A Multiple Cropping System for Vegetable Production Under Subtropical, High Rainfall Conditions[1]

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Abstract. Over a 3-year test period a system of multiple cropping using minimum tillage was compared with conventional methods. The minimum tillage operation consisted of rebuilding raised beds in November of each year and planting successive crops with no preparation beyond that required to remove residues of the preceding crop. Using a cropping sequence of crimson clover (*Trifolium incarnatum*), sweet corn (*Zea mays*, cv. Aristogold Bantam Evergreen), and southern peas (*Vigna sinensis*, cv. Calhoun Purple Hull), yields obtained with minimum tillage were equal or superior to those obtained using conventional methods. In addition, minimum tillage left enough time annually to produce a fourth crop of Chinese cabbage (*Brassica campestris*, cv. Earlytop 16).

Tillage can be the source of major problems in the production of vegetable crops in tropical and subtropical areas subject to high rainfall. In such regions frequent rains can delay seedbed preparation for weeks, or even prevent crop establishment during wet periods. Also, with high soil moisture and temperature, tillage introduces excessive soil aeration which promotes rapid microbial decomposition of organic matter. Webster (7) discussed these problems and suggested that with the advent of selective herbicides, reduced tillage might permit better land utilization in the rainforest tropics by maintaining higher soil organic matter levels.

The concepts of no-tillage and minimum tillage have been studied extensively as a means of reducing labor and erosion hazards in corn production (2). No-tillage refers to a system under which a crop is produced without the use of any tillage except that necessary to plant the crop seed. Minimum tillage systems employ different amounts of soil manipulation and may or may not involve plowing as a primary operation.

We investigated a multiple cropping sequence, using minimum tillage under high rainfall conditions. Minimum tillage as defined for this study consisted of constructing raised beds in the autumn and planting several successive crops, with no more soil manipulation than necessary to plant the seed, before reforming the bed the next autumn. The raised beds were used to improve drainage during periods of high rainfall.

Materials and Methods

The soil of the experimental field was a Typic Fragiudalf (Loring silt loam), which is a moderately well-drained loessial soil. This field had been heavily infested with a wide range of annual weeds, primarily large crabgrass (*Digitaria sanquinalis* (L) Scop.), goosegrass (*Eleusine indica* (L) Gaertn.), and red root pigweed (*Amaranthus retroflexus* L.). The dominant perennial was purple nutsedge (*Cyperus rotundus* L.) with scattered moderate to heavy infestations. The field also contained scattered areas of Bermuda grass (*Cynodon dactylon* (L) Pers.) and of Johnson grass (*Sorghum halepense* (L) Pers.).

In July, August, and September 1970 the field was disked 7 times to reduce the perennial infestation. During this time the field was graded to a uniform 0.5% slope. The area was then limed to pH 6.0. The field was subsoiled to a depth of 75 cm in lines 152 cm apart and parallel with the direction of the slope. Raised beds which settled to a height of 15 cm were built directly over the subsoiled lines.

Experimental treatments began on November 1, 1970, when the field was divided into 12 plots of 4 raised beds each, 12.2 m long. The experimental design was one of paired comparisons with 6 replications. The comparison used a cropping sequence of crimson clover, sweet corn, and southern peas under minimum and conventional tillage. Under minimum tillage an additional fall crop of broccoli, bush snap beans, or Chinese cabbage was also planted (Figs. 1–3). Under minimum tillage the crimson clover was killed in later February with 2 applications of 1,1′dimethyl-4,4′-bipyridinium ion (paraquat) (0.28 kg/ha) and corn was planted through the mulch in the early March. The last harvest was made in mid- or late May. On the same day the stalks were cut at ground level with a rotary cutter and southern peas were planted. When the peas were harvested in mid-August, the vines were cut in the same manner and a fall crop was planted.

Under conventional tillage the objective was to disk the winter crop under in early February, disk again a week later and rebed the plots in time to plant corn in early March. After the last corn harvest, the stalks were cut with a rotary cutter. The plots were disked twice and rebedded after the more succulent portion of the corn residue had decomposed. Southern peas were planted in the raised beds. After the final harvest of peas the plots were disked and rebedded to be planted with crimson clover in November.

The corn and peas were planted with a John Deere 24B planter using a sword type opener. Chinese cabbage was direct seeded with a #900 Mulch Planter.[5] All crops were hand harvested. Yield was computed from 10 m of the 2 center rows in each plot.

A complete fertilizer (900 kg/ha of 12-12-12) was applied as a band (below and to one side of the seed) each year during the corn planting operation. Ammonium nitrate (70 kg/ha) was used to sidedress the corn twice each year and the Chinese cabbage once. Southern peas and crimson clover received no supplemental fertilizer.

During times of moisture stress, the field was furrow irrigated by damming the lower end of each plot and filling the furrows with water to the level of the raised beds at that end. The water was retained until the beds were saturated over the length of the plot.

In 1971, Bermuda grass and Johnson grass were spot-treated with sodium 2,2-dichloropropionate (dalapon). The preemergence herbicide used in corn was 2-chloro-2′,6′ diethyl-N-(Methoxymethyl) acetanilide (alachlor, 2.24 kg/ha), with paraquat (0.14 kg/ha) or amine salts of 2,4-dichlorophenoxy) acetic acid (2,4-D, 0.56 kg/ha) postemergence. With southern peas and the fall crops the preemergence treatment was surface-applied N-*sec*-butyl-4-*tert*-butyl-2,6-dinitroanaline (butralin, 2.24 kg/ha). Directed postemergence applications of paraquat (0.14 kg/ha) were made with a knapsack sprayer. The number of postemergence treatments required varied with

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[5] Mechanical Transplanter Company, Holland, MI.

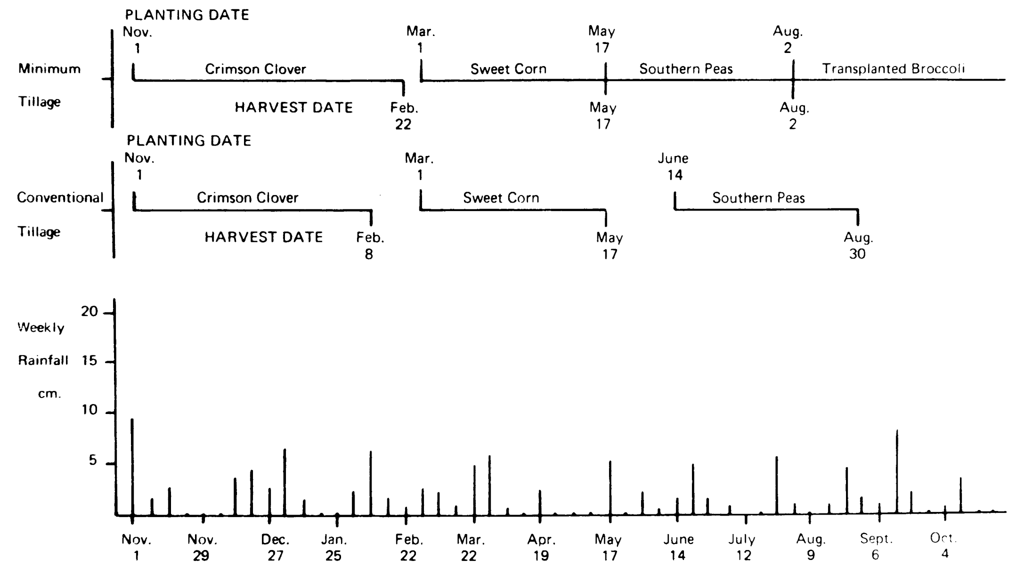

Fig. 1. Planting sequences and weekly rainfall during the cropping period 1970–71 of the minimum tillage trial.

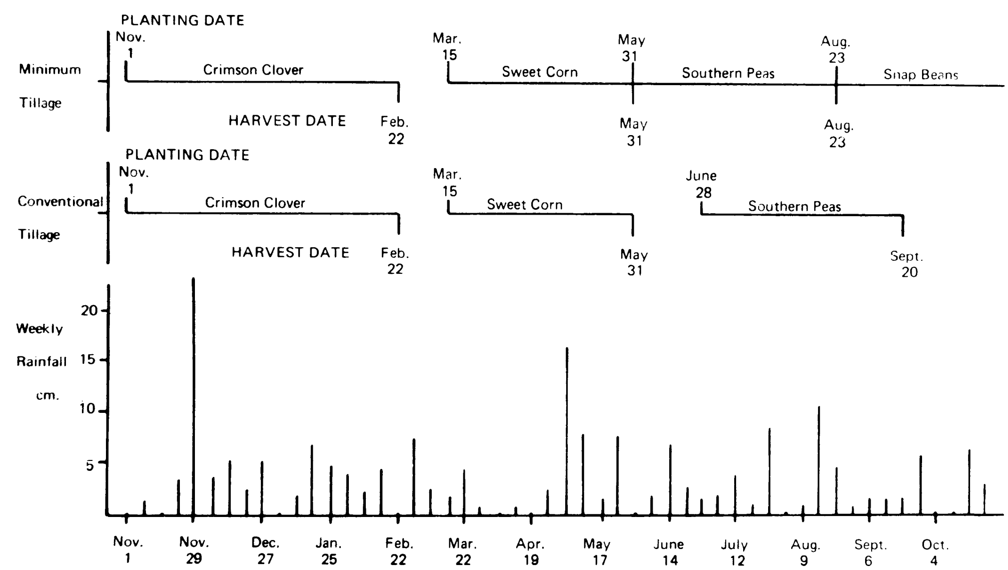

Fig. 2. Planting sequences and weekly rainfall during the cropping period 1971–72 of the minimum tillage trial.

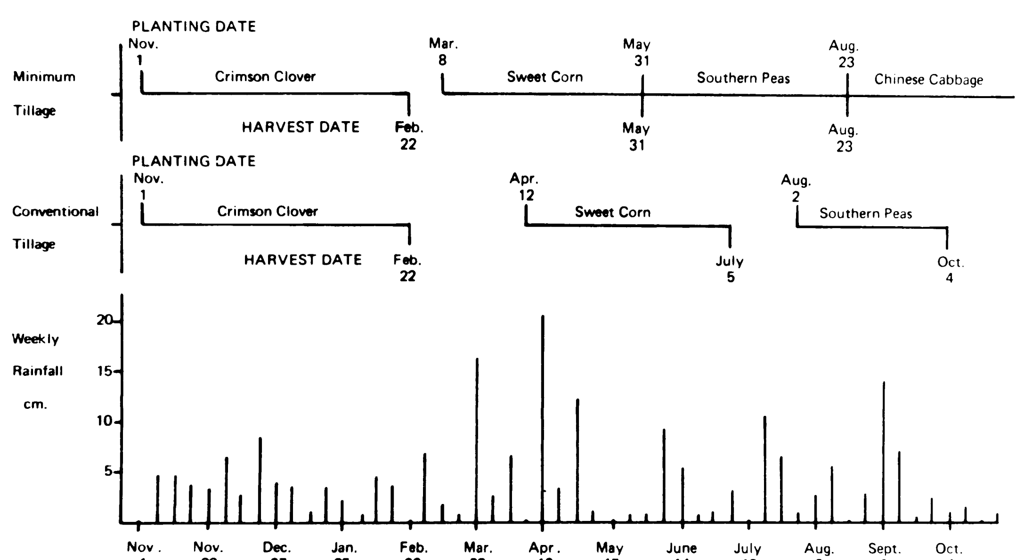

Fig. 3. Planting sequences and weekly rainfall during the cropping period 1972–73 of the minimum tillage trial.

growing conditions, but usually 2 or 3 applications were used with each crop. The maximum number was 4 applications of paraquat to southern peas in 1972.

By November, normal weathering of seedbeds under minimum tillage had reduced their height to about 6 cm. Because this was too low for adequate drainage, a disk hiller was used to take soil which had washed into the water furrows and return it to the beds. In this way the new cropping season was begun each year with beds 15 cm high for plots under both tillage practices.

In August of each year soil samples were taken at depths of 0-5 cm and 5-10 cm for determination of soil organic matter, using chromic acid digestion. For each depth a plot sample was the composite of borings taken from 20 locations on the 2 center beds.

Results

Comparison of crop yields under these systems is not completely valid because the planting times were quite different. In 1971 and 1972 corn was planted at the same time under both treatments. Yields in 1971 were extremely low because of severe bird predations which may have masked differences due to treatment (Table 1). The 1972 yields were significantly higher in the minimum tillage plots. Frequent rains in March 1973 made it possible to plant the conventional plots until the first week in April. The minimum tillage plots, again, produced significantly higher yields, but the comparison was between treatments planted 5 weeks apart.

With one exception, there were no southern pea yield differences between treatments (Table 2). The delayed corn planting in 1973 with conventional tillage was reflected in late planting of the southern pea crop and its maturation under unfavorable conditions in the fall.

Although the minimum tillage system afforded enough time to produce a fall crop before November, the selection of the fall crop presented some difficulties. The labor requirement for transplanted broccoli as a fall crop (Fig. 1) made it impractical under our experimental conditions. Severe seedling disease problems occurred in bush snap beans, possibly because they followed another legume (Fig. 2). Direct-seeded Chinese cabbage, however, produced a satisfactory

Table 1. Yields of sweet corn under conventional and minimum tillage methods—1971, 1972, 1973.

Treatment	1971 Ears/ha	1972 Ears/ha	1973 Ears/ha	1972 Wt/12 ears (kg)	1973 Wt/12 ears (kg)
A. (Conventional)	18,248	32,973	34,863	3.2	3.1
B. (Min. prep.)	18,248	44,863	52,521	3.9	3.1
LSD (1%)	NS	11,624	5,686	0.4	NS
LSD (5%)	NS	—	—	—	NS

Table 2. Yields of southern peas under conventional and minimum tillage methods—1971, 1972, 1973

Treatment	kg/ha		
	1971	1972	1973
A. (Conventional)	3,998	5,326	1,466
B. (Min. prep.)	5,478	5,880	4,275
LSD (1%)	NS	NS	759
LSD (5%)	NS	NS	—

Table 3. Soil organic matter levels under conventional and minimum tillage

A. Percent organic matter at 0 5 cm depth

Tillage	1970	1971	1972	1973	Treatments × depths
Conventional	0.39	0.44	0.53	0.62	0.50
Minimum	0.38	0.47	0.71	0.82	0.60
Years × depths	0.38	0.46	0.62	0.72	0.55

B. Percent organic matter at 5 10 cm depth

Tillage	1970	1971	1972	1973	Treatments × depths
Conventional	0.39	0.53	0.61	0.69	0.56
Minimum	0.39	0.42	0.62	0.75	0.55
Years × depths	0.39	0.48	0.62	0.72	0.56

C. Percent organic matter (treatments × years)

Tillage	1970	1971	1972	1973	Treatment means
Conventional	0.39	0.49	0.57	0.66	0.53
Minimum	0.38	0.45	0.67	0.79	0.57
Year means	0.38	0.47	0.62	0.73	0.55

Analysis of variance

Source	F
Years	99.8**
Treatments	12.1**
Years × Treatments	5.8*
Depths	NS
Years × Depths	NS
Treatments × Depths	10.3**
Years × Treatments × Depths	2.4*

crop (Fig. 3). The cabbage yield did not have a conventional control for comparison.

In comparison with conventional methods, minimum tillage shortened the time between harvesting and planting the next crop by a total of 6 to 12 weeks each year, permitting the production of 4 crops per year (Figs. 1, 2, 3). Because no soil preparation was required, except during the normally dry period of late October, wet weather was never a serious obstacle in planting operations. Soil in the water furrows of the minimum tillage plots would usually support a tractor within a day after a substantial rain. In contrast, frequent rains often delayed seedbed preparation and planting in the conventional plots (Figs. 1, 2, 3).

The organic matter level of this soil under normal cropping practices is reported to be about 0.7 to 0.8%. Because of the intensive mid-summer tillage program used for perennial weed control as well as previous management of the area, the organic matter level was reduced to 0.4% prior to the initiation of our test. During the course of this experiment, the organic matter levels rose consistently under both tillage practices and at both sampling depths (Table 3). The greatest increase was in the upper 5 cm of plots under minimum tillage where the soil contained 0.82% organic matter in contrast with 0.62% under conventional practice. Initially the pattern was reversed at the 5-10 cm zone with plots under conventional tillage having a higher level, but in 1973 the plots under minimum tillage had a slightly higher (0.75 vs. 0.69) level in the 5-10 cm zone.

Weed control is a primary problem under a multiple cropping system because it is not possible to use long residual herbicides which might injure the following crop. Multiple disking in 1970 eliminated all but a few plants of Bermuda grass and Johnson grass. These were eradicated in 1971 with spot treatments. Earlier studies (3) had shown repeated applications of 2,4-D or paraquat to be effective in nutsedge control. In 1971 and early in 1972 nutsedge shoots were numerous while the plots were exposed to full sun. After June, 1972, the amount of regrowth was progressively reduced, and by September, 1973, the weed had apparently been eliminated in all but 2 plots. The preemergence herbicides were less effective in the minimum tillage plots than in those under conventional tillage. The escaping seedlings were not a serious problem because they were killed by the postemergence applications used for nutsedge control.

Discussion

The concept of multiple cropping is common in most tropical and subtropical areas of the world. Fundamentally, it is a labor intensive system for optimum land use efficiency (1). Bradfield (4) modified the system, using increased mechanization to reduce the labor requirement. In Malaysia, we were unable to follow Bradfield's schedule on a somewhat poorly drained soil because it required extensive soil manipulation with each crop. In the present study we were able to use Bradfield's concepts under wet soil conditions by employing minimum tillage methods.

The problems which we encountered with the fall crops in 1971 and 1972 do not reflect on the system, but rather on adaptation to labor conditions and to specific crops. Fungicides are not used in Lousiana with fall-planted snap beans, but we should have anticipated a disease problem when they followed southern peas.

The yields of corn and of southern peas were about normal for this area. The higher yields under minimum tillage appeared to be due to management bias. The month of April was relatively dry in 1971 and 1972. Plants in the plots under conventional tillage began wilting each afternoon for about a week before plants under minimum tillage showed this symptom. When moisture stress was evident in minimum tillage plots the entire field was furrow irrigated. Higher yields of corn under a no-till system are quite common (5) and are attributed largely to differences in water stress (6). In retrospect, it might have been better to irrigate each plot when necessary, but at the time that seemed to introduce a bias toward the conventional system.

Apparently the better water utilization under minimum tillage was due to the dead clover mulch which provided almost complete soil cover throughout the corn cropping period. It was possible, but difficult to operate the rotary cutter so that it shredded the corn stalks without damaging this mulch. In most plots the soil surface was essentially bare when southern peas were planted. Where the clover mulch was retained, it persisted for about 3 weeks, with some fragments still evident when the peas were harvested.

Organic matter determinations made over a relatively short term of 3 years can do little more than show trends, but we felt that this aspect should be followed closely because it is so critical in the management of tropical and subtropical rainforest soils (7). The patterns of soil organic matter developed in this study require some interpretation. Under minimum tillage, decaying crop roots in the 0-5 cm level probably contributed to the higher organic matter levels. Also, the shredded residues from the corn and southern pea crops fell into the water furrows and decomposed. In November, disk hillers redeposited the soil-residue mixture on the raised beds. In contrast, residue from the conventional tillage plots was uniformly mixed after each crop. A possible reason for the upper zone having less organic matter is that the bedding operation placed soil from the lower depths on the surface of the raised beds.

This is a system for utilizing the multiple cropping concept with a reduced labor requirement under wet soil conditions. Multiple cropping is fundamentally land efficient and labor demanding. Even with minimum tillage, it probably cannot compete in labor efficiency with large scale mono or double cropping methods. For this reason, economic evaluation must consider the availability of land and fuel relative to the labor and management requirement.

We believe that, at this time, the most practical application of the system lies with small scale producers in high rainfall, tropical and subtropical areas. A grower with limited land and financial resources could contract for a tractor to rebed each year during a dry season. Herbicides could be applied with a knapsack sprayer and all other operations could be accomplished by hand. Because most small producers have had no experience with timely and accurate herbicide applications, it seems that the practical development of this system would depend heavily on a strong extension program. The specific herbicide program to be used would vary with weed species and crops being produced. At the time our test was started, we selected herbicides primarily on the basis of nutsedge control. In a new study, the program could be simplified somewhat because of recently developed chemicals which are more effective on this weed.

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