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# Morphological and cytological differences within the species *Lupinus luteus* L.

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Abstract

The *Lupinus luteus L.* from five different geographical proveniences were investigated morphologically and cytologically. The plants originating from Palestine differ from the rest in many morphological traits. Cytologically they differ by one chromosomal translocation. The Palestinian plants give semisterile $F_1$ hybrids with the rest of the species. They are described as a new subspecies: *Lupinus luteus* L. ssp. *orientalis* Kazim. et. Kazim.

## INTRODUCTION

In the taxonomic and floristic elaborations from Linnaeus (L i n n a e i 1835) to Flora Europaea (1968) it is mentioned that one of the main diagnostic characteristics of yellow lupin is that the flowers in the inflorescence are arranged in regular whorls (Photo 1). Each whorl comprises 5 flowers. This description is correct for the central European cultivated forms and the primitive ones originating from the Pyrenean peninsula, Sicily, Anatolia and north Africa. The inflorescence of yellow lupin growing in Palestine exhibits a different arrangement.

We received from dr M. Arar in 1964 some seeds of several lupin species and forms from Israel which are endemic for this country. Among them were also seeds of *L. luteus*. Dr Arar mentioned that the seeds were collected by him from plants growing on sandy soil with acid pH in an uninhabited region. These seeds gave rise to plants with flowers disposed alternately on the inflorescence (Photo 2), thus like in *L. angustifolius* and *L. albus*.

The yellow lupin plants from Israel differ from those of the cultivated forms and from those originating from the Pyrenean peninsula, Sicily and Anatolia not only by the structure of the inflorescence but also by other traits. A description of the seeds and plants of the yellow lupin from Israel and of the primitive forms of this species from other regions of the Mediteranean basin is given below. According to the geographical regions from which the investigated yellow lupin forms originate, they were classified to the following geographical groups: Palestinian (Israelian), Anatolian (represented by 2 forms), Sicilian and Pyrenean (represented by 4 forms) and the central European cultivated one (represented by 2 forms).

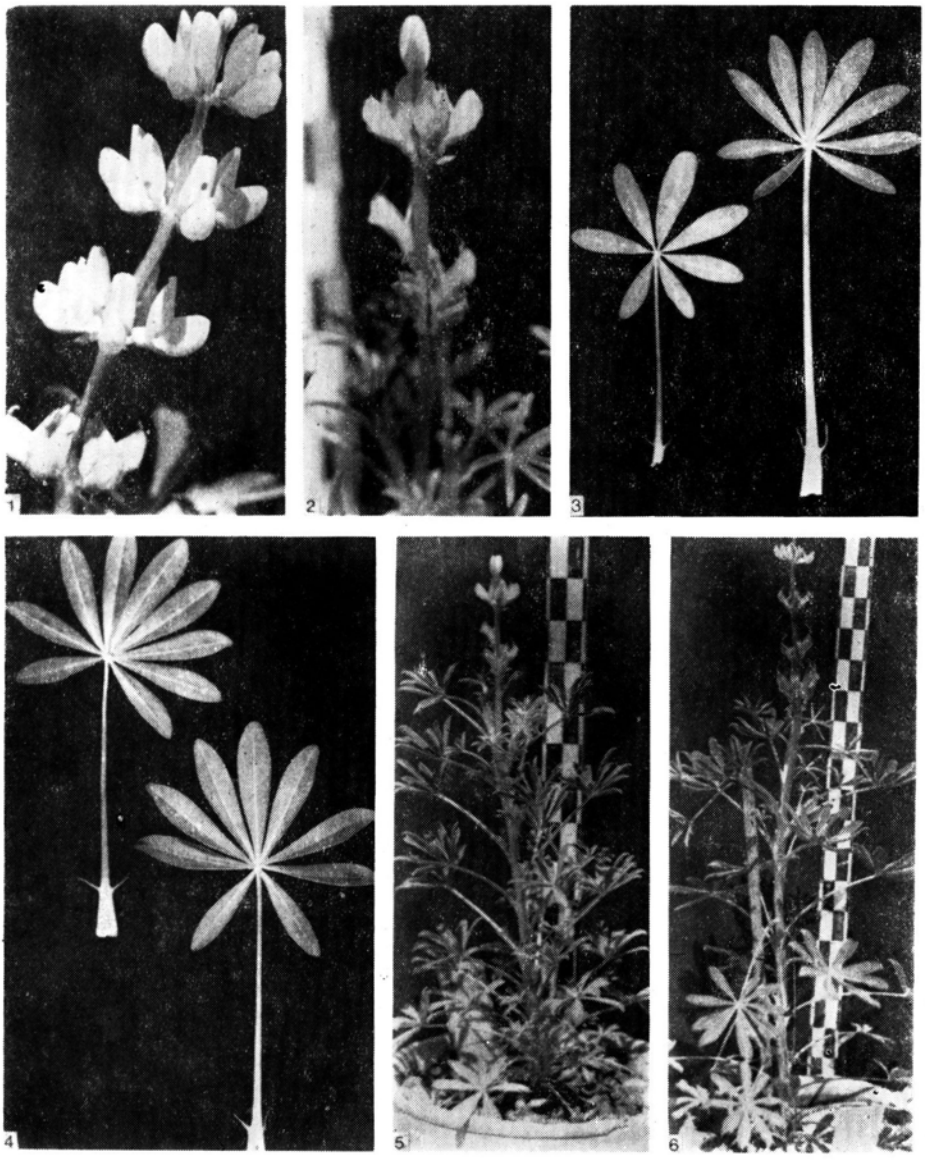
## DESCRIPTION OF CERTAIN TRAITS

### Leaves

The length of leaf petioles and stipules, the length and breadth of the leaf blades and the number of leaflets in the leaf were determined on leaves of plants growing in identical conditions. Leaves for measurement were collected from the basal and the upper part of the shoot. The results are shown in table 1. As seen in the Palestinian form, the petioles and stipules are shorter, and the leaf blades shorter and narrower than in the remaining geographical forms of yellow lupin (Photos 3 and 4). The leaves of the Anatolian form resemble most closely in size those of the Palestinian form. The shape of the leaf blades shows hardly any differences between the geographical forms of yellow lupin investigated. The number of leaflets in the leaf in the cultivated forms does not exceed nine and in the primitive forms the maximal number is 10—11 (Table 1).

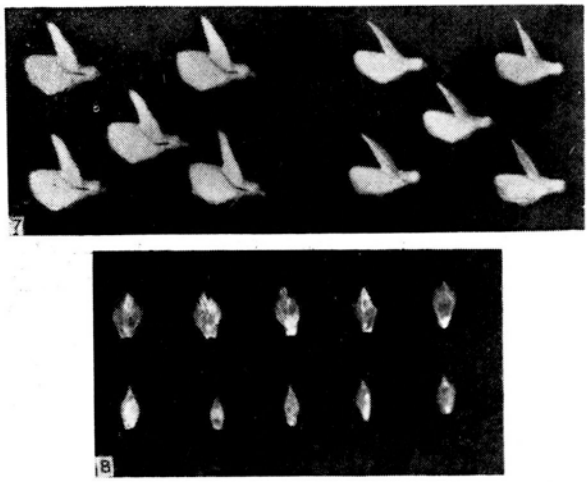
The upper surface of the leaf blades is almost glabrous, the lower one in the Palestinian form is covered with rare short white adherent hairs. The petiole is also covered with such short adherent rarely disseminated hairs and the edges of the stipules are bordered with short cilia. In other forms investigated the above mentioned organs are covered with longer and denser distributed hairs.

The mean number of stomata on the lower leaf surface of plants of the Palestinian group is almost twice that falling to the leaf surface area unit in other geographical groups (Table 2). The stomata on the leaves of plants of the Palestinian form are by 4—6 μ shorter and by 2 μ narrower than those of the remaining plant groups. Only in the Anatolian group the stomata are on the average by 1.2 μ narrower than in the Palestinian one.



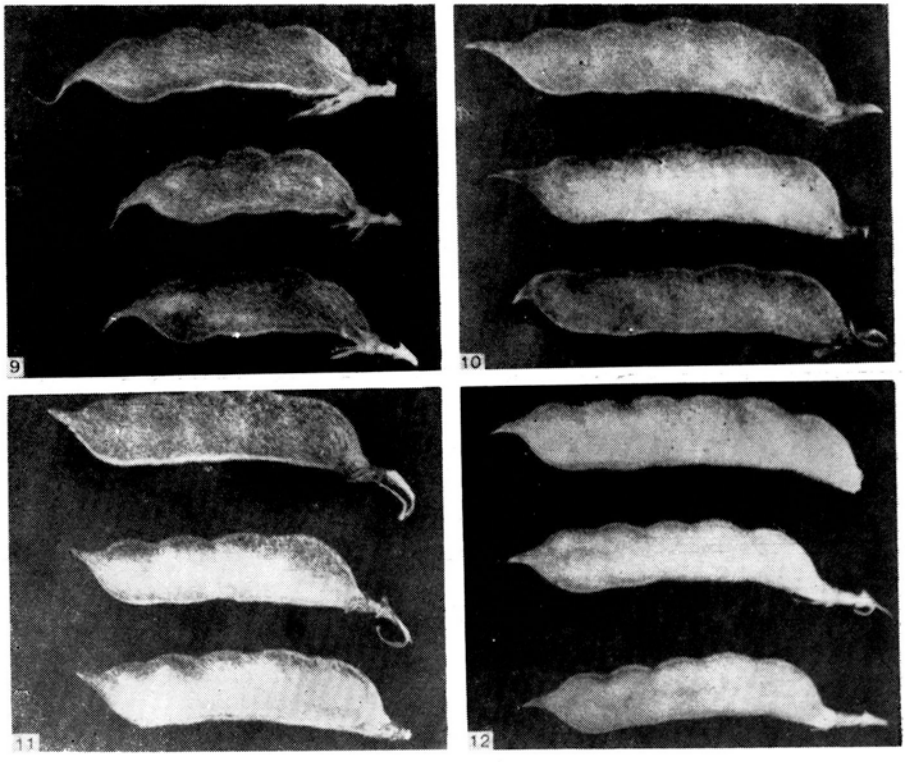
Phot. 1—6. Inflorescences, leaves and whole plants from different geographic proveniences of yellow lupin

1-2 — Inflorescences (1 — of plants from Sicily, flowers in regular whorls, 2 — of Palestinian group, flowers in alternale positions); 3-4 — Leaves, left — from lower part, right — from upper part of the stem (3 — Palestinian group, 4 — cultivated plants from Middle Europe); 5-6 — Plants (5-from Palestinian group, 6 — from Sicilian group); in the middle part of the stem leaves different angles with the axis



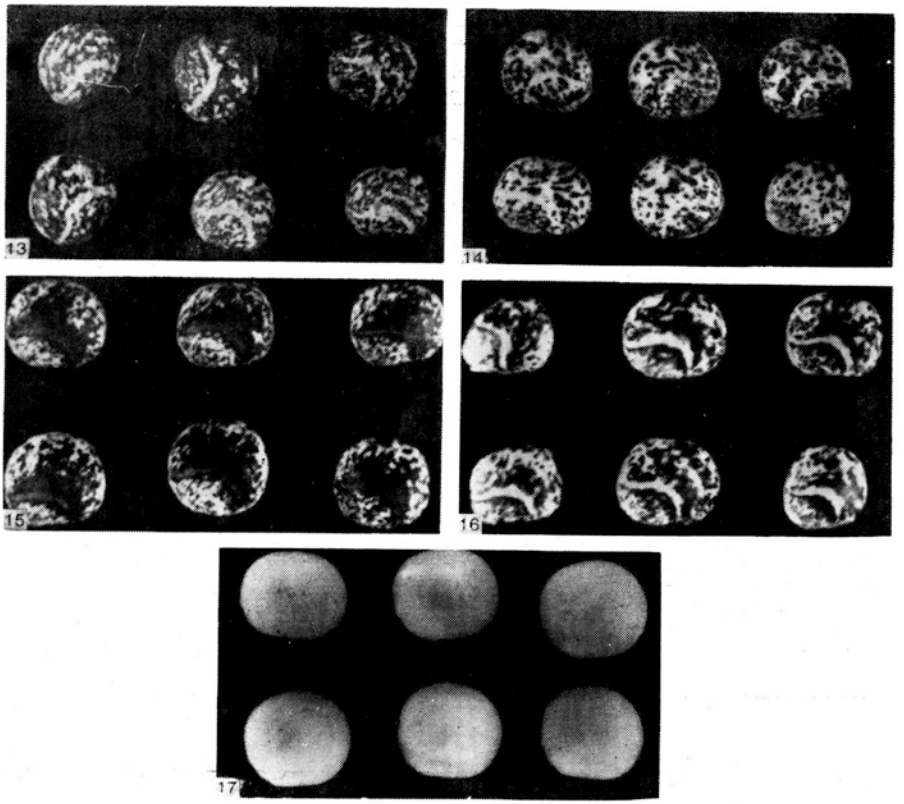
Phot. 7—8. Flowers and bracts from different geographic groups of yellow lupin

7 — Flowers (left — from Portugal, right — from Palestine), 8 — Bracts, upper row, cultivars from Middle Europe, lower row — from Palestine



Phot. 9—12. Pods from different geographic groups of yellow lupin

9 — from Palestine; 10 — cultivated middle European; 11 — from Sicily; 12 — from Portugal



Phot. 13—17. Seeds from different groups of yellow lupin

13 — from Palestine; 14 — from Anatolia; 15 — from Sicily; 16 — from Portugal; 17 — cultivated Middle European

Table 1

Length of leaf petioles and stipules, length and breadth of leaf blades and number of segments in leaf in geographical yellow lupin groups

| Geographical group | | Length (cm) | | | | | | | | | Breadth (cm) | | | Length to breadth ratio | No. of segments in leaf | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | of petiole | | | of stipule | | | of leaf blade | | | | | | | | |
| | | minimal | maximal | mean | minimal | maximal | mean | minimal | maximal | mean | minimal | maximal | mean | | from | to |
| Palestinian | a | 5,4 | 6,7 | 5,9 | 1,2 | 1,6 | 1,4 | 1,6 | 3,6 | 2,66 | 0,5 | 1,0 | 0,77 | 3,46 | 5 | 10 |
| | b | 10,1 | 11,9 | 11,1 | 2,0 | 2,4 | 2,3 | 2,3 | 4,3 | 3.25 | 0,5 | 1,0 | 0,80 | 4,05 | 5 | |
| Anatolian | a | 5,4 | 7,3 | 6,6 | 1,2 | 1,8 | 1,3 | 2,0 | 5,0 | 3,58 | 0,6 | 1,4 | 1,10 | 3,24 | | 11 |
| | b | 11,7 | 15,0 | 13,0 | 2,7 | 3,1 | 2,9 | 3,0 | 6,0 | 4,62 | 0,8 | 1,5 | 1,17 | 3,94 | | |
| Sicilian | a | 6,9 | 9,5 | 7,8 | 1,6 | 2,0 | 1,7 | 2,0 | 5,0 | 3,43 | 0,6 | 1,5 | 1,14 | 2,99 | 5 | 10 |
| | b | 11,0 | 15,4 | 13,1 | 2,1 | 3,6 | 2,4 | 2,2 | 5,6 | 4,69 | 0,7 | 1,4 | 1,39 | 3,35 | | |
| Pyrenean | a | 6,9 | 11,0 | 8,5 | 1,7 | 2,7 | 1,9 | 2,2 | 5,5 | 4,09 | 0,8 | 1,7 | 1,21 | 3,37 | 5 | 11 |
| | b | 11,6 | 16,8 | 14,4 | 2,5 | 4,2 | 3,2 | 2,7 | 6,0 | 4,88 | 0,7 | 1,5 | 1,22 | 4,00 | | |
| Cultivated — — central European | a | 6,2 | 9,5 | 7,7 | 1,7 | 2,2 | 2,0 | 2,1 | 5,0 | 3,69 | 0,6 | 1,3 | 1,01 | 3,70 | 5 | 9 |
| | b | 12,6 | 15,4 | 14,3 | 3,0 | 4,0 | 3,4 | 4,0 | 6,9 | 5,46 | 0,9 | 1,8 | 1,34 | 4,07 | | |

Explanation; a—leaves from lower part of the shoot
b—leaves from upper part of the shoot

Table 2

Stomata — number and dimensions — on lower surface of leaf in plants of various geographical yellow lupin groups

| Geographical group | No. of stomata per surface area unit (enlarged 10×44) | | | Stomata mean (μ) | |
|---|---|---|---|---|---|
| | minimal | maximal | mean | length | breadth |
| Palestinian | 3 | 11 | 6.0 | 34.51 | 27.55 |
| Anatolian | 2 | 7 | 3.6 | 38.95 | 26.34 |
| Sicilian | 2 | 6 | 3.3 | 41.08 | 29.60 |
| Pyrenean | 1 | 9 | 3.5 | 41.77 | 29.13 |
| Cultivated — central European | 1 | 6 | 3.2 | 41.95 | 29.66 |

## Shoots

As seen from the measurements listed in Table 3, plants of the Palestinian form grow slowest. Other geographical forms (Sicilian, Anatolian and Pyrenean) as well as the cultivated forms growing normally — represented by the variety Pomorski Pastewny — exhibit a more rapid growth and do not differ between themselves in growth rate. Quickest growing are the plants of the Express variety which in the present study represent a quickly growing cultivated form.

The plants of the Palestinian form are most profusely foliated, the remaining forms show 3—10 leaves less on the shoot (Table 3). From among the examined yellow lupin groups the plants of the Palestinian form are the lowest (Table 3).

Table 3

Rate of growth (cm), number of leaves on shoot and height of mature plants of various geographical yellow lupin groups

| Geographical groups | Dates of measurements | | | | No. of leaves on shoots (mean) | Height of mature plants (mean, cm) |
|---|---|---|---|---|---|---|
| | 29. IV. | 9. V. | 21. V. | 29. V. | | |
| Palestinian | 9.7 | 11.6 | 12.4 | 13.7 | 33.3 | 33.1 |
| Anatolian | 11.0 | 13.2 | 14.0 | 16.3 | 28.3 | 53.5 |
| Sicilian | 11.8 | 13.0 | 13.4 | 14.2 | 30.0 | 49.0 |
| Pyrenean | 12.3 | 13.8 | 13.9 | 16.6 | 22.8 | 40.8 |
| Cultivated — central European form | | | | | | |
| slow growing | 11.2 | 12.6 | 13.2 | 14.5 | 26.7 | 55.0 |
| fast growing | 19.4 | 25.2 | 31.0 | 39.2 | 25.0 | 60.2 |

In the latter form the leaves on the middle part of the shoot are set at a 30° angle (Photo 5), in the remaining forms the angle between the petiole and the shoot is 50—60° (Photo 6). The leaves differ in colour, in the Palestinian form they are intensively green, while in the remaining ones dark green.

## Inflorescence and flowers

Plants of the cultivated group flowered earliest, the period from seeding to inflorescence did not exceed 80 days. The latest to flower were the plants of the Palestinian group, for them the period from seeding to flowering varied from 90 to 109 days. Closest to the Palestinian plants in this respect were those of the Anatolian group (Table 4).

Table 4

Length (days) of time period from emergence to efflorescence in various geographical yellow lupin groups

| Geographical groups | No. of days from seedling to efflorescence | |
|---|---|---|
| | from | to |
| Palestinian | 90 | 109 |
| Anatolian | 83 | 96 |
| Sicilian | 78 | 82 |
| Pyrenean | 79 | 87 |
| Cultivated — central European | 71 | 77 |

As already mentioned, the flowers in the Palestinian form alternated on the inflorescence, whereas in the plants of other groups they are arranged in regular whorls — 5 flowers in each. The mean inflorescence length in the Palestinian form is 6 cm (4—8 cm) and the mean number of flowers in the inflorescence is 16.8 (Table 5). In the other geographical yellow lupin groups studied the inflorescence was on the average 13 cm long (9—17 cm) and the number of flowers in the inflorescence ranged from 30—40. Thus, from among the geographical groups of yellow lupin the Palestinian form shows the shortest inflorescence and lowest number of flowers on it.

The calyx of yellow lupin is bilabiate, and the upper lip is split to the base. The end of the lower lip in part of the Palestinian plants is tripartite and in some it is undivided. In plants of the other groups the end of the lower lip is tripartite.

The bracteoles are linear, ending sharply. In the forms containing much anthocyanin (Sicilian, Anatolian, Pyrenean) the bracteoles are more intensely coloured than the calyx (Photo 7). The Palestinian plants have shorter bracteoles than the remaining ones and the same amount of anthocyanin in them as in the calyx so they do not stand out against the light background of the flower (Photo 7).

Table 5

Number of flowers in inflorencence of plants from various geographical yellow lupin groups

| Geographical groups | No. of flowers in inflorescence | | |
|---|---|---|---|
| | minimal | maximal | mean |
| Palestinian | 5 | 24 | 16.8 |
| Anatolian | 30 | 55 | 34.5 |
| Sicilian | 25 | 35 | 30.0 |
| Pyrenean | 25 | 50 | 35.1 |
| Cultivated — central European | 30 | 50 | 40.4 |

In the Palestinian yellow lupin form the bracts are by one half narrower than those of the remaining groups (Table 6) and they have an almost winged shape (Photo 8). In the other groups they look like a short-necked carafe.

Table 6

Mean dimensions of flowers and bracteoles (mm) in plants from various geographical yellow lupin groups

| Geographical groups | Bracteoles | | Flowers | | |
|---|---|---|---|---|---|
| | length | breadth | length | breadth | |
| | | | | of vexillum | of wings |
| Palestinian | 5.6 | 2.0 | 14.0 | 9.8 | 7.8 |
| Anatolian | 5.3 | 4.1 | 15.0 | 10.0 | 8.1 |
| Sicilian | 5.0 | 4.6 | 16.0 | 10.3 | 8.0 |
| Pyrenean | 6.2 | 3.5 | 15.5 | 10.0 | 8.3 |
| Cultivated — central European | 5.6 | 3.9 | 16.5 | 11.0 | 8.5 |

The flowers of the Palestinian form are yellow with a hue distinctly lighter than the chromic yellow flowers of other lupin groups, they are also smaller (Table 6, Photo 7). From among the groups studied the cultivated group exhibits the largest flowers and those of the Anatolian group are closest in size to the flowers of the Palestinian plants.

## Pods

The plants of the Palestinian group have the shortest and narrowest pods from among the investigated groups with the smallest number of ovules in the ovary (average 4) and seeds in the pod (on the average less than four; Table 7, Photos 9—12). The pods are covered with pubescence. No major differences were noted between the studied forms as regards the length of the hairs, their density and distribution.

In the period of ripening depressions form on the dorsal and lateral sides of the pod. In plants of the cultivated, Pyrenean, Anatolian and Sicilian groups these depressions are less pronounced than in the Palestinian group where they are well visible (Photos 9—12).

Table 7

Length and breadth of pod (cm) and number of ovules in ovary and seeds in pod on plants of various geographical yellow lupin groups

| Geographical groups | Number of | | | | | | Pods | |
|---|---|---|---|---|---|---|---|---|
| | ovules in ovary | | | seeds in pod | | | | |
| | minimal | maximal | mean | minimal | maximal | mean | length | breadth |
| Palestinian | 3 | 5 | 4.0 | 3 | 4 | 3.7 | 4.2 | 0.9 |
| Anatolian | 4 | 6 | 5.0 | 3 | 6 | 4.3 | 4.7 | 1.1 |
| Sicilian | 4 | 5 | 4.4 | 3 | 5 | 4.1 | 5.0 | 1.1 |
| Pyrenean | 4 | 7 | 5.2 | 3 | 6 | 4.7 | 5.3 | 1.2 |
| Cultivated — central European | 5 | 7 | 5.6 | 3 | 6 | 5.1 | 5.9 | 1.2 |

The beak — the sharp end of the pod — form in the cultivated forms an almost straight line with the dorsal edge, in the Sicilian group it is somewhat curved upwards and in the Portuguese form it lies in the middle of the pod breadth, whereas in the Palestinian form it is distinctly bent downwards (Photos 9—12). Ripe pods of yellow lupin show in cross section a shape resembling a convex lens. The convexity is more pronounced in the Palestinian form.

## Seeds

The seeds of the Palestinian form differ in size, shape and pigmentation from those known to us from autopsy and descriptions of yellow lupin forms originating from the Pyrenean peninsula, Sicilia, Anatolia, north Africa and central Europe (Zhukovsky 1929; Klinkowski, 1938; Hackbarth and Troll, 1957; Atabiekova and May-

surian, 1974). The primitive and cultivated forms — with the exception of the Palestinian and Sicilian ones — have flattened seeds with depressions on the sides (Photos 13—17). The seeds of the latter two forms are more vaulted, on cross section they resemble the shape of a lens. From among the primitive forms examined the longest and broadest seeds are seen in the Pyrenean form, the seeds of which are only slightly shorter and narrower than those of the central European cultivated forms (Table 8). The smallest of all are the seeds of the Palestinian form, they are somewhat larger in the Anatolian plants. Those of the Sicilian form are intermediate in size between the Anatolian and Pyrenean forms (Table 8).

Table 8

Mean dimensions of seeds (mm) and 1000-seed weight (g) in yellow lupin geographical forms

| Geographical groups | Seed dimensions | | | 1000-seed weight (g) | | |
|---|---|---|---|---|---|---|
| | length | breadth | thicknees | minimal | maximal | mean |
| Palestinian | 6.2 | 5.5 | 3.9 | 74.3 | 114.0 | 95.9 |
| Anatolian | 6.8 | 5.9 | 3.6 | 86.6 | 129.5 | 110.8 |
| Sicilian | 6.8 | 6.3 | 4.6 | 104.8 | 146.4 | 123.1 |
| Pyrenean | 7.1 | 6.0 | 3.7 | 95.1 | 128.5 | 120.4 |
| Cultivated — central European | 7.8 | 6.6 | 3.9 | 110.1 | 180.3 | 137.5 |

The 1000-grain weight is lowest for the Palestinian form, (Table 8).

The seeds of the Palestinian form are brightly coloured. On the cream-coloured background large light and dark brown spots are superposed with irregularly outlined edges. On the side surfaces light arcs covered in some places with light brown pigment are distinctly outlined. Other known geographical yellow lupin forms have white seeds or diversely pigmented seeds (Photos 13—17). In the forms with coloured seeds the pigment is very dark, frequently passing to black and the light arcs on the sides are mostly white.

## Chromosome number and hybrid fertility

The somatic cells of the Palestinian plants have a chromosome number $2n=52$, thus a number typical for yellow lupin (Savtchenko, 1935). The chromosomes are short, varying from 1.4 to 2.7 $\mu$.

The $F_1$ plants from crosses between the Palestinian and the cultivated form (Kazimierski and Kazimierska, 1975) and also with the Anatolian and Pyrenean forms (Kazimierski and Kazi-

mierska, in preparation) have a by 50 per cent lowered pollen and female gamete vitality as compared with the parent form, and $F_1$ hybrids from crosses of the cultivated and Anatolian and Portuguese forms (Kazimierski and Nowacki 1971) and $F_1$ hybrids from crosses of the Portuguese and Anatolian groups. The reduction of generative cells vitality by 50 per cent in the $F_1$ plants obtained by crossing the Palestinian form with the remaining groups is due to translocation which distinguishes the Palestinian form from the remaining yellow lupin groups (Kazimierski and Kazimierska, 1974, in preparation).

## Alkaloids

Large quantities of the following alkaloids are present in the vegetative organs and seeds of yellow lupin: lupinin and spartein (Nowacki, 1960). The Palestinian form contains, however, another alkaloid — gramin.

## CONCLUSIONS

Comparative description of five geographical yellow lupin groups and the fertility of the hybrids from crosses between them indicate that the Palestinian form differs from the remaining ones by the following traits and properties: structure and size of inflorescence, size of flowers, number of ovules in the ovary and seeds in the pod, the shape and pigmentation of seeds, the length of the time period between emergence to efflorescence, the alkaloid composition and translocation. In view of this we consider the Palestinian form as a distinct taxonomic unit and assign to it the name *Lupinus luteus* L. ssp. *orientalis* Kazim. et Kazim.

*Plantae annuae, pubescentes albis, brevibus as adiacentibus capillis, altitudine 26—35 cm. Foliolae oblongae, inverse ovatae, in superficie superiore prope nudae, in inferiore raro adiacenter pubescentes. Folia coloris valde viridis. Numerus foliarum in folio a 5 ad 10. Angulus sedimenti foliorum in parte media cauliculi 30°. Stipulae potius longae a 1,0 ad 2,3 cm, in 1/4 ad 1/3 concrescentes cum petiola, ultimae partes stipularum rectae, lanceolatae. Inflorescentia brevis altitudinis a 4 ad 8 cm cum parvo numero medi modi gilvorum florum, positorum in axe inflorescentiae alternus.*

*Calix duolabialis, labium superum secatum a fundamento, ultima pars labii inferioris in parte plantarum tripartitus, in parte non partitus. Bracteae angustae, longae, pubescentes, defluae. Semina in figura lenticulae pulvinatae, altitudine 6,2, latitudine 5,5, crassitudine 3,9 mm maculosa, cum arcu claro in superficientibus laterum. Legumena habents non plus quam quattuor semina. A subspecie L. luteus L. ssp. luteus Kazim. et Kazim. translocatione differt. Habitant in orientali parte terae Mari Mediterraneo adiacentis — in Palestina.*

Thus yellow lupin considered so far as a homogeneous species as regards taxonomy and cytogenetics should be classified to two subspecies:

*Lupinus luteus* L. ssp. *luteus* Kazim. et Kazim.

*Lupinus luteus* L. ssp. *orientalis* Kazim. et Kazim.

The information concerning the morphological and cytological differentiation of this species indicates that geographical forms belonging to the former subspecies occupy the area from Anatolia to Sicily, central Europe, the Pyrenean peninsula and probably the Maghreb countries. The area occupied by the latter subspecies is so far limited to Palestine.

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## *Zróżnicowanie morfologiczne i cytologiczne w obrębie gatunku Lupinus luteus L.*

Streszczenie

Badania prowadzone na pięciu grupach geograficznych łubinu żółtego, mianowicie: palestyńskiej, anatolijskiej, sycylijskiej, pirenejskiej i uprawnej — środkowoeuropejskiej wykazały, że grupa geograficzna palestyńska różni się od pozostałych szeregiem cech morfologicznych a także cytologicznie. Rośliny grupy geograficznej palestyńskiej mają kwiatostan krótki (4—8 cm), a kwiaty są na nim rozmieszczone naprzemianlegle. Kwiaty roślin grupy palestyńskiej są mniejsze, liczba zalążków w zalążni i nasion w strąku jest także mniejsza niż u roślin innych grup geograficznych łubinu żółtego. Strąki roślin grupy palestyńskiej są węższe i krótsze o kształcie nieco odmiennym jak u innych grup łubinu żółtego. Nasiona są marmurkowe, z jasnym paskiem na powierzchniach bocznych, rozmieszczenie pigmentu na powierzchni nasienia i jego barwa są także odmienne niż u pozostałych grup. Palestyńska grupa od pozostałych różni się także translokacją. Mieszańce $F_1$ między roślinami grupy palestyńskiej i innych grup charakteryzują się m.in. tym, że płodność ich zmniejsza się o 50%.

Pewne odrębności morfologiczne i różnice cytologiczne między formą palestyńską i innymi badanymi grupami łubinu żółtego skłaniają do uznania formy palestyńskiej łubinu żółtego za odrębną jednostkę taksonomiczną; formie tej nadajemy nazwę *Lupinus luteus* L. ssp. *orientalis* Kazim. et Kazim. Zatem łubin żółty, uważany dotychczas za jednolity taksonomicznie i cytologicznie, należy podzielić na dwa podgatunki:

*Lupinus luteus* L. ssp. *luteus* Kazim. et Kazim. i

*Lupinus luteus* L. ssp. *orientalis* Kazim. et Kazim.