# EFFECT OF TILLAGE SYSTEM AND NITROGEN RATE ON TOMATO YIELD

by

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# INTRODUCTION

The no-tillage system of crop production under its different forms (zero tillage, sod planting, sod suppressed planting and direct drilling, has been successfully used by commercial growers particularly with field crops. Many reasons are available to explain why this system has been so widely accepted including: increased water use efficiency; reduced requirements for fossil fuels; reduced wind and water erosion; and enhanced convenience in the performance of certain activities under wet soil, not possible with conventional tillage such as planting, spraying and harvesting.

The use of a no tillage system of production for vegetable crops has produced mixed results for various reasons, including: reduced soil temperature, poor plant stand, reduced soil temperature, poor weed control, and in some cases nutritional problems.

There have been several problems associated with nitrogen nutrition with no-tillage. Many reports point out that crops grown with no-tillage often show more nitrogen deficiency and lower yield when compared to conventional tillage. There appears to be a strong interaction between the tillage system and the nitrogen fertilization rate. Split nitrogen fertilization or increasing the rate of applied fertilizer have been suggested to avoid nitrogen deficiency. The evaluation of the interaction between the tillage system and the nitrogen fertilization will allow us to utilize no-tillage at its greatest potential.

Experiments were carried out to evaluate the response to tillage system (no-tillage mulch and conventional tillage) and the rate of nitrogen fertilization for fresh market tomatoes at Blacksburg, Virginia 1981 and 1982 and at Carrasco and Jackson, Uruguay 1981-2.

# LITERATURE REVIEW

A detailed review of literature on most topics relevant to this dissertation was published in 1981 by Tessore (64). This current review will focus primarily on factors affecting the availability of nitrogen on soil under no-tillage and conventional tillage. Because tomatoes and other vegetables are not commonly grown under no-tillage, most of the literature cited in this review will be from research on agronomic crops especially corn and soybeans.

## Factors Affecting Nitrogen Availability in the Soil

Nitrogen availability in soils depends upon many factors that can be summarized in the scheme outlined in Figure 1.

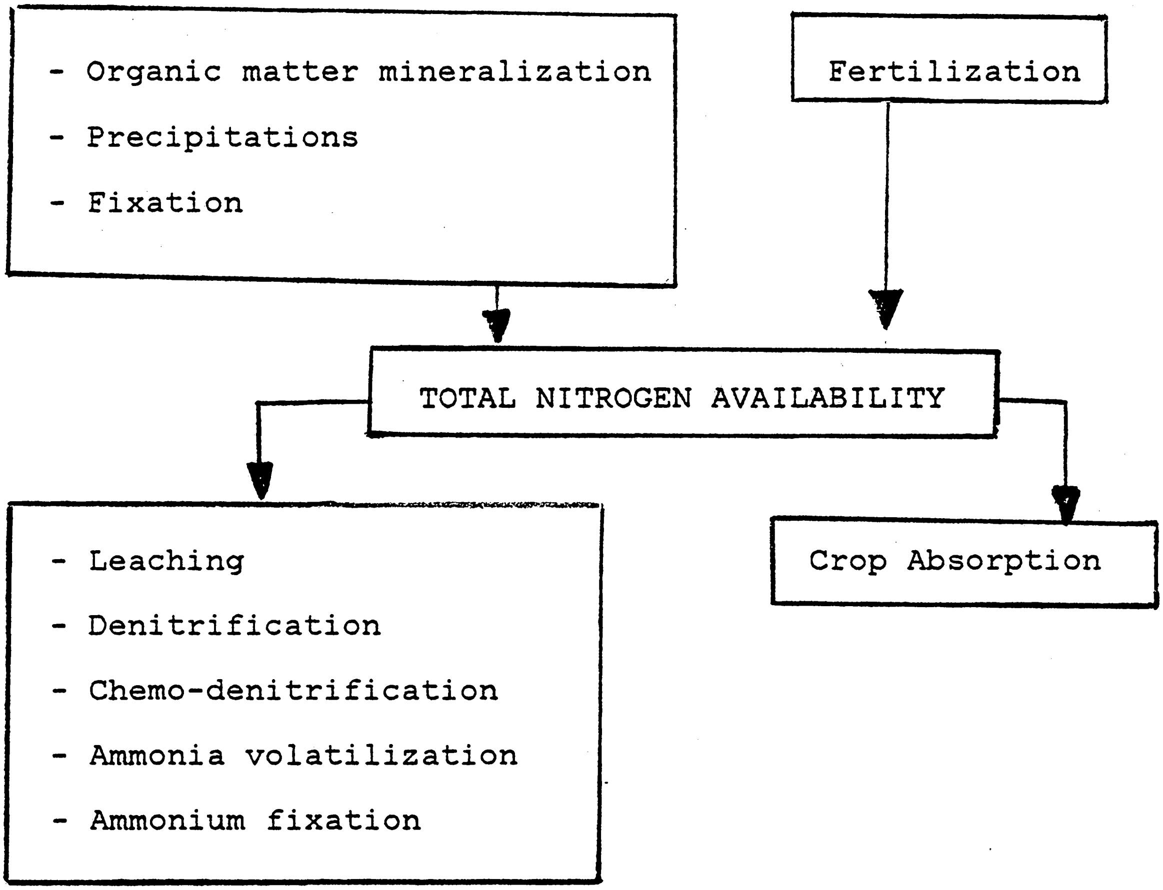

Figure 1: Factors affecting N availability in the soil.

## Organic Matter Mineralization

Most of soil nitrogen (N) is in the form of organic compounds. Organic N becomes available to plants through a process of microbial mineralization. It follows this general outline (39):

Organic N ------ Ammonia ------ Nitrite ------ Nitrate

Ammonification          Nitrification

Plants absorb most of their N in the form of ammonium and nitrate; only very small amounts of organic N are taken up. Some of the most important factors affecting the rate of N mineralization are (42) (a) soil moisture, (b) soil temperature, and (c) nitrogen fertilization.

*Soil moisture*. Generally ammonification is the step that limits the rate of total N mineralization. Ammonium (NH4) is oxidized to nitrate (NO3) over a wide range of soil conditions (40). Miller and Johnson (51) found that optimum matric suction for N mineralization ranged from 0.15 to 0.5 bars in silt loam and clay loam soils. This range corresponds with the most readily available portion of the soil water near field capacity. The amounts of N mineralized declined exponentially as the matric suction increased from optimum to 15 bars, which corresponds to permanent wilting point.

Similar results were found by Reichman et al. (57) who showed that N mineralization decreased proportionally as matric suction increased from 0.2 to 15 bars. Data of Miller and Johnson (51) and Reichman et al. (57) indicated that small though significant amounts of N were mineralized from 15 bars to air dryness. Standford and Epstein (63) concluded that the relation between mineral N accumulation and soil water content was essentially linear as soil moisture dropped from near optimum (0.10 to 0.33 bars) to the permanent wilting point (15 bars). The coefficient of determination ($r^2$) indicated that 93 to 99% of the within soil variability in the N mineralization were attributable to associated variation in soil water content (63).

Nitrogen mineralization continued to decline between 15 bars and air dryness (63). These findings suggest that supply of plant available N may accumulate during periods of drought and contribute significantly to crop growth upon resumption of favorable growing conditions. When the optimum water requirement was exceeded, N accumulation often was reduced.

Soil temperature. According to Harmsen and Kolenbrander (40), ammonification and nitrification are affected in different ways by soil temperature. Both processes are inhibited by low temperature although nitrification is most affected. Nitrification does not take place at temperature higher than 45 C while ammonification occurs at temperatures as high as 50 to 75 C.

Nitrogen fertilization. Many workers (23,37,40) have found that organic N mineralization was stimulated by the addition of N fertilizers. Hahne et al. (37) found an unaccountable excess of N after 5 years cropping period, which could only be attributable to a synergistic influence of the N fertilization. Allison (3) suggested that the stimulatory effect of the N fertilization may result from an increase in microflora activity caused by the addition of N.

### Precipitations

Rain usually contains a certain amount of N in various forms. The amount of N in soils derived through this process is probably of little relevance to plant nutrition. In a survey of 28 places throughout the world, Miller, quoted by Allison (4), found that the amount of N supplied to soils through this mechanism was from 1.8 to 21 kg/ha/year. Schreiner and Brown, quoted by Allison (4), found that the amount added through this mechanism averaged 7 kg/ha/year.

## Biological Fixation

Symbiotic fixation by leguminous plants is the most important method through which nitrogen gas (N2) is fixed in agricultural soils. The amounts of N fixed have been reported to vary from 45 to 230 kg/ha/year (55). Non symbiotic fixation by free living organisms generally contributes relatively little N to most plant ecosystems. Reports on the amount that can be fixed through this mechanism show a wide variability. Allison (3) stated that the quantity of asymbiotically fixed N is too small to be of any importance in agricultural soils.

## Leaching

Nitrogen can be found in soils in both organic and inorganic forms. Of all inorganic forms, NH4 and NO3 are the most important for plant nutrition while only small amounts of N is taken up as organic compounds. Ammonium ions are positively charged and can be retained by negatively charged sites (cation exchange capacity) of the soil and thus are not susceptible to leaching. Nitrate ions are negatively charged and can be easily leached since soils have very limited capacity to retain negatively charged ions.

According to Allison (3,4) most leaching studies have been carried out with lysimeters under conditions that were too artificial to explain what takes place under normal conditions. He suggested that N-tagged studies are far more accurate than lysimeter studies. Under field conditions N losses through leaching sometimes cannot be differentiated from other processes such as denitrification, plant absorption, etc.

The amount of N lost by leaching depends on a large number of variables. Each will be discussed briefly.

Form and amount of soluble and unadsorbed N present or added. If the amount of soluble N is higher than the quantities plants can absorb, the potential for losses increases (48). Schuman et al. (58), working with corn and two N rates, 169 and 448 kg/ha, found that NO3 in the water table were 10 ppm for the higher N rate while for the lower rate NO3 water table content only increased from 2 ppm to 4 ppm.

Amount and time of rainfall. The quantity of NO3 leached throughout the soil profile increases with the amount of rain. Vallis et al. (68) found that in a dry year losses were quite small ranging from 0-17% of applied N. Henzell (41) reported losses as high as 43% of applied N in a rainy year for the same type of soil. Rain intensity is also very important for the same amount of rain, the higher the intensity the smaller are the losses through leaching. Catchpoole (23) found that N losses through runoff were not very important.

Infiltration and percolation rates. There is ample evidence that NO3 movement is very important in light textured soils because of their low water holding capacity. Under similar conditions losses from sandy soils were 8 times greater than in clay soils (13). High NO3 accumulation occurred in soils with heavy clay horizons especially if they had low permeability. Soil structure seems to play a very important role in N losses - highly structured soils showed lower losses of N through leaching than soils with poor structure, especially if the soils with good structure had big drainage channels (31,72). In soils with poor drainage where water moves slowly, losses are very high compared to well structured soils.

Water holding capacity of the soil and its moisture content throughout the soil profile at the time the rain occurs. Nitrate leaching will only take place when the soil water content is over field capacity. If evaporation is greater than rainfall during a period of time, no NO3 leaching will take place. On the other hand, if rainfall is greater than evaporation, NO3 leaching will take place once the soil has reached field capacity (1,5). Nitrate movement in soils is linearly related to the excess of rain over evaporation.

Presence or absence of a crop and its growth characteristic. Crop plants play an important role in reducing N losses through leaching:

1. Crop plants absorb water from the soil profile thereby reducing the chances of reaching field capacity;
2. crop plants absorb NO3 and thus reduce the amount of N that can be potentially leached; and
3. crop plants reduce water runoff to a minimum (3).

Crop rooting pattern. Rooting pattern also plays a very important role in N losses through leaching. Deep root systems allow plants to absorb N from deep in the soil profile and thus minimize leaching losses. Hipp and Gerard (43), working with cotton and sorghum, found that after 4 years NO3 accumulated at 60 cm depth in the cotton plots and at 120 cm depth for the sorghum plots. Apparently sorghum was able to absorb N from deeper in the soil profile than cotton.

Extent to which there is upward movement of the N in the soil during periods of drought. During dry periods when evapotranspiration is greater than rain, water and soluble salts tend to move up in the soil profile. Wetselaar (71) found a peak accumulation of NO3 in the 1.9 to 2.5 cm depth under the zone where the physical continuity of the soil was broken. When the soil was wetted artificially during the dry season, NO3 accumulated in the top 5 cm and decreased in the 15- to 30-cm zone over a 9.5 week period.

## Denitrification

According to the Soil Science Society of America denitrification is the biological reduction of NO3 and nitrites (NO2) to gaseous nitrogen (molecular nitrogen or the oxide of nitrogen). Microbial degradation of NO2 and NO3 is brought about by a number of species of facultative anaerobic bacteria. Most of them use oxygen preferentially as the hydrogen acceptor but may use also NO2 and NO3 as a substitute. Sometimes an organism may use both types of hydrogen acceptors simultaneously but not until oxygen levels are very low (5). Under favorable conditions for denitrification this process can account for losses of up to 80 to 86% of the total added N to the soil (31).

According to Allison (5) under common field conditions denitrification is probably second only to leaching as the cause of poor recovery of N. It occurs to the greatest extent under conditions of high moisture, especially during rainy periods provided, of course, that NO3 are present. But denitrification is not limited to periods of excessive soil moisture; it may also occur in the fine textured soils where moisture is below field capacity. Greeland (36) obtained evidence of denitrification and nitrification taking place at the same time in the soil. In such soils macropores may be well aereated, while oxygen is deficient in the center of the larger aggregates or pockets of organic matter. The diffusion of oxygen into these aggregates is often not rapid enough to replace the oxygen that has been consumed by the microflora.

The major factors affecting the rate of denitrification in the soils are discussed below.

Soil pH. Bremmer and Shaw (19) found that in very acid soils (3.6 to 4.8 pH) denitrification was very slow but it was rapid in soils with basic pH (8.0 to 8.6). They also suggested that losses through denitrification were not significant if soil pH was below 5.0. In addition the same authors explored the possibility that slow rate of denitrification in the soils with low pH was due to a deficiency in calcium or molybdenum. It was found that the rate of denitrification in a soil with pH 3.6 was not affected by the addition of calcium sulfate or by the addition of 20 ppm of sodium molybdate.

Soil temperature. The rate of denitrification increases rapidly with the rise in temperature from 2-25 C. The relative amounts of N2O and N2 produced during denitrification depend upon the temperature; at low temperatures N2O production is greater than N2 and at high temperature N2 production is greater than N2O (21).

Soil water content. Denitrification is greatly affected by soil water content (19). If moisture content is less than 60% of the water holding capacity of the soil, losses of N through denitrification will be insignificant. The greatest losses of N through this mechanism took place at water contents higher than 100% water holding capacity.

Oxygen availability. The effect of soil water on denitrification are readily explicable since supply of oxygen in water saturated soil is not adequate to meet the requirements of the soil microorganisms and consequently the denitrifying microorganisms utilize NO3 instead of oxygen as a hydrogen acceptor. Low levels of oxygen can also be found in soils with good aeration; this may be due to many factors such as high temperature, high organic matter, or high microbial activity (19). In soils with large aggregates, aeration is difficult since it takes a long time for oxygen to diffuse into aggregates.

Organic materials. Denitrification of NO3 by heterotrophic microorganisms cannot occur unless the substrate contains some organic compounds that can support denitrification (19). The rate of denitrification in soils will depend upon the amount and the type of organic matter present. Bremmer and Shaw (19) found that denitrification increased with the amount of straw added and that large amounts were required to obtain the same rate obtained with small amounts of glucose. A comparison of the effects of adding different levels of straw, sawdust, and grasses to water logged soils was studied by Bremmer and Shaw (19). The rate of denitrification with these materials varied with the resistance to decomposition by microorganisms. The rate was most rapid with cellulose which readily decomposes in the soil and least with lignin and sawdust which are largely resistant to decomposition.

Soil management. Allision (3) concluded that denitrification was lower in soils being cropped than with fallow soils since crop plants absorb NO3 and thus reduce the possibility of denitrification. Dilz and Woldendorf (26) found that denitrification was greater for cultivated soils than those being fallowed. Plant root systems stimulate denitrification by creating an anaerobic environment in the root zone. Boswell and Anderson (18) found losses through denitrification were greater in a soil being fallowed than being cropped. Root channels allowed better aeration of the soil profile, thus reducing denitrification.

## Chemo-denitrification

Gaseous losses from the soil as a consequence of chemical decomposition of NO3 and NO2 are defined as chemo-denitrification (21). There are several pathways through which this process can take place depending upon soil pH and organic matter (20). In soils with low pH, NO2 may be decomposed into N2O, HNO3 and H2O. According to several researchers (5,21) N losses through this pathway may be very important but only under very special conditions such as high rates of fertilization with urea or ammonia, and in light acid soils with poor buffer capacity where oxidation stops at the HNO2 level.

The formation of N2 gas as a result of the reaction of nitrous acid with alpha aminoacids is often called the true Van Slyke reaction (21). There is little likelihood that this reaction occurs at any appreciable rate under common soil conditions. Not only are alpha aminoacids uncommon in soil constituents but nitrous acid if formed is not stable, at pH 5 or lower. Where the Van Slyke reaction can occur at an appreciable rate, NO2 is more likely to decompose in the presence of air than react with amino acids to form N2.

The possibility of a reaction of nitrous acid with NH4 to form gas both in plant and soil has been emphasized for a long time. Nevertheless, reliable quantitative data that characterize the reaction with respect to concentration, pH and temperature, are very scarce. Gerretsen and Hoop (35) reported the importance of ammonia nitrite reaction as a mechanism of loss of N from the soil. They observed that considerable amount of N was lost in the process of raising the pH in acid sandy soils treated with 100 mg of N as ammonium sulfate per 100 g and limed to pH 6.5 to bring about active nitrification.

## Nitrogen Immobilization

Immobilization is the transformation of inorganic N to organic N (13). Biological immobilization occurs in all soils, even though uncropped, because soils contain living organisms that are simultaneously assimilating mineral N and decomposing organic matter (5).

Maximum biological immobilization of N in soils occurs when large quantities of readily decomposable crop residue of large C/N ratio such as straw, corn stalks, etc. are added. Under such conditions the heterotrophic microorganisms grow so rapidly that frequently they may utilize all available N. When the C/N ratio is below 20, usually no external source of N is needed. In fact N in the form of NH4 may be released. Nitrogen may also be released slowly from crop residue that originally had C/N ratios greater than 30 but only after biological production of CO2 has reduced this ratio to about 20 or less. When mineral N is added to cropped soils, a portion of it is assimilated by microorganisms and thereby converted into organic forms, chiefly proteins. The amounts thus immobilized in the cropped soils are greater than in the uncropped soils because more energy sources and microorganisms are present (5).

Hiltbold et al. (48) observed that during the periods of rapid growth of oat, immobilization into organic matter was 2 to 4 times as rapid as in fallow soils.

### Ammonia Volatilization

A number of workers (44,60) have shown that, where an ammonia fertilizer was applied as top dressing on grasses or bare soil, the losses of NH4 may be as much as 15 to 25% and often higher. On calcareous soils NH4 may be lost even from salts such as ammonium sulfate if applied to the surface.

According to Mortland (53) NH4 may be chemically sorbed by clay minerals, sorbed by soil colloids or it may be merely dissolved in soil moisture. If not chemically sorbed it is free to diffuse to the atmosphere.

In acid soils NH4 is mainly sorbed by clay minerals, while in alkaline soils organic matter is responsible for most of the fixation. Therefore, NH4 volatilization is not likely to occur if ammonia fertilizers are properly placed. Low efficiency can be expected if ammonia fertilizers are surface broadcast without being mixed with the soil. Soil conditions and management practices that favors losses of NH4 are (10), (a) surface application of ammonia fertilizers in light soils, (b) high pH, (c) fertilizer banding, and (d) high rates of applications of ammonia fertilizers.

### Ammonium fixation

Ammonium can be fixed in soils either by clay minerals or by organic matter. Clay minerals such as vermiculite, illite and montmorillonite have the capacity to fix NH4; 1:1 clay minerals such as kaolinite are not able to fix NH4. Organic matter can also fix NH4. Mattson and Andersen quoted by Allison (3) found that the greatest majority of humus N comes from NH4 fixation.

### Crop Absorption

As an average 50% of the N in the soils is absorbed by crop plants; the other 50% escapes the soil by one of the processes mentioned above (5,9). In general it is believed that in most agricultural soils of the remaining 50% losses through leaching are the most important followed by the losses through denitrification (5). In some cases N remains within the rooting zone but it is not absorbed by the crop plants and losses occur after the crop has been harvested. The crop rooting pattern is one of the most important factors in reducing losses of N from soils. Crops such as wheat and corn with relatively deep root systems, are far more efficient in N absorption than potato for instance that has a very limited root system (61).

Nitrification inhibitors have been used to increase N efficiency by reducing the formation of NO3 and thus reducing leaching and denitrification (21). Slow release fertilizers is another method that has been suggested to increase N use efficiency (1).

## Nitrogen Availability--No-tillage (NT) vs. Conventional Tillage (CT)

Soil nitrates. There is ample evidence that soils under NT contain lower amounts of NO3 throughout the soil profile when compared to CT (6,16,50,67). Several studies have found different reasons for this reduction in NO3 with NT depending on the soil type and environmental conditions. Thomas et al. (67) studying the concentration of NO3 in CT vs. NT soils (sod planting) found after three storms totaling 6.5 cm of rain that there was no movement of NO3 with CT but only one third of the NO3 remained in NT plots. These researchers concluded that there were two reasons for these differences:

1. Upward movement of salts and water was practically nil since evaporation from NT soils was negligible when compared to CT. Reduced evaporation accounts for the failure of NO3 to move back to the soil surface. Under laboratory conditions evaporation from NT treatments was 6 times lower than with CT.
2. With NT there is reduced runoff. Rain water moves downward bypassing the saturated aggregates while with CT the soil is dryer and water moves into the aggregates; thus movement of water and solutes tends to be reduced on CT soils. Under the conditions of this study differences in organic matter mineralization were not enough to explain the differences found. Denitrification was also negligible, since the redox potential of the soil was considerably higher than that required for denitrification.

Dowdel and Cannell (29) analyzing the cause of lower concentration of NO3 under NT concluded that the differences were due to a much lower rate of nitrification with NT, since under the conditions of this study denitrification and leaching were not important. McMahon and Thomas (50) found anaerobic pockets in which denitrification was taking place under certain types of fine textured soils with NT.

## Nitrogen Deficiency

N deficiency has been reported by many researchers for crops under NT (8,17,46). Most researchers attribute this N deficiency to one or more of the reasons mentioned above. Some researchers also reported earlier maturity and lower yield with NT compared to CT (8,17).

In a large number of research reports on the response of NT crops to different rates of N, the most common response was that the NT plots yielded lower than CT plots at low rates of N and very often showed N deficiency (48) in addition to early maturity due to N nutrition stress (6).

Effect of the nitrogen source. Bandel et al. (7) concluded that ammonium nitrate is more efficient than granular or prilled urea because the latter resulted in greater volatilization losses. Thus the authors concluded that urea in any form should be incorporated when using NT.

## No-tillage Tomato Production

There are only a few papers on NT tomato production. Doss et al. (28) studying the effect of the tillage system and the N rate on tomato performance found that NT plots yielded less than CT plots. The reasons for the poor performance of the NT system were attributed to the effect of the rye depleting soil moisture. This effect might have been alleviated if the rye had been killed 1 month in advance of transplanting instead of 1 week. No consistent effect of the N rate was found.

Beste et al. (12) found that tomato yield for plots with adequate weed control were about the same for both tillage systems; however, tomato maturity was significantly earlier in the NT plots. In a three year experiment Knavel et al. (46) found that tomato produced higher yield with CT than with NT.

Tessore (64), comparing CT and NT for fresh market tomato production, found that NT plots outyielded CT plots for two different planting dates. The effect of the tillage system was on the number of fruit that reached marketable size rather than in the average weight. The same author, working in Uruguay, found NT plots produced higher yield than CT plots and also that blossom-end rot was substantially reduced by this tillage system (65).

# MATERIALS AND METHODS

Experiments to evaluate the response to tillage systems and N rates on growth and yield of tomato were carried out at Blacksburg, Virginia (1981 and 1982) and at Carrasco and Jackson, Uruguay (1981-2).

## Experimental Design and Treatments

All experiments employed a split plot design with tillage system as main plot and N rate as subplots. Four different N rates were used: 40, 80 and 120 kg N/ha broadcast at transplanting; and a 40/40 split application - 40 kg N/ha at transplanting and another 40 kg N/ha after the flowers of the first cluster had set. During 1982 at Blacksburg a 0 kg N/ha was included. Each treatment plot was replicated 4 times and consisted of 4 rows; only the 2 central rows were harvested for yield data.

Cereal rye (Secale cereale L.) was seeded at all locations (mid October at Blacksburg, 1981 and 1982; and mid June at Carrasco and Jackson 1981-2) as a cover crop. Two tillage systems were established in mid June at Blacksburg both years and in late November at Carrasco and Jackson 1981-2: (a) conventional tillage (CT), plowed, disced and rototilled; and (b) no-tillage (NT) using paraquat (1,1 dimethyl 4-4-bipyridinemion) at a rate of 0.5 kg/ha. In

Blacksburg, the rye cover was planted over the entire site (both NT and CT) while no cover crop was planted onn the CT plots at Carrasco and Jackson. At all locations the CT plots were plowed and prepared shortly after spraying with paraquat.

## Soil Types and Crop Production

Soil types were a Groseclose silt loam (Typic Hapladult) at 5.4 pH in Blacksburg, a sandy (Typic Arguidoll Thapto Typic Udipsament) at 5.1 pH in Carrasco, and a clay loam (Typic-Vertic Arguidoll) at 6.4 pH in Jackson. Phosphorus and K fertilization rates were determined according to soil test. At Blacksburg in 1981, 88 kg of P/ha and 62 kg of K/ha were applied; in 1982, 44 kg of P/ha and 83 kg of K/ha were used. At Carrasco, 44 kg of P/ha and 83 kg of K/ha were used, while at Jackson only 44 kg of P/ha were applied. The fertilizer was surface broadcast in NT plots and incorporated in CT plots before planting for all locations and years.

'Pik Red' tomato (Lycopersicon esculentum Mill.) plants grown in Jiffy 7 pellets were used for all locations. Uniform plant density (0.40 x 1.20 m) was established and maintained at all locations by setting equal number of plants. At Blacksburg, tomatoes were planted on 06/26/81 and

06/18/82 and at Carrasco and Jackson on 11/29/81. After transplanting a starter solution was used each plant was irrigated with 0.25 liter of a solution containing 0.7 kg of 9N-19P-12K per 100 liters of water.

Herbicides were applied for weed control at all locations after transplanting: Blacksburg (1981), pebulate (s-Propylbutylatethylthio carbamate) at 4 kg/ha; Blacksburg (1982), diphenamid(N,N-Dimethyl-2,2-diphenylacetamide) at 5 kg/ha; Carrasco and Jackson, metribuzin (4-Amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5 (4H)-One) at 0.3 kg/ha. Plants at all locations were sprayed periodically for insect and disease control: Blacksburg (1981 and 1982), chlorotalonil (tetrachloroisophthalonitrile) at 1.5 kg/ha and methomyl (s-Methyl-N-((methylcarbamoyl)-oxythioacetamide) at 1.8 kg/ha; Carrasco and Jackson, mancozeb (zinc ion manganese ethylene bis dithiocarbamate) at 2.0 kg/ha and endosulfan (6,7,8,9,10-Hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano -2,3,4 benzodioxanthiepin-3-oxide) at 0.4 kg/ha.

## Soil Measurements

Blacksburg, 1981 and 1982. Soil moisture content of the top 10 cm of each main plot was determined periodically by the gravimetric method (32). Soil temperature was recorded from each main plot at a 10-cm depth within the row with a soil thermocouple thermometer. Soil bulk density was determined by core sample method (74) at a 5-10 cm depth for each main plot at the end of the growing season. Soil NO3 content from each subplot was determined by specific ion electrode method (24) at a 0-15, 15-30, 30-45 and 45-60 cm depth at the end of the growing season in 1981. In 1982, soil NO3 content was determined periodically at 0-10 cm depth from all subplots.

Carrasco and Jackson, 1981-82. At Carrasco soil moisture samples were taken periodically at 0-30, 30-60 and 60-90 cm depth from each main plot. At Jackson soil moisture percentage was determined periodically from main plots at 0-20 and 20-50 cm depth. Soil temperature was determined for each main plot at a 10 cm depth at approximately 1.00 PM with soil thermometers for both locations. Soil bulk density was determined at 5-10 and 15-20 cm depth at mid season and at the end of the growing season. Soil NO3 content was determined from each subplot for the same depth as for moisture at both locations.

### Plant Growth and Tissue Analysis (Carrasco and Jackson)

At Carrasco and Jackson plant fresh and dry weight were determined periodically by sacrificing plants from guard rows. Fully developed leaves (20 per subplot) were taken at first fruit ripening for tissue analysis at both locations. Nitrogen was determined by the Kjeldahl method, and P by the colorimetric method and K, Ca, Mg and micronutrients were determined by the flame photometric method.

### Yield Data

All plots were harvested every five days and fruit were classified as marketable or unmarketable. Unmarketable fruit were classified as undersized, cracked, late blight, rotten, catface, blossom end rot and sunscalded. The number of harvests for each year varied according to the condition of the crop and the length of the growing season. Rain data were collected for all locations and years.

# RESULTS

## Soil Moisture Content

Average monthly soil moisture content in NT plots was equal or higher than with CT for all years, locations and sampling depths except for the month of November in Jackson when the CT plots were higher than NT plots for both sampling depths (Table 1). In Carrasco average soil moisture in CT plots was also higher than NT plots in November although the difference was not significant.

Differences between tillage systems in soil moisture content decreased with the increase in the sampling depth up to a point where no differences were found; similar results have been reported by Blevins et al. (15). The largest differences were found soon after transplanting for all years and locations. Toward the end of the growing season differences tended to diminish or disappear, probably due to the decomposition of the mulch.

## Soil Temperature

Soil temperature in NT plots was lower than with CT at 10 cm depth measured at approximately 1:00 p.m. for all years and locations (Table 2). The largest differences in soil temperature were found early in the growing season;

Table 1 .Effect of no-tillage (NT) and conventional tillage (CT) on soil moisture content.

| | Sampling | Sampling | Soil moisture (%) | | |
|---|---|---|---|---|---|
| Location | depth (cm) | period | NT | CT | ANOVA |
| Blacksburg, 1981 | 0-10 | 07/1-30 | 25.2 | 18.7 | *** |
| | | 08/1-30 | 15.1 | 10.5 | *** |
| | | 09/1-30 | 21.0 | 16.2 | *** |
| | | 10/1-15 | 12.8 | 9.9 | *** |
| Blacksburg, 1982 | 0-10 | 07/1-30 | 17.5 | 9.4 | *** |
| | | 08/1-30 | 16.4 | 11.8 | ** |
| | | 09/1-30 | 16.3 | 13.3 | *** |
| Carrasco, 1981-2 | 0-30 | 11/1-30 | 8.5 | 9.0 | NS |
| | | 12/1-30 | 7.7 | 6.7 | ** |
| | | 01/1-30 | 6.2 | 5.6 | * |
| | | 02/1-28 | 8.9 | 8.5 | NS |
| | 30-60 | 11/1-30 | 11.2 | 11.0 | NS |
| | | 12/1-30 | 8.0 | 7.1 | ** |
| | | 01/1-30 | 6.4 | 6.0 | * |
| | | 02/1-28 | 7.7 | 7.6 | NS |
| | 60-90 | 11/1-30 | 21.3 | 21.3 | NS |
| | | 12/1-30 | 19.1 | 18.9 | NS |
| | | 01/1-30 | 18.7 | 18.5 | NS |
| | | 02/1-28 | 21.2 | 21.4 | NS |
| Jackson, 1981-2 | 0-20 | 11/1-30 | 24.2 | 25.5 | ** |
| | | 12/1-30 | 25.3 | 23.2 | ** |
| | | 01/1-30 | 21.0 | 19.1 | ** |
| | | 02/1-28 | 24.4 | 23.2 | ** |
| | 20-50 | 11/1-30 | 24.4 | 27.1 | ** |
| | | 12/1-30 | 23.0 | 23.0 | NS |
| | | 01/1-30 | 20.5 | 18.9 | * |
| | | 02/1-28 | 22.8 | 22.0 | NS |

*,**,***,NS Significant at 5% (*), 1% (**), 0.1% (***) or not significant (NS) according to F test.

Table 2. Effect of no-tillage (NT) and conventional tillage (CT) on soil temperature at a 10 cm depth.

| Location | Sampling period | Soil temperature (°C) | |
|---|---|---|---|
| | | NT | CT |
| Blacksburg, 1981 | 07/1-30 | 19.1 | 21.0 |
| | 08/1-30 | 20.5 | 21.9 |
| | 09/1-30 | 18.3 | 18.9 |
| | 10/1-15 | 16.4 | 16.2 |
| Blacksburg, 1982 | 07/1-30 | 24.0 | 25.4 |
| | 08/1-30 | 21.9 | 22.9 |
| | 09/1-30 | 19.6 | 20.7 |
| Carrasco, 1981-2 | 12/1-30 | 21.9 | 25.0 |
| | 01/1-30 | 26.6 | 28.0 |
| | 02/1-28 | 25.3 | 25.4 |
| Jackson, 1981-2 | 12/1-30 | 23.1 | 24.2 |
| | 01/1-30 | 25.6 | 26.6 |
| | 02/1-28 | 24.0 | 24.7 |

differences tended to decrease or disappear toward the end of the growing season. Increased soil moisture content and a shading effect of the mulch in the NT plots are believed to be responsible for the difference in soil temperature between tillage systems.

Soil Nitrate Content (Carrasco and Jackson)

Soil NO3 content was equal or lower in NT plots than with CT for all locations and sampling depths (Tables 3 and 4). Similar results have been reported by several researchers (6,16,50,67). Differences in soil NO3 content between tillage systems decreased with increases in the sampling depth. The largest differences between tillage systems were found in the first sampling, 5 days after application of paraquat and before N fertilizer was applied. Following N fertilizer application the NO3 levels tended to decline as the season progressed at all depths sampled except at 60-90 cm in Carrasco where the NO3 level remained at approximately 2 to 3 ppm.

At 21 (12/20/81) and 42 (01/10/82) days after transplanting, increasing the amount of applied N tended to increase the soil NO3 except at the 60-90 cm depth in Carrasco. On 01/10/82 at both locations, soil NO3 levels in the split N application plots were higher than those from the

Table 3 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on soil $NO_3$ content, Carrasco 1981-2.

| Sampling | | N-$NO_3$ (ppm) at sampling depths (cm) of: | | |
|---|---|---|---|---|
| date | Treatment | 0-30 | 30-60 | 60-90 |
| 11/25/81[z] | Tillage system | | | |
| | NT | 0.6 | 0.5 | 0.9 |
| | CT | 6.1 | 3.9 | 1.1 |
| | | ** | ** | NS |
| 12/20/81 | Tillage system | | | |
| | NT | 9.7 | 10.3 | 2.0 |
| | CT | 11.7 | 12.1 | 2.6 |
| | | NS | NS | NS |
| | Nitrogen (kg/ha) | | | |
| | 40 | 9.4b[y] | 8.3b | 2.1 |
| | 40/40 | 9.4b | 9.0b | 2.4 |
| | 80 | 11.5ab | 11.8ab | 2.3 |
| | 120 | 13.0a | 16.3a | 2.4 |
| | | | | NS |
| 01/10/81 | Tillage system | | | |
| | NT | 7.6 | 7.1 | 2.5 |
| | CT | 11.0 | 9.4 | 2.6 |
| | | * | NS | NS |
| | Nitrogen (kg/ha) | | | |
| | 40 | 5.3b | 6.5 | 2.0 |
| | 40/40 | 16.8a | 9.8 | 2.6 |
| | 80 | 8.0b | 9.0 | 2.5 |
| | 120 | 7.3b | 7.8 | 2.9 |
| | | | NS | NS |
| 02/24/82 | Tillage system | | | |
| | NT | 4.0 | 5.0 | 2.5 |
| | CT | 4.2 | 4.8 | 2.6 |
| | | NS | NS | NS |
| | Nitrogen (kg/ha) | | | |
| | 40 | 3.5 | 5.0 | 2.1 |
| | 40/40 | 5.0 | 5.2 | 2.8 |
| | 80 | 3.5 | 4.8 | 2.3 |
| | 120 | 4.0 | 4.8 | 2.8 |
| | | NS | NS | NS |

[z] Soil sampling on 11/25/81 was before N was applied.

[y] Mean separation within columns for each sampling date by Duncan's multiple range test, 5% level.

*,**,NS Significant at 5% (*), 1% (**) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

Table 4 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on soil $NO_3$ content, Jackson 1981-2.

| Sampling<br>date | Treatment | $N-NO_3$ (ppm) at sampling depths (cm) of: 0-20 | 20-50 |
|---|---|---|---|
| 11/25/81$^z$ | Tillage system | | |
| | NT | 1.8 | 1.0 |
| | CT | 13.0 | 5.7 |
| | | ** | ** |
| 12/20/81 | Tillage system | | |
| | NT | 21.4 | 22.8 |
| | CT | 30.9 | 21.6 |
| | | ** | NS |
| | Nitrogen (kg/ha) | | |
| | 40 | 16.9b$^y$ | 16.2b |
| | 40/40 | 17.8b | 15.0b |
| | 80 | 31.9a | 30.0a |
| | 120 | 38.0a | 27.5a |
| 01/10/82 | Tillage system | | |
| | NT | 16.2 | 24.8 |
| | CT | 22.9 | 23.9 |
| | | ** | NS |
| | Nitrogen (kg/ha) | | |
| | 40 | 11.6c | 17.5bc |
| | 40/40 | 38.4a | 30.2a |
| | 80 | 17.2b | 14.5c |
| | 120 | 19.0b | 28.0ab |
| 03/03/82 | Tillage system | | |
| | NT | 5.1 | 7.9 |
| | CT | 5.8 | 7.3 |
| | | NS | NS |
| | Nitrogen (kg/ha) | | |
| | 40 | 5.0 | 5.8 |
| | 40/40 | 5.4 | 8.5 |
| | 80 | 5.2 | 8.5 |
| | 120 | 6.2 | 7.8 |
| | | NS | NS |

[z] Soil sampling on 11/25/81 was before N was applied.

[y] Mean separation within columns for each sampling date by Duncan's multiple range test, 5% level.

[*,**,NS] Significant at 5% (*), 1% (**) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

single N application plots, reflecting the sidedressing of 40 kg N/ha applied on 12/30/82. There was no effect of N rate on soil NO3 content for all depths sampled at the end of the harvest period (02/24/82 and 03/03/82 at Carrasco and Jackson, respectively).

### Yield Data

No interactions between tillage systems and N rates were found for any of the yield variables (yield and yield components) under study.

Total yield. The tillage system did not have any effect on the number of fruit, weight or average fruit weight for all locations and years except for Blacksburg in 1982, where the NT plots produced 83% more fruit than CT plots (Tables 5, 6, 7 and 8). The N rate did not affect the yield variables except for Blacksburg in 1981 where the average fruit weight for the 120 kg N/ha rate was lower than the 40 kg N/ha rate.

Marketable yield. The NT system consistently increased marketable yield for all locations and years. At Blacksburg in 1981, marketable yield was increased by 44% with NT; no effect on the number of average fruit weight was found. At the same location in 1982, the NT plots averaged 121% more fruit and 114% more weight than CT plots (Tables 5 and 6).

Table 5 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on the number of fruit, weight and fruit size, Blacksburg 1981.

| Treatment | No. of fruit/ha (x 1000 ) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Total yield$^z$ | |
| Tillage system | | | |
| NT | 206.3 | 33.1 | 160 |
| CT | 198.6 | 31.8 | 160 |
| | NS | NS | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 212.2 | 35.8 | 168a$^y$ |
| 40/40 | 179.6 | 28.0 | 156ab |
| 80 | 190.8 | 32.0 | 168a |
| 120 | 227.1 | 33.9 | 149b |
| | NS | NS | |
| | | Marketable yield | |
| Tillage system | | | |
| NT | 129.5 | 22.1 | 171 |
| CT | 91.3 | 15.4 | 169 |
| | NS | * | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 122.1 | 21.7 | 178 |
| 40/40 | 96.8 | 16.6 | 172 |
| 80 | 96.0 | 17.0 | 164 |
| 120 | 125.6 | 19.8 | 158 |
| | NS | NS | NS |
| | | Unmarketable yield | |
| Tillage system | | | |
| NT | 76.8 | 11.0 | 143 |
| CT | 107.3 | 16.4 | 153 |
| | NS | * | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 90.1 | 14.1 | 156 |
| 40/40 | 82.8 | 11.4 | 138 |
| 80 | 94.8 | 15.0 | 158 |
| 120 | 101.5 | 14.1 | 139 |
| | NS | NS | NS |

[z] Total yield = marketable plus unmarketable yield.

[y] Mean separation within columns by Duncan's multiple range test, 5% level.

*, NS Significant at 5% (*) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not signifcant.

Table 6 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on the number of fruit, weight and fruit size, Blacksburg 1982.

| Treatment | No. of fruit/ha (x 1000) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Total yield$^z$ | |
| Tillage system | | | |
| NT | 323.1 | ---- | ---- |
| CT | 176.6 | ---- | ---- |
| | ** | | |
| Nitrogen (kg/ha) | | | |
| 0 | 215.1 | ---- | ---- |
| 40 | 256.0 | ---- | ---- |
| 40/40 | 254.7 | ---- | ---- |
| 80 | 249.8 | ---- | ---- |
| 120 | 272.7 | ---- | ---- |
| | NS | | |
| | | Marketable yield | |
| Tillage system | | | |
| NT | 243.8 | 42.4 | 174 |
| CT | 110.4 | 19.9 | 179 |
| | ** | ** | NS |
| Nitrogen (kg/ha) | | | |
| 0 | 156.0 | 25.5 | 163 |
| 40 | 193.0 | 33.7 | 175 |
| 40/40 | 175.5 | 31.1 | 178 |
| 80 | 172.5 | 32.4 | 188 |
| 120 | 189.0 | 32.8 | 173 |
| | NS | NS | NS |
| | | Unmarketable yield | |
| Tillage system | | | |
| NT | 79.3 | ---- | ---- |
| CT | 66.2 | ---- | ---- |
| | NS | | |
| Nitrogen (kg/ha) | | | |
| 0 | 59.1 | ---- | ---- |
| 40 | 63.0 | ---- | ---- |
| 40/40 | 79.2 | ---- | ---- |
| 80 | 77.3 | ---- | ---- |
| 120 | 83.7 | ---- | ---- |
| | NS | | |

$^z$Total yield= marketable plus unmarketable yield.

$^{**,NS}$Significant at 1% (**) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

Table 7 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on the number of fruit, weight and fruit size, Carrasco 1981-2.

| Treatment | No. of fruit/ha ( x 1000 ) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Total yield$^z$ | |
| Tillage system | | | |
| NT | 320.6 | 39.7 | 124 |
| CT | 374.4 | 44.2 | 118 |
| | NS | NS | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 330.2 | 39.8 | 121 |
| 40/40 | 342.0 | 42.6 | 124 |
| 80 | 364.2 | 43.0 | 118 |
| 120 | 353.6 | 42.4 | 120 |
| | NS | NS | NS |
| | | Marketable yield | |
| Tillage system | | | |
| NT | 235.5 | 32.3 | 138 |
| CT | 196.3 | 27.3 | 139 |
| | ** | * | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 210.5 | 28.8 | 137 |
| 40/40 | 220.5 | 30.9 | 140 |
| 80 | 225.5 | 30.8 | 136 |
| 120 | 206.9 | 28.8 | 139 |
| | NS | NS | NS |
| | | Unmarketable yield | |
| Tillage system | | | |
| NT | 85.1 | 7.4 | 87 |
| CT | 178.1 | 16.9 | 95 |
| | ** | ** | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 119.7 | 11.0 | 92 |
| 40/40 | 121.5 | 11.7 | 96 |
| 80 | 138.7 | 12.2 | 88 |
| 120 | 146.7 | 13.6 | 93 |
| | NS | NS | NS |

$^z$Total yield = marketable plus unmarketable yield.

$^{*,**,NS}$Significant at 5% (*), 1% (**) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

Table 8 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on the number of fruit, weight and fruit size, Jackson 1981-2.

| Treatment | No. of fruit/ha (x 1000 ) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Total yield[z] | |
| Tillage system | | | |
| NT | 397.6 | 48.2 | 121 |
| CT | 313.3 | 36.7 | 117 |
| | NS | NS | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 343.1 | 42.4 | 123 |
| 40/40 | 344.8 | 42.6 | 123 |
| 80 | 368.5 | 43.1 | 113 |
| 120 | 365.3 | 41.6 | 114 |
| | NS | NS | NS |
| | | Marketable yield | |
| Tillage system | | | |
| NT | 282.0 | 38.3 | 136 |
| CT | 190.2 | 25.6 | 134 |
| | * | * | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 243.9 | 33.1 | 1136 |
| 40/40 | 239.7 | 32.7 | 136 |
| 80 | 226.4 | 30.9 | 137 |
| 120 | 234.2 | 31.0 | 138 |
| | NS | NS | NS |
| | | Unmarketable yield | |
| Tillage system | | | |
| NT | 115.6 | 9.9 | 86 |
| CT | 123.1 | 11.1 | 90 |
| | NS | NS | NS |
| Nitrogen (kg/ha) | | | |
| 40 | 99.2 | 9.3 | 93 |
| 40/40 | 105.1 | 9.9 | 95 |
| 80 | 141.1 | 12.2 | 86 |
| 120 | 131.1 | 10.6 | 81 |
| | NS | NS | NS |

[z] Total yield = marketable plus unmarketable yield.

[*,NS] Significant at 5% (*) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

At Carrasco, the NT plots averaged 19% more weight than CT plots (Table 7); no effect on the number of fruit and average weight was found. At Jackson, both the number and the weight were increased with NT (Table 8). The NT plots averaged 48 and 50% more fruit and weight, respectively, than CT plots. For all locations N rate did not have an effect on any of the yield variables under study (Tables 5, 6, 7 and 8).

Unmarketable yield. The CT plots produced higher or equal yields of unmarketable fruit than NT plots for all years and locations (Tables 5, 6, 7, and 8). At Blacksburg in 1981, the unmarketable yield was 48% higher with CT than with NT; no effect was found on the number and average fruit weight. At the same location in 1982, no effect of the tillage systems was found (Table 5 and 6). At Carrasco, both the number and the weight of unmarketable fruit were higher with CT than with NT (Table 7). No effect of the tillage systems on the unmarketable yield was found at Jackson (Table 8). The N rate did not affect any of the variables under study for all locations and years.

### Leaf Nutrient Concentrations (Carrasco and Jackson)

At Carrasco, N, P and K tissue concentrations of plants grown in NT plots were higher and the Ca and Mg concentrations were lower than those in CT plots (Table 9). Except for N concentrations, similar trends in levels of these same macro nutrients occurred in Jackson, although only the Mg concentration was significantly different between tillage systems. Nitrogen rate did not affect the P, K, Ca and Mg tissue concentrations at either location. Nitrogen tissue content was decreased by approximately 10% at the lowest N rate at both locations, although tissue N difference between tillage systems were only significant at Carrasco. No differences in tissue N were found among the other three N rates at Carrasco.

### Blossom-end Rot (BER)

The incidence of BER was consistently reduced by the NT system at all locations and years (Table 10). CT plots had from 2 to 20 times more fruit affected by the disorder than with NT. The N rate did not have any effect on the incidence of the disorder (Table 10).

Table 9 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on N, P, K, Ca, Mg content and Ca/Mg (dry weight basis), Uruguay 1981-2.

| | | Nutrient (%) | | | | | |
|---|---|---|---|---|---|---|---|
| Location | Treatment | N | P | K | Ca | Mg | Ca/Mg |
| Carrasco | Tillage system | | | | | | |
| | NT | 3.35 | 0.218 | 3.84 | 3.83 | 0.71 | 5.5 |
| | CT | 2.91 | 0.197 | 2.76 | 5.01 | 0.95 | 5.4 |
| | | * | ** | ** | ** | ** | NS |
| | Nitrogen (kg/ha) | | | | | | |
| | 40 | 2.88b[z] | 0.210 | 3.35 | 4.81 | 0.77 | 6.2 |
| | 40/40 | 3.21a | 0.211 | 3.42 | 4.19 | 0.78 | 5.4 |
| | 80 | 3.18a | 0.205 | 3.15 | 4.12 | 0.96 | 4.3 |
| | 120 | 3.25a | 0.204 | 3.29 | 4.55 | 0.81 | 5.6 |
| | | | NS | NS | NS | NS | NS |
| Jackson | Tillage system | | | | | | |
| | NT | 3.72 | 0.325 | 2.87 | 4.46 | 1.00 | 4.5 |
| | CT | 3.75 | 0.287 | 2.56 | 4.98 | 1.10 | 4.6 |
| | | NS | NS | NS | NS | * | NS |
| | Nitrogen (kg/ha) | | | | | | |
| | 40 | 3.46 | 0.310 | 2.72 | 4.65 | 1.05 | 4.4 |
| | 40/40 | 3.77 | 0.300 | 2.74 | 4.67 | 1.04 | 4.5 |
| | 80 | 3.78 | 0.300 | 2.52 | 4.82 | 1.08 | 4.5 |
| | 120 | 3.92 | 0.320 | 2.87 | 4.73 | 1.03 | 4.6 |
| | | NS | NS | NS | NS | NS | NS |

[z] Mean separation within columns for each location by Duncan's multiple range test, 5% level.

[*,**,NS] Significant at 5% (*), 1% (**) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

Table 10. Effect of no-tillage (NT), conventional tillage (CT) and N rate on blossom end rot incidence.

| Treatment | Blacksburg 1981 | Blacksburg 1982 | Carrasco | Jackson |
|---|---|---|---|---|
| | No. of fruit/ha (x 1000) | | | |
| Tillage system | | | | |
| NT | 3.1 | 0.1 | 1.6 | 22.8 |
| CT | 16.0 | 2.0 | 31.2 | 49.2 |
| | * | ** | ** | * |
| Nitrogen (kg/ha) | | | | |
| 0 | ---- | 0.9 | ---- | ---- |
| 40 | 12.1 | 1.3 | 9.4 | 34.5 |
| 40/40 | 9.8 | 1.2 | 19.7 | 33.4 |
| 80 | 6.5 | 1.1 | 16.1 | 40.7 |
| 120 | 9.6 | 0.7 | 20.5 | 39.6 |
| | NS | NS | NS | NS |

*,**,NS Significant at 5% (*), 1% (**) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

# DISCUSSION

## Tillage and Location Effects on Soil Moisture

The higher soil water availability under NT than under CT has been reported by many researchers (15,17,43,45,65). The reasons believed to be responsible for the higher water availability under NT than under CT are (a) reduced soils surface evaporation (43,45) and (b) reduced water runoff (43,95).

An overwintering rye cover was grown only on the NT plots at Carrasco and Jackson, while rye was grown on both NT and CT plots at Blacksburg. Thus, in Carrasco and Jackson but not in Blacksburg, transpiration of rye in NT plots would have reduced soil moisture more in these plots than in CT plots. This probably accounted for the November soil moisture levels in both Carasco and Jackson being lower in NT than CT plots and for the smaller differences in soil moisture between tillage systems in Carrasco and Jackson than in Blacksburg throughout the entire growing season.

In Blacksburg, since rye covered the entire research site, soil moisture was the same prior to plowing (CT plots) and killing the rye (NT plots); thereafter the soil profile was recharged with water in the NT plots, thereby resulting in a relatively large difference in soil moisture throughout the tomato growing season. In Uruguay at plowing time, soil moisture was greater in CT plots than in NT plots; however, rain throughout the growing season was apparently not enough to recharge the NT plots with water and maintain large differences in soil moisture between tillage systems.

### Factors Affecting Soil NO3 Levels

Absorption of NO3 by the rye cover crop appears to be primarily responsible for the lower levels of soil NO3 in the top 20-30 cm of NT plots than CT plots. Soil NO3 as well as water content were lower in NT plots than with CT prior to application of N fertilizer. These differences are attributed to absorption by the cover crop in the NT plots. Soil evaporation was possibly reduced in NT plots (43,45) although it was not specifically measured in our experiments. Upward movement of NO3 in soil pores as the soil surface dries is a well-known phenomenon (71). Reduced surface evaporation in NT plots possibly resulted in less upward movement of NO3 in NT soils than soils in CT plots. Immobilization of NO3 near the soil surface was possibly greater in NT plots than CT plots because of the tendency for increased levels of microorganisms in the upper 10-15 cm in NT soils (27).

Nitrate leaching is not believed to have played a major role in causing greater NO3 depletion in the surface soils of NT than CT plots. There were no significant differences in soil NO3 levels between NT and CT plots in the subsoil depths at both locations. This lack of downward movement of NO3 in NT plots is attributed to evenly distributed rainfall thereby resulting in the soil moisture content remaining below field capacity throughout most of the growing season (Table 13, Appendix). According to Allison (4) the soil moisture content must be equal or greater than field capacity for leaching to take place. Soil moisture levels for both tillage systems did not favor loss of N through denitrificaiton since this mechanism is only important in soils with moisture levels greater than field capacity (19).

### Soil Temperature and Plant Growth

The reduced soil temperatures in NT plots probably were not an important factor in affecting yield differences between tillage systems because the decrease in soil temperature in NT plots was relatively small and the soil temperatures were not considered to be critically low or high for plant growth in NT plots. The possible exception might have been in Carrasco where soil temperatures averaged 3.1 C lower in NT than CT plots. In Carrasco early plant growth was reduced in NT plots compared to CT plots (Table 24,25, Appendix) plots; however growth tended to be greater in NT than CT plots throughout the whole growing season in the other three experiments.

## Soil Moisture Content - The Limiting Factor

Under the conditions of these experiments, soil moisture content, not N supply, was the factor that limited marketable yield. In general with all fertilizer N rates, the tissue N levels found in these studies were in the normal ranges for tomatoes (34). Nitrogen rates had no significant effect on yield measured under either CT or NT. This was surprising since NT improves soil moisture and positive interactions between N level and soil moisture are common for many crops (69). Lack of interaction effects between tillage systems and N fertilizer rates under the conditions of these experiments is attributed to several factors discussed below.

1. The tomato plant has a relatively high efficiency to absorb soil N because of its deep, extensive root system (25). Deep root systems tend to minimize the effects of N losses through leaching. Perhaps, in our experiments there was greater leaching of NO3 in NT plots; but the larger, deep-rooted tomato plants

in NT plots were able to absorb the extra NO3 at the 30-60 cm depths, thereby reducing NO3 levels to that in CT plots. Hipp and Gerrard (43) found that sorghum (deep rooted) was able to absorb NO3 from 120 cm soil depths while NO3 absorption by cotton (shallow rooted) growing on the same soil was limited to 60-cm depths.

2. Without irrigation, soil moisture content was inadequate for maximum plant growth, thereby reducing the N requirement per ha. Kovach (47) obtained tomato yields of 113 MT/ha in 1977 when the soil was maintained above 50% field capacity with irrigation. There was a yield response to N fertilizer at 45 kg N/ha; the tomato cultivar ('Pik-Red') and soils (silt loam, Blacksburg) used by Kovach were the same as the 1981-1982 experiments, compare Table 5 and 6.
3. Possibly there was greater availability of N in NT plots than with CT, which could have offset or at least partially compensated for the lower levels of NO3 in NT plots compared to CT. Viets (69) states that nutrient availability is highest for most crops when soil moisture is high.

## Factors Affecting Leaf Nutrient Content

Soils in NT had equal or lower NO3 content than in CT soils (Tables 3 and 4), yet leaf analysis showed that plants grown in NT plots had equal or greater levels of tissue N than plants grown in CT plots. The possible explanation for this apparent contradiction is that moisture supply was an important limiting factor to absorption not just soil NO3 levels. Phosphorus concentrations in plants under NT were higher than under CT. Knavel et al. (6) found that NT tomatoes were higher in P content than CT tomatoes. The factors believed to have improved P absorption in the NT soils are (a) higher levels of moisture in the surface soils under NT, which incrased P solubility and root proliferation and (b) reduced soil-P contact because P was not incorporated, which decreased P fixation by soil colloids (11).

Soil moisture content is known to influence the ratio of cations in the soil solution (66). As the soil moisture is increased the concentration of ions in the soil solution decreases because of a dilution effect, but the concentration of Ca and Mg decreases more rapidly than does the concentration of K. Thus, with increasing soil moisture there tends to be a net absorption of Ca and Mg and release of K(OO). The above phenomenon would explain the Ca, Mg, and K tissue analysis reported in Table 9. Tomato leaf tissue in

NT plots had higher concentrations of K and lower concentrations of Ca and Mg than plants in CT plots. Knavel et al. (66) found lower tissue concentrations of Ca and Mg in tomatoes under NT than under CT.

## Calcium and the Incidence of BER

Increases in the incidence of BER with decreasing soil moisture content have been reported by Shaykewich et al. (59); similar results were found by Pill and Lambeth (56). In our experiments BER was reduced in NT plots, suggesting that the improved soil moisture in NT plots was a contributing factor. There are many reports (33,49,69) in the literature that have shown convincing evidence that Ca is the factor that directly affects BER and that moisture availability merely facilitates the uptake of Ca by the plant.

Tissue analysis at Carrasco and Jackson showed that plants in CT plots had equal or higher levels of Ca than plants grown in NT plots. For both locations and tillage systems, the values found for leaf Ca content were within the values reported as common by Geraldson et al. (34). Thus, the differences in leaf Ca concentration of NT and CT plants do not explain the differences in the incidence of BER. A possible explanation for this apparent contradiction is that a steady Ca supply to the fruit is more important than Ca leaf levels at any given time. The higher moisture availability with NT than with CT probably allowed a more steady Ca supply to the fruit and thus reduced the incidence of BER. Pill and Lambeth (56) reported that decreasing soil water potential had no effect or increased Ca and Mg content in the leaves but decreased their concentrations in the fruit. Since Ca translocation from leaf to other tissues is very reduced in plants (50), a steady flow of Ca to fruit tissues would be essential, even if leaf Ca concentrations were adequate.

# CONCLUSION

The major findings from these experiments are summarized below.

1. Water availability in NT plots was higher or equal to CT after transplanting for all years and locations. The largest differences in soil moisture were always found early after transplanting. Differences in soil moisture content decreased as the sampling depth increased up to a point where no differences were found between tillage systems.
2. Soils under NT had lower temperature than under CT at a 10-cm depth for all locations and years. The largest difference in soil temperature was found in the sandy soil (Carrasco) where early growth in NT plots was restricted.
3. Soil NO3 content throughout the whole growing season was equal or lower in NT plots than with CT. Differences in soil NO3 content between tillage systems decreased with the increase in sampling depth.
4. In general leaf concentrations of N, P and K were higher and Ca and Mg levels were lower in plants grown in NT soils than in CT soils. The more efficient absorption of N and P by plants in NT plots is attributed to improvements in soil moisture content

with NT which increased nutrient availability. The lower leaf Ca and Mg and higher K concentrations on NT plants than CT plants is believed to have resulted from relative increase of K compared to Ca and Mg in the soil solution with increased soil moisture in NT soils.

5. Total yield was not affected by the tillage systems at all locations and years except for Blacksburg in 1982 where the NT plots outyielded the CT plots. Marketable yield was consistently increased by the NT system at all locations and years. Yield increases ranged from 19% at Carrasco to 114% at Blacksburg in 1982. At two locations (Blacksburg in 1981, and Jackson) the increase in marketable yield was accompanied by an increase in the number of marketable fruit. Unmarketable yield was equal or higher with CT than with NT. The N rate did not have any effect on total, marketable and unmarketable yield except for the average total weight in Blacksburg in 1981. Under the conditions of these experiments, soil moisture was the limiting factor to yield not N availability.
6. Blossom-end rot was consistently reduced by the NT system at all locations and years. Plants in CT

plots contained equal or higher amounts of leaf Ca than NT plots; for both tillage systems the Ca levels found in the leaf tissue are considered normal.

# LITERATURE CITED

(1) Alessi, J. and J. F. Power, 1973. Effect of source and rate of nitrogen on N uptake and fertilization efficiency by spring wheat and barley. Agron. J. 65:53-55.

(2) Allison, F. E., M. Kefauver and E. M. Roller. 1953. Ammonia fixation in soils. Soil Sci. Soc. Amer. Proc. 17:107-110.

(3) Allison, F. E. 1955. Enigma of soil nitrogen balance sheets. Advan. Agron. 7:213-252.

(4) Allison, F. E. 1965. Evaluation of incoming and outgoing processes that affect soil nitrogen. In: W. V. Bartholomew and F. E. Clark (eds.) Soil nitrogen. Agronomy 10:573-606. Amer. Soc. Agron., Madison, WI.

(5) Allison, F. E. 1966. The fate of nitrogen applied to soils. Advan. Agron. 18:218-258.

(6) Anderson, C. H. 1971. Comparison of tillage and summer fallow in a semi arid region. Can. J. Soil Sci. 51:397-403.

(7) Bandel, V. A., S. Dzenia and G. Standford. 1980. Comparison of N fertilizers for no-till corn. Agron. J. 72:337-341.

(8) Bandel, V. A., S. Dzenia, G. Standford, and J. O. Legg. 1975. N behavior under no-till vs. conventional tillage corn culture. I. First year results using unlabeled N fertilizer. Agron. J. 67:782-786.

(9) Bartholomew, W. V. 1971. N-15 in research on the availability and use of crop nitrogen. In: Nitrogen-15 in Soil-Plant Studies. International Atomic Energy Agency, Vienna.

(10) Bartholomew, W. V. 1972. International soil fertility evaluation and improvement program. Bul. Tech. No. 6, North Carolina State University.

(11) Belcher, C. R. and J. L. Ragland. 1972. Phosphorus absorption by sod planted corn (Zea mays L.) from surface applied phosphorus. Agron. J. 64:754-756.

(12) Beste, C. E. 1973. Evaluation of herbicide in no-till planted cucumber, tomatoes and lima beans. N. E. Weed Sci. Soc. Proc. 27:232-239.

(13) Black, C. A. 1957. Soil plant relationship. John Wiley & Sons, New York.

(14) Blake, G. R. 1965. Bulk density. In: C. A. Black (ed.) Methods of soil analysis. Part I. Agronomy 9:374-377. Amer. Soc. Agron. Madison, WI.

(15) Blevins, R. L., D. Cook, S. H. Phillips and R. E. Phillips. 1971. Influence of no-till on soil moisture. Agron. J. 63:593-596.

(16) Blevins, R. L., G. W. Thomas and R. E. Phillips. 1973. Moisture relationship and nitrogen movement in no-tillage corn production. In: No tillage system symposium. Columbus, Ohio, 1972. p 142-145.

(17) Bennett, O., E. Mathias and C. Sperow. 1976. Double cropping for hay and no-till corn production as affected by sod species with rate of atrazine and nitrogen. Agron. J. 68:254-258

(18) Boswell, F. C. and O. E. Anderson. 1964. Nitrogen movement in undisturbed profiles of fallowed soils. Agron. J. 56:278-281.

(19) Bremmer, J. M. and K. Shaw. 1958. Denitrification in soil. II. Factors affecting denitrification. J. Agr. Sci. 51:40-51.

(20) Bremmer, J. M. 1977. Role of organic matter in volatilization of sulphur and nitrogen from soils. In: Soil organic matter study, vol. II. International Atomic Energy Agency, Vienna.

(21) Broadbent, F. E. and F. E. Clark. 1965. Denitrification. In: W. V. Bartholomew and F. E. Clark (eds.) Soil nitrogen. Agronomy 10:344-359. Amer. Soc. Agron., Madison, WI.

(22) Campbell, C. A., V. O. Biderberk, F. G. Warder and F. G. Robertson. 1973. Effect of rainfall and subsequent drying on P changes in dryland fallow loam. Soil Sci. Soc. Amer. Proc. 37:909-915.

(23) Catchpoole, V. R. 1975. Pathways for losses of fertilizer nitrogen from Rhode grass pasture south eastern Queensland. Aust. J. Agr. Res. 26:259-268.

(24) Dahnke, W. C. 1971. Use of nitrate specific ion electrode in soil testing. Comm. Soil Sci. and Pl. An. 2:73-84.

(25) Danielson, R. E. 1967. Root system in relation to irrigation. In: R. M. Hagan, H. R. Haise and T. N. Edmister (eds.). Irrigation of agricultural lands. Agronomy 11:390-424. Amer. Soc. Agron., Madison, WI.

(26) Dilz, K. and J. W. Woldendorp. 1960. Distribution and nitrogen balance of N-15 labelled nitrate applied to grass sod. 8th Int. Grassland Cong. (Reading):150-152.

(27) Doran, J. W. 1982. Tillage changes soil. Crop and Soils Magazine. 35(9):10-12.

(28) Doss, B. D., J. L. Turner and C. E. Evans. 1981. Influence of tillage, nitrogen and rye cover crop on growth and yield of tomatoes. J. Amer. Soc. Hort. Sci. 106:95-97.

(29) Dowdell, R. J. and R. Q. Cannell. 1975. Effect of ploughing and direct drilling on soil nitrate content. J. Soil Sci. 26:53-60.

(30) Epstein, E. 1972. Mineral nutrition of plants: principles and perspectives. J. Wiley & Sons, New York.

(31) Fried, M. and H. Borehart. 1967. The soil plant system in relation to inorganic nutrition. Academic Press, New York.

(32) Gardener, W. H. 1965. Water content. In: C. A. Black (ed.). Methods of soil analysis. Part I. Agronomy 9:92-96. Amer. Soc. Agron., Madison, WI.

(33) Geraldson, C. M. 1957. Control of blossom-end rot of tomatoes. Proc. Amer. Soc. Hort. Sci. 69:309-317.

(34) Geraldson, C. M., G. R. Klacan and O. A. Lorenz. 1973. Plant analysis as an aid in fertilizing vegetable crops. In: L. O. Walsh and J. D. Beaton (eds.). Soil testing and plant analysis. Soil Sci. Soc. Amer. Madison, WI.

(35) Gerretson, F. C. and H. de Hoop. 1957. Nitrogen losses during nitrification in solution and acid soils. Can. J. Microbiol. 3:359-380.

(36) Greenland, D. J. 1962. Denitrification in tropical. J. Agr. Sci. 58:227-233.

(37) Hahne, H.C., W. Kroontje and J. A. Lutz. 1977. Nitrogen fertilization I. Nitrate accumulation and losses under continuous corn cropping. Soil Sci. Soc. Amer. Proc. 41:562-572.

(38) Harding, R. B., T. W. Embleton, W. W. Jones and T. M. Ryan. 1963. Leaching and gaseous losses of nitrogen from non-tilled California soils. 55:515-518.

(39) Harmsen, G. W. and D. A. Van Schreven. 1955. Mineralization of organic nitrogen. Advan. Agron. 7:299-397.

(40) Harmsen, G. W. and G. J. Kolenbrander. 1965. Soil inorganic nitrogen. In: W. V. Bartholomew and F. E. Clark (eds). Soil nitrogen. Agronomy 10:43-71. Amer. Soc. Agron., Madison, WI.

(41) Henzell, E. F. 1971. Recovery of nitrogen from fertilizer applied to Rhode grass in small plots. Aust. J. Exp. Agr. Anim. Husb. 11:420-430.

(42) Hill, J. D. and R. L. Blevins. 1973. Quantitative soil moisture use in corn grown under conventional tillage and no-tillage method. Agron. J. 65:945-949.

(43) Hipp, B. W. and C. J. Gerard. 1973. Influence of previous crop in nitrate distribution in a clay soil profile and subsequent response to applied N. Agron. J. 65:712-714.

(44) Hiltbold, A. E., W. V. Bartholomew and C. H. Werkman. 1951. The use of tracer technique in the simultaneous measurements of mineralization and immobilization of nitrogen in soil. Soil Sci. Soc. Amer. Proc. 15:166-173.

(45) Jones, J. N., J. E. Moody and J. H. Lillard. 1969. Effect of tillage, no-tillage and mulch on soil water and plant growth. Agron. J. 61:719-721.

(46) Knavel, D. E., J. Ellis and J. Morrison. 1977. Effect of the tillage system on the performance and elemental absorption by selected vegetable crops. J. Amer. Soc. Hort. Sci. 102:323-327.

(47) Kovach, S. P. 1978. Effect of irrigation regime and nitrogen rate on tomato yield and quality on a humid climate on a silt-loam soil. Ph.D. Dissertation, Virginia Polytechnic Institute and State Univ., Blacksburg.

(48) Linville, K. W. and G. E. Smith. 1971. Nitrate content of soil cores from corn plots after repeated nitrogen fertilization. Soil Sci. 112:249-255.

(49) Maynard, D. N., W. S. Barham and C. L. Mccombs. 1957. Effect of calcium nutrition of tomatoes as related to the incidence and severity of blossom-end rot. Proc. Amer. Soc. Hort. Sci. 69:319-322.

(50) McMahon, M. A. and G. W. Thomas. 1976. Anion leaching in two Kentucky soils under conventional tillage and a killed sod mulch. Agron. J. 68:437-442.

(51) Miller, R. D. and D. D. Johnson. 1964. Effect of soil moisture tension on carbon dioxide evolution. Soil Sci. Soc. Amer. Proc. 28:644-647.

(52) Mitchell, W. H. and M. R. Teel. 1977. Winter annual cover crop for no-tillage corn production. Agron. J. 69:569-573.

(53) Mortland, M. M. 1958. Reaction of ammonia in soils. Advan. Agron. 10:325-348.

(54) Moschler, W. W. and D. C. Martens. 1975. Nitrogen, phosphorus and potassium requirements in no-tillage and conventional tilled corn. Soil Sci. Soc. Amer. Proc. 39:885-891.

(55) Nutman, P. S. 1965. Symbiotic nitrogen fixation. <u>In</u>: W. V. Bartholomew and F. E. Clark (eds.). Soil nitrogen. Agronomy 10:360-376. Amer. Soc. Agron., Madison, WE.

(56) Pill, W. G. and V. N. Lambeth. 1980. Effect of soil water regime and nitrogen form on blossom-end rot, yield, water relations, and elemental composition of tomato. J. Amer. Soc. Hort. Sci. 105:730-734.

(57) Reichman, G. A., D. I. Grunes and F. G. Viets. 1966. Effect of the soil moisture on ammonification and nitrification in two northern plain soils. Soil Sci. Soc. Amer. Proc. 30:363-366.

(58) Schuman, G. E., T. M. McCalla, K. E. Saxton and H. T. Knox. 1975. Nitrate movement and its distribution in the soil profile of differentially fertilized corn watershed. Soil Sci. Soc. Amer. Proc. 39:1192-1197.

(59) Shaykewich, C. F., M. Yamaguchi and J. D. Campbell. 1971. Nutrition and blossom-end rot of tomatoes as influenced by soil water regime. Can. J. Plant Sci. 51:505-511.

(60) Simpson, D. M. and S. W. Melsted. 1963. Urea hydrolysis and transformation in some Illinois soils. Soil Sci. Amer. Proc. 27:48-50.

(61) Singh, B. and G. S. Sekhon. 1977. Some measures of reducing leaching loss of nitrates beyond potential rooting zone. III. Proper crop rotation. Plant and Soil 47:585-591.

(62) Spurr, A. R. 1959. Anatomical aspect of blossom-end rot with reference to calcium nitrition. Hilgardia 28:269-295.

(63) Standford, G. and E. Epstein. 1974. Nitrogen mineralization-water relation in soils. Soil Sci. Soc. Amer. Proc. 38:103-107.

(64) Tessore, C. M. 1981. Soil properties and plant performance under no-till vegetable production. M.S. Thesis, Virginia Polytechnic Institute and State Univ., Blacksburg.

(65) Tessore, C. M. 1982. Effect of tillage system on tomato production. (unpublished data).

(66) Thomas, G. W. and B. W. Hipp. 1968. Soil factors affecting potassium availability. p. 269-291. In: V. J. Kilmer, S. E. Younts and N. C. Brady (eds.). The role of potassium in agriculture. Amer. Soc. Agron., Madison, WI.

(67) Thomas, G. W., R. L. Blevins, R. E. Phillips and M. A. McMahon. 1973. Effect of a killed sod mulch on nitrate movement and corn yield. Agron. J. 65:736-739.

(68) Vallis, I., E. F. Henzell and P. J. Ross. 1973. Isotopic studies on the uptake of nitrogen by pastures. V. N-15 balance experiments microplots. Aust. J. Agr. Res. 24:693-702.

(69) Viets, F. G. 1967. Nutrient availability in relation to soil water. In: R. M. Hagar, H. R. Haise and T. W Edminster (eds.) Irrigation of agricultural lands. Agronomy 11:458-471. Amer. Soc. Agron., Madison, WI.

(70) Viets, F. G., and R. H. Hageman. 1971. Factors affecting the accumulation of nitrates in soil water and plants. Agriculture Handbook No. 43. Agriculture Research Service. U.S.D.A.

(71) Wetselaar, R. 1961. Nitrate distribution in tropical soils II. Effect of capillary accumulation of nitrates in the subsoil. Plant and Soil. 15:121-133.

(72) Wild, A. 1972. Nitrate leaching under bare fallow at a site in northern Nigeria. J. Soil Sci. 23:315-324.

# Appendix A

Table 11. Effect of no-tillage (NT) and conventional tillage (CT) on soil bulk density at 5-10 and 15-20 cm depth for two sampling dates, Uruguay, 1981-2.

| Location | Sampling date | Tillage system | Sampling depth (cm) 5-10 | 15-20 |
|---|---|---|---|---|
| | | | -----(g/cm$^3$) | ----- |
| Carrasco | 01/10 | NT | 1.58 | 1.65 |
| | | CT | 1.47 | 1.63 |
| | | | NS | NS |
| | 03/03 | NT | 1.57 | 1.62 |
| | | CT | 1.57 | 1.64 |
| | | | NS | NS |
| Jackson | 01/20 | NT | 1.30 | 1.40 |
| | | CT | 1.35 | 1.40 |
| | | | NS | NS |
| | 03/10 | NT | 1.36 | 1.41 |
| | | CT | 1.36 | 1.35 |
| | | | NS | NS |

NS Not significant at 5% level according to F test.

Table 12 .Rainfall for all years and locations.

| Locations | Period | Rainfall (cm) |
|---|---|---|
| Blacksburg, 1981 | 06/1-30 | 9.5 |
| | 07/1-30 | 8.0 |
| | 08/1-30 | 5.1 |
| | 09/1-30 | 4.9 |
| | 10/1-15 | 0.8 |
| Blacksburg, 1982 | 06/1-30[z] | 10.9 |
| | 07/1-30 | 4.6 |
| | 08/1-30 | 2.4 |
| | 09/1-30 | 1.3 |
| Uruguay, 1981-2 | 11/1-30 | 8.2 |
| | 12/1-30 | 8.2 |
| | 01/1-30 | 4.2 |
| | 02/1-28 | 7.5 |
| | 03/1-15 | 0.6 |

[z] This total includes one irrigation ( 0.5 cm) at planting and a second irrigation ( 0.5 cm ) inmediately after herbicide application.

Table 13. Soil water content for different matric suctions, Uruguay 1981-2.

| | Sampling | Soil moisture (%) at matric suction (atm) of: | | | | |
|---|---|---|---|---|---|---|
| Location | depth (cm) | 0.1 | 0.3 | 1.0 | 3.0 | 15.0 |
| Carrasco | 0-30 | 9.5 | 7.6 | 5.8 | 5.0 | 0.60 |
| | 30-60 | 12.2 | 9.8 | 7.9 | 7.3 | 1.10 |
| | 60-90 | 27.1 | 23.7 | 19.6 | 17.6 | 13.40 |
| Jackson | 0-20 | 28.1 | 24.0 | 19.5 | 16.5 | 14.50 |
| | 20-50 | 35.0 | 33.9 | 27.7 | 24.0 | 21.60 |

Table 14. Effect of no-tillage (NT), conventional tillage (CT) and N rate on soil $NO_3$ content at the end of the growing season, Blacksburg, 1981.

| | $N\text{-}NO_3$ (ppm) at sampling depths (cm) of: | | | |
|---|---|---|---|---|
| Treatment | 0-15 | 15-30 | 30-45 | 45-60 |
| Tillage system | | | | |
| NT | 7.7 | 5.1 | 6.3 | 7.6 |
| CT | 11.8 | 10.8 | 6.3 | 6.9 |
| | * | NS | NS | NS |
| Nitrogen (kg/ha) | | | | |
| 40 | 6.3 | 4.0 | 4.8b[z] | 4.9 |
| 40/40 | 9.6 | 8.8 | 4.0c | 4.0 |
| 80 | 11.2 | 9.0 | 9.0a | 9.1 |
| 120 | 12.4 | 10.0 | 8.0ab | 10.7 |
| | NS | NS | | NS |

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

[*,NS] Significant at 5% (*) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

Table 15. Effect of no-tillage (NT), conventional tillage (CT) and N rate on soil $NO_3$ content at 0-10 cm depth, Blacksburg 1982.

| | $N\text{-}NO_3$ (ppm) | | |
|---|---|---|---|
| Treatment | 07/03 | 08/19 | 09/28 |
| Tillage system | | | |
| NT | 26.5 | 23.5 | 9.3 |
| CT | 25.7 | 31.2 | 6.1 |
| | NS | NS | NS |
| Nitrogen (kg/ha) | | | |
| 0 | 15.2 | 17.2 | 7.4 |
| 40 | 22.8 | 34.5 | 5.6 |
| 40/40 | 18.5 | 28.4 | 7.9 |
| 80 | 40.7 | 17.5 | 6.5 |
| 120 | 34.3 | 39.5 | 10.9 |
| | NS | NS | NS |

[NS] Not significant at 5% level, according to F test. Interactions between tillage systems and N rate were not significant.

Table 16 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on blossom-end rot (BER), catface, undersized, rotten and cracked fruit, Blacksburg 1981.

| | No. of fruit/ha (x 1000) | | | | |
|---|---|---|---|---|---|
| Treatment | BER | Catface | Undersized | Rotten | Cracked |
| <u>Tillage system</u> | | | | | |
| NT | 3.1 | 17.4 | 10.3 | 11.6 | 34.4 |
| CT | 16.0 | 17.8 | 9.5 | 8.9 | 55.1 |
| | * | NS | NS | NS | NS |
| <u>Nitrogen (kg/ha)</u> | | | | | |
| 40 | 12.1 | 17.1 | 8.3b$^z$ | 8.7 | 44.0 |
| 40/40 | 9.8 | 16.2 | 9.0b | 9.6 | 38.2 |
| 80 | 6.5 | 14.8 | 5.2c | 7.3 | 61.1 |
| 120 | 9.6 | 22.3 | 17.0a | 15.6 | 37.0 |
| | NS | NS | | NS | NS |

$^z$Mean separation within columns by Duncan's multiple range test, 5% level.

$^{*,NS}$Significant at 5% (*) or not significant according to F test. Interactions between tillage systems and N rate were not significant.

Table 17 .Effect of no-tillage (NT), conventional tillage (CT) and N rate on blossom-end rot (BER), catface, rotten, undersized, sunscald and late blight fruit, Blacksburg 1982.

| | No. of fruit/ha (x 1000) | | | | | |
|---|---|---|---|---|---|---|
| Treatment | BER | Catface | Rotten | Undersized | Sunscald | L. blight |
| Tillage system | | | | | | |
| NT | 0.10 | 3.87 | 7.20 | 52.90 | 0.10 | 15.20 |
| CT | 2.00 | 2.47 | 10.70 | 46.50 | 1.00 | 3.90 |
| | ** | NS | NS | NS | NS | NS |
| Nitrogen (kg/ha) | | | | | | |
| 0 | 0.90 | 1.75 | 6.20 | 39.20b[z] | ---- | 11.20 |
| 40 | 1.30 | 2.67 | 7.00 | 47.70ab | 1.10 | 3.50 |
| 40/40 | 1.20 | 2.67 | 11.50 | 51.50ab | ---- | 11.60 |
| 80 | 1.10 | 2.50 | 12.00 | 50.20ab | 1.40 | 10.30 |
| 120 | 0.70 | 5.25 | 7.37 | 59.50a | 0.20 | 10.80 |
| | NS | NS | NS | | NS | NS |

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

[**,NS] Significant at 1% (**) or not significant (NS) according to F test.
Interactions between tillage systems and N rate were not significant.

Table 18. Effect of no-tillage (NT) and conventional tillage (CT) on blossom-en rot, sunscald, rotten and others, Carrasco 1981-2.

| Tillage system | No. of fruit/ha ( x 1000 ) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Blossom-end rot | |
| NT | 1.6 | 0.2 | 103 |
| CT | 31.2 | 3.2 | 101 |
| | ** | ** | NS |
| | | Sunscald | |
| NT | 7.1 | 0.9 | 130 |
| CT | 13.9 | 2.0 | 144 |
| | NS | NS | NS |
| | | Rotten | |
| NT | 1.0 | 0.1 | 108 |
| CT | 1.3 | 0.1 | 98 |
| | * | NS | NS |
| | | Others[z] | |
| NT | 75.7 | 6.2 | 82 |
| CT | 131.6 | 11.2 | 88 |
| | * | ** | NS |

[z] Others include undersized, cracked, mishappen and insect damaged fruit.

*,**,NS Significant at 5% (*), 1% (**) or not significant (NS) according to F test. Interactions between tillage systems and N rate were not significant.

Table 19. Effect of no-tillage (NT) and conventional tillage (CT) on blossom-end rot, sunscald, rotten and others, Jackson 1981-2.

| Tillage system | No. of fruit/ha (x 1000 ) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Blossom-end rot | |
| NT | 22.8 | 2.2 | 96 |
| CT | 49.2 | 4.9 | 100 |
| | * | * | NS |
| | | Sunscald | |
| NT | 2.0 | 0.2 | 108 |
| CT | 2.3 | 0.2 | 98 |
| | NS | NS | NS |
| | | Rotten | |
| NT | 1.8 | 0.2 | 124 |
| CT | 7.7 | 0.9 | 124 |
| | ** | ** | NS |
| | | Others[z] | |
| NT | 88.9 | 7.2 | 81 |
| CT | 63.8 | 5.0 | 79 |
| | NS | NS | NS |

[z] Others include undersized, cracked, mishappen and insect damaged fruit.

*,**,NS Significant at 5% (*), 1% (**) or not significant (NS) according to the F test. Interactions between tillage systems and N rate were not significant.

Table 20 .Effect of N rate on blossom-end rot, sunscald, rotten and others, Carrasco 1981-2.

| Nitrogen (kg/ha) | No. of fruit/ha (x 1000 ) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Blossom-end rot | |
| 40 | 9.4 | 1.0 | 102 |
| 40/40 | 19.7 | 1.5 | 78 |
| 80 | 16.1 | 1.7 | 106 |
| 120 | 20.5 | 2.4 | 118 |
| | NS | NS | NS |
| | | Sunscald | |
| 40 | 19.9 | 1.6 | 149 |
| 40/40 | 12.5 | 1.7 | 139 |
| 80 | 10.9 | 1.4 | 130 |
| 120 | 7.7 | 1.1 | 141 |
| | NS | NS | NS |
| | | Rotten | |
| 40 | 1.2 | 0.1 | 96 |
| 40/40 | 1.6 | 0.1 | 90 |
| 80 | 1.1 | 0.1 | 119 |
| 120 | 0.8 | 0.1 | 102 |
| | NS | NS | NS |
| | | Others[z] | |
| 40 | 98.1 | 8.3 | 84 |
| 40/40 | 87.8 | 8.3 | 94 |
| 80 | 110.6 | 9.0 | 81 |
| 120 | 117.8 | 10.1 | 85 |
| | NS | NS | NS |

[z] Others include undersized, cracked, mishappen, and insect damaged fruit.

[NS] Not significant at 5% level according to the F test. Interactions between tillage systems and N rate were not significant.

Table 21 .Effect of N rate on blossom-end rot, sunscald, rotten and others, Jackson 1981-2.

| Nitrogen (kg/ha) | No. of fruit/ha ( x 1000 ) | Weight (MT/ha) | Avg. weight (g/fruit) |
|---|---|---|---|
| | | Blossom-end rot | |
| 40 | 34.5 | 3.4 | 110 |
| 40/40 | 33.4 | 3.9 | 115 |
| 80 | 40.7 | 3.7 | 91 |
| 120 | 39.6 | 3.3 | 84 |
| | NS | NS | NS |
| | | Sunscald | |
| 40 | 1.7 | 0.1 | 76 |
| 40/40 | 2.3 | 0.3 | 120 |
| 80 | 2.0 | 0.2 | 103 |
| 120 | 2.7 | 0.3 | 105 |
| | NS | NS | NS |
| | | Rotten | |
| 40 | 3.6 | 0.4 | 122 |
| 40/40 | 3.8 | 0.4 | 103 |
| 80 | 6.4 | 0.8 | 132 |
| 120 | 5.3 | 0.7 | 126 |
| | NS | NS | NS |
| | | Others[z] | |
| 40 | 63.6 | 5.4 | 84 |
| 40/40 | 65.6 | 5.4 | 83 |
| 80 | 92.8 | 7.5 | 80 |
| 120 | 83.5 | 6.3 | 76 |
| | NS | NS | NS |

[z] Others include undersized, cracked, mishappen and insect damaged fruit.

[NS] Not significant at 5% level according to the F test. Interactions between tillage systems and N rate were not significant.

Table 22. Effect of no-tillage (NT), conventional tillage (CT) and N rate on Fe, Mn, Zn and Cu content (dry weight basis), Uruguay 1981-2

| | | Nutrient (ppm) | | | |
|---|---|---|---|---|---|
| Location | Treatment | Fe | Mn | Zn | Cu |
| Carrasco | Tillage system | | | | |
| | NT | 143 | 821 | 54 | 13 |
| | CT | 141 | 872 | 63 | 9 |
| | | NS | NS | NS | NS |
| | Nitrogen (kg/ha) | | | | |
| | 40 | 147 | 842 | 56 | 12 |
| | 40/40 | 140 | 809 | 51 | 10 |
| | 80 | 136 | 862 | 60 | 11 |
| | 120 | 145 | 872 | 66 | 12 |
| | | NS | NS | NS | NS |
| Jackson | Tillage system | | | | |
| | NT | 117 | 136 | 90 | 21 |
| | CT | 141 | 142 | 79 | 22 |
| | | NS | NS | NS | NS |
| | Nitrogen (kg/ha) | | | | |
| | 40 | 123 | 118 | 102 | 23 |
| | 40/40 | 129 | 130 | 80 | 21 |
| | 80 | 135 | 149 | 74 | 23 |
| | 120 | 128 | 160 | 83 | 21 |
| | | NS | NS | NS | NS |

[NS] Not significant at 5% level according to F test. Interactions between tillage systems and N rate were not significant.

Table 23. Effect of no-tillage, conventional tillage and N rate on plant dry weight, Carrasco 1981-2.

| Nitrogen | Plant dry weight (g/pl) | | | | |
|---|---|---|---|---|---|
| (kg/ha) | 12/03/81 | 12/20/81 | 01/10/82 | 01/30/82 | 02/20/82 |
| No-tillage | | | | | |
| 40 | 2.0 | 4.8 | 25.6 | 159.7 | 54.6 |
| 40/40 | 2.0 | 4.9 | 24.0 | 171.8 | 47.5 |
| 80 | 1.8 | 5.7 | 22.2 | 152.9 | 53.6 |
| 120 | 2.0 | 5.8 | 21.0 | 160.0 | 63.0 |
| Conventional tillage | | | | | |
| 40 | 2.2 | 14.6 | 44.2 | 148.2 | 35.3 |
| 40/40 | 2.4 | 14.0 | 44.0 | 131.5 | 42.5 |
| 80 | 2.5 | 13.1 | 47.2 | 145.7 | 40.2 |
| 120 | 2.5 | 14.6 | 43.8 | 148.1 | 39.6 |

Table 24. Effect of no-tillage, conventional tillage and N rate on plant dry weight, Jackson 1981-2.

| Nitrogen | Plant dry weight (g/pl) | | | | |
|---|---|---|---|---|---|
| (kg/ha) | 12/09/81 | 12/20/81 | 01/19/82 | 02/09/82 | 03/01/82 |
| No-tillage | | | | | |
| 40 | 2.4 | 4.4 | 79.6 | 185.7 | 58.7 |
| 40/40 | 2.8 | 4.4 | 87.6 | 182.1 | 81.5 |
| 80 | 2.6 | 4.2 | 75.3 | 208.4 | 68.9 |
| 120 | 2.9 | 4.6 | 72.3 | 185.7 | 68.7 |
| Conventional tillage | | | | | |
| 40 | 2.0 | 3.3 | 66.5 | 144.5 | 72.5 |
| 40/40 | 2.2 | 3.3 | 59.2 | 167.6 | 77.0 |
| 80 | 2.0 | 3.0 | 59.1 | 154.0 | 58.0 |
| 120 | 2.1 | 3.2 | 61.3 | 164.8 | 60.0 |

# EFFECT OF TILLAGE SYSTEM AND NITROGEN RATE ON TOMATO YIELD

by

Carlos Tessore

(ABSTRACT)

Experiments to evaluate the effects of tillage systems and nitrogen fertilizer rates on fresh market 'Pik Red' tomato (Lycopersicon esculentum Mill.) production were carried out at Blacksburg, Virginia (1981 and 1982) and at Carrasco and Jackson, Uruguay (1981-2).

Two tillage systems were used: (a) conventional tillage (CT) - plowed, disced and rototilled, and (b) no-tillage (NT) using paraquat at 0.5 kg/ha. Four different nitrogen (N) rates were used: 40, 80 and 120 kg N/ha broadcast at transplanting and a 40/40 kg N/ha split applications - 40 kg N at transplanting and another 40 kg N after the flowers of the first cluster had set. During 1982, at Blacksburg a 0 kg N/ha rate was added.

For all locations and years water availability was equal or higher in NT plots than with CT after transplanting. The largest differences were found at the beginning of the growing season. Soil under NT tended to be cooler than under CT; these differences in soil temperature are attributed to higher moisture content with NT than CT and the shading effect of the mulch in the NT plots.

Soil Nitrate (NO3) content was equal or lower with NT than with CT at Carrasco and Jackson. Absorption of NO3 by the rye cover crop in NT plots probably was a major cause of NO3 differences between tillage systems.

Nitrogen, P and K content in leaf tissue were equal or higher while Ca and Mg were equal or lower in NT plants than in CT plants. Nitrogen tissue content was increased by the N rate only at Carrasco; no effect of N rate was found on absorption of other nutrients at Carrasco or Jackson.

Total yield was not affected by the tillage systems except for Blacksburg in 1982 when the NT plots outyielded CT plots. Marketable yield was consistently increased by the NT system at all locations and years. Unmarketable yield was equal or higher with CT than with NT. No effect of the N rate was found for any yield or yield components except for Blacksburg in 1981 where the total average weight was affected by the N rate. Water availability rather than N supply is believed to be the limiting factor to yield production at all locations and years.

Blossom-end rot was consistently reduced by the NT system at all locations and years. Improved water availability with NT than with CT was probably responsible for a more steady Ca supply to growing fruit with NT than with CT, thus reducing the incidence of the disorder.