High Soil Moisture Effects on Pupation of Sugarbeet Root Maggot, *Tetanops myopaeformis* (Roder) (Diptera: Otitidae)

Ian MacRae[1] and J. Scott Armstrong[2]

[1]Dept. of Entomology, University of Minnesota, St. Paul, MN 55108
[2]Dept. of Plant & Soil Science, Texas Tech. Univ., Lubbock, TX 79409

ABSTRACT

The sugarbeet root maggot (SBRM), *Tetanops myopaeformis* Roder, is the most important insect pest of sugarbeet in the Red River Valley of Minnesota and North Dakota. During the flood year of 1997, the adult emergence model for this pest failed to predict a late, prolonged emergence of adults. Low soil moisture has previously been reported to prevent SBRM development. It was suspected, because of the high soil moisture resulting from the flood in 1997, that an upper threshold of soil moisture also may exist above which SBRM do not successfully complete development. Developmental trials were conducted in controlled environment chambers to characterize this threshold. SBRM had significantly greater pupal mortality in soils with greater than 45% soil moisture by weight. Soils ranging from 10% to 30% soil moisture by weight had no significant effect on SBRM pupal development.

KEY WORDS: Developmental threshold, adult emergence, sugar-beets, pupal mortality

The sugarbeet root maggot (SBRM), *Tetanops myopaeformis* Roder, was first reported in the Red River Valley of Minnesota and North Dakota in 1947 and has since become the most important insect pest of sugarbeet in the region (McBride et al. 1990). Yield losses from SBRM injury can range from 0.5 to 2.8 metric tons/ha (Campbell et al 1998). The average yield loss has been estimated at 1.6 metric tons/ha in the absence of control measures. Larvae overwinter in the soil at a depth of 15 to 250 cm. Maggots become more active in the spring with warmer temperatures,

moving to within 2.5 to 12.5 cm of the surface in late March or early April (Whitfield 1984, Bechinski et al. 1989 & 1990). SBRM larvae then pupate near the soil surface and become adults, emerging in mid-May. Sugarbeet is rotated with other crops; adult SBRM generally emerge in fields that were planted in sugarbeet the previous year (wheat is the most common following crop in the Red River Valley), in which they spend 3 to 10 days before flying into sugarbeet fields to mate, find suitable plants and lay their eggs. Mating and oviposition occurs until mid-July with larvae hatching in early June when they start feeding on the maturing sugarbeet root. Larvae stop feeding in September and initiate diapause (Whitfield & Grace 1985).

An emergence model based on degree-day accumulation correlated with mature fly emergence has been developed to predict annual peak emergence periods (Bechinski et al. 1990). In the summer of 1997, the emergence of SBRM adults was later than the model predicted and more prolonged than usual, indicating that SBRM development may have been slowed (Armstrong et al. 1997). The Red River Valley suffered extensive flooding in 1997 with much of the sugarbeet fields under water from early April through to mid May, the period during which SBRM would normally be pupating. The immersion of sugarbeet production fields in the Red River Valley for part of the spring is not unusual. The Valley is extremely flat and overland flooding in the spring often leaves fields partially flooded. This in itself does not seem to overly affect SBRM populations. Indeed, attempts to rear larvae in the lab involved experiments wherein SBRM larvae were collected from the field and held under water for up to 1 year without significant mortality (R. Dregseth, NDSU Dept. of Entomology, personal communication). However, the amount of flooding was excessive in 1997; not only did most areas in production fields experience flooding (i.e. both high and low areas within fields) but many of these areas were under water for 2 and 3 weeks longer than usual, resulting in wide regions with saturated soils. We thought the high soil moisture might have some influence on the late larval or pupal development of SBRM developing in those areas of the field that experienced excessive flooding. SBRM development can be influenced by soil moisture; SBRM have a minimum developmental threshold of soil moisture below which pupal development does not occur (Anderson 1987, Anderson et al. 1990, McBride et al. 1990). We suspected that an upper threshold might also exist, above which development slows or stops.

A series of laboratory trials were conducted in controlled environment chambers to examine the effect of soil moisture on SBRM development. Trials involved holding SBRM post diapause larvae at predetermined soil moisture regimes while gradually increasing temperatures in the chamber and allowing the larvae to be exposed to accumulating degree-days.

METHODS AND MATERIALS

To facilitate laboratory investigations into SBRM biology, larvae are collected annually in the field and held in moistened sand below 8.5C, the lower developmental temperature threshold for SBRM (Whitfield 1984). This method of collection and storage can maintain diapausing larvae in the laboratory with minimal mortality for up to 52 months (Anderson 1982).

Standard 15 cm diameter growing pots were weighed and filled with sifted field soil and then reweighed to obtain the soil weight. Pots were placed into controlled environment chambers set at 8.5C and held for 3 days to lower the temperature and relative humidity of the soil. Eight diapausing SBRM larvae, collected from the field through the summer and held at 8.5C to induce diapause, were then placed into each pot at a depth of approximately 7.5 cm. Pots were randomly assigned to one of five soil moisture regimes: < 5%, 10%, 20%, 30%, and >45% soil moisture by weight. The trials were replicated four times. The moisture regimes were established and maintained in each individual pot by calculating a target weight for the soil and water combined which would result in the desired soil moisture by weight. The pots were weighed daily and, if necessary, water added by slowly dripping the lacking amount into each pot until it reached the target weight. It was assumed that with the sifted soil and the shallow pots, soil moisture would be relatively uniform or at least reflect dry field conditions. This method maintained the soil moisture in each pot within 2% of the desired level. One of the treatments received no water and was maintained only by the relative humidity in the environment chamber; this treatment maintained soil moisture at <5% by weight.

The pots were replaced into the controlled environment chamber at 8.5C for 24 hr and the temperature was raised 2C per day for ten days. The temperature was maintained at 28.5C for the remainder of the experiment. Pots were covered with netting bags, secured around the pot rim with an elastic band. Adult emergence and the total degree-days accumulated for each pot were recorded daily. The mean percentage of SBRM adults that successfully emerged as adults was calculated. The square roots of the percentages were arcsine transformed and compared with an Analysis of Variance (Zar 1984). Fisher's Protected LSD was used for mean separation at each sample date and for the total percentage of SBRM that successfully emerged as adults over the course of the experiment (Zar 1984).

The trials were concluded 1 week after the last adult emergence. After the pots were removed from the controlled environment chamber, the soil was washed and sieved to remove any SBRM immature stages remaining. Field observations indicated that mortality would predominantly be among larvae at low soil moistures and among pupae at high soil moistures

(MacRae, unpublished data). The stages of remaining larvae were therefore compared for each moisture treatment using a one-tailed t-test (Zar 1984).

RESULTS

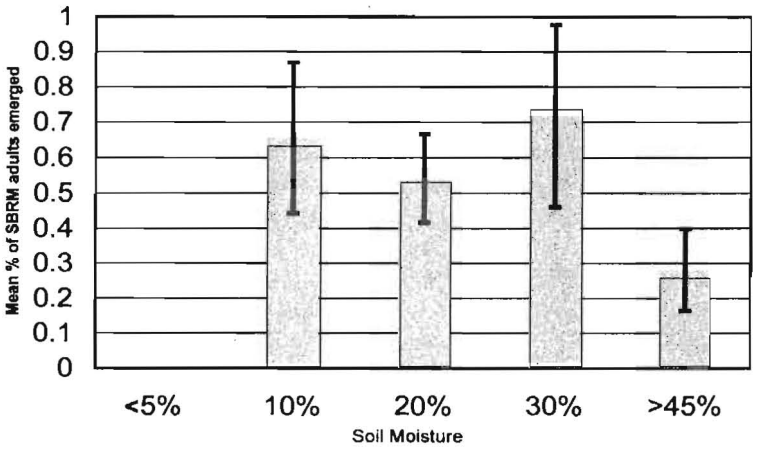

Figure 1. Mean total percent of SBRM per treatment that successfully emerged as adults. Vertical bars represent 95% CI's (calculated before data transformation for ANOVA).

Adults did not emerge from the dry treatment (<5% soil moisture by weight) (Fig. 1). Soil moisture had an effect on the pupation of SBRM ($F=61.765$; $df=4,15$; $P<0.0001$). However, pairwise comparisons indicated no significant difference in the total number of adults emerging from the 10%, 20%, or 30% soil moisture treatments (Fig. 1). The emergence of adults from the >45% soil moisture treatment was significantly less than from the 10%, 20% or 30% treatments (Fig. 1). Adult SBRM was first noted from all water-added treatments at approximately the same accumulated degree-day point, 174.7C DD with mean peak emergence occurring at 214.9C DD (Fig. 2). A significantly greater percentage of adults emerged from the 10%, and 20% moisture treatments at 174.7C DD and 194.8C DD than those in either the 30% or the >45% soil moisture treatments. No significant difference in the mean percent emergence of adult SBRM from the 10%, 20%, and 30% treatments occurred by the third day of emergence (accumulated DD = 214.9C). After 3 days, the >45% soil moisture treatment had significantly less successful pupation than the 10%, 20% and 30% moisture treatments and this continued through to the end of the

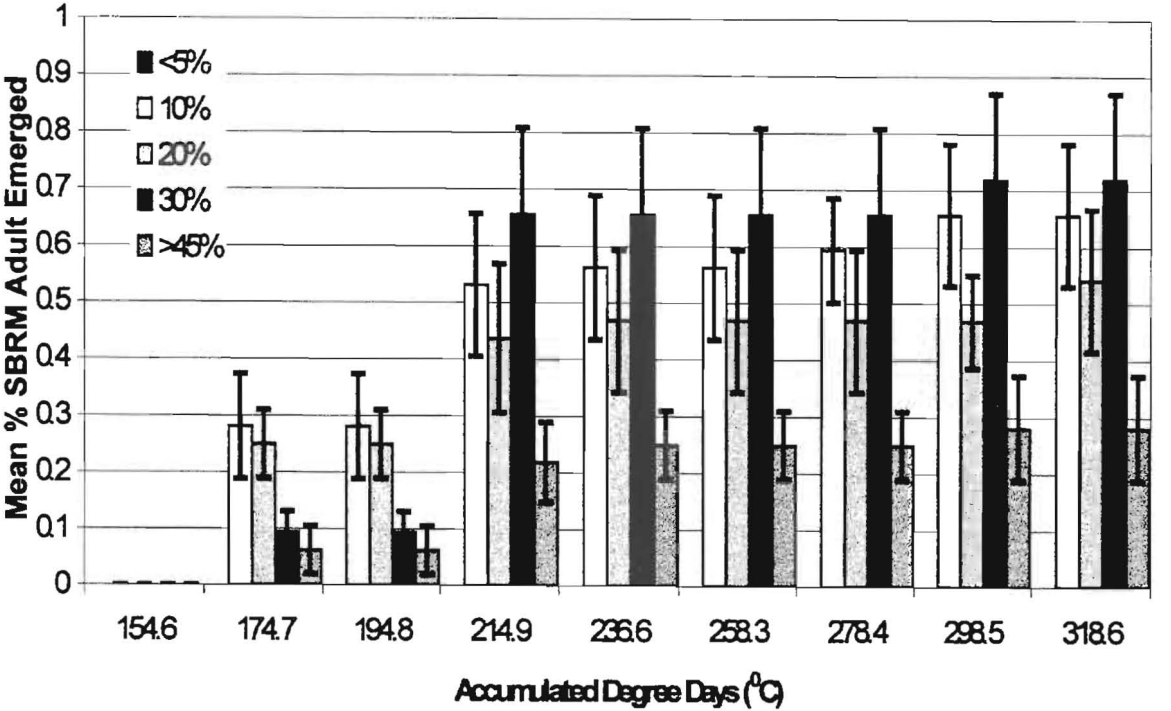

Figure 2. Mean percent of SBRM emerged as adults by accumulated degree-day (°C). Vertical bars represent 95% CI's (calculated before data transformation for ANOVA).

experiment. By the end of the experiment, fewer than 1/3 of the larvae placed into the pots with soil moistures maintained at >45% had successfully pupated. In the other pots receiving water (10%, 20%, and 30% soil moisture) at least 50% of the larvae placed into pots successfully pupated and emerged as adults (Fig. 1). All of the immatures recovered by washing and sieving the soil after the trials were dead or moribund. Significantly more dead larvae were recovered from the dry treatment (<5% soil moisture) than dead pupae ($P = 0.0175$). Conversely, with the wettest regime (>45% soil moisture), significantly more dead pupae were recovered than dead larvae ($P = 0.012$). The number of dead larvae and pupae recovered was similar in the other soil moisture treatments.

DISCUSSION

It is not surprising that SBRM larvae failed to successfully emerge from the dry (<5% moisture) treatment. A lower threshold of soil moisture for SBRM development has been reported (Anderson 1987, Anderson et al. 1990, McBride et al. 1990). It was interesting that no significant difference was observed in the number of adults emerging from the soil moistures ranging from 10% to 30%. The relationship between soil moisture and successful SBRM pupation does not appear to be linear, but rather a threshold above which development in SBRM immatures slows or stops. Comparing the stages of recovered dead immatures from the pots indicates that this upper threshold functions through pupal mortality. This explains why populations were decreased in 1997 when soils were saturated and SBRM were pupating, but not necessarily why adult emergence was delayed. Data from these experiments do not indicate that development is slowed, rather that some pupal SBRM die when exposed to very high soil moistures through the developmental period. Further experiments examining the effect of timing and duration of soil saturation on pupal development are planned.

In the Red River Valley, any soil moisture exceeding 40% by weight would represent saturated soils and be possible only when the field is flooded. However, in the spring, overland flooding occurs frequently and many portions of production fields, typically lower lying areas, are under water for at least part of the time when SBRM are pupating. Biological data can be used to establish site specific management (MacRae 1996). Mapping the topography of fields may enable scouting efforts to be focused on areas where SBRM are more likely to successfully pupate.

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