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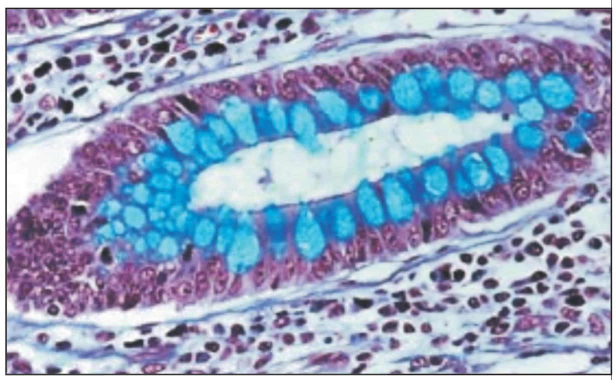

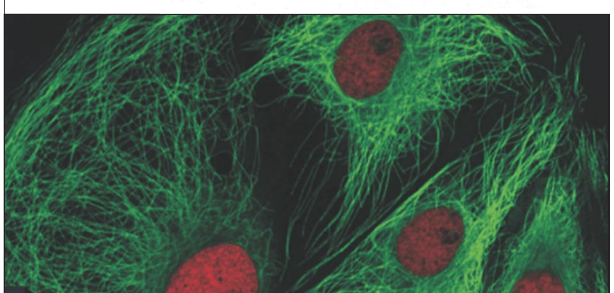

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Production Systems

Designing lavender plantations in relation to the mechanized harvesting of lavender blossom

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Abstract. *For the efficient use of lavender harvesting aggregates and transportation vehicles it is necessary as early as with the designing of the lavender plantation to take into account their parameters. Two approaches have been considered in designing new lavender plantations: use of minimum number of transportation vehicles in the field and forming a minimum number of intermediary roads for unloading. The first approach means small length of sections which the field is divided into in order to fill the machine hopper in two goes. That allows unloading of the hopper on one end of the section only and needs one transportation vehicle. With the second approach sections are of greater length. Unloading is done at both ends of the section and two waiting transportation vehicles are needed, but the number of intermediary roads is smaller and agricultural land is used more efficiently. Correlations have been found for defining the number and length of sections which the field has to be divided into when establishing the lavender plantation. A method has been identified for defining the kinematic length and width of various lavender harvesting aggregates – symmetric and non-symmetric, correlations for defining the length of various turns performed by aggregates, as well as the width of stripes for the turning of aggregates at the end of sections on the field.*

Keywords: designing lavender plantation, mechanized harvesting technologies, length of turn, width of turning stripe

Introduction

When a perennial plantation is started such as the lavender plantation, a number of requirements need to be observed. Currently a basic requirement is the mechanization of all processes in growing and harvesting lavender. With regard to the organization on the field when new plantations are started the most problematic issue is to take into consideration mechanized harvesting technologies. In recent years the use of harvesting machinery has expanded in older plantations as well where disadvantages of non-compliance of plantation parameters with the parameters of lavender harvesting machinery could be best observed. The following problems arise:

- Narrow reversion stripes at the end of the field not complying with the opportunities for manoeuvres of lavender harvesting machines.
- Non-compliance of the length of field plots with the capacity of harvesting machine hopper resulting in filling up the hopper before the end of the plot.
- Locations for unloading are inefficiently allocated which results in the use of greater number of waiting vehicles or extra manoeuvres of vehicles.
- The number of plots into which the field has been subdivided is very big (great number of intermediary roads), resulting in inefficient utilization of agricultural land.

Harvesting time is usually limited not only by the short blossoming period but by unfavourable climatic conditions as well. Because of that it is necessary to utilize to the maximum the capacities of the harvesting machinery which can be achieved only with well designed plantation. Lavender harvesting machines are either self-propelled or mounted (Delchev and Trendafilov, 2003). Self-propelled machines can be with one and two rows (very rarely with more rows) with a header in the front. Mounted machines are usually with one row with a header on the side of the tractor. Machines differ in their kinematic parameters as well and each of them has different optimum mode of movement on the field. All that means that with field organization, i.e. when defining the length of plots, the width of turning stripes, the mode of movement of the unit and locations for unloading we have to take into consideration the parameters of the specific harvesting machine.

The objective of the present study is according to parameters and mode of movement of lavender harvesting units to construct relationships for defining the number and length of plots which the lavender plantation is divided into. These relationships shall be used in determining the number and location of intermediary roads in relation to minimizing the number of vehicles waiting and less losses of arable land.

Material and methods

In designing the field the following limitations have been taken into account:

– minimum width of turning stripe – in relation to maximum utilization of arable land;

– minimum length of the turn of the harvesting unit – in relation to achieving maximum productivity;

– minimum number of intermediary roads used for unloading – in relation to maximum utilization of arable land;

– minimum number of vehicles waiting – in relation to reducing transportation costs. The greater part of vehicles wait for being filled up (they are idle), and at this season they are badly needed for harvesting other crops;

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– maximum yield – in relation to the fact that the yield from the same variety of lavender grown at the same place with the same technology varies with years.

The way covered by the machine to fill in the hopper *S* has been determined according to the hopper volume, the volume weight of the harvested blossom, the yield per hectare and the operation width of the unit. The study deals with self-propelled and mounted lavender harvesting machinery with individual hopper and also self-propelled and mounted machinery with a trailer attached. The latter are used most frequently when the stuff is chopped and gathered in containers in which boiling takes place as well. Containers are transported onto the trailer or a trailer-container is used.

Lavender harvesting machines have the following ways of movement:

- for a header located in front – shuttle- or bed-like with stretched turns;
- for a header located on the side – bed-like with stretched turns.

For these ways of movement the length of turn and the width of turning stripe (Svirshtevski 1953, Levi 1975, Kolev 1999), kinematic unit length l_a (Figure 1) and kinematic unit width *B* (Figure 2) have been specified.

Results and discussion

1. Determining the way S covered by the machine to fill up the hopper (trailer) depending on its volume.

$$S=\frac{10000.V_h.p}{D.B_w},m \qquad (1)$$

where *S* is the way covered by the machine to fill up the hopper (trailer), m;

V_h – machine hopper volume, m^3;

ρ – volume weight of harvested blossom, kg/m^3;

D – maximum yield per hectare, kg/ha;

B_W – operation width of the unit, m.

With the accepted maximum yield the hopper for the lavender harvesting machine won't be filled before the end of the row. In case of less yield the machine will come out to the unloading area with partially filled hopper. In both cases productivity in hectares per hour,

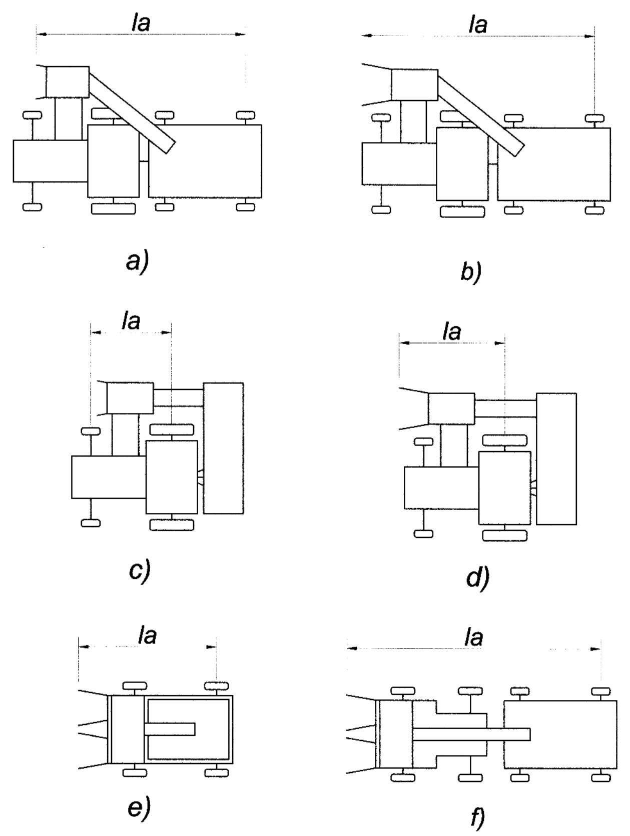


Figure 1. Diagram for determining the kinematic length of units for harvesting lavender blossom. a – lateral mounted machine with a header behind the front axle and a trailer for collecting the blossom, b – lateral mounted machine with a header in front of the front axle and a trailer for collecting the blossom, c – lateral mounted machine with a header behind the front axle and a hopper for collecting the blossom, d – lateral mounted machine with a header in front of the front axle and a hopper for collecting the blossom, e – self-propelled machine with hopper for collecting the blossom, f – self-propelled machine with a trailer for collecting the blossom.

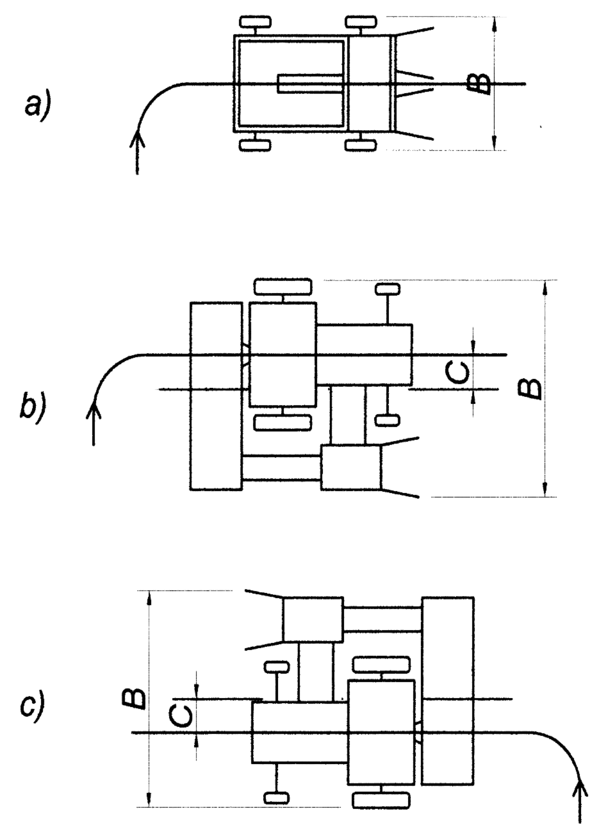


Figure 2. Diagram for determining the kinematic width of lavender harvesting units. a – symmetric unit, b – non-symmetric unit when performing right turn, c – non-symmetric unit when performing left turn.

per shift, per day and per season will be the same. Only productivity in tons will differ. In case of less yield planned, the hopper will be filled before reaching the unloading area and the lavender harvesting machine will have to return to harvest the rest of the row which will significantly reduce its productivity.

2. Determining the width of stripe for turning of the unit

The width of stripe for turning and the length of turn shall be defined by the generally accepted correlation given in Table 1. The designations in the table are as follows:

l_T – length of turn;

R_{min} – minimum radius of turn of the unit;

X – distance between two consecutive moves of the unit;

l_a – kinematic length of unit;

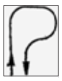
E – width of stripe for turning;

B – kinematic width of unit;

C – distance between longitudinal axis of the power device (tractor) and the longitudinal axis of the unit.

In determining those parameters it is extremely important to define kinematic length and width of unit appropriately. For that purpose possible kinematic diagrams of lavender harvesting units are presented on Figures 1 and 2 and their kinematic widths and lengths are given. It is evident from Figure 1, and in practice, that the unit length is greater when blossom is gathered in a trailer or a container-trailer. These units will require great width of the turning stripe and also the length of turns will be greater. The advantage of these units is that when the trailer is filled, it is attached directly to the transporting tractor, no re-loading is done and transportation costs are reduced (transportation is optimized).

Table 1. Length of turn and width of stripe for turning in various types of turns performed by lavender harvesting units.

Type of turn	Shape	Length of turn	Width of stripe for turning
Pear-shaped symmetrical		$l_T = 3{,}14R_{\min}\ 3\quad \frac{1}{45}\arcsin\frac{X+2R_{\min}}{4R_{\min}}\quad + 2l_a$	$E = \frac{1}{2}\sqrt{12R_{\min}^2\quad 4R_{\min}X\quad X^2} + R_{\min} + 0{,}5B \pm C + l_a$
Pear-shaped non-symmetrical		$l_T = 8{,}28R_{\min} + X + 2l_a$	$E = 3R_{\min} + 0{,}5B \pm C + l_a$
Eight-shaped		$l_T = 7{,}42R_{\min} + X + 2l_a$	$E = 3R_{\min} + 0{,}5B \pm C + l_a$
Eight-shaped with lateral moving out		$l_T = 8{,}28R_{\min} + X + 2l_a$	$E = 3R_{\min} + 0{,}5B \pm C + l_a$
Mushroom-shaped open		$l_T = 5{,}14R_{\min} + X + 2l_a$	$E = R_{\min} + 0{,}5B \pm C + l_a$
Mushroom-shaped closed		$l_T = 5{,}14R_{\min}\quad X + 2l_a$	$E = R_{\min} + 0{,}5B \pm C + l_a$
Non-symmetric with rear move		$l_T = 5{,}14R_{\min} + X + 2l_a$	$E = 2R_{\min} + 2l_a$
Double		$l_T = 13{,}42R_{\min} + X + 2l_a$	$E = 2R_{\min} + 0{,}5B \pm C + l_a$
Along semicircle		$l_T = 3{,}14R_{\min} + 2l_a$	$E = R_{\min} + 0{,}5B \pm C + l_a$
Stretched		$l_T = 1{,}14R_{\min} + X + 2l_a$	$E = R_{\min} + 0{,}5B \pm C + l_a$

Mounted units that are most frequently non-symmetric have the widest application. It is evident on Figure 2 that when defining the turning stripe the direction of turn of the unit has to be taken into account. In case of non-symmetric units the longitudinal axis of the tractor and the longitudinal axis of the unit do not coincide. They are at distance C. When defining the width of the turning stripe by using the correlations in Table 1, the parameter C has a „+" sign when the mounted machinery is on the outer side of the turn and a „–" sign when the machine is on the inner side of the turn. In case of symmetric units $C=0$. For more efficient utilization of the field area turns shall be selected so that the width of the turning stripe should be minimum and the length of turn is also minimum, respectively.

The latter is a prerequisite for higher production and less costs.

3. Determining the length and number of sections which the field shall be divided into.

With minimum waiting transportation vehicles (Figure 3).

In this case the length of field sections shall allow for unloading to be done at one location only (at the same turning stripe) in order to use only one vehicle. In this case the following condition shall be valid

$$L_y = \frac{S}{n_x} \tag{2}$$

where L_y is the length of one field section, m;

n_x – the number of moves to fill the hopper (trailer). In this case $n_x=2$.

That condition can be expressed as $L_y=0,5S$.

To define the number of plots the following inequality shall be used

$$L_f \leq n.L_y + (n + 1) E \tag{3}$$

where L_f shall be the length of lavender field;

n – the number of plots which the field is divided into.

Respectively, the number of plots shall be determined by the formula

$$n \geq \frac{L_f - E}{L_y + E} = \frac{L_f - E}{0{,}5S + E} \tag{4}$$

The result obtained is rounded up to the greater integer. The last field with length L_x will always have length smaller than *0,5S*. When lavender is harvested from that field a full hopper will not be unloaded. If $L_x < 0{,}25\,S$ unloading has to be done after each 4 moves in order to unload with maximum full hopper and not diminish productivity.

The Figure 3 shows that for the specific case the field has been divided into four plots and one of them is with smaller length. A total of 5 stripes are used for turning and in harvest of each plot the adjoining stripe is used for turning of the unit and the other one – for turning and unloading.

With minimum number of intermediary roads used for unloading (Figure 4)

In this case the condition is $L_y=S$, i.e. the bunker will be filled for 1 move and there must be two unloading vehicles at the end stripes

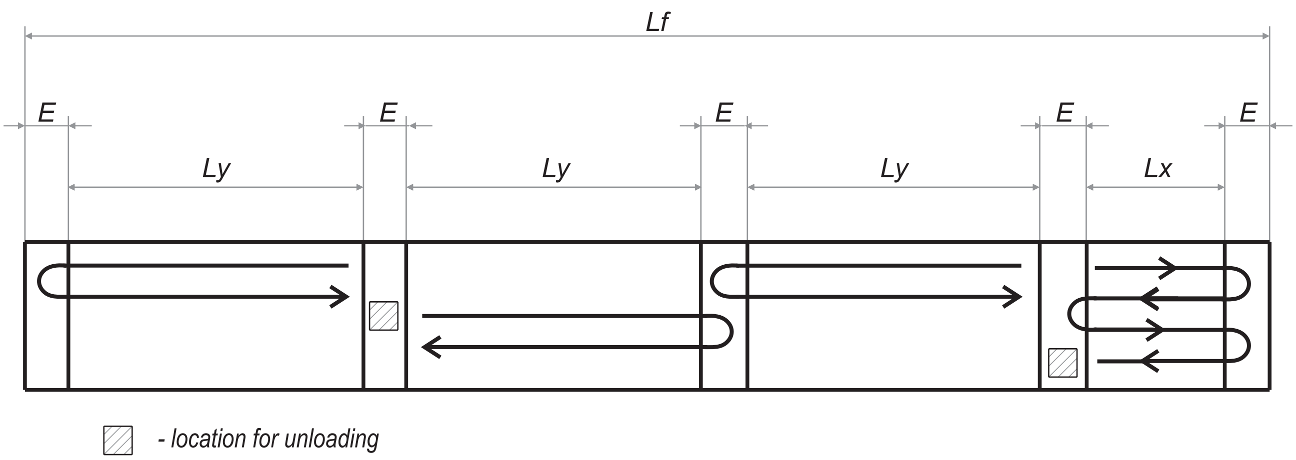


Figure 3. Field organization diagram with minimum number of waiting vehicles.

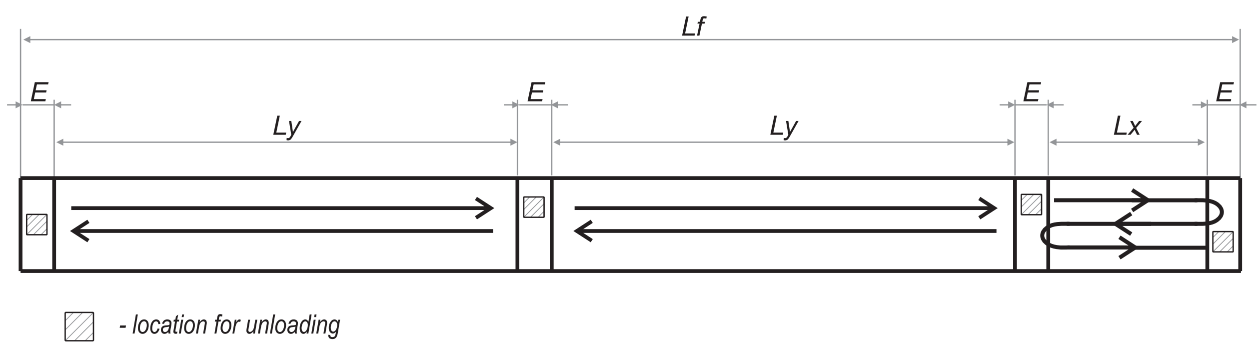


Figure 4. Field organization diagram with minimum number of intermediary roads used for unloading.

of the harvested plot. The number of fields shall be determined by the expression

$$n \geq \frac{L_f - E}{L_y + E} = \frac{L_f - E}{S + E} \quad (5)$$

The last field with length L_x will always have length smaller than S. When the length of the last field $0,5S<L_x<S$, unloading will also be after one move with half-filled hopper and two waiting unloading vehicles are used. Respectively, if:

$0,33S<L_x<0,5S$ – two moves, one waiting vehicle;

$0,25S<L_x<0,33S$ – three moves, two waiting vehicles;

$L_x<0,25S$ – four moves, one waiting vehicle, etc.

The Figure 4 shows that for the specific example the field has been divided into three plots, one of which has smaller length. A total of 4 stripes are used for turning and in harvest of each plot there must be a waiting unloading vehicle on both adjoining stripes since they are used for turning and unloading.

It is evident that there are two approaches for designing lavender plantations: using minimum number of waiting vehicles and forming minimum number of intermediary roads for unloading. The choice of both approaches should be economically substantiated for each specific case according to area, length of field, yield, parameters of the harvesting unit, parameters of the transportation unit, distance for transport, fuel price, labour cost, etc.

When the station for collecting the produce is far from the field, it is advisable the designing of the lavender plantation to be made on the basis of minimum number of waiting vehicles since in that season some of the vehicles are busy with other agricultural operations.

Conclusion

The design of a new lavender plantation has to conform to the technology of mechanized harvesting. Two approaches are possible: use of minimum number of waiting vehicles and formation of minimum number of intermediary roads for unloading. Correlations have been produced on the basis of which the length and number of field plots in both approaches for designing lavender plantations have been defined to guarantee efficient use of harvesting machinery. When determining the width of the turning stripe the parameter *C* – distance between longitudinal axis of the power device and longitudinal axis of the unit shall be used when harvesting is by a non-symmetric unit.

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