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NOTE

A NOVEL APPROACH TO GROWING MANGROVES ON THE COASTAL MUD FLATS OF ERITREA WITH THE POTENTIAL FOR RELIEVING REGIONAL POVERTY AND HUNGER

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Abstract: About 700,000 mangroves, chiefly *Avicennia marina*, were grown in the tree-less mud flats of Eritrea by a newly developed technology that provides required nitrogen, phosphorus, and iron. A method of fertilization was devised that eliminates the possibility of fertilizer runoff. Novel methods have been developed for planting seeds at the final site and protecting seedlings from uprooting by wave action and encircling wrasse. Methods were developed for preserving mangrove seeds by sun-drying, which results in a stable grain-like product. However, dried mangrove seeds and foliage are insufficient for supporting good growth of sheep, which was a desired outcome. Supplementation of mangrove material with small quantities of a stress food for sheep, consisting of fat-soluble vitamins and minerals renders the mangroves an adequate food. Together, these findings are capable of forming a profitable sea water agriculture and relieving hunger and poverty in many regions of the world.

Key Words: mangroves, nitrogen, phosphorus, iron, sheep stress food

INTRODUCTION

Eritrea has approximately 1500 kilometers of desert sea coast (including islands). Mangroves grow in only about 15% of the coastal intertidal zone, and where they grow, they form a narrow fringe, usually no more than 100 meters wide (Ross et al. 1996). We observed that mangroves typically occur in areas called ersas where the seasonal rains are channeled to enter the sea each year. The conventional explanation is that fresh water *per se* is required (Spalding et al. 1977). This explanation is untenable because the amount of fresh water and the duration of flow are too short to affect salinity to any extent. Our explanation, which is a radical departure from conventional belief, is that the fresh water is bringing nitrogen, phosphorus, and iron from land, and the fringes are no more than 100 meters wide because the fresh water may not be able to carry these minerals in sufficient quantity more than 100 meters from the high tide line.

On comparing the composition of sea water to that of a complete algal medium, Zarouk medium, it can be seen that sea water contains all the mineral elements in sufficient quantity to support plant growth except for nitrogen, phosphorus, and iron (Fox 1996). We predicted that the treeless, intertidal areas of Eritrea, which occupy 85% of the coast, could be successfully planted with mangroves if these elements were provided and that the mangrove fringes could be widened if the trees were provided with nitrogen, phosphorus, and iron. Both of these predictions have proven true. Methods were developed to deliver fertilizer at a controlled rate that greatly reduces the possibility of runoff. Experiments were carried out to find ways of rendering mangrove foliage and seeds to serve as a complete food for livestock.

MATERIALS AND METHODS

We used predominantly the mangrove, *Avicennia marina* (Forsk.) Vierh., and to a much lesser extent *Rhizophora mucronata* Poir. Both plants are indigenous to the area. *Rhizophora* are almost extinct in Eritrea because of their value as construction timber. Our plantings will contribute to its preservation. *Avicennia* seeds are planted in their final site by placing them in a metal can cylinder constructed by removing the top and bottom of the can (Figure 1). The can is embedded in the soil about one centimeter above the ground and is held in place with an iron rod. The top of the can

Figure 1. Technique of planting seeds at the final site.

Figure 2. Test of seedlings to fertilizer release.

is covered with a wire mesh to prevent the seeds from being washed away by wave action. Planting seeds in the final site saves considerably in time and effort by avoiding the necessity of transplantation. To prevent encircling wrasse and wave action from uprooting young seedlings, we use a modification of the Riley encasement device (Riley and Kent 1999). We construct a wire-mesh cylinder about 25 cm long and about 5 cm in diameter fastened to an iron rod 60 cm in length (Figure 2). The rod is pushed into the soil to a depth of 35 cm until the cylinder encloses the newly emerging plant.

Our method of providing a slow release fertilizer to trees growing in an area continually awash in sea water is to place 500 g of a 3:1 mixture of urea and diammonium phosphate in a polyethylene bag, tie the bag so it is sealed shut, and puncture one surface three times with a 0.2-cm-diameter nail. The bag is buried next to the tree with its upper surface and the nail hole punctures about 10.0 cm below the soil surface. This arrangement allows the fertilizer to exit the bag by slow diffusion—fast enough to nourish the tree but slow enough not to be wasteful. By digging up bags after various times, we estimated that the bags deliver all their fertilizer in about three years. From the density of planting, 5000 trees per hectare, we estimate that the fertilizer is delivered at a rate of about one ton per hectare per year. This is approximately the desired rate. The desired rate is calculated as follows: a hectare of *Avicennia* drops about 10 tons of litter per year, which is about 19% protein, or two tons of protein (Hamilton and Snedaker 1984, Steinke and Ward 1988). We assume that the trees synthesize three tons of protein per hectare per year. To synthesize three tons of protein requires about one ton of fertilizer.

A barbed wire fence is erected around the trees, and guards are employed to prevent camels from destroying the trees. To measure possible fertilizer runoff, water was collected a few meters offshore from our plantings and from a natural mangrove forest about a half hour before the tide reached its lowest level. The water was analyzed for nitrogen and phosphorus content by the analytical laboratory of the Ministry of Fisheries by the method of Parsons et al. (1984).

Avicennia seeds are soaked in sea water for three days to remove the cover and facilitate drying. They are then placed in the sun to dry resulting in a grain-like material that is avidly eaten by animals up to a year after drying.

To test the response of seedlings to fertilizer release, concrete pots were placed in an intertidal area where trees had not grown before and filled with soil from the same area (Figure 3). Each pot had a plastic bag of fertilizer and piece of iron. Two bare root seedlings at the four leaf stage were planted in each pot. The number of holes punched in the bags varied from right to left −0, 1, 2, 4, and 8. The trees were photographed five months after planting.

RESULTS

In the test of seedling response to fertilizing, it took five months for the trees to die for lack of fertilizer because they could apparently survive a long time by

Figure 3. A three year old planting of mangroves where mangroves had not grown before.

Table 1. Analysis of fertilizer content of seawater offshore from our plantings, offshore from a natural mangrove forest, and from the open sea.

	Nitrogen Content	Inorganic Phosphate
Area A in Hargigo with 3 tons of fertilizer per hectare	Not detectable	0.04 mg/L
Area B in Hargigo with 3 tons of fertilizer per hectare	Not detectable	0.03 mg/L
Natural mangrove forest	0.02 mg NH$_3$/L	0.04 mg/L
Unfertilized	0.01 mg NO$_3$/L	
Water from open sea	Not detectable	0.06 mg/L

getting nutrients from their cotyledons. Without any holes, and therefore no added nitrogen and phosphorus, the trees died. All pots had extensive root growth in the soil beneath the pot, as the roots grew through the drainage holes and formed a volume of roots greater than in the pot—even for the two trees that died. This shows that the soil of the area cannot support the growth of trees without fertilizer. Increasing the number of holes from 1 to 4 improves the growth, while 8 holes probably results in over-fertilization. Our standard procedure is to use fertilizer bags with 3 holes.

Figure 4 shows a planting that is about three years old. No trees grew in this area before we planted it. Before we realized the need for fertilizer, over a hundred trees were planted in this area and all died. After the need for fertilizer was understood, virtually all trees grew successfully with our method of fertilization.

Table 1 shows the measurement of nitrogen and phosphorus offshore from our plantings and offshore from a natural mangrove forest that was not fertilized by us compared to the fertilizer content of water from the open sea. It can be seen that offshore from our plantings, where three tons of fertilizer is applied per hectare, no evidence of nitrogen or phosphorus runoff is found. Offshore from a natural mangrove forest, nitrogen and phosphorus levels are appreciably higher than the open sea. This tends to support our assumption that natural mangrove forests are provided with fertilizer by the seasonal rains.

Figure 4. Modification of the Riley Encasement device.

Table 2 shows the growth of recently weaned sheep on a diet of dried mangrove seeds and foliage, as well as seeds and foliage supplemented with 7 g of Blue Seal stress food (Blue Seal Feeds, Inc., Londonderry, NH, USA) per sheep per day compared to weanlings that were free to forage. Free range foraging produced optimal growth, while seed and foliage produced little growth and the animals appeared unhealthy. Supplementing the mangrove material with 7 g per day of Blue Seal 20/5 increases the growth rate of sheep. This shows that mangrove material can provide the bulk of the food if supplemented with small amounts of other nutrients. For most of the year there is insufficient for-

Table 2. Growth of sheep on a free range forage, unsupplemented mangrove feed, and mangrove feed supplemented with Blue Seal stress food.[1]

	Weight at time 0	Weight at 56 days
Group A	8.5 kg	16.3 kg
Group B	7.5 kg	9.0 kg
Group C	10.4 kg	16.0 kg

[1] Freshly weaned sheep were kept on different diets. Group A was allowed free range forage, group B was fed mangrove foliage and dried seeds, and group C was fed mangrove seeds and foliage plus a supplement of 7 g per day per sheep of Blue Seal stress food. Each group consisted of three sheep, and the average weight was recorded. Group C was set up after it was found that group B showed little weight gain. The age of group C is a little older; hence, their starting weight is a little greater.

age, which makes mangrove material highly desirable. These growth experiments are being continued to find a locally produced supplement. For example, we are experimenting with fish meal and *sargassum,* which are in plentiful supply.

DISCUSSION

Sea water is deficient in nitrogen, phosphorus, and iron. It follows that plants growing in the intertidal area must have a source of these minerals. This is almost always furnished by fresh water from land. In arid countries, areas where fresh water enters the intertidal zone are limited. It is in these areas where mangroves grow naturally. We have developed new ways of substantially increasing the mangrove forests in tropical coastal deserts by making it possible to grow mangroves in the tree-less mud flats by artificially providing these elements. Such mud flats make up the greater part of the intertidal area of these coastal deserts. Even in tropical countries with plentiful rain, we can increase mangrove forests by widening the growth area by fertilization. This can potentially reduce the damage due to tsunamis. We have also shown that mangroves can provide the bulk of the food for sheep with small and inexpensive supplementation of nutrients. Each of these findings is very simple but new and original. We believe that our approach has the potential to create a cost-effective sea-water agriculture and eliminate hunger and poverty in many regions of the world.

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