An alternative, low-input production system for fresh market tomatoes

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Abstract. *An alternative, low-input production system for fresh market tomato was developed using strip tillage practices in conjunction with established bahiagrass pasture. The alternative system was designed to reduce the impact of soilborne pests, minimize agricultural inputs, improve soil conservation and optimize yields. Field experiments indicate that competition from bahiagrass for nutrients within the tilled strips significantly impacted yield. Selective colonization of tomato roots by arbuscular mycorrhizal fungi isolated from field plots was observed. Damage from root-knot nematodes was minimized by planting tomato into established bahiagrass pastures. The alternative system was validated on a commercial tomato production farm in a side by side comparison with a conventional production system consisting of raised beds, fumigated with methyl bromide and covered by black polyethylene plastic. Yields were 6.5 t/ha greater under the conventional system. However, the net return was $568/ha greater in the alternative system. The results indicate that the alternative system has the potential to replace or supplement the conventional production system.*

Key words: agricultural production systems, methyl bromide, mycorrhizal fungi

Introduction

Production of fresh market tomato (*Lycopersicon esculentum*) is a major agricultural industry in the southeastern United States. In Florida alone, 19,600 ha harvested during the 1994/95 production season generated over $461 million in sales (Florida Agricultural Statistics, 1997). The majority of growers use a "raised bed-plastic mulch" production system. Fertilizers are incorporated into 15- to 30-cm high by 69- to 90-cm wide beds that are then fumigated with methyl bromide and covered with a black or white polyethylene plastic mulch. The raised bed-plastic mulch system was developed in the 1960s (Geraldson et al., 1965; Jones et al., 1966; Overman et al., 1965) and has served a pivotal role in the economic success of southeastern tomato producers (Cantliffe et al., 1995; Geraldson, 1975).

Recently, conditions associated with the use of this system have conflicted with emerging environmental and economic issues, jeopardizing its continued widespread use. Fumigation with methyl bromide for soil disinfestation has become such an integral component of the production system that Florida tomato producers currently account for about 24% of the total pre-plant methyl bromide consumption in the United States (EPA, 1997). Methyl bromide has been identified as a major ozone-depleting substance and a ban on production and sale in the United States will be implemented (Federal Register, 1993). In the absence of methyl bromide, conventional tomato production is projected to decline by 69% (Spreen et al., 1995). While replacement chemicals have been identified (Locascio et al., 1997; Ohr et al., 1996), reliance upon broad-spectrum biocides for soil disinfestation will continue to leave the industry vulnerable to future regulatory policies.

Crop rotation has been used to disinfest soil and increase productivity in many agronomic production systems (Cook and Baker, 1983; Glynne, 1965). Traditional applications involve the establishment of a rotational crop in fields where the persistence of soilborne pests limits crop yields. As a nonhost, the rotational crop is maintained for periods sufficient to reduce or eliminate soilborne pests. This approach has been difficult to implement when the rotational crop results in a loss of revenue for farmers. Rather than waiting until fields become unproductive before establishing a rotational crop, an alternative approach is to rotate high cash value crops to locations where the beneficial rotation crops are presently established. Florida has about 2.5 million ha of improved bahiagrass (*Paspalum notatum*) pasture located throughout the major tomato-producing regions that is used for grazing, hay, seed, and sod production (Chambliss, 1996). Rotations utilizing bahiagrass have been shown to reduce major soilborne pests of tomato including diseases caused by *Sclerotium rolfsii* and *Fusarium oxysporum* f.sp. *lycopersici*, and damage from root-knot nematodes (Brenneman et al.,

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1995; Dickson and Hewlett, 1989; Rodriguez-Kabana et al., 1988).

Other issues also impact the long-term sustainability of the raised bed-plastic mulch production system. Disposal of the polyethylene plastic is a problem as landfills are reaching capacity, burning of the plastic in the fields is no longer permitted in some regions, and commercially-viable recycling programs are not readily available. Residual plastic remaining in the fields after clean-up builds-up in the soil following successive cropping cycles.

Use of plastic mulch can intensify soil erosion from storm water runoff when 50% or more of the planted area is covered. Soil compaction in row middles from repeated tillage and movement of heavy equipment can further escalate soil erosion problems.

Damage from plant pests also can be enhanced from conditions created by the raised bed-plastic mulch production system. Rain splash dispersal of plant pathogens is significantly increased (Madden et al., 1993). Windblown soil from the bare row middles creates plant injury, and significantly increases the incidence of foliar diseases (Pernezny et al., 1992). The incidence of *Phytophthora* blight in bell pepper was reduced using minimum tillage techniques (Ristaino et al., 1997).

Finally, production costs have increased from $17,490/ha in 1984/85 to $26,150/ha in 1995/96 (Taylor, 1984; Smith and Taylor, 1996), due in part to the high level of agricultural inputs associated with the conventional raised-bed plastic-mulch system. Average yields and market prices have not kept pace with increasing production costs (Florida Agricultural Statistics, 1997), undermining the economic stability of farmers with limited financial resources.

Our objectives were to design, develop and evaluate an alternative production system for fresh market tomatoes in view of certain environmental and economic issues. The specific goals were to: 1) eliminate dependence upon broad-spectrum soil fumigants for soil disinfestation, 2) minimize production costs, 3) improve soil conservation, and 4) optimize yields. The conceptual framework for this production system is patterned after an ecological approach to pest management described by Levins (1986).

Materials and Methods

Experimental conditions

The alternative production system utilized the existing bahiagrass pasture in order to avoid the impact of several key soilborne pests. Tomatoes were transplanted directly into the bahiagrass pasture with minimum tillage and an area of sod was maintained between rows to function as a living mulch. Elimination of methyl bromide fumigation and plastic mulch resulted in a savings of $1,926/ha (Smith and Taylor, 1996).

Utilization of bahiagrass as a living mulch improves water infiltration and soil tilth due to the channels left by the deep penetrating root system (Burton, 1954) and the organic matter is conserved (Beaty and Tan, 1972). With minimum tillage, reductions in soil erosion from storm water runoff, plant injury from blowing soil, and soil compaction were expected. Yields must be optimized to ensure economic profitability. Competition from a living mulch can negatively impact yields and must be accounted for in the fertility requirements. Some level of sod management is needed to minimize the impact of competition for nutrients and water.

Field experiments

Two experiments in 1995 measured the impact of tillage practices, sod management, fertilizer rates and application methods on marketable yield of tomatoes. One experiment in 1996 determined the influence of cultivar and row spacing. The field experiments were conducted in established plots of bahiagrass (cv Pensacola) at the University of Florida, Institute of Food and Agricultural Sciences, North Florida Research and Education Center, Quincy, Florida.

Experiment 1. In the spring of 1995, three sod management and two fertilizer application methods were arranged in a randomized complete block design (RCBD) with four replications per treatment. Sod management treatments consisted of mechanical mowing between rows, chemical mowing with applications of sethoxydim (2-[1-(ethoxyimino)butyl]5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one) (0.20 kg ai/ha) at 1 and 4 weeks after transplanting, and a 60-cm-wide strip of clear, low-density polyethylene (LDPE) plastic (AEP Industries, Hackensack, NJ) laid down prior to transplanting. Fertilizer applications consisted of 179-78-126 kg/ha of N-P-K applied as a preplant treatment or with 40% of the N applied preplant and 10% applied at 2, 4, 6, 8, 10, and 12 weeks after transplanting. Fertilizer was surface applied as a band 5 cm wide on both sides of the row. The source of N-P-K was NO_3:NH_4 (50%:50%), K_2O, and P_2O_5, respectively, for the preplant application and NH_4 for the postplant application.

Plots were single rows, 10 m in length. Plant spacing within the row was 46 cm. Spacing between rows was 1.8 m. Prior to transplanting, paraquat (1:1-dimethyl-4,4′-bipyridinium dichloride) was applied at a rate of 0.53 kg/ha to a 45-cm-wide strip to kill the sod, and a single chisel set at 15 cm depth was used to prepare a planting groove. Tomato transplants (cv AgriSet 761) were set into the chisel slot on 7 April and cultivated on a trellis using wooden stakes and string (stake culture). Drip irrigation was provided. Pesticide applications for control of insects and diseases were made based upon weekly scouting reports. Yield data were collected from 12 contiguous plants in each replicate plot. Fruits were sorted as marketable and unmarketable based on USDA size and grading standards. Analysis of variance was used to examine treatment effects and interactions (MSTAT, Michigan State University).

Experiment 2. In the fall of 1995, three sod management and two fertility treatments were arranged in a RCBD with four replications per treatment. Sod management treatments consisted of mechanical mowing up to the sides of a tilled strip, silver LDPE plastic (AEP Industries) or a white over black, coextruded LDPE plastic (Edison Plastics, Newport News, VA). The plastic mulch was applied in a 45-cm-wide strip prior to transplanting. Fertility treatments consisted of 179-48-78 or 291-48-72 kg/ha of N-P-K. For both treatments, 40% of the N was applied preplant and an additional 15% was surface applied as a side dressing 2, 4, 6, and 8 weeks after transplanting.

Prior to transplanting a 45-cm-wide strip was sprayed with glyphosphate (N-(phosphonomethyl)glycine) (1.12 kg a.i./ha) and, after several days, was rototilled. Metribuzin (4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-S-(4H)-one) (0.56 kg a.i./ha) and napropamide (N,N-diethyl-2-(1-naphthalenyloxy) propionamide) (1.1 kg a.i./ha) were applied to the tilled strips prior to transplanting the cultivar Solar Set on 14 August. Plot size, row and plant spacing, source and incorporation of N-P-K, irrigation, pest management practices, harvest procedures, and data analysis were the same as employed in Experiment 1.

Experiment 3. In the spring of 1996, the impact of cultivar and row spacing were examined in a 2 x 2 factorial design with six replications per treatment. Cultivars were Agriset 761 (stake culture) and NC134G (ground culture) and spacings between rows were 1.2 and 1.8 m, respectively. Each plot consisted of three rows with 13 plants per row and with a 46-cm spacing between plants. A 3-m buffer area was created between replicate plots. A 46-cm-wide strip was tilled using a PTO driven rototiller. Four passes were made over a 14-day period to ensure uniform tillage of the strip. A banded application of fertilizer was applied to the strip at the rates (kg/plant) of 12.5 N - 15.4 P - 10.4 K (146 - 180 - 102 kg/ha using a 1.8 m row spacing). The fertilizer was incorporated into the strip using a rototiller. Two additional applications of N were made at 8.5 g/plant (34 kg/ha using a 1.8 m row spacing) at 4 and 7 weeks after transplanting by banding the application immediately adjacent to the plants.

The bahiagrass between the rows and the tilled strip was managed using a combination of chemical and mechanical mowing. Row middles were mowed 6 times (22, 34, 43, 54, 60, and 74 days after transplanting). Sethoxydim (0.20 kg a.i./ha) was applied to the tilled strip and the row middles at 20 and 48 days after transplanting. In addition, grass and weeds in the tilled strip were physically removed by hoeing 22 days after transplanting.

Tomatoes were transplanted on 11 April 1996. The cultivar AgriSet 761 was tied and staked after transplanting while NC134G was kept as a ground cultivar. Plants were routinely scouted for insects and foliar diseases and pesticide applications were made accordingly. Irrigation was provided through drip tubing.

Yield data were obtained by harvesting six contiguous plants in the center row of each plot on three separate occasions. NC134G was harvested 64, 74, and 83 days after transplanting. AgriSet 761 was harvested 74, 83, and 92 days after transplanting and fruits were sorted as marketable or unmarketable based upon USDA standards for size and grades. Analysis of variance tested treatment means and interactions for significant differences using PROC GLM of SAS (release 6.04 for personal computers; SAS Institute, Cary, NC).

Arbuscular mycorrhizae (AM) were collected in soil cores (4.5-cm diam. x 20-cm deep) on 4 June from the root zones of tomato and bahiagrass in three replicate plots. Samples were placed in plastic bags and kept cool until they were stored at 4°C. Roots and spores of AM fungi were extracted by decanting and wet sieving followed by sucrose-density-gradient centrifugation for separation of spores (Sylvia, 1994). Spores were grouped by morphological characteristics and then used to establish single-species pot cultures in the greenhouse. Roots were cleared in KOH, stained with trypan blue, and colonized root lengths were estimated with the gridline-intersect method (Giovannetti and Mosse, 1980). Arbuscular mycorrhizal fungi were isolated from the roots of bahiagrass and tomato in the experimental sites and tested for the host specificity, root colonizing ability, and impact on shoot dry mass using pure cultures inoculated into pots containing sterilized sand and tomato (cv Solar Set) or bahiagrass (cv Pensacola).

The response of tomato to selected isolates of AM fungi was evaluated in the greenhouse. The plants were grown from seed in 600 ml Deepots containing pasteurized, low P soil inoculated with the following AM fungal isolates: S3029, S3060 (from tomato), S3061 (from bahiagrass), or a mixture including all three isolates. There were five replicates per treatment. The soil inoculum provided an equivalent of 125 spores per pot. The mycorrhizal inoculum potential of each isolate was also estimated (Sylvia, 1994). The experiment was initiated on 10 January 1997 and harvested on 10 March 1997. The average maximal and minimal greenhouse temperatures were 33 and 17°C, respectively, and the average maximal photosynthetic photon flux density was 1229 μmol m^{-2} sec^{-1}. Shoot dry mass, P content, and percentage root length colonized were determined on 10 March 1998.

Field validation

Two plots were established side by side in a 3.0 ha pasture of Pensacola bahiagrass that had been established 3 years earlier. Prior to bahiagrass, the field had been planted to peanut (*Arachis hypogea*) and tomato. The original soil pH was 5.8. The pasture was limed at the rate of 2.2 t/ha prior to cultivation.

A 1.8 ha section of the field was used to produce tomatoes under the conventional system. Ground preparation consisted of repeated tillage followed by leveling of the plot. Fertilizer was incorporated into 20-cm high by 76-cm wide beds at a rate of 118-64-223 kg/ha of N-P-K. Beds were fumigated with a 98:2 mixture of methyl bromide:chloropicrin using a broadcast rate of 448 kg/ha. Methyl bromide was injected with three chisels per bed spaced 30 cm apart at a depth of 15 to 20 cm. Beds were immediately covered with black LDPE plastic.

The remaining 1.2 ha of the field was used to produce tomatoes under the alternative system. Paraquat was applied in a 61-cm wide band down the center of each row. When the sod had died, a subsoil chisel was used to break the ground. Four passes with a PTO-driven rotovator were used to prepare 61-cm-wide tilled strips. Fertilizer was incorporated into the strips at a rate of 118-64-223 kg/ha of N-P-K and herbicide (metribuzin) was applied to the strip prior to transplanting. The herbicide sethoxydim (0.4 kg a.i./ha) was applied to the strips after transplanting. Mechanical mowing was not used but the tilled strips were hand weeded four times.

Drip irrigation was used on both production systems. An additional 184-0-188 kg/ha of N-P-K was applied during the season through the drip tube. Spacing between rows was 1.7 m in both systems. Both systems were planted 1 April 1997 using the cultivar Florida 47. Scouting was performed to assess the density of foliar diseases and insect pests and pesticides were applied accordingly. Six harvests were made. Fruits were sorted according

Table 1. Analysis of variance for experiments measuring the impact of fertility, sod management, row spacing and cultivar on yield of tomato.

Source	Significance (*P*)
Experiment 1	
Sod management	<0.001
Fertility	0.027
Interaction	0.217
Experiment 2	
Sod management	<0.001
Fertility	0.105
Interaction	0.313
Experiment 3	
Cultivar	<0.001
Row spacing	0.067
Interaction	0.042

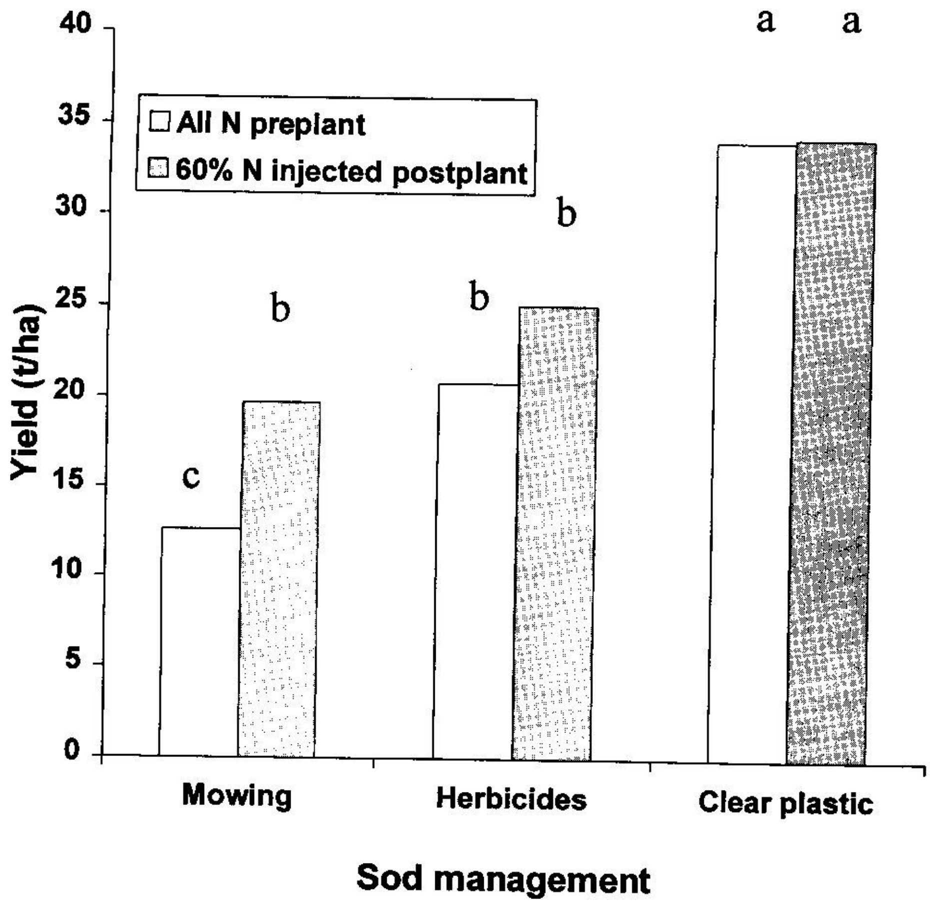

Figure 1. Effect of three sod management treatments and two nitrogen management treatments on the marketable yield of tomato in Experiment 1.

to USDA standards and the marketable yields were determined.

Components within the enterprise budget included land rent, equipment costs, production costs, and clean-up costs. Production costs were comprised of labor, pesticide, fertilizer and plant costs. Clean-up costs consisted of labor and fuel costs. Expenditures were recorded for both production systems under the appropriate components and the dollar net return/ha determined.

Nematode assessment

Populations of plant-parasitic nematodes in the soil were monitored prior to transplanting and after postharvest for the three field experiments. Postharvest root-gall index ratings were made from four plants in each plot using a 0-10 scale where 0 = no root galling and 10 = 100% galling of the root-system. A limited survey was conducted on four commercial tomato farms and nine bahiagrass pastures to examine the diversity of phytoparasitic nematode genera. In each pasture a single 2 to 3 ha area was selected that contained good coverage of bahiagrass and was relatively free of weeds. Soil samples (12 to 15 cores each) were randomly collected to a 20-cm depth and composited. Nematodes were extracted from 100 cm^3 of soil by the centrifugation-sugar flotation method.

Results

Experiment 1. Sod management and fertilizer application had a significant impact on the marketable yield of tomato (Table 1); there were no significant interactions. Highest yields were obtained in plots utilizing clear plastic mulch (Fig. 1). When 60% of the N was applied after transplanting, significantly higher yields were obtained in mechanically mowed plots.

Experiment 2. Response to N rate was not significant, but management of the bahiagrass had a highly significant impact on yield (Table 1). Yields were highest in plots where a plastic mulch was used in the row to manage growth of the sod (Fig. 2). Within individual sod management treatments there were no significant differences between the two rates of fertilizer applied. A general trend towards higher

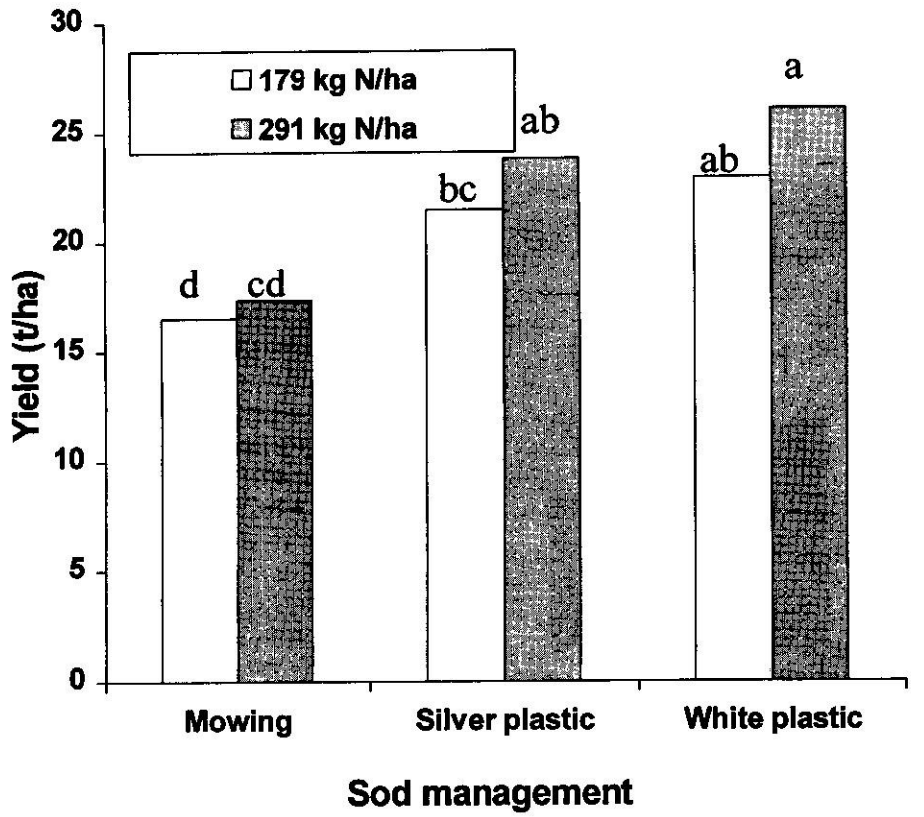

Figure 2. Effect of three sod management treatments and two nitrogen rates on the marketable yield of tomato in Experiment 2.

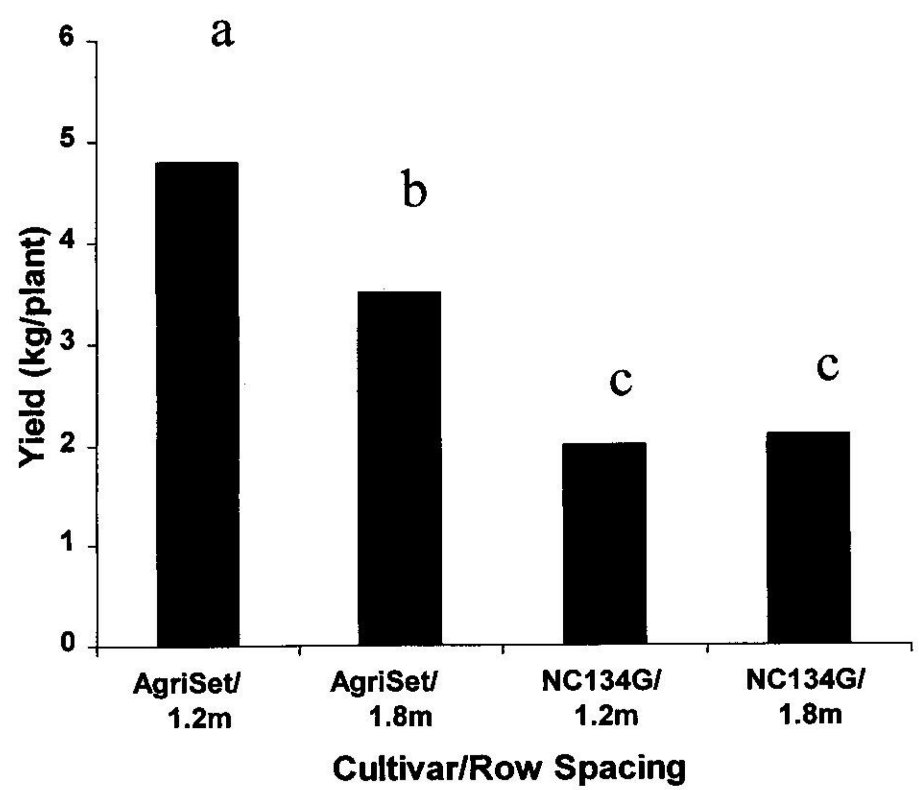

Figure 3. Effect of two cultivars and two row spacings on the marketable yield of tomato in Experiment 3. Yield expressed on a per plant basis.

yields was observed in plots receiving additional N.

Experiment 3. Yield was significantly greater with the cultivar AgriSet 761 than with NC134G (Table 1). The 1.2-m row spacing also impacted yield and was significant at the $P < 0.10$ level. There was a significant interaction between cultivar and row spacing. With different row spacings, highest yields on a per plant basis were obtained from plots containing "AgriSet 761" grown with a 1.2-m row spacing (Fig. 3). Row spacing had no effect on yields of "NC134G." Highest yields on a per ha basis were also obtained with "AgriSet 761" at the 1.2-m spacing (Fig. 4). Cultivar had a significant effect on fruit quality but row spacing did not. The highest percentage of marketable fruit (packout) was obtained with "AgriSet 761" (Fig. 5).

In the field, mycorrhizal colonizations of tomato and bahiagrass roots were 52% ± 6% and 54% ± 11%, respectively. The mycorrhizal spore population was dominated by *Glomus* spp. with mean values of 5 ± 2 and 8 ± 1 spores/g of soil associated with ± tomato and bahiagrass, respectively. Single-species cultures were established for *Glomus fasciculatum*-like strains associated with tomato (S3060) and bahiagrass (S3061).

Controlled inoculations in the greenhouse produced mycorrhizal inoculum potentials of 9 ± 2, 17 ± 3, 13 ± 1, and 10 ± 1 for isolates S3029, S3060, S3061, and the mixed isolates, respectively.

Field validation. Six harvests were made in the conventional system and seven in the alternative system. Marketable yields in the first five harvests were greater with the conventional system (Fig. 6). Total marketable yields were greater in the conventional system (Table 2).

Preharvest production costs were $2375/ha higher in the conventional system (Table 2). The ratio of yield (boxes/ha) to preharvest costs showed a preharvest cost of $0.29/box more for the conventional system. The net return/box was $0.91 in the alternative system as compared to $0.62 in the conventional system.

Nematode assessment. Average numbers of *Meloidogyne* spp. were less than 10/100 cm^3 of soil in preplant sampling prior to the three field experiments (Table 3). While populations increased in the sub-

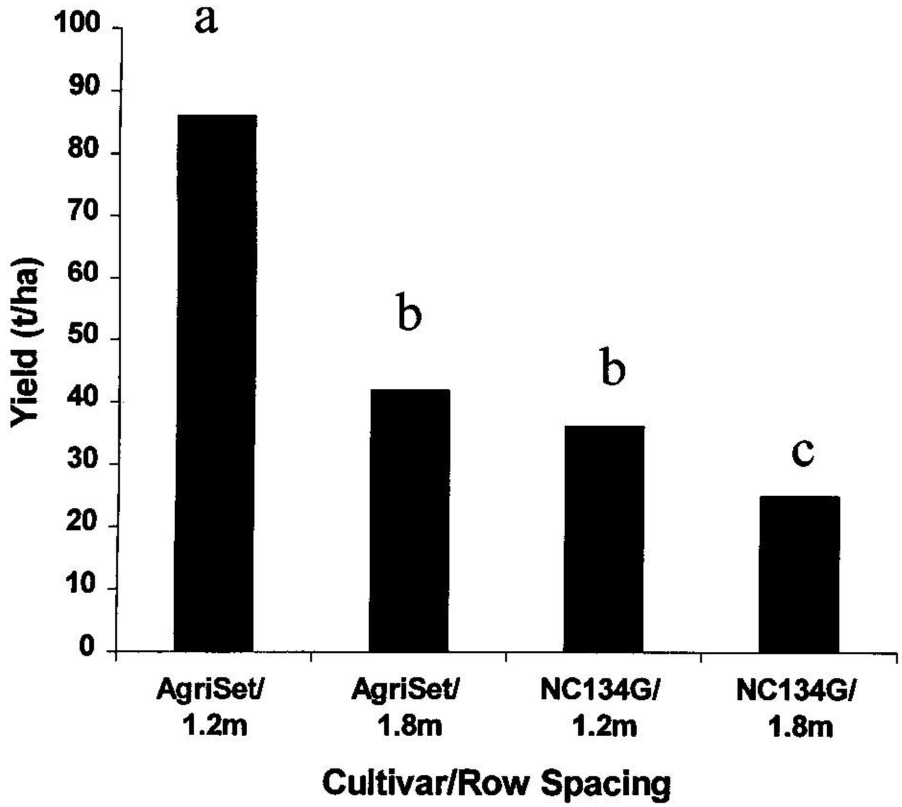

Figure 4. Effect of two cultivars and two row spacings on the marketable yield of tomato in Experiment 3. Yield expressed on a per ha basis.

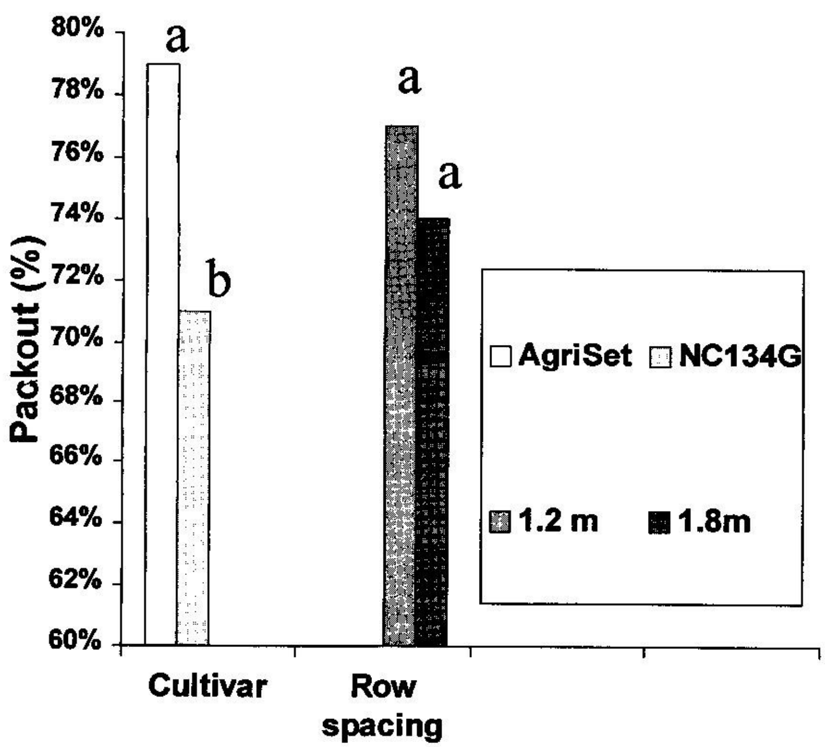

Figure 5. Effect of two cultivars and two row spacings on fruit quality (% packout) in Experiment 3.

sequent tomato crop postharvest sample numbers remained low. Root-gall index ratings were similarly low in all experiments except for selected replications, where root gall ratings on individual plants were as high as 7.5.

Seven genera of phytoparasitic nematodes were identified in commercial pastures and five genera were identified in commercial tomato production fields (Table 4). Nematode genera identified in tomato production fields mirrored those identified in pastures. *Belonolaimus* spp. and *Pratylenchus* spp. were identified in pastures but not in tomato fields. *Meloidogyne* spp. were identified in three of the nine commercial bahiagrass farms surveyed and in all four tomato production fields surveyed.

An epidemic of tomato spotted wilt virus (TSWV) was observed in the field validation site and disease progress was monitored in both the conventional and alternative plots. Disease incidence was noticeably higher in the alternative plots and reached 20.8% by 86 days after transplanting (Fig. 7). In contrast, disease incidence reached a maximum of 9.8% in the conventional system.

Discussion

The production of tomatoes using the alternative low-input production system is a radical departure from the conventional production system consisting of raised fumigated beds covered by plastic mulch currently in use by many southeastern tomato growers. The alternative system has the economic potential to replace or supplement current production techniques. However, further work is needed to optimize the management of water, nutrients, insects, and diseases.

By use of nematode counts, indications are that nemotode problems can be avoided by planting tomatoes into strip-till bahiagrass. Numbers of the key nematode pest of tomatoes, *Meloidogyne* spp., remained low in these tests and did not impact yields. Root galling indices were greater in some replicates of Experiments 1 and 2. These were the result of bahiagrass management that did not eliminate broadleaf weed hosts of *Meloidogyne* spp. Additionally, in the three pastures where *Meloidogyne* spp. were found, the bahiagrass was only two years old. The remaining fields were more than five years old and possessed few weed species; no *Meloidogyne* spp. were observed. Therefore, more than two years of rotation for bahiagrass is recommended to reduce the impact of *Meloidogyne arenaria* on susceptible crop hosts (Dickson and Hewlett, 1989). The selection of bahiagrass cultivars is not expected to be a factor since similar reductions in nematode populations were observed in a study by Rodriguez-Kabana et al. (1988) using several different cultivars.

Resurgence of *Meloidogyne* spp. in a susceptible crop will occur despite a rotation with bahiagrass (Dickson and Hewlett, 1989; Rodriguez-Kabana et al., 1991). However, resurgence is avoided in the alternative system by rotating tomato into a different established pasture each season. Rotation in and out of established pastures is possible because the strip tillage techniques minimize disruption of the pasture. Other nematodes recovered, such as *Heliocotylenchus, Criconemoides, Pratylenchus,* and *Xiphinema,* are not known to cause damage in tomato. However, presence of *Belonolaimus* and *Trichodorus* and their damage levels need further study.

Competition for nutrients by the bahiagrass remains a major limiting factor in production. In the first two experiments, yields were consistently higher in treatments where plastic mulch was used to suppress growth of bahiagrass in the planted rows. In plots without plastic mulch, significantly higher yields were obtained when N was added incrementally during the season (Fig. 1). Increasing the total amount of N did not result in higher yields (Fig. 2) indicating that additional N is being removed from the system before the crop can utilize it. The higher yields obtained in Experiment 3 were due in part to the increased level of tillage in the planted strip and the physical removal of grass (hoeing) during the season. It is interesting to note that higher yields were obtained under the narrow (1.2 m) row spacing in Experiment 3. The narrow spacing had increased shading in the row middles, producing a noticeable decrease in growth of the bahiagrass. In California, studies examining transition from conventional to low-input production of processing tomatoes indicated that more re-

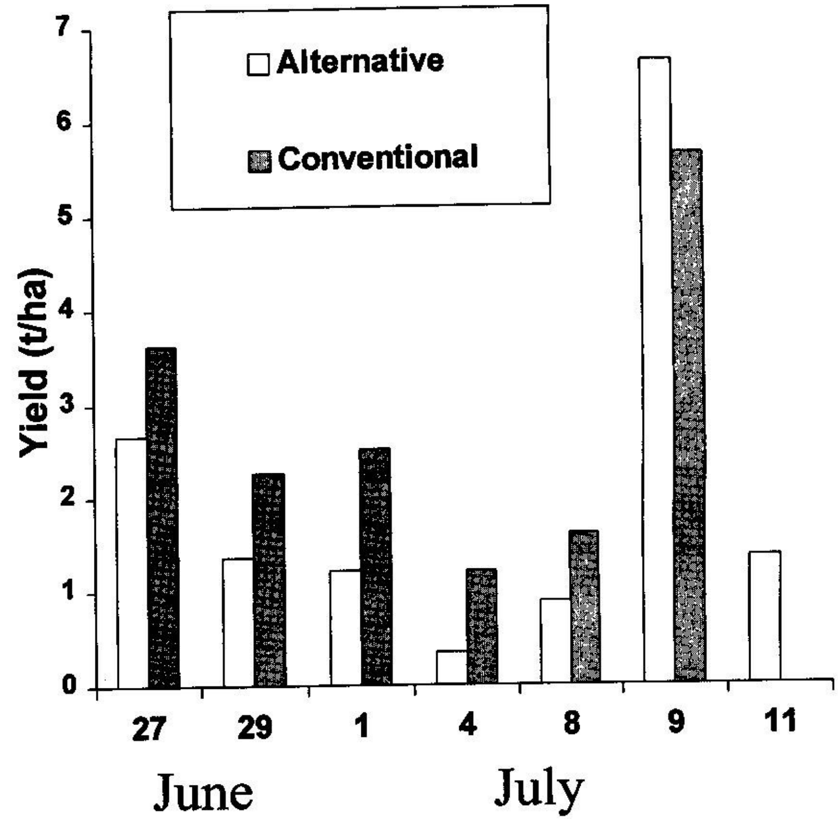

Figure 6. Marketable yield of tomato from individual harvest dates for the two production systems in the field validation trial.

Table 2. Production costs and economic returns (US$) from the field validation site.

	Alternative	Conventional
	$/ha	
Land rent	$750	$750
Equipment	$1000	$1000
Production	$5000	$7000
Clean-up	$375	$750
Total preharvest costs	$7125	$9500
Yield (tons)	36.0	42.5
Yield (no. boxes)	3175	3745
	$/box[1]	
Preharvest costs	$2.24	$2.53
Harvest costs	$2.75	$2.75
Average market price	$5.90	$5.90
Net return	$0.91	$0.62
Net return (per ha)	$2888	$2320

[1] Box = 10.9 kg

Table 3. Meloidogyne spp. numbers and root-galling.

Experiment	Preplant	Postharvest	Root-galling
	Number[1]		Scale[2]
1	10	52	1.62
2	<1	18	0.85
3	0	ND[3]	0.30

[1] Average number of nematodes/100 cm^3 soil.
[2] Average root-galling using a scale of 0 - 10 where 0 = no galling and 10 = 100% of the root system galled.
[3] Not determined.

Table 4. Phytoparasitic nematode genera identified in commercial bahiagrass pasture and tomato production fields.

Bahiagrass pasture	Tomato fields
Meloidogyne	*Meloidogyne*
Helicotylenchus	*Helicotylenchus*
Criconemoides	*Criconemoides*
Trichodorus	*Trichodorus*
Xiphinema	*Xiphinema*
Belonolaimus	
Pratylenchus	

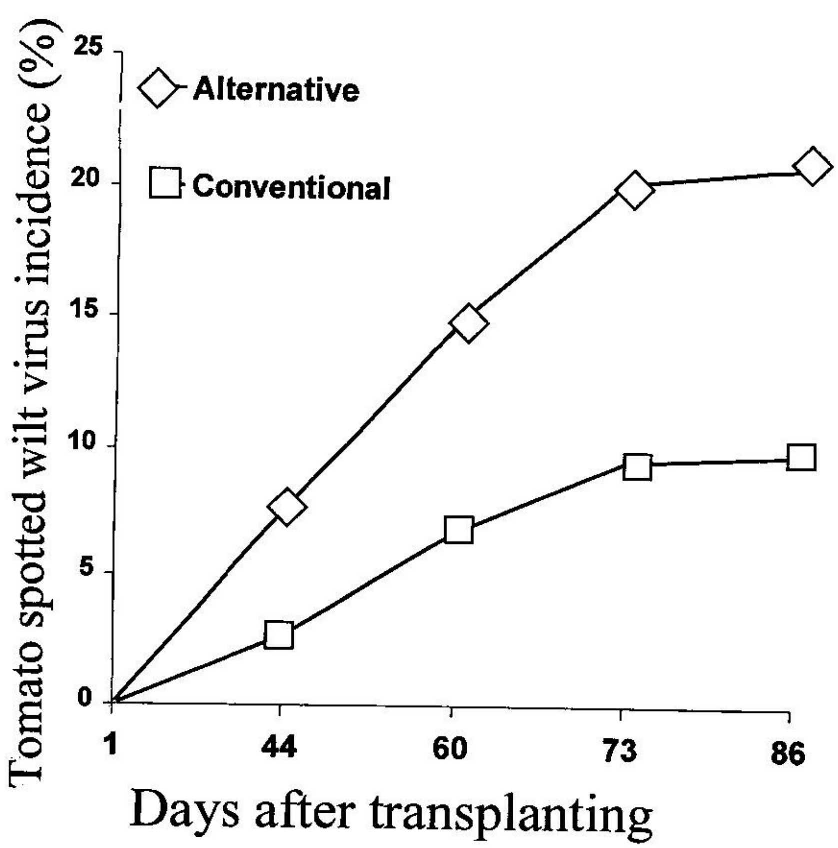

Figure 7. Disease progress curves for tomato spotted wilt virus (TSWV) for the two production systems in the field validation study.

search was needed into the dynamics of soil nutrient availability in low-input systems (Scow et al., 1994).

Mycorrhizal fungi appear to be an active component of the alternative production system and may impact the level of competition from the bahiagrass. Even though there were small differences in inoculum potential, all AM fungal inoculation treatments resulted in similar root colonization at harvest (overall mean of 78%) (Fig. 8). However, P content and shoot dry mass varied markedly with the inoculum. These data indicate that AM isolates vary in their effectiveness on tomato and suggest that their manipulation could affect plant growth in alternative production systems.

The incidence of TSWV was twice as high in the alternative system. *Frankliniella occidentalis*, a primary vector of TSWV in the southeastern United States, is color sensitive (Moffitt, 1964). Use of reflective plastic mulches have been shown to reduce the incidence of TSWV in tomato fields (Greenhough et al., 1990). It is very possible that the subtle differences in color between the bahiagrass and the tomato plants may have attracted viruliferous thrips to the field. The increased incidence of TSWV was not evident in the experimental sites indicating that studies affected by immigration of insects into the alternative production system should be initiated in larger field plots.

In the field validation study, yields were 6.5 t/ha greater under the conventional production system. This was expected as the raised bed-plastic mulch production system was designed to maximize the yield potential of vegetable crops (Geraldson, 1977). The singular goal approach of the conventional system resembles an industrial approach to pest management outlined by Levins (1986), where biological constraints such as pest outbreaks are overcome through increased levels of inputs. In the conventional system, the efficiency of contributing components such as pesticides, plastics, and fertilizers is maintained through increases in productive output. The singular goal of achieving profitability by maximizing yield potential is valid in situations where pesticides are viewed favorably by the general public, oil-derived inputs are inexpensive, competition with urban and suburban populations

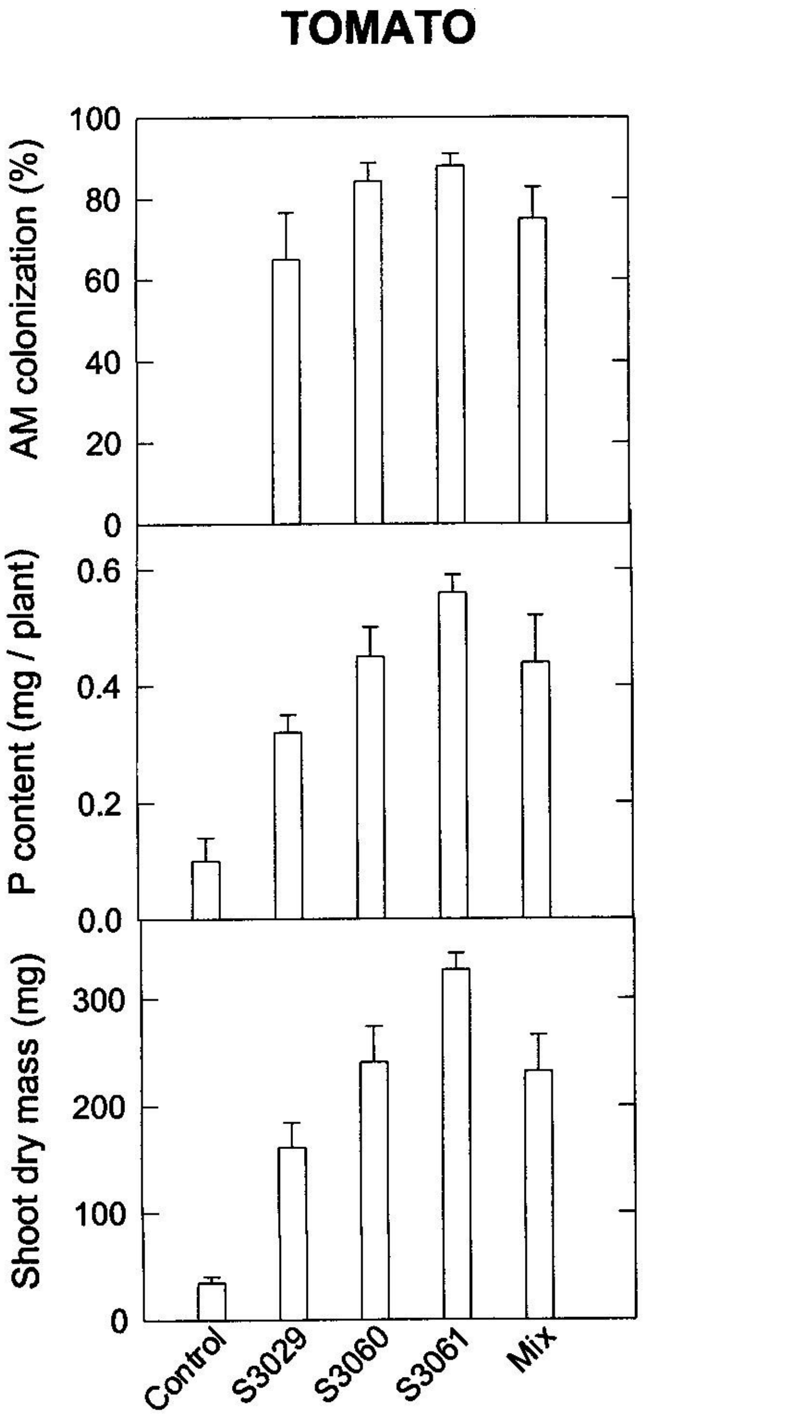

Figure 8. Root colonization, shoot-P content, and shoot dry mass of tomato plants inoculated with selected isolates of AM fungi and grown in the greenhouse for 60 days. Bars represent the mean of 5 replicates ± S.E.M.

for natural resources is minimal and competition from developing countries can be regulated through tariffs and quotas. In the southeastern United States, recent increases in urbanization, government regulation, water and soil conservation, and energy costs are issues that should be addressed in design and implementation of future agricultural production systems.

Traditionally, vegetable production systems were considered most efficient when maximum yields were obtained (Geraldson, 1977). In this study, net returns were $568/ha greater in the alternative production system (Table 2). This was accomplished even though marketable yields were lower. These results demonstrate that profitable yields can be obtained in a vegetable production system designed to meet several environmental and economic goals.

Summary and Conclusions

An alternative production system for fresh market tomatoes was designed to eliminate dependence upon broad-spectrum soil fumigants for soil disinfestation, minimize production costs, conserve soil improvement and optimize yields. The system was developed using three separate field experiments to identify suitable sod management programs, fertilizer application practices, cultivar selection and plant spacing. The alternative production was validated by comparing yields and production costs in a 1.2 ha plot implemented immediately adjacent to 1.8 ha conventional tomato production field. Marketable yields were 6.5 t/ha greater under the conventional system. However, the net return was $568/ha greater in the alternative system indicating its potential to replace or supplement the conventional production system.

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