application, NH_4^+-N (NH_3-N) and NO_2^--N were inhibited and declined causing the increase of NO_3^--N contents. Because alga, which are primary producer, can use the form of NO_3^--N for nitrogen source directly, so when NO_3^--N contents increase, the primary productivity rise, as finally promote the growth of feed-filtering fish.

2.9 Effective nitrogen(EN)/effective phosphorus(EP)

Alga can use directly the effective phosphorus and effective nitrogen, the ratio between them and inner composition profiles of effective nitrogen affect greatly the primary productivity in ponds. The ratio of nitrogen to phosphorus in trophic composition of feed for is approximately 7 and researchers has showed the maximum ratio is 4:1 in fish culture(Fan, 1995). Usually phosphorus is the limiting trophic factor in saline-alkali fishponds, i.e., the effective phosphorus content is lower or the effective nitrogen is higher.

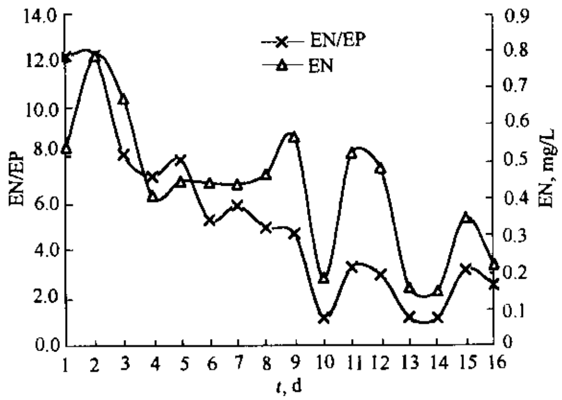

Fig.4 Changes of the effective nitrogen (EN) content and the ratio of effective nitrogen (EN) to effective phosphorus (EP) during the test

The ratio of EN to EP is shown in Fig.4. After PSB application, effective nitrogen declined with slightly great range, which was similar to the result after fertilizers containing phosphorus were applied(Wang, 1992). This may be in relation to the more great range decrease of the sum of total ammonia contents and NO_2^--N contents than the increase of NO_3^--N contents.

The ratios of EN to EP showed decline trend from previous 12.2 to the lowest point at 10d, and then ascend again, but range of which was low. The base ratio of EN to EP was 12.2, which suggested phosphorus was the limiting factor, but after PSB application, it decreased rapidly, as demonstrated that PSB could solve effectively the problem of lack of phosphorus, and promote the usage rate of effective nitrogen in fishponds. So PSB was a good improver which could regulate the ratio of two nutrients of nitrogen and phosphorus.

In conclusion, PSB application could increase DO, NO_3^--N and effective phosphorus contents, decrease COD, NH_4^+-N (NH_3-N) and NO_2^--N values, and improve the structure of nutrients to beneficial circles in the saline-alkali wetland ponds. The efficiency was also be proved by the color change of water from previously black-brown color to light green color, which implied good water quality. PSB was a suitable water improver in saline-alkali wetland ponds, one-time application concentration and sustainable effect duration of which is 10×10^{-6} mg/L and more than 15 days respectively.

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