LEPA IRRIGATION DEVELOPMENTS

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ABSTRACT

Advances in LEPA irrigation during the 1990's were primarily in equipment development, surface storage measurement, runoff control, and guidelines for LEPA irrigation of specific crops. LEPA application efficiencies in the 95 to 98% range are attainable when surface runoff and deep percolation are negligible. Uniformity coefficients along the irrigation system mainline can exceed 0.95 and, in the direction of travel, can exceed 0.80 with furrow dikes spaced about 2.0 m apart. Surface runoff has the largest detrimental effect on LEPA application efficiency and uniformity. Without tillage to control runoff, runoff fractions exceeding 50% of the LEPA irrigation have been measured. The two primary methods for controlling runoff are basin and implanted reservoir tillage. With alternate furrow irrigation, they provide surface storage depths on a field basis of 25 mm or more and 12 mm or more, respectively. Bubblers and socks or sleeves have become the two most commonly used LEPA application devices. Bubblers are available in multi-function application devices that also include flat spray and chemigation modes. Single-ended and double-ended socks are usually attached to a spray application device for controlling the discharge rate. LEPA irrigation guidelines have been developed for corn, cotton, grain sorghum, wheat, and some minor crops. With full irrigation, crop yields and water use efficiencies are similar to those of other highly efficient irrigation methods such as spray and subsurface drip. With deficit irrigation, the runoff potential decreases, and LEPA tends to be more efficient than spray for drought tolerant row crops such as cotton and grain sorghum.

KEY WORDS

LEPA irrigation, Sprinkler, Application efficiency, Uniformity coefficient, Water use efficiency

INTRODUCTION

The goals of this paper are to review LEPA irrigation research including equipment development during the past decade as a summary of the present state of LEPA irrigation knowledge. LEPA (low energy precision application) is defined as "a low pressure irrigation method for uniformly applying small frequent irrigations at or near ground level to individual furrows (usually alternate furrows) with a mechanical-move system accompanied by soil tillage methods or tillage plus crop residue management to increase surface water storage capacity" (ASAE, 1999). LEPA is only adapted to center pivot and lateral move irrigation systems where the movement of the irrigation system distributes the water discharged in small patterns along the irrigation system mainline. Crop rows running parallel to the direction of travel of the irrigation system are desirable, and circular rows are recommended for center pivot systems. The goal of LEPA is for every plant in a sprinkler irrigated field to have equal access to water applied with nearly 100% application efficiency and uniformity. Unlike conventional sprinkler system design being based on the soil infiltration rate, LEPA design is based on the application volume per irrigation not exceeding the soil surface storage volume (ASAE, 1999). With droplet evaporation, drift, and canopy evaporation essentially eliminated, high frequency irrigation is more effective with LEPA irrigation than with spray or impact sprinkler irrigation.

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Schneider (1999 & 2000) reviewed application efficiencies and uniformity coefficients for the LEPA sprinkler method. Application efficiencies for LEPA, with surface runoff curtailed, typically were in the 95 to 99% range (Lyle and Bordovsky, 1981, 1983; Schneider and Howell, 1990; Howell, et al., 1991a). When surface runoff occurs, application efficiencies are difficult to quantify. Lyle and Bordovsky (1983) measured application efficiencies of 99% with basin tillage to prevent runoff and 88% with conventional tillage to allow runoff. Other researchers have measured lower application efficiencies due to larger percentages of runoff (Buchleiter, 1992; Schneider and Howell, 1999). Uniformity of LEPA irrigation is affected by the start and stop movement of mechanical move irrigation systems. Along the irrigation system mainline, uniformity coefficients can easily exceed 0.95 and are only limited by the finite number of nozzle size increments available. In the direction of travel, uniformity coefficients less than 0.50 have been measured in the interior of mechanical move irrigation systems with collectors 0.30 m long or shorter (Fangmeier et al., 1990; Buchleiter, 1992). Basin tillage with about a 2.0-m long spacing between dikes is recommended to average the nonuniform irrigation depths while the system is moving and while it is stopped . Uniformity coefficients in the direction of travel then increase to 0.80 or more along the entire irrigation system (Hanson et al., 1988; Fangmeier et al., 1990).

RUNOFF AND SURFACE STORAGE

Researchers have measured both the quantity of surface runoff from LEPA and the effects of the runoff on crop yields. Buchleiter (1992) estimated runoff by subtracting the soil infiltration from 30 to 35-mm irrigations applied to slopes of 1, 3 and 8% with a LEPA equipped center pivot. The 1% slope had a soil water gain of 25% over the irrigation application due to runon from other locations in the field, and the 3 and 8% slopes had runoff losses of 32 and 57%, respectively. Schneider and Howell (1999) compared surface runoff from LEPA and above canopy spray irrigation of diked and undiked furrows on a slowly permeable clay loam sloping 0.25% in the direction of the furrows. With full irrigation applied in 25-mm applications, 2-y average surface runoff as a percent of seasonally applied water was 22 and 52% with and without furrow dikes. The two-year average grain yields were 5.59 and 5.14 Mg/ha with and without furrow dikes. Surface runoff was significantly larger, and grain yields were significantly smaller than with the above canopy spray method. Spurgeon et al. (1995) evaluated the effect of the LEPA bubble and flat (in-canopy) spray sprinkler methods and conventional, basin and implanted reservoir tillage on corn yields. For the LEPA bubble method, yield declined 1.46, 1.60 and 0.95 Mg/ha with the three respective tillage methods for each 1% increase in field slope. Yield reductions with all three tillage methods were larger for the LEPA method than for the spray method. Martin et al. (1997) simulated infiltration and runoff from LEPA irrigation and predicted uniformity coefficients and runoff fractions from design and management parameters. Simulated uniformity coefficients were highly dependent on surface storage and, with 20 mm of surface storage volume, exceeded 0.90 in the direction of travel.

Basin and reservoir tillage are the tillage methods commonly used for controlling runoff from LEPA irrigation. Basin tillage is the process of constructing dams or dikes in furrows to create surface storage (Lyle and Dixon, 1977). For 0.76-m spaced furrows, Howell et al. (1995) reported a rainfall storage depth of nearly 50 mm and little runoff from alternate furrow LEPA irrigations of 25 mm or less for corn. Solomon et al. (1994) used 1.42-m spaced LEPA bubblers on straight 1.42-m wide, diked furrows and stored all water from irrigations as large as 30-mm with a center pivot. Reservoir tillage consists of a subsoiler or chisel shank pulled at a depth of about 0.3 m followed by a paddle wheel that penetrates to the depth of the chisel shank to form pits with small dikes between the pits (Coelho et al., 1996). These researchers reported a reservoir surface water storage depth of 20 to 22 mm that increased slightly during the year. The corresponding storage depth for alternate furrow LEPA irrigation was 10 to 11 mm. Basin tillage provides a larger surface storage capacity than reservoir tillage, but the storage capacity can be severely reduced as the furrow dikes erode. Reservoir tillage provides increased infiltration capacity from the subsoiling and surface storage capacity that is likely to either remain constant or increase as the tilled soil beneath the reservoirs compacts. The storage volume of either method decreases as the soil slope increases, and large rains can erode the soil between basins or reservoirs so that surface storage is unacceptably small.

EQUIPMENT

LEPA equipment consists of the application devices and the furrow arms and pipe or hose drops for placing an application device at the desired spacing and height (New and Fipps, 2000). Equipment is also available for converting center pivots originally equipped with impact sprinklers or low-pressure spray heads to LEPA irrigation (New and Fipps, 1990). LEPA irrigation systems cost more than similar systems equipped with spray heads or impact sprinklers. The increased cost varies with the type of LEPA devices being installed and the spacing and cost of the sprinkler devices being replaced.

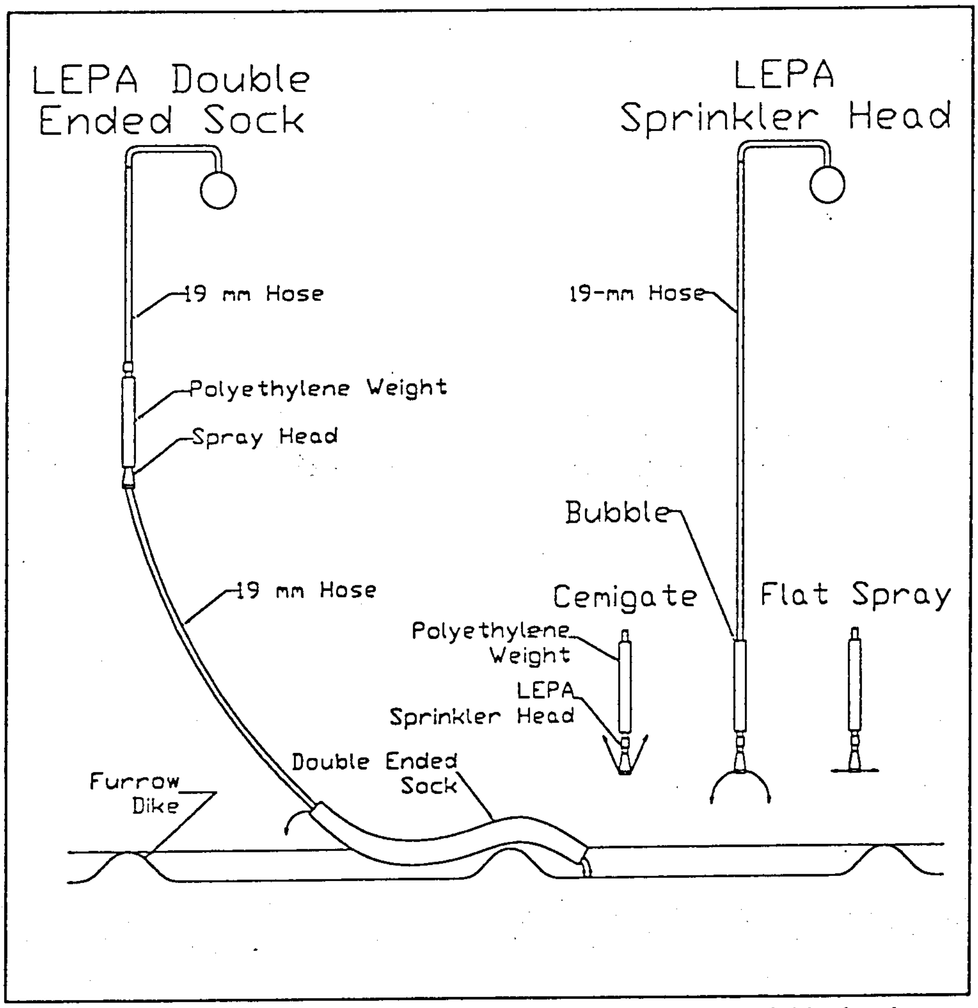

Figure 1. Major components of LEPA double-ended sock and sprinkler head devices, both commercially available.

Figure 1 illustrates bubblers and socks or sleeves, the two most commonly used LEPA application devices (New and Fipps, 1990). It also illustrates polyethylene weights used to reduce movement due to wind of the flexible 19 mm LEPA hose. A steel pipe approximately 1 m long can be placed between the 19-mm hose and the sprinkler head to eliminate the polyethylene weight. Multi-function LEPA sprinkler heads can be used in the LEPA bubble, chemigation, and low elevation (flat) spray modes. Single ended LEPA socks discharge at the end only while double ended LEPA socks discharge at the furrow end and at an intermediate point about midway along the sock. The double-ended discharge protects furrow dikes by allowing water to be discharged on either side of the dikes but not directly on the dikes, (Fig. 1).

Converting an existing sprinkler system to LEPA irrigation usually requires adding additional outlets by piping from existing outlets or installing new outlets into the mainline. The least expensive method is to connect one or more LEPA drops to existing outlets with hoses (Fig. 2). Cutting into or welding on the pivot mainline is unnecessary, and the clamps allow the drops to be moved along the mainline and raised or lowered as needed. Another method is to saw correctly spaced holes along the pivot mainline and swage additional outlets into the pipe, (Fig. 3). A precision hole saw is required to cut a smooth, burr free opening into the pipeline. Outlets are swaged into the sawed holes with a pull-type hydraulic ram to form a watertight connection between the pipe and the outlets. For non-galvanized pipe, additional outlets can be welded into the mainline at the desired locations.

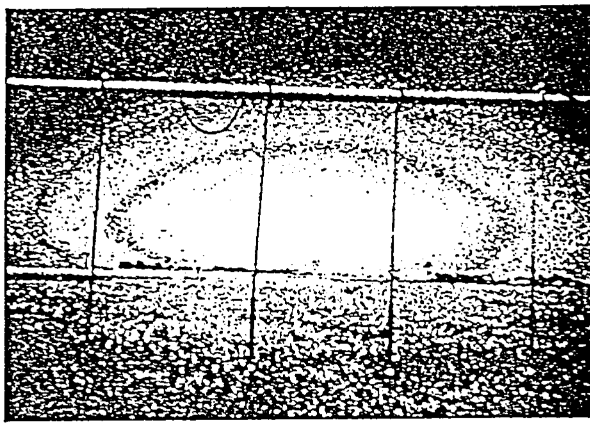

Figure 2. LEPA system added to a center pivot by connecting additional LEPA drops to existing outlets.

LEPA spray heads have a chemigation spray plate designed to apply water and chemicals upward into the crop canopy, (Fig. 1). This chemigation mode was originally designed to apply insecticide in corn, but it has been adapted for other crops. In addition to desirable features such as uniformity, economy, and timeliness, LEPA chemigation greatly reduces the potential for pesticide drift outside the field area and in some instances reduces the quantity of chemical required (Lyle et al., 1989).

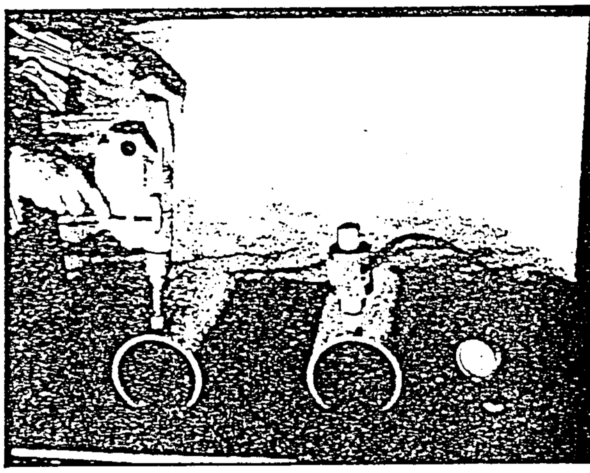

Figure 3. Drill with precision hole saw on the left and hydraulic equipment on the right for sawing holes and swaging outlets into an irrigation system mainline.

CROPPING STUDIES

During the past decade, cropping studies with LEPA irrigation have been reported for corn, cotton, grain sorghum, onions, wheat, and forage sorghum. Table 1 lists the irrigation scheduling method, crop yield, water use efficiency (WUE), and irrigation water use efficiency (IWUE) for each of the reported studies. The irrigation amount or scheduling method listed in Table 1 resulted in the largest LEPA irrigated crop yield and generally the largest WUE. All the field studies except the one with forage corn were conducted in the Southern Great Plains so yields and water use efficiency for a single crop are comparable. Grain yields and the corresponding water use efficiencies are reported at 0% moisture content. WUE is defined as crop yield divided by estimated evapotranspiration, and IWUE is defined as the difference between irrigated and non-irrigated yields divided by irrigation amount. Some field studies were of LEPA irrigation only, and others were a comparison of LEPA with spray irrigation or subsurface drip irrigation (SDI). In all the comparisons, crop yield and water use efficiency with LEPA irrigation were similar to those with spray irrigation or SDI.

Table 1. Irrigation scheduling procedure, crop yield, water use efficiency, and irrigation water use efficiency for cropping studies with LEPA irrigation and any comparison irrigation method.

Investigators	Year	Irrigation Scheduling Procedure	LEPA			Comparison Irrigation Method			
			Yield[a] Mg/ha	WUE kg/m³	IWUE kg/m³	Type Irrig.	Yield[a] Mg/ha	WUE kg/m³	IWUE kg/m³
Corn									
Spurgeon & Makens	1991	1.0 ET[b], 3.5-d interval	11.1	1.69	2.62	None	–	–	–
Howell et al.	1991b	1.1 SWD[c], med. seeding rate and maturity	7.40	1.46	–	None	–	–	–
Lyle & Bordovsky	1995	1.3BI[d], 3-d interval	12.8	1.73	2.49	None	–	–	–
Howell et al.	1995	100% soil water replenishment	11.8	1.35	1.73	None	–	–	–
Spurgeon et al.	1995	1.0 ET, implanted reservoirs	9.92	–	–	Spray	12.1	–	–
Schneider & Howell	1998	100% soil water replenishment	11.1	1.36	2.11	Spray	11.7	1.47	2.25
Cotton									
Bordovsky et al.	1992	0.4BI, 3-d interval	1.13	–	0.40	None	–	–	–
Bordovsky & Lyle	1998	7.6 mm/d, 1-d interval	1.30	0.26	0.31	SDI	1.41	.28	.34
Grain Sorghum									
Howell et al.	1991b	1.1 SWD, med. seeding rate and maturity	6.77	1.36	–	None	–	–	–
Schneider & Howell	1995	100% soil water replenishment	7.38	1.27	–	Spray	7.79	1.33	–
Bordovsky & Lyle	1996	0.7BI, 3.5-d interval	7.72	1.58	1.24	None	–	–	–
Schneider & Howell	1999	100% soil water replenishment, diked	5.59	0.79	0.95	Spray	7.38	1.11	1.30
Winter Wheat									
Schneider & Howell	1997	100% soil water replenishment	3.94	.60	.59	Spray	4.24	.64	.64
Forage Corn									
Kincaid	1994	1.0 ET, reservoir till.	48.9	17.0	–	Spray	54.3	16.0	–

[a]Grain yields at 0% moisture, cotton as lint yield.
[b]ET=irrigation plus rainfall to meet evapotranspiration calculated from meteorological data.
[c]SWD=1.5-m profile soil water deficit [d]BI=modified Penman evapotranspiration minus rainfall

Corn

Corn yields for the six LEPA irrigation studies ranged from 7.40 to 12.8 Mg/ha (Howell et al., 1991b; Howell et al., 1995; Lyle and Bordovsky, 1995; Schneider and Howell, 1998; Spurgeon and Makens, 1991; Spurgeon et al., 1995). The larger yields are representative of high-yield onfarm corn production in the area. The two-year average yield of 7.40 Mg/ha reported by Howell et al. (1991b) was reduced by very low yields during the drought year of 1990. For the six studies, WUE ranged from 1.35 to 1.73 kg/m^3, and IWUE ranged from 1.73 to 2.62 kg/m^3. Spurgeon et al. (1995) and Schneider and Howell (1998) suggested that larger grain yields and water use efficiencies with spray irrigation were due to increased runoff with the LEPA method.

Cotton

The two cotton studies by Bordovsky et al. (1992) and Bordovsky and Lyle (1998) were conducted in the northern part of the plains cotton producing area where lint yields are often limited by available heat units rather than evapotranspiration. In the 1992 study, cotton was irrigated with fractions of a base irrigation amount (BI) defined as ET estimated by a modified Penman equation minus rainfall. The largest cotton lint yield of 1.13 Mg/ha occurred with BI = 0.4 and an every third day irrigation frequency. When LEPA was compared with SDI in the1998 study, the lint yield of 1.31 Mg/ha was slightly less than the 1.41 Mg/ha with SDI. WUE and IWUE were also slightly larger with SDI than with LEPA. In the same study, deficit LEPA irrigation amounts of 2.5 and 5.1 mm/d, resulted in lint yields of 1.03 and 1.28 Mg/ha - both being above average irrigated cotton yields for the area. The two cotton studies verified that deficit LEPA irrigation of cotton is a highly efficient use of irrigation water.

Grain Sorghum

The two grain sorghum studies conducted by Schneider and Howell (1995, 1999) were a comparison of the LEPA and spray sprinkler methods. In the 1995 study with 100% soil water replenishment, the LEPA grain yield of 7.38 Mg/ha was 0.41 Mg/ha smaller than with overhead spray irrigation. With 50% soil water replenishment, however, the 7.32 Mg/ha yield with LEPA was 1.12 Mg/ha larger than with overhead spray. With this deficit irrigation amount, WUE was also significantly larger for LEPA than for overhead spray. In the 1999 field study, the two-year average grain yields with furrow diking were 5.59 and 7.38 Mg/ha for LEPA and spray irrigation, respectively. The two-year average LEPA grain yield and water use efficiency were greatly reduced by the 1998 drought year yield of only 4.04 Mg/ha. For deficit irrigation in the 1999 study, grain yields with LEPA were generally comparable to those with overhead spray. In the study by Bordovsky and Lyle (1996) grain yields with 0.7BI were essentially equal to those with 1.0 and 1.3 BI, and the resulting and WUE and IWUE were larger with 0.7BI than for the two larger irrigation amounts. The results of Bordovsky and Lyle (1996) and Schneider and Howell (1995) illustrate that deficit LEPA irrigation of grain sorghum is a very efficient use of irrigation water.

Other Crops

Single cropping studies are reported for onions (Lyle and Bordovsky, 1991) winter wheat (Schneider and Howell, 1997), and forage corn (Kincaid, 1994). No specific yield data were reported for onions, but the 0.7 and 1.0 ET irrigation amounts produced larger yields than 0.4 or 1.3 ET amounts. An irrigation interval of 2 or 4 days resulted in more jumbo size onions than an 8-d interval. Although not developed for a close-spaced crop, LEPA has been used by some growers to irrigate wheat in the Southern Great Plains. In the field study reported by Schneider and Howell (1997), LEPA irrigated wheat yielded 3.94 Mg/ha in comparison with a spray irrigated yield of 4.20 Mg/ha. There was no statistically significant difference between yields, WUE, and IWUE for the two sprinkler methods. Kincaid (1994) compared LEPA and a low elevation spray system to irrigate forage corn using reservoir tillage. He used LEPA bubblers until the crop was above the bubblers and in-canopy-spray for the remaining irrigations. For the LEPA and spray sprinkler methods, forage yields were 48.9 and 54.3 Mg/ha, respectively. Because of larger soil water depletion on the spray irrigated plots, the 17.0 kg/m^3 WUE with LEPA was larger than the 16.0 kg/m^3 WUE with spray.

CONCLUDING REMARKS

LEPA irrigation is the only sprinkler method with an application efficiency that can approach 100%. Uniformity coefficients can exceed 0.95 along the irrigation system mainline, and with basin tillage, can exceed 0.80 in the direction of system travel. Crop yields and water use efficiencies are similar to those of other highly efficient irrigation methods such as low elevation spray and SDI. LEPA may be more efficient than other sprinkler methods for deficit irrigation, but irrigation system capacity must be maintained for maximum yields with full irrigation. Although the full LEPA concept is not used extensively, spray irrigation has been modified during the past decade to mimic the LEPA concept. Many low-pressure spray irrigation systems now use the narrow LEPA spacing and have the spray heads lowered into the crop canopy. This increases the irrigation efficiency without requiring precise placement of the spray heads and reduces the runoff.

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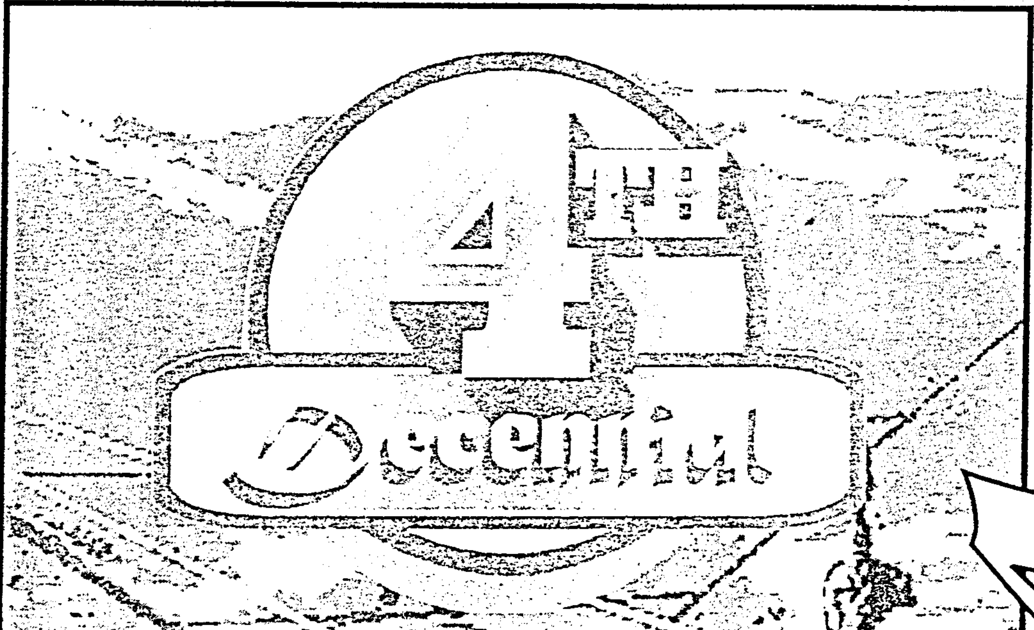

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