A DETAILED DESCRIPTION OF THE INTERNAL TRANSPORT SYSTEMS IN POT-PLANT NURSERIES WITH ROLLING CONTAINERS

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Abstract

IMAG-DLO is working on scheduling the flow of rolling containers in pot-plant nurseries. In the initial phase of the project, the internal transport systems of eleven pot-plant nurseries with rolling containers have been described in detail. The objectives were

- to get an impression of the real dimensions of internal transport systems in pot-plant nurseries with rolling containers;
- to discover which methods the managers use for strategic, tactical, and operational planning of internal transport; and
- to make an inventory of the main problems concerning internal transport.

This paper presents the detailed results of this survey.

Key index words

Recording data, Mechanization, Production plan, Scheduling

1. Introduction

The current trend in the production systems of pot-plants is to separate the growing compartments and the processing compartment. A separation calls for an adapted internal transport system, i.e., a system which uses rolling containers. A rolling container is a flat rectangular aluminum box with a limited size, which can hold pot-plants and can be transported through the company. In the growing compartment it is rolled in a row on a supporting framework. A rolling container doubles as both the growing system and the transportation system.

An advantage of this system is that it is possible to use specialized machines for potting, spacing and harvesting. Another advantage is that climatic conditions can be adjusted for the workers, who accomplish most of their tasks in the processing compartment, while the climate remains optimal for the pot-plants in the growing compartments. The main disadvantage of this system is that a spatial separation causes much more internal transport between the growing compartments and the processing compartment.

IMAG-DLO is working on the problem of scheduling the flow of rolling containers in such a system. A simulation model is being developed to test the effects of different kinds of heuristic scheduling rules (Annevelink & Vink, 1994). The optimization of internal transport with iterative improvement methods is also part of the research. In the initial phase of the project, the internal transport systems of eleven pot-plant nurseries with rolling containers have been described in detail. The objectives were

- to get an impression of the real dimensions of internal transport systems in pot-plant nurseries with rolling containers;
- to discover which methods the managers use for strategic, tactical and operational planning of internal transport; and
- to make an inventory of the main problems concerning internal transport.

This paper will present the main results of this survey. Details can be found in the original report (Annevelink & van der Voort, 1995).

2. Method of research

The eleven participating pot-plant nurseries were selected because they are more highly mechanized, and thus are not representative.

The research method consisted of making a single visit to the pot-plant nursery, during which the specific features of the internal transport system were studied, followed by an interview with the manager. A detailed questionnaire was used, which contained questions in the following categories: company, labor, crops, automation, recording, mechanization, internal transport system, strategic planning (organization/layout of the company), tactical planning (production plan), operational planning (scheduling), and main problems.

Some of the questions remained unanswered at some companies. After a visit, a draft report was made and sent to the manager. This gave the manager the opportunity to correct the report and fill in missing data for the unanswered questions.

3. Results

3.1 Company

In this research both small and large companies were visited (Table 1). The total area of the companies varied from 6,300 to 60,000 m^2, distributed over 1-10 growing compartments. A growing compartment is divided into rows, which can hold a certain number of containers. All companies used the rolling container system. The number of rolling containers per row varied from 7 to 113. The total area of container compartments was 5,200-56,000 m^2. The total net growing area on rolling containers was 4,290-48,920 m^2. This gave a high space use in the container compartments of 83-94%, mainly because there were no paths between the rows. Three companies combined the rolling container system with the concrete floor system. The area of the processing compartment was 450-5000 m^2. The processing compartment constituted 4-22% of the total area. The number of pot-plants produced was 0.5-6.5 million per year.

3.2 Labor

The number of workers in the companies varied from 3 to 34, most of whom were fully employed. At most of the companies only a few workers were involved in internal transport, typically one manager and 1-3 other workers.

3.3 Crops

The number of species produced varied from 1 to 25 (Table 2). Both green and flowering pot-plants were grown on the rolling container system. The most commonly used pot sizes were between 8.5 and 17 cm. Both fast growing pot-plants with an average crop duration of less than

13 weeks, and very slow growing pot-plants with an average crop duration of more than 26 weeks, were grown on the rolling container system. A shorter crop duration usually requires more internal transport. The number of growing phases (periods between operations such as potting, spacing and harvesting) was 2 to 5. The length of a growing phase was 2-7 weeks. The pot-plants were respaced 0-4 times. The number of pot-plants per container differed strongly among the companies. Most pot-plants were harvested within a period of 1 to 2 weeks.

3.4 Automation

All companies used a climate computer and a management computer. However, these two types of computers were never directly connected or integrated. Almost all of the companies had and used software to make a connection with the auction, for recording purposes and for tactical planning.

3.5 Recording

Most of the managers recorded data on selling price, costs, space requirements, labor requirements, energy consumption, gross margins, locations, crop protection, crop growth, climate, treatment of orders, and pot-plants in stock. They often used the code number of the crop batch to track all data. All companies had been recording data for at least three years. Five had recorded data for more than eight years. The recorded data were used to understand crop growth and price trends, for internal comparisons, to make and monitor the production plan, and for space allocation and cost price calculations. All the companies used software to process and analyze recorded data.

3.6 Mechanization

All visited managers were enthusiastic users of advanced mechanization techniques. The potting process, the spacing, and the sorting process were mostly mechanized at each company. The harvesting process was less mechanized. This was probably due to the diversity of operations which have to be performed during the harvesting process, and to the complicated visual selection task. Only one of the companies used a newly developed computer vision system for sorting.

3.7 Internal transport system

Most companies used half or fully automatic guided vehicles (AGVs) for the internal transport of rolling containers (Table 3). The number of AGVs was 1-3 per company, and the number of containers which could be transported was 1-6. AGVs were equipped with a special device which automatically recorded data on transport movements and the placement of containers in the growing compartments. These data could be used for scheduling and monitoring internal transport from day to day and from hour to hour. However, in most of the companies, these data were still not recorded properly for use in a management support system.

The maximum transport distance of the AGV's was short (44 m) to much longer (up to 500 m). The total number of containers in the growing compartments was 600-8,428. The size of containers was not standardized. The length tended to be adjusted for greenhouse dimensions. The width of the containers varied less, at 1.56-1.80 m, so that half the width corresponded to the reach of a worker. In the processing compartment, buffers were provided to avoid waiting time. The possible number of containers in the various buffers varied enormously.

A separation between the growing compartments and the processing compartment was found in almost all of the visited companies. Two entry systems to the rows were used in roughly equal numbers: First In First Out (FIFO, see Figure 1) and Last In First Out (LIFO, see Figure 2). Three companies used both systems, but in separate compartments. From the questionnaire results, it cannot be concluded that one of the systems is better.

3.8 Strategic planning: organization/layout of the company

All visited managers were innovators. They continually think about the renewal of their companies. Strategic planning concerning the organization and layout of a company was always done in consultation with the builders and suppliers of systems. During strategic planning, the managers paid special attention to the interaction between mechanization and labor, the budget, space available, container size, crop specifications, project phases, the choice of internal transport system and the choice of mechanization. Objectives of strategic planning included improved Labor and space use, lower costs, and expanding or modernizing the company. Many companies focused on growing one or two species. In theory they can switch between products, but in practice this was very difficult to accomplish.

3.9 Tactical planning: production plan

Estimates of required space and the gross margin are important considerations in constructing a tactical production plan. Five companies used computer software packages for production planning. The main constraints taken into account during planning were available space and labor. The planning horizon was usually 1 year. Most of the companies used planning periods of one week. The number of containers needed for a crop batch (the number of plants started in a given week) often increased dramatically in each phase of growth, with considerable consequences for the amount of internal transport needed for the batch.

A company must assure that the tactical production plan is feasible on the operational level, including internal transport. However, this should not influence the size of the crop batches in the production plan too much, because maximizing the profit should have priority. Many of the visited companies tried to fill complete rows in a growing compartment with the same crop batch to avoid extra internal transport. Thus, the tactical production plan was partly subordinated to the operational planning of internal transport.

3.10 Operational planning: scheduling

Most of the companies did not schedule internal transport daily. They only fixed the transport routes and reserved different destinations for different phases of crop batches: a potting zone, a spacing zone and a harvesting zone. The zone determined the preferred position of the containers in the growing compartments. The borders between the zones could vary during the year. A few companies did record the allocation positions of the containers during internal transport, but they did not schedule these positions or determine the transport route towards them.

Most companies did use 'rules of the thumb' to schedule day-to-day internal transport (Table 4). These 'rules of the thumb' referred to potting process, spacing process, harvesting process, growing process and choice of a row. Different rules applied to FIFO and LIFO systems.

Table 1. Company data.

Company	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Total area (m^2)	60000	35000	31000	30100	29000	26000	22000	16400	14000	7600	6300
# of growing compartments	10	7	2	8	6	6	6	4	2	2	1
Total area container compartments (m^2)	56000	19520	30900	24680	26560	22680	18170	10350	13000	6500	5200
Total growing area (m^2) on containers (%)	48920 87	18320 94	28134 91	22320 90	22720 86	21031 93	15660 86	9020 87	12000 92	5850 90	4290 83
# of containers per row/ # of rows	29/137; 36/113	70/23; 34/26	7/2; 11/4 21/6; 104/26	26/43; 28/36	20/80; 22/80	61/26	53/44	54/18	10/18; 12/24 113/13	13/34; 23/34	34/18
Area processing (m^2) compartment (%)	2360 4	5000 15	2340 8	3870 16	1300 5	2500 11	1700 9	2420 15	1600 12	450 7	1150 22
# plants/year (million)	3.5	2.8	3.0	3.2	1.3	6.5	2.3	0.5	2.6	1.3	0.5

Table 2. Crop data.

Company	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
# of species	11	1	2	2	2	25	1	1	2	10	1
Used pot sizes (cm)	13/17	11/14/15 17/19/21	12	9/12	9/15	8.5/11/17	12	17	12	10,5/14	13
Average crop duration (week)	39-52	18-22	10-18/ 16-26	9	52-60	10-12/ 9-10/13-17/ 20-28/	10	11-12	10-12	8-10/ 8-10/ 16-18	11
# of growing phases	3	3	3	2	2/4	2/ 2/3 /5	3	3	2	2 / 3 /4	3
Crop duration growing phase (Week) 1	9-13	4	3-6/6-8	3	26/13	6 / 4-5/ 5-6/ 4	4	5-6	4-5	4 / 3 /4	4
2	13-17	14-18	3-6/6-8	6	26/13	4-6/ 4-5/ 4-5/ 4	4	3	6-7	4-6/ 3 /4	4
3	17-22	7	3-6/6-8	-	- /17	-/ - / 4-5/4-6	2	2-3	-	-/ 2 /4	3
4	-	-	-	-	- /17	-/ -/ - /4-7	-	-	-	-/ - /4	-
5	-	-	-	-	-	-/ -/ - /4-7	-	-	-	-/ - /-	-
Times spaced	2	0	2/2	1	1/2	1/ 1/ 2/ 4	2	2	1	1/ 2 / 3	2
Plants per container per phase 1	seeds	168-644	700/700	576/522	726/726	1600/1600/ 896/1600	432	240	456	400/250/400	392
2	275	168-644	350/350	576/261	363/363	520/ 676/ 440/ 676	208	105-120	170-194	200/105/170	156
3	153	-	175/175	-	- /180	-/ - / 224/ 306	176	60- 85	-	- / 60/100	107
4	-	-	-	-	- / 95	-/ -/ - / 144		-	-	- / - / 50	-
5	-	-	-	-	-	-/ -/ - / 68		-	-	-	-
Duration harvest from crop batch (week)	4-5	2	1	1/1	3/2	1/ 1/ 3/ 5	1	1	2	1 / 1 / 1	2

Table 3. Internal transport system data.

Company	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
# of automatic guided vehicles capacity	2 6/3	3 2/1/1	0 -	1 1	2 4/4	2 3/1	1 2	1 3	1 1	1 3	0 -
Maximum transport distance automatic guided vehicle (m)	500	185	-	70	160	192	230	144	44	108	-
# containers	8428	2400	2700	2132	2500	1800	2800	1050	2000	1200	600
Length (m) x width (m) of container	3,03x 1,61	4,50x 1,63	6,09x 1,60	6,00x 1,75	3,75x 1,80	6,20x 1,80	4,20x 1,60	5,66x 1,64	3,90x 1,56	3,00x 1,60	4,45x 1,62
Area container (m2)	4,88	7,33	9,74	10,50	6,75	11,16	6,72	9,28	6,08	4,80	7,21
# containers in buffer output potting input spacing/sort. output spacing/sort. input harvesting	 18 6 18 10	 20 15 20 10	 416 11 416 22	 0 - - 11	 20 20 20 20	 24 35 59 34(+97)	 15 25 25 16	 9 35 13 35	 12 30 20 5	 13 13 13 18	 8 19 8 18
Capacity buffer empty containers	252	320	210	126	420	150	270	160	143	120	72
Access to rows	LIFO	FIFO	FIFO	LIFO FIFO	LIFO	LIFO	FIFO	FIFO LIFO	FIFO LIFO	LIFO	FIFO

ad company 1: only the details of the small containers are mentioned in this table

Table 4. "Rules of the thumb" used to schedule day-to-day internal transport.

Category	Rules
potting process	• use the sequence of potting crop batches to influence the sequence in a row • transport containers to the growing compartment as soon as the output buffer of the potting machine is full to prevent waiting • transport containers from the output buffer of the potting machine to the furthest end of the growing compartment (longest transport distance with the highest number of pots per container) • determine the exact destination within the potting zone depending on the type of crop batch
spacing process	• transport the containers that need to be spaced early in the morning to the input buffer of the spacing machine to create empty positions for allocating the containers of the output buffers • FIFO system: allocate containers with flowering pot-plants of the same color in the same rows in the last phase before harvesting
harvesting process	• transport the containers that need to be harvested early in the morning to the input buffer of the spacing machine to create empty positions for allocating the containers of the output buffers • locate the harvesting zone close to the processing compartment (pot-plants close at hand and shortest transport distance with the lowest number of pot-plants per container) • keep the input buffer of the harvesting process filled
growing process	• keep large pot sizes in a separate growing compartment • allocate containers with pot-plants of a certain growing phase only in qualified rows, with the required nutrient, water, and light conditions • transport containers temporarily to other rows if they need to stand underneath artificial light (lamps)
choice of row	• keep containers of a crop batch together (in one row), without containers of other crop batches in between them • fill a complete row with one crop batch • use empty positions which are created on a daily basis for reorganizing the sequence of containers • reserve a special zone for each phase of the crop batch • FIFO system: use a special row with a high throughput speed for containers with residues (pot-plants which are not ready to be harvested) • LIFO system: avoid allocating containers in a row where the containers behind them have to be transported within a little while

3.11 Main problems

The difficulty of strategic planning of the organization/layout of the company was mentioned. Often it was not possible to have accurate data in advance and to foresee all situations. Some managers think a management support system could improve the strategic planning process.

One company was interested in a scheduling system for daily internal transport, because the AGV was occupied for too much time each day to reorganize the sequence of containers in rows.

The integration of the different planning levels (strategic, tactical, and operational) was also mentioned as a difficult problem. It was considered a difficult problem to schedule the sequence of all of the different operations.

The problem of the lack of uniformity of crop batches was especially apparent with flowering pot-plants. Often the pot-plants on a container did not all flower at the same time, and transport of the residues (pot-plants which are not ready to be harvested) back into the growing compartments disturbed the original plan.

4. Discussion

The aim of this research was not a comparison of the visited companies. It only sought to describe and analyze them individually. It is not possible to judge the quality of a certain way of working or the planning process of one company in comparison to another company, because the companies are so dissimilar that another research method is needed. Because the chosen companies are innovators, they are also not representative.

The questionnaire was proven to be a good instrument during this research, although the interpretation of certain terms or concepts was sometimes a problem. Formal definitions were not given during the interviews, so the managers may have used their own interpretations of some terminology. Another problem was the great length of the questionnaire, which made it impossible to deal with all of the questions at all of the companies.

In spite of these remarks, the description of the companies in this article does match the objectives mentioned in Paragraph 1. With this approach it was possible to describe in great detail the individual transport systems of the eleven companies and the way they were managed on all of the three planning levels.

5. Conclusions

Most of the data were not detailed enough to support the operational planning of internal transport. Research will therefore be needed to determine which data are necessary and how to record them efficiently. The recorded data of these pot-plant nurseries are hardly ever compared with other pot-plant nurseries in practice.

Automatic Guided Vehicles are equipped with a special device which can record data automatically about transport movements, and then be used for scheduling and monitoring internal transport. However, in most of the companies, these data are still recorded insufficiently for use by any kind of management support system.

Some of the visited companies give priority to filling complete rows in the growing compartment with the same crop batch to avoid extra internal transport. In such a case the tactical production plan is partly subordinated to the operational planning of internal transport.

The "rules of the thumb" are a common practice in scheduling daily internal transport. Therefore IMAG-DLO is working on a simulation model to test the effects of different kinds of rules (Annevelink & Vink, 1994) and on the optimization of internal transport with iterative improvement methods.

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