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Improvement of Work Methods in Pepper Greenhouses

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1 Introduction

In Israel there are 5,000 acre of pepper and 40,000 ton of pepper are export, out of which 30% are produced in greenhouses. Greenhouse pepper growing processes are labor intensive and require 280-360 working days per acre. The large numbers of workers involved in the various operations cause bottlenecks that affect costs and working efficiency.

Work methods analysis is a commonly employed technique to improve production and operations management (Globerson, 2002). The determination of standard times for greenhouse production systems is essential for efficient labor management (Luxhoj and Giacomeli, 1990). Simulation is an important tool to compare different work methods (Tersine, 1985). The advent of simulation in agricultural systems provides the ability to compare several alternatives under predefined controlled conditions, without the need for repeated field experiments, and independently of the growing season. The influence of differences between and within cultivars can be examined by means of a computerized model of the system, and statistical comparisons can be made among the various possible combinations of all crop parameters, such as the geometry of the crop and fruit distribution (Edan and Miles, 1994).

Simulation has been successfully used in a variety of agricultural engineering applications including: management of cotton combines (Chen et al., 1990) and watersheds (He, 2003); design of agricultural robots (Elkabetz et al., 1998; Edan and Miles, 1994), automatic transplanting machines (Bar et al., 1996), nursery material handlings operations (Chen et al., 1978; Jagtap and Verma, 1983a, b; Fang et al., 1990) and a site-specific sprayer (Elkabetz et al., 1998); systems engineering of automatic transplanting machines (Kutz et al., 1987), mechanical harvesters in the tomatoes industry (Brandt and French, 1983), and seedling quality classification (Muttiah and Miles, 1988); and facility design of a cowshed for a robotic milking environment (Halachmi et al., 2003), a grape packing house (Otmi and Karni, 2000) and an aqua-farm (Eranst et al., 2000).

Work efficiency improvement is extremely important due to the high dependency and unstable availability of manpower. The objectives of the research were to improve work methods in pepper greenhouses, in order to reduce the manual labor required. Work methods were analyzed and simulation tools were developed to compare alternatives.

2 Methods

Farm Data

Data were collected on a modern farm in southwest Israel; it included 16 acres of pepper greenhouses and operated two annual growing cycles. The farm is operated by 30 workers. Work studies were performed in greenhouses of 2.5 acres. The distances between the pepper rows were 1.5 m and the spacing between plants within the rows were 0.4 m (figure 1a). In several rows, rails were mounted in order to improve cart conveying along the rows (figure 1b).

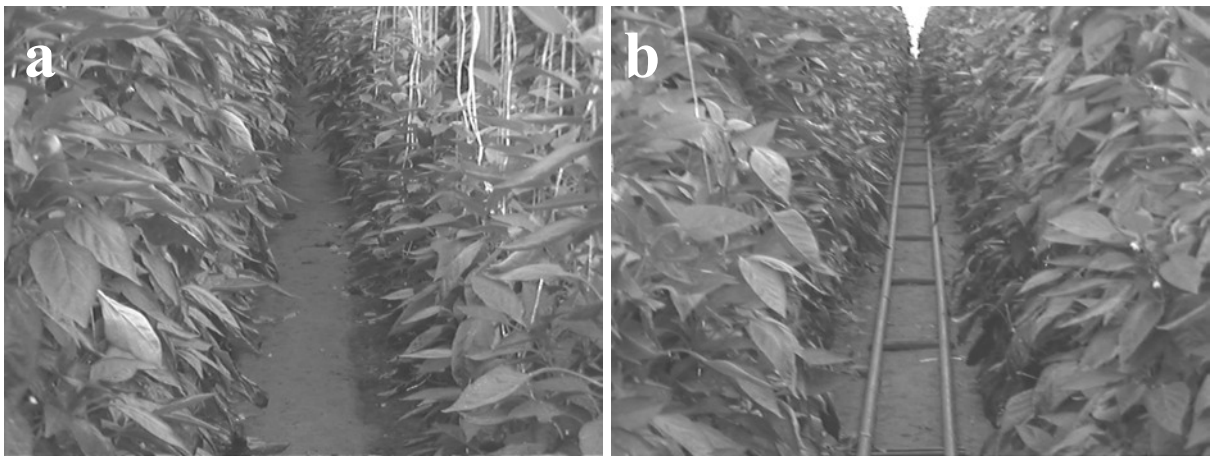

Figure 1: Pepper row (a) without rails, (b) with rails

Work Studies

Work studies were performed on two of the cultivation processes (trellising and harvesting) which together account for 70% of the total number of working days invested in this product.

Work studies were performed by means of direct measurements and multi-observation methods (Barnes, 1980). In the direct measurement method, each stage was divided into elements and the performance time of each element was measured. For each stage the measurements were repeated 20-2200 times.

The trellising operation is performed between once a week to twice a month; it includes trimming the plants and wrapping each plant top on the trellising rope. The trellising period starts two weeks after planting and extends through the last harvest time. The trellising operation performed using carts and plastic boxes (figure 2). The trellising process includes cutting fruit sets, removing surplus leafs, wrapping the plant top, placing the leafage in boxes on a cart, conveying the carts along the row, rearranging the boxes on the cart, conveying the carts for unloading, empting the boxes into two containers, returning to the row and emptying the containers.

The harvest period last between three to seven months in according to the season, the markets demands and the farmer decisions. Harvesting is performed between once a week to twice a month. The fruits are picked singly and placed in plastic boxes on a picking cart. The harvesting process includes detaching the pepper from the stem using a cutter and placing it in a box, conveying the carts along the row, rearranging the boxes on the cart, conveying the carts for unloading, unloading the boxes into cart towed by tractor and loading the picking cart with empty boxes and returning to row.

Figure 2: Trellising/Harvesting cart and plastic boxes

Simulation

A detailed graphical simulation models for working processes of pepper in greenhouses were developed in ARENA, a simulation environment that uses a graphical flowchart presentation; it included simulation of all work processes in the actual operational sequence at the single-plant level. In this simulation model the entity is the worker and the server is a pepper plant. The treatment time of the entity by the server is represented by the harvesting or trellising time spent by the worker on each plant. The time distribution of the worker's arrival at the plant is defined by the statistical distribution of the peppers in the greenhouse. The simulation describes a single tomato row with one worker, and the number of workers needed for the entire greenhouse is derived from this. The simulation inputs were: the number of rows in the greenhouse, the row length, the number of plants in a row, the operating time per plant, the machinery or tool in use, the number of workers, and the number of repetitions required. The calculated outputs of the simulation were: total working time per row, yield weight per row, net working time (the time during which the worker was productive) and walking time.

Alternative working methods were compared, with specific attention to: 1) routes for progressing along a row in the trellising and harvesting stages; 2) task allocation in the harvesting stage, and 3) influence of laying rails along the rows.

3 Results

Work Study

Trellising – the operation performs on one side of one row side in standing posture. Trellising inside a row consists of three elements: 1) cutting fruit sets, removing surplus leafs, wrapping the plant top and placing the leafage in boxes on the cart; 2) conveying the cart along the row to the next untreated plants; and 3) rearranging the boxes on the cart in a way that an empty box will be on top. Outside the row there are additional elements which appear in low frequencies: 4) entering into the greenhouse; 5) locating the containers along the main path; 6) loading empty boxes on the cart; 7) conveying the carts outside the rows for unloading the leafage; 8) empting the boxes with the leafage into the containers; and 9) returning to rows

and searching for an untreated row. Table 1 shows the values of the main elements in the trellising stage. The activities inside the row requires 82% of the total working time while the rest is required for conveying the carts outside the rows, emptying the boxes and returning to the rows. 20% of the working time of activities inside the row is required for conveying the carts inside the row and rearranging the boxes on the carts. The trellising activities of element 1 require about 68% of the total working time while 32% are required for different conveying and servicing activities.

Table 1: Values of the major elements in the trellising stage. The different times are in seconds

Element No.	Average	S.D.	N	Frequency	Time to cycle	Part of working time
1	6.6	4.5	1837	1:1	6.6	82.4%
2	5	3.6	387	1:4.7	1.05	
3	15.6	3.9	46	1:40	0.39	
7	67.7	41.03	61	1:300	0.22	4.6%
8	76.7	117.2	61	1:300	0.25	5.2%
9	114.7	36.2	61	1:300	0.38	7.8%

Harvesting – the operation performs on one side of on row in standing posture. Harvesting inside a row consists of three elements: 1) picking a pepper and placing it in a box; 2) conveying the cart along the row to the next untreated plants; and 3) rearranging the boxes on the cart in a way that an empty box will be on top. Outside the row there are additional elements which appear in low frequencies: 4) entering into the greenhouse; 5) entering empty boxes into the greenhouse; 6) loading empty boxes on the picking cart; 7) conveying the carts outside the rows for unloading the pepper boxes; 8) uploading the pepper boxes on the tractor towed cart; and 9) returning to rows and searching for an untreated row. In case that the tractor towed cart is become filled the rest of the pepper boxes are upload outside the greenhouse. This operation is usually happen at the end of the working day and they are rare.

Table 2: Values of the major elements in the harvesting stage. The different times are in seconds

Element No.	Average	S.D.	N	Frequency	Time to cycle
1	4.53	2.24	2289	1:1	4.53
2	3.88	2.32	633	1:3.616	1.07
3	24.16	8.16	77	1:29.7	0.81
7 inside the greenhouse	34.6	21.6	121	1:300	0.11
7 outside the greenhouse	53.32	30.1	28		
8 inside the greenhouse	81.6	42.1	103	1:300	0.27
8 outside the greenhouse	147.5	87.0	31		
9 inside the greenhouse	35.4	22.5	113	1:300	0.12
9 outside the greenhouse	54.4	24.2	21		

Table 2 summarizes the values of the major elements of the harvesting process. The activities inside the row require 90% of the total working time. 70% of the working time of the activities inside the row is required for picking element. The picking element requires 70% of the

working time inside the rows and about 63% of the total working time while 37% are required for different conveying and servicing activities.

The work study results indicates that for both trellising and harvesting stages, more than 30% of the total working time is spend on activities which are not the trellising and the fruit picking itself.

Simulation

Evaluation of alternative methods in trellising stage – Two alternatives were examined: 1) current situation; and 2) trellising without searching time for untreated rows and usage of six containers. Figure 3 shows the working time for a 2.5 acre pepper greenhouse for the two alternatives. The results show that increasing the number of containers to six and reducing the time requires to locate an untreated row is reducing the total working time by 11%.

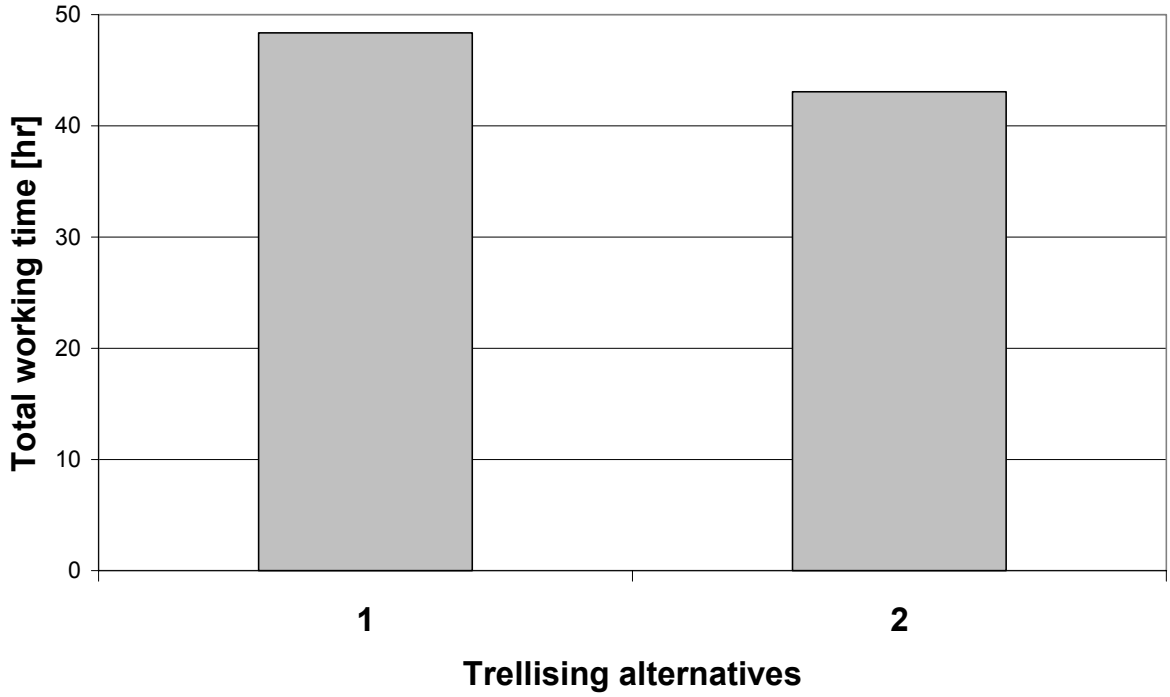

Figure 3: Total working time for two trellising alternative in a 2.5 acre pepper greenhouse

Evaluation of alternative methods in harvesting stage – Five alternatives were examined: 1) current situation; 2) harvesting and uploading pepper boxes to towed cart inside the greenhouse; 3) harvesting into picking carts which are mounted on rails inside the rows and uploading pepper boxes to towed cart inside the greenhouse; 4) harvesting into picking carts which are mounted on rails inside the rows and uploading pepper boxes to towed cart inside the greenhouse, the workers are allocated into different tasks, one worker performs the boxes conveying from the end of the rows to the towed cart and the others are allocated to work in the rows; and 5) harvesting into picking carts which are mounted on rails inside the rows, the pepper boxes conveying and uploading to the towed cart is performed after all the rows are harvested. Figure 4 shows the working time for the different harvesting alternative in a 2.5 acre greenhouse. The results indicate that adding rails inside the rows can reduce the working time by up to 25%.

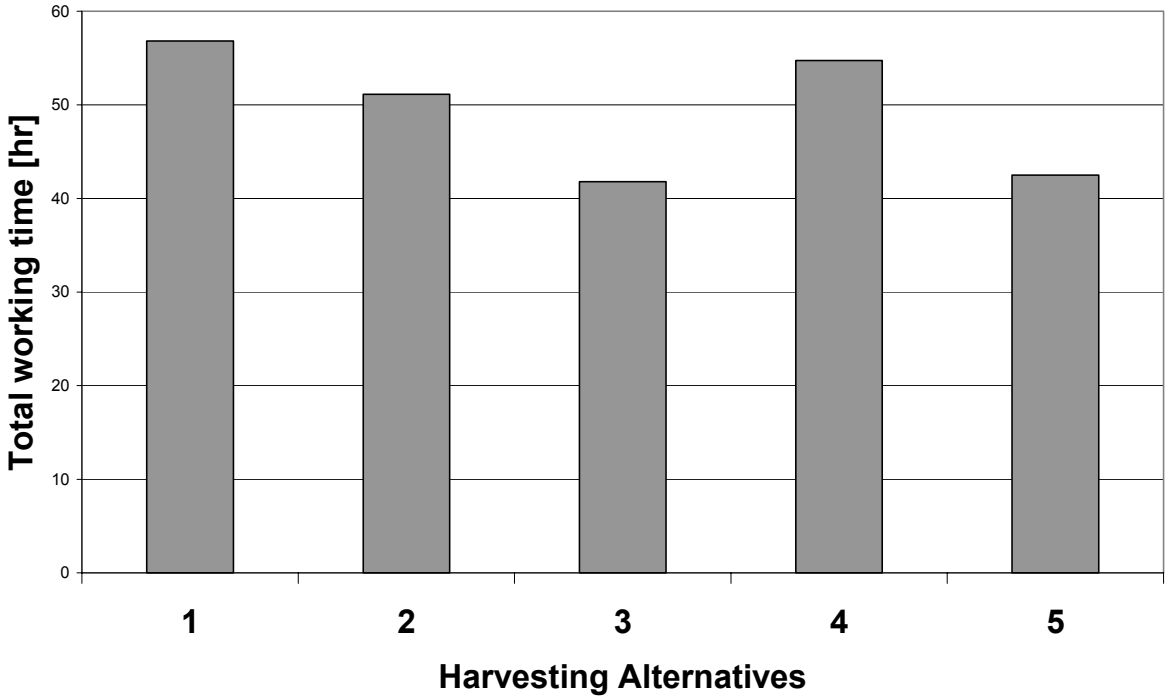

Figure 4: Total working time for five harvesting alternative in a 2.5 acre pepper greenhouse

4 Summary and Conclusions

Work studies were performed on the trellising and harvesting stages in pepper greenhouse. Several inefficient processes were found in these stages. It was found that more than 30% of the total working time in the trellising and harvesting stages is wasted on conveying operations.

A detailed simulation model of the work processes in pepper greenhouse was developed in ARENA. Several alternative working methods were examined for the trellising and harvesting stages. It was found that in the trellising stage, increasing the number of containers to six and reduce in the return to untreated row time will reduce the trellising time by 11%. In the harvesting stage, the usage of rails inside the row and uploading the pepper inside the greenhouse will reduce the total working time by 25%.

This research proved the usefulness of applying advanced industrial engineering techniques such as work method analysis and simulation to the improvement of horticultural production and operation management.

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