Vetiver Research and Development:
A Decade Experience from China

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Abstract

Soil erosion increases with expanding human activities. New clearing of marginal lands for food production on the steep slopes, deforestation for commercial timber production, and large scale construction of highways, railways, dams, mining, quarrying and buildings have caused this problem. Natural forests can conserve water very effectively, but man-made forests consisting of newly planted young trees on the degraded land can hardly conserve any water, which can lead to severe erosion. Vetiver grass can grow quickly and control erosion very efficiently. Since 1988, comprehensive research has been conducted through out the country on vetiver, and the grass is now widely used for farmland protection, agricultural infrastructures protection, river bank and coastal protection, sandy dune stabilization and revegetation, highway embankment stabilization, etc.

Soil Erosion and Natural Disasters

Soil erosion has been a problem ever since man started to cultivate land. It became more critical with increasing population. It was estimated that the soil loss reached 76 900 mill.t. each year in the world. China is one of the most serious soil erosion country with annual soil loss of about 5 000 mill.t. (Zhang 1995).

In addition to the large number of new farm land being reclaimed for food production on very steep slopes, in recent years following national economy reform, farmers and government officers have increased their interest in clearing forests for commercial tree production, and they called it “forestry revolution”. They cleared vegetation, built earth terrace, and planted tea, mulberry, longan, and chestnut, etc. in a large scale. Because this kind of new farming development does not provide soil protection measures, but led to more soil erosion, resulting in the decline of soil fertility. Consequently, commercial trees cannot grow well. And more often, the soil was usually eroded off before commercial trees and new vegetation mature.

In developing countries, in addition to farming, non-agricultural practice resulted in rapid increasing soil erosion as well. These developments included the construction of highways, railways, dam, mining, quarrying, and buildings, etc. Studies in the US some years ago showed that construction constituted some 20 times the rate of other forms of erosion attributable to land use on average (Hengchaovanich 1997). Unfortunately, this serious erosion problem is not fully understood by policy makers and scientists in developing countries. In China for example, since the national economic reform the construction of highway forms the major component of economic development and was deemed as an important means of poverty alleviation. The total length of highway increased from 1 118 000 km in 1994 to 1 186 000 km in 1996. The annual increase reached 34 000 km. In Fujian Province 4 000 km of highways were established from 1992-1996 (Xie 1997). However, because of financial limitation many highway embankments were not properly protected and caused serious new erosion. This has not only led to the unstable highway foundation but also to the pollution of the surrounding environment.

Sediments raised the beds of rivers and lakes and caused frequent flooding and threatened people’s life seriously and led to disastrous consequence. For example, the sediments passed through the Three Gorges each year in the 1990s reached up to 720 mill.t. Investigations revealed that the level of the riverbed of main reaches of the Yangtze River raises 1 m in every ten years. As a result, during the flooding season, the water level became much higher than that of the surrounding land surface.

In 1998, based on official statistics, the heavy flooding caused 4,150 deaths and direct economic loss of 255,090 mill.Yuan RMB (about $31,108 mill.) in this country. There were 6.85 mill. houses destroyed. And 18.393 mill. people had to immigrate to safety places.

Vetiver Introduction

Grass for Fast Control of Soil Erosion

Natural forests can conserve water very effectively not only with its high density crown but also with its think soft layer of litters on the ground and the surface horizon and sub-horizon of soil which contain much organic matter and has high porosity and low bulk density, which can store water significantly. But man-made forests consisting of newly planted young trees on the degraded land can hardly conserve any water that can lead to severe erosion. As a result, in the recent years, people prefer planting grasses that can grow quickly and control erosion efficiently. Of several grasses species tested, vetiver grass (*Vetiveria zizanioides* L.) has been most successful in this regard as it grows quickly and tolerant different conditions. Since 1988, comprehensive research has been conducted on vetiver worldwide.

Introduction and Initiation of Vetiver Grass

Although vetiver grass was used for essential oil extracting early in the 1950's, but it was recorded that vetiver grass was introduced to China by Mr. Richard Grimshaw from India for soil erosion control in 1988. The planting of the grass was incorporated in the World Bank funded Red Soil Project that covered five provinces in southern China: Jiangxi, Fujian, Zhejiang, Hunan, and Guangxi. Just a few months later it was introduced to other southern provinces in China. To test and to promote vetiver applications more effectively, a field workshop was co-sponsored by the World Bank, Water Conservation Ministry, and Agricultural Ministry of China in Saowu of Fujian Province in October 1989. Since then the grass was experimented by many institutions in various provinces.

Growth Behavior and Factors Influencing the Growth of Vetiver

Experiments and tests by dozens institutions in various provinces showed that vetiver grass was adaptable to different natural condition in China.

Soils

Vetiver grass can grow on brown earth, yellow brown earth, red soil, laterite, skeleton soils, wind-blown sands (alluvial area and coastal area), which covers Entisols, Inceptisols, Alfisols, Ustisols, and Oxisols. In coastal area the grass can tolerate and grow well on saline land affected by sea waves (Zhang 1998). In Hubei Province the grass grew better than local weeds on the river banks even suffering from repeated grazing by cattle. Although the grass can grow on different soils, from sandy to clayey, it grows much better on loamy soil. Therefore, it is important to select loamy soil as nursery site so that roots can be fully developed and it is easy to divide tillers when planted. Gao et al. (1998) indicated that although soil texture affected the growth of vetiver, the most important factors were heat and water. Lu et al. (1994) indicated that vetiver grew better than several local weeds on the plinthtic horizon of a serious eroded red soil containing organic matter of 1.51 g/kg.

Temperature and Water

Vetiver grass was tested in China from Hainan Island (10^{o}N latitude) to Tianjing (39^{o}N latitude). In Tianjing where the mean temperature in January was -4^{o}C with minimum -22^{o}C and minimum annual rainfall was 550 mm, the grass was planted on coastal salty soils and it was 60-160 cm high after one growing season. The survival rate was from 30 to 90% depending on the quality of planting materials (Shu et al. 1999). It was recorded that the grass grew well after a severe winter with -15.9^{o}C in winter of 1991 and early 1992 while the trunks and branches of orange trees were completely damaged and local cold tolerant grass *Erianthus arundinaceus* was also injured to some degree (Lu and Zhong 1998). Cheng et al. (1994) pointed out that vetiver grass started to grow when daily mean temperature reached 10-15^{o}C or higher, and entered fast-growing period in 20-30^{o}C or higher with daily increase of height for more than 2-3 cm. The daily increase was 0.5 cm when the maximum temperature reached 40^{o}C or higher, indicating that it was tolerant to high temperature. Xia et al. (1998) indicated that in southern China in Guangdong Province vetiver the grass started to grow in March and reached fast-growing season from June to August, but the tillering peak appeared later (August) than height increase (June). But, it was also reported that the peak of tillering appeared in late April or early May (Mo 1998).

In September the grass started flowering and then stopped growing in October in south China. It was reported that the grass did not produce flower in northern area as in Anhui province (Huang 1999). It seems that the height of the grass and the biomass depended on the fertility of the soil, rather than temperature. For example, the grass reached over 3 m after one growing season since planting in Luotian of Hubei Province. But for the grass on white sand with little nutrients in Jiangxi Province it was around 1 m high.

The experience from Du'an County of Guangdong Province confirmed that the grass could withstand serious drought and long term water logging. The grass was planted on 1 April 1998. There were heavy water logging for three times: from 11 to 16 May with water depth for 50 cm above ground surface, from 23 to 30 June for 80 cm, and from 25 July to 5 August for 150 cm deep. Later from 1 September there was a long period of drought for two months. Inspection at the end of October showed that vetiver still grew well with 2 m high, while the elephant grass which was planted at the same time died during the first water logging (Science Bureau of Du'an County 1999). The determination of conductivity of leaf electrolysis showed that vetiver grass was more tolerant to drought than the other well-known grass such as *Alternanthera philoxeroides*, and *Paspalum notatum*. Also, vetiver grass was more tolerant hot and cold than the others (Xia and Li 1998). However, although vetiver can stand long term water logging, it could not grow well or even survive when water level was higher than the tillers during planting season (Po 1999, pers. comm.).

Shading

It was shown that shading played a negative effect on vetiver grass, both height and tillering and the total biomass considerably. The tillers accounted for 8.57 when 23.2% sunshine permitted compared with the control for 15.7. The increase of height was only 90.8 cm in nine months. When shading was removed, tillering recovered to normal, but height and biomass recovered slowly (Xia et al. 1998). It is commonly considered that vetiver was a pioneer grass for revegetation and afforestation on barren land. Later, when trees or other plants grew up vetiver grass would be degraded or disappeared.

Elevation

Application of using vetiver for highway protection in Wuyi Mountain indicated that vetiver height and tillering were limited when planted at 729 m in Wuyi Mountain (28^{o}N). A delayed regreening in spring after planting was recorded. Chen (1999) presented at Conference on Vetiver Bio-Engineering Technology for Erosion and Sediment Control and Civil Construction Stabilization, Nanchang, China). However, on Yunnan Plateau vetiver grass grew well in An Ning and Chu Xiong (25^{o}N) with elevation of 1 650-1 800 masl. It seems that the growth of vetiver grass was influenced not only by absolute altitude, but also by relative altitude, and also influenced by latitude. In the mountain areas with heavy fog and with less sunshine, the growth should be affected.

Fertilizer Requirement

On infertile slope land, fertilizer and manure application were good for vetiver grass. If the fertilizer was short of phosphorus element, vetiver growth was limited. For the same amount of fertilizer several applications were better than one application during the planting. On the contrary, large amount application of fertilizer influenced the survival of the planting materials. Although the survival rate and initial growth was influenced by fertilizer application, the quality of planting materials proved to be a dominant factor (Chen 1998). Experiment showed that urea application promoted the best growth and tillering only in a short period of time. When the application of fertilizer stopped, growth returned to normal level (Xia et al. 1998). Ding (1997) indicated that for nurseries it was not necessary to use fertilizers during planting season, while 300 kg/ha urea was needed when the grass started to grow. He suggested applying urea into the holes 15 cm deep from ground surface. Zhang (1998) indicated application of human waste was better than chemical fertilizers. And it was useful for vetiver survival and growth to dip the roots with clay paste when the grass was planted on wind blown sands which contained very little nutrients (Zhang 1997).

Pruning

Experiments in Guangdong province in the 1950's showed that when vetiver was 150 cm high, pruning to approximately 30 cm height produced on average 18.6 more tillers in 40 days compared with uncut plants. Meanwhile, the leaves after pruning looked much healthier than control (Mo 1998). Two prunings each year in February (or March), and August (or September) accelerated tiller formation (Xia 1995). More pruning may be needed if the grass was planted very close to crops. However, in the colder area one pruning each year may be enough.

Although research indicated that pruning improved tillering, most of the growers did not want to do so as they worried that pruning might influence the growth especially during the first year of planting.

Vetiver Technology for Erosion Control and Crop Production

Vetiver for Water Erosion Control

A lot of researches on the effect of vetiver hedges on soil conservation were implemented in southern provinces of China. The conclusion was almost the same, i.e. contour planting vetiver hedgerow was very efficient in soil conservation. When the grass hedges was established on red soil of 50-80 slopes the annual run off and soil loss reduced by between 50 and 67%. The depth of roots was twice as much as the grass *Erianthus arundinaceus* and Africa foxtail grass. The average range of the diameter of root system was 5.0 and 3.2 times those of the *Erianthus arundinaceus* and Africa Foxtail grass respectively. And the dry biomass was 3.8 times of that of *Erianthus arundinaceus.* As a result, when vetiver was planted 20 cm apart, the hedges row formed just after one growing season (Lu and Zhong 1998). He et al. (1997) indicated that vetiver grass grew quick enough to form hedgerows in a short time resulting in excellent soil erosion control. When vetiver hedgerows were established every 1 m of vertical spacing, in the third year run off was reduced by 12.7 and 48.1% of that of contour terrace and slope cultivation respectively, while the soil loss reduced by 21.5 and 86.1% than the control. Similar results were obtained in Guangdong Province (Xia et al. 1998; Chen 1998).

Vetiver for Wind Erosion Control

In Pingtan Island where windstorm and sand storm occurred frequently and threatened crop production affected people's life. Although trees such as *Casuarina equisetifolia* L. were planted years ago the sandy storm was still serious. Farmers had to use dead plants to build fence for crop production. Since 1992, vetiver was used to establish windbreaks at 6-8 m spacing to stabilize sandy dunes and prevent sandstorm, and protect jojoba and vegetable crops quite successfully. It was recorded that the wind speed was reduced by 58 and 79.4% at the site of 5 and 2 m, respectively, from vetiver hedgerows (Zhang 1998).

In the Poyang Lake area of Jiangxi Province, according to satellite information, there are altogether 264 000 Mu (1Mu = 1/15ha) sandy land and mobile dunes, covering more than one dozen of counties. Most of these areas have very little, if any, vegetation cover. People in the area have been suffered from wind-blown sands for years. In Xingjian County, about 20 km west to Nanchang, the capital of Jiangxi

Province, there were 15 000 Mu of land damaged by dune and two villages were forced to remove. In 1998, vetiver grass was introduced to stabilize these sand dunes very successfully. Tests showed that vetiver promoted other weeds to grow and helped the revegetation.

Vetiver for Soil Fertility Improvement and Crop Production

Research showed that every 100 m hedgerows produced 800-1500 kg fresh pruning, i.e. when vetiver hedgerows was established every 2 m interval there were be 4.0-7.5 t of pruning/ha/yr. When it was used as green manure the soil organic matter, bulk density, porosity, and C, N, P, and K contents improved considerably, and therefore corn yield increased by 34.8% (Lu and Zhong 1998). Xia et al. (1996) indicated that in vetiver protected orange orchard the temperature at ground surface, 20 cm below ground surface, and 150 cm above surface were all lower than the orchard without vetiver in hot summer, while air moisture increased. Chen (1998) obtained a similar result. Hu et al. (1997) indicated that in the dry autumn in the vetiver hedgerow protected orange orchard the soil moisture at 0-60 cm increased by 10.3 and 27.8% when vetiver pruning was used as mulch than that straw mulch orchard and the orchard without mulch respectively. Further more, the vetiver mulch behaved better and longer than straw, since vetiver decomposition loss in 114 days was only 39.2%, while straw was 75.0%. The amino acid content of soil from vetiver protected orchard was 57.4 mg/kg higher than control, also indicating that vetiver increased soil organic nitrogen (Chen et al. 1994).

Vetiver Technology for Embankment Stabilization

Highway Embankment Stabilization

In addition to the outstanding results of vetiver applications in the protection of river bank, sea shore, fish pond, and terrace stabilization mentioned below, the most inspiring issue was that vetiver grass was most welcomed by highway institutions for embankment stabilization. In 1995 in a trial conducted in Guangdong Province. Vetiver was contour planted with spacing of 2-3 m between rows on the embankment of national highway No.105 where soil erosion was serious. Some species of trees were planted between rows such as *Acacia mangium*, *Syzygium cumini*, and *Melaleuca leucadendra* (Ao et al. 1998). Later in 1997 a demonstration was established by an NGO in Jianyang of Fujian Province. Vetiver was contour planted and also in crisscross pattern (honeycomb). The test showed that the honeycomb pattern planting was more effective than contour planting in stabilizing highway batters and protecting rice field along the road at lower part. The successful test attracted interests of the Highway Bureau and also rice farmers, and a follow up larger demonstration was implemented with tens of thousands square meters in 1998. In 1999, more application for highway embankment stabilization started in Jiangxi, Fujian, Zhejiang, and Yuannan Provinces.

Since the establishment of Chonqing Municipality, highways have been constructed in a large scale in the Three Gorge area. However, most of the highways were built along rivers and a lot of soil and rock were dumped into the river and caused further risk of slope instability and erosion. Vetiver was selected as first species for vegetation cover and slope stabilization. The Fuling Forestry Institute has actively involved in the coordination of vetiver technology development in this area.

Based on these successful examples, vetiver grass was introduced into highway institution very rapidly and widely through joint efforts of scientists and engineers. The grass was introduced during several national and regional highway conferences. Vetiver papers were published by several national or regional highway journals. The Fujian Highway Bureau acted as a pioneer in officially accepting vetiver for standard highway embankment stabilization. On 8 July 1998, the Highway Bureau formally issued a memorandum asking all highway institutions throughout the province to study vetiver technology and to use the grass to protect the embankments. So, Fujian Province became the first one to authorize vetiver as a grass for highway stabilization in China, and possibly in the world. This year many more large demonstrations are being established in other province, Fujian, Jiangxi and Zhejiang Provinces in particular. The grass is being planted for highway stabilization in Zhangzhou, Quanzhou and Sanming Prefectures, and for dam stabilization in Pingtann Island of Fujian Province. More engineers want to see the demonstrations and to test the grass as they realized that the grass can help them save money and solve their erosion problem. It costs only 1/10 using vetiver than using rocks that may cause further environmental problem. Through the International Vetiver Workshop held in October 1997, and the International Conference on Vetiver Bio-Engineering Technology for Erosion and Sediment Control and Civil Construction Stabilization held in October 1999, it is hoped that vetiver grass technology (VGT) will be spread more widely to engineers in railway, dam, reservoir, and other engineering institutions.

River and Coastal Bank Stabilization

In Pingtan Island of Fujian Province, with the annual average wind speed at 8.4 m/s, and the days with wind speed of 14 -17m/s amounting to 125 days each year, rain storm and sand storm often destroyed river and sea banks and threatened people's lives. Farmers had to clean the silts from river and used rocks to stabilize banks to save their valuable fresh water resources. But it was expensive to use rock and the rock wall was also subjected to collapse in the sandy area. Besides, farmers had to move their houses from the coast to avoid collapsing. Since vetiver grass was planted, the riverbanks were well protected and farmers no longer have to de-silt the rivers. Farmers then introduced the grass to protect coastal shore against sea wave. Results showed that the vetiver protected coastal bank from typhoon damaging quite successfully. In 1996, there was a typhoon, which led to sea water level 7.5 m high over bank. After the storm, there was no damage on vetiver protected bank, while where there was no vetiver the bank was destroyed for 200 m long.

Fish Pond Protection

Since economic reform, farmers built many fish ponds in the coastal area to improve their standard of living. Unfortunately, the ponds were damaged from wind storm and sea wave. Following the successful results described above, farmers voluntarily planted the grass for fishpond protection and have found it was very effective. After several years of hard work since 1992, there were 660 ha of vetiver grass planted. Now, the grass was used to protect water reservoirs in Fujian Province, and as living hedges to protect home gardens and irrigation channels.

New Tests and New Applications

Water Pollution Control

Many new tests and new application are emerging in the recent few years. The purification of eutrophicated water with vetiver was tested. Vetiver was grown in river water polluted by domestic sewage, in pond water and in tap water using the 'floating island' technique. During a 4-week culture, vetiver grew normally in these three water bodies, but did the best in the polluted river water. Net increases in plant height were 80, 60, and 50 cm with tillers numbering 4, 1, and 0 for river water, pond water and tap water, respectively. The appearance of river and pond water was clearly improved and transparency increased after planting vetiver. For river water, the total N and water-soluble P removed was 34, and 68.1% after 1 week of growth respectively; the removal rate was up to 99% for P after 3 weeks, and 82% for total N after 4 weeks. The removal of N and P in pond water was not as obvious as in river water because of less contaminants (0.014 mg N/L and 0.70 mgP/L) (Zheng et al. 1998). These findings suggested that vetiver is a good plant for purifying eutrophic water and has application potential for the purification of Taihu Lake where the agricultural non-point nitrogen pollution was as high as 35 000 t N/yr, accounting for 25.2% of the total annual N application and resulting in water eutrophication (Environmental Group 1997).

Contaminated Land Rehabilitation

Experiments on the effect of heavy metals on vetiver growth were conducted. The tests included slight pollution (Cu 33 mg/kg, Pb 100 mg/kg, Zn 66 mg/kg, Cd 0.5 mg/kg, and As 10 mg/kg) and heavy pollution (Cu 100 mg/kg, Pb 300 mg/kg, Zn 200 mg/kg, Cd 1.5 mg/kg, and As 30 mk/kg), and control treatment. Results indicated that the high contents of pollution elements limited the growth of vetiver in the first year, but the effect reduced in the second year. For the slight pollution, there was no difference with the control in the second year. Other experiments showed that when 5% of waste soil or wood powder was applied to mine tailings, vetiver grew better than that applied with N, P, K. Based on the results of these tests, vetiver grass was planted in a large scale for pollution control and mine tail stabilization in Jiangxi Province in 1999 (Chen 1999).

Flood Erosion Control

In Chongqing Municipality, situated at the upper reaches of the Yangtze River, in the Three Gorges area, soil conservation became a critical issue to reduce the harmful effect of sediments to the dam and to minimize the economic losses caused by heavy flooding in the lower reaches. Supported by local government vetiver was introduced to the area, to be used as pioneer plant for afforestation, controlling new soil erosion caused by resettlement of immigration, and retaining sediments on lower land.

Salt Tolerance

Vetiver died when it grew on artificial sea water with salt content of 48 dS/m (Chen 1999). However, pot trial and field tests on the site 200m from sea in Tianjing (39^{o}N) of north China showed that vetiver grew well on the soils containing salt 0.8%. The grass reached a height of 160 cm in the first year of planting (Shu et al. 1999).

Benefit

Hu et al. (1997) indicated that in addition to conserve soil and therefore increase the crop yield, vetiver pruning was used for feeding cattle and goat, and fish, especially in northern China such as in Anhui and Hubei Provinces where there were very few fodder species. But geese did not feed on the grass possibly due to its smell. Zhang (1998) pointed out that when using vetiver pruning to cultivate edible mushroom, there would be 5.28 t of fresh mushroom produced from one Mu of land, which can generate over 20 000 Yuan RMB. Therefore, vetiver was also beneficial to the environment as it could save a lot of wood that was normally used for mushroom cultivation.

For engineering, it was commonly recognized that vetiver hedges could save 9/10 of the construction cost of using concrete. Just one cut slope in Fujian as an example along highway with 20 000 m^2 saved costs for 1.008 mill.Yuan using vetiver than using concrete. As a result, VGT is being extended very rapidly to highway. The railway institutions are also starting to use the grass in Yunnan Province. Since there is a large demand of planting materials in highways and other constructions, small farm holders are also earning money from selling planting materials. The price for a single tiller was $0.012 in spring of 1999. In Yuannan Province vetiver was used as fuel, and in Fujian Province farmers use vetiver pruning to produce small handicrafts. Chen (1998) indicated that it would save 1 060 Yuan/ha using vetiver as mulch.

Jiji Grass for Soil Conservation in Cold and Dry Area

In 1998 three field investigations were carried out in Loess Plateau area involving 12 counties in 4 provinces in order to study the possibility of using Jiji grass (*Achnatherum splendens*) as a ‘cold tolerant vetiver’ for the extremely dry and cold area. Mr. Richard Grimshaw of The Vetiver Network led the first investigation in May. Through field investigations and discussion with villagers the group realized that Jiji grass was similar to vetiver but extremely drought and cold tolerant. Its characteristics are:

1. Its natural habitat is the saline soils in northwestern China such as Inner Mongolia, Ningxia, and Xinjiang Provinces. When planted on upland soils (such as the Loess soils) it grows extremely well.
2. Like vetiver it also belongs to the grass family (Poaceae). Some farmers in northern Shanxi use it to stabilize the vertical cuts made in the hill slopes above their houses to prevent slippage and damage to the house, and also to use it to protect their home garden from collapsing.

3. The grass has a strong, deep (at least 3 m) and profuse root system.
4. It is completely drought proof, and withstands extremely cold.
5. It has good longevity and is usually propagated vegetatively by plant division and is not invasive under cultivation condition.
6. The grass was also used to feed animals with young leaves, to make basket, broom, mattress, rope, curtain, shed roof cover, and as traditional medicine. It was also used to make pulp and for highway stabilization (as we saw in Inner Mongolia).

The Jiji grass appears to have many similarities to vetiver grass, although there are some very distinct differences, including a less dense and weaker leaf system. However, since there are enough similarities, as well as farmer experience and knowledge, it is suggested that Jiji grass could be the key to long-term embankment stabilization (terraces, dams, and roads) in northern China and other similar areas in the world. They should be planted closely in contour hedgerows across the slope of embankment as has been widely proven for vetiver. It also may well be possible to use it as an effective contour hedgerow on non-terraced sloping land. The China Vetiver Network's newsletters included information on jiji grass. Some experiments were conducted in Ningxia Province on Loess Plateau, including:

- Effect of Jiji grass hedges on runoff and sediments (amount and nutrients),
- Effect of Jiji grass hedges on the intercropped plants,
- Ecological change of surface soil layer and micro climate of intercropped land,
- Growth behavior of Jiji grass under different water, pH, soil, fertility, and landform.

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