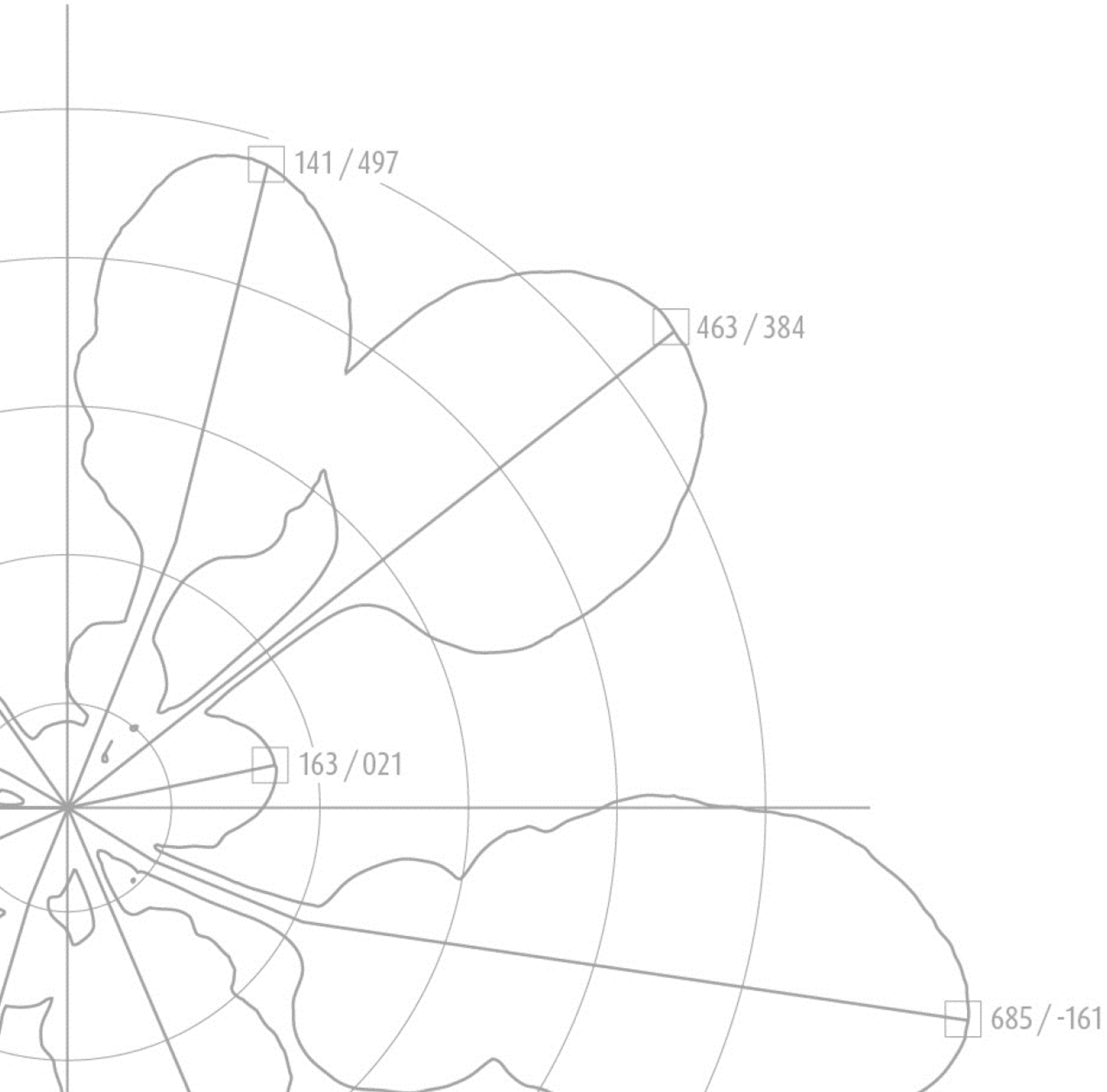
LemnaTec

» MovingField

The Moving Field Concept

for LemnaTec Greenhouse Management Systems



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Introduction

Most plant breeding finally leads to plant cultivation in a field. The better and the more realistic the growth conditions in greenhouses can simulate the field conditions, the more relevant these greenhouse tests will be, minimising the risk of selecting plants merely for greenhouse phenotype artefacts instead of agriculturally important traits.
The following text illustrates how specific LemnaTec conveyor systems can maximise plant density in greenhouses, both to generate a larger number of field-like phenotypes or measurements and to increase efficiency by making the most of the available space.

Why is field density in greenhouses important?

Greenhouse studies allow scientists to eliminate or at least reduce the influences of external, uncontrollable environmental parameters such as temperature, illumination, humidity and watering on their test objects. A controlled environment provides the opportunity to determine and change growth conditions at specific points in time during an experiment, thus exposing plants for example to stress situations in decisive growth development periods, e. g. during flowering. In this way, relatively homogeneous but less controllable growing conditions on a field plot are substituted by closely defined conditions inside a greenhouse. If plants are handled continuously on conveyor belts, randomisation as well as defined and recorded watering procedures ensure a high degree of homogeneity within treatment groups, which would otherwise often be lower than under field conditions. In addition, each plant can be completely quantified in its phenotypic development and individual use of resources.

Figure 1: Field corn plant (left, with almost straight leaves) versus greenhouse plant (right, with massively bent leaves and much wider stature).

Nevertheless, one significant challenge to any greenhouse experiment is the attainable plant density, which is frequently far lower than in the field.

While almost unlimited access to resources such as light, water and nutrients may be one way to identify genetic expressions in the phenotype, exposing plants to realistic competitive situations close to those in the field could also help to identify specific plants fast and efficiently, if breeding is the aim of the studies.

Figure 1 shows an example of the general leaf angle structure in greenhouse corn plants (where a defined angle is almost impossible to measure due to the curvature), while field plants usually have straight, upward leaves due to the light competition in rows with around 60 cm distance.

Field densities of corn plants in relation to plant sizes

Corn plants with a height of about 2 m may often have a maximum width of 80 cm with the regular field line distance of 60 cm. As a result, leaves have an overlap of 20 cm (see sketch below). This overlap may even occur with shorter plants such as cereals when the conveyor lines are very compact. Overlap should generally be taken into consideration and tested under realistic conditions.

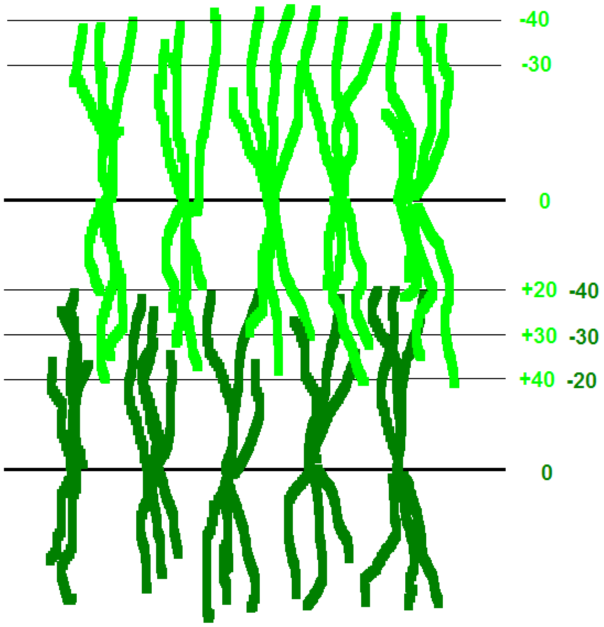

Figure 2: Schematic sketch of corn plants from top, showing line width in the field and plant width as measured in a field with plants of about 2 m height. The distances between sowing lines in the field are 60 cm, plants have a width of around 80 cm, leading to an overlap of around 20 cm on each side (data taken from field conditions). The degree of overlap may vary between different cultivars.

Technical conveyor distances between lines

Table 1 shows the minimum technical distances required between two neighbouring conveyor belts. Those layouts where plants change orientation when turning around corners are called Standard. These modules provide the greatest flexibility for any layout design, but they do need certain distances between the belts if the plants on each belt should be moved independently. Only some minor overlap is acceptable if plants are not to damage each other. The Standard layout refers to a normal ladder scheme in 99:1 or 50:50. Double Standard has the same layout, but all 6 m conveyor belts are separated into two belt units (using one motor) to maximise the load per pallet. In some cases this may slightly reduce the number of pallets per unit.

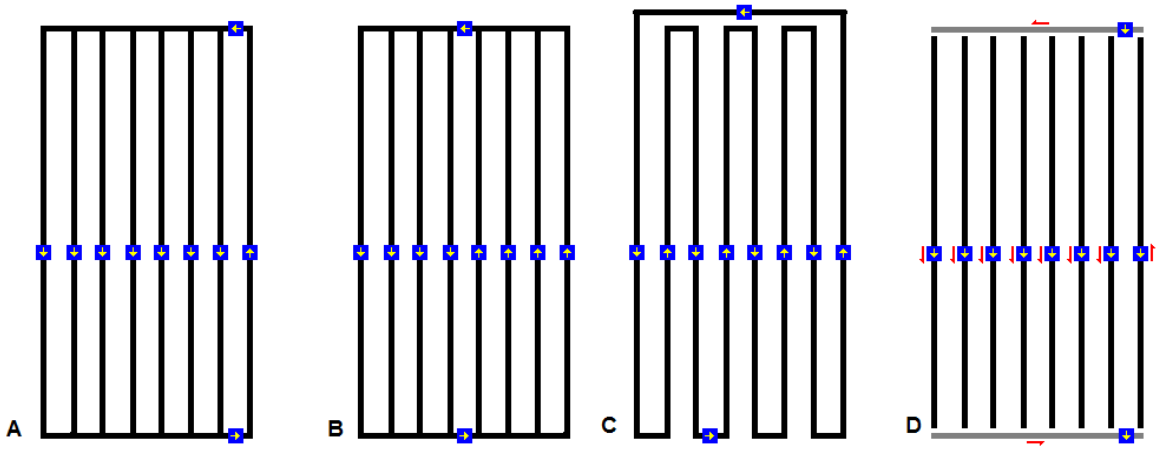

Figure 3: A. Standard layout 99:1; B. Standard layout 50:50; C. Standard Snake Movement layout and D. Heavy-Duty layout. Arrows on the pallets (symbolised in blue) signify both transportation direction and plant orientation except for D, where plants always keep orientation. Red arrows show how plants are transported on (black) conveyor lines or on a (grey) shuttle line.

The Snake Movement layout can generate quite high plant densities, but any plant overlap could inflict damage due to the constantly reversing movement of the neighbouring belts. Therefore plant overhang must be carefully controlled if plants grow at maximum density.

For big pots with a high pot weight, the Heavy-Duty concept can be employed. Here the lines may almost touch and plants do not change orientation when changing the direction at complex corner units or with shuttle cars.

Table 1: Conveyor belt and car parameters

Conveyor belt width in mm	Layout concept	Minimum conveyor belt distance (mm)	Standard car format (length*width in mm)	Max. band length (mm)/usable band length (mm)/total weight per band unit/ pallet per belt	Max. weight per standard car (car + pot) at max. length belt (kg)
100	Standard	215	160*100	3000/2500	1
100	Snake	180	160*100	3000/2500/25	1
200	Standard	440	200*200	6000/5200/26	4
200	Standard double	440	200*200	6000/4800/24	10
300	Standard	620	300*300	6000/5100	5.8
300	Standard double	620	300*300	6000/5100	11.6
400	Standard	840	400*400	6000/5200	7.7
400	Standard	840	400*400	6000/5200	15.4
400-500 (flexible)	Heavy-Duty	450–550	400*400 500*500		30

The cars are generally as long as the conveyor is wide. Where necessary, the cars can be wider and longer by approximately factor two, if they are rounded instead of square to avoid jams in corners. This provides some flexibility to use bigger and wider pots than the width of the conveyor belt would normally allow. Nevertheless, it should be considered that the total weight of pots (+ cars) to be put on each motorised unit is limited, meaning that higher pot weights will automatically lead to more and shorter motorised units (see example for 200 mm conveyor in table 1).
All values shown here are only first estimates and need a detailed check before the final test as they may also be liable to technical changes.

Plant distances within lines

As described above, the format of cars and pots is subject to restrictions. In cases where the distances for plants within a line may be much shorter than the technically available pot/car length, planting more than one plant per pot should be considered, as long as there is sufficient soil for the root systems. Of course imaging would equally include more than one plant at a time. However, more realistic growths conditions and higher replicate numbers are a compensation for the fact that it is not possible to monitor each plant separately. This makes sense as long as plant replicates are not significantly different, e. g. for crossing experiments. To avoid root interaction, separate pots can be positioned on one car by applying bottom watering.

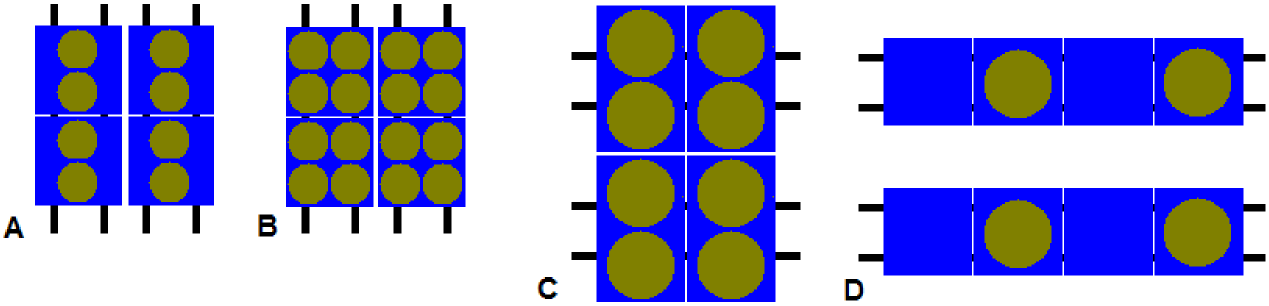

Figure 4: Plant density options in pots with multiple plants or plant arrays with multiple pots per tray. A: 2 pots in one line to maximise density within a line; B: 4 or more pots per car as single pots or trays. If trays with more than 2 plants are used, analysis is preferably done only from the top. Each plant can be named and analysed individually, even in cases of large numbers per tray. Overlap between plants must be either minimised, e. g. by planting in the centre of pots, or accepted as an intrinsic parameter of the experiment; C: 2 pots side by side to maximise plant density and number of plant lines, using pots wider than the belts; D: If plants or trays are longer than one standard car, every 2nd car may be left empty to prevent large plants from damaging each other.

The concept of multiple plants per car would be interesting e. g. for cereal plants and corn plants as well as for “Arabidopsis”-like rosette-forming plants, where plant densities need to be maximised.

Managing overlap without leaf destruction

The key issue for high density plant growth with virtually field intensity is the management of overlap between plants. Under field conditions plant leaves may touch occasionally, but on the whole they avoid each other. Under greenhouse conveyor belt conditions overlapping plants easily damage or destroy each other if one belt moves while the other one is standing still.

To avoid damage, the LemnaTec Moving Field concept combines specific conveyor layouts with the First Plant Systematic concept. The conveyor layout is in most cases a 99:1-layout, but the front stoppers are – particularly for corn plants – nested to provide maximum leave space for the plants and minimum friction when they are taken out of the row.

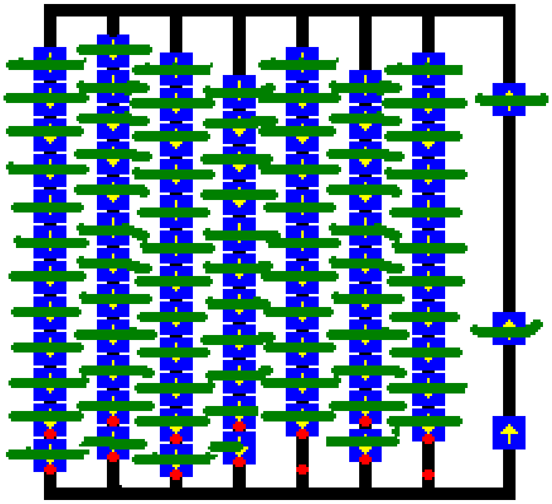

Figure 5: Moving field design for a 99:1-layout. Two stoppers (red dots) and an alternating positioning of the rows ensure minimum overlap and damage of the leaves. By always moving the first row out first (every 2nd plant and then taking the alternating row somewhat behind), mechanical stress for the leaves is minimised. Filling of the lanes is done in the opposite way, always filling the more empty lanes first. The back-lane has a larger clearance to avoid any mechanical damages.

To avoid shearing of the first row, plants are taken out of the rows in a predefined sequence, taking the plant nearest to the connection belt out first. Only when all plants of this first row have been taken out, all belts are then started simultaneously, thus moving the whole greenhouse forward almost in parallel. Retardations of far less than a second between the lines are used to minimise mechanical impacts on the system in total. This concept requires a good electrical power supply as it needs many motor units to be run at the same time.
It is feasible with all layouts except for the Snake Movement layout.

Background colour

As plants react not only to light intensity and direction, the light quality from bottom and side may also be important to suggest competitive situations. The key information is – at least for corn – encoded in the higher intensity of very near infrared light (700–800 nm) in relation to normal visible light (for details check literature on shade avoidance). To imitate this competitive situation in the greenhouse, the area between the belts can be laid with plates showing the specific colour characteristics which allow them to absorb more visible light than very near infrared light. To minimise border effects, plates of a similar colour may be placed along the outside conveyor belts, thus simulating neighbouring plants.

Conclusion

The LemnaTec Moving Field concept combines controlled greenhouse conditions with randomisation methods to minimise differences in growth conditions and achieve virtually field density of plants. In contrast to any field experiment, each plant (or in any case very small plant groups) may be monitored individually through weighing, watering and imaging, while at the same time generating growth phenotypes relatively close to those originating from field conditions.

For any questions or development of customised solutions tailored to your particular needs, please contact LemnaTec.

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