TECHNICAL ELEMENTS AND QUALITY INDICES OF SPRAY IRRIGATION IN FORESTRY NURSERIES

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Abstract
This paper presents technical elements and quality indices of spray irrigation in forestry nurseries

Key words: irrigation, physical properties, soil humidity.

INTRODUCTORY NOTIONS

A major component of irrigation process represents the irrigation operation. After Huguet and Fourcade (1980), before the establishment of a system of spray irrigation, it should answer to the following major questions: the frequency and the duration of irrigation, the flow rate, the number and the position of the water sprayers.

To a kind of soil corresponds only a kind of flow rate which can assure the necessary quantity of water without producing plashes. This flow rate depends mostly on the physical soil properties. The frequency and the duration of irrigation depend on the soil properties and the water requirements of the seedling. The number of water sprayers depends of the maximum water quantity necessary to a mature plantation. (Popescu, I., 1984)

As a consequence, the establishments of the water requirements for the plants and of the most proper methods to cover them gets a complex characteristic, and it requires a higher attention from the specialists mostly regarding the investigations which are at the base of the design of the irrigation systems.

The notion of irrigation operation is very large, being connected to the plant, climate, soil etc. It refers to all the irrigation norms which all in all represent the irrigation norm that is applied to a crop at different periods.
MATERIAL AND METHOD

One of the most important aims of the experiences is the determination of the total water consumption in conditions of non irrigation and irrigation. It will also be determined the day consumption in monthly averages, depending on the irrigation operation. The used methodology for calculating water consumption was that of the balance of soil water.

For the proper determination of water consumption it will be established precisely the water supply from soil at the beginning and at the end of the vegetation period, carrying out a precise evidence of water quantity from the rainfalls and irrigation. It will be followed the fact that through irrigations not to overhaul the humidity values over the field capacity, avoiding in this way the water drift losses.

To observe the influence of the spray irrigation upon the ecological factors from worked soil it is necessary the determination of some of these factors which are: soil humidity and water supply.

Soil humidity U (%)

Soil humidity is the water quantity that exists in soil in the moment of the analysis expressed in percents from the mass of dry soil (at 105).

The results of the determination are obtained with the formula (1):

\[ W = \frac{a - b}{b - c} \times 100 \]  

(1)

where: 
- \( W \) – soil humidity (weight percents);
- \( a \) – the weight of the weighing bottle with wet soil [g]
- \( b \) – the weight of the weighing bottle with dry soil [g]
- \( c \) – the tare of the bottle.

Soil water supply \( R_a \) (m3/ha)

Water supply is the water quantity which can be found at certain depths on the ploughed soil layer. It was determined on the base of soil humidity \( U \), expressed in percents from the soil volume using the relation (2):

\[ R_a = U \times D_a \times h \]  

[m3/ha]  

(2)

Where: 
- \( U \) is the humidity (%)
- \( D_a \) – the apparent density (g/cm3)
- \( h \) – the determination depth (m) (Canarache A., 1990)

Quality indices of irrigation:

Rain intensity

The height of the water layer made by spray irrigation in the time unit, expressed in mm/h is the rain intensity or pluviometry, the water sprayers functioning in the irrigation scheme below. There are more notions of rain
Hour average intensity (ih) is that shown in the characteristics tables of the water sprayers and it is calculated with the formula:

$$i_h = \frac{1000q_a}{d_1d_2} \text{ [mm/h]}$$

(3)

where: $q_a$ is the flow rate of the water sprayer, in m$^3$/h;

$d_1$ – the distance among the water sprayers from the wing, in m;

$d_2$ – the distance among the spray irrigation wings, in m.

The real average intensity (ir) is obtained experimentally; collecting water in pluviometric recipients set on the surface delimited by those four water sprayers or under an only one water sprayer (isolated), but the results should be processed in the schemes $d_1 \times d_2$.

$$i_r = \frac{\sum h}{n} \text{ [mm/h]}$$

(4)
where:
\[ \sum h \] is the sum of the rain height collected in the pluviometric recipients during an hour, in mm;
n – the number of the pluviometric recipients.

The real average intensity has lower values than the hour average intensity, the difference being the water loss from the water sprayer flow, which in the conditions of our country those average losses during 24 hours are of 10%.

The maximum intensity corresponds to the limit of the rainfalls with the higher value, appears at the wind speed of over 3 m/s and it is studied for avoiding the phenomenon of plashes and leaking at the surface of water.

The sudden intensity \((i_s)\) is conventionally the high of water which fall at each rotation of the water sprayer:

\[
i_s = \frac{1000 \cdot q_a \cdot t_r}{3600 \cdot d_1 \cdot d_2} \quad (5)
\]

where:
\(q_a\) is the flow rate of the water sprayer, in m³/h;
d₁ – the distance among the water sprayers from the wing, in m;
d₂ – the distance among the spray irrigation wings, in m;
tᵣ – time of rotation of the water sprayer, in s.

This intensity is calculated to avoid the phenomenon of plashes and leaking at the surface of soil. For the correlation of the rain intensity with the soil and slope factors the following values are recommended:

Table 1
Rain intensities identified on different soils

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Identified rain intensities (mm/h)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>12.7-19.5</td>
<td>12-30</td>
</tr>
<tr>
<td>Medium</td>
<td>6.3-12.5</td>
<td>6-12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy</td>
<td>2.5-6.3</td>
<td>&lt;6</td>
</tr>
</tbody>
</table>
Table 2
The decrease of the identified rain and the flow beam at different slopes of the field

<table>
<thead>
<tr>
<th>I</th>
<th>The decrease of the identified intensity (%)</th>
<th>The decrease towards upstream</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>beam jet (%)</td>
<td>area jet (%)</td>
</tr>
<tr>
<td>0-0.05</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.06-0.08</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>0.09-0.12</td>
<td>40</td>
<td>9</td>
</tr>
<tr>
<td>0.13-0.20</td>
<td>60</td>
<td>19</td>
</tr>
<tr>
<td>&gt;0.20</td>
<td>70</td>
<td>-</td>
</tr>
</tbody>
</table>

b). The rain sensitivity

The rain sensitivity from the water sprayer depends on the size of drops and it is important in the practise of irrigation through the correlation that is established with the soil and the slope.

Many experiments highlight the influence of the drops size upon the infiltration speed. For example, on the heavy soils, at a diameter of the drops of 1 mm, after 15 minutes the infiltration speed is reduced with 10%, while beginning with 2 mm the reduction is of 40%. (Pleşa I., 1979)

As a rule, it is recommended that the size of drops should be between 0.5 - 1 mm. The drops smaller than 0.5 mm bring to large losses through the evaporation of water from the flow and at slight stability at wind, changing a lot the action beam of the water sprayer.

For different correlations of the drops size with different factors, the rain sensitivity is calculated with the help of sensitivity indices $K_p$ and $B$ as well as the atomization coefficient $\alpha$.

\[ K_p = \frac{d}{H} \]  
\[ \beta = \frac{R}{H} \]  
\[ \alpha = \frac{H}{d} \]

where:
D is the diameter of the spray nozzle, in mm
H – the water pressure at the water sprayer
R – spraying beam of the water sprayer, in m
c). Irrigation uniformity

The technique of the sprayed water distribution on the surface of soil is of highly importance for the appreciation of the irrigation quality. This distribution, expressed through the uniformity coefficient has implications in the crops development and also upon the obtained productions.

In the experiments of researches from our country and other countries, the uniformity coefficient is used mostly (Cu), after Christiansen.

\[
C_u = 100 \left[ 1 - \frac{\sum (h - m)}{m \cdot n} \right] \quad [\%]
\]

where:
- h is the water height in each pluviometric box, in mm;
- m – water average height fell in pluviometers, in mm
- n – the number of the pluviometers recipients (Săulescu N., 1967)

d). Irrigation efficiency

The expressing of the irrigation efficiency is done according to the irrigation uniformity and water losses, highlighting that at air temperatures of 30-35 C and at the wind speed of 4.5 – 5 m/s the water losses through evaporation can reach at a moment, during the day, values of 33 – 36 %. It is interesting the average of the losses during 24 hours, which records values of 10% in the conditions of our country.

e). Irrigation time

Time of irrigation application (t) in a position of the wing of spray irrigation (immobile) is established with the formula:

\[
t = \frac{m}{10 \cdot i_h} \quad [\text{ore}]
\]

where:
- m is the norm of the coarse irrigation, in m³/ha;
- I_h – hour average intensity, in mm/h.

At the irrigation applied during the night a reduction of time can be done up to 10% having into consideration the fact that the water losses are reduced.

THE PLACE OF RESEARCH

From the climatic point of view the area where research was taken is presented in table 3.
The general characterisation included in the experiment

Table 3

<table>
<thead>
<tr>
<th>Nrb.</th>
<th>Nursery</th>
<th>The altitude m</th>
<th>Vegetation area</th>
<th>Climatic province Köppen</th>
<th>Stoenescu</th>
<th>Annual rainfall (mm)</th>
<th>Type of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Iarac</td>
<td>100</td>
<td>Forest steppe (of water meadow)</td>
<td>C.f.a.x.</td>
<td>I.B.p.1</td>
<td>500-600</td>
<td>erratic soil</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSIONS

An ideal water sprayer should achieve an intensity whose value to increase continuously with low values from the flow periphery towards the water sprayer. These types of water sprayers achieve a good irrigation uniformity when the work schemes are established prudently, taking into consideration the distribution of the intensity on the beam.

Picture 2. Irrigation intensity resulted after the superimpose
The interpretation of rain quality is the following:

- $K_p < 0.3$ – sensitive rain recommended for seed-tree plants, sensible crops, fields sowed recently, on heavy soils;
- $K_p = 0.3 - 0.5$ – average rain, recommended for trees, herb plants, on average soils up to heavy soils;
- $K_p > 0.5$ – harsh rain, recommended for the pastures and hay on sandy and light soils.

For the spraying coefficient $\infty$ it is considered: $2.5 < \infty < 5.0$. More than 5.0 it is not recommended, because a too high quantity of energy is used and smaller than 2.5 the harsh rain is produced. For the interpretation: when $Cu = 100-85\%$ a very good and good uniformity, $Cu = 85-75\%$ an average uniformity, $Cu = 75-65\%$ a low uniformity, $Cu = a$ misfit uniformity.

The irrigation uniformity depends on the wind speed and its direction, on some technical characteristics of the water sprayers, the high of their fixing. (Vlad I. S, 1982). The research done in our country regarding the wind speed and its frequency, the finding of most favourable distance of water sprayers fixation are shown in the below table:
The optimal distance of fixing the water sprayers depending on the wind speed

Table 4

<table>
<thead>
<tr>
<th>Wind speed, m/s</th>
<th>The distance among the water sprayers, % from the diameter</th>
<th>Wind speed, m/s</th>
<th>The distance among the water sprayers, % from the diameter</th>
<th>Wind speed, m/s</th>
<th>The distance among the water sprayers, % from the diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calm</td>
<td>65</td>
<td>1-2</td>
<td>60</td>
<td>0-1.5</td>
<td>60-70</td>
</tr>
<tr>
<td>0.0-2.5</td>
<td>60</td>
<td>2-3</td>
<td>50</td>
<td>1.5-3.0</td>
<td>50-60</td>
</tr>
<tr>
<td>2.5-5.0</td>
<td>50</td>
<td>3-4</td>
<td>30-50</td>
<td>3.0-4.0</td>
<td>40-50</td>
</tr>
<tr>
<td>&gt;5.0</td>
<td>30</td>
<td>&gt;4</td>
<td>30</td>
<td>4.0-5.0</td>
<td>30-40</td>
</tr>
</tbody>
</table>

Up to the wind speed of 2m/s significant changes do not appear in the irrigation uniformity. This speed is frequently identified in the irrigate regions of our country, being included in the speed category from 1-3 m/s, a dominant category in the irrigation period March – October.

At the change of the schemes should be taken into consideration the wind speed and the height of the water sprayer.

The wings are fixed perpendicularly as possible on the dominant wind, and the water sprayers are fixed at the height of 40 – 60 cm above the soil, to avoid wind slime which is formed immediately on the soil.

Regarding the irrigation uniformity along the wings of spray irrigation, this is considered acceptable if the capacity loss between the first and the last water sprayer (Kp) does not overtake 20% from the operation pressure: Kp < 0.2 Hₐ, where Hₐ is the operation pressure of the water sprayer.

The water quantity stored in soil before and after the irrigation process through spray irrigation is shown in table 5.

Quantity of water stored in soil

Table 5

<table>
<thead>
<tr>
<th>Soil physical characteristics</th>
<th>U.M.</th>
<th>Depth of sample taking, cm</th>
<th>Average, non irrigated soil</th>
<th>Average, irrigated soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural humidity, W</td>
<td>%</td>
<td>0-5</td>
<td>20.04</td>
<td>21.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-10</td>
<td>18.91</td>
<td>23.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-20</td>
<td>17.14</td>
<td>25.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-30</td>
<td>16.27</td>
<td>27.37</td>
</tr>
<tr>
<td>Water supply, Ra</td>
<td>m³/ha</td>
<td>0-5</td>
<td>176.05</td>
<td>135.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-10</td>
<td>331.61</td>
<td>292.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-20</td>
<td>449.10</td>
<td>485.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-30</td>
<td>731.97</td>
<td>793.47</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Irrigation intensity as well as irrigation uniformity are mostly influenced by the work pressure and the used spray nozzle. So, when the water sprayer works at a too low pressure, large drops are obtained and also a non-uniform distribution of water. When the pressure is too high, the flow of the water sprayer is sprayed in too tiny drops which are distributed around the water sprayer. Moreover, water distribution is strongly influenced by wind. Functioning at the work pressure recommended assures a normal distribution of water.

For the normal running of the physiological processes, each plant needs that the soil should have a certain amount of water, called optimum amount of humidity.

It was proved that this optimum amount of humidity, coincides, approximately, with the value of the field capacity for water, the humidification level at which it is achieved through the soil pores a favourable balance between water and air.

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