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Net Economic Values of Eight Soil Management Practices Used in Stake Tomato Production

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Abstract. **Staked tomatoes (*Lycopersicon esculentum* Mill) grown in 8 soil management systems are compared for differences in marketable yields, gross revenues, treatment costs, and net economic values. Maximum marketable yields were obtained using a fumigant and straw mulch combinatory practice, but the highest net economic value (gross revenues less treatment costs) was realized by a fumigant and herbicide ground management practice. These data suggest that the use of mulch materials and/or herbicides increased yields and net returns over standard cultivation practices.**

One production challenge encountered by stake tomato growers is the development of a cost effective soil management program (4). Growers face seemingly conflicting objectives in attempting to increase marketable yields, minimize costs, improve harvest timeliness, and increase net returns. An economic approach to soil management procedures emphasizes an evaluation of the per unit revenue and cost impacts as well as estimations of the internal benefits and costs associated with alternative soil management systems. Comparisons are simplified in this study, because only treatment benefits and costs are used rather than total revenues and costs.

For this study, 8 methods of preplant soil treatments for stake tomato production were compared to assess the net economic value of each treatment. Specifically, a common, commercial soil treatment practice was compared with seven alternative practices over a 2-year period. Costs which were not affected by the selection of a soil treatment strategy, such as plant or stake costs, were not included in the analysis. Thus, net economic values (NEV) represented total gross revenues less treatment costs and should not be equated with net profits since NEV estimates included production costs which were common to all treatments.

Materials and Methods

The experiment was conducted in 1980 and 1981 using 'FloraDade'. Transplants were greenhouse-grown in 5 cm cubes. In 1980, the field soil was a sandy loam at pH 6.0, with an organic matter content of 1.4%. In 1981, the site was a loamy sand with organic matter of 2.5% and a pH of 6.2. Fertilizer and lime were applied in each year according to recommendations for North Carolina tomato production in the area (4, 6). Preseason nematode assay tests revealed low nematode populations in both years.

The 8 treatments were replicated 5 times in a randomized, complete-block, experimental design. In 1980, plots were 7.5 m wide by 10.5 m long and contained 5 rows with about 50 cm between plants within a row. The 1981 arrangement was similar, except rows were shortened to 9 m, and plant spacing was increased to about 60 cm. Yields were collected from the center row in each plot for both years.

The 8 soil treatment strategies are identified in Table 1. Soil management programs differed primarily by: (a) the level or type of fumigant used (treatment 8 did not include a fumigant); (b) the use of chemicals, hand-hoeing, or cultivation for weed control; and (c) the inclusion or exclusion of straw or plastic mulch. For each management strategy shown in Table 1, the inclusive elements are identified by an "X" in the activity row. The check (treatment 1) represented a common soil management program for tomato production in western North Carolina. Treatments 1 and 3 differed only by the amount of hand-hoeing labor utilized with treatment 3 receiving 10 additional hours of hoeing. Freisen, Rajagopal and Sankaran, and Kasasian and Seeyave suggest that additional, timely hoeings could improve yields (2, 3, 5). Additional hoeings for treatment 3 occurred about 28 days after transplanting. Three weeks after transplanting in 1980 and 2 weeks after transplanting in 1981, plots scheduled to receive straw mulch were clean cultivated, and mulch was applied. Treatment 2 received 2.5 kg/ha of napropamide, and 0.28 kg/ha of metribuzin preplant incorporated prior to transplanting. At the time of transplanting, treatment 8 received 0.57 kg/ha of paraquat to kill existing weeds and also received a surface application of napropamide plus metribuzin (between the plastic) at the same rates as above.

Data were collected on weeds, insects, and diseases by taking counts. Weed data were collected about 30 days after transplanting by sampling five, 0.09 m^2 areas in each plot. Similar sampling techniques were utilized to obtain insect and disease counts during the season.

Material costs, including herbicides, fumigants, and mulches, were based on local market prices. Herbicide application costs were estimated to be $12.50/application/ha whereas fumigation and black plastic application charges were expensed at local custom applicators rates. Cultivation charges were expensed at $25/ha/application while all labor expenses (hand hoeing, cleanup, etc.) were charged at a rate of $3.00 per hour.

Mature fruit were harvested over 7 weeks at 2- to 3-day intervals beginning in late July and were graded according to USDA standards (7). Fruit were classified into 1 of 3 marketable categories or as culls. Marketable classes included: (a) combination grade fruits larger than 64 mm and designated as large-extra large; (b) combination grade fruit between 51 and 63 mm and designated as mediums; and (c) fruit less than 51 mm. All others were categorized as culls. Culled fruit was weighed, and

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Table 1. Fumigant, herbicide, and mulch materials included in each soil treatment programs.

Materials used in soil treatments	1 EDB-PIC + cult (check)	2 EDB-PIC + herb	3 EDB-PIC + clean cult[z]	4 EDB-PIC + straw	5 MB-PIC + cult	6 MB-PIC	7 MB-PIC + herb + plastic	8 Plastic + herb
Fumigants								
(a) 230 kg/ha of ethylene dibromide + chloropicrin (EDB-PIC), injected preplant	X	X	X	X				
(b) 270 kg/ha of methyl bromide + 125 kg/ha of chloropicrin (MB-PIC), injected preplant					X	X		
(c) 170 kg/ha^{-1} of methyl bromide + chloropicrin, preplant							X	
Herbicides								
(a) Conventional cultivation	X		X	X	X			
(b) Hoeing	X		X				X	X
(c) Chemical[y]		X					X	X
Mulch								
(a) 1000 bales of straw/ha				X				
(b) 1.5 ml black plastic							X	X

[y]Specific chemical identified in the Methods and Materials section in the text.
[z]Treatment 3 differs from treatment 1 only by its inclusion of 10 additional hours of hoeing. For brevity, treatment 3 is referred to as EDB-PIC + clean cultivation.

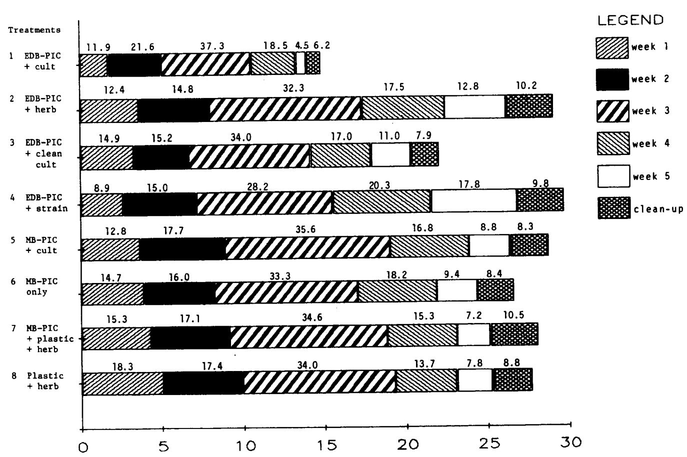

Fig. 1. Gross revenues and the distribution of gross revenues by week for each treatment (combined average of 1980 and 1981 data). Treatment weekly distribution percentages may not sum to 100% due to roundings.

defects were noted. Daily shipping-point price quotations for the region were obtained from published reports of the Market News Service branch of USDA (8). Gross revenues by treatment were calculated for each harvest date using the appropriate price and quantity data. For analysis and discussion, data were combined across years and grouped into 5 weekly harvest periods plus a clean-up harvest. Data were analyzed using conventional ANOVA statistical packages (1).

Results

Marketable yields increased significantly for all experimental systems (treatments 2 through 8) relative to the control (Table 2). Yield averages for 2 years showed that treatment 1 resulted in 37,000 kg/ha (16.6 T) of marketable fruit harvested per acre. An additional 10 hr of hoeing (treatment 3) increased marketable yields to 53,000 kg/ha (23.7 T), an increase of 43% above the check. All remaining practices registered even larger gains, with marketable yields of 63,000 kg/ha (28.1 T) or greater — an increase of 69% or more above the check treatment. In general, treatments increased average fruit weight (Table 2), but the magnitude of the increase was slight when compared with the total yield per hectare increase. Therefore, these data suggest that increased yields occurred as a result of an increase in the number of fruit harvested.

Within the EDB-PIC subgroup (treatments 1 through 4), the use of either herbicides or straw mulch to control weeds increased yields over standard cultivation practices. Disturbance of tomato roots at critical growth periods appeared to reduce total fruit set and yield for treatments 1 and 3. However, this hypothesis does not appear valid when comparing yields for cultivated versus uncultivated treatments for the MB-PIC subgroup (treatments 5 and 6, respectively).

The proportion of defective fruit (culls) ranged from 6.8% in treatment 8 to nearly 10% in treatment 3 (Table 2). Early blight lesions were the main cause for cullage, but proportions were not related to treatment. Blossom end rot was a minor source of cullage, but the proportion did change with treatment. Cultivated plots tended to show less blossom end rot than unculti-

Table 2. Production response of 'FloraDade' tomatoes to 8 ground management systems.

Treatment	Yield (kg/ha) Total marketable	Cull	Grade (in % of total marketable) XL+L	Med.	No.3	Avg wt fruit (g)[z]	Defects (%)[y] Early blight	Blossom end rot	Fruit worm
1. EDB-PIC + cult. (check)	37341	2899	69.1	17.9	13.0	163	4.3	0.6	2.3
2. EDB-PIC + herb	67253	6457	72.7	10.9	16.4	173	6.7	0.8	1.3
3. EDB-PIC + clean cult.	53270	5724	70.2	11.9	17.9	173	5.7	0.5	3.5
4. EDB-PIC + straw	68550	5835	73.2	10.6	16.2	173	5.6	0.8	1.4
5. MB-PIC + cult.	68087	5517	73.0	10.5	16.5	177	5.2	0.4	1.9
6. MB-PIC only	63011	6175	72.0	10.4	17.6	177	5.1	1.4	2.4
7. MB-PIC + plastic + herb	67725	5859	69.9	11.4	18.7	177	5.3	1.2	1.5
8. Plastic + herb	66213	4845	71.5	9.1	19.4	186	3.6	0.9	2.3
LSD (0.05)	8226	1791	3.9	2.9	2.7	9	NS	0.5	NS

[z]Average weight based on large, extra-large and medium sizes.
[y]Based on total yields.
[NS]Nonsignificant at 0.05 level.

vated plots. There is no apparent reason for this observation. Cullage due to insect damage was not significant among treatments and did not vary by treatment.

NEV was affected not only by yields, but also by harvest timeliness. Weekly gross revenues are depicted in Fig. 1. The highest initial gross revenues were realized by the 2 black plastic treatments (7 and 8), but subsequent weekly revenue changes were much more modest. A comparison of first week gross revenues for plots with or without plastic reveals that plastic mulched plots gave 30% higher gross revenues (on average) than treatments without plastic. These early gains were not sustained, however, as revenues increased more slowly (or even declined for treatment 8) than for treatments without plastic between the first and 2nd harvests.

Gross revenues, direct treatment costs, and NEV estimates are summarized in Table 3. In addition, indirect treatment costs, such as higher harvesting expenses due to increased yields, are itemized in Table 3. All treatments produced significantly higher gross revenues than the check. Within the experimental group, slightly lower gross revenues were recorded for treatment 3, but few differences were observed among other treatments. Direct costs included material, application, and labor expenses for each treatment. The check treatment was assumed to represent normal yields and harvesting cost levels, and thus, zero additional indirect costs were incurred. Treatment 2 resulted in 29,912 kg/ha more marketable fruit than treatment 1, and an additional $1097/ha in harvesting wages were incurred indirectly due to the increased yield level. Similar calculations resulted in indirect cost estimates for the remaining indirect cost entries in Table 3. NEV's are calculated as the residual of the difference between gross revenues and treatment costs (direct and indirect). Treatment 2 resulted in the highest NEV among all management strategies, whereas the check resulted in a substantially lower economic value. However, the similarity in NEV magnitudes among the experimental treatments suggests that few differences existed among the alternative practices. Other factors, such as marketing considerations or the level of risk associated with each practice, would exert greater influence on a grower's soil management selection within this superior NEV subgroup.

Selected weed and disease count results are provided in Table 4. For 1980, nutsedge (*Cyperus esculentus* L.) pressures were moderately greater in the EDB-PIC group than in other treatments. In 1981, *Echinochola crusgalli* plus *Setaria virdis* and *Galinsoga ciliata* were controlled in all experimental treatments, but counts were significantly higher than for the check. In general, either the use of a fumigant or the combination of fumigant with herbicides or cultivation provided effective weed control. Early blight foliage counts differed among treatments only for the June 1981 rating (Table 4), but a pattern of control effectiveness among treatments was not evident.

Table 3. Gross revenues, treatment costs, and net economic values, per hectare, for combined 1980 and 1981 seasons by treatment.

Treatment	Dollars/ha Gross revenue	Direct treatment[z]	Extra harvest cost due to treatment[y]	NEV	Rank[x]
1. EDB-PIC + cult.	14866	1000	0	13866	8
2. EDB-PIC + herb	29192	808	1097	27287	1
3. EDB-PIC + clean cult.	22088	1075	586	20427	7
4. EDB-PIC + straw	29847	2918	1146	25783	4
5. MB-PIC + cult.	28772	2565	1129	25078	5
6. MB-PIC only	26556	2360	941	23255	6
7. MB-PIC + plastic + herb	28113	1186	1114	25813	3
8. Plastic + herb	27702	511	1060	26131	2
LSD (0.05)	3842	---	---	---	

[z]Direct costs reflect material, application, and labor charges associated with each treatment.
[y]Higher yields for the alternative treatments resulted in additional harvesting expenses.
[x]Rank determined by assigning highest NEV the number 1, the 2nd highest 2, etc.

Table 4. Selected weed and disease count data by treatment.

Treatment	Weed species[z]				Early blight lesion[x]
	Annual grasses[y]	Hairy Galinsoga[y]	Nutsedge[y]	Pigweed[y]	
1. EDB-PIC + cult.	402	46	86	2.4	90
2. EDB-PIC + herb	4	0	134	0.0	169
3. EDB-PIC + clean cult.	0	0	43	0.6	123
4. EDB-PIC + straw	0	0	- - -[w]	- - -[w]	38
5. EDB-PIC + cult.	1	0	3	0.0	85
6. MB-PIC only	2	1	0	0.0	205
7. MB-PIC + plastic + herb	0	0	5	0.0	108
8. Plastic + herb	0	0	17	0.4	96
LSD (0.05)	325	37	96	1.6	69

[z]Annual grasses and hairy galinsoga recorded on 9 June 1981, nutsedge and pigweed on 24 June 1980.
[y]Weed counts per 0.5 m^2 area.
[x]Count per 1.5 m^2 area.
[w]Data not collected.

Discussion

In this study, all alternative practices increased gross revenues, marketable yields and NEV's significantly above the check. The selection of a superior ground management program from the experimental group is more difficult since marketing conditions, prices, inputs, and risk preferences vary over time and will change with location and grower. In addition, the lack of significant differences in NEV's among treatments 2, 4, 5, 6, 7, and 8 would suggest that growers would be indifferent with respect to these choices. However, an estimation of the internal benefits received for each treatment dollar invested would provide growers one method of choosing desirable strategies. Calculation of a benefits-cost index measure is facilitated by constructing a partial budget which focuses on changes in gross revenues and costs associated with different soil treatments.

Partial budget comparisons for all experimental treatments are presented in Table 5. Added revenues and costs plus reduced revenues and costs are shown as adjustments to the control revenues and costs. For example, the treatment 2 column indicates that direct costs were $193 less than the check, whereas gross revenues and indirect expenses were $14,327 and $1,097 per ha, respectively, more than the check. Combining net positive and net negative effects results in an estimate of the change in net economic value by switching to an alternative practice.

By definition, the benefit-cost index is the ratio of net positive effects to net negative effects minus 1.0 (9). Practices which offer significantly higher benefit-cost indices are preferred to strategies which offer lower ratios. Index calculations in Table 5 indicate that all experimental practices are preferred to the check, but specific ratio values also permit some comparisons within this preferred management subset. Based on benefit-cost ratios, 3 basic groupings can be identified: (a) treatments 2 and 8, which have indices exceeding 12.1; (b) treatments 3 and 7 having indices of about 9.0; and (c) treatments 5, 6, and 4 which have ratios of about 4.0. An index value of 12.0 would indicate that for every extra dollar invested in a soil management practice, the marginal internal return or benefit would be $12. Substantial increases in revenues or significant cost reductions increase the value of benefits-cost index. It is interesting that the highest yielding practice (treatment 4) results in the lowest benefit-cost ratio value among all experimental practices. This result is not surprising, since little benefit is realized for the high investment expense associated with utilizing straw mulch (when compared to other practices). Using benefit-cost criteria, the preferred ground management strategies would be treatments 2 or 8.

Table 5. Partial budget and benefit-cost index for 7 tomato ground management systems as compared with the check practice.

Partial budget	Soil treatment and dollars/ha							
	1[z]	2	3	4	5	6	7	8
Added revenue	0	14,327	7223	14,982	13,907	11,690	13,247	12,837
Reduced cost	0	193	0	0	0	0	0	489
Net positive effect	0	14,520	7223	14,982	13,907	11,690	13,247	13,326
Added cost:								
materials	0	0	74	1918	1564	1359	185	
harvest labor	0	1097	586	1146	1129	941	1114	1060
Reduced revenue	0	0	0	0	0	0	0	0
Net positive effect	0	1097	660	3064	2693	2300	1299	1060
Change in net economic value	0	+13,423	+6563	+11,918	+11,214	+9390	+11,948	+12,266
Benefit-cost index[y]	0	12.23	9.95	3.89	4.16	4.08	9.19	12.57

[z]Treatment 1 is the check practice and represents the base value to which all experimental systems are compared. Therefore, all values in this column are zero.

[y]Index estimated via formula as $\frac{\text{net positive effect}}{\text{net negative effect}} - 1$.

The economic value of MB-PIC as a soil fumigant is unclear. Treatments 7 and 8 differed only by the inclusion and exclusion of MB-PIC; yet, marketable yields were similar. The lack of any substantial nematode population, other soil-disease problems, and relatively low weed pressures, likely contributed to the lack of yield differences between these treatments. In circumstances where preseason nematode assays reveal low population levels and where there are no known soil-borne diseases, the fumigant expense could be treated as an insurance purchase rather than a treatment cost. In this instance (where the probability of disease outbreak is very small) treatment 8 would be preferred due to its low cost. However, this decision may prove to be imprudent, given the high value of the crop and the relatively low cost of fumigation.

The lack of significant differences among yields, gross revenues, and NEV's for EDB and MB groups suggests that the recent ban on EDB field use will not jeopardize the financial positions of most tomato growers. Growers must, however, continue to evaluate the benefits and costs realized with the large range of soil management programs available for them to use.

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Strawberry Receptacle Growth and Endogenous IAA Content as Affected by Growth Regulator Application and Achene Removal

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***Abstract.* Parthenocarpy was induced in emasculated strawberry (*Fragaria* × *ananassa* Duch.) flowers with aqueous solutions of $10^{-3}M$ NAA, GA_3 or GA_{4+7} in 2% DMSO plus 0.1% Tween 80. All fruit except those treated with NAA stopped growing within 12 days of treatment. Repeat application with NAA or GA_{4+7} 20 days after initial treatment stimulated continued growth of NAA-induced fruit, but had little or no effect on growth of GA_{4+7}-induced fruit. The diameters of mature parthenocarpic fruit ranged from 70% to 90% of that of pollinated fruit. Achene removal 12 days after pollination greatly reduced subsequent growth of receptacle tissue, complete removal being more effective than partial removal. Following achene removal 16 days after pollination, treatment with aqueous solutions of NAA in 2% DMSO and 0.1% Tween 80 produced receptacles 75% the size of controls with intact achenes, but neither GA_3 nor GA_{4+7} stimulated growth. Achene removal 24 days after pollination did not influence further receptacle enlargement. Concentration of free indoleacetic acid (IAA) in NAA-treated fruit was 5-times that in controls and 3-times that in GA_{4+7}-treated fruit 6 days after treatment. By 14 days after treatment, the levels had declined in all treated fruit. Free IAA concentration in the receptacle tissue of intact fruit was nearly equal to or greater than that in achenes 14 days after pollination. The growth rates of receptacles were positively correlated with numbers of intact achenes and free IAA content of the receptacle. Chemical names used: naphthaleneacetic acid (NAA); gibberellins (GA_3 or GA_{4+7}); dimethylsulfoxide (DMSO)**

Exogenously-applied auxin and GA induce fruit set in many species, including strawberry (4, 16, 17). Parthenocarpic strawberry fruit induced by auxin are larger than those induced by GA (16, 17). When aqueous solutions are used, growth of parthenocarpic fruit parallels that of pollinated fruit during the first 10 days after treatment, then slows (17). These observations suggest that a continuous supply of hormone is required to maintain growth.

Achene removal markedly inhibits strawberry receptacle enlargement (10, 11, 12); removal late in development hastens fruit ripening (12). Replacing achenes with lanolin containing auxin or GA permits continued receptacle growth (10, 11, 12, 15), suggesting that enlargement is mediated by achene-derived hormones. Achenes are rich sources of hormones (2, 8, 11, 13), but receptacle growth is not well correlated with endogenous hormone content of achene or receptacle tissue.

To our knowledge, no data are available on the effects of growth regulator application and/or achene removal upon levels of endogenous hormones in strawberry receptacles. Therefore, our purposes were to: (a) compare the effects of auxin and GA

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