Potato Tuberworm[1] Damage to Potatoes Under Different Irrigation and Cultural Practices[2]

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ABSTRACT

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Potatoes grown under furrow irrigation sustained over 58 times greater infestation by *Phthorimaea operculella* (Zeller) and 3 times more green tubers than potatoes grown under sprinkler irrigation even though foliage tuberworm populations, soil type, and soil moisture levels were similar. Water usage on a per ha basis was more efficient under sprinkler irrigation.

Under furrow irrigation, hilling the rows 4 times significantly reduced the percentages of greenheads, infested whites, and total infestation over those rows hilled twice. The method of vine removal affected the level of tuber infestation in rows hilled twice but not in rows hilled 4 times. Under frequent sprinkler irrigation potato tuberworm damage was low and not significantly affected by cultural practices.

Soil cracking was more extensive under furrow than under sprinkler irrigation, and infestation was significantly correlated with the depth of soil cracks regardless of hilling practices.

The potato tuberworm, *Phthorimaea operculella* (Zeller), is a serious pest of potatoes in California (Bacon 1960). Most economic damage by this insect occurs when it infests potato tubers, but foliar infestations also may cause yield losses, especially when the insect mines in the stem and kills plant tissue above the site of infestation (Bald and Helson 1944).

Early attempts at control of this insect emphasized cultural controls utilizing deeper seed planting, hilling the rows, and early harvest (Langford 1933). These controls alone are not always compatible with current production techniques and consequently the use of insecticides has played a major role in the management of this insect (Shorey et al. 1967, Bacon et al. 1972, Hofmaster and Waterfield 1972) although control of foliage infestation does not always prevent tuber infestation (Bacon 1960, Foot 1974).

In warmer potato growing areas, irrigation is required to insure good potato yields, and O. G. Bacon (pers. comm.) indicated that sprinkler irrigated potatoes sustain lower potato tuberworm infestations when compared to furrow irrigated potatoes. Reported here are results of studies to determine levels of tuber infestation under different irrigation systems and cultural controls and to quantify the reasons for differences.

Materials and Methods

Experiments were conducted in 1977 at the University of California's Moreno Field Station, Riverside Co., with summer planted (Aug. 16) 'Norgold' potatoes grown on a uniform sandy clay loam soil. The planting consisted of 106 rows, 101 m long, spaced 81 cm apart (0.86 ha). This area was subdivided into halves, one of which was irrigated by a sprinkler system and the other by furrow. The 2 fields were separated by 25 buffer rows. Each field was set up as a 5×5 randomized complete block. Each replicate (0.005 ha) consisted of 4 rows, 15.2 m long, and plots were separated by 3 buffer rows on the sides and 3 m of buffer on each end. Aldicarb (15G) was applied at planting (3.35 kg AI/ha) for leafhopper control and 2 applications of nitrogen were used (202 kg/ha). Moisture levels at a depth of 30 cm were monitored by 6 tensiometers in each field, and 6 soil samples/field were analyzed for soil type. Irrigation was begun 40 days after planting. Sprinkler laterals were spaced 12.2 m apart with 12.2 m between uprights, and 2.4 mm nozzles were used to give a light spray. For the 1st 3 wk of irrigation, sprinkler water was applied for 9 continuous h/week and furrow water was applied to every row for 18 continuous h/week. During the remainder of the growing season when tubers were setting, more frequent sprinkler irrigations with fewer h per set and longer continuous furrow irrigations were used. This schedule fluctuated with ambient temperatures but averaged 3 times/week with 4 h/set for the sprinkler and 24 h/week of continuous irrigation for the furrow.

The 4 rows of each plot received different cultural practices for hilling and vine removal. Two rows were hilled twice and 2 were hilled 4 times. Hillings occurred at planting and 48, 65, and 124 days after planting, with the last 2 hillings omitted on rows which were hilled only twice. The vines on one row of each hilling practice were killed with a rotochopper, which shreds the vines, and on the other with a commercial roller, which kills the vines more slowly but compacts the bed. Those rows that received the last hilling (7 days after the vines were killed) also were rolled at that hilling.

Bed dimensions in all plots were recorded at each hilling by measuring the width at the top and bottom and the height of each row. All measurements were taken at the same site to determine changes in bed profile over the growing season. At harvest, the beds were sliced open and the positions of 10 tubers from each row were measured in relation to bed profile. The depths of tuber set from the top and nearest side of the bed surface were measured.

The amount of bed cracking was determined at 109 days into the growing season prior to an irrigation cycle. The number of cracks in 90 cm of each of the 4 rows/plot (183 m total) was counted and their maximal length,

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depth, and width measured by insertion of a flexible plastic ruler.

The population of potato tuberworm in the foliage was assessed 70 days into the growing season to determine if any difference in tuber damage was due to the presence or absence of the insect under the different irrigation systems. Populations were surveyed by removal of 5 plants at random from each plot (125 plants/irrigation system) and examination of the bottom 6 laterals and the main stem of each for potato tuberworm larvae. During the growing season (90–120 days after planting) the potato tuberworm field population was augmented by evenly distributing 26,000 laboratory reared (Platner and Oatman 1968) mature pupae throughout the field.

Tubers were harvested 139 days after planting (Dec. 21), and at this time, all tubers were weighed to obtain yields and were examined for potato tuberworm infestation and greenheads (tubers rendered unmarketable due to exposure to sunlight).

Results and Discussion

Effect of Irrigation Systems

The numbers of greenheads and tubers damaged by tuberworm were distinctly different between the 2 types of irrigation (Table 1). Greenheads were more abundant under the furrow irrigation (1.65 vs. 0.55%) and there was a higher level of infestation of them by potato tuberworm (66.96 vs. 10.25%). White tubers sustained higher levels of infestation under the furrow system (5.90 vs. 0.05%) and the total infestation (whites plus greens) under furrow irrigation was over 58 times greater than under sprinkler irrigation. Tuberworm populations in the foliage did not differ between irrigation regimes with 162 and 150 larvae/field under the sprinkler and furrow systems, respectively. Irrigation systems did not affect total tuber yield between sprinkler and furrow irrigation (7.8 and 8.2 kg/row, respectively).

Soil moisture levels at 30 cm throughout the season averaged 10.8 millibars (S=4.2) under sprinkler irrigation, and soil was slightly drier with more variability (13.5 millibars, S=8.4) under furrow irrigation. Water usage on a per ha basis for the season was considerably more efficient under sprinkler irrigation (1357 m^3) than furrow (5181 m^3).

Effect of Hilling and Vine Removal

Significant differences ($P<0.01$) in the percent greenheads, infested white tubers, and total infestation occurred between rows hilled twice or 4 times under furrow irrigation but not under sprinkler irrigation (Table 2). Under furrow irrigation, hilling the rows 4 times reduced the level of infestation compared to those rows hilled twice with the same vine removal practice. In rows which had the vines killed by rolling, hilling 4 times reduced the number of greenheads (0.27 vs. 2.39%), infested whites (4.01 vs. 7.65%) and total infestation (4.16 vs. 9.39%). In rows which had the vines chopped, hilling 4 times reduced the number of greenheads (0.53 vs. 3.42%), infested whites (1.92 vs. 10.02%) and total infestation (2.15 vs. 12.55%).

Table 1.—Effects of irrigation systems on yield, greenhead formation, and tubermoth damage of potatoes, Moreno, Calif., 1977.

Parameter measured (mean/row)	Irrigation system	
	Sprinkler	Furrow
Yield (kg)	7.8	8.2
Greenheads (%)	0.55	1.65
Infested greenheads (%)[a]	10.25	66.96
Infested whites (%)[b]	0.05	5.90
Total infestation (%)	0.12	7.06

[a] No. infested greenheads/no. greenheads.
[b] No. infested whites/no. whites.

Table 2.—Effect of hilling and vine removal practices on potato tubermoth infestations and greenhead formation in potatoes, Moreno, Calif., 1977.

Parameter measured (mean %/row)	Cultural practice[a]			
	Hilled twice		Hilled 4 times	
	Vines rolled	Vines chopped	Vines rolled	Vines chopped
	Furrow irrigation			
Greenheads	2.39 a	3.42 a	0.27 b	0.53 b
Infested whites[b]	7.65 b	10.02 a	4.01 c	1.92 c
Total infestation	9.39 b	12.55 a	4.16 c	2.15 c
	Sprinkler irrigation			
Greenheads	1.50 a	0.51 b	0.05 b	0.13 b
Infested whites	0.13 a	0.09 a	0.00 a	0.00 a
Total infestation	0.24 a	0.25 a	0.00 a	0.00 a

[a] Mean separation horizontal. Means in same row flanked by same letter are not significantly different according to Duncan's multiple range test (0.01 level).
[b] No. infested white tubers/no. white tubers.

When rows were hilled twice, vine removal practices significantly affected tuberworm infestation. Under furrow irrigation rolling the vines, in contrast to chopping, significantly ($P<0.01$) reduced the number of infested whites (7.65 vs. 10.02%) and total infestation (9.39 vs. 12.55%) but did not affect the occurrence of greenheads (2.39 vs. 3.42%). The method of vine removal did not produce significant ($P>0.01$) differences in the number of greenheads, infested whites, or total infestation when rows were hilled 4 times.

Infestation levels under sprinkler irrigation were considerably lower than those under furrow irrigation, and differences in infestation between hilling and vine removal practices were masked. However, when rows were hilled only twice, vine removal by chopping significantly ($P<0.01$) reduced the percentage of greenheads (0.51%) when compared to rolling (1.50%).

Bed Dimensions and Tuber Depth

Both hilling and vine removal practices caused significant differences in bed dimension and tuber depth (Table 3). After the 2nd hilling, there was very little variation in bed dimensions. When the 3rd hilling occurred, soil was removed from the bed edge and added to the top of the bed and, thus, caused significant decreases in bed width at the top and significant increases in bed height over those beds which received only 2 hillings. This trend was continued with the 4th hilling, and the beds hilled 4 times were again significantly higher and narrower at the top than those hilled twice. The progressive narrowing of the bed top and increase in bed height

Table 3.—Effect of hilling and vine removal practices on bed dimensions and setting depth of potatoes grown under sprinkler and furrow irrigation, Moreno, Calif., 1977.

Cultural practices for season		Bed dimensions (cm)[a]									Mean tuber depth at harvest	
		After 2 hillings[b]			After 3 hillings[c]			After 4 hillings[d]				
		Width			Width			Width				
No. of hillings	Vine removal	Top	Bottom	Height	Top	Bottom	Height	Top	Bottom	Height	From side	From top
					Furrow irrigation							
2	Rolled	29.2a	61.2a	25.5a	30.6b	60.6a	23.1a	34.0c	63.8a	21.3a	10.1a	7.1a
2	Chopped	29.7a	63.0b	26.1a	30.6b	62.4ab	23.4a	27.7ab	63.9a	22.1a	11.6ab	8.7b
4	Rolled	29.2a	62.7a	25.9a	27.3a	61.9ab	29.5b	26.9a	63.0a	26.5b	12.6ab	12.0c
4	Chopped	29.3a	61.7ab	26.1a	27.9a	63.7b	28.9b	29.7b	64.1a	27.6c	12.8b	12.9c
					Sprinkler irrigation							
2	Rolled	28.6a	64.2a	25.8a	30.6b	61.4a	23.6a	34.0c	62.6ab	21.3a	11.1a	6.7a
2	Chopped	29.0a	63.1a	25.7a	29.7ab	61.7a	24.6a	29.4b	60.9a	22.3a	12.4a	7.9a
4	Rolled	28.1a	64.4a	25.9a	28.1a	62.8ab	30.4b	25.3a	60.3a	26.6b	11.6a	11.9b
4	Chopped	29.1a	63.8a	26.0a	29.7ab	64.4b	30.5b	26.2a	63.5b	27.7b	11.1a	11.9b

[a] Mean separation vertical. Means in the same column flanked by the same letter are not significantly different according to Duncan's multiple range test, 0.01 level.
[b] Hilling practices identical.
[c] Hilling practices varied.
[d] Hilling and vine removal practices varied.

Table 4.—Effect of irrigation systems on bed cracking in potatoes, Moreno, Calif., 1977.

Parameter measured	Mean crack dimensions (cm)	
	Sprinkler	Furrow
No. cracks/90 cm	1.53	2.28
Width	2.61	4.61
Depth	3.20	4.94
log vol + 1	1.3317	1.7122

through the season were best illustrated on rows where vines were removed by chopping. When vines were rolled, the bed tops were compacted which reduced the height and increased the top width when compared with chopped beds with identical hilling practices.

Mean tuber depth in the beds at harvest corresponded to bed height. Tubers were significantly ($P<0.01$) deeper in the beds which were hilled 4 times than in those hilled twice. When only 2 hillings were used, the method of vine removal significantly affected tuber depth with tubers in rolled beds being significantly closer to the top of the furrow irrigated beds, but rolling eliminated cracks and helped prevent late-season infestation. Bed height and hence tuber set depth progressively diminished through the season with the breakdown in bed profile (Bishop et al. 1976) and this contributed to the higher level of infestation in rows hilled twice.

Amount of Cracking

The width, depth, volume (log+1) and number of soil cracks were greater under furrow irrigation than under sprinkler (Table 4) although soil type was uniform in the experimental area. Cracks were 49% more abundant, 77% wider, and 54% deeper and consequently of greater volume in furrow irrigated rows than in those which were sprinkled. Soil cracking is associated with drying of the surface soil layers and thus sprinkler irrigated beds which receive overhead water are less susceptible to cracking. Additionally, the tops of furrow irrigated beds are drier than sprinkler beds and tuberworm larvae can more easily penetrate the drier soil (unpublished data).

Tuber infestation by potato tuberworm is dependent on the accessibility of tubers to both adult moths for oviposition and larvae migrating from foliage. Thus, soil cracking would increase the probability of tuber infestation, and such damage was largely confined to the furrow irrigated fields (Table 1) where cracking was more extensive (Table 4). Hilling and vine removal practices which significantly affected bed dimension and tuber depth (Table 3) also would influence soil cracking. Under furrow irrigation, where infestation was high, tuber damage in beds which were hilled twice was significantly ($P<0.05$) correlated with depth and volume of cracks. When beds were hilled 3 times and bed height and tuber depth were significantly increased, infestation of tubers was significantly ($P<0.05$) correlated only with crack depth.

Tuber infestation under furrow irrigation was considerably greater than under sprinkler irrigation even though soil type and potato tuberworm populations in the 2 fields were quite similar. Hilling, vine removal practices, soil cracks, and depth of tuber set also affect infestation. Irrigation and cultural practices, therefore, play a vital role in the management of the potato tuberworm on potatoes.

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