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RESPONSES OF *LENS ESCULENTA* MOENCH  
TO CONTROLLED ENVIRONMENTAL  
FACTORS

P. M. SAINT-CLAIR

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**RESPONSES OF *LENS ESCULENTA* MOENCH TO CONTROLLED  
ENVIRONMENTAL FACTORS**

Dit proefschrift met stellingen van

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De Rector Magnificus van de Landbouwhogeschool,  
**J. M. POLAK**

*Wageningen, 24 april 1972*

# RESPONSES OF *LENS ESCULENTA* MOENCH TO CONTROLLED ENVIRONMENTAL FACTORS

*(WITH A SUMMARY IN DUTCH, FRENCH, SPANISH)*

## PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD  
VAN DOCTOR IN DE LANDBOUWWETENSCHAPPEN  
OP GEZAG VAN DE RECTOR MAGNIFICUS, MR. J. M. POLAK,  
HOOGLEERAAR IN DE RECHTS- EN STAATSWETENSCHAPPEN  
VAN DE WESTERSE GEBIEDEN,  
IN HET OPENBAAR TE VERDEDIGEN IN DE AULA  
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## THEOREMES

### I

L'utilisation de la prégermination comme moyen d'assurer l'uniformité du matériel végétal soumis à l'influence des traitements a pour effet d'accroître la précision des résultats des expériences.

La thèse

### II

Le cultivar de lentille 'Large blonde' est une plante de jours longs tandis qu'Anicia est plutôt une plante indifférente.

La thèse

### III

On sous-estime le rythme relatif de croissance des jeunes plantes lorsqu'on le calcule à partir du poids sec des semences.

### IV

L'opinion de RINGOET d'après laquelle le coefficient de transpiration varie avec la teneur en eau du sol est discutable.

RINGOET, A. Recherches sur la transpiration et le bilan d'eau de quelques plantes tropicales. I.N.E.A.C. Sér. sci. 56, p. 125 (1952).  
DE WIT, C. T. Transpiration and crop yields. Versl. landbouwk. onderz. 64.6, 88 pp. (1958).

### V

Les limites de la tolérance de la lentille à la salinité se trouvent à des concentrations comprises entre 8.4 et 13.1 mmhos/cm.

La thèse

### VI

La diminution sensible de la production de matière sèche au niveau de sodium échangeable correspondant à un 'ESP' de 10 suggère que la lentille ne puisse pas survivre dans des milieux caractérisés par un fort pourcentage de sodium échangeable.

La thèse

## VII

Cette affirmation de KANDE: Les acides aminés soufrés constituent le facteur limitant primaire des protéines de la lentille et du pois chiche, doit être prise en considération quand il s'agit d'équilibrer des rations à base de ces légumes secs.

KANDE, J. Valeur nutritionnelle de deux graines de légumineuses.  
An. Nutr. et Alim. 21(1), 45-67 (1967).

## VIII

La municipalité de Chicago a fait dépendre la construction d'un aéroport sur le lac Michigan du résultat d'enquêtes écologiques. Cet exemple mérite d'être suivi.

Superjet airports run into trouble. U.S. News and World Rep.  
March 22 (1971).

## IX

Bien qu'elles s'appuient sur des méthodes différentes, les philosophies idéalistes de JEAN-JACQUES ROUSSEAU (1712-1778) et d'ANTOINE CARITAT, MARQUIS DE CONDORCET (1743-1794) visent un objectif commun: l'amélioration morale de l'homme.

To: *MYRIAM* and *PASCAL*



## PREFACE

La préparation de la thèse a bénéficié de la contribution de plusieurs personnes appartenant soit au monde académique, soit aux services administratifs. Comme il est difficile de les mentionner toutes, je crois utile de souligner que tout apport a été grandement apprécié.

Plus particulièrement celui du Professeur Dr J. D. FERWERDA à qui je dois notamment le choix de la lentille comme sujet de recherches. Cette option a la vertu de renforcer l'originalité de la thèse. En effet, la littérature concernant cette légumineuse est fort modeste, bien que la plante soit cultivée dans beaucoup de pays du monde, surtout dans les régions surpeuplées du sous-continent indien. Il est aussi à porter au crédit du Professeur Ferwerda des suggestions en rapport avec l'orientation à donner aux expériences et des critiques relatives à l'interprétation des résultats. L'expérience acquise en traitant les aspects inclus dans le présent ouvrage pourra toujours servir à guider des recherches sur les possibilités d'adaptation d'espèces ou de cultivars à une région donnée.

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La contribution apportée par Ir. F. WESTPHAL à la classification botanique des cultivars utilisés pour les expériences a été fort appréciée.

Dans l'interprétation statistique des résultats, j'ai tenu compte des intéressantes suggestions faites par Ir S. H. JUSTESEN, Ir. J. R. VERDOOREN et M. KEULS.

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# 1. INTRODUCTION

## 1.1 OUTLINES

### 1.1.1. *History and distribution*

There is much evidence to suggest that lentil is one of the first plants brought under cultivation by man (PAKISTAN, 1963). The property of dried lentils to keep well helps appraise the ancientness of the crop. Lentils were eaten, collected or cultivated in the Near East in the 6th or 7th millenium BC. The crop was known to the Assyrians, being cultivated along with other vegetables in the garden of King Merodach-Baladan of Babylon (8th century BC.). A paste of cooked lentils was discovered in a Thebes tomb built in the 12th dynasty period, proving that like peas, lentils were used as food in ancient Egypt. Archaeological finds in Greece permitted to date back the use of lentils to the early Bronze Age. Herodotus reported that lentils constituted like grain, onions, leeks and millet a major food for the Callipidae, a Graeco-Scythian tribe (BROTHWELL, 1969).

Lentils are mentioned in sacred literature. The sanskrit names of lentil are given by KIRTIKAR (1933). It is reported in the first book of the Old Testament of the BIBLE (GENESIS 27) that Esau sold his birthright to Jacob for a dish of lentils.

The oldest cultivation areas are located in Western Asia, Egypt and Southern Europe. From these, there was a northwards distribution to Europe, eastwards to India, China and southwards to Ethiopia (PURSEGLOVE, 1968).

Lentil is now being cultivated in the Mediterranean area, in Africa (North and South-East), in the Middle East, in Southern Asia, in North America (USA and Mexico) and South America. According to FAO statistics, 1.723,000 ha were covered by lentil in the world in 1970 whilst the total production was estimated at 1.058,000 tons. India is the largest producer, followed by Ethiopia and Pakistan (FAO, 1971).

### 1.1.2. *Composition and uses*

In nutritive value, lentil occupies a place second only to Bengal gram (*Cicer arietinum*) and black gram (*Phaseolus mungo*) among the pulses commonly consumed in India (INDIA, 1962). Appreciable amounts of vitamins, mainly of the B group, are present in the seeds, as indicated by the data of Table I collected in India (INDIA, op. cit.).

The seeds represent also an interesting source of proteins. An Indian strain is reported to contain about 30%. Lentil proteins are similar to those of beans and peas and consist of globulin (44.0%), glutelin (20.6%), prolamin (1.8%) and a water soluble fraction (25.9%). Two proteoses were also found in the seeds (INDIA, op. cit.).

It was observed in Teheran that the percentage of proteins in lentils (27-30%) was higher than that of black chick peas (22-28%), white chick peas (18-28%),

TABLE 1. Vitamin content of lentil seeds in mg/100 g.

Vitamins of the B group	Content	Others	Content
Thiamine	0.26	Carotene	1.60
Riboflavin	0.21	Ascorbic acid	4.20
Nicotinic acid	1.70	Vitamin K	0.25
Choline	223.00	Tocopherol	2.00
Folic acid	107.00		
Inositol	130.00		
Pantothenic acid	1.60		
Biotin	1.30		
Pyridoxine	0.49		

TABLE 2. Amino Acids present in lentil proteins expressed in g/16 g N after HARVEY (op.cit.); the data of WASSERMANN (op. cit.) are put in brackets.

Essential amino acids <sup>1</sup>	Content	Others	Content
Methionine	0.5- 0.8 (0.4)	Arginine	4.3-9.3
Tryptophan	0.2- 0.8	Histidine	2.2-3.8
Phenylalanine	3.6- 6.3 (2.6)	Cystine	0.6-1.8
Threonine	3.3- 5.0 (2.7)	Tyrosine	1.8-3.1
Valine	4.2- 6.4 (4.1)	Glycine	2.1-5.2
Leucine	6.9-10.9 (4.6)	Proline	3.7-5.4
Isoleucine	3.7- 6.4 (3.2)	Alanine	3.5-4.8
Lysine	5.7-11.6 (7.9)	Serine	4.6-6.0

<sup>1</sup> According to DEN HARTOG (1966)

cow-peas (22-29%) and mung beans (22-25%). The percentage of proteins found in the Persian strains is comparable with those indicated by Indian and Pakistanese sources (IRAN and INDIA, 1969).

The amino acid composition of the total proteins of lentil seeds is given by WASSERMANN (1967) and HARVEY (1970).

The food value of lentils was compared in Pakistan with that of wheat and rice (PAKISTAN, 1963). The data are presented in Table 3.

TABLE 3. Comparative food value of lentils

Crop	g per 100 g				mg per 100 g		
	Protein	Fat	Carbohy- drates	Calories per 100 g	Calcium	Phospho- rus	Iron
	1	2	3	4	5	6	7
Lentils	23.7	1.2	65.0	354.0	47.3	71.9	5.4
Wheat	9.3	1.9	78.6	363.0	93.1	639.2 <sup>1</sup>	5.0
Rice	6.5	0.4	82.2	356.0	23.3	76.0	1.3

<sup>1</sup> This figure seems to be too high when compared with the value of 444 mg/100 g given by ROHRlich and THOMAS (1967).

Lentil contains then more proteins than wheat and rice. It is not without reason it is called the poor man's meat in Pakistan (PAKISTAN, op.cit.). It contains also more iron than the two cereals whilst its energetic value is similar.

Data collected in Spain pointed also to the dietetic importance. The digestibility of lentils is considered superior to that of the other pulses (MATEO BOX, 1963).

The importance of lentil is not restricted to the use of the seeds for human nutrition. It is often employed as green manure. In Pakistan it contributes to the improvement of nitrogen-deficient soils where sheep graze. The wool production is closely related to the N-fixing property of lentil (PAKISTAN, 1963). In India, lentil husk and bran are given as feed to livestock, especially to dairy cows. Lentil hay and straw is also used for this purpose (INDIA, 1962).

Lentil starch has an industrial importance. It is used in textile and calico printing industries because its viscosity keeps well across a wide range of temperatures.

## 1.2. CLASSIFICATION

*Lens esculenta* MOENCH belongs to the Order *Rosales*, Sub-Order *Rosineae*, Family *Leguminosae* and Sub-Family *Lotoideae*. Many botanists consider this Sub-Family as an independent Family termed *Papilionaceae* (LAWRENCE, 1951). The latter is also designed by the name *Fabaceae* and transferred to the Order *Fabales* (DE WIT, 1963). BARULINA (1930) has given the following description of lentil: Plant annual, 15–75 cm high, pubescent with short hairs; the degree of pubescence varies in the separate varieties. Stem almost erect or slightly climbing, with anthocyan over the whole surface or only at the base, more rarely green. Leaves compound, even-pinnate with 2–8 pairs of leaflets. Leaflets oval or linear, stipules semi-hastate or lanceolate, entire. Peduncle shorter than leaf, with 1–4 flowers. Flowers 5–8 mm long; colour of corolla varies from white to blue or pink; of most frequent occurrence is a white standard with violet-blue veins of different intensity. Ten stamens, nine of them united in a tube, while one is free. Seeds flattened or almost globose, 3–9 mm in diameter greatly various in colour, ranging from light green to perfectly black.

The same author has also proposed a key to determine the varieties. The species are divided in 2 subspecies (ssp.): *macrosperma* (large-seeded) and *microsperma* (small-seeded).

a- ssp. *macrosperma* (BAUMG. pro var.) BARUL.

Pods large, flat (15–20 mm long, 7.5–10.5 mm width). Seeds large 6–9 mm in diameter, flattened, Flowers large (7–8 mm long), white (standard with blue or light blue veins) rarely light blue; 2–3 flowers on peduncle. Calyx-teeth longer than corolla. Height of the plant 25–75 cm.

b- ssp. *microsperma* (BAUMG. pro var.) BARUL.

Pods small (6–15 mm long, 3.5–7 mm width). Seeds small or medium-sized (3–6 mm in diameter). Flowers small (5–7 mm long), violet-blue, light blue,



white or pink. Peduncle with 1-4 flowers. Height of the plant 15-35 cm. The material used in the experiments, which will be described later, comes from both sub-species: *macrosperma* ('Large blonde') and *microsperma* ('Anicia'). 'Large blonde' is a cultivar of the variety *nummularia* A1. (BARULINA). Its characteristics are: Pods green when unripe; ripe, straw-coloured. Seeds yellow-green and with dark green marbled pattern.

An attempt has been made to find out in which grex<sup>1</sup> and in which variety 'Anicia' has to be located. It has been concluded that it suits to the description given by BARULINA (1939) for grex *europae* s. and variety *dupuyensis* s. Grex *europae*: Flowers 2-4 on peduncle, white with light blue veins.

Calyx-teeth much longer than corolla. Leaflets of medium size. Plant most frequently light-green (yellow-green) coloured.

Variety *dupuyensis*: Erect habit. Pods before maturity with purple patches.

Seeds 4-5 mm. in diameter, yellow-green with dark-green marble and dark purple spots. Cotyledons yellow. This description is comparable with that of 'Anicia' given below. Specimens grown under greenhouse conditions (day and night temperatures 26°C and 20°C respectively, relative humidity 50%) are described according to the method recommended by PORTER (1959) are kept at Herbarium vadense, Wageningen.

a1 - *Lens esculenta* MOENCH, ssp. *macrosperma* (BAUMG.) BARUL. var. *nummularia* A1. cv. Large Blonde. (Reference SC<sub>1</sub> and SC<sub>4</sub>, Herbarium vadense).

Roots: Colour brown, a primary root (8.5 cm long), many secondary roots (length 3-8 cm).

Stem: Herbaceous, 60 cm long, colour light green; the stem is divided at the 2nd node in 3 branches.

Leave: Colour light green, arrangement alternate; pinnately compound with an average of 13 leaflets in a branch; leaflets (length 16 mm) oval, entire, apex obtuse, base acute; 2 stipules lanceolate (length 3 mm).

Flowers: Length 8 mm; colour white, calyx colour light green, slightly pubescent, 5 sepals longer than corolla; corolla (6 mm long) white, standard white with violet stripes; 10 stamens.

Pod: Unripe light green; ripe, straw-coloured; flat, large, average length 18 mm, width 8.5 mm.

Seed: Flattened, colour yellow-brown, diameter 7.5 mm.

Cotyledons: yellow.

b1 - *Lens esculenta* MOENCH, ssp. *microsperma* (BAUMG.) BARUL. var. *dupuyensis* Barul. cv. Anicia. (Reference SC<sub>2</sub> and SC<sub>3</sub>, Herbarium vadense).

Roots: Colour brown, a primary root (4.5 cm. long), many secondary roots (length 1.5-10 cm).

Stem: Herbaceous 50 cm long, colour light green, divided at the 1st node in 2 branches.

<sup>1</sup> The varieties of *Lens esculenta* MOENCH, ssp. *microsperma* (BAUMG.) are grouped by BARULINA (1930) in six grexes or morphologic-geographical subdivisions. CARLES (1939) used the term race instead of grex.

Leaves: Colour light green, arrangement alternate; pinnately compound with an average of 10 leaflets in a branch; leaflets (length 11 mm) oval, entire, apex obtuse, base acute; 2 stipules lanceolate (length 2,5 mm).

Flower: Length 6 mm, colour white; colour calyx light green, calyx more pubescent than Large blonde calyx, 5 sepals; corolla white, length 5 mm, standard white with violet stripes; 10 stamens.

Pod: Unripe light green; ripe yellow-brown; small, length 12.5 mm, width 6 mm.

Seed: Small, colour dark-green marble pattern, diameter 4 mm.

Cotyledons: Yellow.

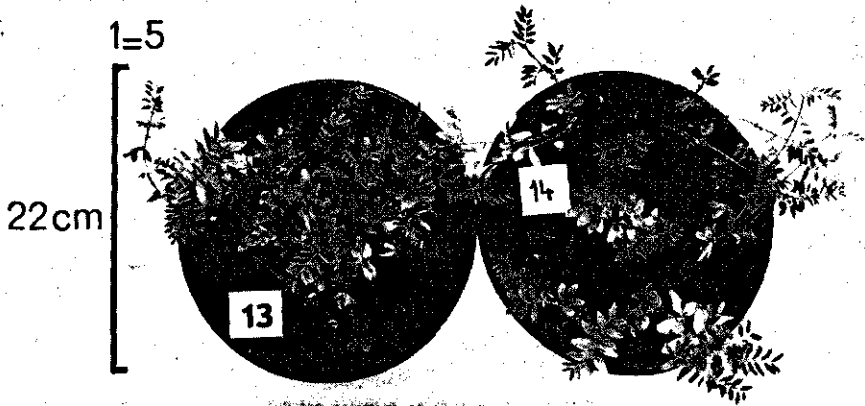


PHOTO 1



PHOTO 2

Photos of four-week old 'Large blonde' (photo 1) and 'Anicia' (photo 2) plants are presented above. These pictures were used as vertical projections of the canopy of plant samples used in the photosynthesis experiment which is described in Chapter 8.

### 1.3. REVIEW OF LITERATURE

#### 1.3.1. General aspect

Lentil served as material for several kinds of research. Its botanical aspect was the subject of the investigations of CHAKRAVARTI (1953) and PAPP (1966). Auxinic and enzymatic studies were conducted by PILET (1951, 1953 and 1971), PILLAI and CHAKRAVARTI (1954), PILET and GALSTON (1955), SIEGENTHALER (1963) and HOFINGER (1971).

The nutritional standpoint was given attention by BAJWA and NASSIB (1967), and KROBER (1968). Genetic work has been carried out by MUKHOPADYAY and SHARMA (1963), and WILSON (1970).

A larger amount of information bears on ecology, cultural practices, physiology, selection and plant breeding.

#### 1.3.2. Ecology and cultural practices

According to BARULINA (1930) the genus *Lens* is typically Mediterranean. The Mediterranean countries are the centres of origin of *Lens esculenta* ssp. *macrosperma*, South-West Asia and partly Spain are birth regions of ssp. *microsperma*. The soil and climatic conditions prevailing in the above mentioned areas may provide some indications on the ecological requirements of lentil.

General information was published in Morocco (FOURY, 1954), India (INDIA, 1962, 1969), Spain (MATEO BOX, 1961) and Pakistan (PAKISTAN, 1963). The FAO (1959) has summarized data on lentil from Cyprus, Egypt and Greece. The response to factors like temperature, frost, shade, drought and salinity was not identical in these three countries. Lentil was found to be moderately resistant to high temperature and drought in Cyprus and Egypt and more resistant in Greece. As the criteria used for this assessment are not indicated, the above information lacks of precision. In Pakistan (PAKISTAN, 1963) recommendations were compiled on suitable soils, methods of sowing, manuring and control of pests and diseases. Loamy soils are reported to favour cultivation. Furrow sowing (30 cm from line to line and 22.5 cm from seed to seed) and broadcast are indicated as methods of sowing. Advice about manuring only concern the soils of West Pakistan (because of their low fertility). It refers on the use of farm manure, compost (800–1200 kg/ha), superphosphate (80 kg/ha) and muriate of potash (80 kg/ha) during the preparation of the land. The pests and diseases mentioned in the publication are the gram caterpillar (*Heliothis obsoleta*), white ants (*Clostermes* sp.), weevil (*Bruchus sinensis*), gram cut worm (*Agrotis flammatra*) and rust (*Uromyces fabae*). As far as control is concerned, the farmers are suggested to contact their Agricultural officers.

MATEO BOX (1961) pointed out that lentil tolerates lower temperatures than chick pea, but is seriously affected by intense and long hoar-frost, that the soil range in which cultivation is possible is rather broad, provided the soil is reasonably fertile and does not suffer from excess of moisture. The author did not specify the temperature conditions under which lentil and chick-pea have thrived. In India (INDIA, 1962) excess of moisture in rich soils caused an excess-

ive vegetative growth at the expense of seed yield. REPP and KILLIAN (1956) in their experiments with irrigated soils of Saharian oases saw some differences between the white lentil from Syria and the red one from Egypt. Although both were moderately drought-resistant, they observed that the resistance of the Egyptian lentil was lower than that of the Syrian. This difference was due to a lower transpiration of the Syrian lentil. Their appraisal of drought-resistance was based on the following classification:

- a. Very drought-resistant: plants which were able to produce new leaves and flowers after four weeks of drought. They were also wind-resistant.
- b. Moderately resistant: plants which matured early and the resistance of which was observed mainly in the vegetative parts.
- c. Weakly resistant.

No criterium was given to differentiate b and c.

SUR and SEN (1965) found that the yield curve of broadcast sowing of lentil at seed rates of 11.25, 16.80, 22.50 and 30 kg/ha, was above that of furrow-sowing (furrows 15, 22.5, 30 and 37.5 cm. apart) at seed rates (calculated from the curve) of 21, 26, 34 and 52 kg/ha.

The two methods were compared through these two curves drawn against the seed rates. It followed that broadcast sowing brought about a larger seed yield than furrow sowing within the theoretical common range of seed rates. The highest yield of the experiment (1500 kg/ha) was obtained with broadcast sowing at a seed rate of 30 kg/ha. As the weight of the seeds is not given it becomes difficult to calculate the number of seeds per unit of area ( $m^2$  for instance). Reference to the weight<sup>1</sup> of the seeds of the cultivars 'Large blonde' and 'Anicia' permits to suppose that the seed rate of 30 kg/ha corresponds to a density of 40 to 120 seeds/ $m^2$  depending on the size of the seeds. It may be argued that the results of this experiment would be more reliable if the seed rate treatments were balanced.

DIMITROV (1970) sowed lentil at rates of 200–400 seeds/ $m^2$  and found that rates of 350–400 seeds/ $m^2$  brought about the highest yields. TODOROV (1971) observed a comparable result: the optimum rate was 300 seeds (yield 1450 kg of seeds/ha). Both results were registered in Bulgaria but difference in the environmental conditions might interfere with the treatments under study.

VAN DER MAESEN (1968) noted that sowing at a depth of 5 cm led to a higher dry matter production than sowing at 0, 2, 7.5 and 10 cm.

Irrigating lentil fields at 10-day intervals in Shiraz (Iran) accounted for the ratio grain/straw being superior to that observed under 4, 7, 14 and 17-day intervals (IRAN and INDIA, 1969).

### 1.3.3. *Physiology*

Experimental data on lentil physiology are assembled in the last 20 years. SHUKLA (1953 and 1955) obtained a shortening of the vegetative cycle by three

<sup>1</sup> The 1000-seed weight of 'Large blonde' is 83 g and that of 'Anicia' is 28 g. This is in accord with the ranges given by BARULINA (1930) for the bold type of lentil (1000-seed weight between 40 and 82 g) and the small-seeded one (1000-seed weight between 11 and 40 g).

weeks either by vernalization ( $6^{\circ}\text{C}$ – $9^{\circ}\text{C}$  during 32 days) or continuous illumination. This result is of little interest when the practical aspect of the problem is considered. The duration of the vernalization period can be excessive under certain natural conditions. CHAKRAVARTI (1964) also applied vernalization. The seeds remained five weeks at a temperature of  $4^{\circ}$  to  $6^{\circ}\text{C}$  before sowing. Vegetative growth registered through the number of leaves at the beginning of flowering and compared with the control was significantly reduced. Vernalized plants produced more dry matter up to eight weeks. PILET and WENT (1956), working on germination in darkness with eight temperatures (5, 7.5, 10, 14, 17, 20, 23.5 and  $27^{\circ}\text{C}$ ) and in light with nine (6, 8.5, 11, 15, 18, 21.5, 24.5 and  $27.5^{\circ}\text{C}$ ) remarked that germination occurred within the first four days in darkness and in light except for the three lowest temperatures. The optimum temperature for dark germination was  $20^{\circ}\text{C}$  and for light germination  $24.5^{\circ}\text{C}$ . The percentage of germination of seeds maintained alternately 16 hours in darkness (at temperatures ranging from 14 to  $27^{\circ}\text{C}$ ) and in light (at temperatures ranging from 15 to  $27.5^{\circ}\text{C}$ ) was recorded after 15 days. It was found that a regime of 16 hours dark at  $20^{\circ}\text{C}$  and 8 hours light at  $24.5^{\circ}\text{C}$  provided also optimum conditions.

It can be observed that only constant temperatures were tested. More information might be obtained if the natural differences between day and night temperatures were simulated and studied. The highest temperature used ( $27.5^{\circ}\text{C}$ ) was too low to draw valid conclusions on the best germination conditions of lentil. The light treatment applied with the optimum germination conditions might have been too short when compared with the actual conditions in the lentil-growing areas.

PAPP (1967) investigating the germination of four small, six medium and five large-seeded lentils at temperatures ranging from 5 to  $45^{\circ}\text{C}$  found that the optimum temperatures ranged from 15 to  $25^{\circ}\text{C}$  and that the small-seeded varieties required a lower optimum temperature than the others.

MOURSİ (1963) conducted some experiments in Egypt on the effect of light durations on the growth of the lentil cultivar 'Giza 9' along with four other legumes (Egyptian lupin, fenugreek, gram and horse bean). Lentil plants treated with 16-hour light period flowered within 84 days. The other light durations 6, 8, 10, 12 and 14 hours caused flowering after 115, 114, 108, 100 and 90 days, respectively. The 10-hour treatment was found to be the best for dry matter accumulation, the 16-hour for stem elongation.

It may be noted that only one lentil cultivar was brought under investigation. Moreover no mention was made of the temperatures which prevailed in the environment in the time of the study.

VAN DER MAESEN (1968) observed that under 12-hour light conditions a temperature regime of  $29^{\circ}\text{C}$  during the day and  $23^{\circ}\text{C}$  by night gave larger dry matter output than a regime of day and night temperatures of  $32^{\circ}\text{C}$  and  $20^{\circ}\text{C}$  respectively.

This work was limited to two treatments.

#### 1.3.4. *Selection and plant breeding*

Since 1966, the Regional Pulse Improvement Project organized by the Iranian, Indian and American governments is undertaking a series of investigations into different aspects of lentil cultivation (yield trials, varietal improvement, virus and insect controls (IRAN and INDIA, 1966, 1967, 1968 and 1969; IRAN, 1969).

The yield trials in Karaj (Iran) were hit by a root disease caused by a complex of fungi. In Punjab (India), the plantings were completely destroyed by lentil wilt. In spite of these retarding circumstances, data are being accumulated on the material. The characteristics tested through breeding are plant size, plant type, number of days to flowering and maturity, number of seeds per pod, pod and seed size, seed colour, disease and drought resistance.

BOEV (1970) has carried out yield trials with two Soviet cultivars and three Bulgarian lentil populations. He remarked that the Bulgarian red-seeded population produced the highest yield (1250 kg/ha).

SINGH and SINGH (1969) noted that bunch number and pod number are closely related with seed yield and considered these characters as very important for yield-increasing investigations.

### 1.4. NEED FOR FURTHER RESEARCH AND SCOPE OF THE PRESENT INVESTIGATIONS

#### 1.4.1. *Need for further research*

The review of literature shows many gaps in the knowledge on lentil which may impair the optimum use of this crop. Investigations are necessary to determine with more precision its soil, temperature and moisture requirements. Studies on drought, salinity and exchangeable sodium tolerance need to be undertaken. Further assays on depth of sowing are desirable. It is also important to study the effects of fluctuating temperatures. The optimum germination temperature requires more precision. Photosynthesis and photoperiodism, investigated separately may bring about a better understanding of the behaviour of the crop under natural conditions. A study of growth and development of lentil in terms of growth curves and dry matter distribution may lead to a better understanding of the yield potential and may provide a better basis for selection and plant breeding works.

#### 1.4.2. *Scope of this thesis*

The thesis is based on a number of aspects of the ecology and the physiology of lentil which were subjected to further investigations and chosen on account of their importance for a better understanding of the ideal conditions for the cultivation of the crop, as summarized in the preceding section. As the climatic conditions in the Netherlands are not suitable for field trials with lentil, all experiments were carried out in growth cabins, growth chambers and greenhouses under controlled conditions. Therefore it was not possible to investigate the seed production on a quantitative basis.

The following subjects were covered within the time available for the thesis and with the experimental facilities provided in Wageningen by the Department of Tropical Crops Husbandry, the Department of Field Crops Husbandry and Grassland Cultivation and the Department of Soils and Fertilizers of the Agricultural University, the Seed Testing Station and the Institute for Biological and Chemical Research on Field Crops and Herbage.

1. temperature requirements for germination
2. depth of sowing
3. photoperiodic requirements
4. temperature requirements for growth and development
5. photosynthesis
6. drought tolerance
7. tolerance to saline conditions
8. tolerance to exchangeable sodium
9. growth curves and dry matter distribution

## 2. ORIENTATION EXPERIMENTS

### 2.1. GENERAL INTRODUCTION

The uniformity of the plant material contributes very much to the precision of pot experiments and to the reliability of their results. It is common experience that irregular germination and emergence may result in large differences between individual plants. This is undesirable for experiments involving such plants and this is more so when pot trials with a limited number of plants per pot are concerned. For that reason, germination and depth of sowing have been investigated before the other aspects of lentil cultivation. The information collected on the optimum germination conditions and on the optimum depth allowed further research to be carried out with more precision in order to obtain more reliable results.

### 2.2. GERMINATION EXPERIMENTS

#### 2.2.1. *Introduction*

Lentil germination has been scarcely investigated. In addition to the works of PILET and WENT (1956) and PAPP (1967) already discussed (see 1.3.3.), the experiment of VAN DER MAESEN (1968) may be mentioned. He studied the effect of eight constant temperatures regularly ranged from 10 to 45°C and three changing temperatures fluctuating daily between 15°C (night) and 25°C (day), 20°C (night) and 30°C (day) and 25°C (night) and 35°C (day). It was found that the best constant temperatures for germination were 20° and 25°C whilst the best fluctuating regime was 15°C (night) and 25°C (day).

The present studies comprise four experiments carried out with 'Large blonde' and 'Anicia'. The basic objective was to determine more precisely the optimum germination conditions. Germination was understood as the emergence and development from the seed embryo of those essential structures which indicate the ability to develop into a normal plant under favourable conditions in soil (INTERNATIONAL SEED TESTING ASSOCIATION, 1966). This process is governed by the environmental factors provided the necessary internal conditions of the seeds are satisfied. General information regarding the influence of substratum and of light on germination is needed in an attempt to find out the optimum conditions. This last objective was the subject of the first experiment.

#### 2.2.2. *Description of the material*

**Substrata.** The substrata used in the experiments were filter paper and sand. The paper used varied with the treatments which were termed according to the international nomenclature (INTERNATIONAL SEED TESTING ASSOCIATION, *op. cit.*) These were: TP (top of paper) and BP (between paper). In the TP (top of paper)



condition, the seeds were placed on discs of filter paper T-300 (diameter 10 cm water-absorbing capacity 2.13 g (water)/g(paper), weight/area 300 g/m<sup>2</sup>). The discs were put on a 2 mm layer of porous paper T-10 D(10.2 × 26.5 cm, water-absorbing capacity 2.20g/g, weight/area 730 g/m<sup>2</sup>). For each treatment (4 × 25 seeds) a set of four discs of T-300 paper with the layer of moist T-10 D paper was used. The above was held by an aluminium germinator tray (27.5 × 11.2 × 1.8 cm) and then brought to the germinator.

For the BP treatments, the seeds were put between two layers of folded filter paper ZH-1224 (23 × 26,5 cm, water-absorbing capacity 2.16 g/g, weight/area 132 g/m<sup>2</sup>) before being carried to the germinator.

The sand used was Zilverzand SiO<sub>2</sub> (size of the particles 0.05–0.8 mm). The material was brought to one third of its water-holding capacity (10 g water/100 g sand) and placed in aluminium trays (17.5 × 14 × 3.5 cm). The seeds were sown 1 cm beneath the sand surface.

**Germinators.** Two types were used: room-type and cabinet. The room-type germinator (3.50 × 3 × 2.30 m) was light-equipped. Light was supplied eight hours a day by eight 40 W TL 33 Philips lamps, two of which being located at the ceiling. The six others, divided into two groups of three, faced two series of shelf-holding metal frameworks (3 × 1.80 × 0.75 m) designed for receiving the germinator trays. The light intensity was 1000 lux ( $4.44 \times 10^{-3}$  cal/cm<sup>2</sup>/min), at the treatment level. The relative humidity was maintained above 90% by water flowing down the walls of the room. The fluid came from and returned to an outside water tank (capacity 3 m<sup>3</sup>). The temperature inside the germinator was settled by warming or cooling the water of the tank. The day-temperature was concomitant to the light period.

The germination cabinet (2.10 × 0.66 × 0.75 m) had no light equipment. It was divided into 18 shelves on which germinator trays could be placed. The door, the walls and the bottom were fitted with an electric heater (iron wires). A water bath was kept in the lower part of the cabinet where an opening facilitated ventilation. This opening was situated above the water level. A glass plate (0.61 × 0.70 m) covered the water bath. Air came in the germinator through the opening, spread over the water bath and caused the relative humidity to reach values higher than 90%. The desirable temperature regime was obtained with the mechanism set in motion by an electromagnetic valve installed at the bottom of the germinator and synchronized with a contact thermometer. When the valve was closed, the heater was switched on and the temperature increased. When it was open, the heater was switched off. Cold water coming from a pipe passed through 31 vertical cooling units situated along the walls of the cabinet and caused a decrease of the temperature. The temperature conditions were regulated by the contact thermometer switched on the desired treatment.

### 2.2.3. First experiment

#### 2.2.3.1. Treatments and design

The treatments are summarized in Table 4. They were displayed in a comple-

TABLE 4. Treatments of the preliminary experiment presented as combinations of substrata and dark or light conditions.

Cultivars and Substrata	Dark		Light	
	Temperature regimes		Temperature regimes	
	20°C	20-30°C	20°C	20-30°C
<i>'Large blonde'</i>				
TP (top of paper)	TP 20°C	TP 20-30°C	TPL 20°C	TPL 20-30°C
BP (between paper)	BP 20°C	BP 20-30°C		
S (sand)	S 20°C	S 20-30°C	SL 20°C	SL 20-30°C
<i>'Anicia'</i>				
TP (top of paper)	TP 20°C	TP 20-30°C	TPL 20°C	TPL 20-30°C
BP (between paper)	BP 20°C	BP 20-30°C		
S (sand)	S 20°C	S 20-30°C	SL 20°C	SL 20-30°C

tely randomized design which was also used in the other germination experiments. Each treatment comprised 100 seeds divided in four replicates of 25.

#### 2.2.3.2. Material and methods

The germination of *'Large blonde'* and *'Anicia'* was studied under two temperature regimes: constant 20°C and fluctuating between 20°C (night) and 30°C (day) and under dark and light conditions. Three substrata: TP (top of paper), BP (between paper) and sand were used. Light was given eight hours a day. It was the same for the day temperature of 30°C under dark and light conditions. The dark treatments were placed in two germination cabinets switched on the requisite temperature regimes (constant 20°C and fluctuating between 20°C by night and 30°C in daytime). The light treatments were held in two room-type germinators providing likewise the above mentioned temperature regimes. As previously indicated (see 2.2.2.), both types of germinators were provided with shelves. It was then possible to put the seed-holding substrata on separate shelves. The replicates of the two cultivars under the same substratum condition were however put in the same shelf. The germination ceased after ten days and the percentage of germination of *'Large blonde'* and *'Anicia'* was recorded for the different treatments.

#### 2.2.3.3. Results

As the design of the experiment was not completely balanced with respect to the substratum treatments, the results are collected in two separate tables.

Table 5 shows the main effects and interactions of all the substrata (A), the cultivars (B) and the temperature regime (C). From this it appears that the average germination for the TP treatment was inferior to that of BP and of S. This discrepancy was mainly due to the low value shown by *'Large blonde'* at the 20°-30°C temperature regime. The average germination of *'Large blonde'* at 20°C was somewhat better than that at the 20°-30°C regime. In the case of

TABLE 5. Average percentages of germination for 'Large blonde' and 'Anicia' after 10 days as influenced by the substrata and the temperature regimes.

Substrata	'Large blonde'		'Anicia'		Average values		
	Temperature regimes		Temperature regimes		'Large blonde'	'Anicia'	General
	20°C	20°-30°C	20°C	20°-30°C			
TP	87	63	92.50	94	75	93.25	84.12
BP	97	98	96	98	97.50	97	97.25
S	95.50	94.50	97	99	95	98	96.50
Average	93.16	85.16	95.16	97.00	89.16	96.08	92.62

Substrata	Average values				
	Cultivars		Temperature regimes		General
	'Large blonde'	'Anicia'	20°C	20°C-30°C	
TP	75.00	93.25	89.75	78.50	84.12
BP	97.50	97.00	96.50	98.00	97.25
S	95.00	98.00	96.25	96.75	96.50
Average	89.16	96.08	94.16	91.08	92.62

TABLE 6. Average percentages of germination of 'Large blonde' and 'Anicia' after 10 days as influenced by the substrata TP and S, the temperature regimes, dark and light conditions.

Substrata	'Large blonde'				'Anicia'				Average value		
	Temperature regimes				Temperature regimes				'Large blonde'	'Anicia'	General
	20°C	20-30°C	20°C	20-30°C	20°C	20-30°C	20°C	20-30°C			
	Dark	Light	Dark	Light	Dark	Light	Dark	Light			
TP	91.00	83.00	60.00	66.00	91.00	94.00	97.00	91.00	75.00	93.25	84.12
S	97.00	94.00	95.00	94.00	97.00	97.00	100.00	98.00	95.00	98.00	96.50
Average	94.00	88.50	77.50	80.00	94.00	95.50	98.50	94.50	95.00	95.62	90.31

Substrata	Average values						
	Cultivars		Temperature regimes		Illumination condition		General
	'Large blonde'	'Anicia'	20°C	20°-30°C	Dark	Light	
TP	75.00	93.25	89.75	78.50	84.75	83.50	84.12
S	95.00	98.00	96.25	96.75	97.25	95.75	96.50
Average	85.00	95.62	93.00	87.62	91.00	89.62	90.31

'Anicia', the contrary is observed but with a smaller difference between the regimes. The comparison of the average germination of 'Anicia' with that of 'Large blonde' is affected by the response of 'Large blonde' to the TP treatment.

When the data were subjected to the analysis of variance (F test) it was observed that none of the main effects and of the interactions reached significance at the probability of 5%.

Table 6 shows the main effects and interactions of two of the substrata (A'), the cultivars (B'), the temperature regime (C') and the illumination (D'). The average results for 'Large blonde', 'Anicia' and the temperature regimes for TP and S and the general averages for TP and S are obviously identical to those of Table 5. The only new information brought out by Table 6 is the influence of the illumination, which appears to have no clear effect on the germination of lentil.

The following effects were found to be significant:

Main effects	Significance
Substrata (A')	$2 < P < 5\%$
Cultivars (B')	$2 < P < 5\%$

The effects of the interactions were not significant ( $P = 5\%$ ).

#### 2.2.3.4. Discussion and conclusions

The data of the present experiment indicate that the overall effect of sand on germination was more beneficial for the cultivars than TP (top of paper). They also point to the conclusion that the average percentage of germination of 'Anicia' was significantly superior to that of 'Large blonde'. As already mentioned (Section 2.2.3.3.) this discrepancy appeared to be dependent of the low values registered for 'Large blonde' under TP 20°C–30°C conditions.

As the germination of the cultivars was not influenced by light, further experiments may be carried out in darkness. The small effects of the temperature regime and of its interaction with the other factors suggest that a wider range of temperature treatments should be investigated.

#### 2.2.4. Second experiment

##### 2.2.4.1. Treatments and design

'Large blonde' and 'Anicia' were put to germinate in sand and dark conditions under four constant temperatures 10°C, 20°C, 30°C and 40°C and six fluctuating regimes: 10°C (night) – 20°C (day), 10°C (night) – 30°C (day), 10°C (night) – 40°C (day), 20°C (night) – 30°C (day), 20°C (night) – 40°C (day) and 30°C (night) – 40°C (day). Four replicates of 100 seeds each were used per treatment for each cultivar. This held also for the third and the fourth experiments. The experimental design was similar to that of the preceding experiment.

##### 2.2.4.2. Material and methods

The effects of the four constant temperatures and the six changing temperature regimes indicated in 2.2.4.1. on the germination of the cultivars 'Large blonde' and 'Anicia' were investigated in trays filled with sand and kept in darkness. Details concerning the trays and the sand have been already given in Section

2.2.2. Four germination cabinets (described also in 2.2.2.) were employed. Each of them provided one of the four constant temperatures (10°C, 20°C, 30°C and 40°C). The trays which contained the seeds which had to be subjected to any of the fluctuating temperature regimes (night temperature of 10°C combined with day temperatures of 20°C, 30°C and 40°C, night temperature of 20°C combined with day temperatures of 30°C and 40°C and night temperature of 30°C associated with a day temperature of 40°C) were kept in daytime in the cabinet which was switched to the requisite temperature. By night, they were moved to another inside which the proper (night) temperature was supplied. Day and night temperatures were given eight and 16 hours (a day) respectively. This last method was also applied to the third and the fourth experiments. The present study was concluded after 11 days and the percentages of germination for the different treatments were recorded.

### 2.2.4.3. Results

The data collected at the conclusion of the experiment are presented in Table 7. The extreme constant temperatures (10°C and 40°C) gave the lowest values. The combinations of 40°C with lower temperatures were better for the germination of the cultivars than the constant regime (of 40°C.) The treatment 10°C (night) – 40°C (day) seemed to be more favourable for 'Large blonde' than for 'Anicia'. The statistical analysis of the results showed that the constant temperature regimes differed significantly from the fluctuating ones ( $P = 0.05\%$ ). There was no difference between the cultivars at the 5% level of significance.

TABLE 7. Percentages of germination of the cultivars after 11 days.

Treatments	Cultivars		Average
	'Large blonde'	'Anicia'	
10°C	69.75	60.75	65.25
20°C	99.00	93.25	96.12
30°C	93.75	94.5	94.12
40°C	27.25	36.50	31.87
10°-20°C	87.50	85.75	86.62
10°-30°C	94.00	93.75	93.87
10°-40°C	94.50	75.50	85.00
20°-30°C	94.75	95.25	95.00
20°-40°C	92.25	94.75	93.50
30°-40°C	92.25	92.25	92.25

### 2.2.4.4. Discussion and conclusions

The results of this experiment confirm those of VAN DER MAESEN (1968). The highest average percentages of germination of 'Large blonde' and 'Anicia' were obtained at a constant temperature of 20°C and at a regime fluctuating between 20°C (night) and 30°C (day). The constant regime of 30°C was slightly worse

than the preceding ones whilst all fluctuating regimes except 10°C–40°C and 10°C–20°C were almost equally good. 'Large blonde' and 'Anicia' showed some differences with each other under the constant regimes of 10°C and 40°C. The first cultivar germinated better than the second at 10°C but this situation was reversed at 40°C. The general conclusions which may be drawn from the study, point to the existence of the optimum temperature between 20°C and 30°C and to the fact that daily fluctuations of temperature have no beneficial effects on the final results. It may be also concluded that daily fluctuations exceeding 20°C reduced markedly the average percentage of germination of the cultivars.

The experiment provided no information on the influence of the treatments on the rate of germination. For this reason, the influence of three temperature regimes with a daily amplitude of 10°C was investigated.

### 2.2.5. *Third experiment*

#### 2.2.5.1. *Treatments and design*

The effects of three temperature regimes in which the night temperatures of 20°C, 23°C and 27°C were combined with the respective day temperatures of 30°C, 33°C and 37°C, were studied with seeds of 'Large blonde' and 'Anicia' which were put to germinate in the same substratum as the preceding experiment and also in the dark. The number of replicates per treatment was also the same. A completely randomized design was employed as noted in section 2.2.3.1. It involved three cabinet-type germinators which provided the three requisite temperature regimes.

#### 2.2.5.2. *Material and methods*

The influence of the combinations of the night temperatures of 20°C, 23°C and 27°C with the respective day temperatures of 30°C, 33°C and 37°C on the germination of the cultivars was studied in conditions similar to those which prevailed in the second experiment. The differences are based on the number of germinators which were used, the way of using them and the manner of analysing the responses. In the current experiment, three cabinets, each one corresponding to one of the temperature regimes above mentioned, served as germinators so that no movement of the germinating seeds from one cabinet to another occurred. The experiment was concluded nine days after sowing. The recording of the data took into account earliness in the production of germinated seeds.

#### 2.2.5.3. *Results*

On the sixth day after sowing, two thirds of the observations showed more than 50% of germination. At this time, germination was better under the regime of 20°C–30°C. The final data collected after nine days confirmed the results of the second experiment pointing to the advantageous effect of the regime 20°C–30°C. In the present experiment, this regime was found to be more beneficial for the germination of the cultivars than 23°C–33°C and 27°C–37°C.

TABLE 8. Percentages of germination of the two cultivars after 6, 7, 8 and 9 days.

Treatments	Number of days from sowing							
	6		7		8		9	
	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'
20°–30°C	53.00	73.75	76.00	81.00	87.00	84.00	90.50	86.50
23°–33°C	17.25	54.75	46.25	63.25	70.75	69.75	70.75	69.75
27°–37°C	3.00	66.50	13.50	72.25	23.25	75.75	53.25	77.25

#### 2.2.5.4. Discussion and conclusion

The regime of 20°–30°C has brought about the highest percentages of germination for the two cultivars. Under this temperature condition, the germination of 'Anicia' at the sixth and seventh day after sowing was better than that of 'Large blonde'. However the last cultivar germinated faster than the other in the intervals 6–7, 7–8 and 8–9 days from sowing. The same tendencies appeared under the regime of 23°–33°C with the only exception that germination ended practically at the eight day after the beginning of the experiment.

The present trial constitutes a progress in the way to the optimum temperature conditions for the germination of the material. A final investigation involving temperatures in a range close to 20°C–30°C became necessary. As the average temperature of the regime 20°C–30°C (16 hours 20°C + 8 hours 30°C a day) is about 23°C, the treatment pattern for the final investigation may be shaped up in dependence of this average. The following experiment groups seven temperatures ranging from 17°C to 29°C.

#### 2.2.6. Fourth experiment

##### 2.2.6.1. Treatments and design

The temperature treatments under which the germination of the cultivars was carried out were the following: 17°C, 19°C, 21°C, 23°C, 25°C, 27°C and 29°C. The information about the experimental design and the number of replicates are indicated in sections 2.2.3.1. and 2.2.4.1., respectively.

##### 2.2.6.2. Material and methods

The study of the effects of the seven constant temperatures (17°C, 19°C, 21°C, 23°C, 25°C, 27°C and 29°C) on the germination of the cultivars was carried out in the same experimental conditions as the preceding experiment. Once more, emphasis was put on earliness in the responses when noting the results which concerned the period five–eight days after sowing.

##### 2.2.6.3. Results

Table 9 shows the data on the germination of 'Large blonde' and 'Anicia' from the fifth to the eight day after sowing. The highest percentages of germination of 'Large blonde' at the fifth day were observed at 27°C and 25°C. The final

TABLE 9. Percentages of germination of 'Large blonde' and 'Anicia' five to eight days after sowing

Treatments	Number of days after sowing							
	5		6		7		8	
	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'
17°C	—	3.00	5.50	68.25	82.25	81.50	88.75	85.00
19°C	80.50	78.75	86.75	86.00	86.75	86.00	86.75	86.00
21°C	79.50	90.25	84.25	93.75	84.25	93.75	84.25	93.75
23°C	78.25	83.25	89.50	86.50	89.50	86.50	89.50	86.50
25°C	82.00	80.50	87.50	86.00	87.50	86.00	87.50	86.00
27°C	82.25	77.25	87.25	82.25	87.25	82.25	87.25	82.25
29°C	73.50	74.66	83.75	80.40	83.75	80.40	83.75	80.40

maximum values shifted to other treatments: 23°C and 17°C. It may be mentioned that these values were quite close to those given by 27°C and 25°C at the conclusion of the study. The 'Anicia' pattern was very regular: 21°C and 23°C caused a better germination than the other treatments throughout the period mentioned in Table 9.

The data related to the fifth day were subjected to the new multiple range test (DUNCAN, 1955). For 'Large blonde', it was observed that the effects of the temperature treatments ranging from 19°C to 29°C were not significantly different ( $P = 5\%$ ). In the case of 'Anicia', significant differences were found between the effect of 21°C and that of each of the following treatments: 19°C, 27°C and 29°C ( $P = 5\%$ ).

#### 2.2.6.4. Discussion and conclusion

The foregoing results indicate that the germination of 'Large blonde' is optimum in the range 19°C–29°C. A narrower range, 21°C–25°C may be recommended for the germination of 'Anicia'. The cessation of the germination process occurred at the sixth day after sowing except for the treatment 17°C. Germination under this treatment was very slow up to six days for 'Large blonde' and up to five days for 'Anicia'. Although both cultivars brought about high percentages of germination by the end of the study, it is permissible to emphasize the disadvantage of germination at 17°C. The retardating effect of this temperature on germination and its consequences on the growth of the seedlings would certainly effect the dry matter production of the adult plants if the germinated seeds were given proper growth facilities along with the batches of the other treatments at the conclusion of the germination study. This reasoning is confirmed by the results of the experiment described in Chapter 4. The dry matter production was found to be influenced by low temperatures. It is also plausible to admit that the average temperatures prevailing in the lentil-growing areas of Morocco such as Safi (15°C to 18°C) at the time of sowing (November–December) accounted for the crop being harvested so late (June).



The information provided by the final germination test permits the seeds of 'Large blonde' and 'Anicia' to be pregerminated at a common temperature in order to obtain uniform seedling populations for further investigations on lentil. The temperature of 23°C was used to pregerminate seed material of future experiments.

As already mentioned in Section 2.1. the next experiment deals with the influence of depth of sowing on different aspects of the growth of 'Large blonde' and 'Anicia'.

### 2.3. DEPTH OF SOWING

#### 2.3.1. *Introduction*

Very few data are available on the depth of sowing requirement of lentil. In some papers, other aspects of the cultural practices such as seed rates, furrow and broadcast sowing are given attention (PAKISTAN, 1963; DIMITROV, 1970; TODOROV, 1971).

DÜRIGEN et al (1910) limited the depth of sowing to 2.5–4 cm. MATEO BOX (1963) recommended a similar range 3–4 cm. These opinions are supported by no experimental work. VAN DER MAESEN (1968) found that a depth of 5 cm was better than 0, 2, 7.5 and 10 cm treatments for dry matter production. He did not study the depth effects on other aspects such as leaf production, stem elongation and flowering.

Hence very little is known on the influence of depth of sowing on lentil. An attempt was made to further investigate into this field. 'Large blonde' and 'Anicia' were sown at three levels of depth (1, 4 and 8 cm). Practical reasons such as lack of space and the difficulty of handling deeper sowing limited the number of treatments.

#### 2.3.2. *Treatments and design*

The influence of depth of sowing on the cultivars was studied under three depth treatments: 1, 4 and 8 cm and through a randomized block design. The model comprised eight complete blocks represented by eight cisterns.

#### 2.3.3. *Material and methods*

The effects of sowing at 1, 4 and 8 cm on 'Large blonde' and 'Anicia' were investigated in the greenhouse C (of the Department of Tropical Crop Husbandry) which provided a relative humidity of 50%, night and day temperatures of 20°C and 25°C, respectively. The average solar radiation in the environment was estimated at  $0.32 \text{ cal cm}^{-2} \text{ min}^{-1}$  for the experimental period (March 17–June 5, 1969). Seed pregerminated during 24 hours was sown in 14-liter 'polythene' black buckets (25 × 25 × 28 cm, catalog No. 405 Hdf) made by Emergo N.V. at Landsmeer. River sand (size of the particles between 0.15 and 0.9 mm) was used to fill the buckets. These have five holes in their bottom to facilitate watering from below. At the beginning of the work and thereafter once a month, the sand was moistened with a solution (2.66 g/2 liters/bucket) containing Nutrifol. The composition of this nutrient powder is given in percent N: 18,

$P_2O_5$ :18,  $K_2O$ :18,  $MgO$ :6,  $Mn$ :0.13,  $Zn$ :0.04,  $Cu$ :0.01,  $B$ :0.07,  $Mo$ :0.007. The buckets were held in eight metal cisterns ( $160 \times 130 \times 35$  cm) divided into two rows of four. Each cistern kept six plots (three per cultivar) separated from each other by gravel. In the daytime the plants (five per bucket thinned later to four) were exposed to the natural daylight. The daytime covered a period of nine hours (8 a.m. to 5 p.m.) at the end of which the cisterns mounted on rails were pulled into two of the eight light-equipped compartments of the greenhouse. Two TLF 55 40 W daylight fluorescent Philips lamps providing an intensity of  $0.021 \text{ cal cm}^{-2} \text{ min}^{-1}$  at the plant level kept burning two and half hours before 8 a.m. and likewise after 5 p.m. in each of the two compartments employed for the experiment. So, the plants were given a photoperiod of 14 hours (9 hours of sunlight + 5 hours of electric light).

Weekly countings of leaves were carried out in the period 2–8 weeks after sowing. The weekly measurements of stem elongation which also started two weeks from sowing were performed until the end of the study (79 days after planting). The first series of data for both leaf production and stem elongation covered the whole population but they were later confined to four plants per treatment and per cultivar. Flowering was registered from the appearance of the first flower clusters in the plants. Harvesting took place two weeks after the beginning of flowering. The dry matter yield of the shoots of the plants was recorded after the material was put in a stove at  $80^\circ\text{C}$  for 48 hours.

#### 2.3.4. Results

##### Leaf production

The data, originated from the leaf counts and calculated on a per plant basis, were analysed statistically. The linear component of the factor depth proved to be significant ( $P = 5\%$ ). This linearity is shown in Fig. 1. The totals of seven

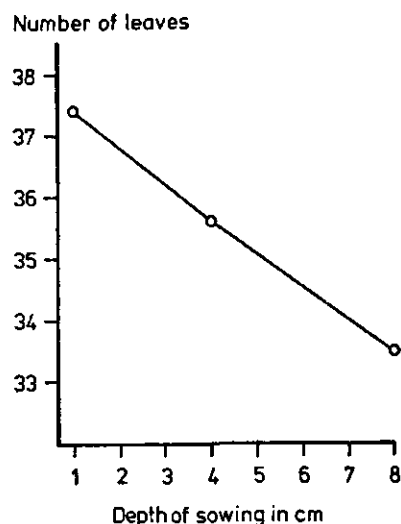


FIG. 1. Change with depth of sowing in the average number of leaves present on the plant material. The data are presented on a per plant and a per week basis and stand for the averages of the values obtained from both cultivars 'Large blonde' and 'Anicia'.

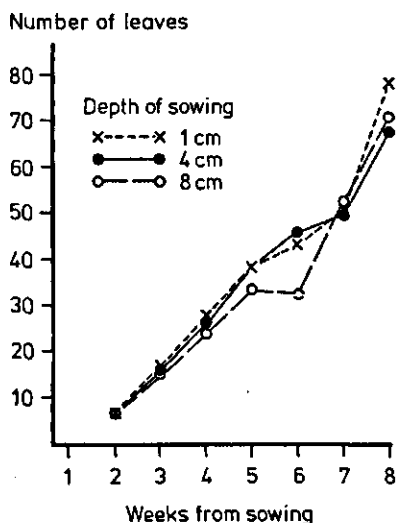


FIG. 2. Change with time in the average number of leaves present on the plant material. The data are presented on a per plant basis and stand for the averages of the values obtained from both cultivars 'Large blonde' and 'Anicia'.

weekly countings of leaves present on the plants of both cultivars were averaged for each level of depth. The cultivar effect and the interaction depth  $\times$  cultivar were not significant ( $P = 5\%$ ).

The data in Fig. 1 indicate that there is no large difference between the treatments. The changes in the average numbers of leaves counted in the course of the time under the three levels of depth, are shown in Fig. 2.

The line corresponding with the 8-cm depth is slightly different from those of the two other treatments. Between the 5th and the 6th week after the sowing, there seems to be a stagnation in the number of leaves counted at 8-cm depth.

### Stem elongation

The factor depth did not cause any significant difference in the elongation of the main stem of 'Large blonde' and 'Anicia' plants. The interaction depth  $\times$  cultivar was not significant either at  $P = 5\%$ . The cultivar effect, on the other hand, was significant ( $P = 0.05\%$ ).

The results permit the values of the stem elongation of the three depth treatments to be averaged (Fig. 3).

The elongation curve of 'Large blonde' is above that of 'Anicia'. However the latter shows at the 11th week a tendency to decrease the discrepancy.

### Flowering

In most of the cases, many flowers appeared simultaneously. Flowering began two weeks before harvesting. At this time all treatments showed flowers and there was no indication that depth of sowing influenced flowering.

### Dry matter output

The analysis of the 48 observations (8 cisterns  $\times$  3 replicates per cultivar) of the experiment revealed significant differences between the depth treatments ( $P = 1\%$ ).

Stem elongation in cm

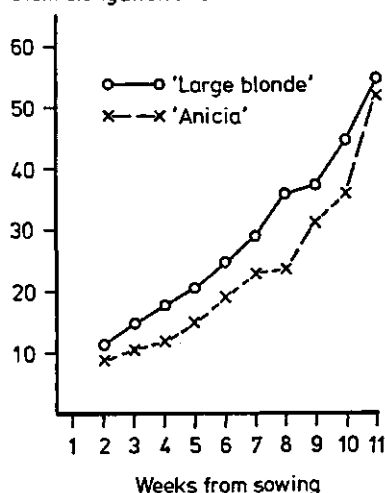


FIG. 3. Course of the elongation on a per plant basis of the stem of 'Large blonde' and 'Anicia'. The data are the averages of the values recorded under the three depth treatments.

TABLE 10. Average flowering time in days calculated for 'Large blonde' and 'Anicia' under depth of sowing of 1, 4 and 8 cm.

Cultivars	Depth of sowing in cm		
	1	4	8
	Flowering time in days from planting		
'Large blonde'	73.2	77.5	75.5
'Anicia'	78.0	79.0	78.5

The quadratic component of the factor depth was significant at a probability comprised between 2.5 and 1%. The cultivars were found to be significantly different ( $P = 0.05\%$ ).

The average productions of the two cultivars are presented in Table 11.

TABLE 11. Average dry matter productions in g of 'Large blonde' and 'Anicia' recorded for 1, 4 and 8-cm depth of sowing. The values between brackets represent percentages of the general average.

Depth of sowing	Cultivars		Average
	'Large blonde'	'Anicia'	
1 cm	6.97 (105.7)	6.30 ( 95.5)	6.63 (100.6)
4 cm	7.61 (115.4)	6.66 (101.0)	7.13 (108.1)
8 cm	6.80 (103.1)	5.20 ( 78.9)	6.00 ( 91.0)
Average	7.12 (108.0)	6.05 ( 91.7)	6.59 (100.0)

'Large blonde' produced more dry matter than 'Anicia' for all the treatments. It may be also observed in Table 11 that the values of 'Large blonde' are always superior to the general average.

#### 2.3.5. *Discussion and conclusions*

The depth treatments caused some difference in the responses of the cultivars with respect to leaf production. Although the linear effect was significant ( $P = 5\%$ ), there were no large differences between the values joined by the line of Fig. 1. When stem elongation is considered, the depth treatments appeared to have no particular effect. The same conclusion applies to flowering in this experiment. The situation is different with dry matter production. The values obtained at 8-cm depth (Table 11) were inferior to those of 1 and 4 cm. This suggests that too deep sowing is not advisable. 'Anicia' seemed to be more affected than 'Large blonde' by the highest depth level. This is probably due to the small size of the seeds of 'Anicia' which are three times less heavy than those of 'Large blonde'. There ensues a poorer food reserve in the seeds of the former cultivar and hence the more marked depressing effect of the deepest sowing on 'Anicia'.

The cultivars show no difference with regard to leaf countings. The stem of 'Large blonde' however was generally longer than that of 'Anicia'. The last cultivar gave a dry matter yield inferior to that of 'Larger blonde' irrespective of the depth treatments (Table 11). Both cultivars showed their highest dry matter output at 4 cm. It may be concluded that the optimum depth of sowing is, irrespective of the cultivar, close to 4 cm. In further experiments, a depth of 3 cm was chosen for practical purposes.

### 3. PHOTOPERIODIC REQUIREMENTS

#### 3.1. INTRODUCTION

HILLMAN (1964) has defined photoperiodism as a response to the duration and timing of light and dark conditions. Photoperiodic studies have been carried out with number of tropical and subtropical crops such as rice (WORMER, 1953; BEST, 1961), sorghum (KEULEMANS, 1959), sesame (SMILDE, 1960), cowpea (WIENK, 1963) and safflower (FERWERDA, 1971). SHULKA (1955) considered lentil as a long-day plant on account of his trial with the cultivar '4315-I'. He found that continuous illumination (natural light in daytime and artificial light at sunset) shortened the vegetative phase by 20 days and the reproductive phase by nine days over the control kept under natural conditions. No indication was made of the environmental temperatures. Moreover, one may point out that wider information might be obtained if other cultivar was involved in the experiment. The same criticism applies also to the work of MOURSI (1963) already mentioned in Section 1.3.3. He observed that the plants of the lentil cultivar 'Giza 9' subjected to a 16-hour photoperiod flowered after 84 days whilst those treated with 6, 8, 10, 12 and 14-hour photoperiods came into flower after 115, 114, 108, 100 and 90 days, respectively. 'Giza 9' behaved quasily as a neutral plant. It flowered under a wide range of photoperiods but the time of the appearance of the flowers varied with the light duration.

The above data appear to be insufficient to define the photoperiodic requirements of lentil. For these reasons, it was thought useful to make a more detailed study of the photoperiodic behaviour of lentil cultivars 'Large blonde' and 'Anicia'. The first two experiments were designed to determine the photoperiodic group to which lentil belongs and at the same time to find out how long the plants should be exposed to short or long-day conditions to obtain the photoperiodic response characteristic for this group. The object of the third experiment was to determine the response curve of lentil with regard to the photoperiod. In all the experiments, the possible effect of differences in photosynthesis caused by differences in illumination was excluded by exposing all the treatments to the same duration of natural daylight for photosynthesis. Different photoperiods were obtained by exposing the plants to different periods of weak fluorescent light, adding insufficient quantities of radiant energy to affect photosynthesis.

#### 3.2. FIRST EXPERIMENT

##### 3.2.1. *Treatments and design*

The experiment included the following 10 treatments:

	Photoperiods	
	10 hours	16 hours
S <sub>1</sub> L <sub>4</sub>	1 week +	4 weeks
S <sub>2</sub> L <sub>3</sub>	2 weeks +	3 weeks
S <sub>3</sub> L <sub>2</sub>	3 weeks +	2 weeks
S <sub>4</sub> L <sub>1</sub>	4 weeks +	1 week
S <sub>5</sub> L <sub>0</sub>	continuous	-

	Photoperiods	
	16 hours	10 hours
L <sub>1</sub> S <sub>4</sub>	1 week +	4 weeks
L <sub>2</sub> S <sub>3</sub>	2 weeks +	3 weeks
L <sub>3</sub> S <sub>2</sub>	3 weeks +	2 weeks
L <sub>4</sub> S <sub>1</sub>	4 weeks +	1 week
L <sub>5</sub> S <sub>0</sub>	continuous	-

The cultivars 'Large blonde' and 'Anicia' were subjected to all the treatments in a completely randomized design with 10 × 2 treatment combinations and two replicates.

### 3.2.2. *Material and methods*

The influence of the above mentioned treatments on both cultivars was studied in the greenhouse C. The environmental conditions have been already described in Section 2.2.3. The average solar radiation related to the the experimental period (March 19–June 13, 1969) was about 0.34 cal cm<sup>-2</sup> min<sup>-1</sup>. A row of four cisterns (two labelled 10 hours and two labelled 16 hours) was used. Each cistern held ten pots (five per cultivar) separated from each other by peat moss and containing garden soil. Watering was performed as indicated in Section 2.2.3.

Seven pregerminated seeds were sown in each pot. After emergence, only four seedlings selected for uniformity were left to grow in a pot. The plants experienced sunlight nine hours a day (8 a.m. to 5 p.m.). The lengthening of the natural light to the requisite photoperiod was performed through the light equipment of one compartment of the greenhouse shed (see 2.2.3.). The treatment of the material began five days after sowing, when the seedlings emerged from the ground. It was realized by moving at the end of 1, 2, 3 and 4 weeks the appropriate number of pots from the cisterns exposed to 16 hours to the others exposed to 10 hours and vice versa. Flowering was recorded as described in Section 2.3.3. Harvesting occurred 86 days from the beginning of the experiments. At this time, the plants which flowered early started dropping their pods. The dry weight of the shoots of the plants was determined after treating them in the way mentioned in Section 2.3.3.

### 3.2.3. *Results*

#### Flowering

At the end of the fifth week after seedling emergence (40 days from planting),

Flowering time of  
'Large blonde' plants  
(Number of days after sowing)

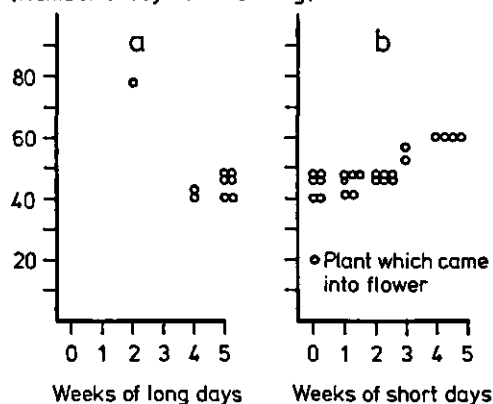


FIG. 4. Flowering responses of 'Large blonde'.

only one treatment ( $L_5S_0$  'Large blonde') showed flowers. All the pots were then kept in their last position for the rest of the time.

In figs. 4 and 5, flowering time is given for the different treatments. Each point represent a plant which came into flower under the relevant treatment. Continuous 10-hour and continuous 16-hour regimes are plotted as 0 week 16-hour and 0 week 10-hour respectively in the above mentioned figures.

It may be seen in Fig. 4 that the treatments clearly influenced the flowering of 'Large blonde'. In general, the shorter the plants were exposed to short-day conditions, the earlier they flowered. The  $L_5S_0$  plants started flowering as soon as 35 days after seedling emergence. The  $S_5L_0$  plants did not flower at all during the experiment. Four weeks of exposure to long days seem to be sufficient for 'Large blonde' to start flowering 40 days from sowing.

Flowering time of  
'Anicia' plants  
(Number of days after sowing)

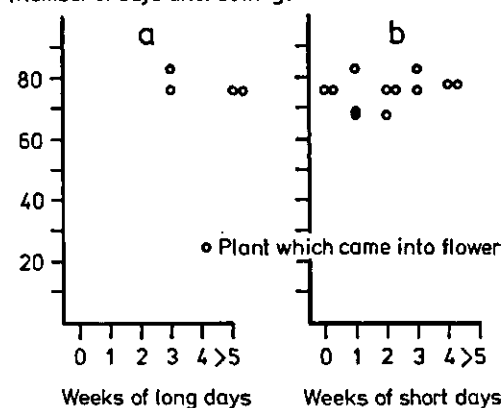


FIG. 5. Flowering responses of 'Anicia'.



Flowering was less abundant in 'Anicia' and was not influenced by 1–4 weeks of exposure to short days after emergence. Flowering commenced between 67 and 78 days after planting. As was the case with 'Large blonde', no flowering occurred under continuous short-day conditions. Three weeks of exposure to long days were sufficient to induce flowering in two plants 76 and 83 days after sowing.

### Dry matter production

The dry weight of the material is shown in figures 6a and 6b representing the total yields (vegetative + reproductive if any) per plant of the two cultivars.

When 'Anicia' plants were exposed to long days for more than four weeks, the dry matter output seemed to decrease. The dry matter yield tended to increase when the plant was exposed to one or more weeks of short days. There was a general tendency of 'Anicia' to produce more dry matter than 'Large blonde'. The differences in the productions did not attain however significance at the 5% level of probability.

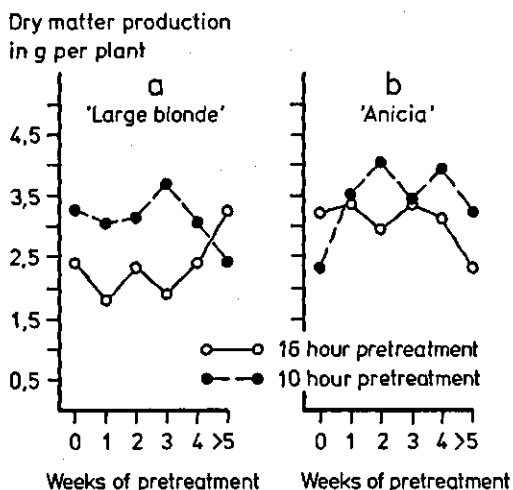


FIG. 6. Influence of short-day and long-day pretreatments on the dry matter production of 'Large blonde' (Fig. 6a) and 'Anicia' (Fig. 6b).

### 3.2.4. Discussion and conclusions

The responses of 'Large blonde' to constant long-day treatment ( $L_5S_0$ ) shows that flowering can occur as soon as 35 days after emergence. 'Anicia' takes about twice as much time to reach the same stage. Both cultivars failed to flower under continuous 10-hour conditions, but four weeks of short-day pretreatment did not prevent them from flowering. 'Anicia' seemed to be less sensitive than 'Large blonde' to photoperiod. The experiment was concluded too early, however, for a complete analysis of the effect of exposures of 1–4 weeks on the flowering habit of these cultivars.

The dry matter productions of the cultivars were not clearly influenced by the

treatments. The short-day pretreatments tended to give higher yields than the long-day ones. 'Large blonde' produced in general less dry matter than 'Anicia'. These conclusions have a tentative character because the experiment was concluded too early as already pointed out.

### 3.3. SECOND EXPERIMENT

#### 3.3.1. *Treatments and design*

The treatments of the second experiment were almost the same as those of the first one. The latter was repeated because there remained some doubt about the reliability of the results. The duration of the first exposure to short or long days was shortened to three days so that the risk of not detecting readiness to flower after seedling emergence would be reduced. The present study involved the following 10 treatments:

	Photoperiods	
	10 hours	16 hours
S <sub>3</sub> L <sub>32</sub>	3 days	+ 32 days
S <sub>10</sub> L <sub>25</sub>	10 days	+ 25 days
S <sub>17</sub> L <sub>18</sub>	17 days	+ 18 days
S <sub>24</sub> L <sub>11</sub>	24 days	+ 11 days
S <sub>35</sub> L <sub>0</sub>	continuous	—

	Photoperiods	
	16 hours	10 hours
L <sub>3</sub> S <sub>32</sub>	3 days	+ 32 days
L <sub>10</sub> S <sub>25</sub>	10 days	+ 25 days
L <sub>17</sub> S <sub>18</sub>	17 days	+ 18 days
L <sub>24</sub> S <sub>11</sub>	24 days	+ 11 days
L <sub>35</sub> S <sub>0</sub>	continuous	—

As in the preceding experiment, all the treatments were applied to each of the cultivars 'Large blonde' and 'Anicia' in a completely randomized design with 10 × 2 treatment combinations and two replicates.

#### 3.3.2. *Material and methods*

The experiment was undertaken in the same greenhouse and with the same material as the first experiment (see 3.2.2.). The average value of solar radiation recorded in the greenhouse was 0.34 cal cm<sup>-2</sup> min<sup>-1</sup> for the experimental period (March 18–June 10, 1970). Five plants were selected to grow in each of the pots used in the investigation. The plants were harvested 84 days from sowing. The responses were studied through the features indicated in Section 3.2.2.

#### 3.3.3. *Results*

##### Flowering

A period of 35 days from seedling emergence was too short to study the

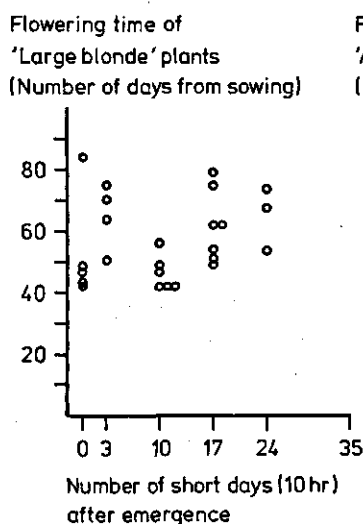


FIG. 7. Flowering response of 'Large blonde' when receiving previously short-day periods.

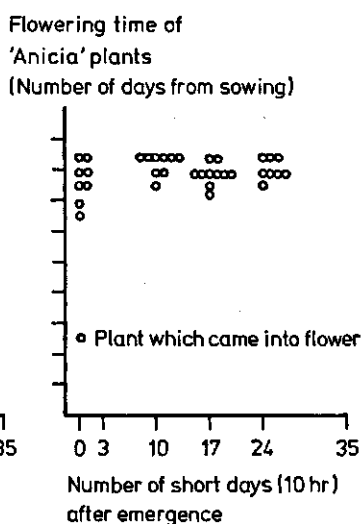


FIG. 8. Flowering response of 'Anicia' when receiving previously short-day periods.

flowering of the cultivars. This problem was remedied by leaving the pots in their last location.

Figs 7 - 8 show how 'Large blonde' and 'Anicia' react to the treatments.

This experiment confirmed many observations of the preceding one. Flowering in both cases and for both cultivars was quantitatively more important when short-day periods were given previously to the plants. Exposed to constant short-day conditions, both cultivars failed to flower. 'Anicia' tended to respond quasi uniformly to the short-day pretreatments.

The data from the first experiment (Fig. 4b) indicated that the shorter the 10-hour pretreatment was, the sooner 'Larger blonde' flowered. In the present study, this tendency was not clearly expressed. Nevertheless, the plants pretreated with 10 short days flowered earlier than those which were given 17 and 24.

Under long-day conditions, 'Large blonde' plants from the first experiment flowered between 35 and 44 days after emergence. In this study, 4/5 of the plants which showed flowers (Fig. 7) gave the same result. 'Anicia' patterns were roughly comparable. In the first experiment, this cultivar came into flower 71 days after seedling emergence. In this experiment, flowering was displayed in the interval 65-79 days.

### Dry matter production

The yields are indicated in figs. 9a and 9b.

The reactions of the cultivars to the pretreatments are not clearly indicated. 'Large blonde' and 'Anicia' produced more dry matter under constant long-day

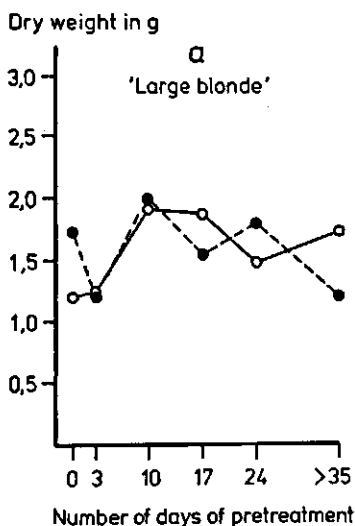


FIG. 9a. Dry matter production per plant of 'Large blonde' in dependence on short-day and long-day pretreatments.

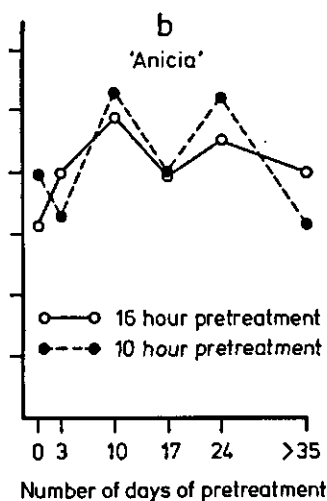


FIG. 9b. Dry matter production per plant of 'Anicia' in dependence on short-day and long-day pretreatments.

conditions than under constant short-day. As in the first experiment, short-day pretreatments tended to bring about more dry matter than the long-day ones. In general, 'Large blonde' produced less dry matter than the other cultivar.

### 3.3.4. Discussion and conclusions

The present work has compensated for the lack of information already discussed (see 3.2.4.). From the intensity of the flowering observed in the second experiment, more reliable conclusions than those indicated in Section 3.2.4. can be drawn. That 'Large blonde' needs at least 35 days from seedling emergence to flower under 16-hour conditions is shown by the observations of figs 4a and 7. 'Anicia' required in the same case at least 65 days. Both cultivars did not flower under constant short-day treatment. However this observation seemed to be affected by the duration of the experiments as far as 'Anicia' was concerned. This cultivar happened to flower 96 days after sowing as shown by Fig. 10b (in the third experiment on photoperiodic requirements). It may be then assumed that harvesting in the experiments on floral indication was undertaken a little too early although this was justified by the pod falls observed in the early-flowering plants.

'Anicia' responded poorly to the photoperiods. This is also shown in Fig. 10b. When the dry matter yields were studied as a second source of data, it turned out that the treatments did not seriously influence the productions. The output of 'Anicia' was in general larger than that of 'Large blonde'.

When the data of figs. 9a and 9b are compared with those of figs. 6a and 6b re-

presenting the dry matter productions of the cultivars in the first experiment, it appeared that 'Large blonde' and 'Anicia', produced less dry matter in the present study than in the first experiment. This was probably due to a depression of the photosynthetic activity of the plants of the present experiment in March and April 1970 with respect to 1969. This consideration is based on the fact that the average values of solar radiation recorded in March and April 1970 were found to be lower (by 18 to 24%) than the corresponding values registered in 1969.

Other data on the photoperiodic requirements of the lentil cultivars: their responses to a wide range of photoperiods (9 to 16 hours) are reported in the third experiment.

### 3.4. THIRD EXPERIMENT

#### 3.4.1. *Treatments and design*

The experiment was carried out with 'Large blonde' and 'Anicia' which were subjected to the influence of the following photoperiods: 9, 10, 11, 12, 13, 14, 15 and 16 hours. The two cultivars were associated to all the treatments in a completely randomized design with  $8 \times 2$  treatment combinations and 5 replicates.

#### 3.4.2. *Material and methods*

The plant material originated from pregerminated seeds grew in the greenhouse C (see 3.2.2.) which was exposed to the natural daylight indicated in Section 3.2.2. Artificial illumination supplied by the shed of the greenhouse was used to obtain the requisite daylengths. Eight cisterns grouped in two rows and corresponding each with a photoperiod treatment were employed. There were 10 pots (five per cultivar) for each cistern. The pots were filled with the same kind of garden soil used in the preceding experiments. They each held four selected plants. Three harvest were carried out in the course of the study, 72 days from sowing (two pots per treatment and per cultivar), 85 days (1 pot per treatment and per cultivar) and 100 days (the rest of the material). Data on flowering and dry matter production were recorded as in the first two experiments.

#### 3.4.3. *Results*

##### Flowering

The observations are presented in figs 10a and 10b.

'Large blonde' did not flower at all at daylengths shorter than 14 hours (Fig. 10a) within 100 days from sowing. It reacted as a long-day plant. 'Anicia' flowered at all daylengths (Fig. 11b), but exposures to 15 and 16 hours caused the plants to flower earlier. The flowering responses of the cultivars under 16-hour conditions were comparable to those reported in the first and second experiment. This was not the same, at any rate not for 'Anicia', for the 10-hour photoperiod. Contrary to what had been observed in the first and second experiments, 'Anicia' flowered abundantly in the present experiment (Fig. 10b). The explanation of this behaviour may be found in the difference in harvesting times. The two

Flowering time of  
'Large blonde' plants  
(Number of days after sowing)

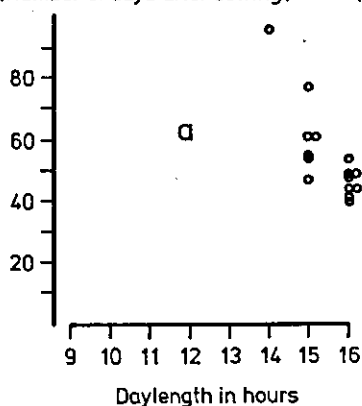


FIG. 10a. Flowering response of 'Large blonde' under different photoperiods.

Flowering time of  
'Anicia' plants  
(Number of days after sowing)

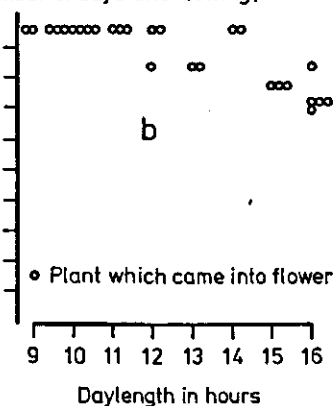


TABLE 12. Dry matter production in g per plant of 'Large blonde' and 'Anicia' 72, 85 and 100 days from sowing.

Photo- periods in hours	Harvesting time in days from sowing					
	72		85		100	
	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'
9	1.23	2.10	1.97	3.42	4.41	3.28
10	1.78	1.87	2.10	2.23	2.48	4.31
11	1.60	1.62	2.00	2.36	2.46	3.11
12	1.92	2.16	2.38	4.50	3.82	5.21
13	1.80	2.04	2.76	2.83	4.31	4.64
14	1.26	1.33	1.17	1.91	2.44	2.68
15	1.76	2.02	2.31	2.94	3.68	4.54
16	2.07	2.12	2.89	3.12	3.47	4.76

#### 3.4.4. Discussion and conclusions

The third experiment has thrown more light on the responses of the lentil cultivars to photoperiod treatments than the preceding ones. 'Large blonde' behaved as a long-day plant whilst 'Anicia' flowered at all the daylengths tested. 'Anicia' was almost day-neutral. Photoperiods of 15 and 16 hours caused earlier flowering.

The dry matter productions of the cultivars also showed some differences. 'Large blonde' produced in general less dry matter than 'Anicia'. Both cultivars showed no specific relations between their dry matter output and the photoperiodic treatments.

#### 3.4.5. General conclusions

The notes accumulated on the three experiments on the photoperiodic requirements of 'Large blonde' and 'Anicia' lead to useful conclusions. 'Large blonde' needs at least 35 days after seedling emergence to come into flower under long-day (16-hour) conditions. 'Anicia' requires twice as much time to attain the flowering stage. 'Large blonde' is clearly a long-day plant. It failed to flower at photoperiods shorter than 14 hours. 'Anicia' is almost day-neutral. It flowered under the wide range of photoperiods tested (9 to 16 hours) but 15 and 16 hour-daylengths promoted earlier flowering than the other photoperiod treatments.

Reference to the dry matter production of the cultivars brings out no clear-cut relationships between this growth parameter and the photoperiodic treatments.

## 4. TEMPERATURE EFFECTS

### 4.1. INTRODUCTION

Temperature plays a controlling part in most plant growth and influences plant distribution (WENT, 1957). In nature, temperature is seldom kept constant throughout the whole year. It follows that it is permissible in studies on the relationships between this factor and plant growth to use fluctuations of temperature. The objective of the current investigation is to obtain information about the temperature requirements of the lentil cultivars 'Large blonde' and 'Anicia'.

### 4.2. EXPERIMENT

#### 4.2.1. *Treatments and design*

The responses of the cultivars were studied under the following treatments:

No. of the treatment	Temperatures night-day	Average
1	9–15°C	12°C
2	13–19°C	16°C
3	17–23°C	20°C
4	21–27°C	24°C
5	25–31°C	28°C
6	29–35°C	32°C

As it may be seen, an amplitude of 6°C was common to all the treatments. The first five average temperatures are experienced by lentil grown in Marrakech area (Morocco) during the following stages: germination, slow growth, rapid growth, flowering and maturity. The last one is registered in the district of Lahore (Pakistan) in May when January-sown lentil is maturing.

A light period of 14 hours was given to all the treatments. These were distributed in a completely randomized design with  $6 \times 2$  treatment combinations and two replicates.

#### 4.2.2. *Material and methods*

The influence of the six temperature regimes on the growth of 'Large blonde' and 'Anicia' was studied with plants grown in the six cabins described in Section 5.2.2. Further details on experimental conditions may be found in this section. Seven selected plants were left to grow in each of the 24 pots used in the experiment. Harvesting was performed seven weeks from planting when floral buds appeared on the plants (of 'Large blonde' grown under an average temperature of 20°C). The responses were recorded at the time of the harvest in terms of leaf



#### Leaf production plant<sup>-1</sup>

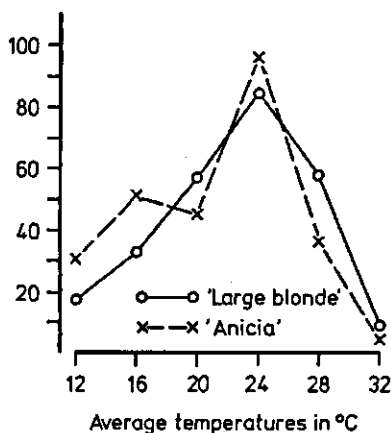


FIG. 11. Leaf production of 'Large blonde' and 'Anicia' in dependence on the temperature treatments indicated in Section 4.2.1. and symbolized by the related averages.

production, stem elongation and dry matter production (of the whole plants). They are presented on a per plant basis.

#### 4.2.3. Results

The plants of the two cultivars which were subjected to Treatment 6 were harvested one month after sowing before death occurred. Those which thrived under Treatment 1 conditions were not healthy but they were able to survive the course of the experiment.

##### Leaf production

The graphs of Fig. 11 show roughly the same tendency: from 12°C to 24°C the productions raise in general: thereafter they decrease rather abruptly.

The significance of the interaction between cultivar and treatment ( $1\% < P < 2.5\%$ ) suggests to compare the effects of the temperature treatments separately for 'Large blonde' and 'Anicia'. For 'Large blonde', no significant differences were brought about by the following comparisons conducted through the new multiple range test: 12°C versus 32°C, 12°C versus 16°C, and 20°C versus 28°C. For 'Anicia', comparing the effects of the Treatments 2, 3, and 5 (respective averages: 16, 20 and 28°C) led to no significant differences ( $P = 5\%$ ).

The cultivars differ significantly from each other ( $2 < P < 5\%$ ) only at 16°C.

##### Stem elongation

The data are shown in Fig. 12.

As in Fig. 11, the values increase from 12°C up to 24°C; they decrease at average temperatures higher than 24°C.

Treatment 4 appeared to be also beneficial to the stem elongation of the two cultivars. For 'Anicia', however, its effect on the stem was comparable to that of Treatment 5 (average 28°C).

The statistical analysis of the set of data indicated that the overall effect of

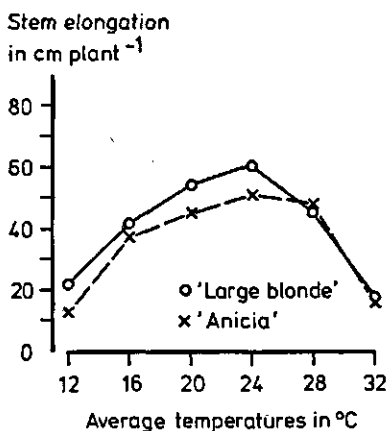


FIG. 12. Stem elongation of 'Large blonde' and 'Anicia' in dependence on the temperature treatments indicated in Section 4.2.1. and symbolized by the related averages.

Treatment 1 was not significantly different from that of Treatment 6. The same holds for Treatment 2 versus Treatment 3; Treatment 2 versus Treatment 5 and for the possible comparisons among the Treatments 3, 4 and 5 ( $P = 5\%$ ).

The cultivars were not significantly different from each other with respect to temperature effects ( $P = 5\%$ ). The average stem elongation of 'Large blonde' (general response) was significantly different from that of 'Anicia' ( $2.5 < P < 5\%$ ). 'Large blonde' plants were in general longer than those of 'Anicia'.

#### Dry matter production

Fig. 13 demonstrates that Treatment 4 (average 24°C) leads to the highest dry matter production of 'Large blonde' and 'Anicia'. In the case of the last cultivar, Treatment 3 (average 20°C) brought about an effect similar to that of Treatment

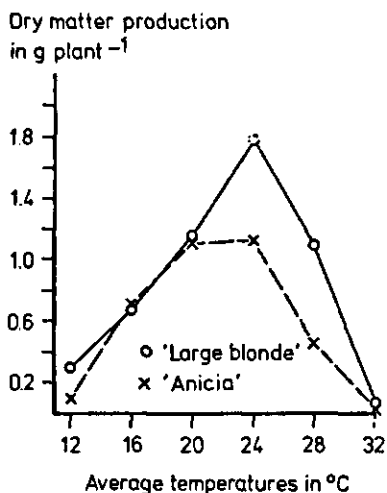


FIG. 13. Dry matter production of 'Large blonde' and 'Anicia' in dependence on the temperature treatments indicated in Section 4.2.1. and symbolized by the related averages.

TABLE 13. Dry matter production in g per plant of 'Large blonde' and 'Anicia' under the six temperature regimes represented by the average temperatures of 12°C, 16°C, 20°C, 24°C, 28°C and 32°C.

Cultivars	Average temperatures						Average
	12°C	16°C	20°C	24°C	28°C	32°C	
'Large blonde'	0.30	0.68	1.17	1.79	1.10	0.06	0.85
'Anicia'	0.11	0.74	1.08	1.13	0.46	0.03	0.58
Average	0.20	0.71	1.12	1.46	0.78	0.04	0.71

Estimate of the standard error:  $\frac{\sigma}{\sqrt{n}} = 0.32$ , d.f. = 12

4. The detrimental effects of the Treatments 1 and 6 already shown in figs. 11 and 12 are also reflected in Fig. 13.

The data are also given in Table 13.

The statistical analysis of the information of this table led to the following results: the average productions given under 16°C, 20°C, 24°C and 28°C were not found to be significantly different; it was the same for those presented under 12 and 32°C ( $P = 5\%$ ). The other possible comparisons among the treatments showed no significant differences.

The cultivars were not significantly different from each other neither at the temperature levels nor in average ( $P = 5\%$ ).

#### 4.2.4. Discussion and conclusions

The experiment permits to collect information about the temperature requirements of the lentil cultivars 'Large blonde' and 'Anicia'. The use of a common amplitude of 6°C increases the reliability of the data. As is pointed out in Section 5.2.4., this amplitude appeared to favour the growth of the cultivars.

Treatment 4 brought about the maximum leaf production, stem elongation and dry matter production of 'Large blonde' and 'Anicia'. Figs. 12 and 13 suggest that treatments 5 and 3 (represented by 28 and 20°C) are not worse than Treatment 4 (represented by 24°C) for the stem elongation and the dry matter production of the last cultivar, respectively.

The experimental results may explain why harvesting of lentil in countries like Morocco is undertaken six months after planting. The growth of the crop is certainly retarded by the environmental temperature. In Fes, Safi and Marrakech for example, the average temperature at the time of sowing is between 11 and 15°C. Average temperatures equal or above 20°C are only registered from May on.

## 5. DAILY AMPLITUDE OF TEMPERATURE

### 5.1. INTRODUCTION

Cyclic fluctuations of night and day temperatures are known to bring about effects different from those of constant temperatures. WENT (1944) noted that the rate of stem elongation and the fruiting of tomato were favoured by a night temperature lower than the day one. JAIN (1968) observed that the dry matter yield of 45-day old maize plants was higher under a night temperature of 15°C combined with a day temperature of 30°C than under the same night temperature combined with day temperatures of 15°, 20° and 25°C. Responses of lentil to the daily amplitude of temperature simulating natural conditions are not reported in the literature. As this may be an important criterion for the environmental requirements of this crop, it was considered useful to investigate into this matter under controlled conditions.

### 5.2. EXPERIMENT

#### 5.2.1. *Treatments and design*

The cultivars 'Large blonde' and 'Anicia' were brought under the influence of the following treatments:

Temperatures night-day	Light duration in hours	Name of the treatment
24°C-24°C	14	T <sub>1</sub> L <sub>1</sub>
21°C-27°C	14	T <sub>2</sub> L <sub>1</sub>
18°C-30°C	14	T <sub>3</sub> L <sub>1</sub>
24°C-24°C	16	T <sub>1</sub> L <sub>2</sub>
21°C-27°C	16	T <sub>2</sub> L <sub>2</sub>
18°C-30°C	16	T <sub>3</sub> L <sub>2</sub>

T<sub>1</sub> may be considered as the average temperature of the regimes T<sub>2</sub> and T<sub>3</sub>. T<sub>2</sub> represents the average night and day temperatures experienced by lentil in Marrakech (Morocco) during the growth period. T<sub>3</sub> is related to Chittagong (East Pakistan). The two light periods 14 and 16 hours were included because it was suspected that a photoperiod of 14 hours might lengthen the growth period.

The treatment combinations were collected in a completely randomized design with 6 × 2 treatment combinations and two replications.

#### 5.2.2. *Material and methods*

The experimental work on the responses of 'Large blonde' and 'Anicia' to daily amplitudes of temperature related three temperature treatments: 18°–

30°C, 21°–27°C and 24°–24°C (night-day) to two light durations: 14 and 16 hours a day. These conditions were provided by six cabins (60 × 60 × 144 cm). A 1000 W HPL Philips lamp giving an intensity of 0.32 cal cm<sup>-2</sup> min<sup>-1</sup> at the plant level, was used for the 14-hour light treatment. The 16-hour regime was obtained by adding to the 1000 W lamp, four 25 W lamps of an intensity of 0.035 cal cm<sup>-2</sup> min<sup>-1</sup>. The latter were left to burn one hour before the former was switched on and one hour after it was switched off. The relative humidity was kept at 50 % in the cabins.

Each cabin held four polyethylene pots (two per cultivar). The pots are of the Kick-Brauckman type and made by the Firma Baumann in Amberg, West Germany. They consisted of two parts, the outer with a diameter of 27 cm and a height of 25.5 cm; the inner with a diameter of 26.6 cm and a height of 24.2 cm. The outer part communicated with a transparent plastic tube (diameter one cm., length 20 cm.) which indicated the level of the water table in the pots. These were filled with 10.5 kg of sand (as described in Section 2.3.3.) each, moistened with two litres of Nutrifol solution (the concentration was given in Section 2.3.3.). The sand was laid on a nylon sieve which prevented it from being drained towards the plastic tube of the pots. The level of water was maintained at 8 cm from the bottom of the pots during the experiment. Once a month, watering was undertaken with the Nutrifol solution.

Five selected plants were allowed to grow in each pot. Harvesting was done 76 days from sowing, when the pods of the early-flowering plants began to fall. The responses were studied by recording flowering in terms of number of plants, the final number of leaves, the final height of the stem and the final dry matter yield (vegetative plus reproductive if any) for the whole plant.

### 5.2.3. Results

#### Flowering

The number of plants which came into flower is given in Table 14 for the different treatments.

These data indicate that 'Anicia' flowered poorly during the experiment. 'Large blonde' brought about the best onset of flowering under the temperature regime of 21°–27°C and the 16-hour light treatment.

TABLE 14. Number of flowering plants of 'Large blonde' and 'Anicia'.

Temperature regimes (night-day)	'Large blonde'		'Anicia'	
	Light duration		Light duration	
	14 hours	16 hours	14 hours	16 hours
24°–24°C	1	6	0	2
21°–27°C	4	9	0	1
18°–30°C	0	3	0	0

TABLE 15. Leaf production per plant of 'Large blonde' and 'Anicia' 76 days from sowing

Temperature regimes	'Large blonde'			'Anicia'			Average for light durations		Average for cultivars		Average
	Light duration		Average	Light duration		Average					
night-day	14 hours	16 hours		14 hours	16 hours		14 hours	16 hours	'Large blonde'	'Anicia'	
24°C-24°C	155	97	126	160	152	156	157	124			140
21°C-27°C	153	165	159	170	125	148	161	146			153
18°C-30°C	135	107	121	99	122	110	117	114			115
Average	148	123	135	143	133	138	145	128	135	138	137

### Leaf production

The final number of leaves produced per plant of 'Large blonde' and 'Anicia' under the different light and temperature conditions is presented in Table 15.

The temperature regime 21°C-27°C gave the highest average leaf production. It is followed by the constant treatment (24°C-24°C). This regime seemed to be more beneficial to 'Anicia' than to 'Large blonde'. The average productions of the temperature regimes, compared through the new multiple range test showed no significant differences ( $P = 5\%$ ).

In average the 14-hour light treatment led to a higher leaf production than the 16-hour but the difference was not significant ( $P = 5\%$ ). The average productions of the two cultivars were practically the same.

### Stem elongation

The measurements of the main stem of the plants undertaken at the time of the harvest are presented in Table 16.

The data collected on stem elongation showed the same pattern as those on leaf production with respect to the effects of the temperature regimes and the behaviour of the cultivars. The treatment 21°C-27°C was found to be the most

TABLE 16. Stem elongation in cm per plant of 'Large blonde' and 'Anicia' 76 days from sowing

Temperature regimes	'Large blonde'			'Anicia'			Average for light durations		Average for cultivars		Average
	Light duration		Aver-	Light duration		Aver-					
night-day	14 hours	16 hours		14 hours	16 hours		14 hours	16 hours	'Large blonde'	'Anicia'	
24°C-24°C	86	105	95	87	90	88	86	97			91
21°C-27°C	94	98	96	90	105	97	92	101			96
18°C-30°C	67	92	79	73	93	83	70	92			81
Average	82	98	90	83	96	89	82	97	90	89	89

favourable for the stem elongation of the cultivars. It was followed by the constant temperature regime as was the case for leaf production. Statistical comparisons of the average elongations recorded under the three regimes brought about significant differences between the effects of 21°C–27°C and those of 18°C–30°C ( $P = 1\%$ ).

The 16-hour light period appeared to be better than the 14-hour for the stem elongation of the cultivars (the differences were significant at  $P = 1\%$ ). A reverse effect was observed regarding the leaf production. The average stem elongation of 'Large blonde' was similar to that of 'Anicia'.

### Dry matter output

The graphs of Fig. 14 showed that the cultivars produced more dry matter under the temperature regime of 21°C–27°C, except for 'Anicia' treated with 14-hour light period. The productions were reduced by a regime of 18°–30°C, irrespective of the light treatment. The longest light period increased the dry matter yields. It appears, however, that the 14-hour light regime was more beneficial for the cultivars under the constant temperature (24°–24°C) conditions.

The data are also presented in Table 17.

The information given in Table 17 shows clearly that the regimes 21°C–27°C and constant 24°C lead to higher average values than 18°C–30°C. This pattern was already found in the results on leaf production and stem elongation. Significant difference ( $2\% < P < 5\%$ ) was obtained between the average production registered for 21°C–27°C and that recorded for 18°C–30°C.

In general the 16-hour light treatment enhanced the dry matter production of the cultivars. The difference between the average outputs of the two light periods was not however significant ( $P = 5\%$ ). 'Large blonde' produced in average more dry matter than 'Anicia' as may be seen in Table 17. The average productions of the cultivars were significantly different ( $2.5\% < P < 5\%$ ).

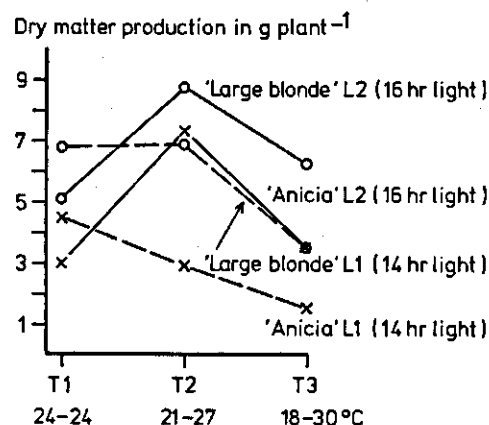


FIG. 14. Dry matter production versus temperature regime of 'Large blonde' and 'Anicia' under 14-hour and 16-hour light periods.

TABLE 17. Dry matter production in g per plant of 'Large blonde' and 'Anicia'.

Temperature regimes	'Large blonde'			'Anicia'			Average for light durations		Average for cultivars		Average
	Light duration		Average	Light duration		Average					
	14 hours	16 hours		14 hours	16 hours						
night-day	14 hours	16 hours		14 hours	16 hours		14 hours	16 hours	'Large blonde'	'Anicia'	
24°C-24°C	6.77	5.11	5.94	4.43	3.00	3.71	5.60	4.05			4.82
21°C-27°C	6.87	8.74	7.80	2.90	7.33	5.11	4.88	8.03			6.45
18°C-30°C	3.49	6.23	4.86	1.50	3.50	2.50	2.49	4.86			3.68
Average	5.71	6.69	6.20	2.94	4.61	3.77	4.32	5.65	6.20	3.77	4.98

#### 5.2.4. Discussion and conclusions

The foregoing results indicate that the temperature regimes exerted no large influence on the flowering of the cultivars. The 16-hour light treatment was favourable to this process. These reasonings carry some reserve because of the poor flowering of 'Anicia'. The general effects of the temperature regimes on leaf production, stem elongation and dry matter production are characterized by a marked uniformity. The amplitude of 6°C appeared to be better than that of 12°C and also better than the constant temperature.

The 14-hour light treatment was conducive to an average leaf production higher than that obtained under 16-hour. It was not better, however, than the other light treatment with respect to stem elongation and dry matter production. It may be noted that no significant differences were found between the effects of the two light periods on the dry matter output.

The cultivars gave similar results (in terms of average values) with respect to leaf production and stem elongation. When dry matter production is concerned it turned out that 'Large blonde' led to a larger output.



## 6. PHOTOSYNTHESIS

### 6.1. INTRODUCTION

The importance of photosynthesis for plants has been already stressed in a number of publications. More than 90% of the dry matter of the plants originates from this process (THOMAS, RANSON and RICHARDSON, 1960). The dry weight of a harvested crop may be in a broad sense considered as the excess of photosynthetic gain over respiration losses (EDDOWES, 1969).

Data have accumulated on the photosynthesis of many crops such as alfalfa and corn. Midday photosynthesis of field-grown alfalfa (in terms of g CO<sub>2</sub> assimilated per 80-minute period) was measured at different light intensities and temperatures (THOMAS and HILL, 1949). The influence of instantaneous temperatures on the photosynthesis of corn plants has also been reported (DE WIT, 1970). No information on the photosynthesis of lentil is found in the literature. In the current study, this aspect is investigated. The photosynthesis of the lentil cultivars 'Large blonde' and 'Anicia' is studied at three temperatures.

### 6.2. EXPERIMENT

#### 6.2.1. *Treatments and design*

The study of the photosynthesis of lentil was undertaken with the cultivars 'Large blonde' and 'Anicia' at 18°C, 24°C and 30°C. These treatments correspond respectively to the average day temperatures of lentil-growing areas like Peshawar (West Pakistan), Macallé (Ethiopia) and Calcutta (India) during the growth period (GREAT BRITAIN, 1958). Two plant populations (4-week and 6-week old) were used per cultivar. A completely randomized design grouping 12 pots of each cultivar was common to both of them.

#### 6.2.2. *Material and methods*

##### Plant material, growth chambers and treatments

Pregerminated seeds of the cultivars were sown in five-liter plastic pots each filled with 3.75 kg of garden soil previously moistened. The pots (diameter 22 cm) with holes in the bottom to facilitate watering were kept in two shallow wooden cases provided with a plastic clothing. Twenty-four pots held in each case were used per cultivar. The cases were placed in the growth chamber (3,5 × 4,5 m) of the Department of Field Crop Husbandry of the Agricultural University of Wageningen, which supplied night and day temperatures of 12°C and 18°C, respectively. Each temperature was provided 12 hours a day. The relative humidity was 50 to 70% and the light intensity at the plant level was found to be 0.170 and 0.177 cal cm<sup>-2</sup> min<sup>-1</sup> at seedling emergence and at the time the plants were 4-weeks old, respectively. The illumination source consisted

of 204 TLM Philips lamps burning 14 hours a day. Light was given at the same time as the highest temperature. Seven plants out of an initial number of eleven were allowed to grow in each pot.

Two weeks later the same operations were repeated according to an identical pattern in another chamber (Chamber no. 2) which only differed from the preceding by night and day temperatures of 22°C and 28°C, respectively. By the time the first population (Chamber no. 1) was six-week old and the second (Chamber no. 2), four-weeks old, the plants were moved to the Institute for Biological and Chemical Research on Field Crops and Herbage of Wageningen where their photosynthesis was studied. Interest was first focused on leaf age but due to the unsuitability of the equipment to register data from such small leaves as those of lentil, the whole aerial parts of the plants were considered. Groups of 12 plants (two pots) from each cultivar were exposed to 15, 30, 50, 75 and 100% of a light intensity of about  $0.4 \text{ cal. cm}^{-2} \text{ min}^{-1}$  at three temperatures: 18°C, 24°C and 30°C. Two measurements were made in darkness at each temperature to estimate the respiration values of plants and soils. The tedious work of calculating the leaf area was overcome by using the vertical and horizontal projections of the canopy. These projections were obtained through photography. This method was thought useful because the leaf cover was very open. The leaves practically did not shade each other as illustrated by photos 1, 2 (see Section 1.2.) and 3. The last photo represents the shoots of 4-week old 'Anicia' plants in horizontal projection.

The areas were finally estimated with WARREN WILSON's formulae (1959):

$$F = F_{90} \sec. \alpha (1)$$

F = foliage denseness or total area of foliage per unit volume of space

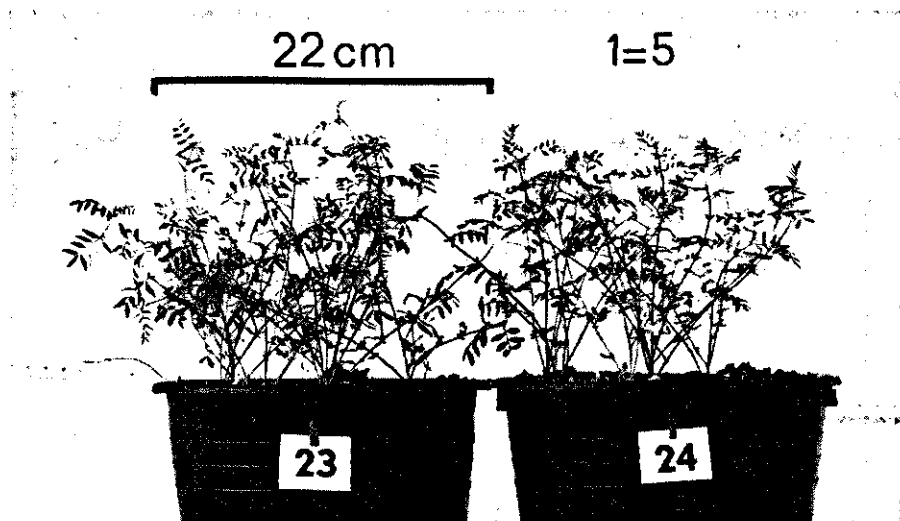


PHOTO 3

$F_{90}$  represents  $F$  in vertical projection

$\alpha$  = foliage angle i.e. the angle between the foliage and the horizontal. Its value is obtained through the formula

$$\tan \alpha = 1.57 \times (F_0 : F_{90}) \quad (2) \text{ where } F_0 = F \text{ in horizontal projection.}$$

### Photosynthesis equipment

Details about the installation used for the photosynthesis experiment may be found in LOUWERSE and OORSCHOT (1969). The light was supplied by four HPLR Philips lamps of 400 W each, which were able to give a maximum intensity of about  $0.4 \text{ cal cm}^{-2} \text{ min}^{-1}$ . The partitioning of the intensity was facilitated by the use of metal screens between the light sources and the plant chamber.

The air temperature of the chamber was controlled with copper constantan thermocouples. The  $\text{CO}_2$  concentration of the air passing in the plant chambers was about 300 ppm. It was secured by a mixture of  $\text{CO}_2$ -free air with pure  $\text{CO}_2$  coming from a cylinder. Two infra-red gas analysers (Beckman Model 15A and Model 215) recorded the  $\text{CO}_2$  content of the incoming and outgoing air of the plant chamber. From the data collected during this operation the photosynthetic activity could be evaluated. A Fortran program and a computer were available for this purpose. Data were obtained in terms of net photosynthesis in  $\mu\text{g CO}_2 \text{ cm}^{-2} \text{ hour}^{-1}$  and in  $\text{g fresh weight}^{-1} \text{ hour}^{-1}$  at different light intensities. Gross photosynthesis values were finally calculated because of the size of the respiratory activity. They were expressed in  $\text{mg CO}_2 \text{ per dm}^{-2}$ . The information on fresh weight was corrected on a dry weight basis to avoid errors which might originate from differences in the thickness of the leaves of the two cultivars.

### 6.2.3. Results

Curves graphed according to the model given in Fig. 15 showed no definite

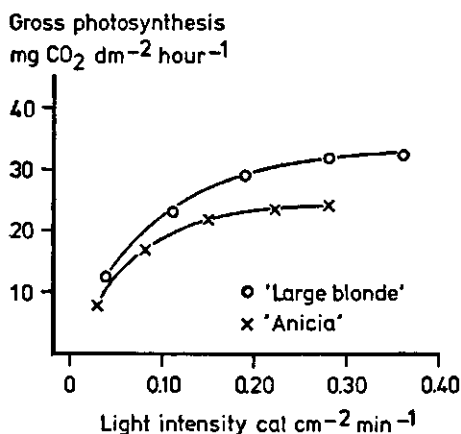


FIG. 15. Gross photosynthesis (leaf area basis) of 4-week old 'Large blonde' (O) and 'Anicia' (x) plants at a temperature of 24°C.

temperature effect on the photosynthesis of the cultivars. An attempt to determine the influence of temperature on the photosynthesis of the cultivars (dry weight basis) was carried out at the intensity of  $0.30 \text{ cal cm}^{-2} \text{ min}^{-1}$ . This intensity may be considered as near the saturation level because, for most of the treatments, the photosynthesis curves were stable or were about to be so near this level. The data are given in Fig. 16 and confirm that the temperature effect is negligible.

The foregoing information permits to present the results in terms of averages. The photosynthesis values recorded at the three temperatures are averaged and plotted against average light intensities in figures 17, 18 19 and 20. The curves relating the observations were smoothed out as in Fig. 15.

The data displayed in figures 17 and 18 indicate that the cultivars have a similar photosynthetic capacity, regardless of plant age. Those provided by figures 19 and 20 prompt that 'Large blonde' and 'Anicia' differ in the surface (of foliage) they form per unit dry weight. As far as dry matter output of the shoots was concerned, the two plant populations were comparable. The average productions of 'Large blonde' were 0.26 g and 0.23 g for the 4-week and 6-week old plants respectively. For 'Anicia' they were found to be 0.19 g and 0.17 g, respectively. The sizes of the ratio leaf area ( $\text{dm}^{-2}$ )/dry weight (g) are given in Table 18.

The statistical analysis of the data of the table demonstrated that the cultivars differed significantly from each other ( $P = 0.1\%$ ). The rest of the statistical information carried no significant differences.

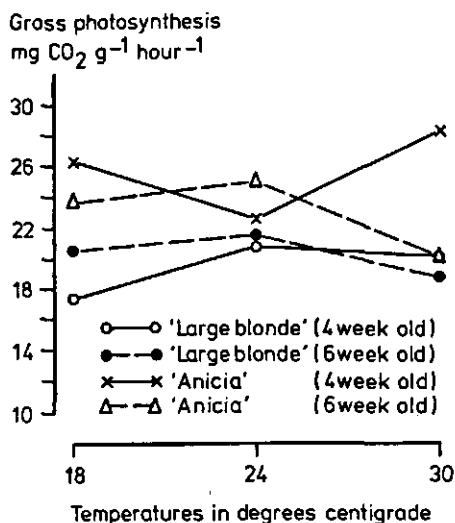


FIG. 16. Gross photosynthesis (dry weight basis) of 'Large blonde' and 'Anicia' at a light intensity of  $0.30 \text{ cal cm}^{-2} \text{ min}^{-1}$  and the temperatures of 18, 24 and  $30^\circ\text{C}$ .

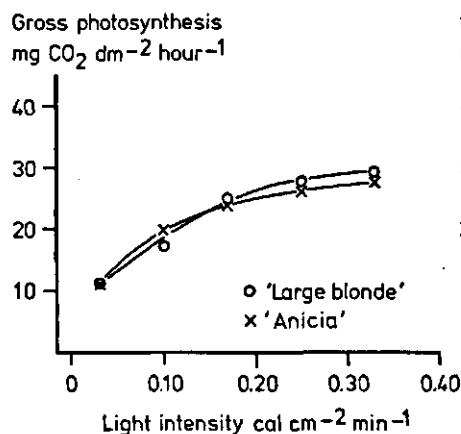


FIG. 17. Average gross photosynthesis (leaf area basis) of 4-week old 'Large blonde' (○) and 'Anicia' (×) plants in dependence on light intensity. The data stand for the averages of the values recorded at 18, 24 and 30°C.

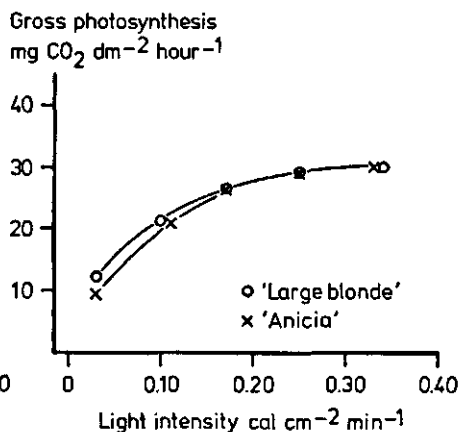


FIG. 18. Average gross photosynthesis (leaf area basis) of 6-week old 'Large blonde' (○) and 'Anicia' (×) plants in dependence on light intensity. The data stand for the averages of the values recorded at 18, 24 and 30°C.

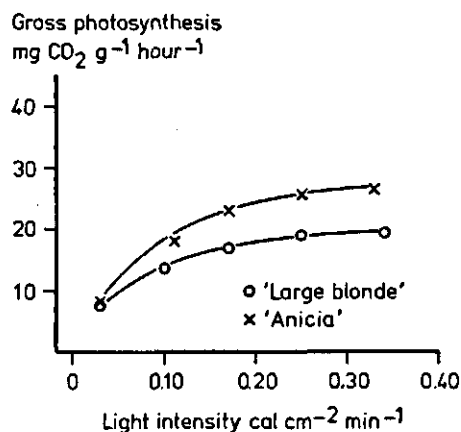


FIG. 19. Average gross photosynthesis (dry weight basis) of 4-week old 'Large blonde' (○) and 'Anicia' (×) plants in dependence on light intensity. The data stand for the averages of the values recorded at 18, 24 and 30°C.

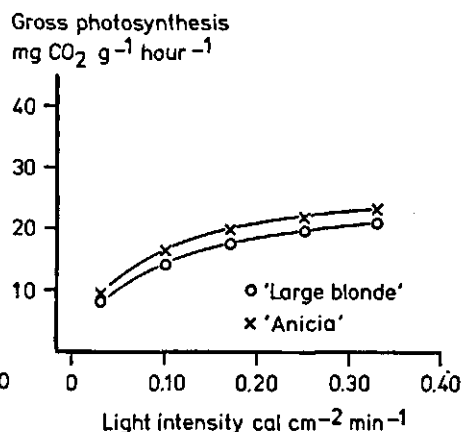


FIG. 20. Average gross photosynthesis (dry weight basis) of 6-week old 'Large blonde' (○) and 'Anicia' (×) plants in dependence on light intensity. The data stand for the averages of the values recorded at 18, 24 and 30°C.

TABLE 18. Values of the ratio leaf area ( $\text{dm}^{-2}$ )/dry weight (g) of the 4-week and 6-week old 'Large blonde' and 'Anicia' plants used in the photosynthesis experiment.

Batches of plants		Photosynthesis temperature treatments			Average
Cultivars	Age	18°C	24°C	30°C	
'Large blonde'	4-weeks	0.65	0.62	0.62	0.63
'Large blonde'	6-weeks	0.71	0.67	0.67	0.68
Average					0.65
'Anicia'	4-weeks	0.77	0.90	0.81	0.82
'Anicia'	6-weeks	0.76	0.92	0.78	0.82
Average					0.82

#### 6.2.4. Discussion and conclusions

The data given in the experiment lead to the conclusion that the photosynthesis of the lentil cultivars 'Large blonde' and 'Anicia' was not influenced in a definite way by the temperature treatments used in this study. The curves of figures 17 and 18 indicate that both cultivars have a similar photosynthetic capacity. Those of figures 19 and 20 indicate that 'Large blonde' and 'Anicia' are different with respect to the surface they form per unit dry weight. As the values of the ratio leaf area ( $\text{dm}^{-2}$ )/dry weight (g) of 'Anicia' are greater than those of 'Large blonde', the photosynthesis curves (dry weight basis) of the former cultivar result in being above those of the latter.

## 7. DROUGHT TOLERANCE

### 7.1. INTRODUCTION

Little is known about the behaviour of lentil under different moisture conditions. The transpiration ratio of the crop is reported to be 600 (liters of transpired water/kg of dry matter produced), (VAN DIEST, 1970). It appeared to be in the range 800–1500 for lentil grown in the semi-arid Volgra area (JOFFE, 1949). The white lentil of Syria and the red lentil of Egypt were found to be moderately resistant according to the criteria given in Section 1.3.2. In Bulgaria, it was observed that the small-seeded cultivars were more drought-resistant than the large-seeded ones (GANEVA, 1971). It is permissible to speak of drought escape in this case because the former cultivars are reported to have a growing period shorter than that of the latter which experienced severe droughts.

From all this, it appears that more information on the water requirements of lentil is desirable. The following note aims at investigating the drought tolerance of the cultivars 'Large blonde' and 'Anicia' in controlled environment.

### 7.2. EXPERIMENT

#### 7.2.1. *Treatments and design*

The drought-tolerance of lentil was studied with the cultivars 'Large blonde' and 'Anicia' under four levels of watering: 3, 4, 8 and 12 times a month. A randomized block design was used. It involved two blocks represented by two growth chambers receiving 16 pots each. At the block level, 'Large blonde' and 'Anicia' disposed then of two pots per treatment.

#### 7.2.2. *Material and methods*

The cultivars 'Large blonde' and 'Anicia' grew in two chambers ( $3.50 \times 1.60 \times 2.06$  m) which supplied night and day temperatures of 20°C and 26°C, respectively and a relative humidity of 50%. The individual light equipment was made of a set of 24 TLF Philips lamps of 40 W, burning 16 hours a day and providing an intensity of  $0.14 \text{ cal cm}^{-2} \text{ min}^{-1}$  at the plant level. In each chamber, four groups of four pots filled with sand (see Section 4.2.2.) were watered to field capacity three, four, eight and 12 times a month, respectively. At the beginning of the experiment and thereafter once a month, the sand was moistened with Nutrifol solution as indicated in Section 4.2.2. Five plants were left to grow in each pot. There were in total 20 plants (in four pots) per treatment for each cultivar.

The drought tolerance was investigated through the following features: leaf area, stem elongation, dry matter production (whole plants and roots separately), water content of the plants and relationships between dry matter production

and evapotranspiration. These determinations were carried out at the conclusion of the experiment (67 days from sowing at the beginning of flowering). The leaf area was measured with the desk type of direct reading optical planimeter described by SCHURER (1971). The measurements were carried out on series of two twenty-leaf samples taken from each treatment and each cultivar. The data were recorded in terms of average area of a 20-leaf sample. The total dry weight produced in each treatment (dry weight of 20 plants/cultivar) and the corresponding amount of water lost by evapotranspiration were recorded to define the relationships between these two features.

### 7.2.3. Results

#### Leaf area

The observations are presented in Table 19. The values correspond with the areas of average 20-leaf samples.

TABLE 19. Average area in cm<sup>2</sup> of a sample of 20 leaves taken from 'Large blonde' and 'Anicia' plants under the four watering conditions.

No. of waterings per month	'Large blonde'	'Anicia'
3 (Treatment I)	78	54
4 (Treatment II)	95	58
8 (Treatment III)	102	63
12 (Treatment IV)	104	64
Average	95	60

The statistical analysis of the data showed significant differences between the effects of Treatment I and those of the other treatments on 'Large blonde': Treatment I versus Treatment II ( $0.2\% < P < 1\%$ ), versus Treatment III ( $0.2 < P < 1\%$ ) and versus Treatment IV ( $P = 0.1\%$ ). In the case of 'Anicia', significant differences were found only between Treatment I and Treatment IV ( $2 < P < 5\%$ ). The cultivars were found to be significantly different from each other ( $P = 1\%$ ). The leaves of 'Large blonde' were more than 50% larger than those of 'Anicia', as suggested by a casual glance at the plants. The interaction treatment  $\times$  cultivar was not significant ( $P = 5\%$ ).

#### Stem elongation

'Large blonde' plants were in general taller than those of 'Anicia' but the difference was not statistically significant. The effects of the treatments were significantly different ( $P = 1\%$ ).

The elongation of the main stem of the cultivars is presented on a per plant basis in Fig. 21.

It may be seen that a quasi linear relationship exists between the stem elongation of the cultivars and the water treatments.



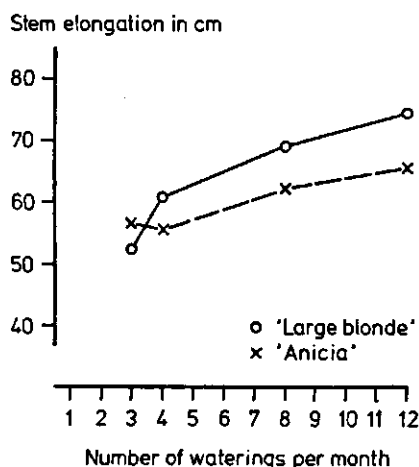


FIG. 21. Stem elongation on a per plant basis of 'Large blonde' and 'Anicia' in dependence on the frequency of watering.

### Dry matter production of the whole plants.

The observations are graphed in Fig. 22. The dry matter output of the cultivars increased with a raise of the frequency of watering. The treatments induced highly significant effects ( $P = 0.05\%$ ). 'Larger blonde' produced more dry matter than 'Anicia' under all moisture conditions. Differences between the dry matter productions of the two cultivars were significant ( $P = 1\%$ ).

### Dry matter production of the roots

The data are shown in Table 20. The treatments produced significant effects

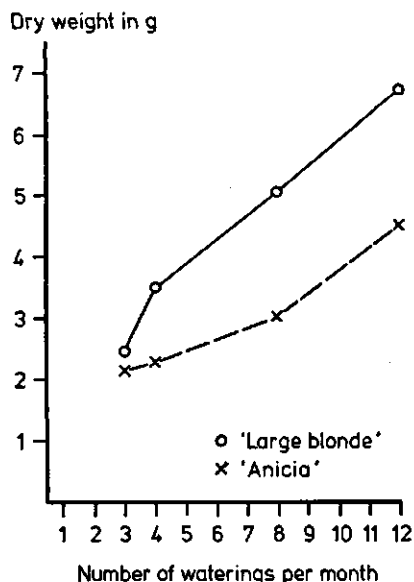


FIG. 22. Dry matter production per plant of 'Large blonde' and 'Anicia' in dependence on the frequency of watering.

TABLE 20. Dry weight in g (per plant) of the roots of 'Large blonde' and 'Anicia' in dependence on the frequency of watering.

No. of waterings per month	'Large blonde'	'Anicia'
3	0.517	0.405
4	0.705	0.375
8	0.862	0.470
12	1.530	0.760

Estimate of the standard error:  $\frac{\sigma}{\sqrt{n}} = 0.13$ , d.f. = 23

( $P = 1\%$ ). The dry weight of the roots of both cultivars increased with the increase in the frequency of watering. The values of 'Large blonde' were always higher than those of 'Anicia'. The cultivars differed significantly from each other ( $P = 0.05\%$ ) with respect to the dry matter accumulated in their roots.

#### Relationships between dry matter production and evapotranspiration

The results presented in Fig. 23 show that the dry matter yields and the amounts of water lost by evapotranspiration have quasi linear relations. These features increase with increasing the frequency of watering. The general tendency of the graphs to reach the origin through extrapolation suggests that evaporation (from the sand of the pots) was low. The values of the ratio evapotranspiration (cc)/dry matter yield (g) for 'Large blonde' range from 622 to 654 for the whole plants and from 782 to 840 for the shoots. For 'Anicia' the respective ranges are as follows 690–771 (whole plants) and 852–1007 (shoots). The difficulty to evaluate losses by evaporation and transpiration independently precludes to estimate the values of the transpiration ratio of the cultivars. One may, however, argue that these values are lower than those of the ratio above mentioned. The information given by VAN DIEST (see 7.1.) seems to apply more to the whole plants of 'Large blonde' and 'Anicia' than to the shoots.

It is interesting to note that the plants which received water at long intervals were more apt to lose leaves.

#### Water content of the plants.

The analysis of the observations of Table 21 led to the conclusion that the

TABLE 21. Average water content in percent of 'Large blonde' and 'Anicia' plants 76 days after sowing

No. of waterings per month	'Large blonde'	'Anicia'
3	78	74
4	73	75
8	78	76
12	69	73

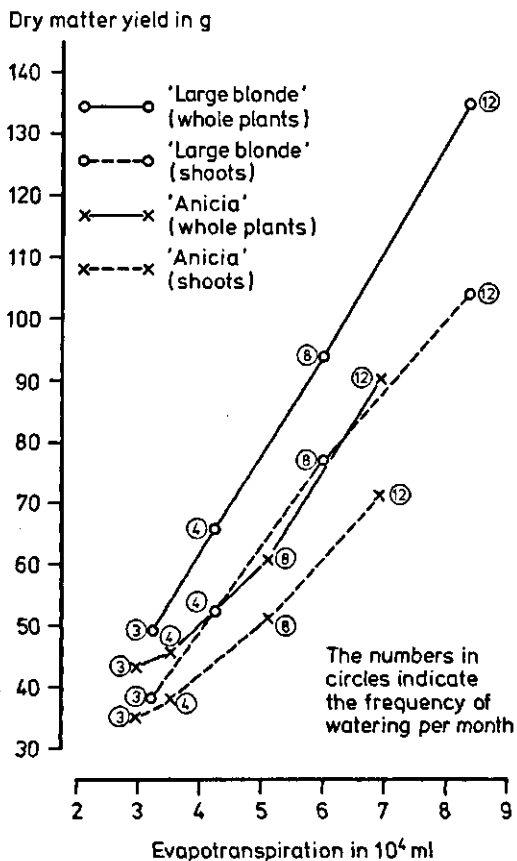


FIG. 23. Relationships between dry matter yield of 'Large blonde' and 'Anicia' and evapotranspiration. The data are presented on a basis of 20 plants grown in 4 pots (filled with sand as indicated in Section 7.2.2.).

water treatments did not significantly affect the water content of the plants of the two cultivars ( $P = 5\%$ ). The percentages ranged from 69 to 78.

Moreover the cultivars were not found to be significantly different ( $P = 5\%$ ) in this respect.

#### 7.2.4. Discussion and conclusions

The water treatments caused differences in leaf area, stem elongation, dry matter production of the plants. These increased when the frequency of watering was raised. It was the same for the water losses by evapotranspiration. The relationships between this feature and the dry matter yields of the plants or of the shoots showed some regularity as indicated by the shape of the graphs of Fig. 23.

The water treatments did not have a clear influence on the final water content of the plants. It seemed that the cultivars succeeded in keeping a certain amount of water irrespective of the moisture treatment to which they were subjected. With reference to the classification of MAY (1962), one may assume that plants thriving unfavourable water conditions may compensate the adverse situation with a high internal water content maintained not by an important root development but by a reduction of transpiration facilitated by losing leaves.

## 8. SALINITY AND EXCHANGEABLE SODIUM TOLERANCE

### 8.1. GENERAL INTRODUCTION

The characteristics of saline and alkali soils have been given by ALLISON (1964) and ALLISON et al. (1969). Saline soil is defined as a non alkali soil, in which the amount of soluble salts is sufficiently high to influence the growth of most crop plants. The electrical conductivity of a saturation extract from this soil is more than four millimhos/cm at 25°C. Alkali soil is soil which contains exchangeable sodium in such an amount that it influences the growth of most crop plants. The exchangeable sodium percentage (ESP) of an alkali soil is greater than 15.

In studies on salt tolerance in sand culture, the level of salinity is indicated by the value of the electrical conductivity of the medium. The alkali tolerance of crops was found to be more closely related to the ESP than to the absolute amounts of exchangeable sodium in the soil (BERNSTEIN and PEARSON, 1956). In general, in the literature related to alkali tolerance, this line of approach is followed by using levels of ESP.

VAN DEN BERG (1952) noted that the order of salt sensitivity of some crops during the germination stage was not the same as that observed at harvest time. ASGHAR and NUR-UN-DIN (1962) found a yield decrease of 55% when gram was irrigated with water of a conductivity of 10 millimhos/cm. FRANCOIS and BERNSTEIN (1964) pointed out that that yields of safflower were depressed to about 20-25% at 11 millimhos/cm. BERNSTEIN et al. (1966) recorded for sugar cane a similar reduction at 5 millimhos/cm.

Other workers were concerned with growth of crops in alkali soils and in soils at different levels of ESP. BERNSTEIN and PEARSON (1956) have given values of ESP corresponding with a 50% decrease in yield of the investigated crops: 53 for beets, 45 for alfalfa, 28 for clover and 16 for beans. AGARWALA et al. (1964) observed that the yield of barley and paddy dropped to about 43% at an ESP of some 30%. MEHROTRA and GANGWAR (1964), using soils of different alkali grades, remarked that the summer crops of India (maize, cotton, paddy) were more alkali tolerant than the winter crops (wheat and barley).

WERKHOVEN et al. (1966) observed that an increase of the ESP level to 20 and 30 enhanced the dry weight of the tops of safflower plants. Higher values of ESP were detrimental to the dry matter yield. As far as lentil is concerned, literature related to salt and alkali tolerance is very scarce. The crop is reported to be moderately salt tolerant (MATEO BOX, 1961) and moderately alkali tolerant (INDIA, 1962), but no investigation was mentioned to support these opinions.

The importance of knowledge on tolerance to salinity and to exchangeable sodium coupled with the poor information on the matter prompted the present studies.

## 8.2. SALINITY EXPERIMENT

### 8.2.1. *Treatments and design*

The experiment involved the lentil cultivars 'Large blonde' and 'Anicia' thriving at four levels of conductivity: 1.2, 4.5, 8.4 and 13.1 millimhos/cm. Each level was assigned six pots (three per cultivar). A randomized block design gathered the 24 pots of this study and the 24 pots of the study related to the four levels of exchangeable sodium percentage (ESP) mentioned in the section 8.3.1. The general model comprised three complete blocks of 16 pots subdivided each into two sub-blocks covered by the cultivars.

### 8.2.2. *Material and methods*

The investigation was carried out in a greenhouse which provided a relative humidity of 50%, night and day temperatures of 20°C and 26°C, respectively. The average value of the solar radiation for the growing period (April 10–June 26, 1970) was  $0.39 \text{ cal cm}^{-2} \text{ min}^{-1}$ . A drip culture system was installed in the greenhouse. Four containers of an individual capacity of 200 liters were connected to a set of plastic pipes (diameter 13 mm.) associated with capillary glass tubings (diameter 0.75 mm). The latter were suspended above sand-holding pots (see Sections 2.3.3. and 5.2.2. for details concerning the sand and the pots) which received five liters of Hoagland half strength (reference treatment) or five liters of Hoagland half strength containing different amounts of  $\text{MgCl}_2$  and  $\text{NaCl}$ , per 24-hour period. These salts were supplied as follows:

Level	Normality of $\text{MgCl}_2$	Normality of $\text{NaCl}$	EC values (millimho/cm)
1	0	0	1.2
2	0.008	0.02	4.5
3	0.02	0.05	8.4
4	0.04	0.10	13.1

Hoagland solution was common to all the treatments.

Photo 4 represents the installation which was used.

As usual, sowing was undertaken with pregerminated seeds at a depth of three cm. Selection after emergence allowed five plants to grow in each pot. Individual harvesting occurred with the appearance of flower. The unhealthy plants, those suffering from the highest level of salinity, were harvested prior to death. The whole study was concluded 77 days from sowing. The relevant data concern only the shoots. They are related to the following aspects: stem elongation, dry matter production per pot, Na and Mg contents of the shoots of the plants.

The measurements of the main stem started 10 days after sowing. They were repeatedly done up to the beginning of flowering, which occurred 33 days after sowing. The Na and the Mg contents were evaluated by GLAS (1970) who also calculated the values of ESP as given in Section 8.3.1. Na was determined flame photometrically and Mg by atomic absorption.

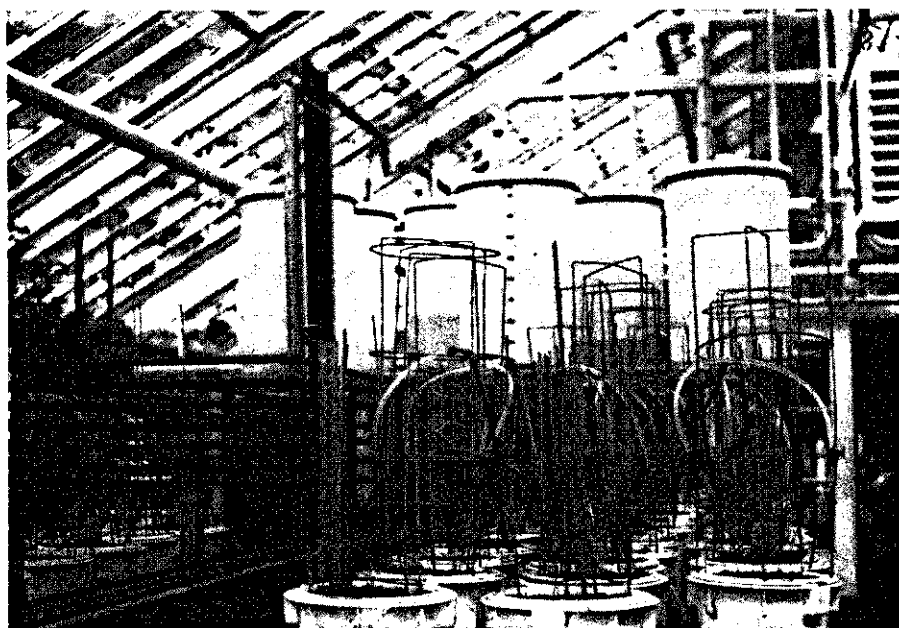


PHOTO 4

### 8.2.3. Results

#### Stem elongation

Both cultivars reacted in the same way. The higher the value of the conductivity, the shorter the plants became ( $P = 0.05\%$ ).

The cultivars were significantly different from each other ( $P = 0.05\%$ ).

The observations are presented in Table 22.

TABLE 22. Average elongation in cm of the main stem of 'Large blonde' and 'Anicia' at different levels of conductivity ( $EC \times 10^3$ ). The figures between brackets represent percentages of the stem elongation of the control.

LB = 'Large blonde', AN = 'Anicia'.

Conductivity in mmhos/cm. ( $EC \times 10^3$ )	Time of measurement No. of days after sowing							
	10		17		24		31	
	LB	AN	LB	AN	LB	AN	LB	AN
1.2	10.2 (100)	9.3 (100)	21.9 (100)	17.5 (100)	26.5 (100)	21.7 (100)	35.3 (100)	26.4 (100)
4.5	10.9 (107)	8.9 ( 96)	21.6 ( 99)	16.8 ( 96)	26.4 (100)	20.5 ( 94)	29.3 ( 83)	24.9 ( 94)
8.4	7.6 ( 74)	7.7 ( 83)	17.3 ( 79)	14.9 ( 85)	22.0 ( 83)	17.4 ( 80)	27.8 ( 79)	22.4 ( 85)
13.1	2.6 ( 25)	3.7 ( 40)	6.7 ( 30)	7.4 ( 43)	8.3 ( 31)	7.9 ( 36)	9.3 ( 26)	7.9 ( 30)

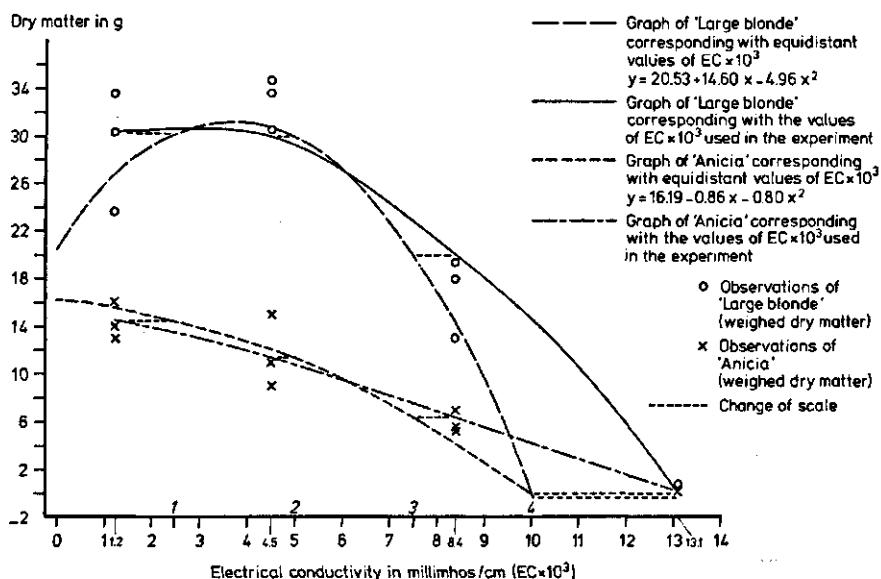


FIG. 24. Dry matter production per pot (5 plants) of 'Large blonde' and 'Anicia' as influenced by levels of salinity. Two graphs are given for each cultivar, one corresponding with equidistant values (1, 2, 3 and 4) of  $EC \times 10^3$ , the other with the values (1.2, 4.5, 8.4 and 13.1) which belong to the experiment.

### Dry matter production

The results are graphed in Fig. 24. Each cultivar is represented by two curves, one corresponding to equidistant values of  $EC \times 10^3$ , the other to the values used in the study.

The treatments caused effects which were found to be markedly different ( $P = 0.05\%$ ). The yields of the cultivars were significantly different ( $P = 0.05\%$ ). 'Large blonde' produced more dry matter than 'Anicia' at all the levels as it may be observed in Table 23.

TABLE 23. Average dry matter yield in g per pot of 'Large blonde' and 'Anicia' shoots at different conductivity levels; between brackets, the productions in percent of the control.

Conductivity in mmhos/cm.	Cultivars	
	'Large blonde'	'Anicia'
1.2	29.20 (100)	14.36 (100)
4.5	32.74 (112)	11.73 (82)
8.4	16.83 (58)	5.94 (41)
13.1	0.51 (2)	0.12 (1)

Estimate of the standard error:  $\frac{\sigma}{\sqrt{n}} = 1.38$ , d.f. = 14

Na and Mg contents of the shoots of 'Large blonde' and 'Anicia' plants at different levels of electrical conductivity

The averages are given in Table 24. Statistical tests with the Na data of the three blocks showed that the treatments caused highly significant effects ( $P = 0.05\%$ ). The cultivars did not differ from each other ( $P = 5\%$ ). When the Mg data were subjected to the tests, the treatments were found to induce also highly significant effects ( $P = 0.05\%$ ). The cultivars showed very significant differences ( $P = 0.05\%$ ).

TABLE 24. Average Na and Mg content in millimols/kg of dry matter of 'Large blonde' and 'Anicia' shoots at different conductivity levels.

EC values in millimhos/cm	Na content		Mg content	
	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'
1.2	6.3	9.3	57.0	45.0
4.5	80.6	150.6	222.3	135.0
8.4	733.0	588.3	494.0	327.1
13.1	1457.0	1574.6	873.3	708.3

Estimate of the standard errors (d.f. = 14)  $\frac{\sigma}{\sqrt{n}} = 37.30$  (Na),  $\frac{\sigma}{\sqrt{n}} = 24.88$  (Mg)

### 8.3. EXCHANGEABLE SODIUM EXPERIMENT

#### 8.3.1. *Treatments and design*

'Large blonde' and 'Anicia' plants were subjected to the influence of four levels of ESP: 0.48 (reference), 4.53, 6.63 and 9.98. Information on experimental design was already given in Section 8.2.1.

#### 8.3.2. *Material and methods*

The experiment was conducted with the same kind of plant material as that of Section 8.2.1. Clayish soil from Beemster polder was used. This soil mentioned is characterized by a humus content of 2.1% in weight, a cation exchange capacity of 31 meq/100 g, and a pH of 6.8. The ground was frozen for two days at  $-38^{\circ}\text{C}$  to increase the stability of the aggregates. It was then sifted to aggregates of 2–8 mm before being used. Twenty-four pots (the same as those of the salinity experiment), divided into groups of six, were employed for the treatments. These were obtained by incorporating 0, 15, 22 and 30 g of  $\text{NaHCO}_3$  in two liters of Hoagland solution half strength which were used for each pot. One liter was used to moisten 8 kg of soil (amount given to each pot) mixed with 8 g of Aerotil, a soil conditioner known to improve the structure of clay soils. The other liter, after dissolving the requisite quantity of  $\text{NaHCO}_3$  suggested by the work of WERKHOVEN et al. (1966), was added to the pots already filled through a hopper containing a column of sand which went down to about half the height of pots.



Moistening through a hopper avoids puddling of the surface of the ground (SCHUFFELEN, LEHR and ROSANOW (1952).

Further details on the experimental procedure are given in Section 8.2.2. The Na content of the dried shoots of the plants was determined as in Section 8.2.2.

### 8.3.3. Results

#### Stem elongation

The cultivars responded to the ESP levels according to a pattern similar to that mentioned in the preceding section. Nevertheless, the depressing effect of the highest grade of ESP is far smoother than that of the conductivity trial.

The effects of the treatments were significantly different ( $P = 0.05\%$ ). So were the cultivars ( $P = 0.05\%$ ).

TABLE 25. Average elongation in cm of the main stem of 'Large blonde' and 'Anicia' at different levels of ESP. The figures between brackets represent percentages of the elongation of the control. LB = 'Large blonde', AN = 'Anicia'.

ESP values	Time of measurement No. of days after sowing							
	10		17		24		31	
	LB	AN	LB	AN	LB	AN	LB	AN
0.48	11.3 (100)	11.2 (100)	22.0 (100)	21.2 (100)	26.5 (100)	27.3 (100)	35.5 (100)	29.8 (100)
4.53	12.0 (106)	9.5 (85)	21.9 (99)	18.9 (89)	26.3 (99)	23.4 (86)	34.1 (96)	26.1 (87)
6.63	10.6 (94)	10.9 (97)	21.5 (98)	19.3 (91)	27.9 (105)	24.5 (90)	33.2 (93)	29.8 (100)
9.98	10.0 (88)	10.3 (92)	19.4 (88)	18.3 (86)	25.6 (97)	21.6 (79)	29.5 (83)	21.4 (72)

#### Dry matter production

The data are presented in the same manner as those of the study on salinity. In Fig. 25 the two cultivars show a linear tendency with respect to the treatments. The effects of the treatments were very significant ( $P = 0.05\%$ ). A significant difference ( $0.1 < P < 1\%$ ) was also recorded for the cultivars.

The average productions are shown in Table 26.

Na content of the shoots of 'Large blonde' and 'Anicia' plants at different levels of ESP.

The analysis of the data derived from the determination of Na in the shoots indicated that the treatments produced very significant effects ( $2.5\% < P < 5\%$ ). The accumulation of Na in 'Large blonde' was not significantly different from the accumulation in 'Anicia' ( $P = 5\%$ ).

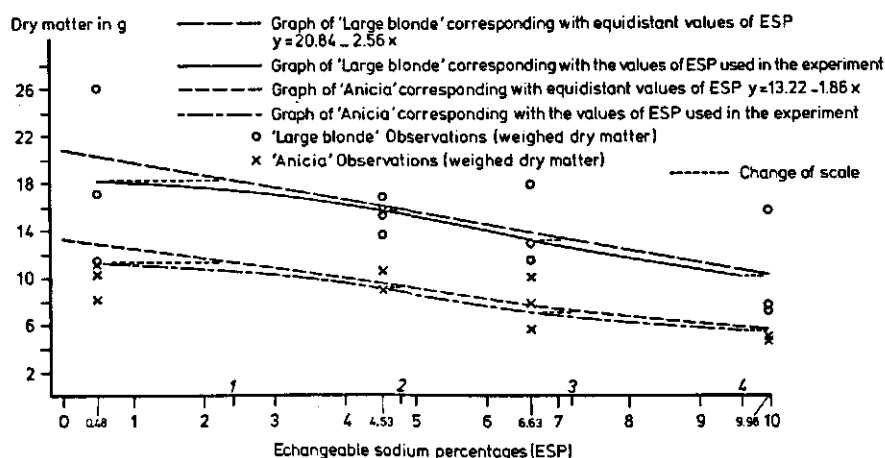


FIG. 25. Dry matter production per pot (5 plants) of 'Large blonde' and 'Anicia' as influenced by ESP treatments. Two graphs are given for each cultivar, one corresponding with equidistant values (1, 2, 3 and 4) of ESP, the other with the values (0.48, 4.53, 6.63 and 9.98) which belong to the experiment.

TABLE 26. Average dry matter yield in g per pot of 'Large blonde' and 'Anicia' shoots at different levels of ESP; between brackets, the productions in percent of the control.

ESP levels	Cultivars	
	'Large blonde'	'Anicia'
0.48	18.25 (100)	9.88 (100)
4.53	15.28 (84)	11.62 (118)
6.63	14.07 (77)	7.78 (79)
9.98	10.14 (55)	4.93 (50)

Estimate of the standard error:  $\frac{\sigma}{\sqrt{n}} = 2.08$ , d.f. = 14

TABLE 27. Average Na content in millimols/Kg of dry matter of 'Large blonde' and 'Anicia' shoots at different levels of ESP.

ESP levels	Cultivars	
	'Large blonde'	'Anicia'
0.48	18.3	19.5
4.53	70.3	107.1
6.63	76.3	122.6
9.98	175.3	227.0

Estimate of the standard error:  $\frac{\sigma}{\sqrt{n}} = 15.60$ , d.f. = 14

#### 8.4. *General discussion and conclusions*

The conductivity and the ESP treatments produced different effects in the plants of 'Large blonde' and 'Anicia'. In particular, the highest level of salinity interfered with the growth of the cultivars. It induced many reactions such as chlorosis, stunting, absence of flowering and strong reduction of the dry matter output. The plants would have died if they had not been harvested prematurely. The highest ESP level also showed growth-retarding effects, but to a lesser extent.

'Large blonde' appeared to be more salt tolerant with regard to the dry matter production (Table 23). The data suggested that the limits of the salt tolerance of the cultivars are somewhere between 8.4 and 13.1 millimhos/cm. The property of the plants to accumulate more and more Na and Mg with increasing contents of salt in the substrate may be considered as a disadvantage as it involves increasing growth reduction. From Table 26, a greater reduction of the dry matter yields of the cultivars is expected at ESP levels superior to 10. The cultivars seemed to be more sensitive than safflower. As mentioned previously (Section 8.1.), the safflower tops continue to increase their dry matter production when the ESP of the soil is raised to 20–30. The decrease begins with ESP levels higher than 30. Reference to the classification found in ALLISON (1964) indicates that 'Large blonde' and 'Anicia' are less sensitive to ESP than certain crops such as citrus, nuts and avocado which already show symptoms of sodium toxicity at ESP values of 2–10.

## 9. GROWTH AND DEVELOPMENT PATTERNS

### 9.1. INTRODUCTION

Growth curves as a tool to analyse growth were used since the beginning of this century (HAMMOND and KIRHAM, 1949). Since then, interest has increased in quantitative evaluation of the growth of plants and parts of plants (HAMMOND and KIRKHAM, op.cit.; BUNTING (1966), WIENK (1969). A growth component on which attention is frequently focused is the Relative Growth Rate (RGR). A definition inspired by BLACKMAN's Compound Interest Law (1919) is found in WILLIAMS and JOSEPH (1970). The Relative Growth Rate at any instant of time is the increase in plant material per unit of material present at the instant of time. FISHER (in WATSON, 1952) developed the formula which rendered possible the calculation of RGR for a time interval  $t_2-t_1$ :

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

$W_1$  and  $W_2$  being the total dry weights at times  $t_1$  and  $t_2$  respectively;  $e$ , the base of the naperian logarithms = 2.718.

The importance of RGR has already been stressed by WATSON (op.cit.) and FRIEND (1965). The latter stated that the RGR provided a means of comparing the efficiency of growth of plants of widely different size. This growth attribute has been calculated for many crops.

Other authors emphasized the interest of studying the accumulation of dry matter in different parts of the plants. DE VRIES, FERWERDA and FLACH (1967) pointed out the importance of the distribution of dry matter in plants. PEARSALL (1927) studied the logarithmic relationships between the dry weights of stems and roots of various plants (cotton, peas, carrots and turnips). THROUGHTON (1955) studied the same mathematical relationships for young grass plants. VAN DE SANDE-BAKHUYZEN (1937) has graphed the dry weights of parts of wheat plants. BROUWER (1962) has calculated the percents of dry matter production per part of the plant for grasses, rapeseed, wheat, and peas. DE BEER (1963) has given the top-root ratios of *Arachis hypogaea* L. plants grown at different temperatures.

The distribution of dry matter in seeds and straw is often reported. DÜRIGEN et al. provided some information about seed and straw yields of lentils. They estimated seed yield at 75–85 kg and straw output at 650–1200 kg. The ratio seed/straw may be considered roughly equal to 0.07–0.11. In Punjab (India) the ratio calculated from the data of ROBERT and KARTAR SINGH (1951) is 0.5. The ratio was found to vary between 0.23 and 0.49 when the number of irrigations per season dropped from twelve to five under Shiraz (Iran) conditions (IRAN and INDIA, 1969). An experiment was carried out from March to July 1971 in a greenhouse of the Department of Tropical Crop Husbandry of Wageningen University to obtain additional information on the growth patterns of lentil.

## 9.2. EXPERIMENT

### 9.2.1. *Treatments and design*

The study of the growth patterns of lentil concerned 'Large blonde' and 'Anicia' plants subjected to eight consecutive harvest during an experimental period of 16 weeks. It involved then eight age treatments under which data were recorded. The plant material thrived in a completely randomized design comprising 144 pots (18 pots per harvest) which were distributed in seven blocks along with 56 border pots.

### 9.2.2. *Material and methods*

'Large blonde' and 'Anicia' plants were left to grow in a compartment of a greenhouse and subjected to eight consecutive harvests during a period of 16 weeks. Inside the greenhouse, the night and day temperatures were about 15° and 25°C respectively, the relative humidity 50–70% and the average solar radiation for the period from March 15 to July 5, 1971 was  $0.34 \text{ cal cm}^{-2} \text{ min}^{-1}$ . Seven shallow metal cases ( $111 \times 98 \times 22 \text{ cm}$ ) were used to hold 200 five-liter pots (6 cases  $\times$  30 pots and 1  $\times$  20) with a perforated bottom. The cases were placed on the ground in four adjoining rows, three of which consisted of two cases. The pots were filled with sand and brought to field capacity shortly before the commencement of the experiment. The sand (size of the particles in Section 2.3.3.) was moistened with a Nutrifol solution (1 g/liter of water/pot). The cases were supplied once a month with this solution. They were provided with water up to a level of 3.5 cm from their bottom.

'Large blonde' and 'Anicia' were sown at a density of twelve pregerminated seeds per pot. The two cultivars were randomized when planted and allowed to grow in an equal number of pots. At two-week intervals beginning a fortnight after sowing, the populations of 18 pots (9 pots for each cultivar) were harvested. The shoots and the roots were handled separately and their fresh weights recorded. The dry weights were calculated after the material was left in an oven at 80°C for 48 hours. The countings of leaves, flower clusters and pods and the measurement of the stems were restricted to 18 plants from each cultivar. The investigation covered 8 harvests in total 144 pots ( $8 \times 18$ ). The remaining pots guarded the borders of the design or held reserve material. After each harvest, the position of the pots was changed to maintain a closed canopy system. These operations involved a reduction in the initial number of cases in the course of the time.

The data were registered on a per plant basis. They included:

- fresh and dry weights of the whole plant (aerial and underground parts)
- Relative Growth Rates (RGR) of the whole plant on a dry weight basis
- shoot and root dry weights
- changes in the shoot/root ratios
- relationship between leaf production and plant age
- relationship between stem elongation and plant age

- g. flower and pod productions in the course of the time
- h. dry matter distribution in the parts of the plants by the end of the study.

### 9.2.3. Results

#### Fresh and dry weights

The observations are presented graphically in Fig. 26

'Large blonde' led to higher fresh weights than 'Anicia' but it reached the maximum value at the same time as 'Anicia,' 14 weeks after sowing. The course of the fresh weight of Large blonde was stagnant between the 8th and the 9th week from planting. 'Anicia' showed a continuous growth (fresh weight) up to the time it reached the ceiling yield which was observed 2 weeks before the end of the experiment. The dry weight pattern of the cultivars did not exactly follow the same course as the fresh weight. When blooming started (eight weeks from sowing), 'Large blonde' was within 66 % of its maximum fresh weight while the accumulated dry matter represented only 38 % of the ceiling yield. A roughly similar pattern is shown by 'Anicia'. The two cultivars reached their maximum fresh weight at the same time. It was not the same for their dry weight. The size of dry matter accumulation of 'Anicia' was in general smaller than that of 'Large blonde'. However the growth of the first cultivar was continuous

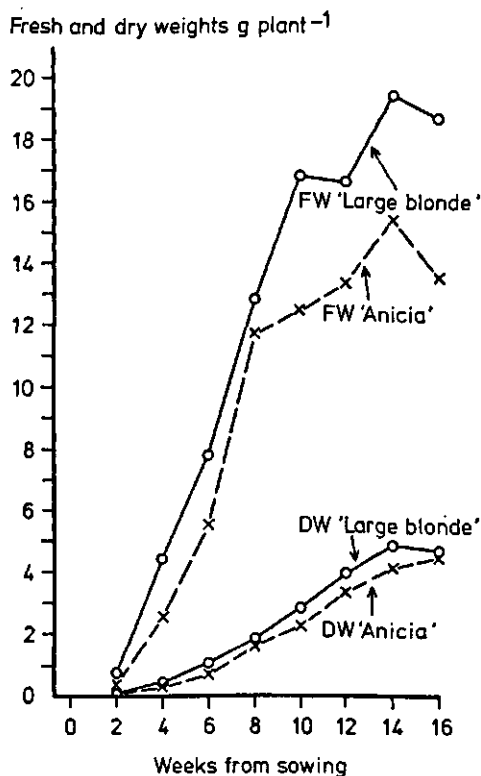


FIG. 26. Course of the fresh weight (FW) and the dry weight (DW) of 'Large blonde' and 'Anicia.'

till the study was concluded. 'Large blonde', in contrast ceased to grow after the 14th week from sowing. The total dry matter production of the cultivars at the last harvest may be estimated as follows: 'Large blonde' 12438.27 kg/ha, 'Anicia' 11833.45 kg/ha.

### Relative Growth Rates

The Relative Growth Rates were calculated for the 8 two-week harvesting periods. The data are given in Table 28.

TABLE 28. Relative Growth Rates (R G R) at 8 consecutive periods of 'Large blonde' and 'Anicia'.

Cultivars	R G R in g/g/week Periods in weeks after planting							
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16
'Large blonde'	0.10	0.81	0.40	0.28	0.22	0.15	0.10	-0.01
'Anicia'	0.27	0.85	0.48	0.47	0.15	0.20	0.09	0.05

From this it may be seen that 'Large blonde' produced dry matter at the greatest RGR between the 2nd and the 4th week. Furthermore there was a continuous decrease of the RGR values till the end of the investigation. During the interval 4th-6th week the rate was curtailed by 50%, compared with the value of the 2-4 week period. Thereafter the reduction process continued more smoothly. The last period was characterized by the cessation of growth. The RGR value was negative, which indicates a very slight decrease in the final dry weight. This situation is also reflected in Fig. 26. 'Anicia' has also its greatest rate of dry matter production between the 2nd and the 4th week. The Relative Growth Rates of this cultivar were greater than those of 'Large blonde' up to the 8th week which corresponded with the beginning of flowering. It is likely that flowering accounted for the rates of 'Anicia' being sharply reduced in the period 8-10 weeks after sowing. In the interval 10th-12th week the RGR of 'Anicia' increased by some 33% of its preceding value but declined rather regularly in the last four weeks of the experiment.

From the information given in Table 29, the lentil cultivars may be compared with soya and maize. The RGR values of the last two crops are found in WIENK (1969).

The data of Table 29 show that the growth of the lentil cultivars is slower than that of soya and maize three to nine weeks from planting. The RGR values of 'Large blonde' and 'Anicia' for the period 7-9 weeks from sowing are, however, very close to that of soya. They became superior to those of soya and maize at the fourth period (9-11 weeks from planting). They are twice as high as that of maize at the last period.

TABLE 29. Comparative Relative Growth Rates of the lentil cultivars, maize and soya for two-week periods starting three weeks after sowing.

Plants	RGR in g/g/week Periods in weeks after planting				
	3-5	5-7	7-9	9-11	11-13
'Large blonde'	0.49	0.32	0.24	0.18	0.12
'Anicia'	0.56	0.47	0.26	0.18	0.14
Soya	1.05	0.62	0.28	0.11	
Maize	1.18	0.62	0.35	0.15	0.07

### Shoot and root dry weights

The accumulation of dry matter in the shoot and the roots of the plants is plotted against time in Fig. 27.

The shoot of 'Large blonde' produced in *general more* dry matter than that of 'Anicia'. At the last harvest the latter was found to reach its highest value whilst the former showed no yield increase. The final weights of both cultivars were practically the same. The dry matter output of the roots was expressed by two graphs which are quasi-parallel. It may be noted that 'Large blonde' roots accumulated more dry matter than those of 'Anicia' in the course of the experiment.

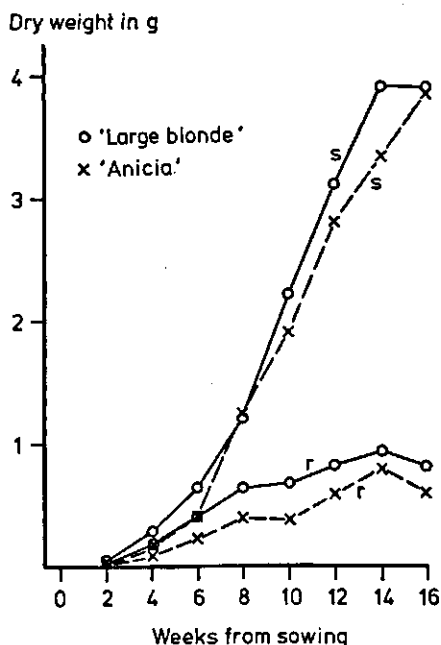


FIG. 27. Course of the dry weight (on a per plant basis) of the shoot(s) and the roots (r) of 'Large blonde' and 'Anicia'.



Shoot\_root ratio

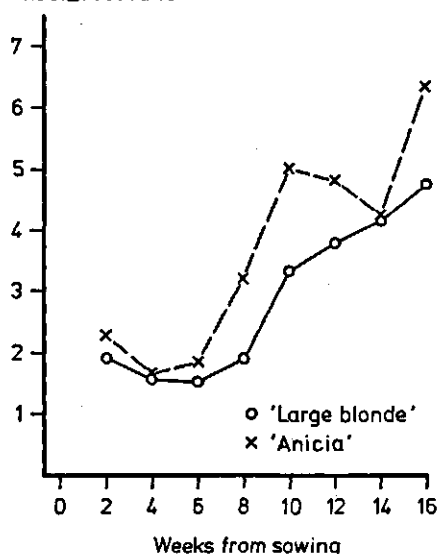


FIG. 28. Change with time in the shoot-root ratio of 'Large blonde' and 'Anicia'.

### Changes in the shoot-root ratios

The information in Fig. 27 was reflected in the fluctuations of the shoot/root ratios (Fig. 28). It may be pointed out that the ratios were always greater than 1. The shoot growth of both cultivars was always superior to root growth. The ratios of both of them were relatively low up to 6 weeks from sowing. So were the discrepancies between shoot and root growth of the cultivars for the same period (Fig. 27). After the 6th week, higher values were registered. The ratios were comparable at the 14th week after sowing. The highest values (4.7 and 6.3 for 'Large blonde' and 'Anicia' respectively) were recorded at the conclusion of the experiment.

### Relationship between leaf production and plant age

The observations are presented in Fig. 29.

The productions of both cultivars were similar up to six weeks. After that, 'Anicia' headed for a second maximum which was obtained at the 8th week. 'Large blonde' graphs showed also breaks but these were very smooth. After the 8th week, the production of 'Large blonde' decreased but this situation was reversed between the 10th and the 14th week. A new decrease was observed between the 14th and the 16th week. 'Anicia' graph is characterized by the abrupt fluctuations undergone in the course of the time. These changes may be tentatively attributed to important leaf falls. Already three weeks after planting, when the leaves started falling, this symptom was shown by eleven 'Anicia'-holding pots as compared with three 'Large blonde'.

Leaf production plant<sup>-1</sup>

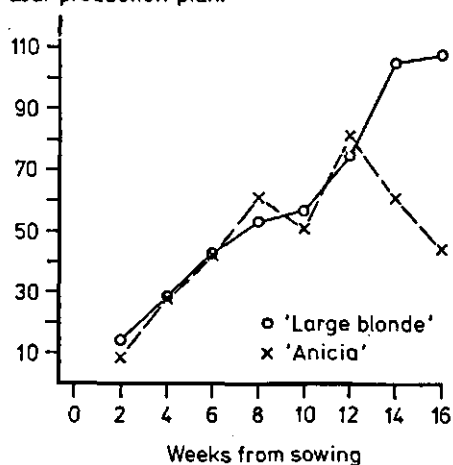


FIG. 29. Change with time in the leaf production of 'Large blonde' and 'Anicia'.

### Relationship between stem elongation and plant age

In general the elongation graphs of the cultivars followed the same trend. The major discrepancies were registered at the 4th and the 16th week. (Fig. 30). The 2 graphs showed a break 10 weeks from planting. This was probably due to blooming. Indeed, more than 25% of the plants of both cultivars had already come into flower at this time. The maximum height of 'Anicia' was observed at the end of the experiment but the recorded value (85.25 cm) was very close to the preceding one (85 cm). So, it may be concluded that the stem of 'Anicia' practically ceased to elongate after the 14th week. This consideration could also be applied to the situation which prevailed after the 12th week because the average stem height at the 12th week was only 84.16 cm.

Stem elongation, cm plant<sup>-1</sup>

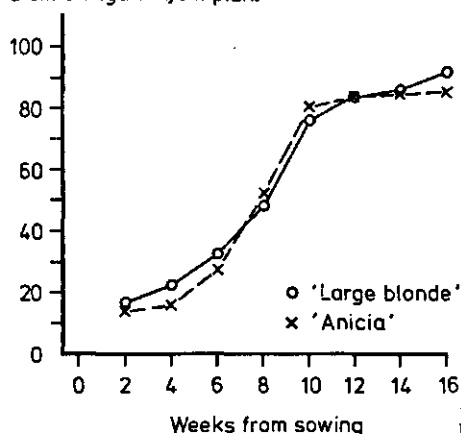


FIG. 30. Change with time in the stem elongation of 'Large blonde' and 'Anicia'.

## Flower and pod productions

The flowering of 'Anicia' was more profuse than that of 'Large blonde' (Table 30). At the 14th week, however, the number of inflorescences per plant of 'Anicia' was inferior to that related to 'Large blonde'. At this time, the flowering of 'Anicia' was complete, that of 'Large blonde' was within 90%. There is some evidence that this decrease in flower production is associated with the relatively high pod yield. Probably part of the flowers present on 'Anicia' initiated pod formation during the interval 12th-14th week from sowing. In support of this reasoning, 'Anicia' was found to produce 1.1 g of seeds/plant (dry weight basis) at the last harvest, as compared with 0.6 g for 'Large blonde'. It may be reminded that the weight of mature 'Anicia' seeds is one third that of 'Large blonde'.

TABLE 30. Flower cluster and pod productions per plant of 'Large blonde' and 'Anicia'. The figures between brackets represent the percentages of plants of the experiment which were flowering when harvested.

Time of counting in weeks from sowing	Flower cluster Cultivars		Pod Cultivars	
	'Large blonde'	'Anicia'	'Large blonde'	'Anicia'
10	2.76 (27)	3.16 (30)	0.28	0.16
12	7.50 (74)	12.90 (85)	12.60	19.00
14	10.80 (90)	5.12 (100)	18.40	35.12
16	-	-	29.00	42.00

## Dry matter distribution in the parts of the plants at the end of the study

Information concerning the distribution of the dry matter accumulated by the plants has been tabulated. The data are presented in Table 31. A sample of 18 plants was used for each cultivar.

TABLE 31. Dry matter distribution in the parts of the plants of the lentil cultivars in percents of the production of the whole plants. Data drawn from the work of WIENK (1969) on soya are given for comparison.

Plants	Plant parts					
	Leaves	Stem	Pods*	Husks	Seeds	Roots
'Large blonde'	21	46	16	5	11	17
'Anicia'	11	45	31	7	24	13
Soya	2	36	56			6

\* Pods = Husks + Seeds

The ratio seed/straw is 0.16 for 'Large blonde' and 0.42 for 'Anicia'. The values fall in the wide range (0.07–0.50) suggested by the data drawn from the works of DURIGEN et al. (1910) and ROBERTS and KARTAR SINGH (1951).

It may be assumed that the ratio seed/straw of soya is higher than that of 'Large blonde' and 'Anicia' even though the percent of the total dry matter represented by the seeds of soya is not reported.

#### 9.2.4. *Discussion and conclusions*

The curves representing the fresh and dry weights of 'Large blonde' are above those of 'Anicia' (Fig. 26). The absolute fresh and dry weights of the former cultivar were then larger than those of the latter. The dry matter production of 'Anicia' did not shift to lower values, unlike that of 'Large blonde' which showed a slight decrease at the last harvest. The final dry matter output per plant of both cultivars was quite close to that estimated for pea from the data of BROUWER (1962). The Relative Growth Rates of 'Large blonde' were in the broadest sense inferior to those of 'Anicia'. Only at the 8–10 week period was the rate of 'Large blonde' markedly higher than that of 'Anicia'. The rates of both cultivars were lower than those of soya and maize (Table 29) up to nine weeks after planting. The shoot growth of 'Large blonde' may be considered to some extent better than that of 'Anicia' up to the time of the cessation of growth. The dry weight of the roots of 'Large blonde' exceeded that of 'Anicia' across all the sampling periods. The shoot-root ratios of the last cultivar were always higher than those of 'Large blonde'. The ratios of both cultivars were similar four and fourteen weeks from sowing. The graph indicating the leaf production of 'Anicia' is by far less smooth than that of 'Large blonde'. The reason probably lies in the loss of leaves to which 'Anicia' seemed to be more subject than 'Large blonde'.

The stem elongation of both cultivars presented no outstanding particularities. The reproductive growth of 'Anicia' was developed at a size greater than that of 'Large blonde'. This resulted in a larger pod production and a higher seed yield per plant. The ratio seed/straw of 'Anicia' was nearly thrice as high as that of 'Large blonde'. The dry matter accumulated in the pods of 'Anicia' (in percent of the output of the whole plant) was twice that of 'Large blonde'. It was however twice as low as that of soya (Table 31) and pea (BROUWER, 1962). It is worth noting that differences in experimental conditions may erase the validity of these comparisons.

## SUMMARY

Many experiments were undertaken to study the responses of the lentil cultivars 'Large blonde' and 'Anicia' to controlled environmental factors. They covered different aspects of the physiology and the ecology of the crop.

The orientation experiments (2) involved germination and depth of sowing. The optimum temperature range for the germination of 'Large blonde' was 19–29°C whilst that of 'Anicia' was 21–25°C. The depth treatments (1, 4 and 8 cm) caused no particular effects on flowering and stem elongation. They brought about a general linear response of the cultivars with respect to average leaf production (Fig. 1.) The 4-cm treatment appeared to be the most favourable for dry matter production. A temperature of 23°C and a depth of 3 cm were used to pregerminate and sow the seeds respectively in carrying out further experiments.

Studies on the photoperiodic requirements of the cultivars (3) led to differences between 'Large blonde' and 'Anicia'. The first cultivar behaved as a qualitative long-day plant: it did not flower at photoperiods shorter than 14 hours. 'Anicia' reacted quasily as a day-neutral plant. It flowered under all the photoperiods (8–16 hours) used, but came somewhat earlier into flower at 15 and 16 hours. The dry matter production of the cultivars seemed not to be influenced.

The effects of the following temperature regimes: 9°C (night)–15°C (day), 13°C (night)–19°C (day), 17°C (night)–23°C (day), 21°C (night)–27°C (day), 25°C (night)–31°C (day) and 29°C (night)–35°C (day) on the plants of both cultivars were investigated (4). The treatment 21–27°C (average 24°C) led to the maximum leaf production, stem length and dry matter production. The regime 29–35°C was particularly detrimental to the growth of the cultivars: the plants were prematurely harvested before death occurred.

An experiment was also conducted on daily amplitudes of temperature (5). It was carried out with three temperature regimes: 18°C (night)–30°C (day), 21°C (night)–27°C (day) and constant 24°C. The amplitude of 6°C (21°C–27°C regime) led to the highest average stem elongation, leaf and dry matter productions.

The photosynthesis of 'Large blonde' and 'Anicia' was not influenced in a definite way by the (instantaneous) temperatures of 18°C, 24°C and 30°C (6). The photosynthetic capacity of the cultivars was similar. The surface they formed per unit dry weight was different, the ratio leaf area ( $\text{dm}^2$ )/dry weight (g) of 'Anicia' being higher than that of 'Large blonde'.

The study of the drought tolerance of the cultivars under four frequencies of watering (3, 4, 8 and 12 times a month) brought out treatment-dependent differences in leaf area, stem elongation, dry matter production and evapotranspiration (7). These features increased with a raise of the level of watering. The final water content of the plants was not clearly affected by the regimes.

The tolerance to salinity and exchangeable sodium (in terms of ESP) was also brought under investigation (8). The cultivars were subjected to the influence of

four salt concentrations corresponding with 1.2, 4.5, 8.4 and 13.1 mmhos/cm. In general, increase in the salt concentration resulted in an increased reduction of stem length and dry matter output. This depressing effect of salt was coupled with a continuous accumulation of Na and Mg in the plants. The tolerance limits of the cultivars were found to be between 8.4 and 13.1 mmhos/cm.

The cultivars responded also clearly to the following ESP levels: 0.48, 4.53, 6.63 and 9.98. The higher the ESP level was, the larger became the growth reduction and the Na accumulation.

Data on the growth and development patterns of 'Large blonde' and 'Anicia' were recorded in the course of an experiment which lasted 16 weeks (9). Both cultivars showed their greatest relative growth rate (RGR) between the second and the fourth weeks after sowing (0.81 g/g/week for 'Large blonde' and 0.85 for 'Anicia'). The final dry matter yields per plant of 'Large blonde' and 'Anicia' were comparable (4.7 and 4.5 g respectively). The seeds of the first cultivar represented 11 % of the final dry matter of the plant whilst those of the second accounted for 24 %. The highest shoot/root ratios (4.7 and 6.3 for 'Large blonde' and 'Anicia' respectively) were registered at the conclusion of the experiment.

## ACKNOWLEDGEMENTS

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## SAMENVATTING

Verscheidene proeven werden uitgevoerd ter bestudering van de reactie van de linze cultivars 'Large blonde' and 'Anicia' op gecontroleerde uitwendige omstandigheden. Hierbij werden verschillende aspecten van de fysiologie en ecologie van dit gewas onderzocht.

Enige oriënterende proeven werden verricht over kieming en zaaidiepte (2). Het optimale temperatuur bereik voor de kieming van 'Large blonde' was 19–29°C, voor 'Anicia' was dit 21–25°C. Zaaidiepte behandelingen (1, 4 en 8 cm) hadden geen bepaald effect op de bloei en stengelstrekking, maar vertoonden wel een lineair verband met de bladproductie (Fig. 1). Voor de droge stof productie bleek een zaaidiepte van 4 cm het gunstigst te zijn. In verdere proeven werd een temperatuur van 23°C aangehouden om de zaden respectievelijk bij voor te kiemen en uit te zaaien.

Onderzoek naar de fotoperiodische gevoeligheid (3) leidde tot een verschil tussen 'Large blonde' and 'Anicia'. 'Large blonde' gedroeg zich als een kwalitatief lange-dag plant: de planten bloeiden niet in fotoperiodes korter dan 14 uur. 'Anicia' reageerde min of meer als een dag-neutrale plant: de planten bloeiden bij alle gebruikte fotoperiodes (8–16 uur) alhoewel iets eerder bij 15 en 16 uur. De droge stof productie van beide variëteiten lijkt niet door de fotoperiode te worden beïnvloed.

Het effect van de volgende gemiddelde temperaturen: 9°C (nacht)–15°C (dag), 13°C (nacht)–19°C (dag), 17°C (nacht)–23°C (dag), 21°C (nacht)–27°C (dag), 25°C (nacht)–31°C (dag) en 29°C (nacht)–35°C (dag) werd onderzocht (4). De gunstigste regime bleek 21–27°C te zijn omdat hierbij de grootste aantal bladen, de grootste stengel lengte, en de hoogste droge stof productie werd gevonden. De regime 29–35°C bleek bijzonder ongunstig voor de groei: de planten moesten voor het afsterven voortijdig worden geoogst.

Ook werd een proef gedaan over de invloed van dagelijkse temperatuur verschillen (5). Drie temperatuur behandelingen werden uitgevoerd: 18°C (nacht)–30°C (dag), 21°C (nacht)–27°C (dag) en constant 24°C. Een verschil van 6°C (21°C–27°C) leidde tot de hoogste gemiddelde stengelstrekking, blad en droge stof productie.

De fotosynthese van 'Large blonde' en 'Anicia' werd niet in bepaalde zin door de temperaturen 18°C, 24°C en 30°C beïnvloed (6). De fotosynthese capaciteit van beide cultivars was gelijk. Het geproduceerde oppervlak per eenheid van drooggewicht was verschillend, de verhouding bladoppervlak (dm<sup>2</sup>)/drooggewicht (g) was voor 'Anicia' groter dan voor 'Large blonde'.

Het onderzoek naar de droogteresistentie (7) leidde tot verschillen in bladoppervlak, stengellengte, droge stof productie en evapotranspiratie, in afhankelijkheid van de frequentie van watertoediening (3, 4, 8 en 12 keer per maand). De genoemde kenmerken namen alle met toenemende watergiften toe. Het uiteindelijke watergehalte van de planten werd niet duidelijk beïnvloed.



De tolerantie voor zout en uitwisselbaar natrium (uitgedrukt in percentage uitwisselbaar natrium of ESP) werd eveneens onderzocht (8). De invloed van vier zout concentraties overeenkomende met 1.2, 4.5, 8.4 en 13.1 mmhos/cm werd nagegaan. In het algemeen leidde een toename in zoutconcentratie tot een toenemende reductie van stengellengte en droge stof productie. Deze zoutschade ging gepaard met een voortgaande ophoging van Na en Mg in de planten. De grens voor de zouttolerantie lag voor beide cultivars tussen 8.4 en 13.1 mmhos/cm. Beide cultivars reageerden ook duidelijk op de volgende ESP niveaus: 0.48, 4.53, 6.63 en 9.98. Naarmate het ESP niveau hoger was, namen groeireductie en Na ophoging toe.

Gegevens over de groei en het ontwikkelingspatroon van 'Large blonde' en 'Anicia' zijn verzameld in een proef die 16 weken duurde (9). Beide cultivars vertoonden de grootsterelatieve groei (RGR) tussen de tweede en de vierde week gerekend vanaf het zaaien (0.81 g/g/week in het geval van 'Large blonde' en 0.85 in dat van 'Anicia'). De uiteindelijke droge stof opbrengst was voor beide cultivars gelijk (4.7 g/plant voor 'Large blonde' en 4.5 voor 'Anicia'). De zaden van 'Large blonde' maakten 11 % van deze droge stof uit, voor 'Anicia' was dit 24 %. De hoogste spruit/wortel verhouding werd gemeten bij het beëindigen van de proef, nl. 4.7 voor 'Large blonde' en 6.3 voor 'Anicia'.

## RESUME

Plusieurs expériences ont été entreprises pour étudier le comportement des cultivars de lentille 'Large blonde' et 'Anicia' en milieu contrôlé. Elles embrassent différents aspects de la physiologie et de l'écologie de la plante.

Les expériences d'orientation (2) concernèrent la germination et la profondeur du semis. La germination de 'Large blonde' était optimale dans l'intervalle 19–29°C, celle d'Anicia dans l'intervalle 21–25°C. Les méthodes de semis (1, 4 et 8 cm de profondeur) n'ont eu aucune influence particulière sur la floraison et la longueur des tiges des plantes. La production foliaire moyenne des cultivars était linéaire par rapport aux traitements (Fig. 1). Une profondeur de semis de 4 cm sembla favoriser la production de matière sèche. Dans les expériences qui suivirent, on a utilisé une température de 23°C pour la prégermination et une profondeur de 3 cm pour le semis.

Les essais sur le photopériodisme (3) ont fait apparaître des différences entre 'Large blonde' et 'Anicia'. Le premier cultivar s'est comporté comme une plante de jours longs: il n'a pas fleuri aux photopériodes inférieures à 14 heures. Le second s'est montré plutôt indifférent. Il a fleuri à toutes les photopériodes qui ont été utilisées (8–16 heures) mais la floraison est survenue plus tôt aux jours de 15 et de 16 heures. La production de matière sèche était apparemment indépendante du photopériodisme.

Les effets des traitements suivants: 9°C (nuit)–15°C (jour), 13°C (nuit)–19°C (jour), 17°C (nuit)–23°C (jour), 21°C (nuit)–27°C (jour), 25°C (nuit)–31°C (jour) et 29°C (nuit)–35°C (jour) sur les cultivars ont été étudiés (4). Les productions les plus élevées de feuilles et de matière sèche ainsi que les tiges les plus longues ont été obtenues au régime 21–27°C (moyenne 24°C). Les plantes qui ont été exposées au traitement 29–35°C ont été récoltées prématurément, leur croissance ayant cessé complètement.

L'influence de différentes amplitudes de température (5) a été l'objet d'une expérience comprenant les traitements suivants: 18°C (nuit)–30°C (jour), 21°C (nuit)–27°C (jour) et 24°C (température constante). L'amplitude de 6°C (traitement 21°C–27°C) était optimum pour la longueur de la tige, la production de feuilles et de matière sèche des cultivars.

La photosynthèse de 'Large blonde' et d'Anicia n'était pas influencée par les températures de 18, 24 et 30°C (6). Les différences entre les cultivars ont porté non sur leur capacité photosynthétique mais sur la surface qu'ils forment par unité de poids sec. Le rapport surface foliaire (dm<sup>2</sup>)/poids sec (g) fut plus élevé chez 'Anicia'.

L'essai sur la tolérance à la sécheresse (7) s'est réalisé avec quatre fréquences d'arrosage (3, 4, 8 et 12 arrosages par mois). Le substratum (sable) était amené chaque fois à la capacité au champ. Les traitements ont causé des différences portant sur la surface foliaire, la longueur de la tige, la production de matière sèche et l'évapotranspiration. La croissance et l'évapotranspiration étaient d'au-

tant plus importants que l'arrosage était plus fréquent. Le pourcentage d'eau dans les plantes au moment de la récolte était pratiquement le même pour tous les traitements.

Les effets de 4 niveaux de salinité (1.2, 4.5, 8.4 et 13.1 mmhos/cm) et de 4 pourcentages de sodium échangeable (0.48, 4.53, 6.63 et 9.98) sur la croissance de 'Large blonde' et d'Anicia ont été étudiés (8). Plus le niveau de ces traitements était élevé, plus la croissance était ralentie. L'accumulation de sodium et de magnésium dans les plantes a augmenté avec l'augmentation de la concentration de sels dans le substratum. Les limites de la tolérance à la salinité se trouvent situées entre 8.4 et 13.1 mmhos/cm. L'accumulation de sodium dans les plantes de l'essai concernant le sodium échangeable est devenue aussi plus importante quand le niveau du traitement est plus élevé.

Des données sur la croissance et la reproduction des plantes ont été obtenues au cours d'une expérience qui a duré 16 semaines (9). Le rythme relatif de croissance des deux cultivars atteignit sa plus grande valeur (0.81 g/g/semaine pour 'Large blonde' et 0.85 pour 'Anicia') entre la deuxième et la quatrième semaine. La production finale de matière sèche de 'Large blonde' (4.7 g/plant) fut comparable avec celle d'Anicia (4.5). Les semences du premier cultivar représentèrent 11 % du poids sec final de la plante tandis que celles du second représentèrent 24 %. Le rapport poids sec organes aériens/poids sec organes souterrains des cultivars atteignit sa plus grande valeur (4.7 et 6.3 pour 'Large blonde' et 'Anicia' respectivement) à la fin de l'expérience.

## RESUMEN

Varios experimentos han sido realizados para estudiar el comportamiento de los cultivares de lenteja 'Large blonde' y 'Anicia' en ambiente controlado. Diversos aspectos de la fisiología y de la ecología de la planta han sido considerados.

Los experimentos de orientación (2) estaban relacionados con la germinación y la profundidad de la siembra. El rango 19–29°C era óptimo para la germinación de 'Large blonde', 21–25°C para 'Anicia'. Los métodos de sembrar (1, 4 y 8 cm de profundidad) no tuvieron ninguna influencia particular sobre el largo del tallo y la floración de las plantas. Se observó una relación lineal entre la producción promedio de hojas y los tratamientos (Fig. 1). La producción más alta de materia seca de los cultivares se consiguió bajo la profundidad de 4 cm.

En los estudios sobre el fotoperiodismo (3) se observaron diferencias entre 'Large blonde' y 'Anicia'. El primer cultivar se ha comportado como una planta de días largos: no floreció bajo fotoperiodos inferiores a 14 horas. El segundo se comportó como una planta indiferente. Floreció bajo todos los fotoperiodos usados (8–16 horas) pero la floración ocurrió más temprano bajo 15 y 16 horas.

Los efectos de los tratamientos siguientes: 9°C (noche)–15°C (día), 13°C (noche)–19°C (día), 17°C (noche)–23°C (día), 21°C (noche)–27°C (día), 25°C (noche)–31°C (día) y 29°C (noche)–35°C (día) sobre los cultivares han sido estudiados (4). La mayor producción de hojas y de materia seca y la mayor elongación de tallos han sido conseguidas bajo el régimen de 21–27°C (promedio 24°C). Las plantas que han sido expuestas al tratamiento 29–35°C han sido cosechadas prematuramente, su crecimiento habiendo sido parado completamente.

La influencia de diferentes amplitudes de temperatura ha sido investigada con los tratamientos siguientes: 18°C (noche)–30°C (día), 21°C (noche)–27°C (día) y constante 24°C (5). La amplitud de 6°C (21–27°C) era la mejor en lo referente al largo del tallo, la producción de hojas y de materia seca de los cultivares.

La fotosíntesis de 'Large blonde' y de 'Anicia' no ha sido influenciada por las temperaturas de 18, 24 y 30°C (6). Las diferencias entre los cultivares se encontraron no en su capacidad fotosintética sino en la área que desarrollaron por unidad de peso seco. La relación área foliar (dm<sup>2</sup>)/peso seco (g) era mayor por 'Anicia' que por 'Large blonde'.

La prueba sobre la tolerancia a la sequía (7) ha sido llevada a cabo con cuatro tratamientos (se llevaron a la capacidad de campo las macetas 3, 4, 8 y doce veces al mes). Los tratamientos causaron diferencias en la área foliar, el largo del tallo, la producción de materia seca y la evapotranspiración. Se observó un incremento en lo referente a esos aspectos cada vez que se subió la frecuencia del riego. El porcentaje de agua en las plantas al acabarse el experimento era prácticamente igual para todos los tratamientos.

Los efectos de cuatro niveles de conductividad eléctrica (1.2, 4.5, 8.4 y 13.1 mmhos/cm) y de porcentaje de sodio intercambiable o ESP (0.48, 4.53, 6.63 y 9.98) sobre los cultivares han sido estudiados (8). Se observó una reducción progresiva del crecimiento al subirse el nivel de los tratamientos. Al mismo tiempo se incrementó la acumulación de sodio y de magnesio en las plantas del ensayo sobre la salinidad. Los límites de la tolerancia a la salinidad se hallaron entre 8.4 y 13.1 mmhos/cm. La acumulación de sodio en las plantas del ensayo sobre el sodio intercambiable se incrementó también al subirse el nivel del tratamiento.

Se consiguieron datos sobre el crecimiento vegetativo y el crecimiento reproductivo de los cultivares con un experimento que duró 16 semanas (9). El ritmo de crecimiento relativo (RGR) de ambos cultivares alcanzó su valor máximo (0.81 g/g/semana por 'Large blonde' y 0.85 por 'Anicia') entre la segunda y la cuarta semana después de la siembra. La producción final de materia seca de ambos cultivares era semejante (4.7 g/planta por 'Large blonde' y 4.5 por 'Anicia'). De eso hay que contar 11 % para las semillas de 'Large blonde' y 24 % para las de 'Anicia'. La relación peso seco de los órganos aéreos/peso seco de los órganos subterráneos alcanzó su valor máximo por 'Large blonde' (4.7) y 'Anicia' (6.3) hacia el fin del experimento.

#### AUTHOR'S EMENDATION

The legitimate botanical name of lentil is *Lens culinaris* MEDIKUS. The description of the plant by MEDIKUS (Vorles. Churpf. Phys. Ges., II, Mannheim, p. 361, 1787) predates that of MOENCH (Meth. pl. p. 131, 1794).

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