Drip Irrigation to Revegetate Mine Wastes in an Arid Environment

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Highlight: Drip irrigation may be an efficient and effective technique for revegetation of steep slopes in an arid environment. Where supplemental irrigation may be necessary for plant establishment, drip irrigation offers many advantages. There is less hazard of runoff and erosion on steep slopes; excessive salts and phytotoxins can be leached from the root zones; it is adaptable to remote areas without pressurized water systems; it conserves water where water is costly or scarce; and it helps to promote deep root growth and better plant development. Drip irrigation may be a very valuable tool for the reclamation engineer to select as a technique needed to meet his particular revegetation needs.

Revegetation of disturbed sites and mineral wastes in an arid environment is extremely difficult. In these areas the main problem is seed germination and plant establishment. With the sporadic and undependable rainfall, any attempt of revegetation is often dependent on moisture conservation or irrigation techniques. Once vegetation is established, through techniques such as range pitting or gouging, moisture collars or condensation traps around individual plants, or supplemental watering by irrigation, the plants will survive (Bengson 1975). Often irrigation is the only solution for the establishment of these plants.

In the arid environment mining disturbances create new adversities for a revegetation program to cope with. Among problems such as harsh soil conditions are the problems of trying to revegetate the steep slopes of loose unconsolidated waste materials. These steep slopes often cannot be graded to contour and so exclude the use of equipment on the slope. Therefore, techniques such as pitting or condensation traps around plants are negated. Added to this problem is the fact that the slope intensifies the droughty conditions by rapidly draining away soil moisture and with accelerated runoff (Bengson 1975). Under these conditions irrigation may be the only way to establish vegetative cover on the slope.

Until recently the only way to irrigate steep slopes was with sprinkler irrigation systems. These created problems of their own. Not only did they demand large volumes of water and high operating pressures, but they also created erosion hazards. These problems become acute in areas where water is unavailable or at a premium, or where the slopes are made up of particularly erosive materials.

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Drip Irrigation

Now there is a new irrigation technique available for use in revegetating these steep and difficult slopes. It's called "drip" or "trickle" irrigation. It was developed in Israel in the 1960's for agricultural irrigation. Its use in arid land reclamation was pioneered by the California Highway Department in revegetation of high berms (DeReemer and Bach 1974).

The primary advantage of drip irrigation is the conservation and efficient use of water. In areas of water shortages it is becoming a more profitable and popular method of irrigating. Today thousands of acres of agricultural crops are being converted to drip irrigation.

Basically drip irrigation is designed to deliver water (and nutrients if injected into the water line) to the individual plants at a very low rate of flow (1–2 gallons per hour). This is accomplished with an emitter which restricts the flow of water by constriction. To operate properly pressures must be regulated to 2–15 psi. By carefully reducing the flow from each emitter in this way the infiltration rate of any soil can be closely matched so that there is very little water on the surface. In this way maximum water penetration is achieved and the plants develop optimum root structures. This is especially advantageous in arid land revegetation because the plants develop deeper, stronger roots faster and are better prepared to survive on the natural rainfall once the irrigation is removed. Also, by deep irrigating, water is more efficiently used by the plant, less is lost to evaporation, and irrigation is required less frequently.

For mine waste revegetation, particularly on steep slopes, drip irrigation offers several advantages (Bengson 1975). First is the reduced hazard of surface runoff and erosion. Plants respond quickly to drip irrigation and the faster vegetative growth means quicker slope stabilization. The deeper wetting patterns will help to leach excess salts and other phytotoxins out of the root zone. Also, poorer quality water may be used in drip irrigation.

Costs of drip irrigation systems are highly variable. The costs of many different emitters on the market vary from just a few cents to a dollar or more each. The cost per acre varies with plant densities since there is at least one emitter for each plant. The cost of a complete drip system, fully installed, may run as high as $1,000 per acre for 335 plants per acre. The systems are quite durable and portable however, so they can be reused over the years to revegetate other areas, thereby spreading the cost out over several acres and reducing the overall cost per acre. One of the cost advantages of drip irrigation is in the water system required for operation. The lower flow and pressure requirements eliminates the need for the sophisticated water systems usually associated with sprinkler irrigation. Inexpensive and smaller diameter plastic pipe can be used. For remote areas a water tank could supply the necessary volume and head pressure required to operate a drip system. Also, savings in fertilizer costs can be realized since nutrients can be supplied directly to the plant through injectors attached to the irrigation system. This concentrates the nutrients at each plant individually and delivers the nutrients to the roots for more efficient utilization, reducing the volume of fertilizer needed.

One serious disadvantage of drip irrigation could involve an accumulation of salts at the edge of the wetting zone (Bengson 1975). These salts could then be drawn back into the root zone after the irrigation is removed and become toxic to the plant. Or, in poorly drained soils, they may present a barrier to root development. Another major disadvantage of drip irrigation is that it is relatively inefficient for establishing solid vegetative cover with grasses (Bengson 1975).

Other disadvantages of drip irrigation to be noted include the maintenance required to keep the system operating properly. Filtered water is essential and a good filter system must be installed and maintained to remove sediments and particulates (Bengson 1975). Although some emitters on the market are more trouble free than others, they can become clogged and must be flushed out or replaced. The plastic driplines need maintenance also. Expansion and contraction caused by temperature fluctuations can cause joints to separate. Another disadvantage of drip irrigation is that the spatial arrangement of plants tends to be linear along the driplines. This is particularly visible from the vertical plane of view (Fig. 1). However, on the horizontal plane this linearity is not as evident when the emitters are randomly staggered (Fig. 2). Other problems experienced include rodent damage to the plants and driplines (Figs. 3 and 4). Often these rodents are attracted to the area from the surrounding desert by the fresh vegetation and water. Also, we have noticed a build-up of salts on the soil surface near some of the emitters. This is due to the highly alkaline soils and could cause a problem in trying to get native annuals to seed in under the plants and fill in the barren areas between plants.

Drip Irrigation Used at Asarco

Drip irrigation has been used to successfully revegetate mine wastes in southern Arizona. At Asarco's Sacaton mine we are using drip irrigation to revegetate the waste dump slopes and other steep slopes.

The Sacaton mine is an open pit copper mine and lies in what is classified as the "Phoenix Desert Shrub Environmental Zone" (Anon. 1973). Here the annual rainfall averages 6–8 inches per year. The mine waste material and native desert soils are highly alkaline with a pH of 8.5–8.9 and of a fine sandy loam

Fig. 1. *Mature plants on water tank hill slope. Note size of plants after 1 year's growth and linearity when viewed on the vertical plane.*

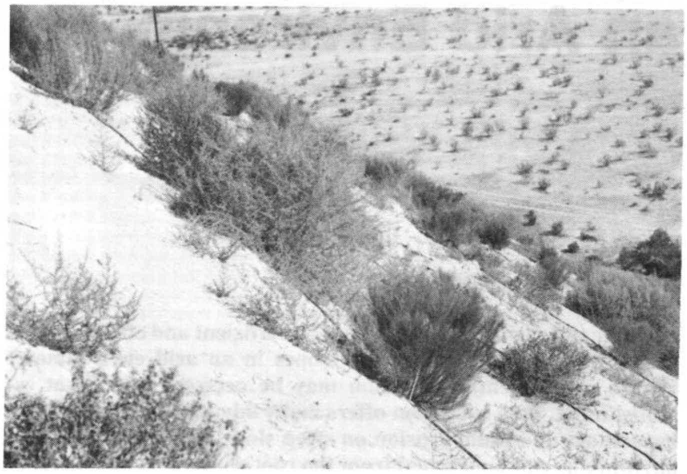

Fig. 2. *Trees and shrubs planted on water tank hill the previous year. Note random spacing and visual loss of linearity when viewed on the horizontal plane.*

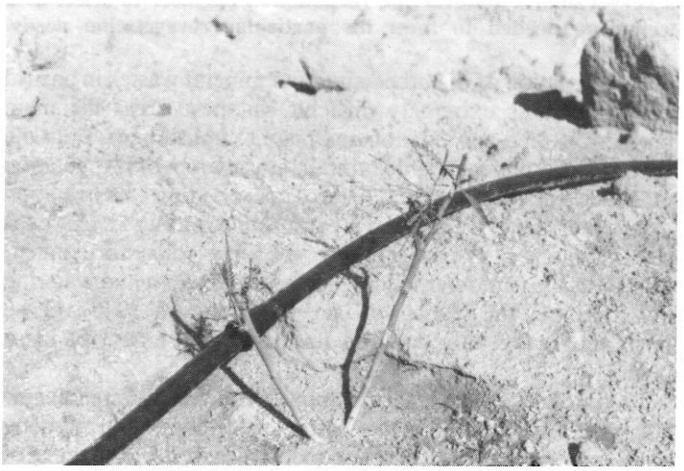

Fig. 3. *Browsing damage to young palo verde by rabbits and rodents.*

Fig. 4. *Rodent damage to drip line. Note chewing and leaks.*

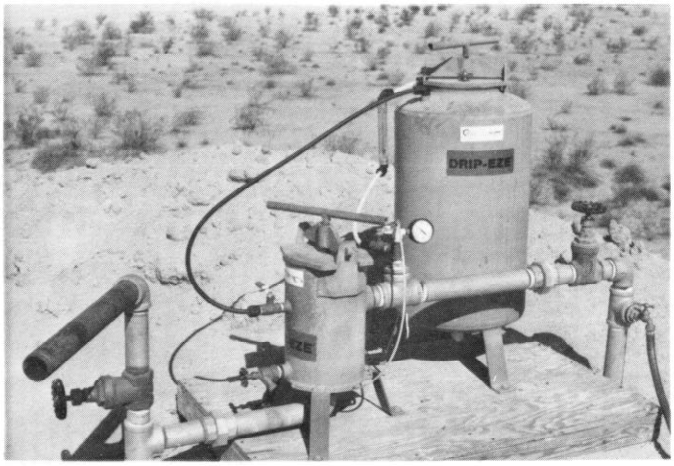

Fig. 5. *Filter/fertilizer injector system (filter is the smaller tank).*

texture. The natural vegetation is characterized by shrubby species such as desert saltbush (*Atriplex polycarpa*) and triangle-leaf bursage (*Franseria deltoides*), with several annual grasses and forbs. A few scattered trees such as palo verde (*Cercidium* sp.) and mesquite (*Prosopis* sp.) are found intermingled with a few cacti. Since there are few, if any, perennial grasses adapted to this environment or found on the surrounding desert, we decided that to try to establish grasses for stabilization of the slopes would not be ecologically sound. Instead we decided to establish shrub and tree species on the slopes and let the annuals fill in between the plants as seed blew off the desert. For this type of revegetation program drip irrigation was the best technique to supply the plants with the supplemental water needed for plant establishment.

We started our revegetation work on the steep slopes of the water tank hill as soon as construction was completed in the spring of 1974. We used a "DRIP-EZE" drip irrigation system and approximately 2,000 one-gallon sized nursery grown plants on an average spacing of 10 by 15 feet over 6 acres. The drip system included the "DRIP-EZE" in-line 1-gallon/hour emitter and a filter-fertilizer injector system (Fig. 5). The "DRIP-EZE" emitter is designed to reduce the flow by constriction through a series of micro-grooves inside a cone shaped chamber. The cone shaped chamber allows for a flushing action to wash sediments out of the micro-grooves, which would otherwise clog the emitter. We planted the following species at a density of approximately 325 plants per acre: palo verdes (*Cercidium floridum* and *Parkinsonia aculeata*), mesquite (*Prosopis* sp.), bursage (*Franseria deltoides*), hopseed bush (*Dodonea viscosa*), brittlebush (*Encelia farinosa*), desert broom (*Baccharis sarothroides*), and saltbushes (*Atriplex canescens* and *semibaccta*). These species were selected for their adaptability to the local environment, fast growth and form, aesthetics, and harmony with the surrounding desert flora. The taller growing species were planted along the top edges to disrupt the smooth, flat visual impact of the edge while the lower growing species were used to stabilize and cover the face of the slope.

To stimulate growth, we added a 21 gram "AGRIFORM" (20-10-5) fertilizer tablet and approximately 2 ounces of "OSMOCOTE" (18-9-13) slow release fertilizer to each planting hole with the plants. This treatment provided each plant with a balanced supply of nutrients for up to 9 months. This year we will supplement the plants' nutrient requirements with the fertilizer injector system. This will help the plants develop their maximum growth before we discontinue the supplemental irrigation.

The initial irrigation schedule called for two 8-hour irrigations per week during the peak of the summer months. During the cool season the plants were maintained by one 8-hour irrigation per week. Using tensiometers placed at 12 and 24 inches (Fig. 6), we determined that this irrigation schedule was sufficient to maintain optimum soil moisture. The growth response of the plants has been phenomenal. In 1 year the plants have grown three or four times their original size (Figs. 7 and 8). This year we will begin to acclimate the plants to the natural rainfall by reducing the irrigation to once a week in the summer, then down to once a month. Next year the plants will not be irrigated, but the drip system will be left in place so we can supply one or two more irrigations if necessary to help the plants make it through the first dry season. Soil moisture will be monitored with the tensiometers to determine the degree of moisture stress the plants can tolerate.

This year we expanded our revegetation program at Sacaton and installed a "DRIP-EZE" system and planted the waste dump slopes. We used the same emitter spacings and planting techniques used on the water tank hill. In addition to the species

Fig. 6. *Tensiometers for measuring soil moisture. Each is placed at a different depth to record both shallow and deep moisture levels.*

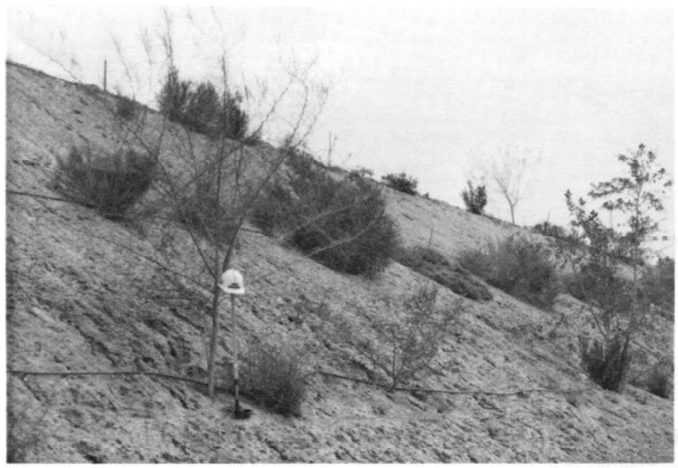

Fig. 7. *Growth of plants on water tank hill slope after 1 year. Note size of palo verdes, saltbushes, and desert broom. Note growth on naturally seeded tree tobacco in lower right hand corner.*

[1]"Tradenames" are used throughout this article for the benefit of the reader and do not imply endorsement of the product by the *Journal of Range Management*.

Fig. 8. *One year's growth of palo verdes planted around parking lot.*

we used last year, we planted creosote bush (*Larrea tridentata*) and several additional varieties of saltbush (*Atriplex torryi, rhagodioiedes,* and *polycarpa*). This year we planted over 3,000 species on 9 acres of slope surface.

To find ways to reduce our revegetation costs, we are experimenting with hydroseeding using drip irrigation. With the rising costs of gallon-sized nursery stock and labor, the cost of revegetating on a plant density of 335 plants/acre is approximately $600 per acre. By direct seeding over a drip irrigation system, we hope to be able to reduce these costs.

We experimented with six of the many different drip irrigation systems available on the market today with different emitter spacings, some buried and some laid on the surface, to determine the feasibility of direct seeding (Fig. 9). One system consisted of the "Chapin Twinwall" dripline woven into Gulf States Paper erosion control fabric "HOLD-GRO." The "Chapin Twinwall" dripline is designed as two plastic tubes bonded one on top of the other. The upper tube is smaller and has emitter holes (about the size of small pin holes) spaced at any distance desired (18 inches in this case). The lower tube is larger and has one feeder hole to supply several emitter holes. The flow is controlled by constriction as water flows through these two chambers. The "HOLD-GRO" material is a paper

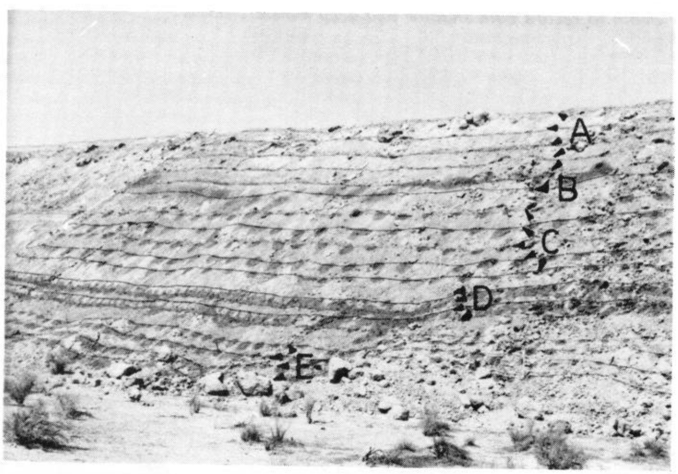

Fig. 9. *Direct seeding with drip irrigation test area on waste dump slope. Note wetting patterns of the different drip systems: A) "VIAFLOW"; B) "REBAT"; C) "CHAPIN Microtube"; D) "ANJAC Biwall"; E) "SUBMATIC." The "HOLD-GRO" fabric with "CHAPIN Twinwall" is visible on the far left.*

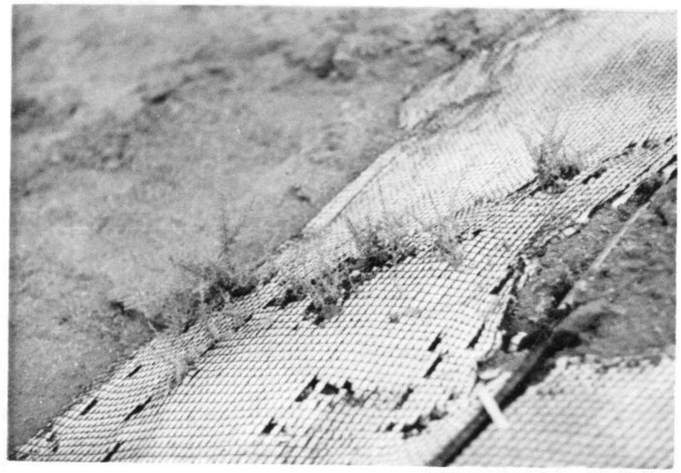

Fig. 10. *Growth of* Atriplex polycarpa *under "HOLD-GRO" erosion control fabric. Note how plants grow through the paper mesh. "CHAPIN Twinwall" drip line is seen in lower right hand corner.*

mesh fabric which is stapled to the surface. We hand broadcast seed of various species and fertilized the prepared slope as the fabric was rolled out and tacked down. The paper mats act to protect the soil surface, spread water, and retard evaporation.

The main drawback to this system was the "Chapin Twinwall" dripline that was used. Being constructed of thin (3 mil) plastic, it was easily damaged and chewed up by rodents and soon developed many leaks. Another problem experienced was that, due to the rough, uneven surface of the slope, good soil contact with the paper was impossible and we could not get the water spread we expected. The other problem that may be experienced in the future involves the nylon netting material. This material does not degrade (as the paper does in a few weeks or months depending on the paper used), and as shrub and particularly tree species grow through the net the nylon may cut into or damage the stems.

The outstanding feature of this "HOLD-GRO" material became evident several months after installation. Within a few short weeks the irrigation system had to be disconnected due to the too numerous leaks. As a result of the severe drought we experienced in the summer, all of the emerging seedlings slowly died. Consequently, we were a little disappointed with the results of this technique. However, with a very limited amount of rain received in the fall (2.27 inches), we began noticing exceptional germination and plant establishment under the paper (Fig. 10). Apparently the paper material has a "mini-greenhouse" effect. It retards moisture loss; helps to heat up the soil surface to stimulate germination; and protects the seed and emerging seedling from wind and water erosion, dessication, and rodent predation.

Another feature of the erosion control fabric that surprised us is its resistance to deterioration. Thus far the paper has held up remarkably. The material has been in place for over a year and the paper hasn't deteriorated to any appreciable degree. This feature is enhanced when considering the factors involved. The material was placed on a very steep (1:1) slope with a southern exposure and subjected to extremely high surface temperatures and wind. We hope to be able to test this material without irrigation on a larger scale in the near future.

The "DuPont VIAFLOW" weeper tube "sweats" water and provides an even flow aong its entire length. The tube is made of multi-porous polyvinyl material, which allows water to "weep" through micron-sized pores along the entire length. However,

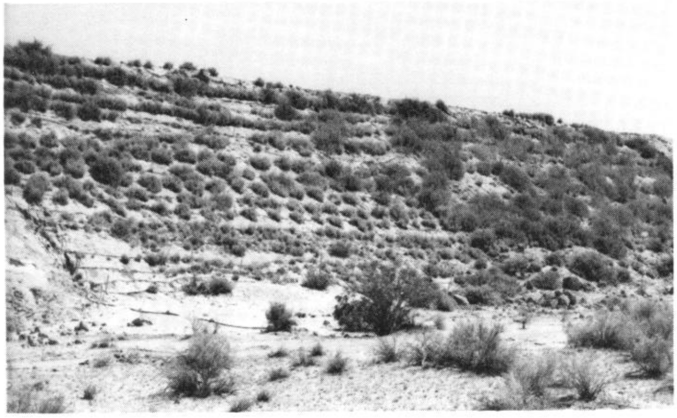

Fig. 11. *General view of drip irrigation test area approximately 6 months after seeding. Note vegetation growth and estblishment on the different drip systems. Note how well slope is stabilized and revegetated.*

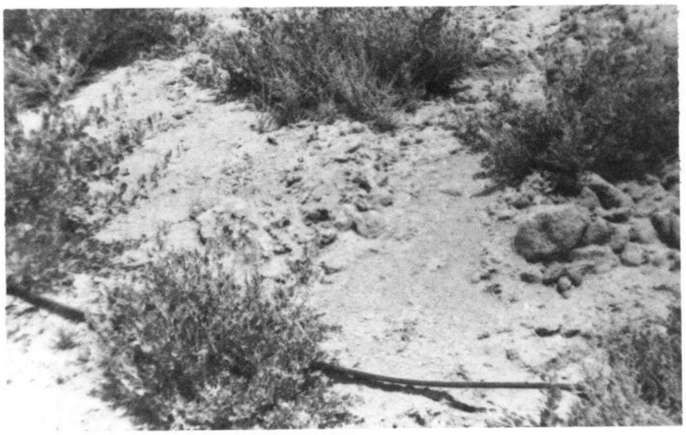

Fig. 12. *Growth of direct seeded species of saltbushes on "CHAPIN Microtube" drip system. Note the size of plants and extent of vegetative cover.*

due to the very low volume of flow (1.5 gpm/1,000 ft) and the high infiltration rate of our soils we did not experience the lateral movement of moisture on the soil surface we anticipated. We also found by burying the lines too deeply we got even less surface moisture for seed germination. Hence, we were only able to establish a thin strip of vegetation along the "VIAFLOW" lines on the surface. Spaced at 5-foot intervals, these strips would adequately stabilize a slope, but would present a very linear appearance. We also found it necessary to bury the "VIAFLOW" to prevent deterioration of the material from the sun's rays and protect it from insect and rodent damage. However, "VIAFLOW" cannot be buried more than 2 inches for adequate moisture to reach the surface for germination.

The "Defacto REBAT" drip emitters designed to act as foggers or misters on 5-foot centers proved to be very ineffective. These emitters restrict the flow by constriction with a stainless steel ball which rides in a specially designed chamber. As water pressure forces the ball up in the chamber the flow is restricted. The very fine spray or mist was easily distorted and evaporated by the wind. This greatly reduced the amount of moisture reaching the seed and we had very little germination. The emitters also had a tendency to plug up and required more maintenance than the other emitters; the emitters also must be in a near vertical to horizontal position to operate properly. Where the emitters faced into the slope, they wet the slope enough to stimulate some germination.

The "Chapin Microtube" drip system worked out very well on a 4 by 4 foot spacing. These emitters control the flow by constriction through a microtube of varying lengths (the length dictates the flow—1 to 2 gallons per hour). Each of the "Microtube" emitters provided enough moisture (1 gallon per hour each; on a 4 × 4 foot spacing this equals approximately a 4 gallons per minute per 1,000 ft) to the surface to achieve good surface moisture and hence good germination. Even the buried lines displayed good surface moisture patterns. A few of the "Microtubes" became plugged, however, and this may cause some problems.

The "ANJAC Biwall" dripline is on a 1½ by 2-foot spacing. The "ANJAC Biwall" is designed on the same principle as the "Chapin Twinwall," only it is made of heavier material and not damaged as easily. Like the "VIAFLOW," due to its low volume of flow and the high permeability of the soil, only a narrow strip of vegetation could be established. Also, the emitters, instead of "weeping" or "dripping," sprayed out a small, short stream of water, which is easily distorted and evaporated by wind.

The last system used was a "SUBMATIC" driphose. This consisted of 1-gallon-per-hour emitters inserted in common garden hose on a 3 by 3 foot spacing. These emitters are merely small orfices to restrict the flow and do not have any true flow control. Spaced this closely together the emitters are functional for only the first 50 to 75 feet of hose. Due to the flow volume restrictions this system is not designed to be run more than 50 feet, whereas the other systems were designed for runs of 200 feet or more.

We hydro-seeded over all of the driplines using a seed mixture of many different species of grasses, forbs, and shrubs (mostly of locally gathered seed and small remnants of our other revegetation programs) seeded at a rate equivalent to approximately 300 pounds per acre. This was hydro-seeded onto the slope with "CONWED" wood fiber hydromulch at a rate equivalent to 1 ton per acre and "WACCO" 15-5-5 fertilizer at a rate equivalent to 600 pounds per acre.

One thing noticeable, and apparently indicative of drip irrigation, was the rapid germination of seed and excellent plant establishment where the driplines were operating properly (Fig. 11). Most of the species seeded have long germination periods, even with sprinkler irrigation, but apparently germination was stimulated by keeping the seed moist all day and providing optimum soil moisture. Most germination began in just a few days. These systems were operated on an 8 hour per day, 5 days per week schedule for the first few weeks. When the rabbits started damaging the driplines, we operated the systems only as often as we could keep the driplines repaired. The plant response has been fantastic and the growth of these direct-seeded plants now approaches the size of our hand-planted, 1-gallon-sized nursery stock, and the area is well stabilized and revegetated (Fig. 12).

Direct seeding with drip irrigation appears to be a very successful technique for revegetating steep and difficult slopes. Cost studies will be made next on various seeding rates to determine the economic practicality of this technique over hand planting. Drip irrigation may be a solution for an effective and efficient way to revegetate steep slopes in an arid envirnment.

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