

## II. WATER AND NUTRITION SUPPLY IN RELATION TO PLANT MOISTURE SUPPLY AND FERTILIZATION OF POT PLANTS

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**Abstract.** - In a pot experiment with gloxinia five nitrogen rates were compared at three moisture levels. The nitrogen rates were 100, 200, 300, 400 and 500 mg N per litre substrate. The soil moisture levels were 90, 65 and 40% of the substrate water capacity.

The salt concentration of the substrate solution seemed to be much affected by both moisture supply and N rate, implying that total suction rather than matric suction should be regarded as representative of soil moisture availability.

Average yield of aerial parts, highest at 90% water capacity, decreased markedly with lowered moisture supply.

Increase in soil moisture stress also depressed yield increment per unit nitrogen applied. This reduction in nitrogen effect represented a decrease in efficiency of nitrogen utilization of the plant, attributable to a disturbance in nitrogen metabolism in the leaf at rising suction tension in the leaf.

For optimum vegetative growth and nitrogen effect, measures to be taken to control leaf suction tension throughout the growing season, should extend over both soil and climatic conditions.

**Introduction.** - The effectiveness of fertilizers, especially of nitrogen, is known to depend strongly on adequate moisture supply. Doss *et al.* (1964), conducting a field experiment with five N rates at three moisture regimes, found that the response of sorghum to nitrogen, largest at the first increment, was markedly increased when a supplementary irrigation was given at 80% depletion of the available soil moisture (i. e. the soil moisture range between field capacity and wilting point) in the surface 24 inches of soil. With supplementary irrigation at 30% depletion the nitrogen response was even higher. Likewise, Bierhuizen *et al.* (1959) found in a pot experiment with tomato plants, that increase of total leaf area per unit of nitrogen applied was distinctly larger when irrigating at 20% depletion than when irrigating at 90% depletion of the available soil moisture.

In pot plants, so far little attention has been paid to the role of moisture supply as a limiting factor in the relationship between nutrition and plant response. This paper presents the results of a trial designed to study the relationship between nitrogen nutrition and moisture supply for gloxinia. Besides the trial served to evaluate the appropriate soil moisture range for pot plants, another topic in need of more elucidative data.

**Some basic concepts.** - When studying plant water relations it is useful to bear in mind the following concepts:

vel.

The trial lasted from April 3 until June 7.

During the trial water use was estimated by loss of weight of the pots, allowing for weight of plants. At the end of the trial the yield of both fresh and dry weight of the aerial parts of the plants were estimated.

### Results and discussion.

a. Salt concentration of the soil solution. - As could be expected the changes in soil moisture content did not fail to affect the salt concentration of the soil solution. In Fig. 1 the specific conductivity (EC) of the extract, expressed from the soil at the required moisture level, has been plotted against N rate. It should be remembered, that EC serves as a measure for  $S_g$ . For the conversion of EC ( $\text{mmho. cm}^{-1}$  at  $25^\circ\text{C}$ ) of press extracts into  $S_g$  (atm at  $0^\circ\text{C}$ ) the relation  $S_g = 0.349 \text{ EC} - 0.19$  can be used (Van den Ende, 1968).

Besides a positive linear relationship between EC and N rate, the graph shows a higher average EC level for the moisture series with decreasing moisture supply. Furthermore, it is evident that the EC rise per unit increment of N increased with decreasing moisture level, resulting in a divergence of the lines. It can be noted that these curves bear a close resemblance to those representing the relationship between the EC of saturation extract and N rate for different substrates (Arnold Bik, 1970).

As  $S_g$  proved to be so much affected by both N rate and moisture supply, it seems all the more justified to regard  $S_t$  rather than  $S_m$  only, as the factor governing soil water availability.

b. Nitrogen rate and yield. - Quadrants II and IV of Fig. 2 give the relationships between plant response and N rate for yield of dry matter (DM) and fresh weight, respectively.

The "vertical" arrangement of the curves in both graphs clearly evidenced the deleterious effect of increasing moisture deficit on yield, which is undoubtedly associated with a rise in  $S_1$ , induced in turn by the increase in  $S_t$  (see Fig. 1 and Equation 1). It is striking that even as slight a decrease of the soil moisture level as that from pF 1.4 to 1.9 could exert such a detrimental effect on plant growth. Nevertheless, this effect is readily explicable by the rise of  $S_1$ , caused, firstly by the increase in  $S_t$  through  $S_g$  as shown by Fig. 1; secondly, by the decrease in the capillary conductivity, which can be very large in this range (Rijtema, 1965).

Another characteristic feature is the reduction in yield increment per unit N applied with lower water availability in the suboptimum N range, a result that confirms those of Bierhuizen *et al.* (1959) and Doss *et al.* (1964).

For fresh weight, optimum N rate appeared to be related to moisture supply, it being 500, 400 and 300 mg N per litre substrate at 90, 65 and 40% water capacity, respectively. For dry matter the N optimum was not changed by moisture regime, being 300 mg N per litre.

At excess rates of N the curves show a decline, the slope of which increased with increasing moisture deficit. As can be seen in Fig. 1,

The water status of the plant is primarily controlled, and therefore, best represented, by the suction tension in the leaf  $S_1$  (Kramer, 1963). Several investigations have shown that  $S_1$  and plant growth rate are inversely related: the higher  $S_1$ , the lower the growth rate (Slatyer, 1957; Brouwer, 1963).

The availability of water in soil or substrate to the plant is a function of the total suction  $S_t$  (Wadleigh and Ayers, 1945).  $S_t$  in turn is defined as the sum of the matric suction  $S_m$  and the osmotic suction  $S_s$ .  $S_m$  depends on the water content (v/v) of the soil in such a way as given by the pF curve which is specific for the pore size distribution of the soil.  $S_s$  is related to the salt concentration of the soil solution. Specific conductivity of the soil extract serves as a proper measure of salinity, and thus of  $S_s$ .

The relationship between  $S_1$  and  $S_t$  is given by the following equation, derived by Rijtema (1965):

$$S_1 = E (R_{pl} + b/k) + S_t \quad (1)$$

in which E is transpiration rate,  $R_{pl}$  resistance to water movement in the plant, b a factor representing the effect of the root system and that of the root activity and k capillary conductivity of the soil.

From Equation 1 it can be seen that  $S_t$  is not the only factor affecting  $S_1$ .

**Material and methods.** - A factorial trial carried out in 1968 included five N rates and three moisture regimes.

The five N rates were 100, 200, 300, 400 and 500 mg N per litre substrate. Nutrients not under test were supplied at 240 mg  $P_2O_5$ , 360 mg  $K_2O$  and 60 mg MgO per litre substrate, minor elements being added in ample amounts. The fertilizers were incorporated into the substrate before planting.

The substrate used consisted of 1 part by volume of coarse sand and 9 parts of sphagnum peat moss, limed up to a pH (water) range of 5.5 to 6.0.

Plastic pots were used with a top diameter of 11 cm and an effective soil volume of 500 ml.

The water regimes were established by daily watering the pots of the treatments concerned to 90, 65 and 40% of the water capacity. To measure the water capacity, normal pots with the usual volume of soil, were allowed to stand overnight in saucers filled with tap water up to a level of 3 cm above bottom, thus enabling the soil in the pots to soak up water to saturation. Then the pots were placed on a rack to allow the excess water to leak out. The pots were weighed as soon as the outflow of water had ceased.

This method rendered a water capacity of 311 ml per pot (the average of ten observations) or 622 ml per litre substrate. The above-mentioned moisture levels proved to coincide with the pF-values 1.4, 1.9 and 3.9 on the moisture characteristic of the substrate, which was determined later on.

The plants used were of the cultivar 'Schweizerland'. To prevent evaporation the soil surface in the pots was covered with a layer of gra-

this course agrees with the divergence of the corresponding EC lines.

From Quadrant I it can be derived that the dry matter content of gloxinia decreased with increasing moisture deficit. N decreased dry matter content between the 3rd and 5th N level for both 90% and 65% water capacity and likewise between the 1st and 3rd N level for 40% water capacity.

Quadrant IV of Fig. 3 shows that the three curves coincide in the range of the three lower rates in which uptake is proportional to N rate. Apparently, in this range (approximately below 300 mg N per litre substrate) an effect of moisture supply on N uptake was absent. However, at higher N levels this effect was quite evident, since when increasing N rate, the curve deviates sooner from the linear relationship, the lower the moisture level.

Quadrant I of Fig. 3 visualizes the efficiency with which the plant utilizes N under the three water regimes. In this respect the range of uptake between 4 and 9 meq N per plant (corresponding roughly with an N rate below 300 mg N per litre) is particularly illustrative. In this range the graph shows a marked decrease in dry matter yield at increasing moisture deficit for the same N uptake. Obviously, the utilization of N absorbed, by the plant is lowered by water stress. This presumption finds support in the result of Barnette and Naylor (1966) that water stress decreased protein synthesis and percentage protein in leaves of Bermuda grass. As N uptake was not affected in this range, the disturbance in nitrogen metabolism by water stress might be considered as the sole cause of the reduction of N effect on dry matter yield mentioned earlier.

In Fig. 4, dry matter yield has been plotted against total water use. The numbers in the graph denote the order of N level for the various treatments. Most points lie on a straight line through the origin. Thus, for the major part of the trial the transpiration coefficient (water use/DM), amounting to about 300 (g/g), seemed independent of N level and moisture supply. Treatments showing higher transpiration coefficients were the lowest N levels of all the three moisture series and the 4th and 5th N level of the lowest moisture supply series. The first three cases might be probably ascribed to an impaired chlorophyll formation by lack of nitrogen, while in the latter two cases an excessive respiration rate due to water stress presumably played a role.

The transpiration coefficient reported here for gloxinia has no general meaning, but applies, to the experimental conditions in this trial only. As Bierhuizen and Slatyer (1965) showed the transpiration coefficient varies with environmental conditions such as light intensity, air temperature, relative humidity and wind velocity.

From the foregoing the prominent role of the leaf suction tension can be concluded in determining vegetative growth and the effectiveness of nitrogen nutrition as well. For optimum results, leaf suction tension should be maintained as low as possible throughout the growing season. As for root environment this means as high a moisture content as adequate aeration would allow along with a low salinity. As for climatic conditions measures should be directed towards prevention of excessive

transpiration.

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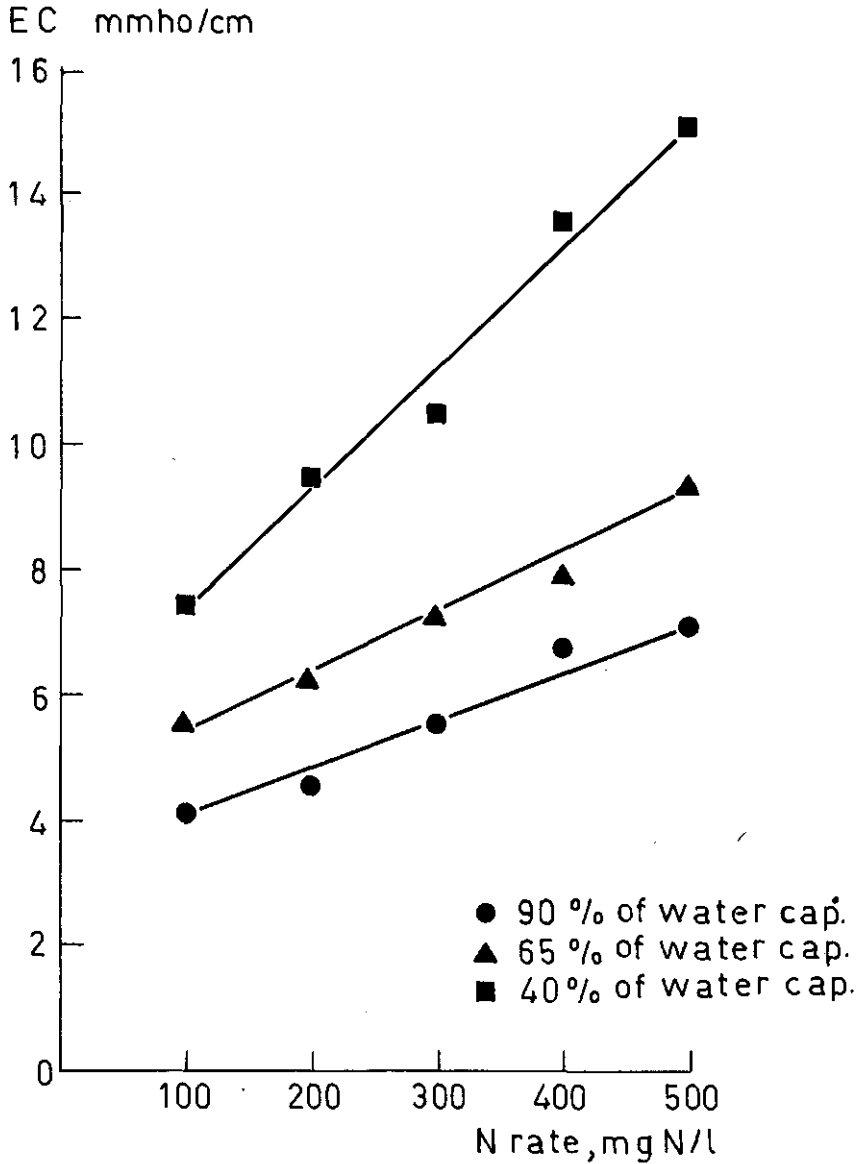


Figure 1 - Specific conductivity (EC) of expressed substrate moisture as affected by nitrogen rate and moisture supply.

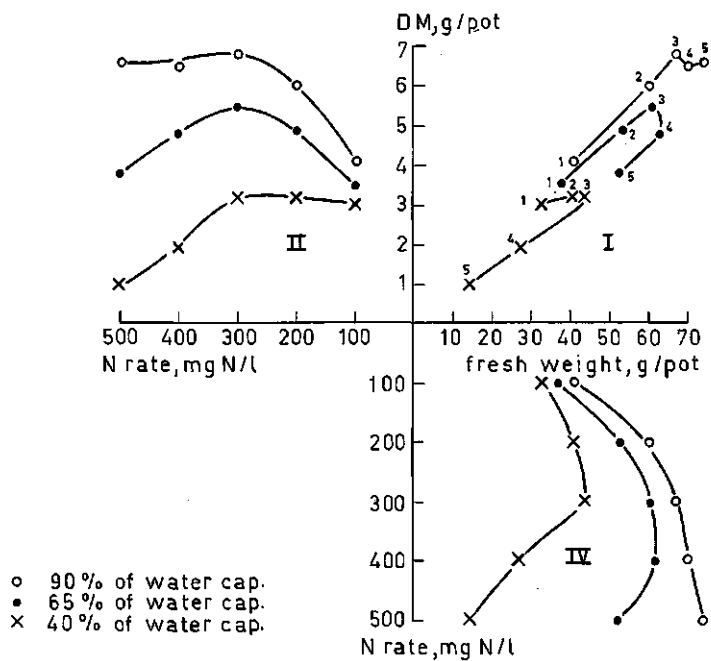


Figure 2 - Relationship between nitrogen rate, yield of fresh weight and yield of dry matter for different moisture levels in the soil.

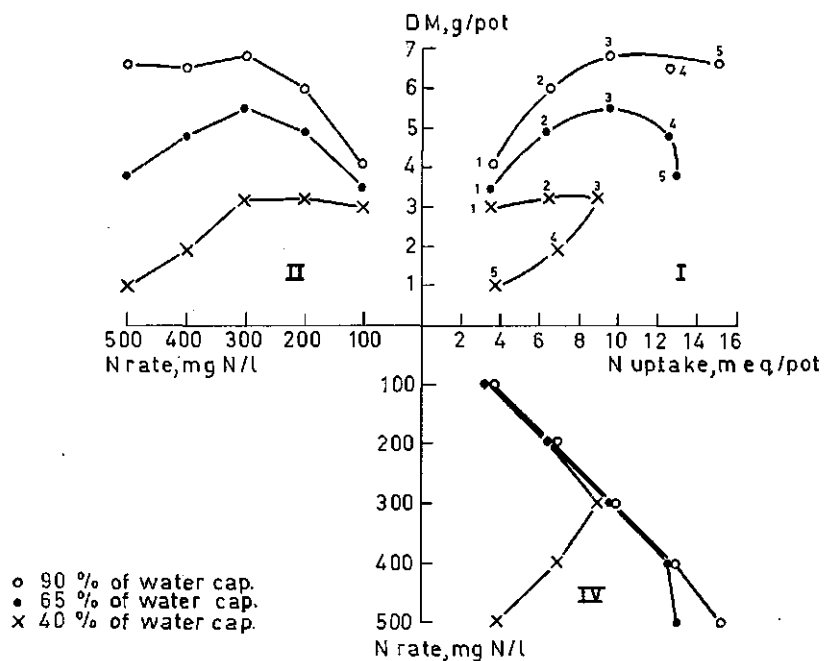


Figure 3 - Relationship between nitrogen rate, nitrogen uptake and yield of dry matter for different moisture levels in the soil.

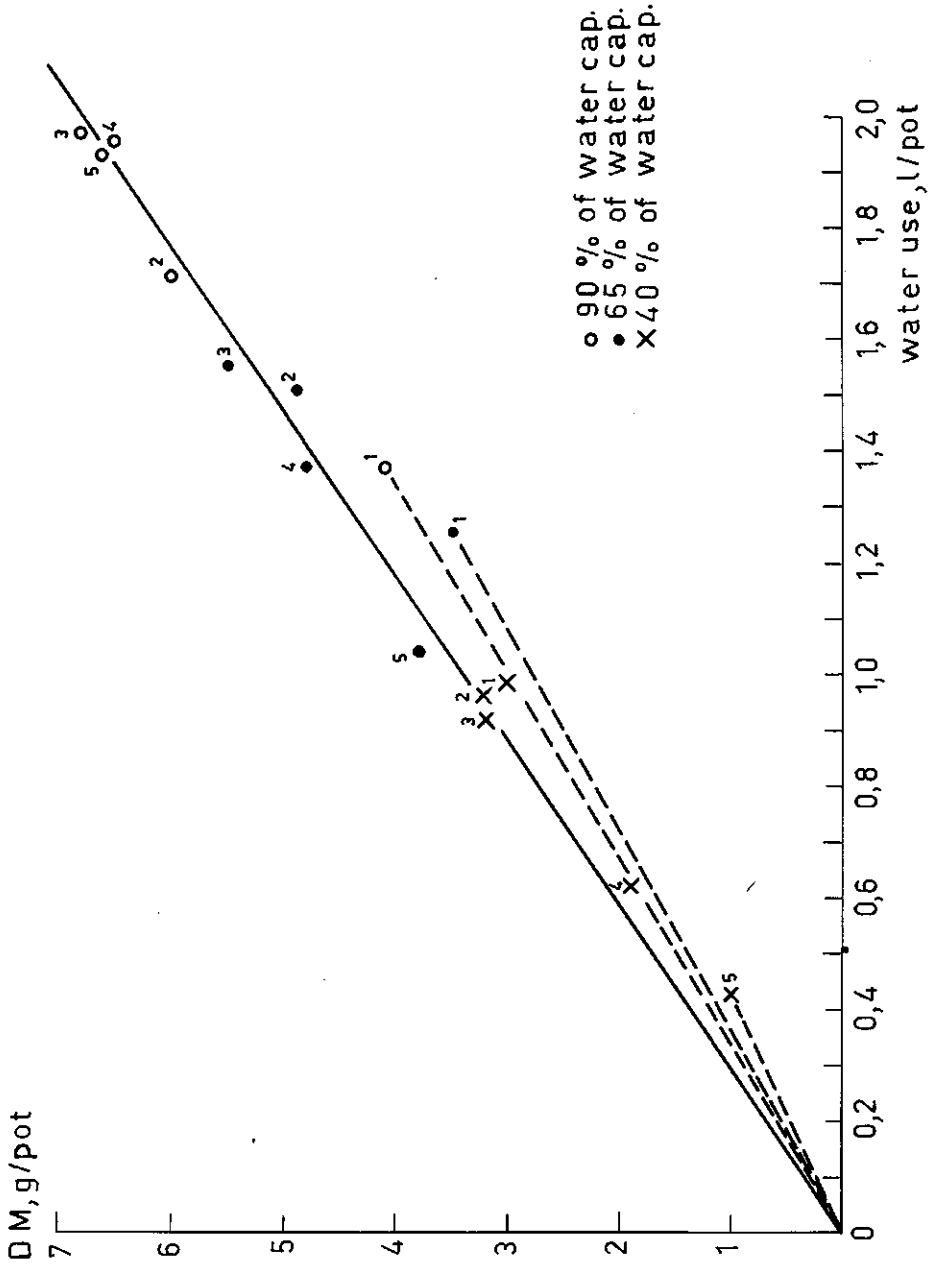


Figure 4 - Relationship between yield of dry matter and water use.





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