Subsurface Herbicide Applicator for Brush Control

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Highlight: *A tractor-drawn machine was designed to apply soil-active herbicides subsurface to experimental brush control plots. The applicator was constructed with a large coulter, 32 inches in diameter, to penetrate soil to a depth of 0 to 8 inches and to cut through woody vegetation. An injector-knife immediately behind the coulter supported a spray nozzle to apply herbicide into the bottom of the slice made by the coulter. The injector applies herbicides in continuous narrow bands spaced on 6-inch centers at 3- to 6-ft intervals and requires low energy input to operate. Spacing of herbicide bands depends upon type and size of brush being treated.*

Some of the early tractor-drawn devices for subsurface application of herbicides consisted of horizontal blades with spray booms and nozzles mounted beneath or to the backside of the blade (Fenster et al., 1962; Wooten and McWhorter, 1961). Subsurface placement of herbicides in cropland is sometimes necessary to increase the effectiveness of volatile preemergence herbicides. Other devices and techniques investigated since 1962 to incorporate herbicides include knife injectors (Wooten et al., 1966), reel incorporators (Barrentine and Wooten, 1967), and various cultivator implements (Bode and Gebhardt, 1969), compared to standard discing or rotary hoe incorporation treatments. In recent years, more sophisticated equipment has been designed to place volatile herbicides under the soil surface in precise spatial relationship to crop seed (Dowler and Hauser, 1970). Rolling coulters placed in front of the knife injector enabled the unit to cut through crop residue left from previous corn, cotton, or soybean crops which would otherwise impede operation of the injector-planter.

Hollingsworth et al. (1973), reported successful incorporation of herbicides into the root zone of salt cedar (*Tamarix pentandra* Pall.) in New Mexico. They used a root plow similar to that described by earlier investigators (Fenster et al., 1962; Wooten and McWhorter, 1961).

On rangeland, sweep blades, root plows and chisels have limitations because of hard rocky soils, large woody vegetation and high-energy requirements to pull the implements. Root plowing on rangeland may also destroy the grass stand.

With the advent of several new soil-applied herbicides that showed promise for woody plant control, we were encouraged to develop subsurface application equipment. In the Southwest, several million acres of brush cannot be treated by aerial broadcast sprays because of proximity to sensitive crops, water sources, and urban and recreation areas. Subsurface application of herbicides on pastures and rangelands minimizes atmospheric drift, movement in surface runoff water, and photodegradation.

Herbicides investigated by this method included liquid sprays of picloram (4-amino-3,5,6-trichloropicolinic acid), bromacil (5-bromo-3-*sec*-butyl-6-methyluracil), diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], prometone [2,4-bis(isopropylamino)-6-methoxy-*s*-triazine], 2,3,6-TBA (2,3,6-trichlorobenzoic acid), karbutilate [*tert*-butylcarbamic acid ester with 3-(*m*-hydroxyphenyl)-1,1-dimethylurea], and tebuthiuron [1-(5-*tert*-butyl-1,3,4-thiadiazol-2-yl)-1,3-dimethylurea] on areas supporting stands of honey mesquite [*Prosopis juliflora* (Swartz) DC. var. *glandulosa* (Torr.) Cockerell], Macartney rose (*Rosa bracteata* Wendl.), huisache (*Acacia farnesiana* (L.) Willd.), and whitebrush (*Aloysia lycioides* Cham.).

Since many of the soil-applied herbicides effective for woody plant control are injurious to desirable forbs and grasses, equipment was designed on the principle of the injector-planter equipment reported by Dowler and Hauser (1970) to minimize exposure of forages to the chemical.

Our objective was to design subsurface herbicide application equipment to: (1) inject herbicides into soil in narrow bands spaced at 3- to 6-ft intervals to place herbicides in the root zone of woody plants, but minimize exposure to roots of forage species; (2) cut through hard, rocky soils and woody vegetation; and (3) develop equipment requiring lower energy input than root plowing or other mechanical methods.

Equipment

Basically the applicator consists of the frame, coulter support, coulter, spray unit and lift mechanism (Fig. 1A).

Frame

The basic frame was constructed from a 3-inch^2 solid steel beam 7.5-ft long at the front, and a 7.5-ft long U-shaped channel iron beam at the rear (Fig. 1B). The rear frame was made of a 0.5-inch thick bottom plate, 3 inches wide, overtopped with an angle iron of similar dimension. The reason for this design will be discussed later. The front and rear frame was connected on either side of the machine by two 3-inch^2 solid steel beams, 3.5 ft long, welded to the 7.5-ft beams. Additional support was provided by a 10 inch wide channel iron welded at a right angle between the 3.5-ft beams. The channel iron also supported the spray tanks.

Coulter Support

Each coulter is supported on either side by two 20 by 26 by 28 inch triangular, 0.5-inch thick metal plates welded to a 0.25-inch thick metal rectangular tube (4 by 6 inch), 3.5 ft in length (Fig. 1C). It is attached to the main frame. The coulter support plates are 0.5-inch thick and are spaced 4 inches apart. To accommodate the coulter axle, a 1.5-inch hole was drilled

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Manuscript received August 23, 1975.

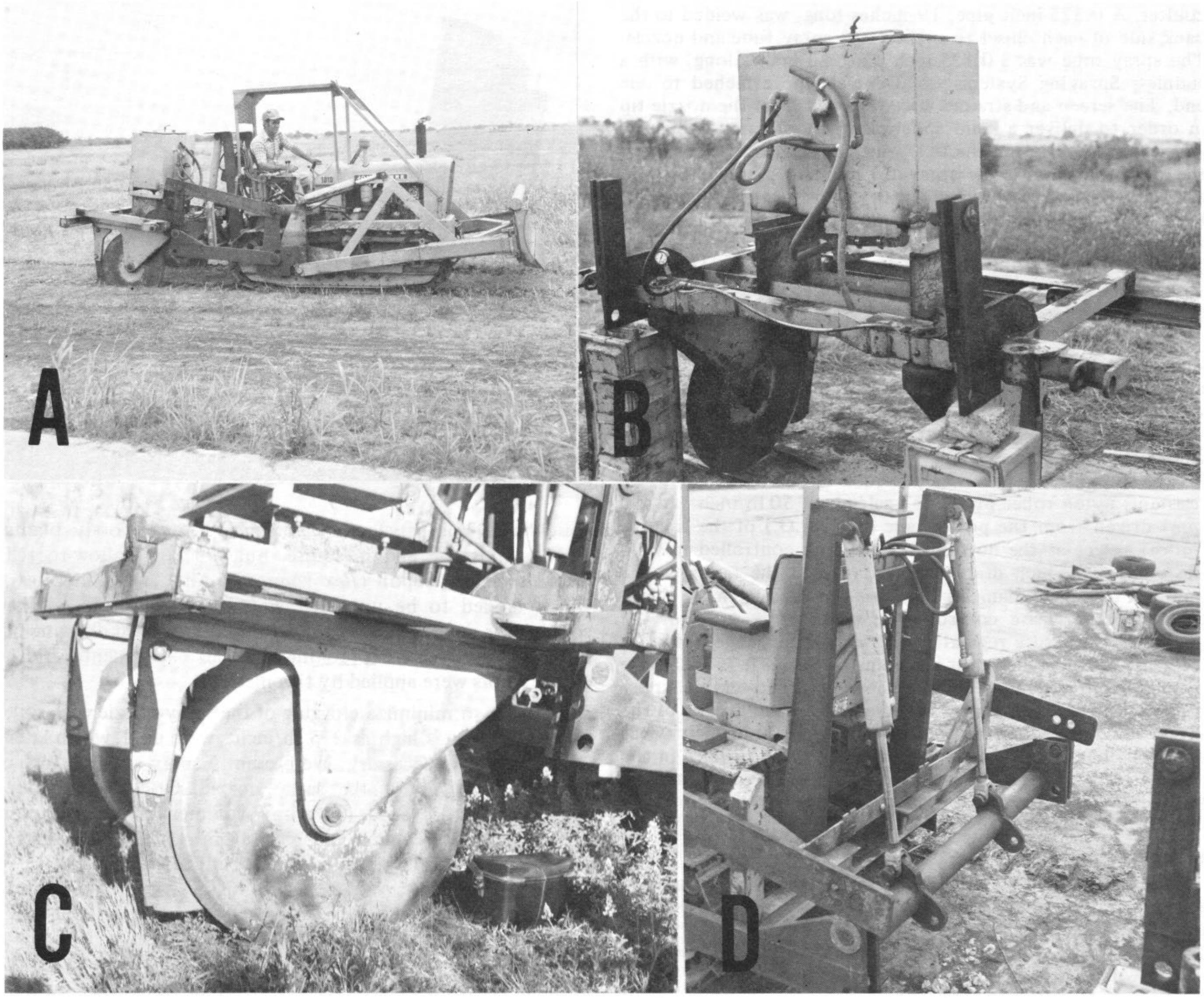

Fig. 1. *(A) Subsurface herbicide applicator attached to tractor showing the entire unit and lift arms between tractor and applicator; (B) frame, spray tank and coulters; (C) close-up of coulter, coulter support frame and chisel spray injector; and (D) twin hydraulic cylinder mechanism to raise and lower applicator.*

through the plates, 1 inch from the lowest point. A 2-inch^2 metal (0.375 inch thick) tie rod pinned between the coulters on the coulter support frame served to maintain and stabilize the coulters, equidistant during operation and turning.

Coulter

The coulter is made of 0.5-inch tempered steel and is 32 inches in diameter (Fig. 1C). A 4 inch long pipe welded in the center of the coulter serves as a bushing, which turns on a 1.5-inch diameter axle. The bushing has an outside diameter of 3.75 inches and an inside diameter of 1.5 inches. A 5-inch long pin with a 4-inch diameter flange welded to one end serves as the axle for the coulter and extends through coulter support plates. The axle is held in place by a large washer and small bolt extending into the axle at the end opposite the flange. A grease fitting was placed in the coulter hub. The coulter was sharpened to cut through soil and brush.

In order to change spacing between the coulters, 6 pipes (1.5-inch inside diameter, 3.75-inch outside diameter), 3 inches long, were welded vertically at 6-inch intervals on the front beam of the frame (next to tractor) (Fig. 1B). A 1.5-inch diameter pin, 3.5 inches long, was welded vertically on the top and front side of the coulter support frame. The coulter frame could then be pinned into any of the six pipe receptacles. The pipe receptacles are placed to give spacings between the coulters of 3, 3.5, 4, 4.5, 5, 5.5, and 6 ft. Pinning of the coulter support frame in front also allowed the coulter mechanism to swivel when turning the machine.

The U-shaped outside frame or channel iron holds the rear side of the coulter frame in place, but allows it to move to back and forth horizontally when turning (Fig. 1C). It also holds the coulter and knife in place when the entire machine is lowered into or lifted from the soil.

Spray Unit

A conventional spray system was used in conjunction with the knife-injector. A chisel-knife to inject herbicide into soil was 26 inches long, 3 inches wide, and 0.5-inch thick (Fig. 1C). A chisel was bolted behind each coulter to braces welded to the coulter support frame. The chisel-knife was constructed with the same contour as the coulter in order to prevent breakage and collection of mud and brush on the chisel or coulter. A 0.375-inch pipe, 19 inches long, was welded to the back side of each chisel to protect the spray tube and nozzle. The spray tube was a 0.125-inch pipe, 20 inches long, with a stainless Spraying Systems Co. Conejet tip[1] attached to one end. The screen and strainer were removed from the nozzle tip in order to deliver a solid spherical spray stream. The spray tube was placed inside the 0.375-inch pipe at the back side of the chisel-knife with the spray tip pointing toward the soil. The spray tips were placed about 0.5-inch from the opening of the 0.375-inch pipe to protect the spray tip from abrasion and clogging with soil during the spray operation. At the other end of the spray tube, a 0.125-inch nozzle body, a 100-mesh screen, and a hose adapter were attached to connect the spray nozzle into the total spray system.

Two (16 by 16 by 24 inches) metal tanks with funnel-shaped bottoms were attached over the herbicide-injecting machine to provide spray solution (Fig. 1B). The two tanks were independent of each other, and two herbicide spray solutions could be prepared at one time, saving travel time to and from the mixing site.

The spraying pressure was provided by a Hypro[1] corrosion resistant, nylon roller pump (27 gal/min at 50 lb/inch^2 at 850 rpm) driven from the power take off (P.T.O.) of the tractor. Cut-off valves at the bottom of each tank controlled flow to the pump. One-inch drain hoses connected the tanks to the pump. A 0.75-inch diameter hose was provided from the pump to the spray release control valve mounted in reach of the operator. A pressure regulator with a pressure gauge (0 to 100 lb/inch^2) was installed near the pump outlet. A 0.75-inch hose by-pass from the pressure regulator returned excess spray solution to the tanks and provided agitation and mixing of the spray liquid. Another pressure gauge (0 to 100 lb/inch^2) was provided in the 0.25-inch hoses leading to the nozzles in the chisels. Two filters, in addition to those near the nozzles, were located in the system between the pump and regulator and near the on-off spray release valve.

Lift Mechanism

The chisel-knife and coulter mechanism was raised from the soil in transport and turning by two lift arms on either side of the machine connected between the tractor and injector (Fig. 1A). The upper horizontal bar was 0.75 inches thick by 6.5 inches wide and 6.5 ft long. The lower bar was 1.25 inches thick by 6 inches wide and 4 ft, 1 inch long. The horizontal bars are pinned to a vertical support on the tractor, 2 ft apart at the front and 2.5 ft apart at the back. The lift arms are attached to the injector machine frame. The lift arms are connected at the rear of the tractor by a 4.5-inch diameter steel pipe, 5.5 ft long (Fig. 1D). Two large hydraulic cylinders attached at one end of the 5.5-ft pipe and at the other end to a vertical support frame on the tractor provide power to lift and lower the sprayer injector. The hydraulic system is also used to regulate penetration of the coulter and injector-knife in the soil when spraying.

Performance

Early Work

First, chisel-knives were constructed of 1-inch steel (Fig. 2). Chisels were 30 inches long, 8 inches wide at the top, and 6 inches wide at the bottom. The leading edge was sharpened to slice through soil and woody plants. A sharpened blade was also welded to the base of the chisel to pull the chisel into the soil and to maintain depth of operation. Nozzle arrangement was similar to that described for the knife-coulter system. The

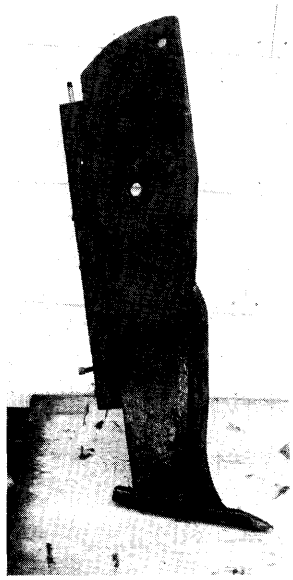

Fig. 2. *Chisel-knife injector developed for first subsurface application of herbicides in brush. Chisel is 30 inches long, 8 inches wide, and constructed of 1-inch steel. A spray nozzle is attached to the backside of the chisel.*

chisel-knife was satisfactory for deep-rooted woody plants such as huisache and mesquite, but not for shallow-rooted plants such as yaupon (*Ilex vomitoria* Ait.) and whitebrush, which tended to be uprooted and drag on the chisel. The coulter was developed to eliminate the raking and dragging of brush on the chisel. Approximately 250 experimental brush control plots were applied by this method.

In order to minimize clogging of the spray nozzle with soil, spray pressures as high as 275 lb/inch^2 were used, which later proved to be unnecessary. We presently spray at 50 lb/inch^2 with no stoppage of the spray nozzle. Original herbicide applications were made at spray volumes of 40 gal/acre. However, spray volumes ranging from 14 to 28 gal/acre (changed by nozzle tip size) have been satisfactory. We are presently using 28 gal/acre, because higher volumes of carrier are required to properly suspend and spray the wettable powder herbicides at rates up to 8 lb/acre.

We originally designed the injector machine to be pushed in front of the tractor. We found it required less energy output and tractor operator effort to pull the injector, as now designed, than to push it (Fig. 1A). We also designed the chisel with a pack wheel immediately following the chisel to regulate its depth of penetration and close the gap made by the chisel. The pack wheel, however, is not necessary with presently designed equipment.

Present Design

With the injector-knife coulter system, we applied a large number of replicated experimental brush control plots in 1973 and 1974 to several locations in Texas on sandy, heavy clay, and rocky soils. Applications with all chisels were made approximately 6 to 8 inches deep in the soil. Application of ^{32}P and H_3PO_4 to an experimental site followed by immediate sampling of cores revealed that no radioactivity was found beyond 3 inches on either side of the treatment trench. Samples were taken at 4, 8, and 12-inch depths. The majority of the radioactivity directly in the trench was between 7.5 and 8 inches. Activity was found as shallow as 5 inches and as deep as 9 inches.

The system was satisfactory in all but the very rocky soil types at Llano, Texas. Preliminary data indicate that most applications made to whitebrush, honey mesquite, Macartney rose, and huisache at herbicide rates ranging from 0.8 to 8

[1]Mention of a trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the U.S. Dep. of Agr. or Texas A&M Univ., and does not imply their approval to the exclusion of other products that may also be suitable.

Fig. 3. *Subsurface application of karbutilate, 6 inches deep, to honey mesquite at Bryan, Texas. (A) Upper photo shows bare strips of soil (10 inches wide) at 4-ft intervals as a result of 4 lb/acre karbutilate. Herbaceous weed and honey mesquite control was obtained, but grass between treated strips, is undisturbed. Photo taken May, 1975, 1 year after treatment. (B) Lower photo shows 8 lb/acre karbutilate applied at a spacing of 4 ft. Strips of denuded soil have disappeared, but honey mesquite has been controlled. Photo taken May, 1975, 2 years after application.*

lb/acre were as effective or more effective than broadcast applications of the same herbicides. Applications of herbicide were made on 4-ft centers (Fig. 3). A surface application of herbicide with the injector was always compared to subsurface treatments, which also may provide effective control of some brush species. The chisel treatments were much less injurious to desirable forage species than broadcast applications of most herbicides studied from both surface and subsurface application.

Advantages of the herbicide injector system for brush control are listed as follows:

1. Eliminates spray drift of herbicides (can treat during windy conditions).
2. Reduces herbicide movement in surface runoff water.
3. Significantly reduces forage injury.
4. Reduces photodegradation of herbicides.
5. Improves water infiltration.
6. Can be used in areas with sensitive vegetation, where conventional aerial and ground sprays cannot be used safely.
7. Requires less energy input than most mechanical methods (cuts through woody vegetation and hard soils).
8. Can be used with present commercial herbicides (wettable powders and emulsions).
9. Equipment is relatively simple and easily constructed.
10. Possible year-round application to brush.

Disadvantages include:

1. Operation slow compared to airplane application.
2. Equipment unproven under large scale rangeland conditions.
3. Soil application is less effective than foliar herbicide application on some woody species.
4. Poor penetration in rocky soil.
5. Difficult to operate on excessively wet soils.

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