

# H-SELECT Nozzle Watch

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## Introduction

Nozzle Watch is an nozzle selection and optimization tool for the users of H-Select. The tool has the following capabilities,

- ❖ It allows the user to select a set of nozzles and define an **objective range**
- ❖ It allows the user to understand,
  - a. the **feasibility** of his selected nozzles for the objective range
  - b. the **efficiency** of his selected nozzles for the objective range when using H-Select
- ❖ It determines an **optimal set of nozzles** for the objective range when using H-Select

The efficiency of the selected nozzles is expressed as a single number called the **performance** of the nozzles.

The tool works with both metric units and Imperial/US units and is available in three languages, French, English and German.

## **Introduction: objective range**

Typically, a user chooses nozzles for a *range* of spraying requirements rather than a fixed one. For instance, he may wish to apply different products at different nozzle pressures (different droplet sizes). Or, he may have to deal with a natural variation in the sprayer speed. In either case, a variation in application rate occurs.

So, the user's choice of nozzles must be evaluated over a range of application rates or over a range of sprayer speeds that he can specify. We term such a range an *objective range*.

The three quantities, application rate, sprayer speed and nozzle pressure are related by a simple linear function, so that by varying any one quantity, we can make the other quantities vary as well.

Using this principle, the tool allows the user to specify:

1. A nozzle pressure range and a sprayer speed OR
2. A nozzle pressure range and an application rate

For the user's choice of nozzles, in the first case, an *objective application rate range* is obtained as the objective range, and in the second case an *objective sprayer speed range* is obtained as the objective range.

## **Feasibility**

Given the user's choice of nozzles and objective range, the tool produces a graph called the *working graph* which tells the user, for each combination of his nozzles,

- what application rate range is tolerated
- what sprayer speed range is tolerated

Thus, the user can ascertain if his choice of nozzles is feasible as regards his objective range. For example, he can see which combinations of nozzles fall outside the objective range.

## Introduction: efficiency

Apart from feasibility, the user may want to know the *efficiency* of his choice of nozzles. A purpose of choosing the right nozzles is to be able to spray droplets of the required size at the required application rate.

This tool determines the efficiency of the chosen nozzles, when H-Select is used, to spray droplets of the required size, over the objective range, expressing it as a single number called the performance.

**Performance:** We define the performance of a set of nozzles to be the *percentage of the objective range in which the nozzles spray droplets of the required size when using H-Select.*

This simple measure gives the user a good idea about whether his nozzles are capable of meeting the spraying requirement.

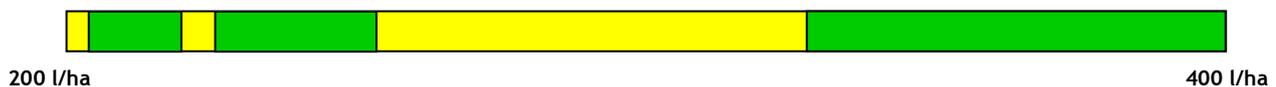
**Example:** Given the conditions,

- (1) the nozzle pressure range is 2 to 4 bar,
- (2) sprayer speed is 8 km/h,
- (3) required droplet size is 'medium',
- (4) nozzle spacing is 50 cm
- (5) objective application rate range is 200 l/ha to 400 l/ha,

the set of ISO nozzles {025, 03, 035, 04} gives a performance of 60%.

This means that during spraying with Vario Select, at any time  $t$ , given conditions (1) to (4), IF the application rate is found to be between 200 l/ha and 400 l/ha, in 60% of this range, medium sized droplets will be sprayed.

Note that the performance is not typically in a continuous block within the objective range; it is distributed over the range. For example, the 60% is distributed approximately as follows (in green):



In the yellow zones, the nozzle pressure would not be appropriate for spraying droplets of the required size.

## Introduction: Optimization

The measure of efficiency allows us to introduce a notion of optimality in choosing nozzles:

**Optimal nozzle set:** For a given objective range, we define an optimal set of  $n$  nozzles (where  $n = 1, 2, 3$  or  $4$ ) to be a set of  $n$  nozzles with the *highest performance*.

The tool has an inbuilt optimizer that is capable of rapidly determining the optimal nozzle set for the user-specified objective range. This enables the user to compare the performance of his nozzle set with an optimal set. The user can thereby correct their choice if required.

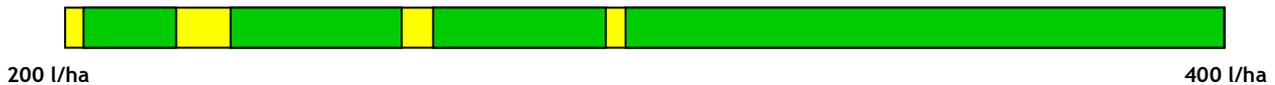
(Not that the performance of an optimal nozzle set need not be 100% for the given objective range.)

**Example** (same as the previous page): Given the conditions,

- (1) the nozzle pressure range is 2 to 4 bar,
- (2) sprayer speed is 8 km/h,
- (3) required droplet size is 'medium',
- (4) nozzle spacing is 50 cm
- (5) objective application rate range is 200 l/ha to 400 l/ha,

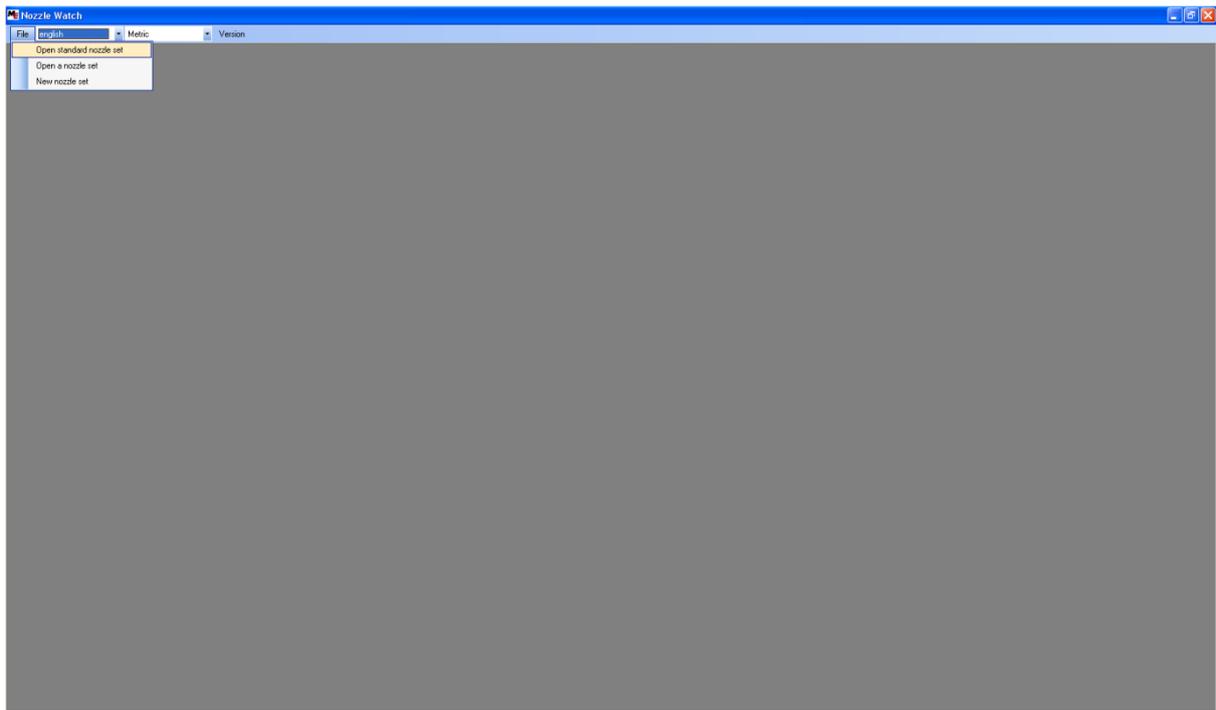
The set of ISO nozzles {015, 02, 025, 03} gives a performance of 86% and it is the optimal set for these conditions.

The 86% is distributed approximately as follows:

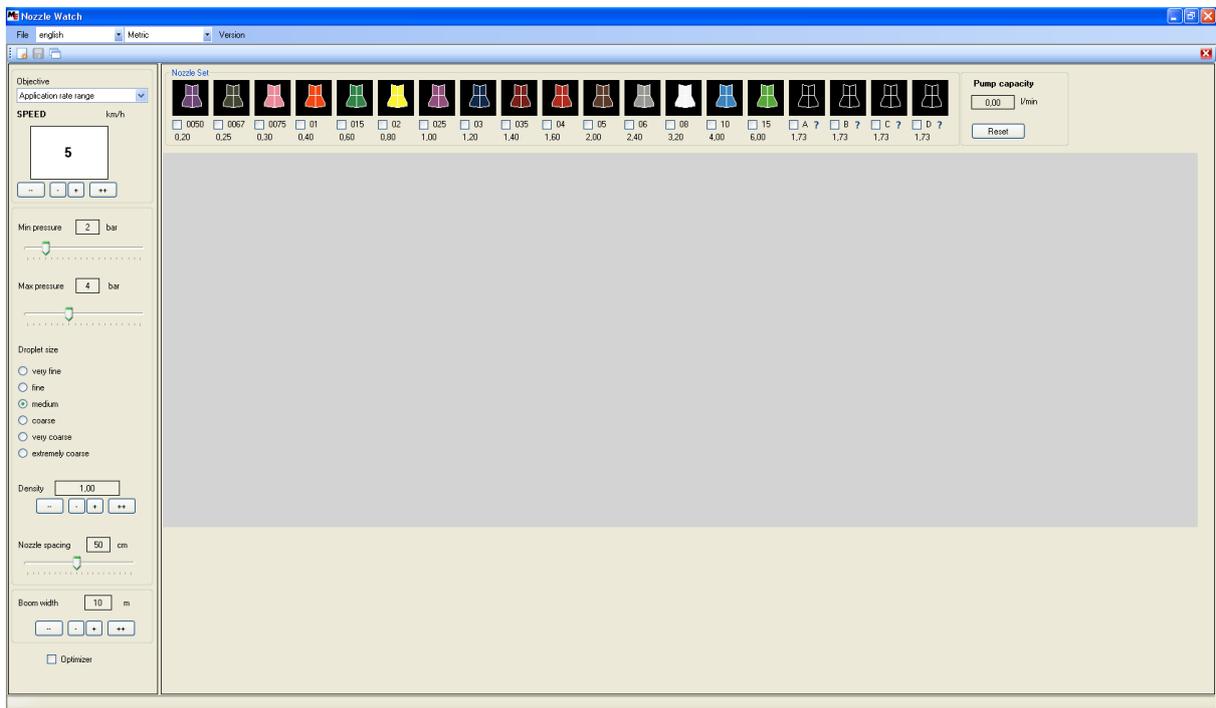


These nozzles cover the objective range more fully than any other set of 4 nozzles.

Click File -> Open standard nozzle set



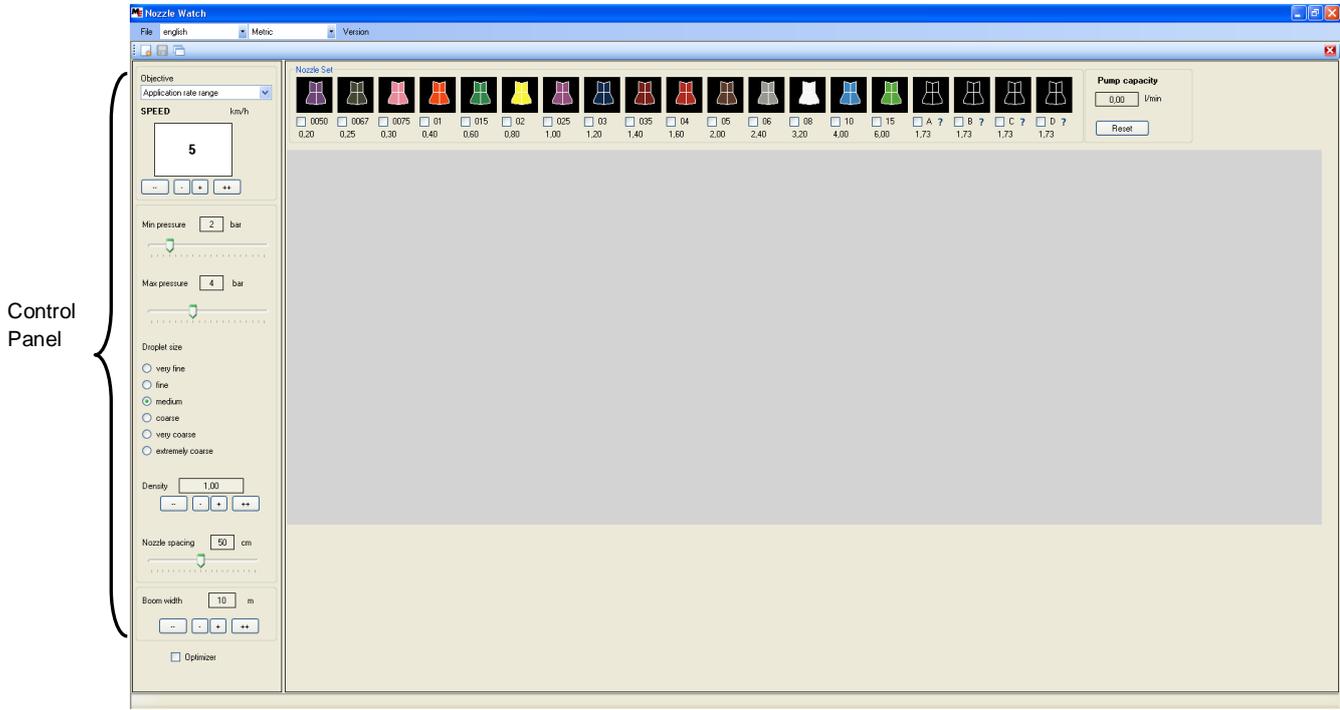
The standard nozzle set consisting of 15 ISO nozzles and 4 non-ISO nozzles is loaded.



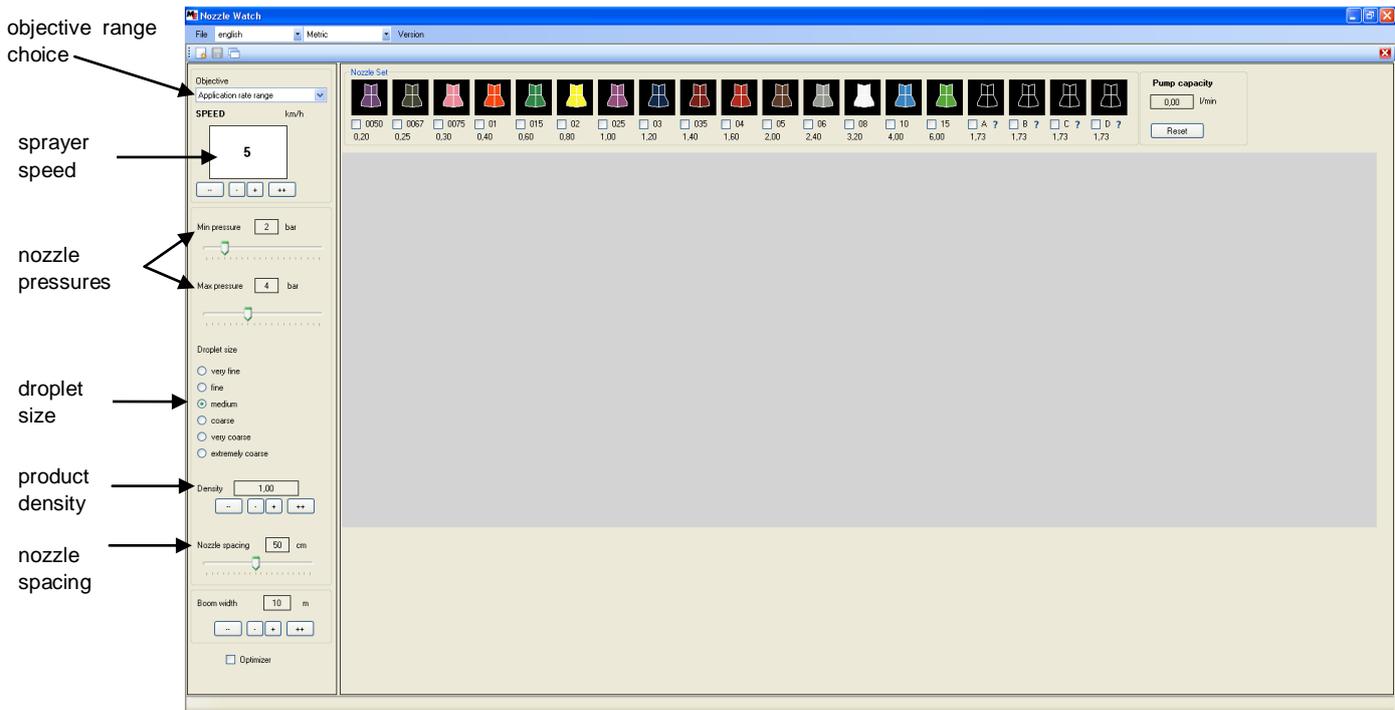
Below each nozzle, its flow (in l/min at 3 bars) displayed.

## Specifying the Objective Range

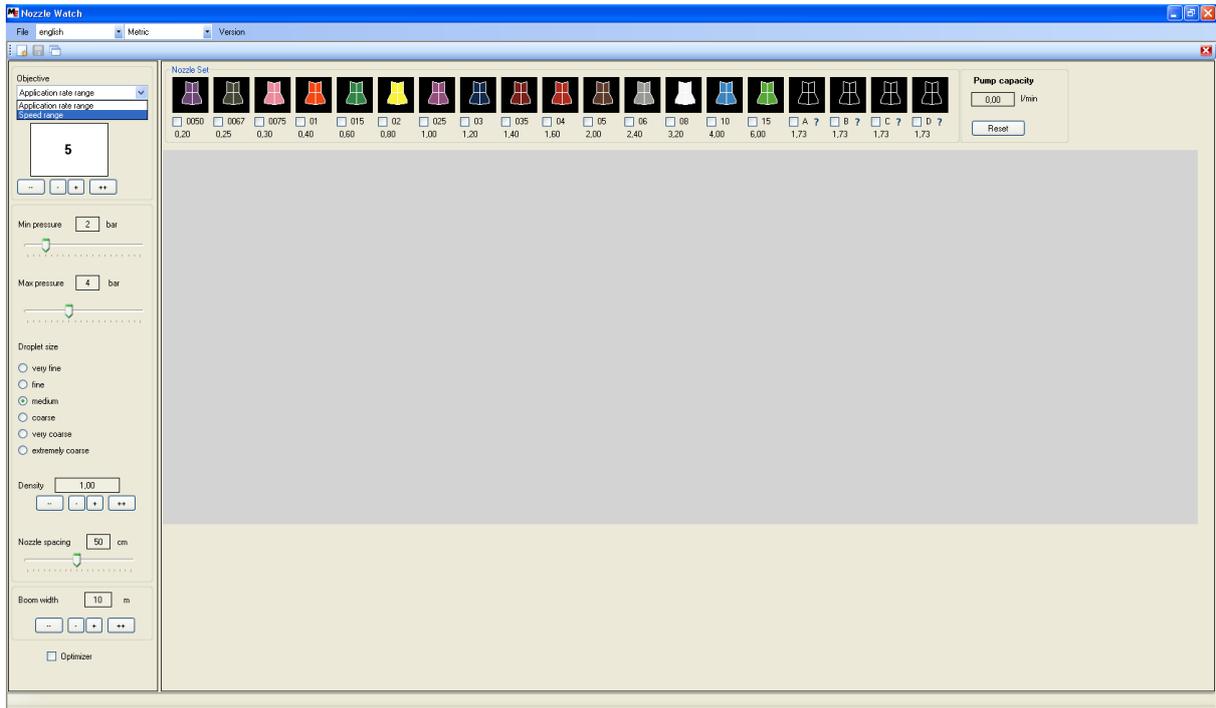
In the control panel, the user can specify fixed parameters such as the nozzle spacing, flow, droplet size and parameters for the objective range.



As stated earlier, the tool allows the user to specify a nozzle pressure range (min and max pressure) and additionally he may either specify a sprayer speed or he may specify an application rate (see next page). When he specifies a sprayer speed, as in the screen below, the objective range is an application rate range.

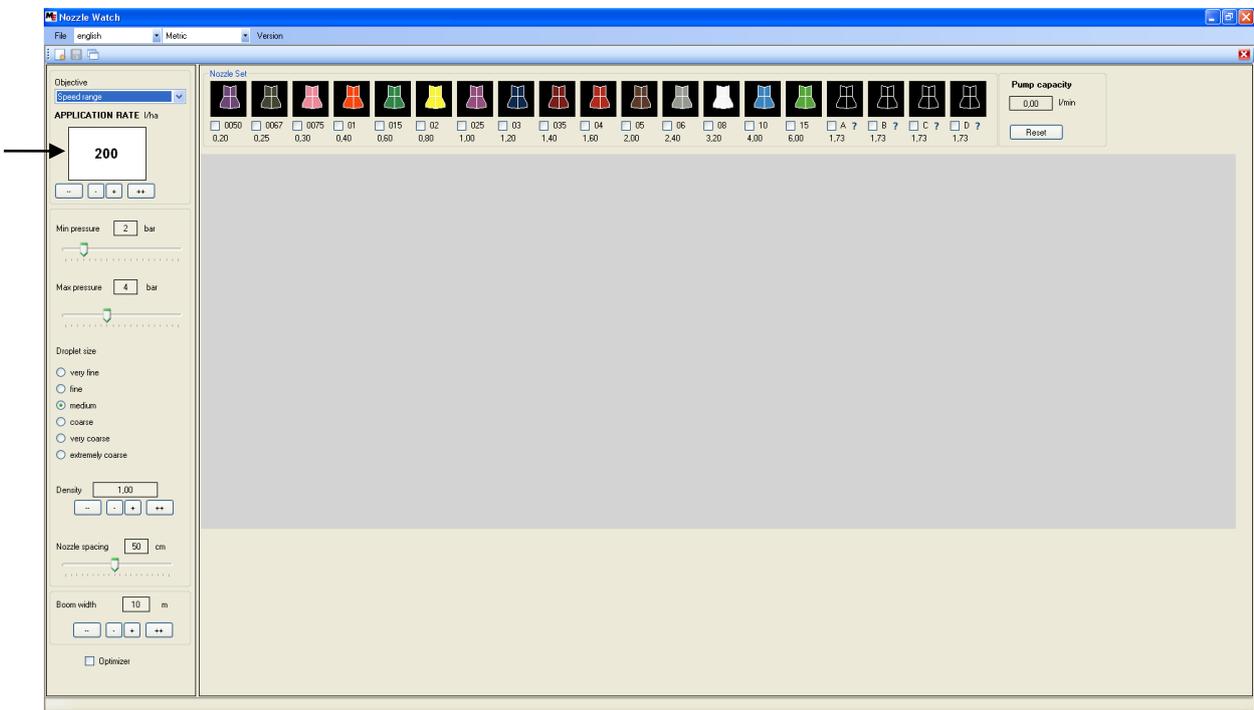


The objective range type can be changed to the sprayer speed range by choosing it from the drop-down list.



The user can then specify the prescribed application rate:

prescribed application rate

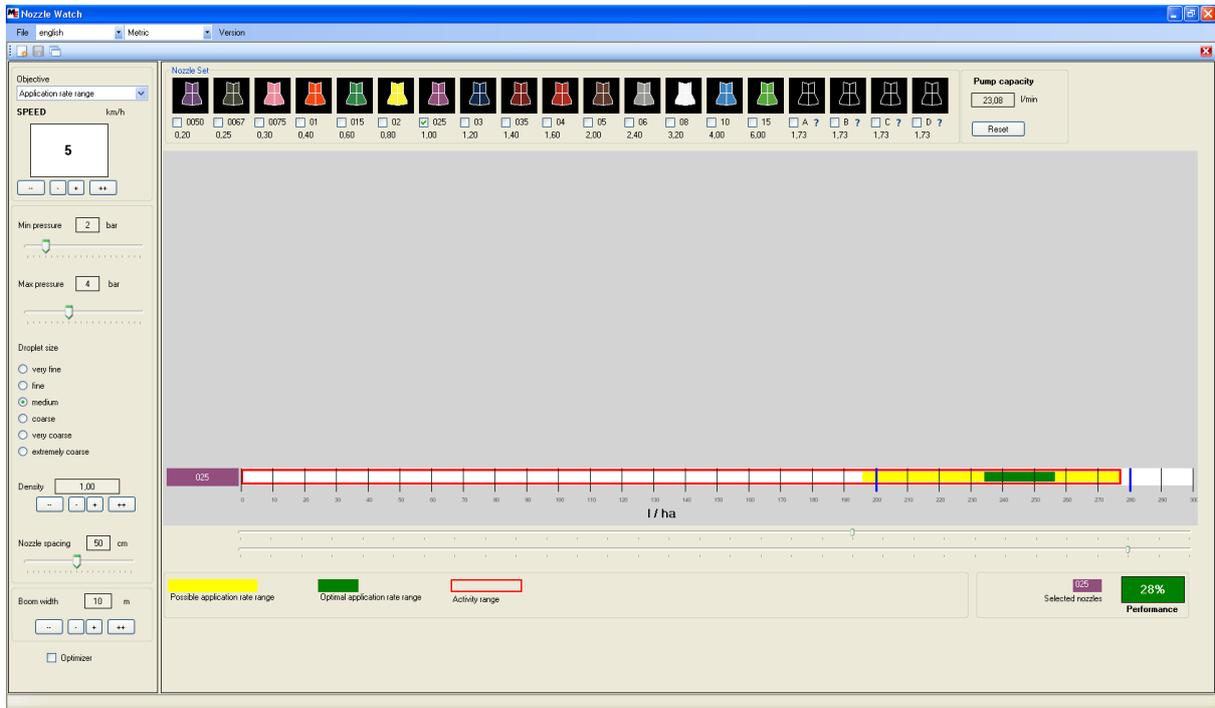


For the example that follows, we shall use the application rate range as the objective range.

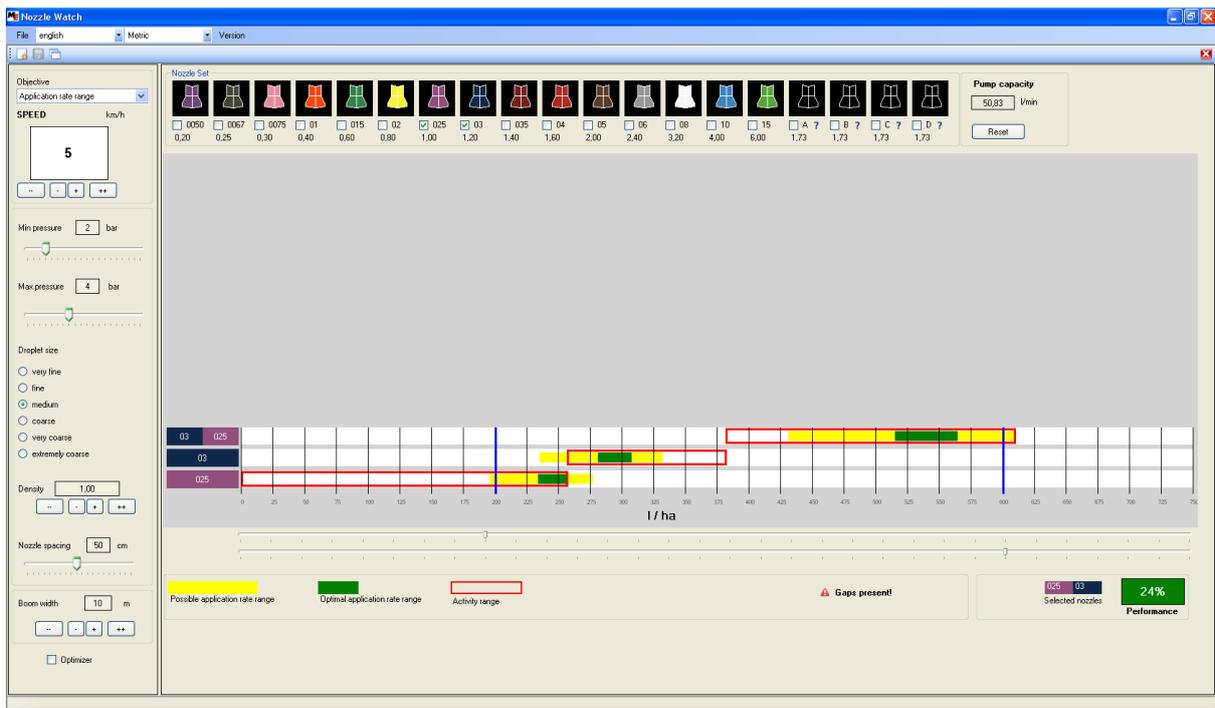
## Choosing Nozzles

Nozzles are chosen by ticking the checkboxes under the nozzles. The **working graph** of the chosen nozzles is automatically updated and displayed after every nozzle choice. When more than 4 nozzles are chosen, the graph is not updated until the sum of nozzles selected is 4 or less.

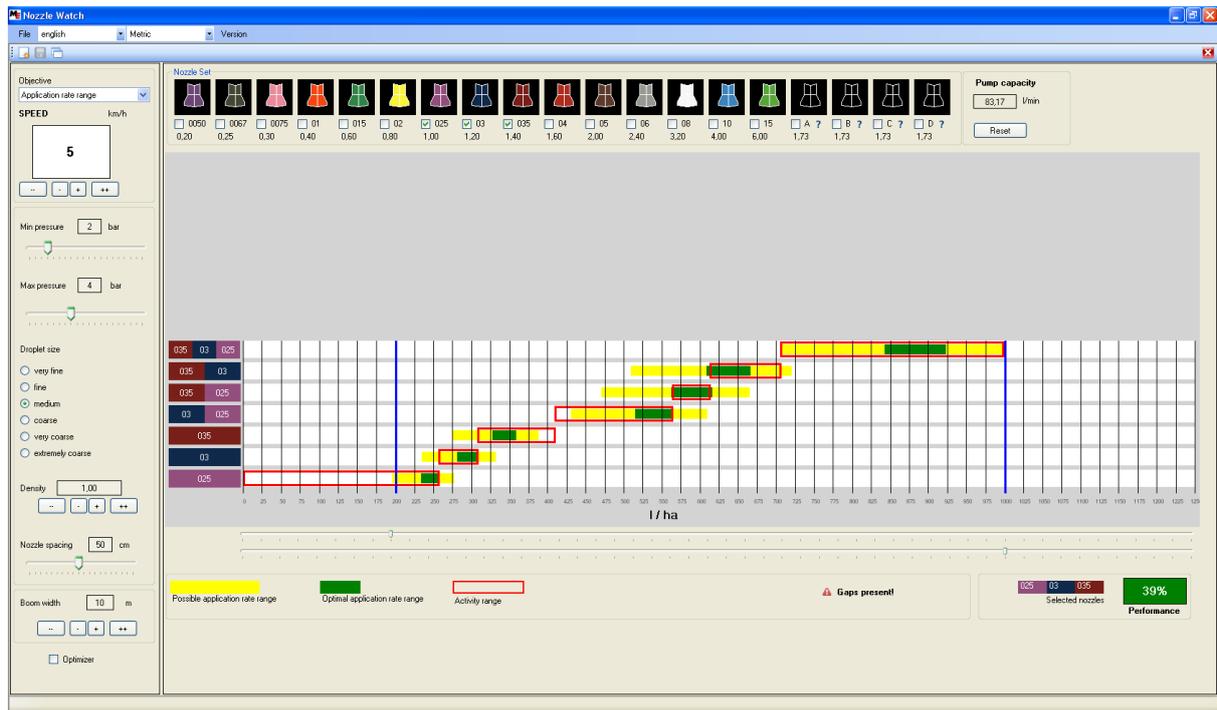
The working graph after having chosen one nozzle {025}:



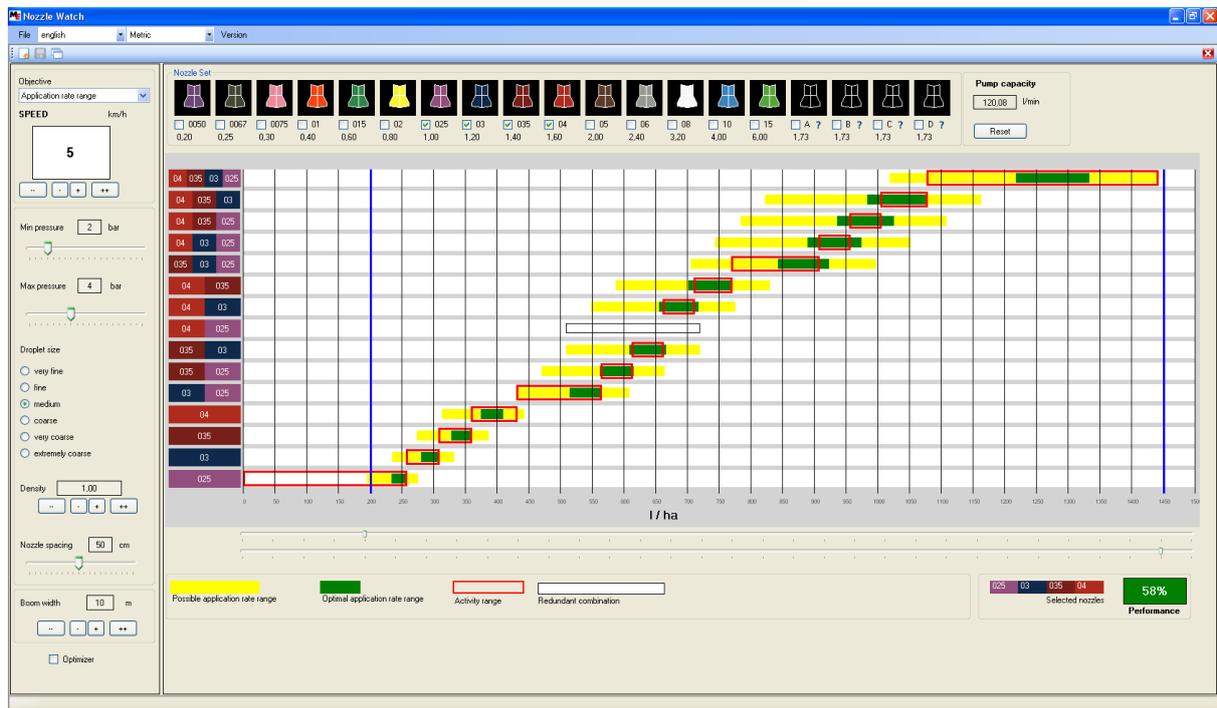
The working graph after having chosen two nozzles {025, 03}:



The working graph after having chosen three nozzles {025, 03, 035}:

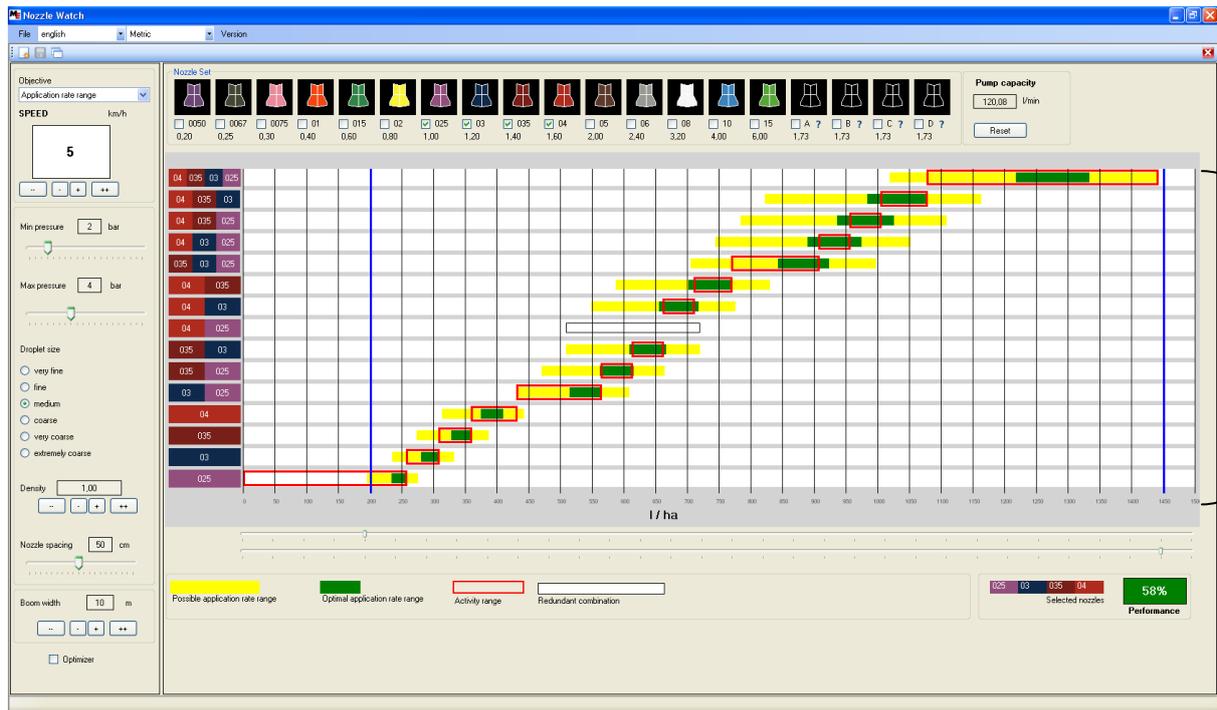


The working graph after having chosen four nozzles {025, 03, 035, 04}:



The reset button un-selects all selected nozzles.

## The Working Graph



Working graph

The main insight of the working graph is the following:

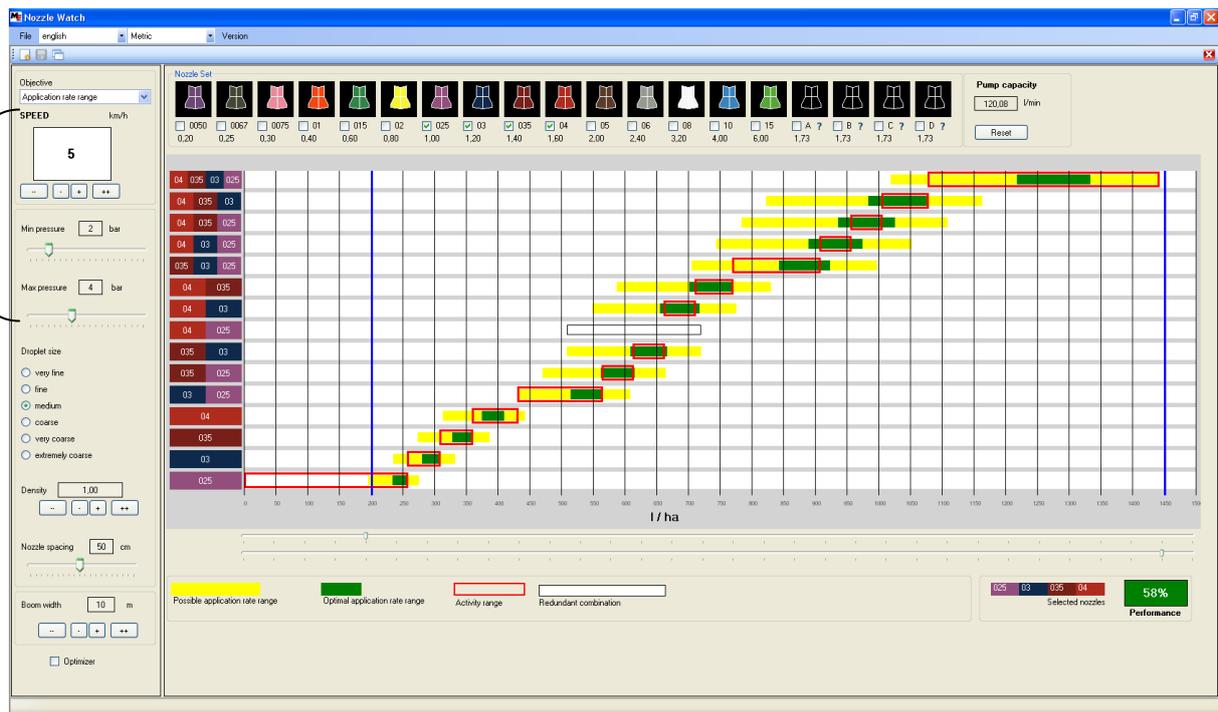
At any time,  $t$ , the application rate of a nozzle combination is essentially a function of the sprayer speed at time  $t$  and the nozzle pressure at time  $t$  (it also depends on the product density and the nozzle spacing, but these are fixed).

- So by varying the nozzle pressure and keeping the sprayer speed fixed, we obtain a range of application rates. So, when the objective range is the application rate range, the working graph is a plot of application rates (x-axis) against nozzle combinations (y-axis).
- Similarly, by varying the nozzle pressure and keeping the application rate fixed, we obtain a range of sprayer speeds. When the objective range is the sprayer speed range, the working graph is a plot of sprayer speeds (x-axis) against nozzle combinations.

In what follows, we shall use the following definition:

**Activated combination:** we say that a combination of nozzles is activated, if all the nozzles in it are open, and all nozzles not in it are closed.

## Working Graph (objective range = application rate range)



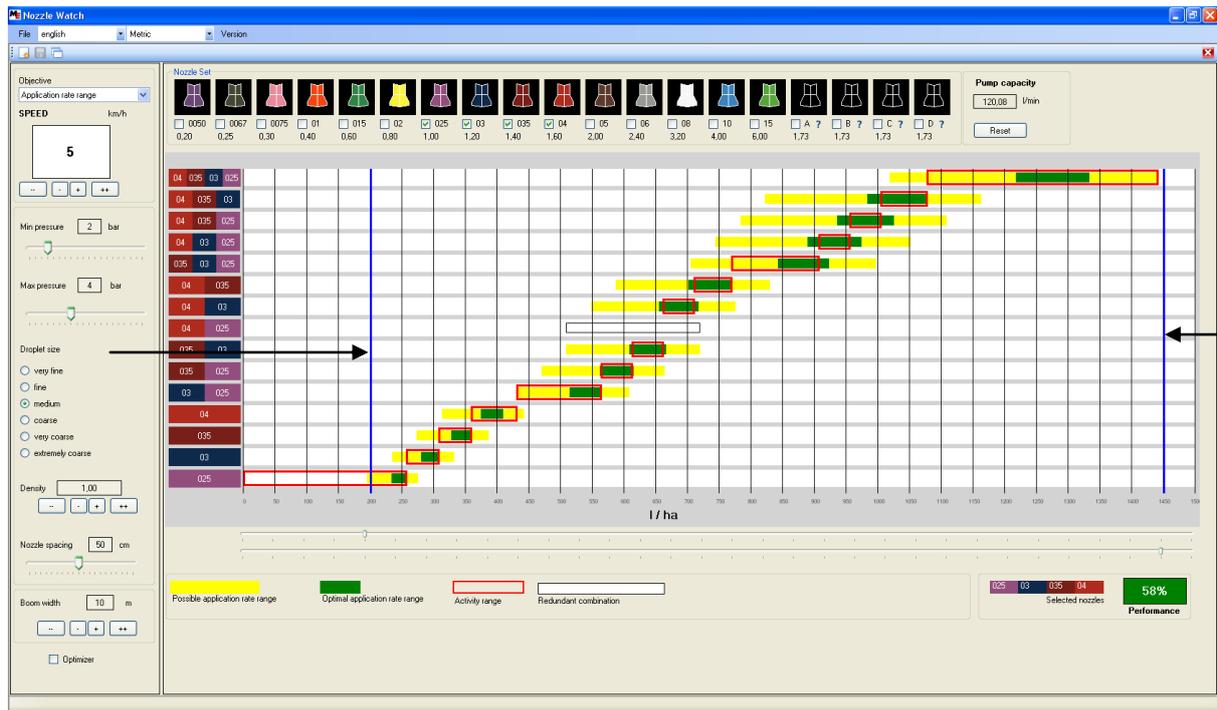
When the objective range is the application rate range, the working graph is a plot of application rates (x-axis) against nozzle combinations (y-axis).

The graph is defined by the user-specified nozzle pressure range and sprayer speed.

The selected nozzles together define a *total application rate range*. In the above graph, it is from 200 l/ha to around 1450 l/ha. Initially, the objective range is set to this total range, as shown by the two vertical blue bars.

This working graph answers the query: for spraying in a given range of application rates, what nozzle combinations may be activated if the sprayer moves at a fixed speed?

## Working Graph (objective range = application rate range)



The yellow bar represents application rates tolerable by the nozzle combination. If the sprayer speed and nozzle pressure is such that the resultant application rate is in this range, then it means that the nozzle pressure is tolerable for the nozzles of the combination; outside this range, the nozzles are under-pressurized or over-pressurized.

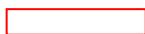
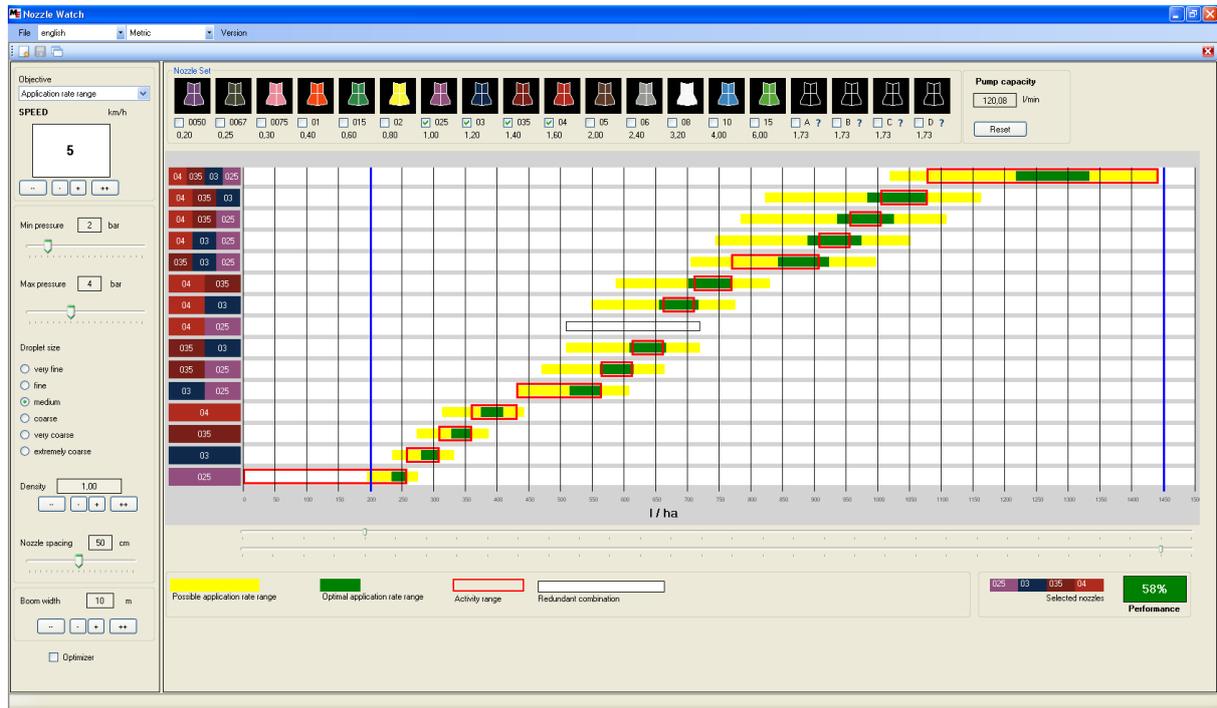
**Example:** If the combination (035, 03, 025) is activated, it would have enough pressure to spray at a rate approximately between 700 l/ha and 1000 l/ha.



The green bar represents the optimal application rates for the nozzle combination. If the sprayer speed and nozzle pressure is such that the resultant application rate is in this range, then the nozzles of the combination have the right pressure to spray droplets of the required size.

**Example:** If the combination (035, 03, 025) is activated, it would have enough pressure to spray droplets of medium size at a rate approximately between 840 l/ha and 925 l/ha.

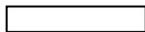
## Working Graph (objective range = application rate range)



H-Select activates each nozzle combination for a part of the total application range. This part is represented by a red box. When the sprayer speed and nozzle pressure is such that the application rate is within the limits of a red box, the corresponding nozzle combination is activated.

By following the red boxes, we can retrace the working of H-Select over the course of a spraying scenario; we can see which nozzles it opens and which it closes.

**Example:** H-Select activates the combination (035, 03, 025) whenever the current nozzle pressure and current sprayer speed cause the current application rate to be approximately between 775 l/ha and 910 l/ha. If it goes above 910 l/ha, it activates combination (04, 035, 025). If it falls below 775 l/ha, it activates combination (04, 035).



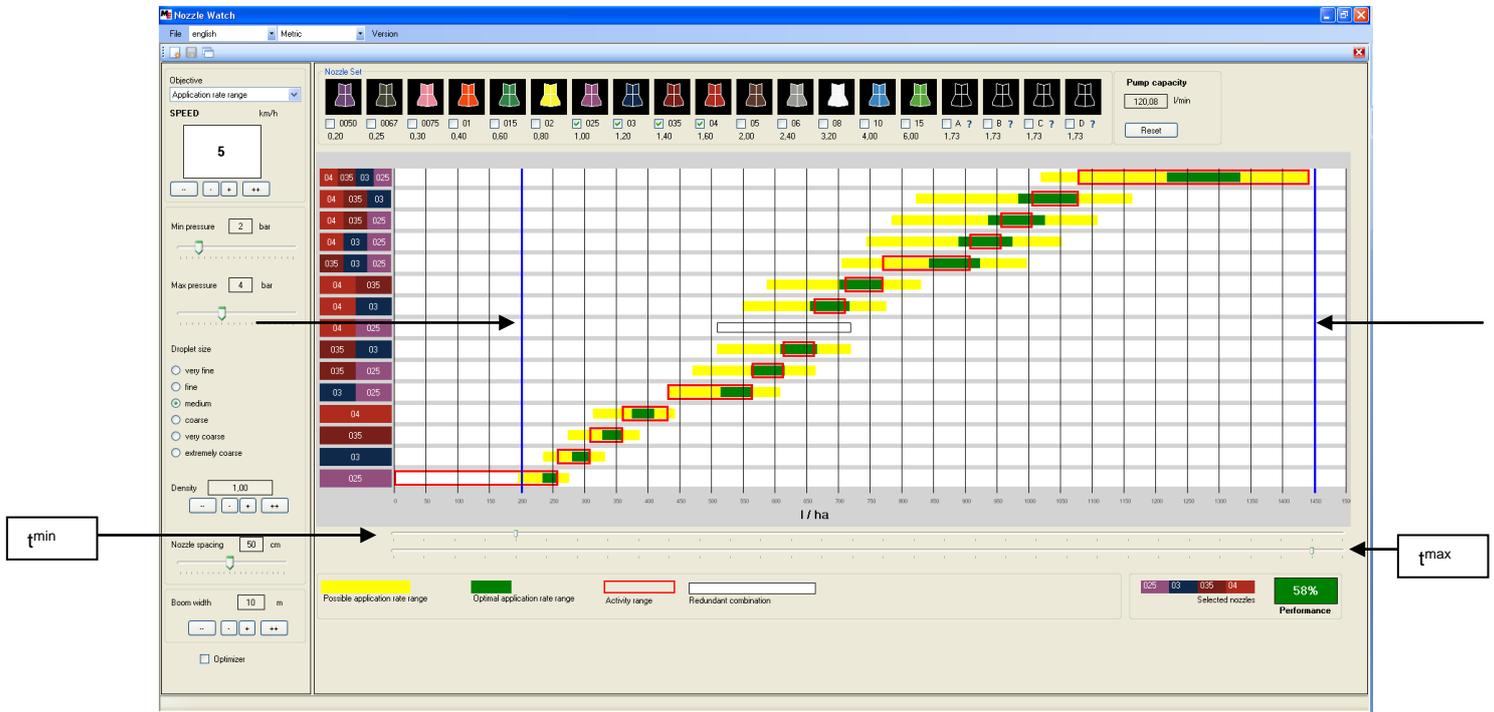
A redundant combination is represented by an empty box. Such a combination is never activated by H-Select because another combination with the same tolerable application rate range exists.

**Example:** the combination (04, 025) is made redundant due to combination (035, 03).

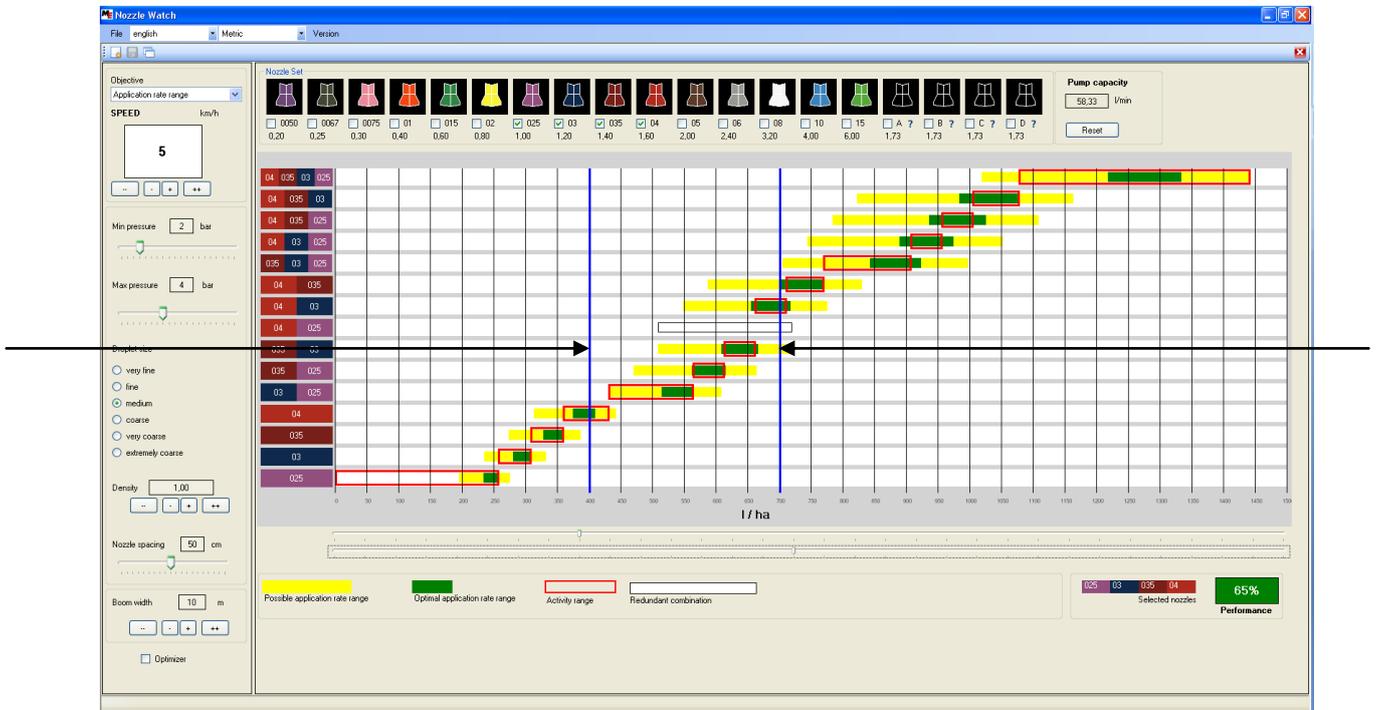
(Note that given two combinations with identical tolerance, H-Select renders the combination containing less nozzles redundant.)

## Refining the Objective Range

The objective range (vertical blue bars) can be refined to a sub-range by means of the two track-bars,  $t^{\min}$  and  $t^{\max}$ .

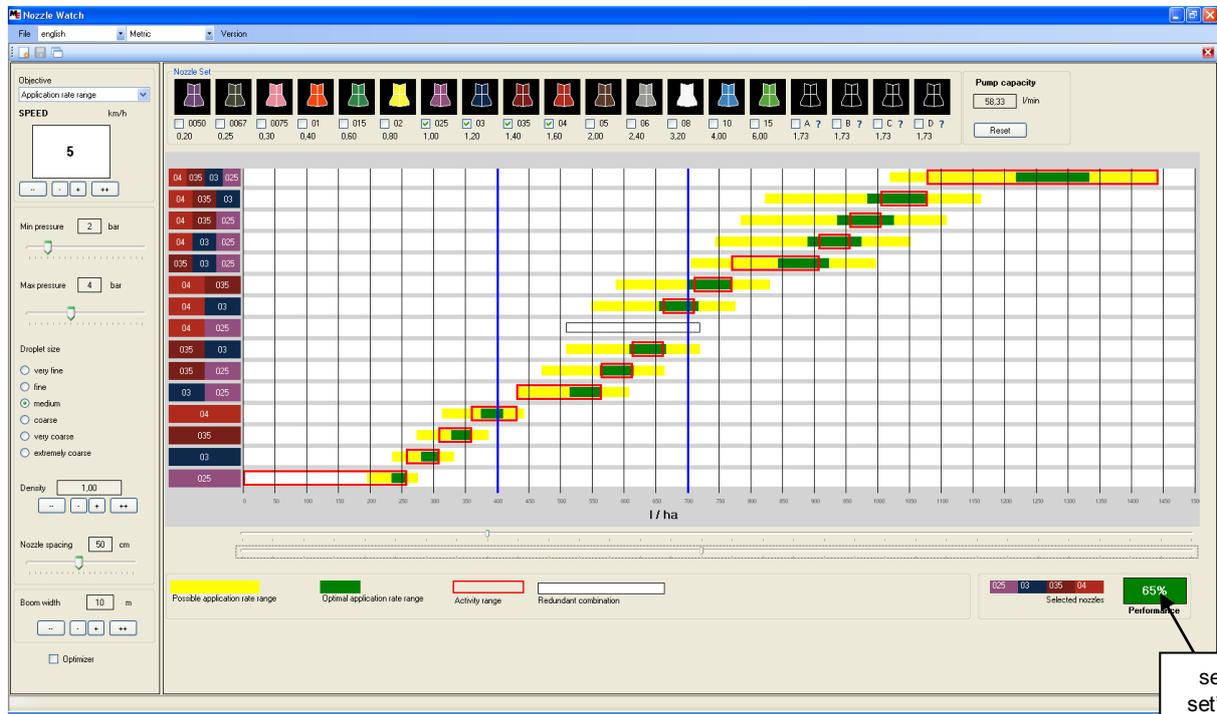


In the graph below, the objective range has been refined to the range 400 l/ha to 700 l/ha.



## Performance

We recall that the performance of the selected nozzles is defined as the percentage of the objective range in which the nozzles spray droplets of the required size.



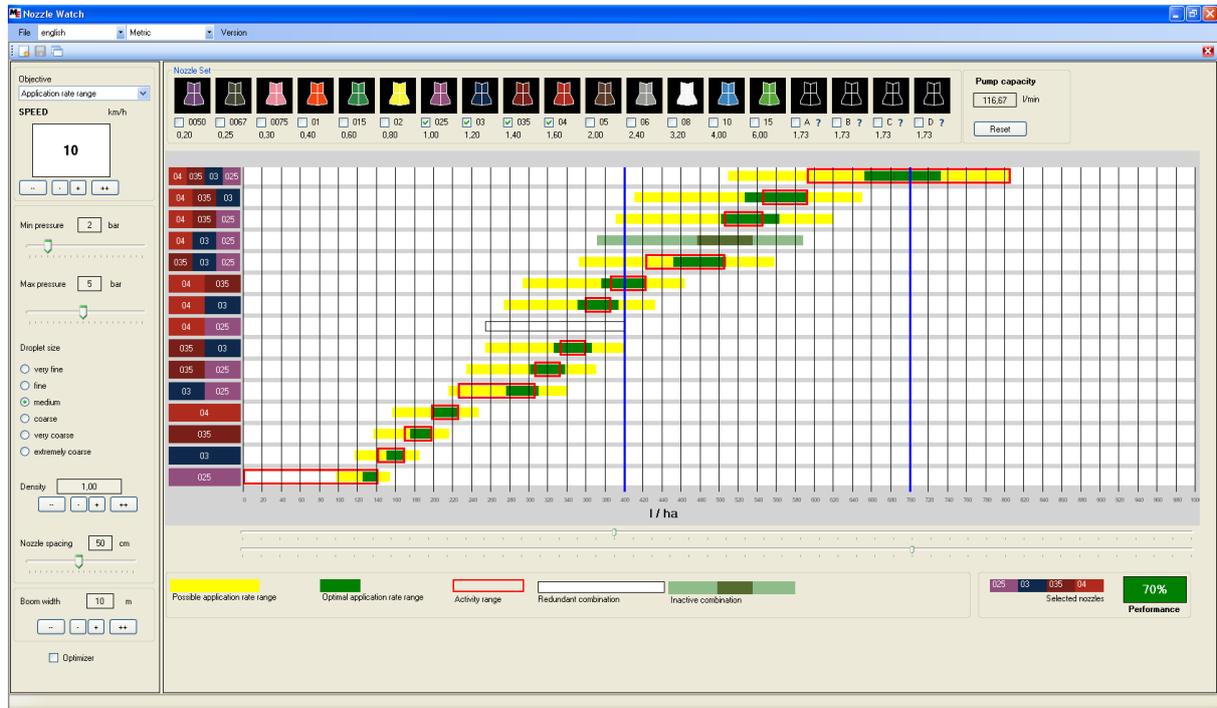
In terms of the working graph, it is the ratio of the sum of the sizes of the green zones that are within the objective range to the objective range. If a green zone is only partially within the objective range, the portion that lies within the objective range is counted.

In the graph above, for the given control parameters and for an objective range of 400 l/ha to 700 l/ha, the selected nozzle set {025, 03, 035, 04} yields a performance of 65%.

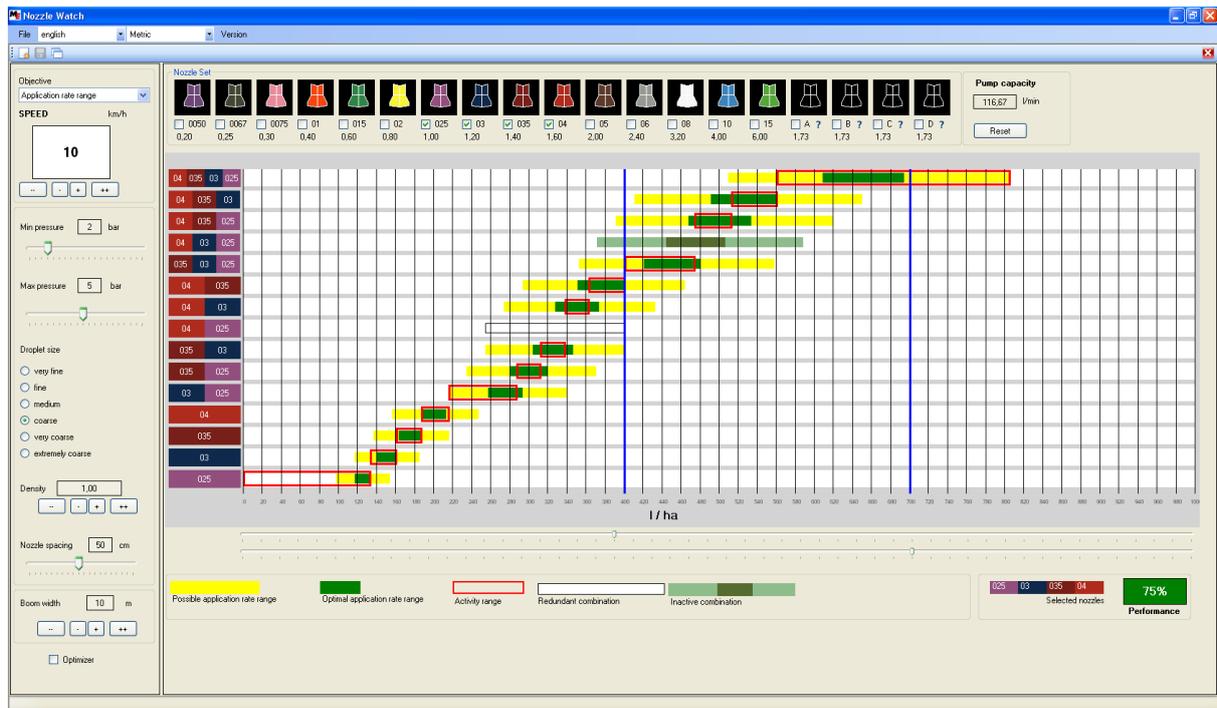
## Performance

Upon any update of the control parameters or refining of the objective range, the performance of the selected nozzle set is instantly updated and displayed.

If the sprayer speed is increased to 10 km/h and max nozzle pressure to 5 bar, we obtain 70% performance.



Furthermore, if the required droplet size is changed to 'coarse', performance goes up, to 75%.



## Optimization

Can we do better than 75% for the given objective range? How do we know if the performance obtained can be improved upon? As stated earlier, the tool has an in-built optimizer that finds an optimal set of nozzles for the specified parameters and objective range. The optimizer is opened by ticking the optimizer checkbox. On checking it, the optimization options panel appears.

The screenshot shows the 'Nozzle Watch' software interface. On the left, there are control panels for 'Objective' (Application rate range), 'SPEED' (10 km/h), 'Min pressure' (2 bar), 'Max pressure' (5 bar), 'Droplet size' (medium), and 'Density' (1.00). The main area is a graph of application rate (l/ha) vs. nozzle combinations. The 'Optimizer' checkbox is checked, and the 'Find optimal set' button is visible. A callout box points to the 'optimizer activation checkbox' and another points to the 'optimization options panel'.

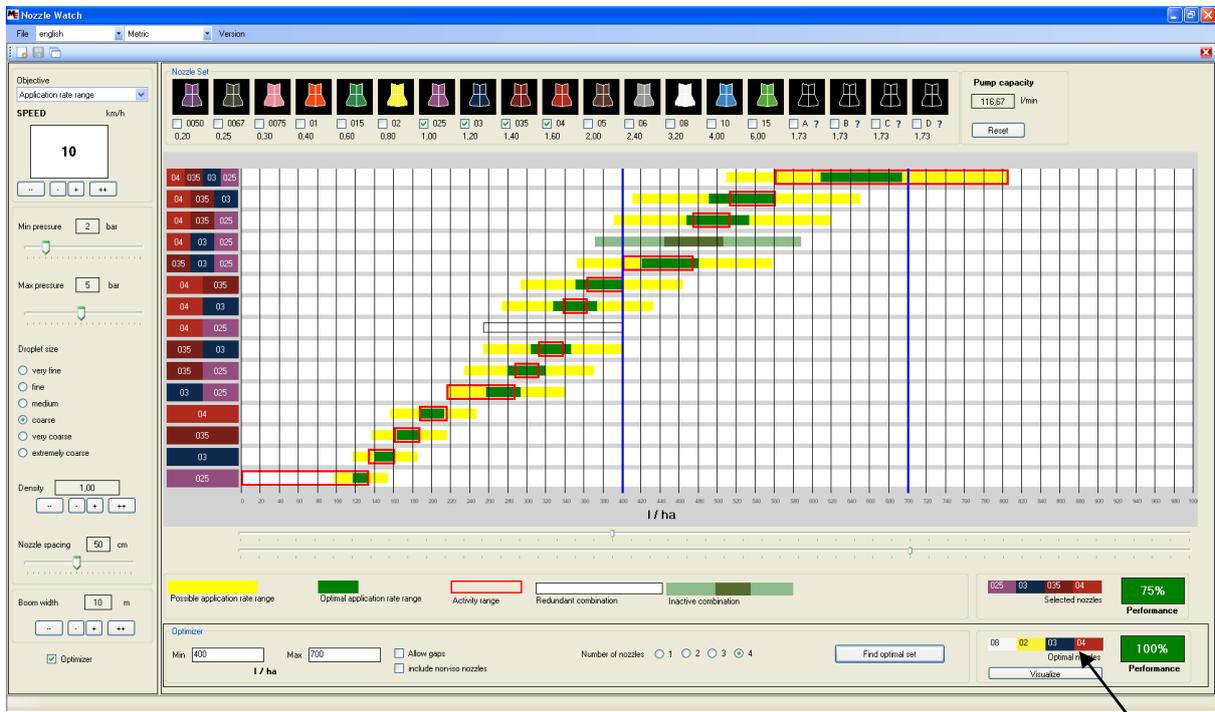
The optimization options panel allows the user to specify, in finding the optimal nozzle set, the following:

- Min and Max of the application rate range (this can also be specified by the two track-bars, as mentioned previously).
- The number of nozzles to be used (1 to 4).
- Two options:
  - whether *gaps* between adjacent nozzle combinations are to be tolerated
  - whether non-ISO nozzles are to be included

By clicking on the “Find Optimal Set” button, the optimal solution is displayed.

## Optimization

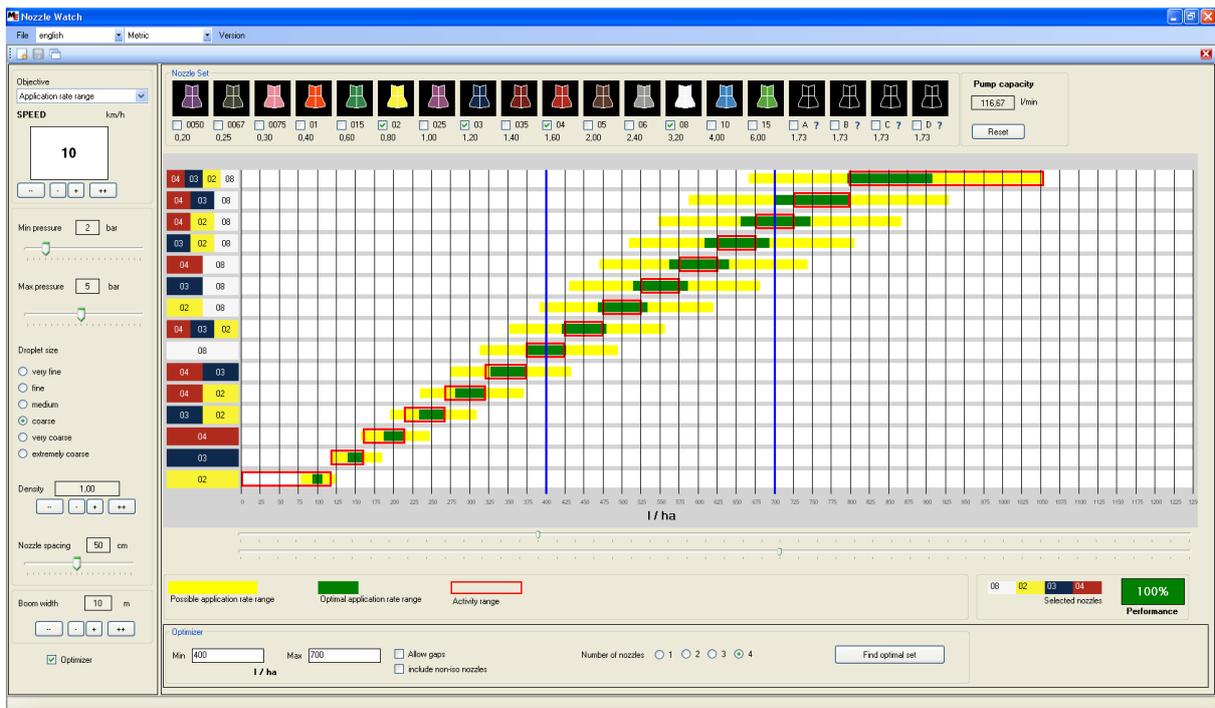
The optimizer has returned us an optimal ISO nozzle set {08, 02, 03, 04} whose performance is 100% for the objective range.



Thus, for if the user wants to spray between 400 l/ha to 700 l/ha, it is clearly better to use the set {08, 02, 03, 04} rather than the set {025, 03, 035, 04} as selected by him originally.

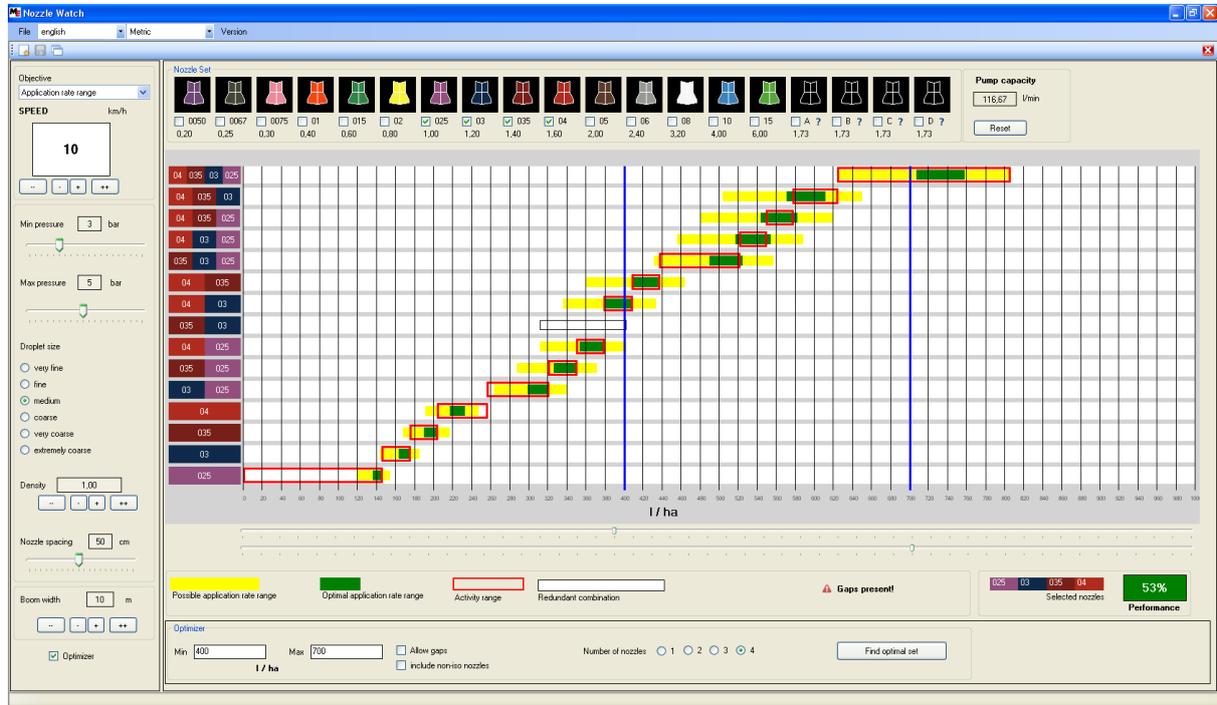
Optimal nozzle set

By clicking the Visualize button, the working graph for the optimal set is displayed:

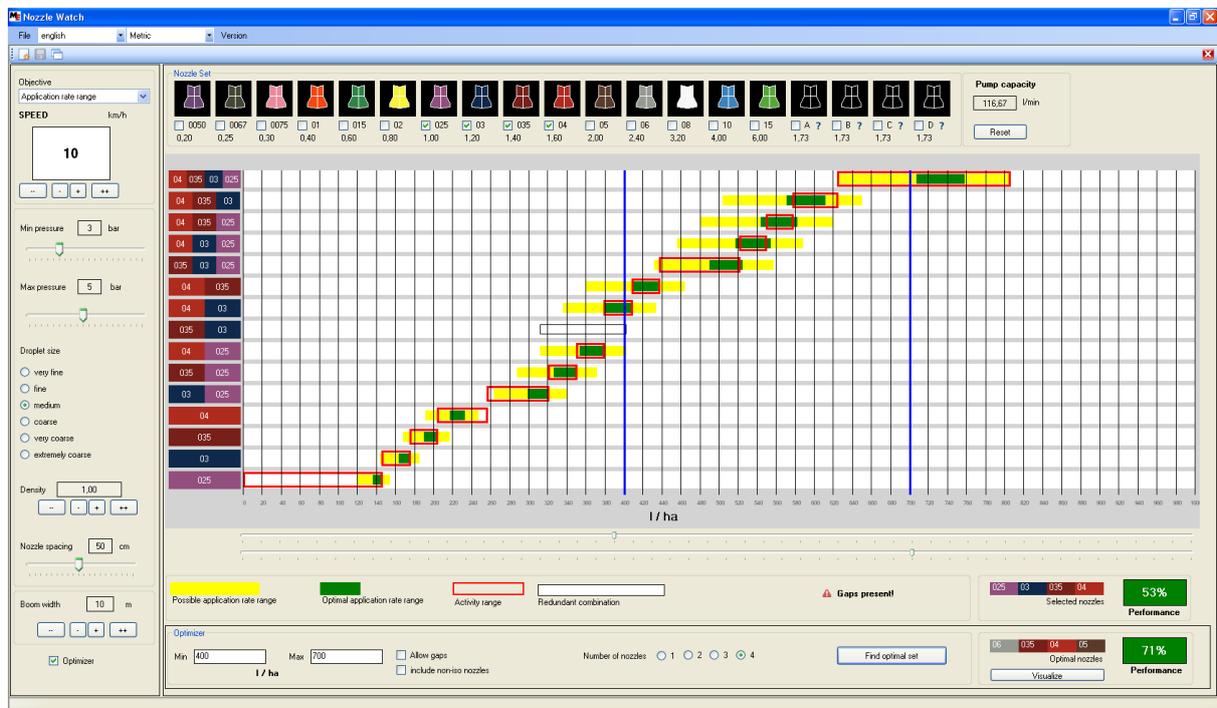


## Optimization

Note that an optimal nozzle set need not necessarily have a performance of 100%. Consider the following example. Using our original choice of nozzles, if we increase the min pressure to 3 bar and change the required droplet size to 'medium', we obtain a performance of 53%.

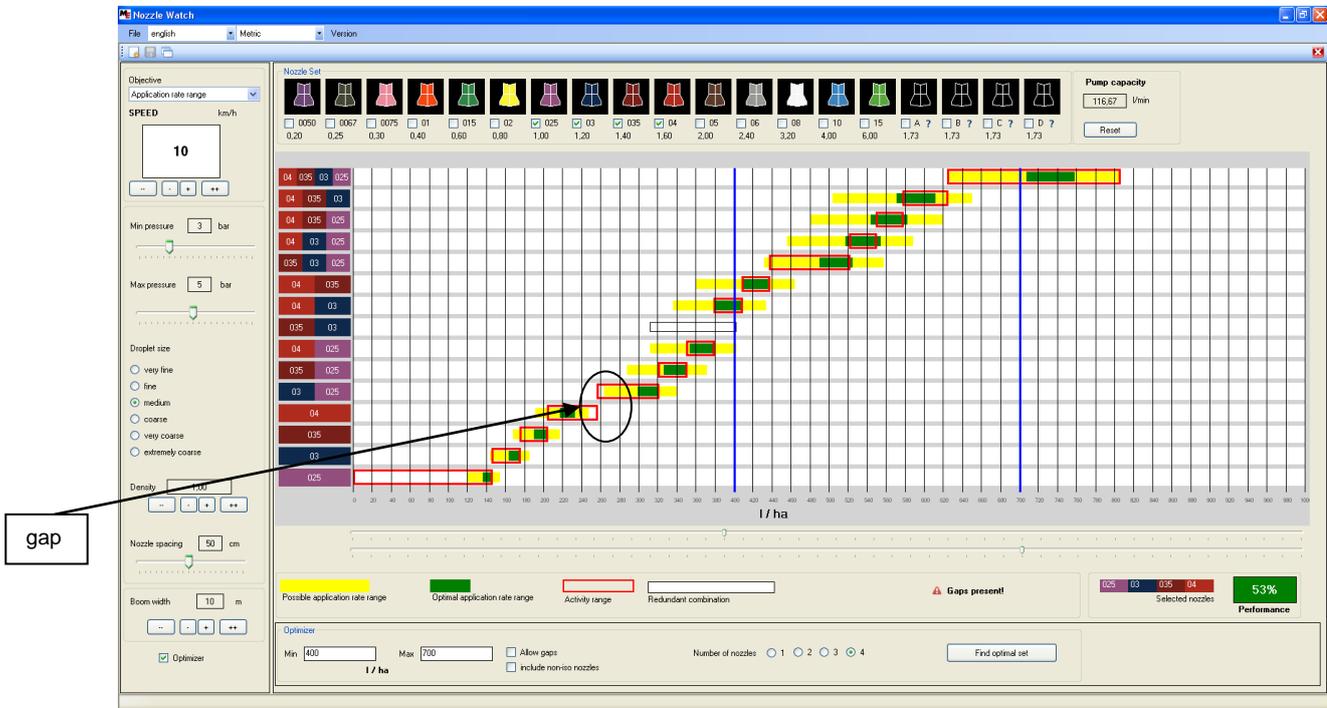


The optimizer returns the optimal solution which has a superior performance, but which is not 100%.

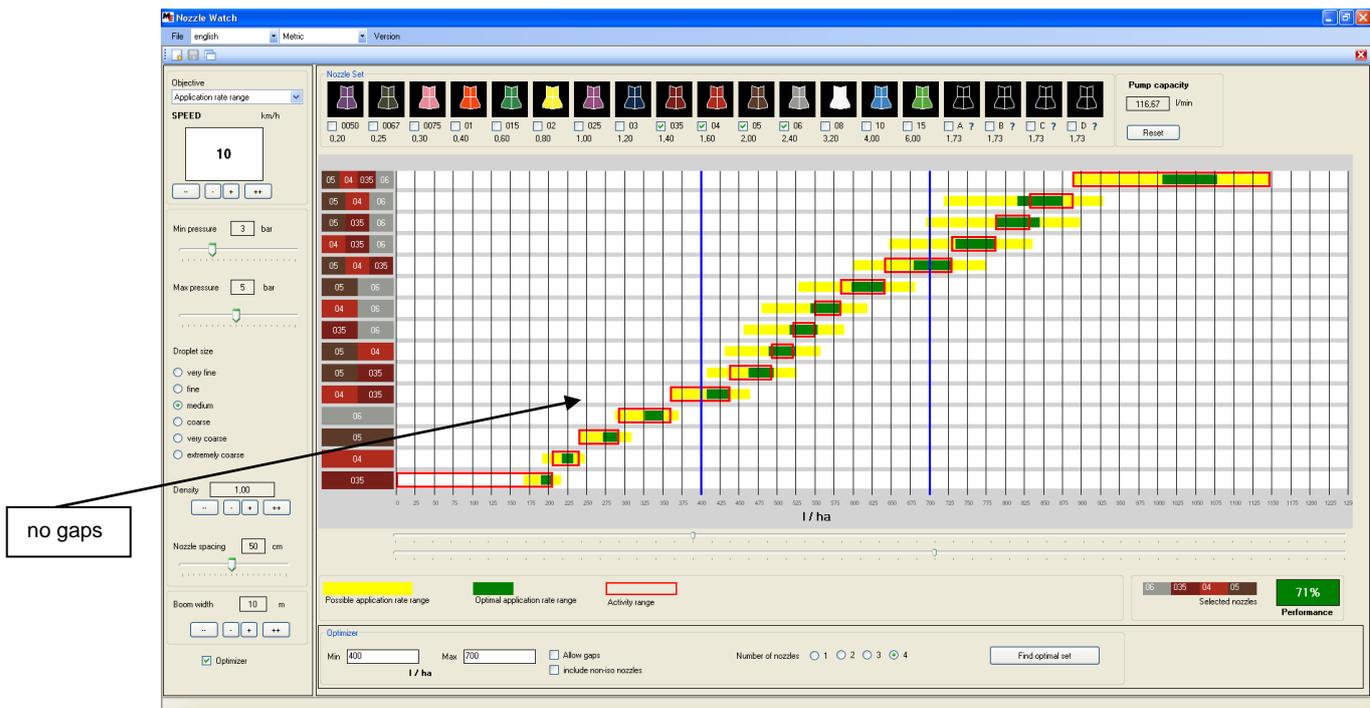


## Optimization (solution without gaps)

The user's choice of nozzles in the previous page not only gave a performance of only 53% but it also had a *gap* i.e., there was a part of the total application rate range in which, at the fixed sprayer speed, the nozzle pressure is either too high or too low for all the nozzle combinations. In a gap, no spraying is possible at all, and the terminal gives an alarm.

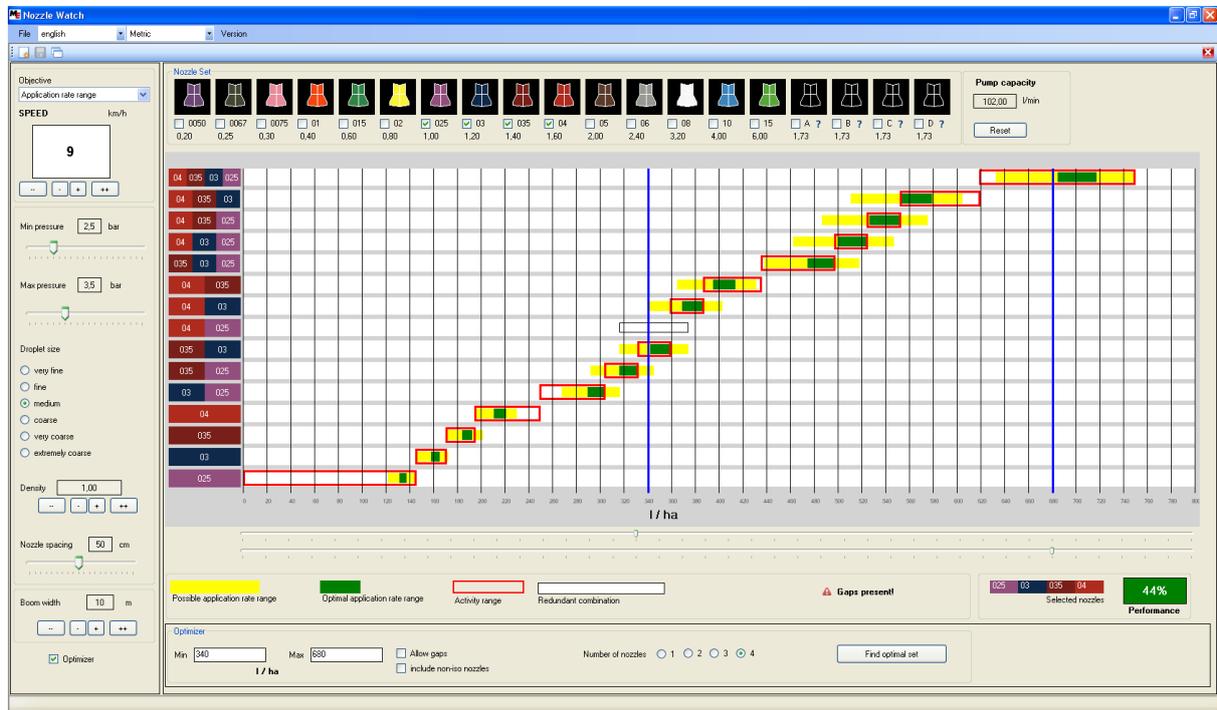


In the solution returned by the optimizer, not only is the performance superior at 71%, but it also is free of gaps:

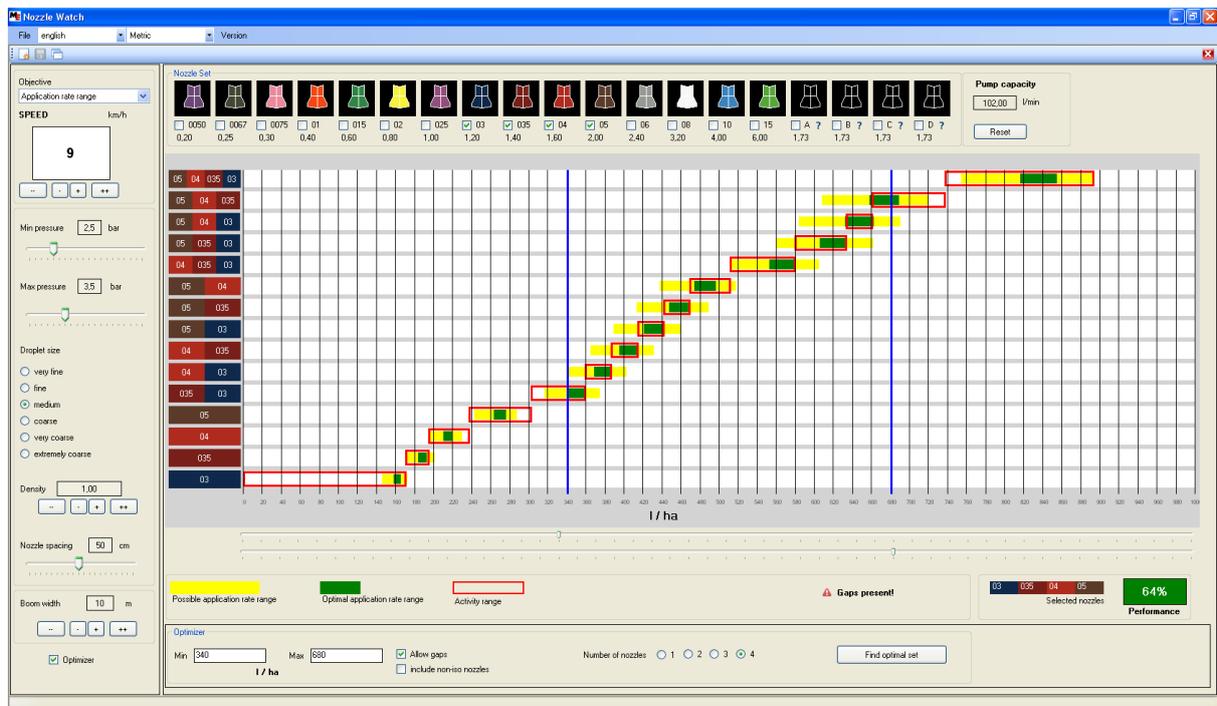


## Optimization (solution with gaps)

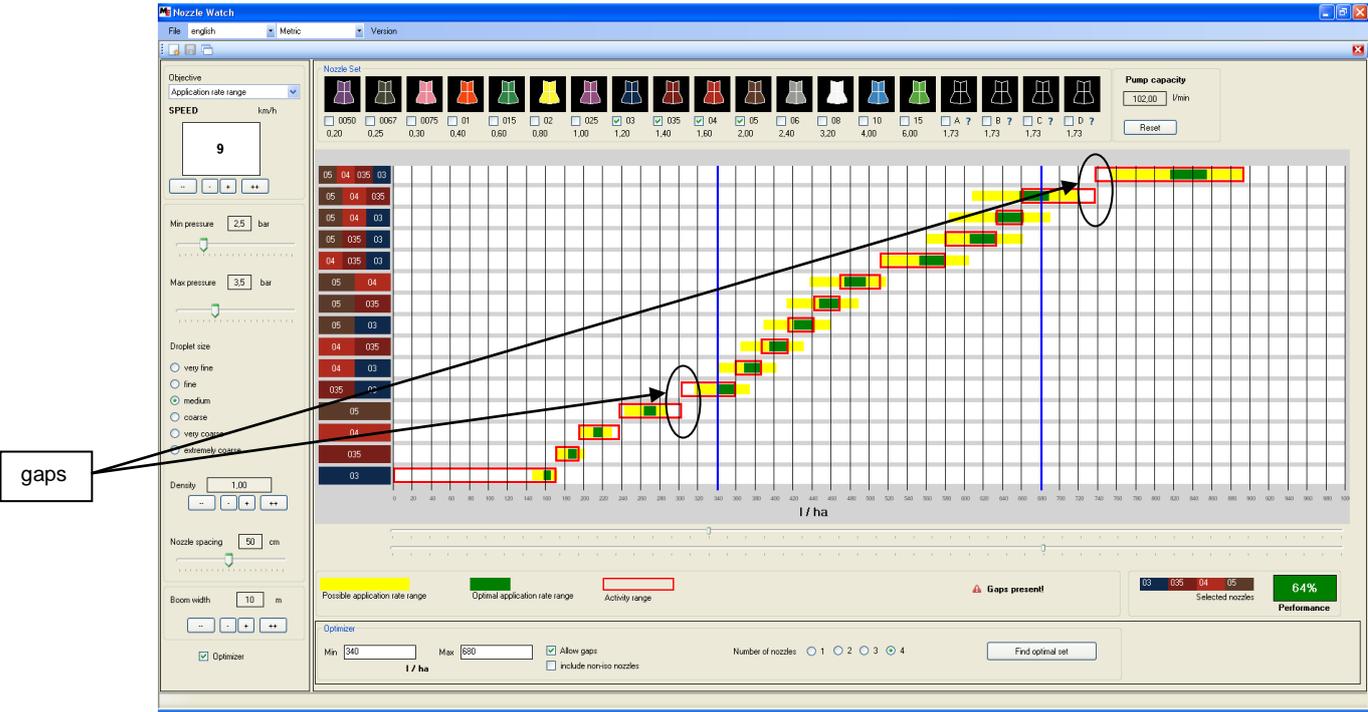
It is possible that for a given set of conditions, no solution exists since a “solution” is supposed to be free of gaps. For the following example, no solution without gaps exists.



On the other hand an optimal solution *with gaps* does exist (in fact, an optimal solution with gaps exists for every set of conditions). By checking “Allow gaps” in the optimization options panel and clicking on Find optimal set, we get the following solution with performance 64%:



# Optimization (solution with gaps)



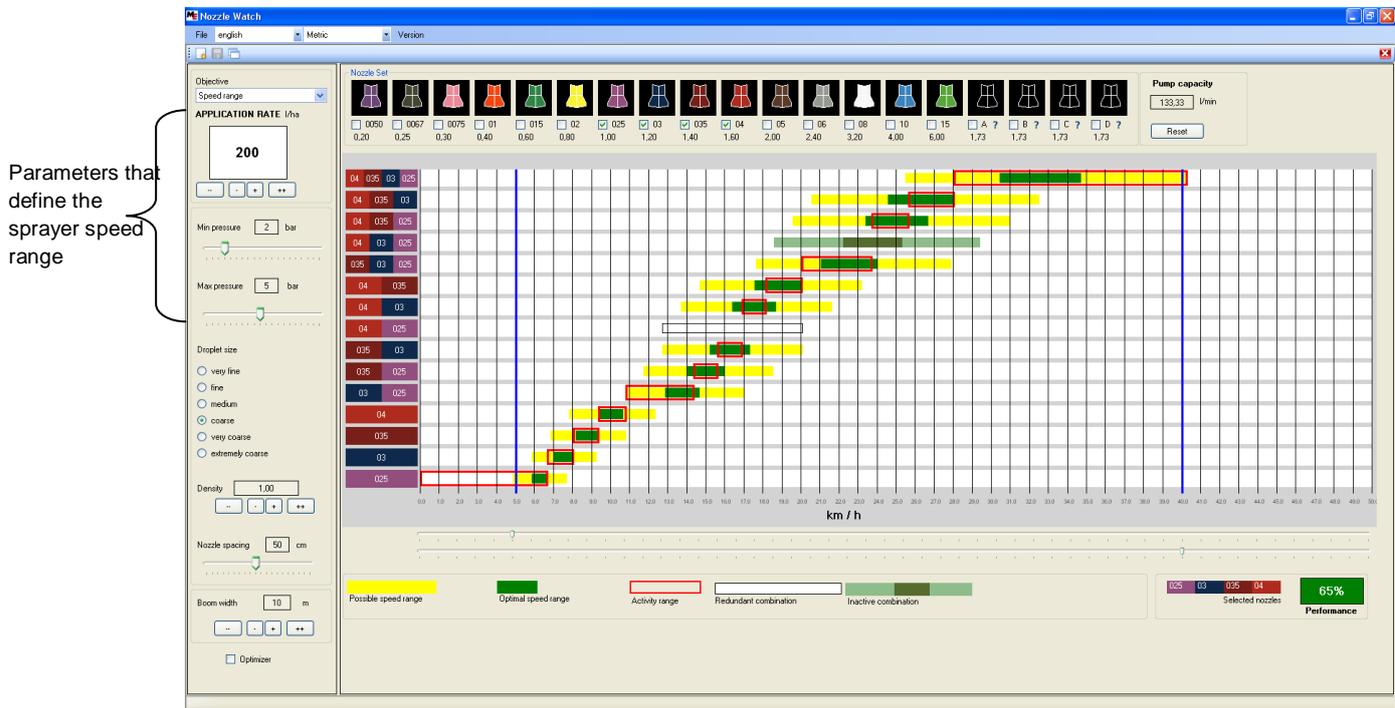
So, the optimizer shows what trade-off between performance and the size of gaps is possible.

The following table summarizes this tradeoff capability of the optimizer: U is the performance of the user's chosen nozzle set, while O is the performance of the optimal nozzle set.

		USER'S NOZZLE SET	
		does not have gaps	has gaps
OPTIMAL NOZZLE SET	does not have gaps	$O \geq U$	$O > U$ or $O = U$ or $O < U$
	has gaps	$O \geq U$	$O \geq U$

## The Working Graph (objective range = sprayer speed range)

We now take a look at the working graph when the objective range is the sprayer speed range.



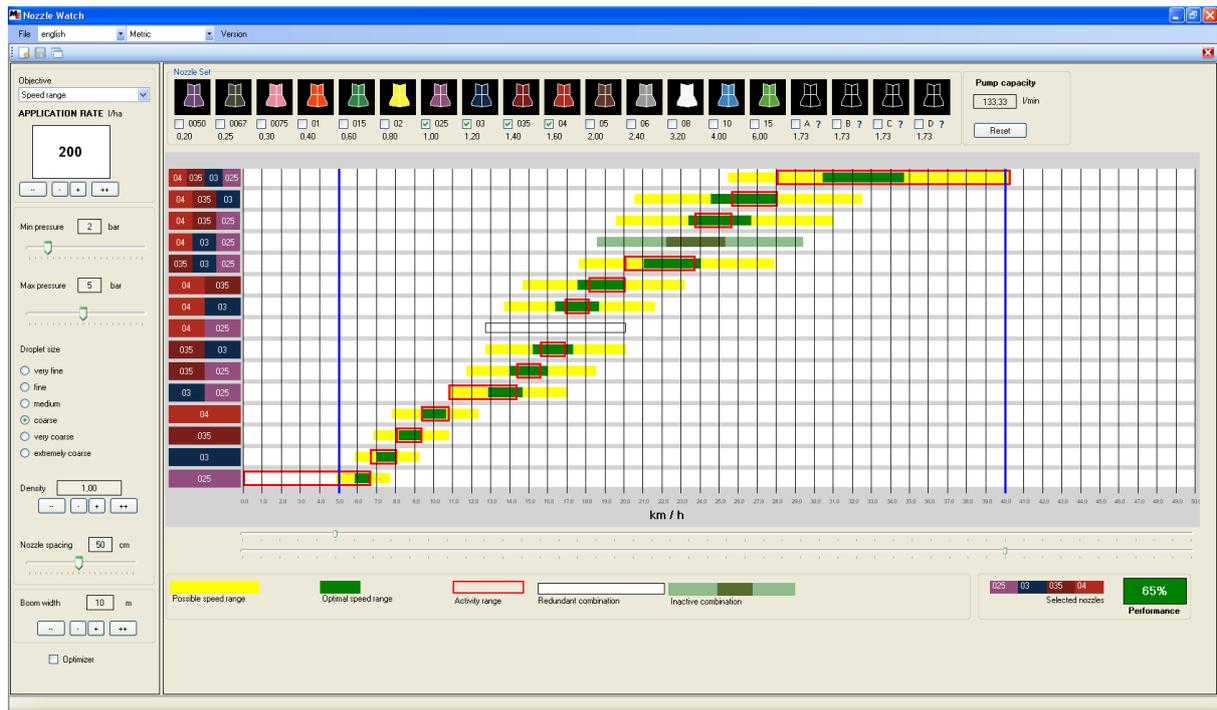
When the objective range is the sprayer speed range, the working graph is a plot of sprayer speed (x-axis) against nozzle combinations (y-axis).

The graph is defined by the user-specified nozzle pressure range and prescribed application rate.

The selected nozzles together define a *total sprayer speed range*. In the above graph, it is from 5 km/h to around 40 km/h. Initially, the objective range is set to this total range, as shown by the two vertical blue bars.

This working graph answers the query: allowing for a variation in the sprayer speed, what nozzle combinations may be activated in order to achieve the prescribed application rate?

## The Working Graph (objective range = sprayer speed range)



The yellow bar represents the tolerable sprayer speeds for the nozzle combination. If the sprayer speed is outside this range, the nozzles of the combination will either be under-pressurized or over-pressurized.

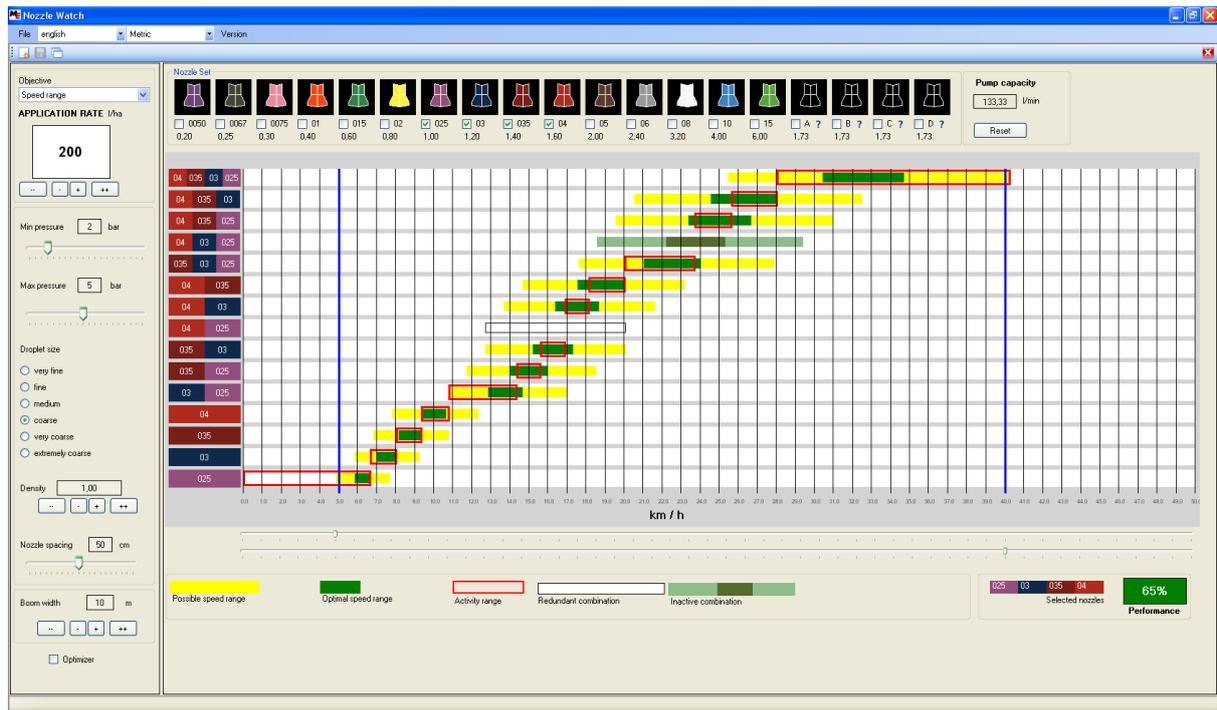
**Example:** For spraying at 200 l/ha, the sprayer speed will have to be approximately in the range 18 km/h and 28 km/h for the nozzles of the combination (035, 03, 025) to have tolerable pressure.



The green bar represents ideal or optimal sprayer speeds for the nozzle combination. At these sprayer speeds, the nozzles of the combination have the right pressure to spray droplets of the required size at the prescribed application rate.

**Example:** For spraying at 200 l/ha droplets of 'coarse' size, the sprayer speed will have to be in the range 21 km/h to 24 km/h for the combination (035, 03, 025) to have the requisite pressure.

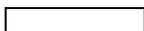
## The Working Graph (objective range = sprayer speed range)



H-Select activates each combination for a part of the total sprayer speed range. This part is represented by a red box. When the sprayer speed falls within the limits of a red box, assuming the nozzle pressure remains between the pressure range defined by the user, H-Select activates the corresponding combination.

By following the red boxes, we can retrace the working of H-Select over the course of varying sprayer speeds.

**Example:** H-Select activates the combination (035, 03, 025) only when current sprayer speed reaches 20 km/h. If the sprayer speed is more than



A redundant combination is represented by an empty box. Such a combination is never activated by H-Select because another combination with the same tolerable sprayer speeds exists.

**Example:** the combination (04, 025) is made redundant due to combination (035, 03).

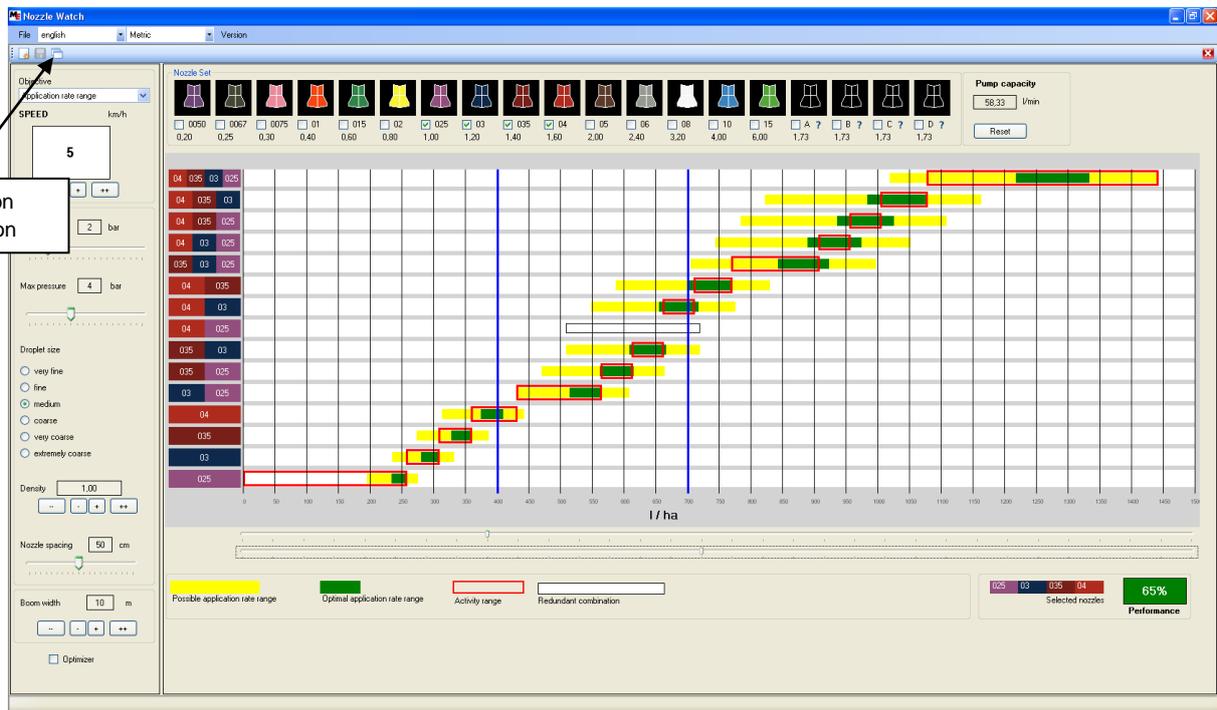


A light green bar represents an inactive combination. For the given the prescribed application rate, the combination is not activated by H-Select since it is not needed. H-Select assigns the combination's role to its adjacent combinations.

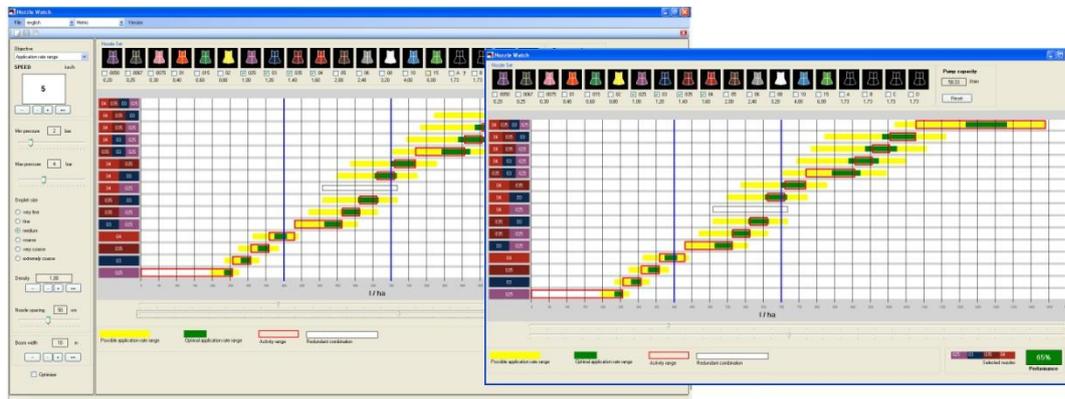
**Example:** the combination (04, 03, 025) is inactive; its usual tolerable speed range is 18.5 km/h to 29.5 km/h. However, if the sprayer speeds enters this range, H-Select activates either the combination (035, 03, 025) or the combination (04, 035, 025).

## Other features: comparing two nozzle sets

The user can compare two sets of nozzles by clicking on the Comparison Window icon:



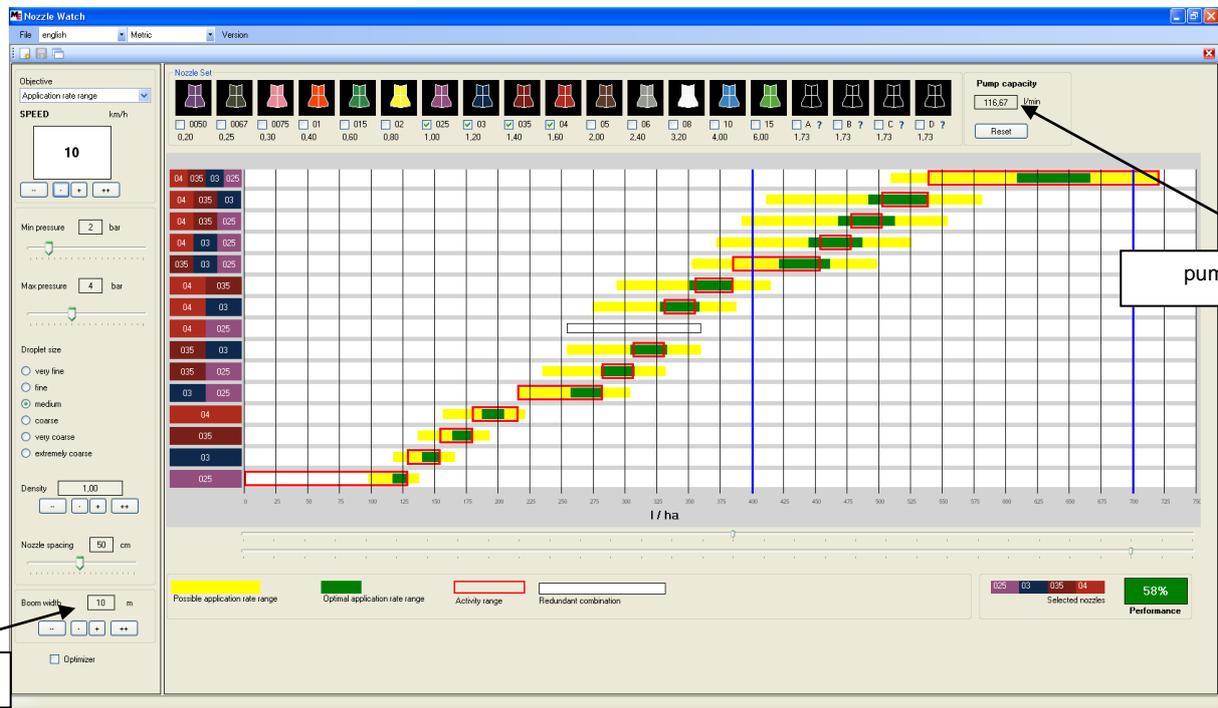
This opens another window from which the user can choose a second set of nozzles:



The objective ranges in the two windows are synchronized (refining the range in one window refines it in the other, so that they are identical). The control parameters are shared by the two windows. This allows a clear comparison.

## Other features: pump capacity

The tool also displays the pump capacity in l/min or (GPM) of the chosen set of nozzles.



The pump capacity is sum of the flows of all the nozzles of the sprayer that are activated at the extreme (maximum) end of the objective range.

The number of nozzles of the sprayer that are activated depends on the number  $H$  of nozzle holders on the sprayer where  $H = \text{boom width} / \text{nozzle spacing}$ .

**Example:** in the figure above, the maximum of the objective range is 700 l/ha. At this application rate, the combination (04, 035, 03, 025) is activated (red box). The nozzle pressure at this application rate for this combination is around 3.77 bar.

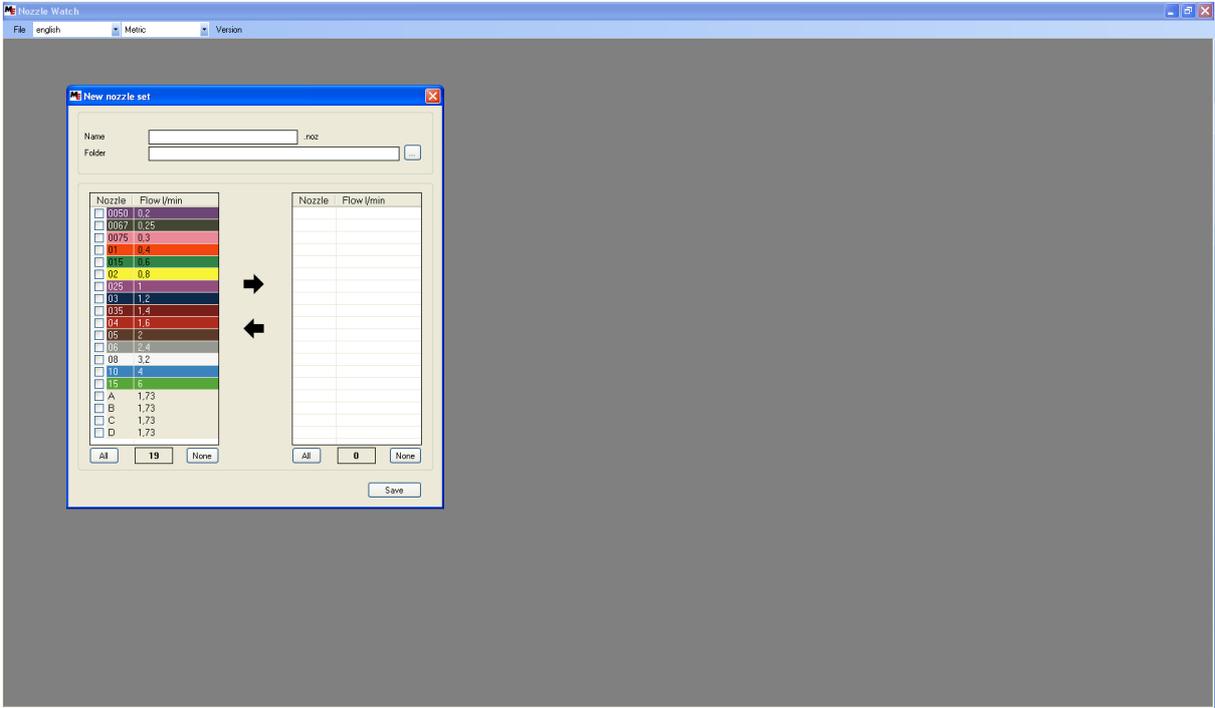
The displayed pump capacity is the sum of the flows of the four nozzles at 3.77 bar multiplied by the number of nozzle holders on the sprayer.

**Other features: creating customized nozzle set**

The tool allows the creation of a customized set of nozzles by excluding some from the standard set. Click on File-> New nozzle set

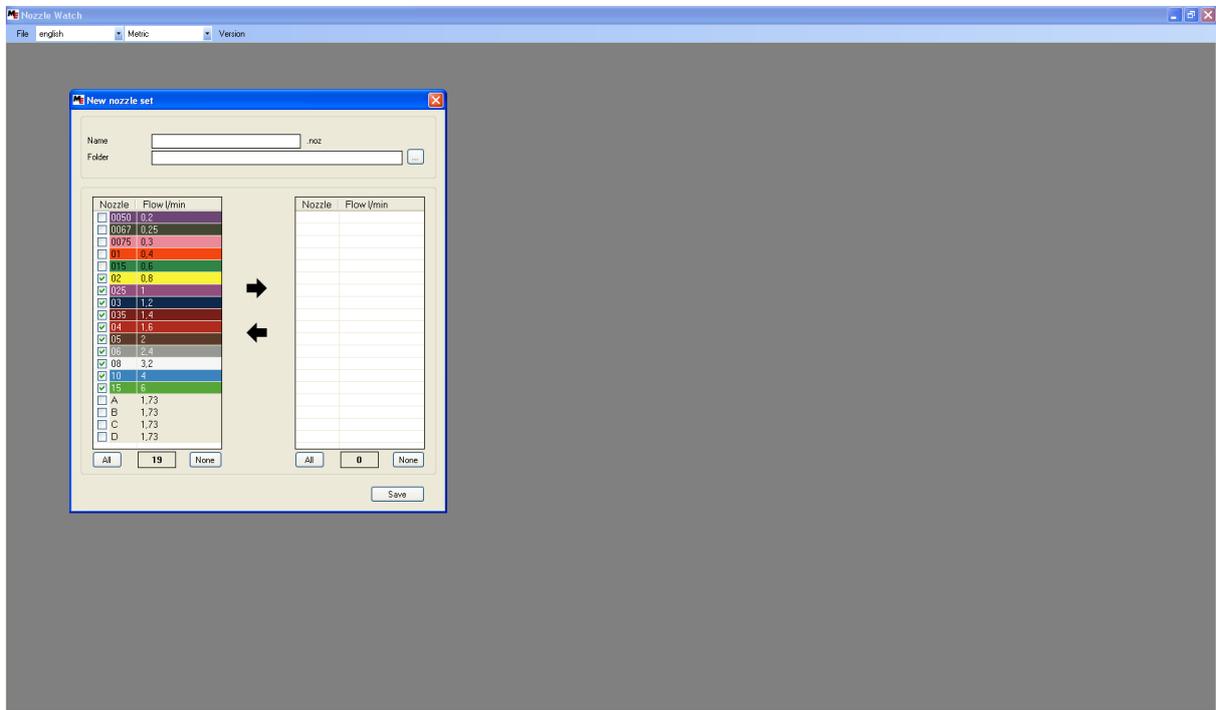


This opens the new nozzle set creation window:

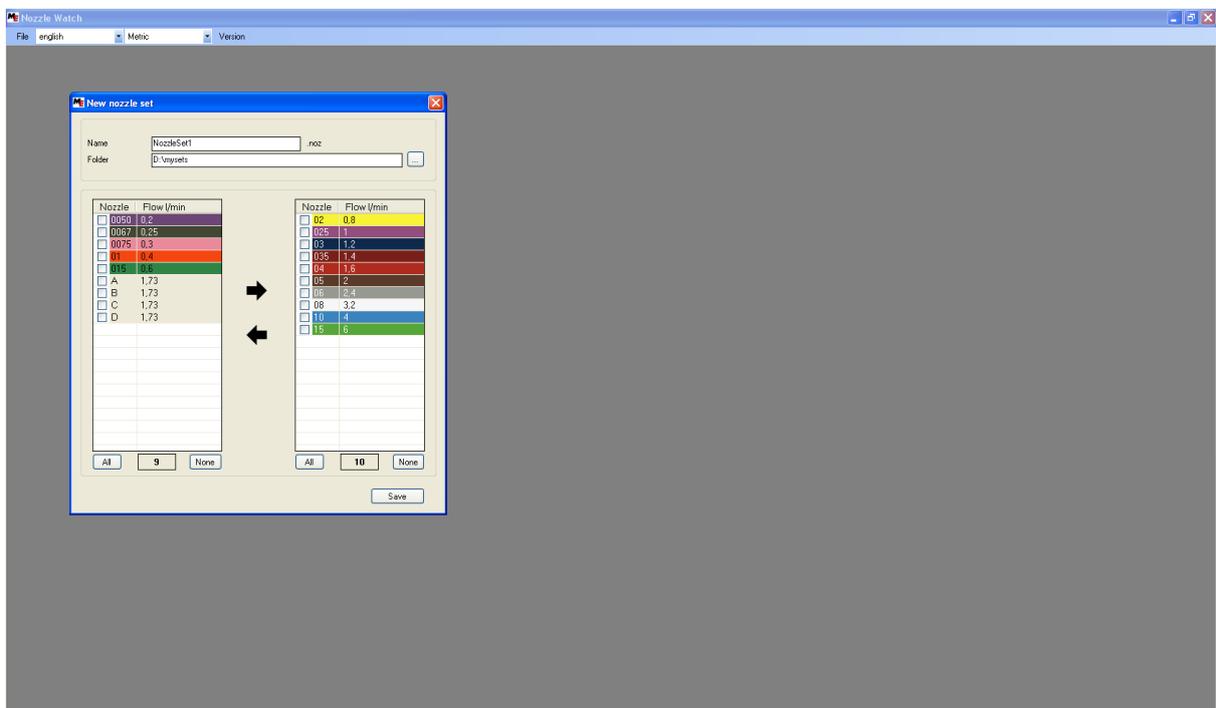


## Other features: creating customized nozzle set

Select the nozzles you want to include in your set by checking them from the left hand panel, and clicking on the -> arrow.



Specify a name and a destination directory for your nozzle set (it will be stored as a .noz file, which can be opened by any text editor). Click on save. Your nozzle set will be created.

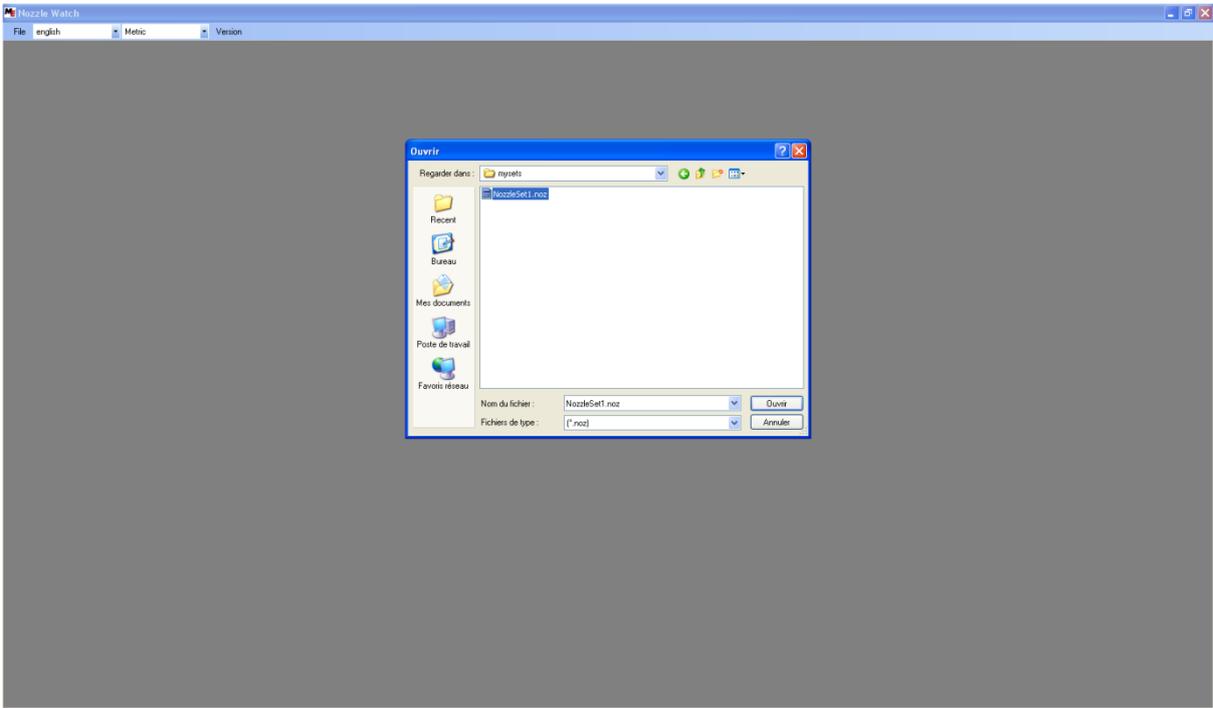


**Other features: loading customized nozzle set**

A customized nozzle set can be loaded by clicking File->Open a nozzle set

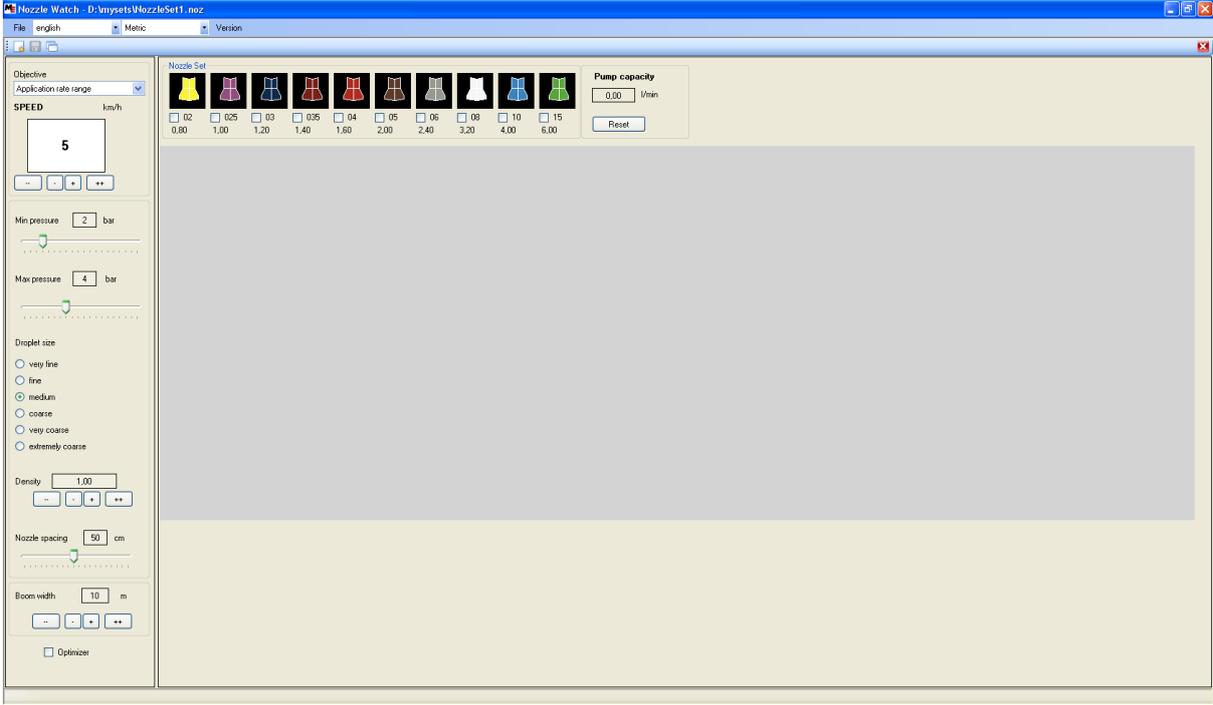


Search the .noz file of the customized nozzle set and click ok.



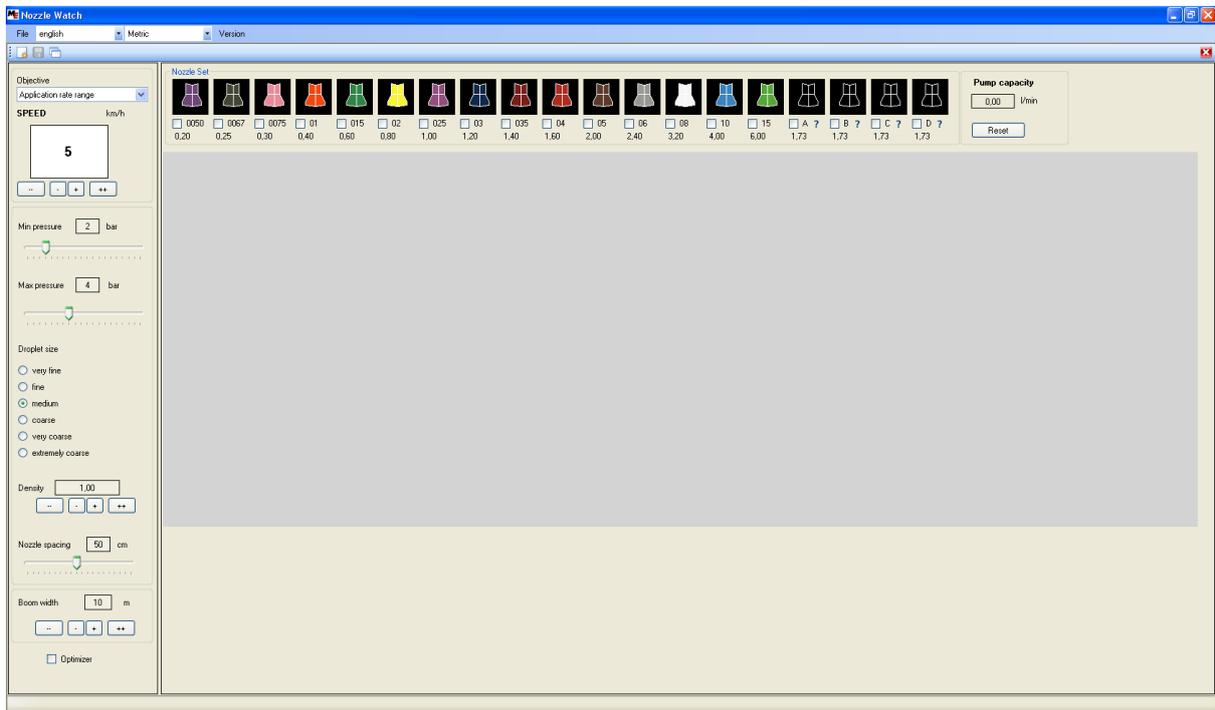
**Other features: loading customized nozzle set**

The customized nozzle set will be loaded.

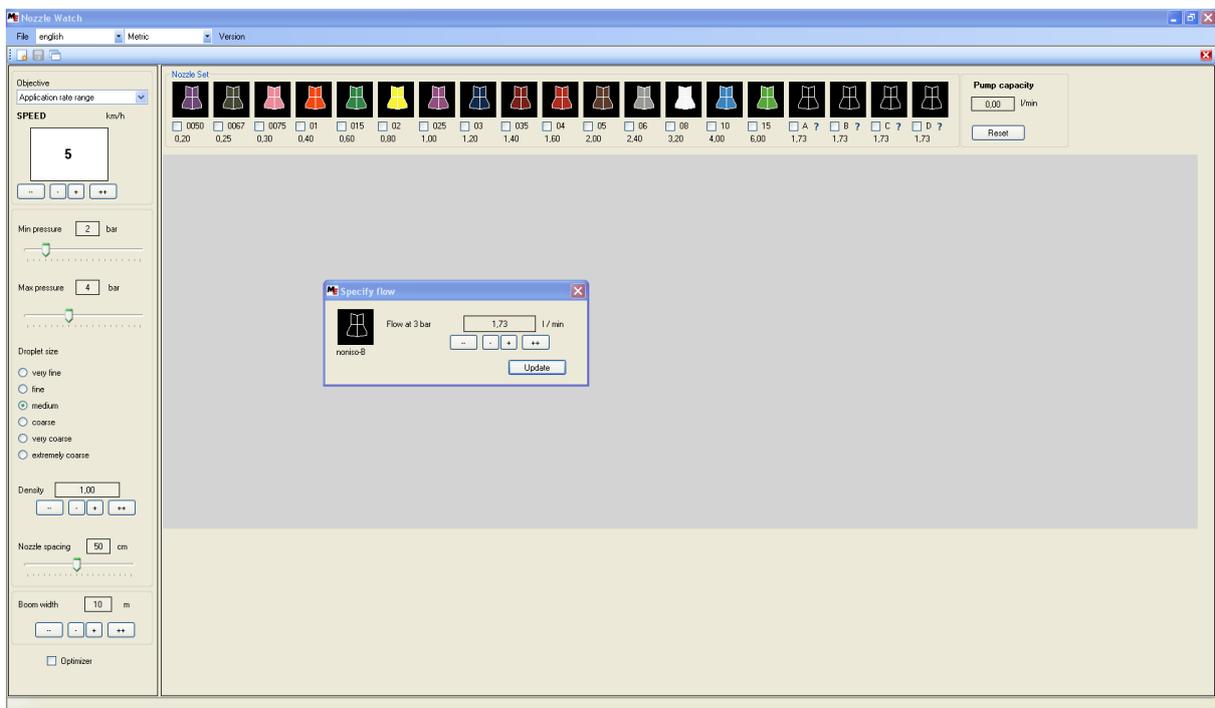


## Other features: non-ISO nozzles

The tool allows defining the standard flow rate (in l/min or GPM) of a non-ISO nozzle. Open the standard set or a customized set that contains a non-ISO nozzle (A, B, C or D):

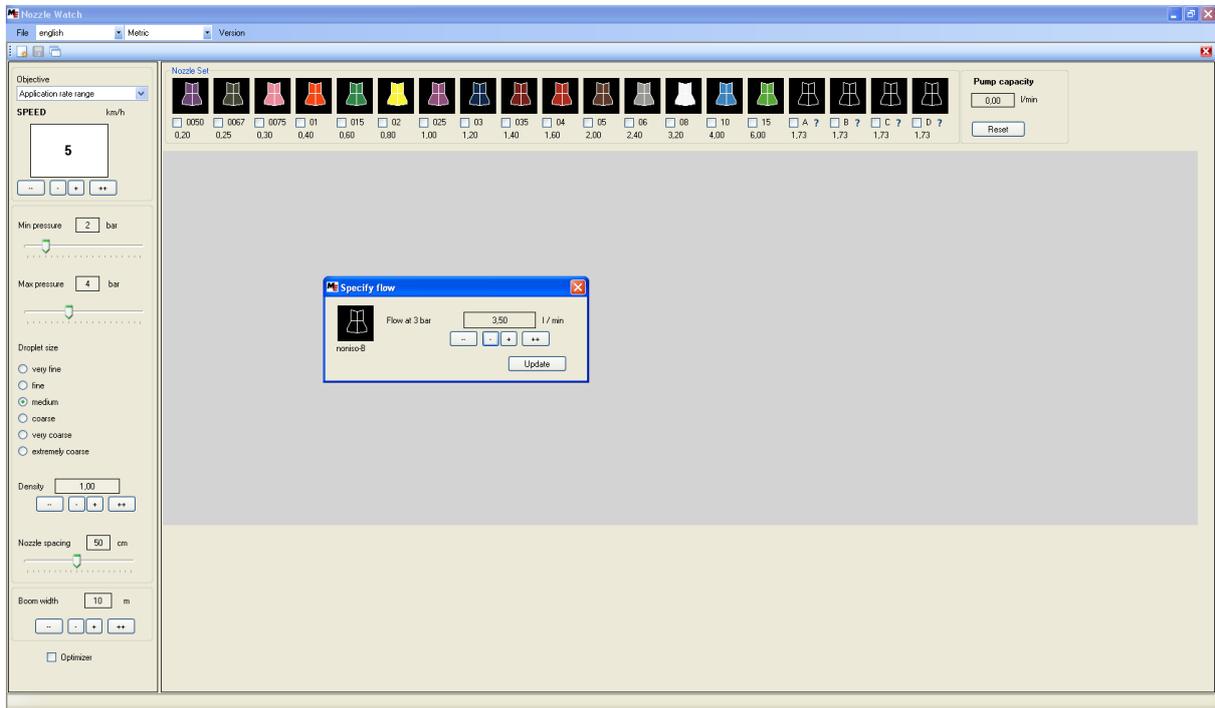


Click on the ? icon below the non-ISO nozzle whose flow is to be defined. The nozzle flow window opens:

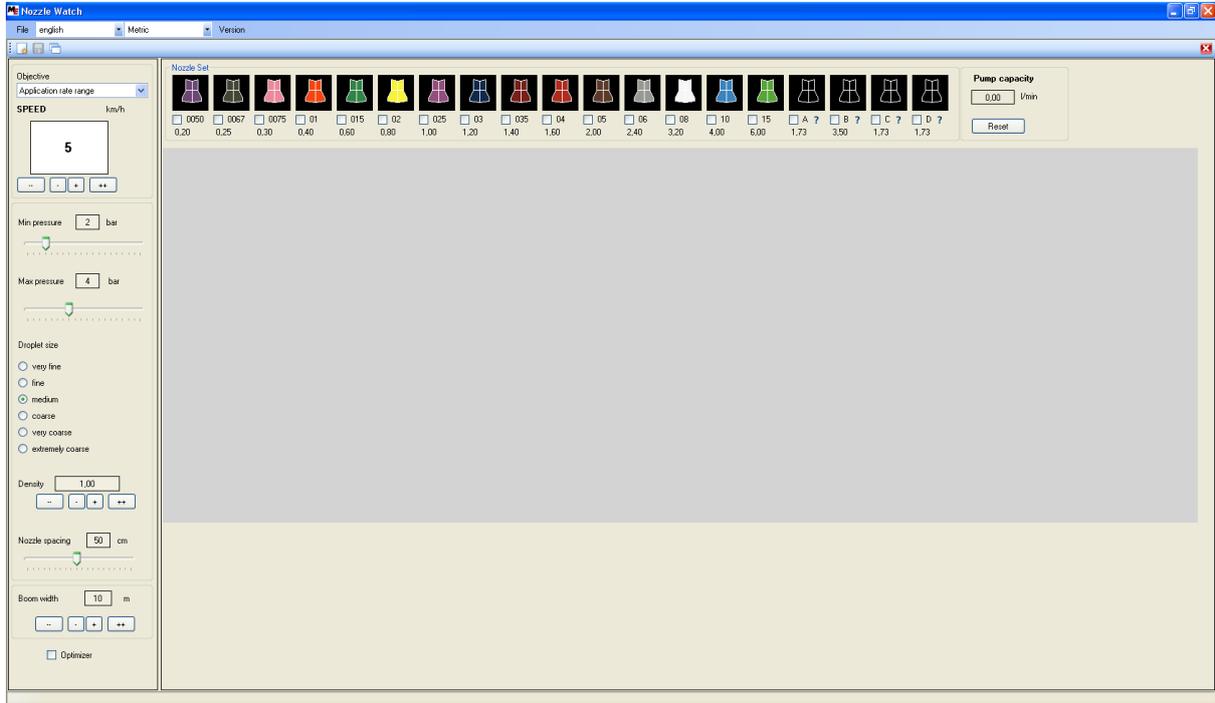


## Other features: non-ISO nozzles

The flow rate can be defined using the '+' and '-' buttons.

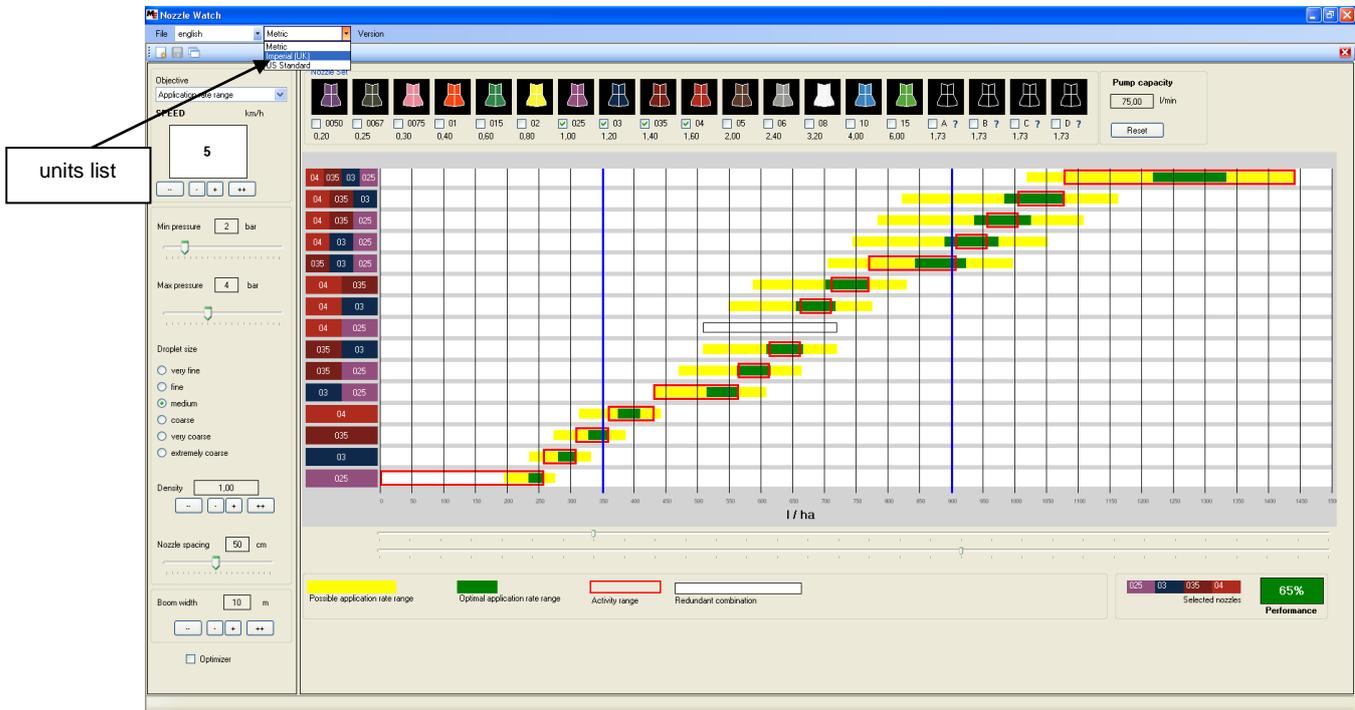


Click on update after changing the flow rate. The new flow rate will appear alongside the nozzle:

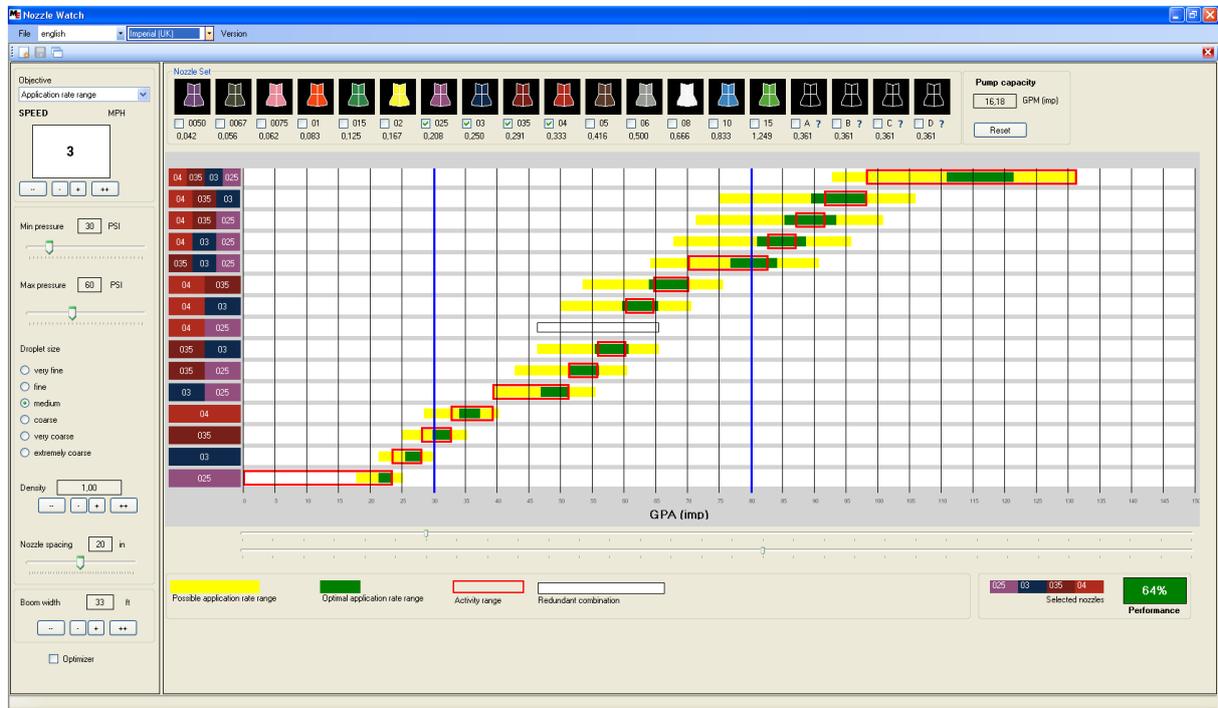


## Other features: changing measurement units

Apart from metric units, the tool allows usage of the other measurement units: imperial and US. The desired units can be selected from the units list:

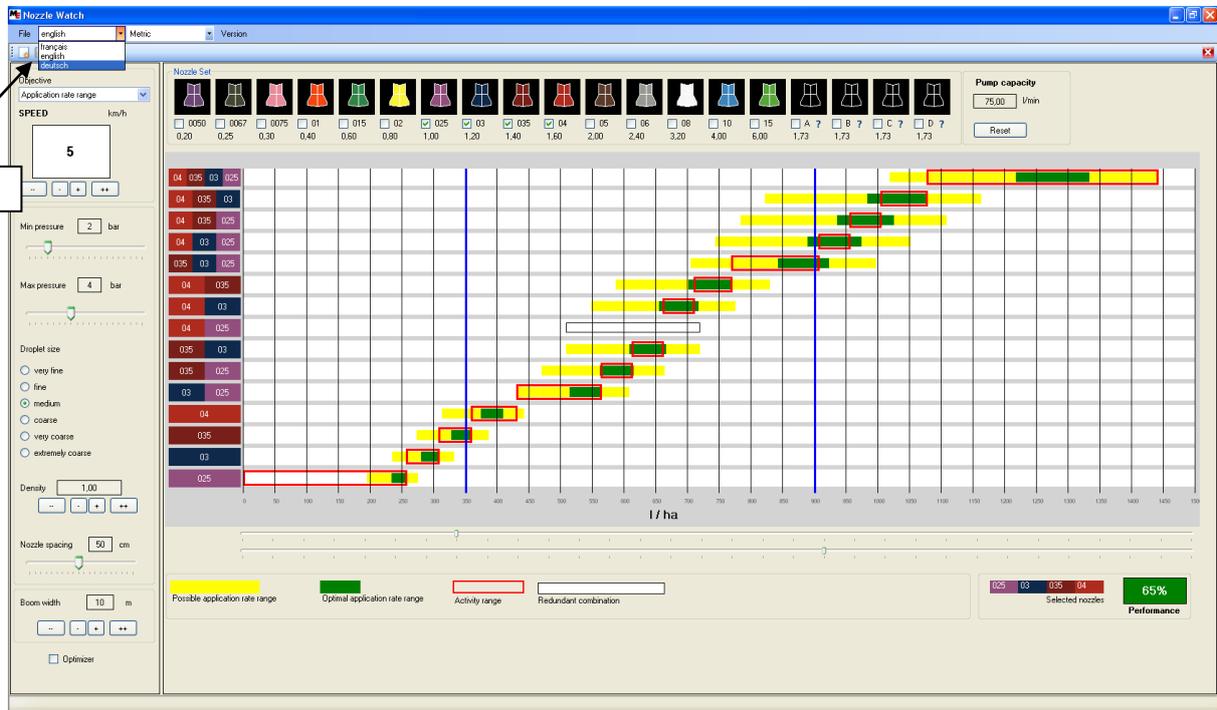


Upon a change of units, the parameters and working graph is instantly updated:



## Other features: changing the language

Besides English, the tool comes in two other languages: French and German. The desired language can be selected from the languages list.



Upon a change of language, the text of the tool is instantly updated:

