YIELD AND ECONOMIC COMPARISONS OF SIX VEGETABLE CROPS
GROWN IN INTENSIVE BEDS AND CONVENTIONAL ROW SPACING

by

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STATEMENT OF PROBLEM

During the summer of 1975, the United States Department of Agriculture sponsored a working conference on research to meet domestic and international food needs. The Agricultural Research Policy Committee members concluded that the nation's "most urgent agricultural research need . . . is to find ways to grow more food using less energy" (32). This is because of the multilayered domestic energy inefficiencies of the American food production system.

Farmers burn as many calories of fossil fuel in their machines as the entire population consumes in the form of food. Modern farming consists of transforming fossil fuel into food (42). Adding the energy cost of producing these machines as well as the fertilizer, pesticides (usually petroleum derived) and other purchased farm inputs casts agriculture in an even more damaging light. For each calorie of food the system harvests, it burns 2.5 calories of fossil fuel (42).

However, little food is consumed on the farm. In America, society uses more energy in processing, packaging, and transporting food than in growing it. The net result is that for each calorie of food produced, more than six calories of fossil fuel are consumed (32).

The international situation is considerably more grim. If the American system of food production is successfully exported around the world, 80 percent of the world's energy supply will be consumed just to produce and market food (42).

Increasing energy costs are a substantial component of a major world problem: the international food supply and world hunger. Today, the major variety of world hunger is chronic undernutrition principally in the poorer tropical and subtropical countries. "The United Nations

Food and Agriculture Organization estimates that as of 1975 around 450 million people were chronically undernourished. Calculated differently, the World Bank put the figure at above 1 billion - one quarter of the population of the earth" (49).

Projected levels of developing countries' food demand by the year 2000 exceed the projected agricultural capacities of the United States, even assuming agricultural production were maximized to meet those demands. The solution to food and hunger problems in the nations of the less developed world lies within their own borders; they must create a self-reliant system of food production and distribution (34).

Energy consumption patterns of the developed world are a major obstacle to achieving such self-reliance. A great deal of the much heralded agricultural productivity in the United States, for example, is due to an agricultural research and practice based on cheap, energy intensive, technology. This technology has out-produced, undersold, and forced off the land small farmers all over the globe. To areas of the world which need labor intensive, land conserving, capital minimizing, mechanically simple agricultural technology, the technology transferred was just the opposite (9,25,26).

This technology consists primarily of new hybrids of "high yielding varieties" of rice and wheat which assume optimum growing conditions (21) and inputs (51) and is principally available to the already large scale farmer (44). While increases in production have been spectacular, they have barely been able to keep pace with the increase in population in the less developed countries. And the population increases lead to a continued cycle of malnutrition, illiteracy, disease, squalor, high infant mortality, and low life expectancy (34). This cycle can only be broken by increasing the production ". . . of the rural people, who in nation after nation still comprise 50 to 80 percent of the population" (12), in an energy conserving manner.

One technique which is energy conserving, labor intensive, land minimizing, mechanically simple, and asserted to be approximately four times more productive, is the intensively planted, organically fertilized, polycropped raised bed cultural system. One grower, Jeavons, asserts it is possible to grow an "entire balanced vegetarian diet for one person on 260 square meters in regions of the world with only a four-month growing season. By comparison, to grow a vegetarian diet in the United States using conventional methods takes 929 square meters and about 2044 square meters to grow a typical American meat diet" (43). Most farmers in the world are small plot farmers, tending pieces of land from 2 to 7 hectares in size. This technique is conceivably of use to them. In the United States during periods of economic decline large numbers of people either do or would like to augment their own diets with food they grow themselves (36). Research on the effectiveness of raised beds would be of use to them also. Therefore, the principle objective of this thesis was to study yields and economic value of six vegetables grown in raised beds and conventional row spacings. Increase in production per plant and per square centimeter should occur by decreasing soil compaction and its secondary or subsequent deliterious effects. It is the intention of this thesis to prepare research findings in manuscript form to submit to HortScience for publication. To pursue these goals information from studies of polyculture, soil compaction and plant spacing are necessary.

REVIEW OF THE LITERATURE

Polyculture

Higher yields per unit of land are achieved in other countries, especially poorer ones, through the use of polyculture cropping systems. A polyculture cropping system is one in which "two or more species of useful plants are grown simultaneously in the same area" (23).

In the introduction to the best current review of domestic and international literature on polycropping, Kass remarks, "Associations of cereal crops and legume-maize were common in the temperate zone until the advent of mechanization and heavy fertilization made them less practical." Furthermore, "mixtures still offer considerable advantages in the tropical zone where use of mechanization and agricultural chemicals remain low" (23).

Polyculture Research Methodology. Polyculture research has focused on whether the practice is more profitable than growing crops with monoculture. However, this narrow economic criterion is both imprecise and irrelevant. With the exception of cotton groundnuts and maize-bean mixtures, which seem relatively independent of price relationship (11), the general conclusion from the literature is that in the more complex experiments, i.e., those which most closely replicate actual farm conditions and practices in the less developed world, the choice of crops generally had a greater effect on the economic returns than did the choice of cropping system (23).

Another problematic methodological variable is production per unit time. Two or more crops involved in polyculture rarely occupy an area for the same length of time. One solution to this problem is to express yields per unit area, per unit time. However, as Kass points out, to do so distorts the comparison towards short cycle crops which are generally grown when environmental conditions are most favorable. Presently the trend is to compare cropping systems over the same time period so they are all subjected to the same conditions (23).

Yet another methodological consideration is plant density. The plant population used in a study of polyculture effects both the results obtained and the validity of comparison to pure stands (15). Extensive experiments carried out by the International Rice Research Institute (IRRI) (18, 19, 20) show plant population becomes most critical when competition between two species is greatest and that high populations will intensify competition. But Kass (23) reports the literature gives little guidance beyond identifying the significance of this variable.

Finally, although methodologically sound, polyculture experiments entail a level of artificiality that does not compare well to actual farm practices. At present, polyculture is most widely practiced by small-scale cultivators holding between 5 and 7 hectares without animals or tractors (39). Growers seemingly plant in a random fashion noteasily reproduced by researchers. This is important because the reseracher's need for uniformity may well entail the loss of the very benefits (such as prevention of disease spread or making use of microvariability of their tiny fields) which induce a small plot cultivator to choose a cropping system in the first place (23). Furthermore, polyculture experiments usually only involve two crops while most farmers who use mixtures grow more than two crops (23).

Additionally, it was found that in regard to labor requirements, choice of crop seemed to be significant in defining both a cropping systems total labor requirement and return per unit of labor (18,19). While there is much evidence to suggest that polyculture is distinctly less profitable at higher management levels, especially at high fertility rates (18, 19, 20, 30, 33, 41), this same evidence strongly suggests the obverse reality. This is borne out by farmers in the less developed countries who choose polycropping for use with low management levels and in low fertility situations (3, 31).

Beyond this type of analysis, the choice of crops and cropping systems is highly influenced by the environmental, social and cultural milieu of individual farmers. To exclude non-economic factors is irrational. It can be seen that the methodological difficulties are substantial.

Crop Yields. Methodological considerations aside, strong claims have been made for polyculture (3, 52) while others hold it is a relic of traditional pre-modern farm methods (15,17). It is useful to review the reported experimental evidence for crop yield. What are the likely consequences of using a polycrop system?

In general, yields of each species in polyculture are reduced in comparison to pure stands (15, 45). On occasion, however, only one species was considered of primary importance and its yield was increased, or at least not significantly decreased, by being grown with another crop. Such a situation is most frequently observed when the intercrop is a legume and the soil is of low fertility (1).

A number of studies have provided sufficient information to compare yields in polyculture with yields of half-hectares of pure stands of the same crops. Comparisons have been made for millet with sorghum (4, 24), for groundnuts with sorghum (8), for soybeans relay-planted into oats (10), for sorghum with groundnuts and cowpeas (6), for maize with beans (11), for mung beans with maize (18, 19, 20), for castor beans with groundnuts (16), and for cotton with groundnuts (22). The conclusion is that polyculture has shown itself superior to monoculture with a wide range of crops and experimental conditions when the yields obtained were compared with the potential of equally dividing the experimental area between pure stands of the crops involved (23).

Pest Management. Pest management has also received attention in the polyculture research literature. The theory of pest management asserts that the pest is constantly changing in response to selection pressures. The more diverse the selection pressures such as pesticides, resistant varieties, natural enemies, and cultural practices, the greater the resilience against pests (28). Polyculture enhances these selection pressures. The most extensive study of the effect of polyculture on pests was carried out at IRRI in 1973 and 1974. Groundnuts were intercropped with maize to attempt to reduce the incidence of corn borer on maize. It was found that interplanting groundnuts in the maize at either 20,000 or 40,000 maize plants per hectare reduced infestation by the number of borer-infested plants, borer number per plant, and the number of feeding or exit holes and tunnels. These parameters were also reduced by lower maize population but were even further reduced by intercropping with groundnuts at the lower maize population. The researchers concluded that groundnuts provided a better habitat for borer predators (19, 20). Crookston (13) reported on work in Oklahoma in which untreated cotton in association with sorghum yielded 24 percent more than did pure stand cotton treated with insecticides. He attributed this to the sorghum having served as a habitat for cotton ball worm predators. In an economic universe in which petrochemical pest management is increasingly unattainable by small plot cultivators in the less developed countries, this form of pest management has increasing value.

In summary, the general research findings indicate polycuture is more beneficial than detrimental (2).

From the perspective of cultural technique for intensive beds, information from polycropping literature is valuable in the following ways: It increases historical and socio-cultural "depth of field". Not everywhere and not always have individual farmers been growing only a single crop upon thousands of hectares of land with immense machines at enormous expense. Academic methodological difficulties would indicate that "traditional farmers" use highly sophisticated decision making categories appropriate to their scale which might well be a form of technological transfer useful to small scale, polycropping growers in the United States. Indications that polycropping as a component of integrated pest management designs enhances biologic pest control are clearly of significance to the home vegetable gardener in the United States as well as to cultivators in the less developed countries.

Soil Compaction

The second principal objective of this thesis was to determine if increased production per plant was attained by decreasing soil compaction and its secondary or subsequent deleterious effects through the use of raised beds. A. C. Trouse has recently written of the consequences of soil compaction.

> Most agricultural crops are not reaching the yield potentials expected with newer varieties because of soil and moisture conditions that hinder root development. Compacted soils can restrict root development. . . . The structure of tilled soil is easily destroyed by vehicular traffic and many recommended and accepted cultural practices reduce the usable moisture, air and much of the organic constitutents of the soil. . . . Although some subsoils may be in suitable physical condition, the moisture stored there is often denied crops because man-made barriers (i.e., plowpans vertical and horizontal) in the tilled surface prevent crop roots from reaching it. Even mild compression impedes root development enough to affect crops but often goes unnoticed or is taken for granted (48).

Root Growth. Good root development occurs when five basic conditions are achieved simultaneously; when soil oxygen level is sufficient for physiological functioning of the root; when soil moisture is adequate for both above- and below-ground needs; when soil temperature is within the range suited to the species; when the plant is able to produce and transport sufficient food and hormones to the root system; and when the amount of toxic chemicals, lethal gasses, diseases, and insect damage are insignificant.

In good soil conditions, roots of grasses, grains, pulses, and horticultural crops extend to great depths. In 4 to 6 weeks, specimens from each of the above plant groups formed root systems which exceeded a depth of 180 cm and a width of 120 cm (47).

In the early stage of a plant's development, roots of many kinds can grow five to ten times deeper than the plant extends above the soil line. When a seedling emerges the need for moisture increases substantially. The roots must be able to meet these demands. Roots of most plants are able to extend, or elongate, 6 cm in 24 hours. Forward thrust comes primarily from the region of cell elongation which may extend several centimeters back from the tip (46).

Oxygen is vitally needed by developing roots. The forward thrust of roots is dependent upon cell division and cell elongation. The energy needed for cell division, for the production of cell materials, for the active absorption of water, and for the thrust to push aside soil particles is released by the reaction of soil oxygen with the foods supplied by above-ground plant parts. With an adequate supply of oxygen, cell division in the growing tip is rapid.

Microscopic studies of tissues in the zone of cell division of a rapidly elongating root in a well aerated environment reveal a predominance of cells undergoing various stages of mitosis. Under reduced oxygen, such as within compressed soils, tissue of the same age shows fewer cells undergoing mitosis. When oxygen is cut off, root elongation stops (Williamson, loc. cit. 53). If the supply is cut off only for a short time, elongation is reinitiated in the dormant root with the resumption of oxygen. If oxygen remains deficient for too long, the root tip will stay dormant until it decomposes; it is killed. Crop production in mildly compacted soils is most affected, given that all other cultural practices are well performed. Roots grow rapidly in loose soil with a bulk density of 1.10 g/cm^3. Soils compressed just 0.15 g/cm^3 can reduce root growth to about half of its capacity. Soils compressed 0.35 g/cm^3 can reduce elongation rates to about a tenth of their capability. At these mild bulk rate densities, soils have considerable macropore volume, but forces applied to the soil have reduced the size and connectability of the macropores so that once the oxygen is removed from a void the slow rate of oxygen replacement prevents continuation of rapid functioning (46). Russell (38) says, "mechanical impedance causes the zone in which cells extend behind the apical meristem to be much shorter; cells may attain their maximum length with 1 mm from the root tip and root hairs often develop in this zone."

Experiments exposing roots to varying pressures have indicated that appreciable reduction of root extension has been caused by pressure in the range of 0.25 to 0.5 bar. (or 3.62 to 7.25 psi) (Goss, loc. cit., 37). If the pore diameter is so small that root axes and laterals are both subjected to mechanical impedances the entire root system is then stunted and can be profusely covered with root hairs. "In a natural environment, the vulnerability of a root system of this type to desiccation as a result of the drying to the surface soil would give little prospect for its survival" (38).

Anerobic Root Environment. Another potential environmental consequence of compacted soils is the creation of anaerobic soil conditions. The air-filled porosity of the soil is the physical characteristic which has greatest influence on gas exchange with the atmosphere. If warm conditions prevail and considerable oxygen is being consumed by boilogic processes, toxic oxygen depletion can occur very quickly. A conservative estimate of oxygen consumption by Russell (37) points out that if a soil which contains 20 percent by volume of air uses oxygen at the rate of 7 g per m^2 surface area per day, the total oxygen contained in the soil air would be exhausted in about 2 days if its surface were completely sealed. Another study, cited as representative of many, shows that at the amount of 17 C^o oxygen consumed per m^2 ground surface (g d^{-1}), oxygen consumed under a crop of kale was 23.7 g per m^2. In this case interruption for less than a day would lead to depletion of oxygen (14).

There are other consequences of anaerobic soil conditions. One of them is the metabolism of organic substrates in the soil which will produce toxic substances in the soil, for instance, organic acids, aromatic acids and volatile fatty acids. In addition, methane and ethylene can be produced. The latter is an endogenous growth regulator in plants and it can induce biological effects in concentrations as low as 2 ppm. Ethylene has been found in concentrations exceeding 10 ppm in water-logged field soils (40).

The response of plants grown in anaerobiotic soil varies according to their sensitivity to it. Rice, for instance, is unusual in its ability to transport oxygen from the leaves to the roots and is consequently quite insensitive to anaerobiotic conditions. On the other hand, tobacco and tomatoes are very sensitive; within hours morphological effects such as wilt and epinasty occur. Later, leaves may become chlorotic and senesce prematurely; elongation of stems may be reduced and root growth is much restricted (38).

A paradoxical response of plant anaerobic soil condition is the greatly reduced ability of the roots to absorb moisture due to lack of oxygen. Decrease in moisture uptake is accompanied by reduction in nutrient uptake, but this does not induce such immediate acute symptoms. Moreover, anaerobic soil conditions reduce the ability of the roots to produce and transport gibberellin and cytokinin, both growth regulators to the shoots (35).

A further negative complication of anaerobic soil conditions is nitrogen loss from the soil both due to the process of denitrification and leaching. Research estimates vary, but field experiments suggest "losses due to denitrification may range from negligible to c. 20 to 40 percent of the nitrogen applied to the soil" (43).

From the point of view of intensive bed systems, enhancement of the gas exchange capacity of the soil, i.e., adequate oxygen availability, and reduction of the consequences of anaerobic soil conditions indicate potential origins of reported yield increases attributed to intensively planted raised beds.

Plant Density and Spacing

The research of several authors (5, 7, 26, 50) strongly suggests that for various legume species, plant spacing affects yields attained. Further, it is reported that the colser to uniform distribution, the greater will be the yield. H. J. Mack (29) demonstrated higher yield when plants were in a square arrangement than when the same population density was either in 24 cm, 51 cm, or 105 cm rows. Plants at 10 by 10 cm and 12 by 12 cm spacings produced highest yields when compared to 8 by 8 cm, 15 by 15 cm, 17 by 17 cm, and 21 by 21 cm spacing.

When considering the intensive bed cultural technique, it is of signal importance that arrangement of plants will positively influence plant yield.

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MANUSCRIPT

YIELD AND ECONOMIC COMPARISONS OF SIX VEGETABLE CROPS GROWN IN INTENSIVE BEDS AND CONVENTIONAL ROW SPACING[1]

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Abstract: Fresh weight yields were compared for tomatoes, eggplants, sweet peppers, sweet potatoes, lima beans, and green beans grown in conventional row spacing or deeply dug intensive beds. Yields per unit area (g/cm^2) and yield per plant (g/plant) of all vegetables grown in intensive beds were consistently higher than yields of vegetables grown in conventional row spacing.

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[2]Instructor and Professor, respectively, Department of Horticulture, Kansas State University.

Optimum vegetable yields are dependent on soil preparation methods that maximize root growth. When the soil is well aerated, fertilized and cultivated root systems are large, deep, and extensive. Some vegetable cultivars, such as sweet potatoes, are capable of reaching root depths of 180 cm and attaining lateral spreads of more than 100 cm in less than a month (6). Today's cultural methods leave the best soil in poor condition for root growth and subject to accelerated erosion (6).

Soil compaction can be minimized by planting in raised beds that combine polycropping techniques. Yields are reported greater than those achieved with conventional vegetable and fruit growing techniques (1, 4, 5, 7).

This study compared yields and economic return of vegetables grown in raised beds with those in standard rows. Higher densities and polycropping six vegetables should produce higher yields (g/cm^2) than conventional row plantings. The experimental site was located in a community garden with two plots used, each being 4.8 x 7.3 meters. Plots were divided creating 17.5 m^2 subplots. The top 15 cm of Eudora sandy loam received 3 m^3/plot of year-old manure and wood shavings.

In each subplot, one was double dug and 4 beds were formed approximately 120 cm wide by 400 cm long by 20 cm high. (Double digging is the approximate hand tool equivalent of a 46 cm subsoil chisel pulled by a tractor.) In the other subplot, rows were formed following plant spacing recommendations of Marr (3).

Spacing. As shown in Table 1, the space per plant for conventional row (CR) and intensive bed (IB) plantings is contrasted for each of the 6 vegetable crops. These are: tomatoes (*Lycoperscion* esculentum 'Jet Star"), sweet peppers (Capsicum frutenscens grossum 'California Wonder"), eggplant (Solanum melongena 'Black Beauty'), sweet potatoes (Ipomea batatas 'Georgia Jet'), lima beans (Phaseolus limemsis 'Fordhook'), and green beans (Phaseolus vulgaris 'Blue Lake'). In all cases the growing space utilized per plant was 50% to 70% less in the beds than in the rows. Solinaceous crops were harvested 11 times, beans twice and sweet potatoes once.

Yield. All vegetables grown in intensive beds produced consistently higher fresh weight yields (g/cm^2) than vegetables in conventional row spacings (Table 1). Sweet potatoes produced twice as much tuber weight in beds as in rows. Fruit fresh weight of tomatoes was 3 times; eggplant 5 times, sweet peppers 7 times, lima beans 8 times, and green beans 10 times as much in raised beds as in conventional rows (Table 1).

On a fresh weight per plant basis (g/plant), all vegetables consistently produced higher yields in intensive beds than in conventional rows even though they were more closely spaced in the intensive beds. Sweet potatoes produced 3 times as much tuber weight in beds as in rows. For tomatoes in the beds fresh fruit weight was about twice that of the rows, but eggplant and peppers were only .03 g more in intensive beds than in conventional rows. The beans were approximately 3½ times more productive in the beds than in the rows (Table 2). Mack (2) reported that use of 12 cm x 12 cm square spacing (and consequently used in this study) rather than 105 cm x 2 cm row spacing increased yield by 36%.

Chi-square analysis indicated that all six vegetable species consistently produced higher yields (g/cm^2 and g/plant) in raised beds than in conventional rows.

Value. A comparison of dollar value of vegetable yields, at prices established by USDA Agricultural Marketing Service, Fruit and Vegetable Division, Market News Branch, at Kansas City, Mo. in 1978 shows tomatoes and sweet potatoes produced higher value yields. Intensive beds produced higher value yields of sweet peppers, eggplant, lima and green beans. The aggregate value of crops in intensive beds was less than those in conventional rows (Table 3). The yield in dollar per square meter ($\$/m^2$) for conventional rows was $5.57; for intensive beds it was $5.33. Both figures are approximately 17% less than the $6.50 reported by Utzinger and Connally (8). Items not considered in cost analysis were plant materials, manure, gasoline, tools, water, land rental, and labor opportunity costs.

Labor. Conventional rows required 15 hrs of labor; intensive beds required 19 hrs of labor per 17.5 m^2 per season (Table 4). The additional time spent on the beds was primarily due to soil preparation. Conventional rows required more time for weed control.

Soil compaction. Cultivars consistently produced higher yields in the intensive beds both on a g/cm basis and on a g/plant basis. It can also be said that on a yield/area and on yield/plant basis, optimum plant spacing has yet to be determined. As no soil compaction measurements were taken there can be no assessment as to the effectiveness or lack of effectiveness of raised beds on yields through the reduction of soil compaction. Further research should include determining the limits of space and densities of various species in beds, measured soil compaction effects, distinctions among cultivars in beds and variation of water consumption between beds and rows.

Conclusion. The assumption of American agricultural land use is generally that agricultural space is a lesser constraint than agricultural labor. For the home gardener or small plot grower this is not true. In attempting to find ways to increase yields of small plot growers, different parameters must be emphasized differently for different situations. If space is a limiting factor, planting more plants in a smaller area will achieve approximately standard yield and will leave room to plant a greater variety of crops.

The most important conclusion of this study is that changes in plant densities, labor input and cultivation techniques do have effects which could benefit small plot growers and whose optimum mix is presently unknown.

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Table 1. Comparison of harvest and spacing of 6 vegetable crops grown in conventional rows (CR) and intensive beds (IB).

Crop	Harvest no.	Spacing (cm^2/plant)	
		CR[z]	IB[z]
Tomato	11	2116	576
Sweet pepper	11	1242	361
Eggplant	11	1242	361
Sweet potato	1	2349	969
Lima bean	2	249	49
Green bean	2	126	36

[z] CR=conventional rows; IB=intensive beds.

Table 2. Comparisons of fresh weight yield/area and yield/plant of 6 vegetable crops grown in conventional rows (CR) and intensive beds (IB).

Crop	No. of plants		Total fresh weight yield/area^y (g/cm^2)		Total fresh weight yield/plant^z (g/plant)	
	CR	IB	CR	IB	CR	IB
Tomato	20	32	3.7	11.6	.19	.36
Sweet pepper	6	32	.6	4.0	.10	.13
Eggplant	6	24	.5	2.6	.08	.11
Sweet potato	18	12	7.6	15.0	.42	1.25
Lima bean	20	48	1.9	15.5	.10	.32
Green bean	22	48	2.1	21.3	.10	.44

$^y X^2 = 5.76$, $p = .25$

$^z X^2 = 0.10$, $p = .99$

Table 3. Comparison of vegetable value ($) from conventional rows (CR) and intensive beds (IB).

Crop	Value ($/kg)	CR	IB
Tomato	1.13	78.93	67.72
Sweet peppers	1.13	4.62	8.97
Eggplant	1.11	3.28	6.80
Sweet potato	.56	10.19	7.98
Lima bean	1.05	.38	.93
Green bean	1.10	.24	.94
Total		97.64[z]	93.34[y]

[z]Value/labor hours = $6.51/hr for CR

[y]Value/labor hours = $4.91/hr for IB

Table 4. Comparison of estimated labor allocation by 17.5 m^2 subplot for conventional rows (CR) and intensive beds (IB).

Tasks	CR	IB
Manuring	2.0	2.0
Rototilling	1.0	1.0
Double Digging	0.0	5.0
Bed Formation	0.0	1.0
Row Formation	0.5	0.0
Planting	1.5	1.5
Maintenance, mulching, weeding, irrigation and harvest	10.0	8.5
Total	15.0	19.0

APPENDIX

The two research plots are distinguished by their location in the east and west ends of the Manhattan, KS community garden, respectively. The experiment was conducted in a community garden to most closely simulate small plot grower field conditions. Further research conducted at a more secluded site, an experiment station for instance, free from minor vandalism and accidents (e.g., children walking through beds) might affect ultimate results. The following more complete information is included for any who would attempt further research on this topic.

The consistently lower yield figures from the west subplots are largely attributable to the lower fertility of their soil, 9.9 ppm N vs. 11.9 ppm N in the east subplots. However, 2 ppm N would not account for the total difference. It is unlikely the remaining difference would have been caused by insufficient water as the west subplots had convenient irrigation while the east plots did not. The only other overt distinction between the subplot locations was that the east subplots were located in a section of the community garden which had historically been restricted to those gardeners who wished to avoid the use of synthetic fertilizers and pesticides and to increase the organic material incorporated in the sandy soil, i.e., in the "organic end of the community garden." The west subplots were located in the section of the garden where such things were not the major concern of the gardeners.

Mole tunneling occured in all subplots making uniform irrigation difficult. Some root damage must be assumed. Earthworm, grub or other insect populations eaten by the moles may have been higher in the beds. Colorado potato beetles were numerous in late July and August, but produced slight damage to research plants. Flea beetles riddled eggplant leaves in both beds and rows. Rotenone powder was applied upon the leaves to control the beetles.

As the season progressed the fungus disease Septoria lycospersici attacked the tomato plants. No fungicides were applied as organic pest control was maintained to adhere to the protocols of the community garden. The disease seemed to affect the conventional subplot tomatoes the most as their rate of fruit production slowed markedly. The bed tomatoes ceased to produce within 31 cm of the ground but none-the-less continued to produce substantial amounts of fruits in their upper regions until the first frost.

Table A-1. Soil Test Report[z]

Plot	pH		Available P lb./A		Available K lb/A		Available N ppm N	
	1979	1980	1979	1980	1979	1980	1979	1980[y]
Community garden east	7.2	7.0	200+	200+	500+	500+	11.9	
Community garden west	7.2	7.3	200+	180	500+	500+	9.9	

[y]No report available for 1980 N.

[z]A soil test showed the nitrogen level in the east set of subplots was 11.9 ppm and 9.9 ppm in the west subplots. The soil pH in all subplots was 7.2. The available phosphorous in pounds per acre was 200+, the exchangeable potassium in pounds per acre was 500+. The post experiment soil test showed the east set of subplots had declined in pH by .2, and the west set of subplots had increased pH by .3. The potassium and phosphorous levels remained unchanged.

YIELD AND ECONOMIC COMPARISONS OF SIX VEGETABLE CROPS

GROWN IN INTENSIVE BEDS AND CONVENTIONAL ROW SPACING

by

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Fresh weight yields were compared for tomatoes, eggplant, sweet peppers, sweet potatoes, lima beans, and green beans grown in conventional row spacing or intensive beds. The research was conducted on two 7.3 x 4.8 m replicated plots located in an alluvial Eudora silty loam soil. Vegetables received similar applications of rotted cattle manure, irrigation, and pest control practices. Differences in cultivation techniques between the two systems included the soil preparation, plant spacing, and polycropping.

Raised beds (120 x 400 x 20 cm) were constructed and vegetables planted in both treatments by May, 1979. Spacing in the beds ranged from 50% to 70% less per plant species than in conventional row systems. Harvesting was completed on a weekly basis for solinaceous crops, two times for beans and once for sweet potatoes.

Total fresh weight yield per area from conventional row subplots was 2.67 g/cm^2 for all vegetables; the intensive beds yielded 11.7 g/cm^2 when a 20% reduction was made for walkways between beds. Labor investment for the conventional row systems was 15 hr, with 19 hr needed for the intensive beds. The retail value of the conventional row system was $\$2.79/m^2$; for the intensive beds it was $\$2.67/m^2$.

Disregarding the labor component, the value for solinaceous crops in conventional rows was $86.63 vs. $83.49 for intensive beds. The value for beans was $.62 in conventional rows vs. $1.87 in intensive beds. The value/m^2 for sweet potatoes in conventional rows was $10.19 vs. $7.98 in intensive beds.