A preliminary Report on Tolerance of Vetiver to Submergence

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Abstract: To date, there are still no ideal bio- or eco- measures protecting or stabilizing inner slopes of rivers, reservoirs, and lakes, as plants established on the inner slopes are almost all drowned by the elevated water level in rainy season. Thereby, the key is screening out strongly tolerant plant species to submergence in order to effectively stabilize and vegetate the "wet" slopes. A comparative study on the tolerance of eight grasses to submergence was conducted. The selected eight grasses were vetiver grass (*Vetiveria zizanioides* Nash), bahia grass (*Paspalum notatum* Flugge), aciculate chrysopogon (*Chrysopogon aciculatus* Trin.), Bermuda grass (*Cynodon dactylon* Pars.), common centipedegrass (*Eremochloa ophiuroides* Hack.), St. Augustine (*Stenotaphrum secundatum* Kuntze.), carpet grass (*Axonopus compressus* Beauv.), and sour paspalum (*Paspalum conjugatum* Bergius). They are all excellent plant species for soil and water conservation in southern China. The tested plants were raised in pots first and then put into a cement tank filled with water to investigate their tolerance to complete submergence. Through 3 years of observation, it was found that vetiver and Bermuda grass could tolerate the longest time of submergence, at least up to 100 days and were probably more than that; bahia grass ranked second, up to 60–70 days, followed by carpet grass, up to 32–40 days and then aciculate chrysopogon and sour paspalum, up to 25–32 days; St. Augustine was penultimate, up to 18–32 days; the poorest species to resist submergence was centipede grass, only 7–10 days. Moss seemed to be an environmental factor influencing the tolerance of plants to submergence, inferring that muddy or polluted water kills plants more easily than clear water. A further experiment, including the final tolerance of vetiver and Bermuda grass and the tolerant mechanisms of the 8 species, is still ongoing.

Key words: herbaceous plant, submergence, tolerance of plant to submergence

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1 INTRODUCTION

It has become increasingly important to apply ecological measures to control soil erosion because it produces ecological benefits and costs less. When eco-measures are adopted to stabilize slopes, the first noticeable issue is selecting suitable plant species. Generally speaking, the various kinds of common soil erosion can be controlled through "bio-dam" or "bio-carpet" as long as the plant species are correctly chosen (Xia *et al.*, 2000). So far, agricultural slopes, and side slopes of highway, railway, architecture and other infrastructures have already had pretty good ecological protection measures. As to the protection of slopes of rivers, reservoirs and canals, however, almost no very effective eco- or bio- protection measures have been found to date (Armstrong *et al.*, 1994; Dalton *et al.*, 1996). The main reason is that this kind of slope usually suffers seasonal inundation, while plants used to conserve soil and water are almost all xerophytes; they will be suffocated to death after a spell of complete submergence. Some hydrophytes can also be used in soil and moisture conservation, but their effects in this aspect are generally quite poor. This is because hydrophytes have much poorer ability to hold soil on the whole; what's more, they are almost always killed under a long drought periods (e.g. in winter) and are also killed perhaps under a relatively long time of total submergence. As a result, these "wet or watery" slopes all assume a huge blank band with a height of meters or dozens of meters in dry seasons and produce severe soil erosion when encountering heavy rains or waves or rapid water flow. This not only greatly influences the landscape and service life of reservoirs, rivers and canals, but also imperils the safety of the lower reaches. At present, more attention has been put to solve the soil erosion problem in these slopes (Gregory *et al.*, 1991; Deng *et al.*, 2001; Xia *et al.*, 2002). Theoretically, the erosion problem of the "wet" slopes that are not soaked permanently should be thoroughly solved as long as certain plant species for water and soil conservation can be found to endure a relatively long spell of complete submergence. Due to this reason, the present study aims at investigating the endurance of several grasses for soil and water conservation to submergence. The objective is to identify one or two species of plants that can stand a long time of submergence and then to provide a scientific basis for selecting plant species to effectively stabilize slopes of rivers, lakes and reservoirs.

2 MATERIALS AND METHODS

2.1 Experimental Materials

Eight grasses were used to test their tolerance to complete submergence, which were vetiver grass (*Vetiveria zizanioides* Nash), bahia grass (*Paspalum notatum* Flugge), aciculate chrysopogon (*Chrysopogon aciculatus* Trin.), Bermuda grass (*Cynodon dactylon* Pars.), common centipede grass (*Eremochloa ophiuroides* Hack.), St. Augustine (*Stenotaphrum secundatum* Kuntze.), carpet grass (*Axonopus compressus* Beauv.), and sour paspalum (*Paspalum conjugatum* Bergius). The common features of the 8 species are high erosion control and high resistance to adverse conditions. They all have been applied widely in erosion control and slope stabilization in southern regions of China. Among them, vetiver is the sole high-stalk type and the other 7 species are procumbent types.

2.2 Research Methods

The experiment was conducted with a method of water-cultivation. A cement tank with a volume of 2.0 m length _2.0 m width _1.3 m height was first constructed and then pots in which the tested plants grew were put into the tank. All tested plants were collected from the grass nursery of South China Institute of Botany; they were all mature and healthy. Soil was mixed thoroughly before it was put into pots and then a little part was sampled for chemical analysis (Table 1). Thereafter grass seedlings were transferred into identical pots with the mixed soil, 3 pots for each species. All pots were carried into the tank after plants grew in pots for 30 days. In order to guarantee the 7 prostrate grasses got enough sunshine, a frame with the height of 0.8 m was installed first in the tank and then these seedling pots were put on the frame. Vetiver pots were put on the cement ground in the tank and moreover vetiver seedlings were controlled to the height of 1.2 m. Then tap water was used to fill the tank until all plants were submerged completely in water. During the period of submergence, the height of all vetiver seedlings was also controlled lest they grew out of water.

Table 1 Soil basic characteristics used in the tested pots

pH	Organic matter (g/kg)	Total N (g/kg)	Total P (P_2O_5) (g/kg)	Total K (K_2O) (g/kg)	Hydrolytic N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)	Soil type
4.94	20.6	0.44	0.31	3.35	78.5	6.27	42.1	Red lateritic earth

When the submerged time was up, water was completely discharged to observe if there were plants drowned. After all survived plants recovered to the normal or almost normal status (ocular estimate), the longer water filling began. It repeated in this way until all tested planted were drowned. The submerged time was gradually increased; concretely speaking, plants began submergence in water from 24 July 2000; it lasted 2 days in the first time (24 – 26 July), 4 days in the second time (28 July – 1 August), 7 days in the third time (4 – 11 August), 10 days in the fourth time (15 – 25 August), 14 days in the fifth time (7 – 21 September), 18 days in the sixth time (10 – 28 October), 25 days in the seventh time (4 –29 December), 32 days in the eighth time (5 February – 9 March 2001), 40 days in the ninth time (19 April – 29 May), 50 days the tenth time (4 July – 24 August), 60 days in the eleventh time (28 September –28 November), 70 days in the twelfth time (15 March – 24 May 2002), 80 days in the thirteenth time (3 July – 21 September), 100 days in the fourteenth time (16 October – 25 January 2003), and 120 days in the fifteenth time (14 May – 14 September). Furthermore, water was filled non-stop into the tank during the period of submergence in order to prevent the water surface from lowering due to evaporation or leakage.

3 RESULT AND DISSCUSSION

Table 2 is the reaction of all tested species to different submergence times. They all could resist 48 hours of submergence. Since none of them was influenced by a 2-day submergence, the second submergence was conducted after discharging water for 2 days. Centipede grass first assumed a slightly damaged symptom after the 4-day submergence, but then recovered in 3 days. After the third submergence, the damage of centipede grass became obviously severe and one of the three pots was killed. Sour paspalum was also hurt slightly in this submergence. All damaged symptoms assumed that plants became shorter, the color of leaves became abnormal, stems and leaves became softer and even rotten. 4 days later, all suffered plants recuperate, thereupon the fourth submergence began. Water was discharged 10 days later, as a result almost all plants were damaged, among them all centipede grass plants were drowned, while vetiver was damaged most slightly. Like the fourth time, the fifth submergence made all survivors damaged but no one was killed. It was difficult to identify, however, which species was damaged severer and which one was slighter. This is because that moss grew out during the period of this submergence, which covered plants' appearance and could not be washed away. All plants survived the fourth submergence also survived this time and recovered in 19 days. The sixth submergence lasted 18 days; as a result St. Augustine was killed in two pots and the moss seemed increase. The seventh submergence killed two pots of aciculate chrysopogon and two pots of sour paspalum, while others, including the left one pot of St. St. Augustine, became almost normal 36 days after water was discharged. However, St. Augustine, aciculate chrysopogon, and sour paspalum (each species one pot alive) were all killed in the eighth submergence. The other four species all recovered and then grew after discharging water for a spell of time. Thereafter, 3 pots of carpet grass were all killed by the ninth submergence. The tenth submergence began after the ninth was over for 36 days, from which all vetiver, bahia grass, and Bermuda grass seedlings lived through in spite of the fact that all of them were severely damaged. The eleventh submergence up to 60 days killed two pots of bahia grass, but neither of vetiver nor Bermuda grass were killed although the shoots of the latter seemed to be dead. Due to the severe damage of plants and cold winter, however, the survivors recovered very slowly. They did not completely recuperate until March 15th, 2002. The twelfth submergence began on this day and ceased on May 24th. The results were: 1) all shoots of Bermuda grass and bahia grass became rotten or dead and furthermore the one pot of bahia grass no longer became green, this means that all bahia grass plants were killed by 70 days of submergence; and 2) there were only two pots of vetiver and two pots of Bermuda grass became green and recovered growth. It was surprising, however, that the two submergences did not result in any new deaths; that is to say that the 2 pots of vetiver and 2 pots of

Bermuda grass were still alive. Why some experimental plants were killed by 70 days of submergence, while the remainders survived the 80 and 100 days of complete submergence?! The experimental site and conditions were completely identical from beginning to end except for temperature, which was natural and therefore changed all year round. However, a strange phenomenon was found that moss adhered to the plants and the water tank become far less in the last two times of submergence than the previous several times, especially the 6th−11th time. The most amount of moss occurred was in the 11th and 12th times, covering almost all appearance of the submerged plants and the inner surface of the water tank. It is probable, therefore, that 1) moss, or mud (if in river or reservoir), not submergence itself is the main killer of flood-resistant plants; and 2) the tolerance of plants to submergence will become weaker when they are soaked by dirty or muddy water. It is incredible, however, why the amount of moss in the 13th and 14th submergences greatly decreased.

4 CONCLUSION AND THE COMING PLANS

It can be seen from the above phases of the experiment, vetiver and bermuda grasses assumed the strongest tolerance to submergence and both of them could endure at least 100 days of complete submergence when the water is relatively clean; bahia grass ranked the second, which could endure submergence for 60 – 70 days; carpet grass was the third, enduring 32 – 40 days; aciculate chrysopogon and sour paspalum were the fourth, enduring 25 – 32 days; St. Augustine ranked the fifth, enduring 18−32 days; centipede grass was poorest, enduring at most 10 days. Thereby, vetiver, bermuda and bahia grasses, particularly the former two, can be used to protect slopes of riverbanks and reservoirs with regard to the tolerance to submergence.

At present, the experiment is still ongoing; the fifteenth submergence began on 14 May 2003 and will finish on 14 September, lasting 120 days. The result will be able to be known at ICV-3. If vetiver or bermuda still survive the 120-day submergence, the longer submergence will continue until all tested plants are killed to thoroughly ascertain the tolerance of vetiver and Bermuda grass to complete submergence. After the trial is over, two further experiments will be conducted. The coming plans are as follows.

1) Investigation of the type of tolerance to submergence. Considering what the tested plants went through was the submergence cultivation of gradually increased time, their tolerance to submergence, therefore, was likely to increase gradually due to the domestication of the submerged environment. In order to make clear which type the tolerance of each species belongs to, adaptive or constitutional type, the submergence trial will be conducted again to all tested plants after the above trial of gradually increased submergence is over. The submergence way is similar to the gradually increased one. Concretely speaking, plants that have never been submerged are first established in the pots and then they are put into the tank one month later. But all species are soaked only once and the soaked time for each species is its tolerant limit obtained from the gradually increased trial above. Then these pots are taken out from the water and an investigation of the survival of each grass is tracked. If one species or parts of its seedlings survive, it indicates that its tolerance to submergence is constitutional; otherwise it is adaptive.

2) Exploration to the tolerant mechanisms of different species. Due to the huge difference among different species with regard to the tolerance to submergence, the tolerant mechanisms among different species are affirmatively different. However, the tolerant mechanism has been poorly documented of the eight plants to submergence (Feng *et al.*, 2003). Therefore it is very necessary to conduct the research to make clear the tolerant mechanism of each species to submergence, which will provide a theoretical basis for their practical application.

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A Brief Introduction to the First Author

Dr. Hanping Xia, a restoration ecologist, is working at the South China Institute of Botany, Chinese Academy of Sciences. Since 1991, he has been engaged in a wide range of R&D on the Vetiver System for the purpose of soil erosion control and polluted environment mitigation, including highway slope stabilization, land reclamation and re-greening, quarry rehabilitation, mine and landfill phytoremediation, wastewater purification, etc. He creatively initiated “the Vetiver Eco-engineering” from his working experience of many years. So far he has one monograph and over 30 academic papers in this aspect published.