VERTICAL DRAINAGE AS A METHOD OF SOURCE REDUCTION FOR CONTROL OF PASTURE MOSQUITOES

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ABSTRACT. Vertical drainage was shown to be an effective method for the elimination of mosquito breeding sources under certain soil profile conditions. Drainage holes were effective where drilling penetrated through a highly impermeable stratum (e.g. clay or hardpan) into sand or loamy sand strata. For fields with no highly impermeable stratum within a meter of the surface, vertical drainage was not necessary and careful water management would eliminate mosquito breeding. Prolonged excessive irrigation and lateral, subsurface saturation from adjacent sources of water negated the benefits of drilling. The use of rate of infiltration (RI) values as described can prove very important in the determination of the cause for long-standing water.

INTRODUCTION

Irrigation water left standing on pastures has long been a problem source of mosquito production. In Central California, *Aedes nigromaculis* Ludlow can complete its immature development within 4 days during the summer months. Raguse *et al.* (1967) stated that water should stand no longer than 24 hr on an irrigated pasture, both for the benefit of pasture productivity and prevention of mosquito production. However water frequently stands for periods sufficient to allow mosquitoes to develop because of excessive irrigation and/or low water permeability of the soil. In addition to mosquito breeding on large agricultural fields, the production of *Ae. nigromaculis* on numerous small acreages on the edges of urban areas is a significant problem for many mosquito abatement districts (M. A. D.'s). There are increased complaints arising from the use of aircraft for controlling mosquitoes in these habitats. The costs for insecticides and ground crews are expensive, and continued applications on a regular basis will lead to resistance.

The concept of vertical drainage, through the drilling of holes or 'dry wells' at the source, has been suggested and was proven to be feasible in some cases (Lewis and Christenson 1971, Lewis et al. 1972). The present study was undertaken to develop information as to the soil profile conditions where vertical drainage will provide operational efficacy as a physical control method. Particular consideration was given to determining the physical nature of the soil strata and their relationship to drainage.

MATERIALS AND METHODS

Experimental fields were chosen from known mosquito producing pastures in Fresno County. These small (2–8 ha) pastures, located in either the Consolidated or the Fresno M. A. D.'s, contained mosquito breeding sources routinely monitored and treated in the district's operational program. Each was observed through 1 irrigation and rated as to suitability for experimentation. Final selection was based on visible evidence of long-standing water, relative ease with which equipment could enter the field, and conduciveness to drainage without a large amount of ditching or other extensive physical changes.

Each of the 8 pastures selected was given a test no. (7801 through 7808). Prior to drilling, the rate of disappearance of water was monitored. Stakes, generally 1/check, were placed about the source area. Daily recordings of water depth were made; the 1st measurement coincided with the shutoff of irrigation water. At the completion of the irrigation cycle, the lowest spots were marked as drilling sites. Wherever possible a control site in an adjacent check was left undrilled next to a drilled site. If either of the sites appeared to hold water longer, that one was designated for drilling.

Vertical drainage holes were drilled at the designated sites using the hydraulic drilling rig described by Lewis et al. (1973). Holes were drilled to a depth of 3.75 m with a 15.5 cm diam auger. Prior to drilling, the surface soil texture at the site was recorded. Throughout the drilling operation the soil texture was recorded at 0.5 m intervals. In order to record the texture the auger was stopped and withdrawn from the hole, which allowed a sample to be taken from the tip of the auger. The soil texture classification used in the study followed that described by the Soil Survey Staff (1951). The depth was measured with a calibrated rod. If a change in soil texture was noted during the drilling process, at that point the texture and depth were recorded. Subtle changes in texture were generally not noticed during the drilling. Coarse 2 cm rock aggregate was used to fill each hole via an hydraulic auger conveyor on a modified dump truck (Lewis and Brandl 1975). Often more rock had to be added at a later date due to settling.

Fields were monitored for one or more irrigation cycles after treatment. In some cases areas originally left as control sites in a field were drilled at a later time. Additional holes were never drilled about a treatment site in an attempt to increase drainage. Sites were chosen where it was thought one hole would be sufficient for drainage. Hand trenching was sometimes necessary to allow complete drainage of an area into a hole.

Statistical analysis of the daily water depth recordings was by least square linear regression. From this analysis a negative slope in cm/day was obtained for each given irrigation at each site. These values were corrected for daily evapotranspiration (ETP) through the use of the mean ETP for the specific interval of time during which the irrigation occurred. ETP units were obtained from the Fresno office of the U. S. Bureau of Reclamation; these values were calculated using the Jensen-Haise method from climatological data from the National Weather Service at the Fresno Air Terminal. A correction factor of 0.875 for irrigated pastures was applied.

Corrected regression slopes were combined into control and treatment groups for each pasture. A Student's t-test for 2 means was then run for each pasture comparing the control (both pretreatment and side-by-side controls) with the drilled treatments. Significance was tested at both the 0.05 and 0.01 levels. The resultant means, both before and after treatment, were designated for comparison as the respective rates of infiltration (RI) for each pasture.

RESULTS AND DISCUSSION

In order to evaluate RI values in relation to the practical elimination of mosquito breeding sources it was necessary to calculate 2 standards for comparison. Each of these is a regression slope (corrected for ETP) which would result in the elimination of standing water within 3 days.

First, a standard rate of infiltration (ScRI) was calculated based on the average initial water depths for all irrigations for all sites (grand mean). This value can be used to predict whether or not an untreated field (no drilling) would result in a greater than 3-day water standing time following an average irrigation. The calculated value for the ScRI was −6.85 cm/day. Thus after irrigation, if water penetrates the soil at 6.85 cm/day, or a greater rate, the water will infiltrate within 3 days, unless excessive irrigation has occurred. If the control RI (cRI) for a given field is below the ScRI, this suggests that an underlying soil permeability problem exists. This standard can be utilized by the M. A. D.'s both as a method for the detection of impermeable layers

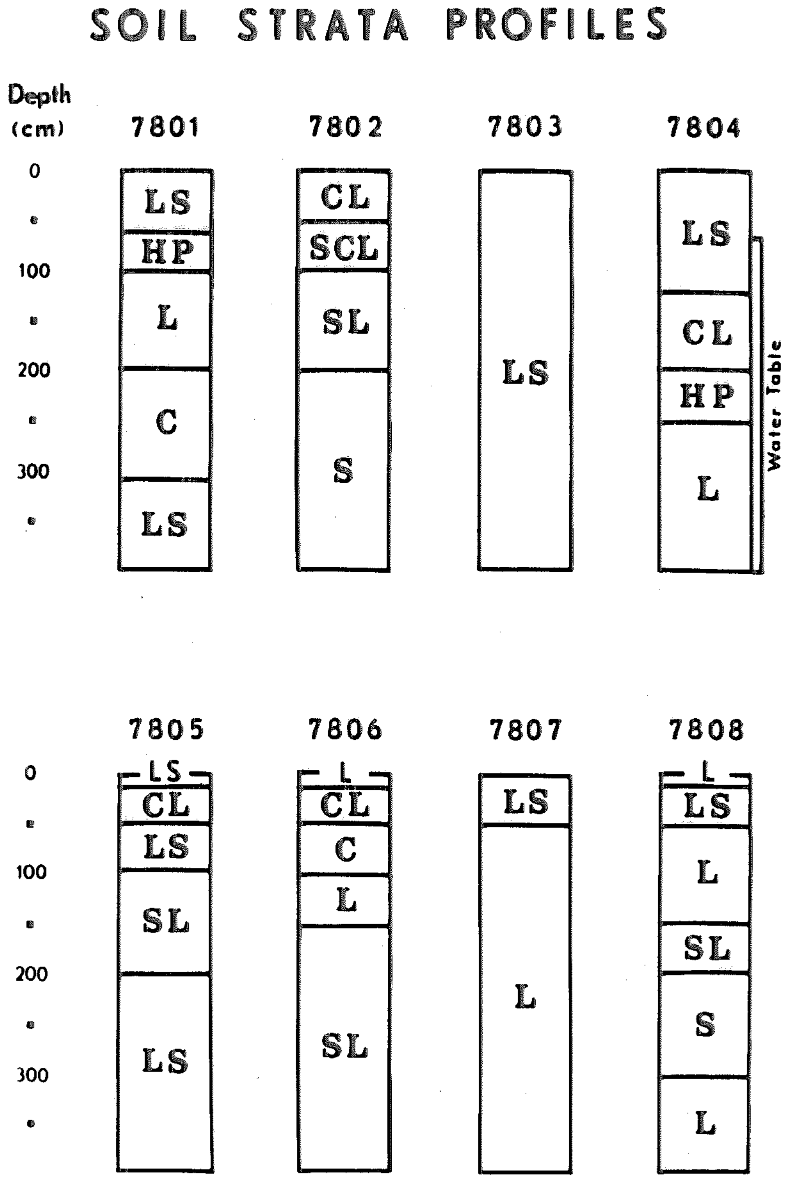

Fig. 1. Individual profiles show the stratification of soil types for each field (field number shown above respective profile). Soil types encountered: sand (S), loamy sand (LS), sandy loam (SL), loam (L), sandy clay loam (SCL), clay loam (CL), clay (C), hardpan (HP). Note that in field 7804 a water table was located 63 cm below the surface.

and as a tool in developing the awareness of the landowner in proper water management.

Secondly, a standard rate of infiltration (StRI) was calculated based on the deepest initial water depth ever measured on each field; this yielded a value of −9.44 cm/day. This value is a higher standard and provides a comparison which increases the probability of success in eliminating standing water within 3 days. Consequently when RI values for drilled fields (tRI) were greater than the StRI, the treatment was judged to have provided successful elimination of the mosquito breeding source.

Figure 1 shows the profile of soil textures found in each pasture. A statistical evaluation of RI values is presented in Table 1.

Studies on pasture 7804 were discontinued when a water table was reached at a depth of 63 cm and the water level had not dropped after 24 hr. This site was immediately adjacent (within 10 m) to a water overflow pond. Lateral, subsurface water movement provided a continuous source of saturation and eliminated any potential benefits through vertical drainage. The cRI for this site was −6.41 which indicates that the upper loamy sand stratum was just about adequate for providing suitable water infiltration in the absence of over-irrigation. The latter was responsible for the presence of water standing longer than 3 days.

No highly impermeable soil strata, e.g. clay or hardpan, were encountered during the drilling of fields 7803, 7807 and 7808. In each of these fields the upper 50 cm was loamy sand and the heaviest soil found was loam. Field 7803 had a cRI (−7.19 cm/day) greater than the ScRI; drilling dramatically increased the tRI to −19.37 cm/day, probably due to the increased surface area available for water infiltration produced by the drains.

Fields 7807 and 7808 are classic examples of mosquito breeding sources resulting from over-irrigation. Figure 2 shows the daily water depths during pretreatment irrigations of these fields as well as a field with an actual water permeability problem—7802. Both fields 7807 and 7808 had extended irrigation periods (6 full days on 7807). There were 3 separate additions of irrigation water to field 7808. On both fields the loamy soils were saturated and this resulted in cRI values of −3.34 and −3.87 cm/day, respectively. Upon drilling in field 7808 a sand stratum was reached and this resulted in a significant increase in the tRI to −8.02 cm/day; but the excessive amount of irrigation water applied was still too great to allow penetration in a time lesser than that required for mosquito breeding.

Table 1. Statistical evaluation of respective rates of infiltration (RI in cm/day[a]) for fields treated by vertical drainage.

	Field no.							
	7801	7802	7803	7804	7805	7806	7807	7808
Control								
cRI	−4.21	−1.69	−7.19	−6.41	−4.65	−3.24	−3.34	−3.87
s^b	1.02	0.59	2.88	1.23	2.19	1.31	2.33	1.19
Treated								
tRI	−5.94	−13.84	−19.37	[c]	−13.53	−3.47	−4.37	−8.02
s^b	0.64	4.39	4.14		6.78	2.03	2.40	4.79
Stat								
t^d	3.05*	4.65**	5.07**		4.51**	0.15	0.58	2.69*

[a] Corrected for daily ETP.
[b] Standard deviation of samples from mean (RI).
[c] Subsurface water reached at 63 cm, evaluation discontinued.
[d] Significance levels: *=0.05, **=0.01.

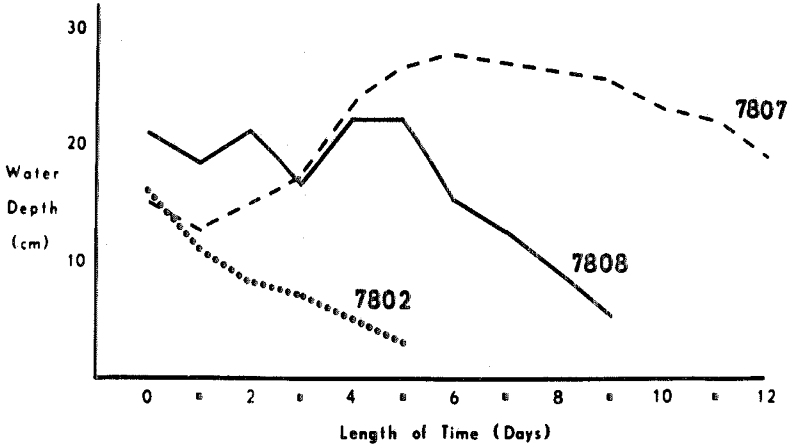

Fig. 2. Daily water depth measurements provide a water management pattern throughout a single pretreatment irrigation for each of three numbered fields. Note the extended irrigation of field 7807, as well as three separate additions of water in field 7808. Compare these with the single water addition and prompt cutoff of field 7802.

It is important to point out to landowners that irrigations of loam soils should be managed carefully. Loam soils do not require as much water, due to their moisture retention properties. Also, continuous over-irrigation of loam soils can lead to development of layers of low permeability, which harms pasture productivity, as well as leads to mosquito production.

All of the remaining pastures did have highly impermeable strata within 65 cm of the surface. Field 7801 had hardpan and clay layers between 60 and 305 cm depth. The vertical drainage holes penetrated into a shallow stratum of loamy sand (305–380 cm); but the increase in tRI, though significant from the cRI at the 0.05 level, was insufficient to eliminate the mosquito breeding source. In fields 7802 and 7805, clay-type upper strata were penetrated and sand or loamy sand strata were reached. The resultant tRI's (−13.84 and −13.53 cm/day respectively) were greater than the StRI (−9.44 cm/day) and elimination of the mosquito breeding source was accomplished.

A sandy loam stratum was located under clayey upper strata in field 7806, however no significant improvement was achieved. An irrigation canal immediately adjacent to the field (within 5–20 m of the drain holes) provided a source for lateral, subsurface saturation of the sandy loam stratum. Once again the presence of such a source for saturation of the drainage stratum negated any possible benefits from vertical drainage.

No information is yet available on the effective life-span of the successful vertical drains.

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