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Effect of Different Constant Soil Moisture Levels on Foliage Development in Maize

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Abstract. The effects of constant soil moisture levels of 90, 60 and 40% of the maximum capillary capacity, applied beginning from the planting of the germinated kernels, on the dynamics of the foliage development of maize was studied in relation to ontogenical changes in leaf area of individual leaves. There were two maxima in the growth of total leaf area (characterized by leaf area duration and leaf area relative growth rate) unrelated to the soil moisture. The first maximum which was less marked, appeared in the phase of 5–8 leaves, the second and main increase being observed before flowering in the phase of 10–12 leaves. The effects of continued decrease in soil moisture were a correspondingly progressive reduction in leaf area and delayed development of the whole plants. Plants with 60% soil moisture attained the same leaf area as those with 90% but only after the end of the vegetative phase. The greatest differences in rate of development between watering treatments appeared at the time of greatest increase in leaf area of control plants. Continued decrease in soil moisture markedly affected the development of the leaves at different insertion levels (especially in elder leaves). Clear-cut prolongation of ontogenesis took place under dry conditions. In conditions of higher soil moisture growth was rather limited or stopped after reaching a certain maximum.

Water stress brings about not only the reduction in total plant growth as characterized by production, but also profound qualitative growth changes (root-shoot ratio often increases, sometimes leaf area is reduced, thickness of the leaves is increased *etc.*). Using methods of growth analysis it was found in maize that under conditions of different soil moisture levels (held constant after planting) the differences in relative growth rate (R.G.R.) were caused chiefly by lower values of leaf-area ratio (L.A.R.) *i.e.* by the character of the leaf apparatus (VÁCLAVÍK 1967).

The leaf apparatus is often considered to be an homogenous functional unit as it is treated in works dealing with production activity, growth analysis etc. Only small attention is usually devoted to the vertical structure and its changes during the vegetative period despite the fact that all such data may bear a great theoretical and practical significance (*e.g.* IWAKI 1959,

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KUROIWA 1959, SAEKI 1960, 1961, 1963, DONALD 1961, MILTHORPE 1961 BLACKMAN 1962, MONTEITH 1965, de WIT 1965).

We therefore found it useful to complete the data on the total leaf area growth in the experiment mentioned above by further characteristics of the dynamics of leaf area growth which are directly related to the development and ontogenical course of the individual leaves.

Material and Methods

Maize plants (*Zea mays* L. cv. Stupická raná) were cultivated singly in Mitscherlich's vegetation pots (d = 20 cm) filled with sandy clay soil (pedological characteristics see VÁCLAVÍK 1967) in the greenhouse from 22. 5. to 18. 8. 1964.

There were three watering treatments with the constant soil moisture kept at 40, 60 and 90% of maximum capillary capacity. The watering doses were determined gravimetrically and increments in plant mass were considered. The water was added to the soil by means of a syringe (VÁCLAVÍK 1966b). The surface of the pots was covered by appropriate PVC discs to prevent water loss by evaporation.

The area of the individual leaf blade was determined by multiplying the maximal length by maximal width and correcting the values obtained according to a regression graph. All developed leaves were measured till their active assimilation area was greater then one half of their total area. When the leaf bladė was clearly distinguishable from the sheath this was considered as a criterion for leaf "maturity".

The total leaf area (A) represents the sum of average leaf areas at different insertion levels. Leaf area duration (L.A.D.) was expressed graphically as an area limited by the curve of increments of leaf area or time changes of leaf area respectively (A/week). The relative growth rate of the leaf area (R) was determined in a similar way as the relative growth rate of the whole plant (WATSON 1958) according to formula:

$$R_A\% = \frac{l_n A_2 - l_n A_1}{t_2 - t_1} \,.\, 100\,,$$

where A_1 is the leaf area at the beginning and A_2 at the end of the time interval $t_2 - t_1$.

Plant development was studied according to the average number of all leaves formed and to the time-course of flowering of male flowers.

Results and Discussion

The slight first maximum in the growth of leaf area appeared in all the treatments in the phase of 5–8 leaves (Fig. 1–3). 60 and 90% treatments reached this maximum between the 32nd and 39th day after planting, the

40 % treatment between the 53rd and 60th day (three weeks retardation). The following transitional drop was clearly caused by the intensive development of the root system during this period (VÁCLAVÍK 1966a).

The growth of leaf area between the 25th and 46th day in the 40 % treatment was so gradual (Fig. 1) that the increments in leaf area showed a slight decrease (Fig. 2) during this period. The relative growth rate of the leaf area

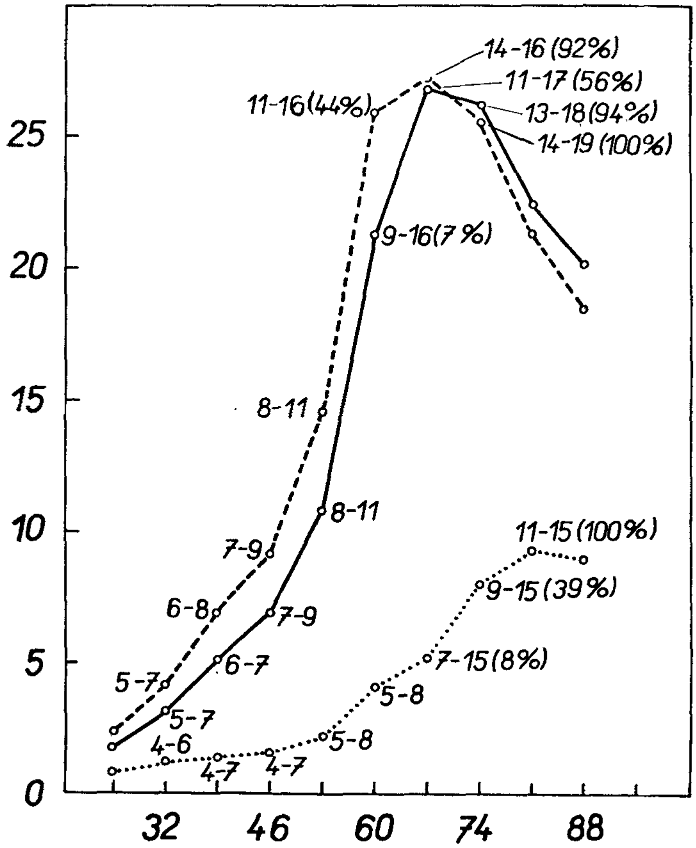

Fig. 1. The growth of total leaf area.
Abscissa: Number of days from planting. Ordinate: Total leaf area in dm^2.
...... 40% treatment, ------ 60% treatment, --- --- 90% treatment.
Number denotes growth phases (number of leaves, appearance of male flowers in per cent).

(Fig. 3) which exhibited a more or less downward trend from the beginning of vegetation started to rise quite abruptly in all the treatments on the 46th day after planting. The maximum was attained in the 60 and 90 % treatments just before the appearance of male flowers in the phase of 10 — 12 leaves (from the 53rd to 60th day after planting). A similar increment in the 40 % treatment corresponded with the first maximum of leaf area growth in the phase of 5 — 8 leaves. Under the 40 % treatment the prefloral maximum

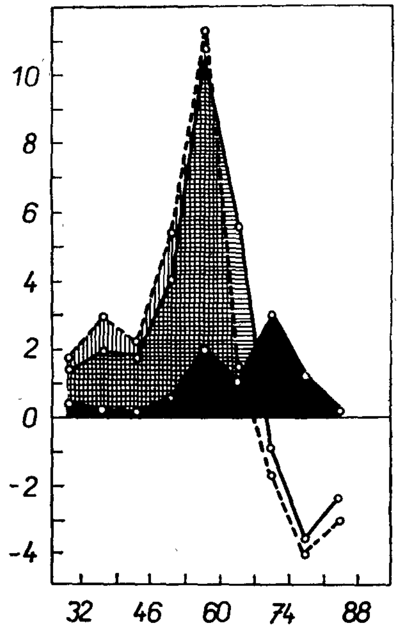

Fig. 2. Graphical expression of leaf area duration (L.A.D.).
Abscissa: Number of days from planting. Ordinate: Increments in leaf area in dm²/week.
...... 40% treatment, ------ 60% treatment, --- --- 90% treatment.

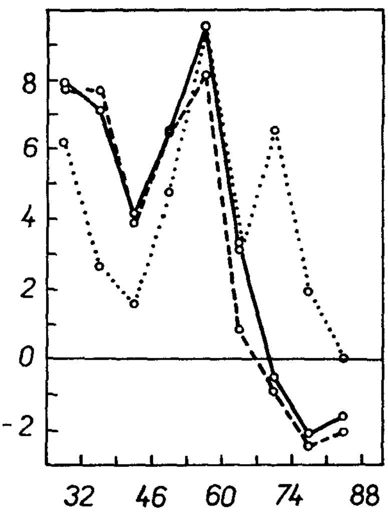

Fig. 3. Relative growth rate of the leaf area (R_A).
Abscissa: Number of days from planting. Ordinate: The relative growth rate in per cent.
...... 40% treatment, ------ 60% treatment, --- --- 90% treatment.

in the relative growth rate of the leaf area was reached in the same phase of development (10 to 12 leaves) only from the 67th to 74th days after planting. The course of the leaf area increments (Fig. 2) in this period revealed the same trend as the relative growth rate of the leaf area. The absolute maximum of the leaf area was attained in the 60 and 90% treatments on the 67th day and in the 40% treatment on the 81st day after planting.

The growth phases (number of leaves) and the course of flowering of male flowers are expressed numerically in the Fig. 1, which shows the leaf area growth. The variability in development which is not related to the soil moisture content increased during the vegetation period and hence it seems that the progressive differences between the 60 and 90% treatments are restricted to differences in the leaf area. The graphical expression of the average leaf number during the vegetative period (Fig. 4b) shows that even between these two treatments the difference in the rate of development occured. This difference reached the value of one and half leaf (higher rate

Fig. 4a.

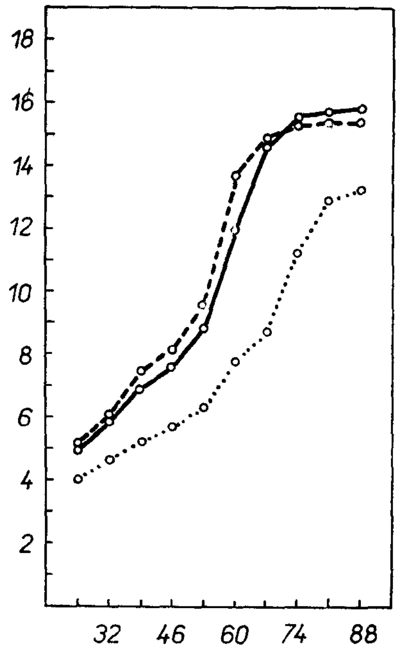

Fig. 4b

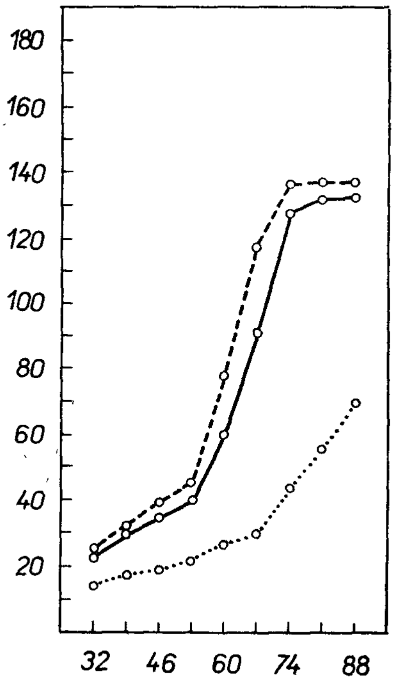

Fig. 4a. Stem elongation.
Abscissa: Number of days from planting. Ordinate: Stem length in cm.
...... 40% treatment, ------ 60% treatment, --- --- 90% treatment.

Fig. 4b. Average number of leaves formed during the vegetation period.
Abscissa: Number of days from planting. Ordinate: Average number of leaves.
...... 40% treatment, ------ 60% treatment, --- --- 90% treatment.

of development in the 90% treatment) at the time of the most intensive growth of the leaf area between the 53rd and 60th day.

Taking into account the fact that even elongation (Fig. 4a) was more intensive in the 90% treatment during the vegetative period, it is understandable that significant differences between these two treatments occured even in the vertical distribution of the leaf area (Fig. 5).

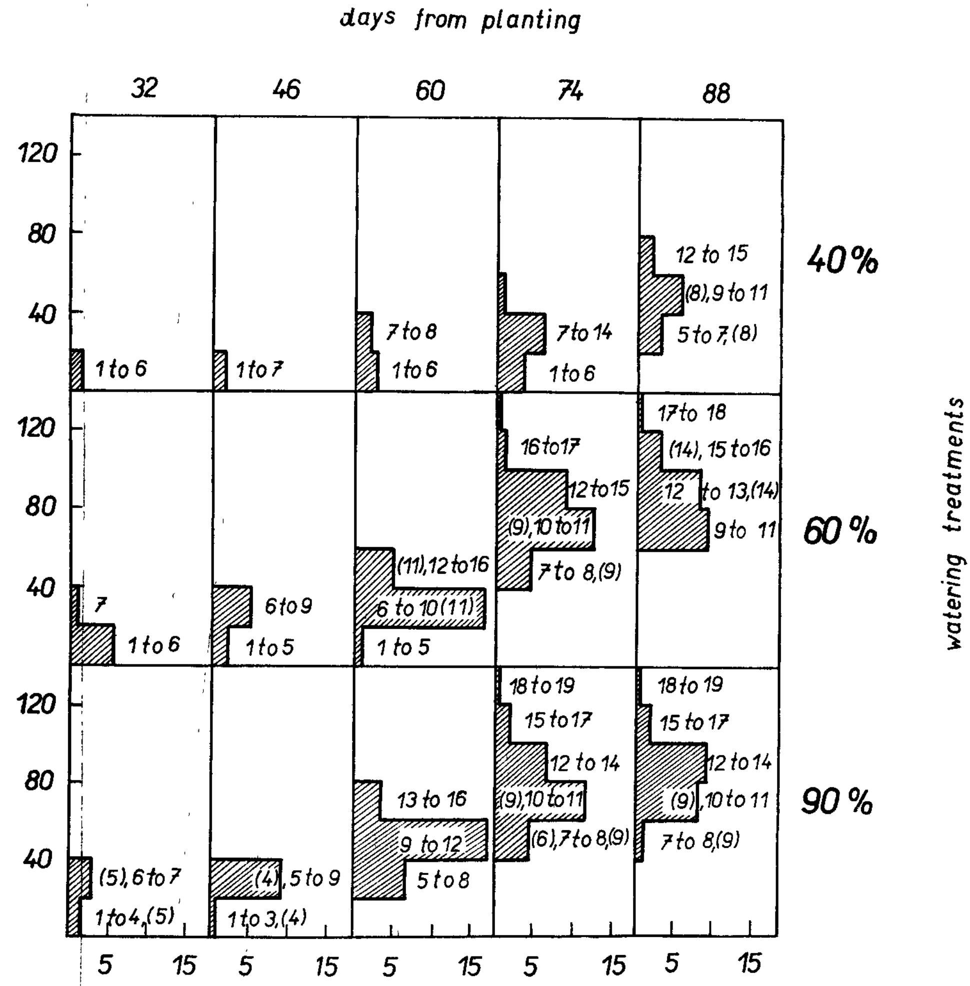

Fig. 5. Vertical distribution of the leaf area on 32nd, 46th, 60th, 74th and 88th day from planting. Abscissa (below): leaf area in dm². Ordinate: Height from the surface of the pot in cm. (Numbers indicate the age of leaves represented at different insertion levels). ...... 40% treatment, ------ 60% treatment, --- --- 90% treatment.

The course of the leaf area growth in leaves of different age indirectly reflects even their viability (Fig. 6a—c). The permanent decrease in soil moisture up to 40% of the maximum capillary capacity caused a clear-cut prolongation of the life span of elder leaves (especially in the 3rd, 7th

Fig. 6a.

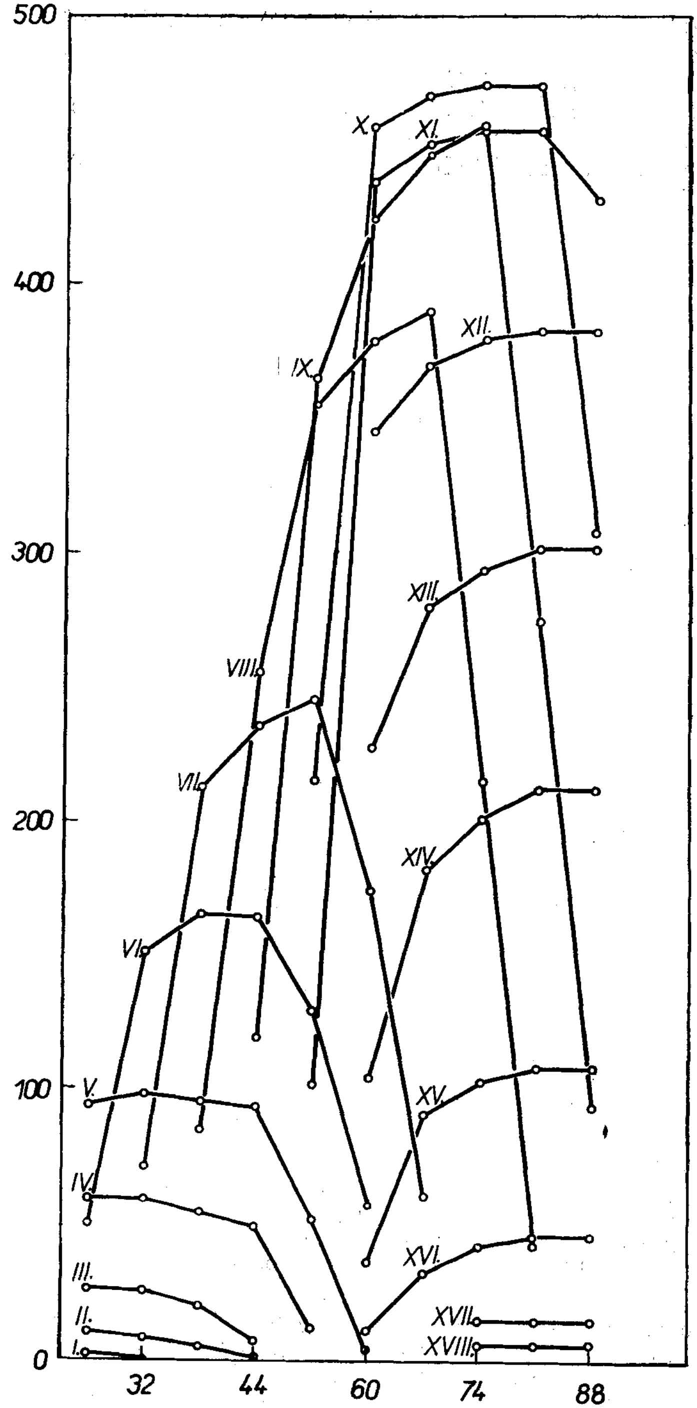

Fig. 6. The changes in leaf area of leaves of different age during their ontogenesis.
Abscissa: Number of days from planting.
Ordinate: Area of individual leaves in cm^2.
(The roman numerals indicate the order of leaf insertion from base to the apex.)
Fig. 6a — 90% treatment

Fig. 6b.

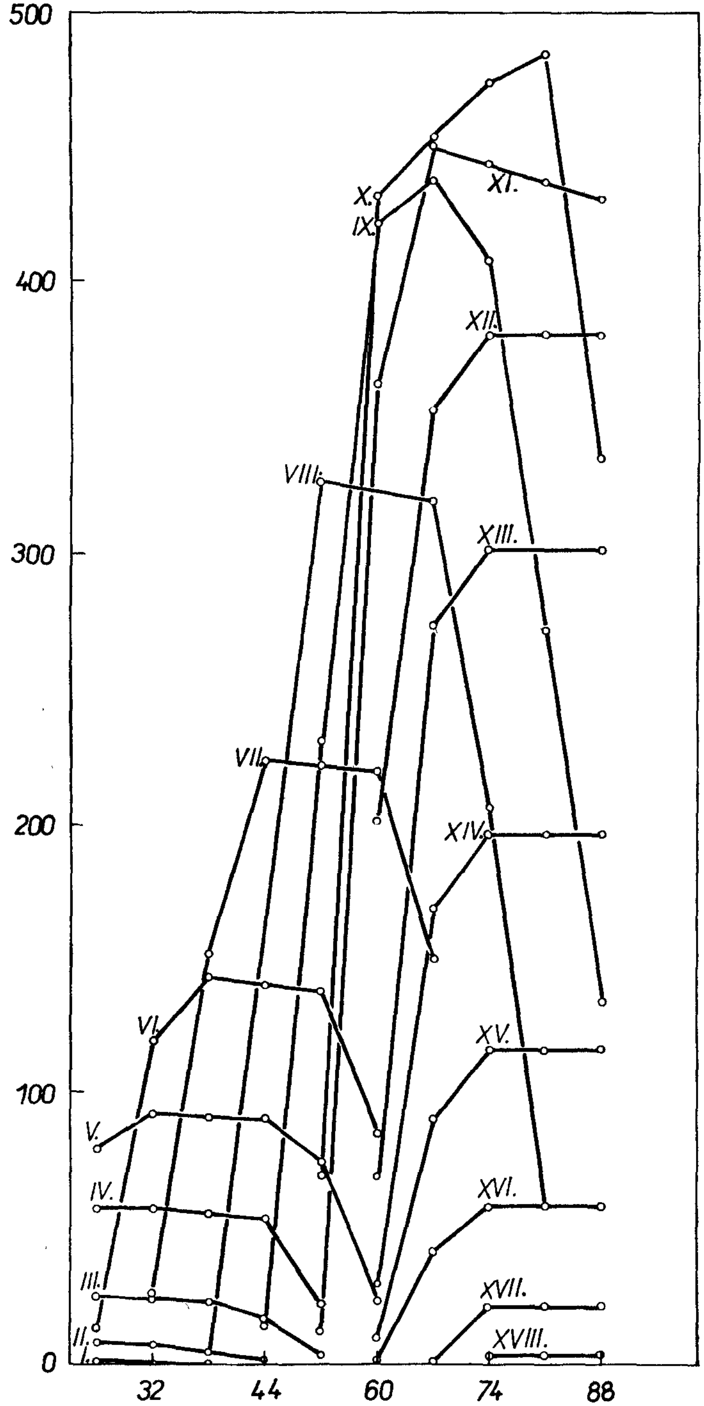

Fig. 6b — 60% treatment

Fig. 6c.

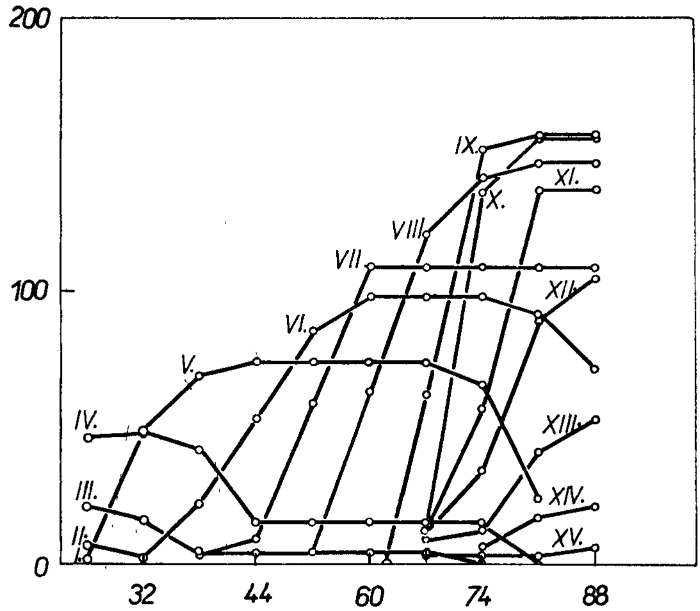

Fig. 6c — 40% treatment

leaf). The dynamics of the plant growth (R.G.R.) were influenced by the anticipated adaptation process (VÁCLAVÍK 1967, 1968). One part of the plants in the phase of 3—4 leaves still capable of producing further leaves, lost the third and fourth leaf relatively soon (faster than 60 and 90% treatments). On the other hand the plants which were more influenced by soil moisture deficit retained the third and fourth leaf nearly up to the end of the vegetative period (decrease in the average area of the third and fourth leaf up to a certain value which was maintained; slow increment of the total leaf area in this period).

The differences between the 60 and 90% treatments were characterized rather by progressively increasing maxima of the leaf area with increasing insertion levels in the 90% treatment than by the duration of ontogenesis of similar leaves. This led to the above mentioned differences in the growth of the total leaf area.

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J. VÁCLAVÍK, Ústav experimentální botaniky ČSAV, Praha: **Vliv různé konstantní půdní vlhkosti na vývoj listové plochy kukuřice.** — Biol. Plant. **11** : 68—78, 1969.

Byl hodnocen vliv různé konstantní půdní vlhkosti (90, 60 a 40 % maximální kapilární kapacity), aplikované od výsevu naklíčených obilek, na vývoj listové plochy kukuřice v souvislosti se změnami plochy různě starých listů během jejich ontogenese. Bez ohledu na půdní vlhkost projevily se v růstu celkové listové plochy, charakterisovaném integrální listovou plochou a specifickou rychlostí růstu listové plochy, dvě maxima: méně výrazné primární maximum ve fázi 5—8 listů a absolutní sekundární maximum před začátkem kvetení ve fázi 10—12 listů. Vliv trvalého snížení půdní vlhkosti se projevil, podle stupně snížení, progresivně menší listovou plochou a zpožděním ve vývoji celých rostlin. Na rozdíl od suché varianty (40%), dostihla varianta s vyšší půdní vlhkostí (60%) velikostí své listové plochy kontrolní variantu (90%), avšak teprve po skončení vegetativní fáze růstu. Největší vývojová diference mezi jednotlivými závlahovými variantami byla zjištěna v době nejintensivnějšího růstu listové plochy kontrolní varianty. Trvalé snížení půdní vlhkosti ovlivnilo výrazně průběh ontogenese jednotlivých listových pater (zvláště starších listů). U suché varianty došlo zjevně k prodloužení ontogenese, zatímco u variant s vyšší půdní vlhkostí spíše k dřívějšímu omezení až zastavení růstu po dosažení určitého maxima.

Й. ВАЦЛАВИК, Институт экспериментальной ботаники ЧСАН, отделение физиологии растений, Прага: **Действие различных постоянных уровней влажности почвы на развитие листовой пластинки у кукурузы.** — Biol. Plant. 11 : 68—78, 1969.

Изучалось влияние различной постоянной влажности почвы (90, 60 и 40% от максимальной капиллярной влагоемкости), в условиях которой растения находились от посева проросших зерновок, на развитие и динамику роста листьев кукурузы в связи с изменениями площади листьев разного возраста в течение их онтогенеза. Независимо от почвенной влажности в процессе роста общей листовой площади, характеризованной интегральной листовой площадью и специфической скоростью роста листовой площади, выявлено два максимума: менее выразительный первичный максимум в фазе 5—8 листьев и абсолютный вторичный максимум перед началом цветения в фазе 10—12 листьев. Влияние постоянного снижения влажности почвы проявилось, соответственно

степени снижения, все более уменьшающейся площадью листа и задержкой развития всего растения. В отличие от сухого варианта (40), вариант с более высоким уровнем влажности почвы (60) сравнялся величиной своей листовой площади с контрольным вариантом (90), однако лишь после окончания вегетативной фазы роста. Наибольшее различие в развитии между отдельными вариантами по влажности найдено в период наиболее сильного роста листовой площади контрольного варианта. Постоянное снижение влажности почвы имело выразительное действие на ход онтогенеза отдельных этажей листьев (особенно листьев старших по развитию). У сухого варианта произошло с очевидностью удлинение онтогенеза, в то время как у вариантов с более высоким уровнем влажности почвы наступало более раннее ограничение или даже прекращение роста спустя того, как они достигли некоторый максимум.