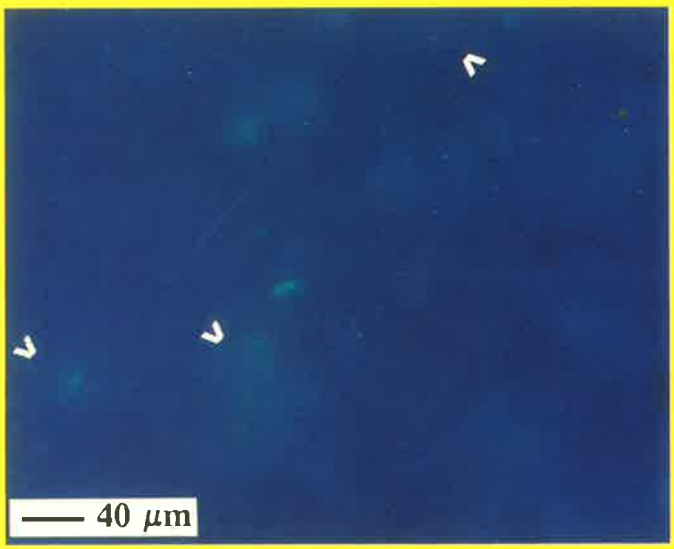
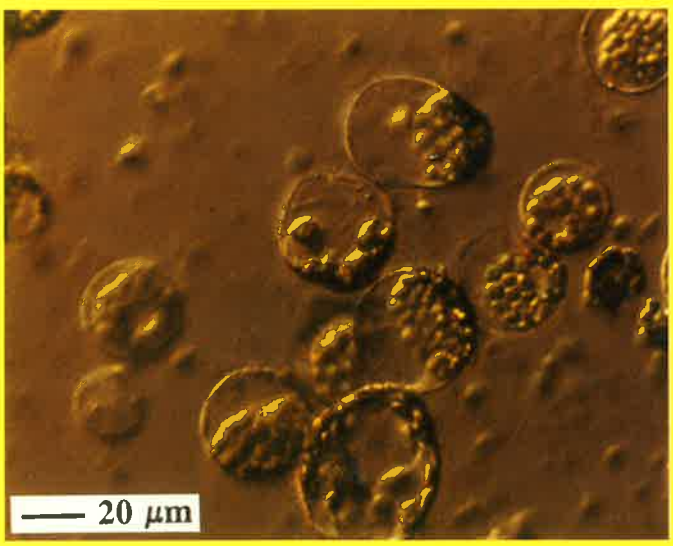
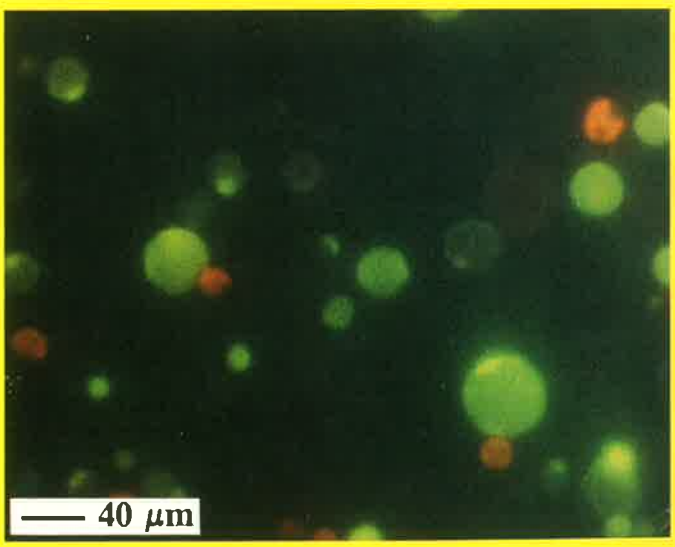
Vol. 18, No. 1/2, 1991

Lens NEWSLETTER







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LENS

LENS Newsletter is produced twice a year at ICARDA in cooperation with the University of Saskatchewan, Canada with the financial support of the International Development Research Center (IDRC), Ottawa, Canada. LENS, the newsletter of the Lentil Experimental News Service, is a forum for communicating lentil research results. Short research articles provide rapid information exchange, and comprehensive reviews are invited regularly on specific areas of lentil research. The newsletter also includes book reviews, key abstracts on lentils, and recent lentil references. The Lentil News Service provides information on lentil research free of charge through a question and answer service, photocopies, and searches of lentil document collection.

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COVER PHOTO: Lentil protoplasts varying in form and growth to show feasibility of callus regeneration. Related article, page 30. (Photos courtesy of Carol Stiff)

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Research Articles

Breeding and Genetics

Induced Macromutations in Lentil

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Abstract

Dry seeds of a lentil cultivar PL 639 were treated with gamma rays and ethyl methane sulphonate (EMS). Plants in M_2 and M_3 generations were screened for the spectrum and frequency of macromutations. The spectrum of macromutations was found to be wider in EMS treatments than in gamma ray treatments. Segregation patterns in all the mutation types suggested monogenic recessive control.

Introduction

Crop improvement by conventional plant breeding depends, to a large extent, on the amount and levels of genetic variability found in gene pools. Induced mutations have been recognized as an important tool for crop improvement and are believed to have sufficient scope in pulses. For mutation breeding, response to treatment with various mutagens also provides valuable information since it facilitates planning of experiments to achieve a high mutation frequency. A number of viable mutants in lentil exhibiting monogenic control have earlier been described by Sharma and Sharma (1977, 1978, 1979, 1980). Dixit and Dubey (1982) studied the effect of different mutagens on maturity, pollen sterility, survival percentage, and fruit and seed yields. Varying degree of sterility and reduced survival rates are the other common features of such treatments (Blixt 1960; Goud 1972; Sharma and Sharma 1986).

During the present study of induced mutations in lentil a number of mutations for a variety of morphological and agronomic characters were obtained and analyzed. The results of this study are presented and discussed in this communication. These mutants are being maintained for further studies of linkage and chromosome mapping.

Materials and Methods

Dry seeds of well-adapted variety PL 639 of lentil (*Lens culinaris* Medik.) were subjected to 50 Kr, 100 Kr, and 200 Kr doses of gamma ray irradiation. Along with a control, seeds of these treatments were soaked in distilled water for six hours before sowing.

For chemical treatments the seeds were soaked in the aqueous solutions of three concentrations; 0.1%, 0.2%, and 0.3% of EMS for six hours. The seeds were washed in running water for 30–35 minutes after each chemical treatment.

In every treatment (including control) 300 seeds were sown in 10 rows, each row with 30 seeds. Plants in a row were kept 15 cm apart, and rows were kept at a 25 cm distance. For raising M_2 generation, M_1 plants were harvested as single-plant progenies. Twenty-five seeds from each plant were sown at a distance of 10 cm within a row, and rows were maintained at 23 cm. As many as seven different types of macromutations were isolated, which involved characters like plant form, flower, and leaf. The different characteristics of these mutation types were studied in detail.

Results

Spectrum of mutations

(a) **Stunted.** Several miniature plants with height ranging from 8 to 13 cm were grouped under this category. Height in these mutants was reduced due to reduction of internode length (0.5 cm) relative to control (2.4 cm).

(b) **Dwarf.** Mutant plants grew up to 18 cm. Seedlings were normal. The mean number of branches per plant was 9.0 in dwarves compared with 7.5 in parent variety PL 639. Appearance was somewhat bushy.

(c) **Bushy dwarf.** The mutant plants were smaller in

height than parent var. PL 639 and compact in appearance, occupying less area. The plants were flowerless.

(d) **Open flower.** The flower-bearing zone in these mutants was greater than in PL 639, but the plants did not set seed showing complete sterility.

(e) **Partial sterile.** The flower-bearing zone in these mutants was greater than in PL 639, but the grain yield was still low, indicating partial sterility. There was only one pod per bunch. Branches per plant also increased in these mutants.

(f) **Complete sterile.** The plants with normal height, dark color, and increased branching were completely sterile. The stigma protruded out of the flower and anthers remained within the bud.

(g) **Large leaved.** The leaves in these mutants were larger and dark green. Though the pods were bigger in size than in the control, the seeds were not.

Mutation frequencies

The frequencies of these viable macromutations were recorded in different treatments on the basis of M_1 plants (M_2 progenies) and M_2 seedlings (M_2 population). The frequencies are presented in Table 1. Mutation frequency generally increased with the increase in dose of gamma rays, while in chemical treatments the frequency was highest at 0.2% of EMS. The spectrum of mutation was also widest in this treatment. The number of surviving plants decreased with increases in the dose/concentration in the physical, as well as chemical, treatments.

Segregation patterns

The segregation patterns of different kinds of macromutations (stunted, dwarf, bushy, open flower, partial sterile, complete sterile, and large leaved) were studied in M_2 and again in M_3 generations. The numbers of segregating plants within rows are presented in Table 2. It can be seen from the table that most of the segregating progenies gave a good fit to a 3:1 ratio in all types of mutations in both generations, and the probability ranged from 0.1% to 1%.

Macromutants for quantitative characters

These mutants were detected in M_3 generation and studied for quantitative characters. The data recorded on different plants of the same type of mutation were used for statistical analysis and are presented in Table 3. It can be observed from the table that a mutation type differs from the parent in more than one character.

Table 1. Mutation frequencies of different morphological mutants in M_2 following treatments of gamma rays and EMS in variety PL 639 of lentil).

	Treatment (dose of gamma rays/conc. of EMS)						
	Control	50 Kr	100 Kr	200 Kr	0.1% EMS	0.2% EMS	0.3% EMS
Total number of M_1 plants survived	250	172	140	100	162	130	86
Total number of M_2 plants	6250	4300	3500	2500	4050	3250	2150
Frequency of M_2 mutant plants:							
Stunted	—	1	—	—	—	—	1
Dwarf	—	3	—	—	—	1	1
Bushy dwarf	—	—	—	—	—	3	—
Open flower	—	2	—	—	—	—	—
Partial sterile	—	—	—	5	3	6	—
Complete sterile	—	—	—	1	—	—	—
Large-leaved	—	—	—	—	—	2	—
Total	00	06	00	06	03	12	02
Mutation frequency/1000 M_2 plants	0.00	1.39	—	2.40	0.74	3.69	0.93
% segregating families	0.00	2.33	—	3.00	1.85	3.85	2.33

Table 2. Segregation of different types of viable morphological mutants in M_2 and M_3 generations of lentil.

Mutation type	M_2 generation			M_3 generation		
	Normal	Mutants	P (3:1)	Normal	Mutants	P (3:1)
Stunted	8	1	0.30–0.50	20	3	0.10–0.20
	4	1	0.70–0.80	22	2	0.10–0.20
Dwarf	20	2	0.05–0.10	20	4	0.30–0.50
	7	1	0.10–0.20	18	3	0.30–0.50
	5	1	0.50–0.70	17	3	0.30–0.50
	10	1	0.20–0.30			
Bushy dwarf	9	3	1.00	20	4	0.30–0.50
				18	4	0.30–0.50
Open flower	7	2	0.80–0.90	14	3	0.30–0.50
				20	4	0.30–0.50
Partial sterile	9	3	1.00	15	4	0.50–0.70
	15	2	0.20–0.30	20	6	0.80–0.90
	3	1	1.00	21	8	0.70–0.80
	10	1	0.20–0.30			
	10	1	0.20–0.30			
	10	2	0.50–0.70			
	20	4	0.30–0.50			
Complete sterile	7	1	0.10–0.20	20	5	0.50–0.70
				15	4	0.50–0.70
Larger leaved	5	2	0.80–0.90	20	5	0.10–0.20
				12	4	1.00

Discussion

In the present study, the mutation frequency was highest in chemical treatments (0.2% EMS), which may be attributed to a difference in the molecular mechanism involved in mutagenesis due to EMS treatments, or alternatively due to specificity of EMS for some regions of chromosomes. Although the segregation data of different morphological mutations suggested recessive monogenic behavior in all cases, the probability of a good fit to a 3:1 ratio is low in few cases. This may be due to one or more of the following three factors: (1) the mutation rate increases with the radiation dose or concentration of chemical used, but the survival rate of the treated embryos decreases. Moreover, the vitality and the seed production of the M_1 plants also decrease, and population may be too small to be satisfactory for goodness of fit tests; (2) because of the chimeras in M_1 plants, a deficit of the recessive trait occurs so that, even in larger M_2 families, the mutant plants may be obtained in a lower frequency; and (3) deficit of the recessive trait due to certation is a peculiarity of many mutant gene characteristics; because of this peculiarity, the proportion of mutants is reduced in the segregating families.

Morphological mutations having reduced plant height offers an interesting study, since it may be due to a reduction in either the number of internodes or length of internodes; the latter itself caused by either the reduction of cell length (cell breadth being unaltered), or reduction of cell numbers (Weber and Gottschalk 1973). Irrespective of the basis of reduction in plant height, most of these mutations have two advantages: (1) due to compactness, they cover very little space. Therefore, by increasing seed-rate, they will give higher yield per unit area; and (2) these plants are resistant against lodging, thus reducing loss from wind and rain, though the latter is not a serious problem in lentils.

Many mutant plants in the present study had open flowers that were completely sterile. In come cases, male organs were found malformed. Reports are available of male sterility being caused through genes by transformation of stamens into carpel-like organs (Gottschalk and Kaul 1974; Gottschalk 1976). Complete or high sterility may be caused either by gene mutations or by deletions (Ekberg 1969). On the other hand, chemical mutagens probably induced sterility due to increased sensitization of seeds as a result of presoaking and decreased intrasomatic selection. Enhanced chemosensitivity caused by presoaking has been attributed to leaching of endogenic protective substances (Kamra et al. 1960).

It should also be recognized, as evident from data presented in Table 3, that many mutants differ from the control for more than one character. These differences may be caused either by a pleiotropic gene effect or an induction of mutations for several genes (each controlling a separate trait) that were very closely linked or overlapped. Because of their close linkage or overlapping, the individual genes of a group are not separated from each other by crossover events. Therefore, the complex of diverging characters is transferred as a unit from generation to generation, showing a monogenic inheritance.

A large number of other morphological mutants (e.g., compact, bushy, fasciated, ramified, highly condensed, waxless, erect, and tendrilar) were also reported earlier in lentil (Sharma and Sharma 1977, 1978, 1979, 1980; Dixit and Dubey 1982). The present study, therefore, extended the spectrum of mutants. The marker stocks made available through such studies will help in genetic studies on linkage maps, which have never been attempted in lentil. To mark the mutant genes, standard gene symbols were allotted for the mutations: stunted, dwarf, bushy dwarf, open flower, partial sterile, complete sterile, and large-leaved were given the symbols st, dw, bsy, opf, pst, st, and ll, respectively.

Table 3. Different quantitative characters of viable morphological mutants in variety PL 639 of lentil.

Character	Stunted	Dwarf	Bushy dwarf	Open flower	Partial sterile	Complete sterile	Larger leaves	Control
Germination after 10 days of sowing (%)	66 ± 6.99† 60–80	71 ± 5.15 60–85	—	—	60 ± 3.25 50–70	—	68 ± 4.5 43–58	81 ± 2.2 78–84
Plant height (cm)	11.5 ± 1.5 8–13	15.6 ± 1.6 14–18	13.5 ± 1.4 12.5–15.0	54.3 ± 1.8 52–56	65 ± 2.4 62–70	52.6 ± 2.0 45–55	39 ± 2.0 30.5–46.0	31.5 ± 2.89 29–34.5
Flower bearing zone (cm)	8.2 ± 4.2 6.5–9.1	11.8 ± 1.1 10–15.5	—	32.4 ± 1.6 26.5–40.6	40.8 ± 1.8 38.4–46.0	36.5 ± 1.6 28.5–40.0	26.8 ± 1.6 20.7–31.0	21.4 ± 1.67 18.0–22.8
Branches–plant	6 ± 0.80 5–7	9 ± 0.87 8–10	1–2	10 ± 1.10 8–14	9 ± 0.82 8–13	9 ± 0.88 7–12	6.2 ± 0.6 5–7	7.5 ± 1.87 5–9
Internode length (cm)	0.54 ± 0.12 0.40–0.70	0.80 ± 0.14 0.70–1.10	0.75 ± 0.15 0.70–0.90	1.9 ± 0.15 1.6–3.0	2.6 ± 0.14 2.2–3.1	2.5 ± 0.14 2.2–3.2	2.6 ± 0.15 2.0–2.9	2.4 ± 0.15 2.1–2.6
50% flowering (days after sowing)	112 ± 1.20 1.9–115	109 ± 1.4 106–110	—	112 ± 1.6 110–115	118 ± 1.69 115–119	120.7 ± 1.72 118–123	115 ± 1.72 110–118	112 ± 1.8 109–114
Maturity (days)	140 ± 1.90 138–143	138 ± 1.9 132–140	—	—	154 ± 2.71	—	142 ± 2.10 138–145	142 ± 2.3 138–144
Pods–bunch (range only)	1–2	1–2	—	—	1	—	1–3	1–3
Biological yield per plant (g)	2.28 ± 0.80 2.0–3.0	3.15 ± 0.92 2.2–3.8	10.5 ± 1.3 8.5–12.0	—	6.40 ± 2.4 3.5–10.0	—	15.11 ± 3.4 11.4–18.5	12.5 ± 3.22 10–14.5
Grain yield per plant (g)	6.90 ± 0.12 1.50–1.2	1.2 ± 0.13 1.1–1.4	—	—	0.8 ± 0.13 0.50–0.95	—	2.4 ± 0.11 1.9–2.6	12.5 ± 3.22 10.0–14.5
Harvest index	39.4 ± 2.6 37.20–44.0	38 ± 2.3 36.8–41.7	—	—	12.5 ± 1.1 10.5–14.2	—	15.5 ± 1.2 12.3–17.1	40.85 ± 4.4 38.0–42.5

† First row indicates mean ± S. D.; second row indicates range.

Theoretically, each gene which is of any agronomic interest can mutate. Therefore, a wide spectrum of mutants can be expected in mutation experiments which have to be tested with regard to their usefulness for specific aims of breeding. It is, however, not yet possible in higher plants to induce specific mutations in distinct loci; the mutational event is still a matter of chance, except while using the recent recombinant DNA techniques used for targeted mutagenesis through transformation.

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إحداث طفرات كبيرة في العدس

الملخص

عوملت بذور عدس جافة من الصنف PL 639 بأشعة غاما وبكبريتات إيثيل الميثان، وغُربلت نباتات من الجيلين الطافرين ط2 و ط3 لمعرفة طيف، وتكرار الطفرات الكبيرة. وقد وجد أن الطيف الطفري للمعاملة بالكبريتات أكبر منه في المعاملة بالأشعة. وأوحت النماذج الانعزالية في جميع الطرز الطافرة بتحكّم لمورّث أحادي متنح.

Genetic Analysis of Yield and Its Contributing Characters in Lentil

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Abstract

An F_1 generation half-diallel cross of five parents—Jhansi local, K-75, Precoz selection, Sehore-74-3, and Lens-4076—was planted in randomized complete block design with four replications. Both D (variance due to additive effects of genes) and H_1 (variance due to dominance effects of genes) components were significant for time to flowering, plant height, and time to maturity (d). This suggested that both additive and dominance gene effects were important for these traits. But the magnitude of D was greater than H_1. This indicates that both components of variance were important, but variance due to additive effects of genes was more pronounced for the expression of these traits. The component H_1 was significant and was greater than D in magnitude for number of primary and secondary branches/plant, number of pods/plant, number of seeds/plant, number of seeds/pod, biological yield, seed yield, 100-seed weight, and harvest index. This indicated that dominance gene action was predominant in the expression of these traits.

The degree of dominance ranged from partial dominance [for days to flowering, plant height, and time

to maturity (d)] to overdominance (for number of primary branches/plant and number of seeds/pod). Symmetrical distribution of positive and negative effects of genes was observed for number of primary and secondary branches/plant, number of pods/plant, number of seeds/plant, seed yield, and 100-seed weight. Positive and negative effects of genes in the parents for days to flowering, plant height, time to maturity (d), number of seeds/pod, biological yield, and harvest index were distributed asymmetrically. Dominant genes outnumbered the recessive genes in the parents for days to flowering, number of primary branches/plant, plant height, time to maturity (d), number of seeds/pod, and harvest index. There were more recessive genes than dominant ones in the parents with respect to number of secondary branches/plant, number of pods/plant, number of seeds/plant, biological yield, seed yield, and 100-seed weight.

Introduction

Yield and its contributing traits are important to plant breeders for crop improvement. The genetic analysis of these traits is difficult because these are usually dominated by quantitative genes (polygenes) or many genes each with small effect. The situation is further compounded by the fact that phenotypic expression is influenced by environmental factors. A diallel cross analysis was used to study the probable gene action involved in the inheritance of yield and its contributing traits in lentil.

Materials and Methods

Five elite lentil varieties—Jhansi local, K-75, Precoz selection, Sehore-74-3, and Lens-4076—with diverse genetic backgrounds, were used as parents and were crossed in all combinations excluding reciprocals, during the 1984/85 winter season. Ten F_1 plants and their five parents were planted in randomized complete block design with four replications during the 1985/86 winter season in single-row plots of 3 m long and 40 cm apart; 100 kg/ha diammonium phosphate, containing 18 N, 46 P_2O_5 were used as a basal fertilizer before sowing. Plant protection measures and irrigation were given as needed.

Five competitive plants per row were selected at random from each replication to record observations on days to flowering, number of primary and secondary branches/plant, plant height, time to maturity (d), number of pods/plant, number of seeds/plant, number of seeds/pod, biological yield, seed yield, 100-seed weight, and harvest index. The data were processed statistically as per procedure outlined by Hayman (1954a, 1954b, 1957) for diallel analysis.

Results and discussion

The genetic components along their respective standard error and other genetic parameters are presented in Table 1.

H_1 (variance due to dominance effects of genes) was positive and significant for all the traits studies. The magnitude of D (variance due to additive effects of genes) was greater than H_1 and was positive and significant for days to flowering, plant height, and time to maturity (d). This indicated that both additive and nonadditive gene actions were important, but additive gene action was more pronounced for the inheritance of these traits. Malhotra et al. (1973) and Sakar and Muehlbauer (1982) also reported the predominance of additive gene action for days to flowering and plant height. Haddad et al. (1982) reported high additive × additive genetic variance in their studies on time to maturity (d).

The magnitude of H_1 was higher than D, positive and significant for number of primary and secondary branches/plant, number of pods/plant, number of seeds/plant, number of seeds/pod, biological yield, seed yield, 100-seed weight, and harvest index; suggesting that the dominance gene action (nonadditive gene action) was predominant for the inheritance of these characters.

The number of primary and secondary branches/plant were reported to be controlled by both additive and nonadditive gene action; the latter was more prominent (Singh et al. 1975). Malhotra et al. (1973) reported the predominance of additive genetic variance for the inheritance of secondary branches.

With regard to seed yield, the results partially confirm the finding of Singh et al. (1975), who observed the importance of nonadditive gene action for this trait. However, Malhotra et al. (1973) also observed additive gene action for this trait.

For number of pods/plant, Malhotra et al. (1973) and Singh et al. (1975) observed the importance of the additive gene action, which is not confirmed by the findings of the present investigation. But nonadditive gene action was also reported for this trait (Singh et al. 1975).

The value of t^2 was nonsignificant for all the traits studied, indicating the fulfillment of assumptions laid down by Hayman (1954a, 1954b, 1957), i.e., homozygous parents, no reciprocal differences, absence of maternal effects, and no linkage. The value of regression coefficient

Table 1. Estimates of genetic components and other genetic parameters for different characters in lentil.

Component	Character											
	Days to flowering	Number of primary branches/ plant	Number of secondary branches/ plant	Plant height	Time to maturity (d)	Number of pods/plant	Number of seeds/plant	Number of seeds/pod	Biological yield	Seed yield	100-seed weight	Harvest index
D	51.22** (1.97)†	0.04 (0.03)	−0.93 (1.56)	10.42** (0.28)	20.31 (1.25)	−46.85 (79.22)	−48.19 (82.65)	0.00 (0.00)	−0.47 (1.44)	−0.07 (0.08)	−0.04* (0.02)	−3.21 (8.98)
H_1	20.61** (5.33)	0.68** (0.09)	42.57** (4.20)	3.19** (0.77)	10.94** (3.38)	1136.00** (213.93)	1186.00** (223.21)	0.03** (0.00)	7.70* (3.90)	1.42** (0.22)	0.38** (0.05)	130.80** (24.23)
H_2	16.92** (4.84)	0.66** (0.08)	43.05** (3.81)	3.46** (0.69)	7.75* (3.06)	1131.00** (194.04)	1185.00** (202.45)	0.03** (0.00)	7.42* (3.54)	1.44** (0.20)	0.37** (0.04)	123.00** (21.98)
F	9.20 (4.93)	0.01 (0.08)	−1.91 (3.88)	2.95** (0.70)	11.67** (3.12)	−68.78 (197.88)	−68.61 (206.46)	0.00 (0.00)	−0.79 (3.61)	−0.11 (0.20)	−0.03 (0.04)	3.96 (22.41)
H^2	−0.02 (3.27)	1.49** (0.05)	132.42** (2.57)	12.73** (0.47)	3.66 (2.07)	2951.65 (131.01)	3090.69** (136.69)	0.10** (0.00)	13.01** (2.39)	3.62** (0.14)	1.03** (0.03)	338.56** (14.84)
E	0.29 (0.81)	0.05** (0.01)	1.61* (0.64)	1.64** (0.12)	0.08 (0.51)	51.57 (32.34)	52.61 (33.74)	0.00 (0.00)	0.49 (0.59)	0.09** (0.03)	0.06** (0.01)	7.62* (3.66)
$(H_1/D)^{0.5}$	0.63	4.21	—	0.55	0.73	—	—	4.35	—	—	—	—
$(H_2/4H_1$	0.20	0.24	0.25	0.27	0.18	0.25	0.25	0.24	0.24	0.25	0.25	0.23
K_D/K_r	1.33	1.09	0.74	1.69	2.29	0.74	0.75	0.30	0.65	0.71	0.77	1.21
t^2	0.70	0.72	0.62	2.49	0.01	6.99	6.58	2.25	3.34	1.82	3.85	7.00
b	1.99	0.66	0.69	0.93	0.95	0.87	0.88	0.85	0.69	0.71	0.64	0.61
S.E. (b)±	0.17	0.23	0.33	0.04	0.21	0.36	0.37	0.39	0.43	0.11	0.20	0.16

* P = 0.01
** P = 0.05
† Figures in parentheses are standard errors for components.

was significantly different from zero, but nonsignificantly different from unity, suggesting the absence of epistatic gene action for all the characters studied.

Partial dominance was observed for days to flowering, plant height, and time to maturity (d). For number of primary branches/plant and number of seeds/pod, overdominance was observed as the value of $(H_1/D)^{0.5}$ ratio was more than one for these characters.

The ratio $H_2/4H_1$ suggests the distribution of positive and negative genes in the parents. There was symmetrical distribution of positive and negative genes in the parents as the value of $H_2/4H_1$ ratio was very close to 0.25 for number of primary and secondary branches/plant, number of pods/plant, number of seeds/plant, seed yield, and 100-seed weight. With regard to days to flowering, plant height, time to maturity (d), number of seeds/pod, biological yield, and harvest index, the value of $H_2/4H_1$ ratio was not close to 0.25, indicating asymmetrical distribution of positive and negative genes in the parents.

The proportion of dominant and recessive genes in the parents was suggested by the ratio $(4DH_1)^{0.5} + F/(4DH_1)^{0.5}-F$, or KD/KR. This ratio was greater than one for days to flowering, number of primary branches/plant, plant height, time to maturity (d), number of seeds/pod, and harvest index, indicating that there were more dominant genes than recessive ones in the parents for the expression of these traits. The value of this ratio was less than one for number of secondary branches/plant, number of pods/plant, numbers of seeds/plant, biological yield, seed yield, and 100-seed weight. This suggested the existence of more recessive genes than dominant ones in the parents for the expression of these traits.

The traits days to flowering, plant height, and time to maturity (d), where additive gene action was predominant, can be improved by any conventional breeding method such as simple selection. But other traits, such as number of primary and secondary branches/plant, number of pods/plant, number of seeds/plant, number of seeds/pod, biological yield, seed yield, 100-seed weight, and harvest index, where dominance gene action was important, may be improved by heterosis breeding. Since the production of hybrids on a commercial scale is very difficult in self-pollinated crops like lentil in the absence of cytoplasmic genetic male sterility, nonadditive variance can be exploited by recurrent selection and/or biparental mating followed by progeny selection.

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تحليل وراثي لغلة العدس والخصائص التي تسهم فيها

الملخص

زُرع هجين من الجيل الأول ثنائي الأليل غير كامل لخمسة آباء – Jhansi local, K-75, Precoz selection, Seshore-74-3, Lens-4076 – بتصميم القطاعات العشوائية الكاملة بأربعة مكررات. وأظهر كل من المكوّنين D (التباين العائد للتأثيرات التجميعية للمورثات) و H1 (التباين العائد لتأثيرات سيادة المورثات) تأثيرا معنويا بالنسبة لموعد الإزهار، وطول النبات، وزمن النضج (d)، مما أوحى بأن كلا من التأثيرات التجميعية وتأثيرات سيادة المورثات مهم بالنسبة لهاتيك الخصائص، لكن مقدار D كان أكبر من H1. وهذا يشير إلى أهمية كل من التباينين، إلا أن الأول منهما العائد إلى التأثيرات التجميعية للمورثات كان أكبر أثرا في التعبير عن تلك الخصائص. في حين كان المكوّن H1 ذا قيمة معنوية وأكبر من D بالمقدار فيما يتعلق بعدد الفروع الرئيسية والفرعية/النبات، وعدد القرون/النبات، وعدد البذور/النبات، وعدد البذور/القرن، والغلة الحيوية، والغلة البذرية، ووزن المئة حبة، ودليل الحصاد. وهذا يدل على أن التأثير السائد للمورثات هو الغالب في التعبير عن هذه الخصائص.

تباينت درجة السيادة ما بين الجزئية [بالنسبة لعدد الأيام حتى الإزهار، وطول النبات، وزمن النضج (d)] والسيادة الكاملة (بالنسبة لعدد الفروع

لاتناظريا. وفي الأبوين تفوقت عدديا المورثات السائدة على المتنحية بالنسبة لعدد الأيام حتى الإزهار، وعدد الفروع الرئيسية على النبات، وطول النبات، وزمن النضج (d)، وعدد البذور/القرن، ودليل الحصاد. وفيما يخص عدد الفروع الثانوية/النبات وعدد القرون/النبات، وعدد البذور/النبات، والغلة الحيوية، والغلة البذرية، ووزن المئة حبة فقد كانت المورثات المتنحية أكثر من تلك السائدة في الأبوين.

Multiple Correlation and Regression Analysis in Lentil

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Abstract

Multiple correlation and regression studies in six varieties of lentil (*Lens culinaris* Medik.) indicated that a combination of two or three variables, viz. height/plant, branches/plant, and pods/plant, was found better than other combinations of the characters for the improvement of seed yield.

Introduction

Multiple correlation and regression are techniques to explain the percentage variation in the dependent variables with the help of characters involved. A suitable character combination that affects yield to the maximum extent is important in formulating an effective selection program. This study was conducted to examine the best character combination in lentil (*Lens culinaris*) through the techniques of multiple correlation and regression.

Materials and Methods

Six varieties of lentil (*Lens culinaris*), representing a broad spectrum of variability from Indian lentils above the seed weight of 3 g/100 seeds (Table 1), were tested in the field at J. N. K. V. V., Regional Agricultural Research Station, Sagar, for three seasons (1987–88, 1988–89, and 1989–90) following a randomized block design with three replications. The climatic conditions were less favorable during 1988–89 as compared to 1987–88 and 1989–90.

Table 1. Origin of the tested Indian lines.

Varieties	Origin	State
K 75	Kanpur	U.P.
L 4126	Ludhiana	Punjab
Damoh local	Damoh	M.P.
L 4125	Ludhiana	Punjab
JL-1	Jabalpur	M.P.
Sehore 74-3	Sehore	M.P.

Five competitive plants in each plot were taken for necessary observations at 50% flowering (X_1); maturity in days (X_2); plant height (X_3); no. of branches/plant (X_4); no. of pods/plant (X_5); pod weight (X_6); no. of seeds/plant (X_7); seed wt./plant (X_8); seed index (X_9); and yield (Y). Multiple correlation and regression analysis was done according to the method suggested by Panse and Sukhatme (1967).

Results and Discussion

The analysis of variance (Table 2) revealed that some of the multiple regressions in one of the three seasons with different combinations of variables were found to be significant except the variables branches/plant and pods/plant. Some of the regression coefficients were also found to be significant at the 5% and 1% levels.

The value of R^2 (coefficient of determination) for two or three combinations of variables indicated that in each combination the relative contribution varied over the seasons (Table 2). The relative contribution during 1988–89 with all the characters considered above was found to be less than 15% due to some drastic changes in weather conditions. It might be due to some other reasons also. The contribution of variables height/plant, branches/plant, and pods/plant was superior to others

Table 2. Analysis of variance for multiple regression in lentil.

Characters involved	Source		D. F.	M. S. S.	R^2
Y with X_1, X_2, X_3	1987–88	Regression	3	0.1929**	0.9144
		error	2	0.0271	
	1988–89	Regression	3	0.0111	0.1013
		error	2	0.1483	
	1989–90	Regression	3	0.3522	0.7409
		error	2	0.1847	
Y with X_3, X_7, X_9	1987–88	Regression	3	0.1779*	0.8431
		error	2	0.0499	
	1988–89	Regression	3	0.0033	0.0304
		error	2	0.1600	
	1989–90	Regression	3	0.4207**	0.8851
		error	2	0.0820	
Y with X_6, X_8, X_9	1987–88	Regression	3	0.1906**	0.9032
		error	2	0.0307	
	1988–89	Regression	3	0.0100	0.0913
		error	2	0.1499	
	1989–90	Regression	3	0.2262	0.4759
		error	2	0.3738	
Y with X_3, X_4, X_5	1987–88	Regression	3	0.1973**	0.9350
		error	2	0.0206	
	1988–89	Regression	3	0.0055	0.0500
		error	2	0.1568	
	1989–90	Regression	3	0.4820**	0.9900
		error	2	0.0099	
Y with X_3, X_6	1987–88	Regression	3	0.2726**	0.8613
		error	2	0.0293	
	1988–89	Regression	3	0.0016	0.0093
		error	2	0.1090	
	1989–90	Regression	3	0.3856	0.5408
		error	2	0.2183	
Y with X_6, X_7	1987–88	Regression	3	0.2673	0.8447
		error	2	0.0328	
	1988–89	Regression	3	0.0238	0.1440
		error	2	0.0942	
	1989–90	Regression	3	0.3526	0.4946
		error	2	0.2403	
Y with X_8, X_9	1987–88	Regression	3	0.2461**	0.7776
		error	2	0.0469	
	1988–89	Regression	3	0.0142	0.0856
		error	2	0.1006	
	1989–90	Regression	3	0.3504	0.4914
		error	2	0.2417	
Y with X_4, X_5	1987–88	Regression	3	0.0006	0.0019
		error	2	0.2106	
	1988–89	Regression	3	0.0072	0.0433
		error	2	0.1052	
	1989–90	Regression	3	0.3280	0.4600
		error	2	0.2566	

* P = 0.05 ** P = 0.01 X_1 = 50% flowering in days X_2 = Maturity in days X_3 = Height in cm X_4 = Branches/plant X_5 = pods/plant X_6 = pod wt/plant X_7 = seeds/plant X_8 = seed wt./plant X_9 = Seed index Y = yield

and its relative contribution was 0.9350 and 0.9700 during 1987–88 and 1989–90, respectively; followed by 0.9144 and 0.7409, respectively, in the same year by the variables days for 50% flowering, days for maturity, and height/plant. The results were also shown taking two combination variables. For example, height/plant and pod weight explained the percentage variations in seed yield as 0.8613 and 0.5408, respectively, during 1987–88 and 1989–90 followed by the variables pod wt. and no. of seeds/plant, increasing the value of R^2 from 50% to 85% in the same season.

Similar types of combinations of two or three variables or even more variables might have been combined and the different percentage of variations in seed yield might have been explained. In fact, in a selection program, a combination of two to three characters at a time will be equally important. Among the different character combinations, the characters contributed 50% to 97% variation in the total seed yield depending upon two different seasons 1987–88 and 1989–90 as 1988–89 seasons might be called an unfavorable season. The findings of this study are almost consistent with the results obtained by several authors (Chouhan and Sinha 1982; Dixit 1974; Muehlbauer 1974; Pandey et al. 1980; Prem Sagar and S. Lal 1980; Singh and Dixit 1970; Singh 1982; Singh and Singh 1969; Singh et al. 1970; Singh 1977; Tikka and Asawa 1981; Tikka et al. 1973; Tosum and Eser 1979).

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تحليل الارتباط والانحدار المتعدد في العدس

الملخص

أشارت دراسات على الارتباط والانحدار المتعدد في ستة أصناف من العدس (*Lens culinaris* Medik) إلى أن تركيبا أو توليفا من متغيرين إلى ثلاثة – أي طول النبات، وعدد الفروع/النبات، وعدد القرون/النبات – هو أفضل من أي تراكيب أخرى من الخصائص بالنسبة لتحسين الغلة البذرية.

Agronomy and Mechanization

Response of Phosphorus and Rhizobium Culture on Grain Yield of Lentil

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Abstract

Response of phosphorus application (0, 20, 40, and 60 kg P_2O_5/ha) and *Rhizobium* culture to lentil variety L9-12 was studied during 1986–87 at three locations in Gurdaspur district, Punjab, India. The grain yield of lentil increased significantly at all levels of P application over control, irrespective of *Rhizobium* inoculation. The response of P application over control decreased with increasing content of soil P. There was a consistent increase in grain yield with the use of *Rhizobium* culture at all levels of P applied. The maximum mean yield of 1562 kg grain/ha was recorded with 60 kg P_2O_5/ha treatment on lentil inoculated with *Rhizobium*, which produced 13 kg grain yield/kg P applied with a return of 13 rupees (Rs) invested in fertilizer.

Introduction

Lentil (*Lens culinaris* cv. L9-12) is one of the three oldest of the grain legumes and is thought to have originated in Asia Minor. It is now successfully grown in the northern part of the Indian subcontinent, the Mediterranean basin, and several countries of North America. It is an easily digestible food legume rich in protein (30%). Lentil is mainly used in the form of *dhal* (a national dish), and the whole seed is often eaten (fried and salted) in some parts of India. It can be grown on a wide range of soil types. In India it is mostly grown on unirrigated, marginal land with conserved soil moisture, or on the flood-affected alluvial soil. The mean grain yield in India is very low as compared to other countries.

Agronomic practices greatly affect the yield potential of lentil. There is significant response to applied phosphorus which is the most useful nutrient for improving nodulation, nitrogenase activity, and grain yield. Lentil yielding 2000 kg/ha seed removes 100 kg N, 28 kg P_2O_5, and 78 kg K_2O/ha from the soil. Therefore, an adequate supply of plant nutrients has to be maintained by careful and judicious use of fertilizers, particularly on soils of poor fertility, to boost the yield of lentil. The present investigation was thus undertaken to study the effect of phosphorus and *Rhizobium* application on grain yield of lentil in soils varying in their phosphorus supplying capacity.

Materials and Methods

Field experiments were carried out at three different locations designated as L_1, L_2, and L_3 in Gurdaspur district, Punjab, India. Composite soil samples were collected at five to seven spots from each field, air-dried, processed, and analyzed for various soil characteristics. Electrical conductivity was measured in 1:2.5 soil-water extract. The organic carbon and available phosphorus were determined by the methods of Piper (1960), and potassium in accordance with Olsen et al. (1954). The soil reaction was normal (Table 1) with pH value varying from 7.5 to 8.5 having a mean value of 8.1 (± 0.3); electrical conductivity ranged from 0.21 to 0.35 millimhos/cm with an average of 0.29 mmhos/cm (± 0.04); and organic carbon varied from 0.18% to 0.34% with a mean of 0.28% (± 0.05). Nutrient status of these sites showed the available potassium from 165 to 188 kg K_2O/ha with an

Table 1. Physical-chemical characteristics of the experimental locations.

Locations	pH (1:2.5) Soil-water Extract	Electrical conductivity (millimhos/cm)	Organic carbon (%)	Available nutrients (kg/ha)		Texture
				P_2O_5	K_2O_5	
L_1	7.5	0.35	0.31	10	180	Loam
L_2	8.2	0.21	0.18	14	165	Loam
L_3	8.1	0.30	0.34	20	188	Loam
Mean	8.1	0.29	0.28	14.7	177.7	Loam
S.E	(± 0.3)	(± 0.04)	(± 0.05)	(± 2.9)	(± 6.7)	—

average of 177.7 kg/ha (± 6.7), whereas the available phosphorus varied from 10 to 20 kg P_2O_5/ha with a mean of 14.7 kg/ha (± 2.9). The soils of these locations were generally loamy in texture and normal in reaction, low in organic carbon, medium in available potassium, and low to medium in available phosphorus.

Eight treatments (consisting of four levels of phosphorus at rates of 0, 20, 40, and 60 kg P_2O_5/ha, each applied once with and without *Rhizobium* culture treated lentil seed) were tested in a randomized block design with three replications and a plot size of 10 × 5 m. Phosphorus was applied through single super phosphate. A basal dose of 12.5 kg N/ha through single urea was applied along with phosphorus before sowing the crop. The seed was treated with *Rhizobium* culture. The lentil variety, L9-12, was sown at rate of 37 kg seed/ha. All other recommended agronomic practices were adopted. The data on grain yield were recorded at maturity and analyzed statistically.

Results and Discussion

The grain yield of lentil as affected by the application of *Rhizobium* culture at different levels of phosphorus is presented in Table 2. Higher yields and significant responses over control were recorded at all rates of phosphorus irrespective of the *Rhizobium* culture used. At 20 kg P_2O_5/ha applied to lentil not treated with *Rhizobium*, the mean response of grain yield ranged from 115 to 220 kg/ha with a mean of 182 kg/ha; at 40 kg P_2O_5/ha, the response varied from 245 to 500 kg/ha with an average of 385 kg/ha. However, at 60 kg P_2O_5/ha, the response ranged from 385 to 730 kg/ha with a mean of 585 kg/ha. By increasing the dose of phosphorus from 0 to 20, 20 to 40, and 40 to 60 kg P_2O_5/ha, the corresponding mean responses recorded were 182, 203, and 200 kg/ha.

Table 2. Effect of phosphorus and *Rhizobium* culture on the mean grain yield of lentil (kg/ha).

Treatment		Locations			
Rhizobium culture	P_2O_5 (kg/ha)	L_1	L_2	L_3	Mean
Without	00	850	680	890	806
Without	20	4350	1090	1135	1191
Without	40	1350	1090	1135	1191
Without	60	1580	1320	1275	1391
With	00	1220	850	1115	1061
With	20	1300	1040	1240	1193
With	40	1590	1280	1385	1418
With	60	1720	1500	1468	1562
C.D. at 5%		96	35	103	
C.D. at 1%		95	48	144	

Rhizobium inoculation significantly increased mean grain yield over the uninoculated control at all levels of phosphorus application. The response at 0 kg P_2O_5/ha ranged from 170 to 370 kg grains/ha with an average of 255 kg/ha. At 20 kg P_2O_5/ha, the response varied from 350 to 450 kg/ha with a mean of 387 kg/ha. At 40 and 60 kg P_2O_5/ha, the responses ranged from 490 to 740 kg/ha, and from 578 to 870 kg/ha, respectively, with the corresponding mean responses of 610 and 756 kg grain/ha which were significantly greater than all other levels of phosphorus.

Levels of phosphate were regressed against grain yield of lentil (Figure 1) and the regression equations were found to be linear [× = levels of P_2O_5 (kg/ha)]:

Y_{L1A} = 838.0 + 12.40 × for location L_1 without inoculation

Y_{L1B} = 1189.0 + 8.95 × for location L_1 with inoculation

Y_{L2A} = 681.0 + 10.55 × for location L_2 without inoculation

Y_{L2B} = 839.0 + 10.95 × for location L_2 with inoculation

Y_{L3A} = 865.5 + 6.93 × for location L_3 without inoculation

Y_{L3B} = 1124.0 + 5.92 × for location L_3 with inoculation

These regression equations indicate a direct relationship between grain yield and levels of phosphorus. It is, therefore, evident that for every increase in the level of phosphate, there is a corresponding increase in the grain yield of lentil. The equations further elaborate a yield potential of 838, 681, and 866 kg grain/ha at locations L_1, L_2, and L_3, respectively, without *Rhizobium* inoculation, whereas the corresponding yields of 1189, 839, and 1124 kg grain/ha will be recorded with the application of *Rhizobium* to the seed.

Examination of the regression coefficients of response to phosphorus application in the three locations shows that at a high basal soil phosphorus level (L_3 Soil P_2O_5 = 20 kg/ha) the response was less than at lower basal soil

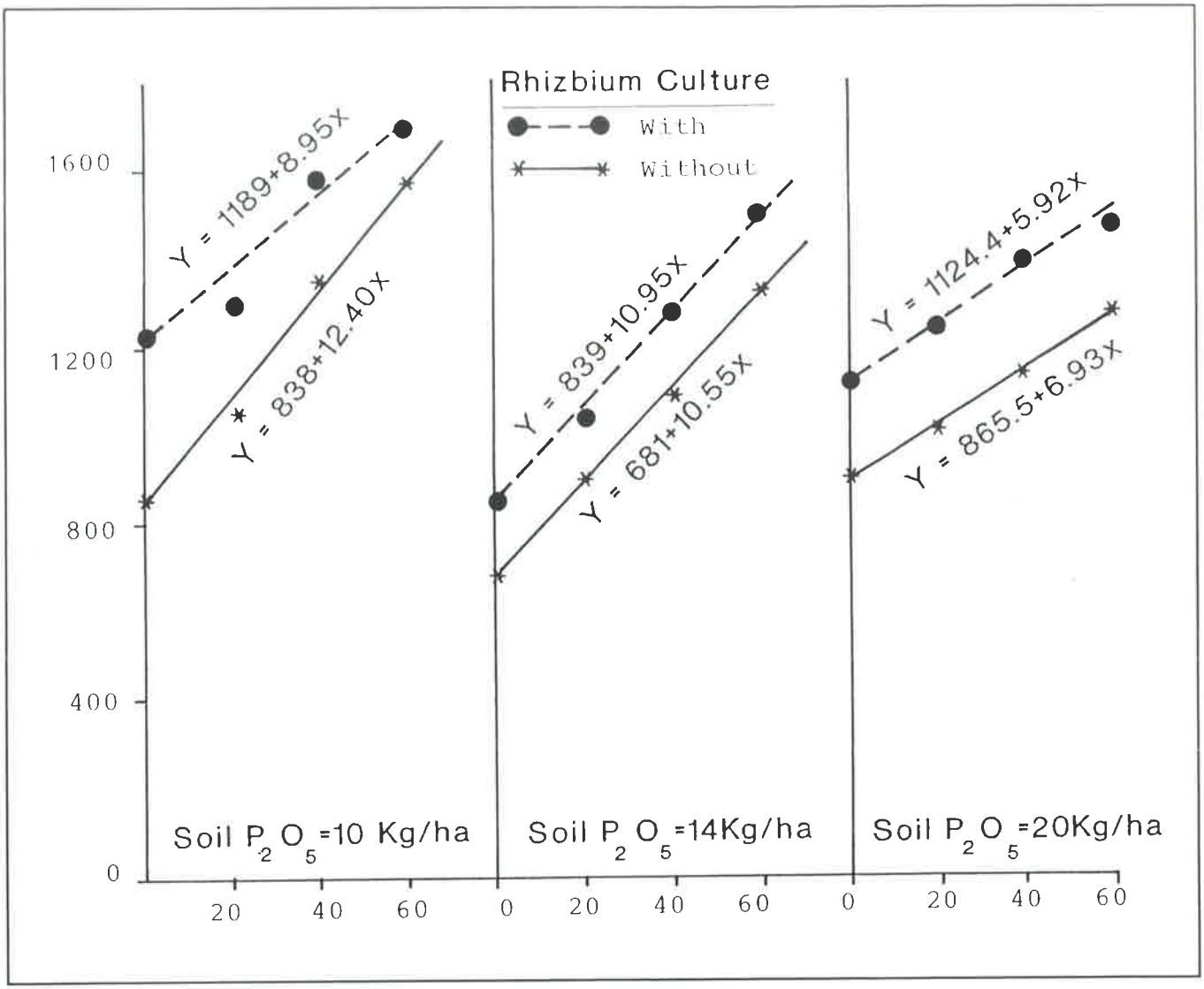

Figure 1. Grain yield of lentil as influenced by the application of phosphorus, *Rhizobium* inoculation, and soil P status.

P levels. Therefore, greater responses of P application with and without *Rhizobium* will be expected in soils of low P content because of these soils' poor supplying capacity of phosphorus.

The pooled data of the three locations (Table 3), indicating the effect of phosphorus and *Rhizobium* culture on the mean grain yield of lentil and economics of its application, reveal that the use of *Rhizobium* culture and application of 60 kg P_2O_5/ha to lentil crop yielded a maximum of 1562 kg grains/ha, which was 94% higher than the control and 47% more than the treatment with only *Rhizobium* inoculation. Additionally, this combined treatment produced 13 kg grain/kg P applied, thereby returning a sum of Rs 4529/ha net return over control and Rs 13/rupee invested in the fertilizer. The cost-benefit ratio of 1:166 was high in the treatment of *Rhizobium* inoculation alone because of the low cost of nutrients applied, but its overall mean yield recorded was the lowest as compared to other treatments with applied phosphorus.

Application of 20, 40, 60 kg P_2O_5/ha with and without *Rhizobium* culture applied to lentil seed resulted in net returns of Rs 1647, 2380, 3718, and Rs 1058, 2278, 3427/ha, respectively. The levels of phosphorus were regressed against net return over control, which were found to be correlated linearly as follows:

$$Y = 34.4 + 57.5 \times \text{ without inoculation}$$
$$Y = 1571.5 + 49.9 \times \text{ with inoculation}$$

Where: Y = net return over control (Rs)
× = level of phosphorus (kg/ha)

Table 3. Effect of different levels of phosphorus and rhizobium culture on mean grain yield of lentil (kg/ha) and economics of its application (pooled data of three locations).

Treatments		Average grain yield	Response over control	Cost of applied treatment (Rs)	Net return over control (Rs)	Cost: benefit ratio	Kg grain /ha/kg P applied
Rhizobium	P_2O_5 (kg/ha)						
Without	00	806	—	—	—	—	—
Without	20	988	182	125	1058	1:9	9.1
Without	40	1191	385	250	2278	1:10	9.6
Without	60	1391	585	375	3427	1:10	9.8
With	00	1061	255	10	1647	1:166	—
With	20	1193	387	135	2380	1:19	19.4
With	40	1418	610	260	3718	1:15	15.3
With	60	1562	756	385	4529	1:13	12.6
C.D. at 5%		127					
C.D. at 1%		176					

which shows a net profit of Rs 57.5 without *Rhizobium* inoculation and 49.9 per kg of phosphorus with *Rhizobium* inoculation.

The effect of phosphorus application on the mean grain yield of lentil has been depicted in Figure 2. At any level of phosphorus applied to lentil crop without *Rhizobium* inoculation, there was an increase. The use of *Rhizobium* inoculation increased grain production by 171–255 kg/ha. This is in accordance with the findings of Loizides (1970) who reported, in soils of low available phosphorus, an average response of 35 kg/ha of lentil at 40 kg P_2O_5/ha. Significant mean yields have been reported with the application of phosphate in soils with available phosphorus status of soil at 6.5 kg P_2O_5/ha (Azad and Gill 1989). Soils of many lentil growing areas are characterized by low available phosphorus content (Chowdhary et al. 1974; Sharma 1970).

Recent studies in lentil by Dhingra et al. (1988) showed that the combination of *Rhizobium* and 20 kg P_2O_5/ha gave yield equivalent to that from application of 40 kg P_2O_5/ha without Rhizobium. The possible reason for increased efficiency of phosphorus with Rhizobium inoculation may be that it influences the growth of mycorrhizal fungi known to be associated with legumes. Bergerson (1971) reported that nitrogen fixation efficiency of root nodules increased as a result of phosphorus nutrition because the P requirement of *Rhizobium* bacteria is quite high. It is commonly accepted that soil microorganisms can stimulate the mycelial growth of mycorrhizal fungi which may increase the availability of phosphorus (Bieleski 1973).

Linear increase in grain yield of lentil up to 40 kg P_2O_5/ha has been reported by Azad and Gill (1989), who further recorded a net return of Rs 2376/ha which is in close conformity with the present study reporting a net return of Rs 2278/ha over control.

The study concludes a decreasing trend in the response of P application at all levels with the increasing level of soil phosphorus level. Maximum response was obtained with an application of 60 kg P_2O_5/ha to lentil crop treated with *Rhizobium* culture, which produced a maximum net return of Rs 4529/ha over control. This study, therefore, suggests that phosphorus application to lentil should be on the basis of soil test values of phosphorus, in addition to using the *Rhizobium* culture with seed. As fertilizer response to the plants depends on the availability of soil nutrients, this combination will contribute to obtaining maximum grain yield and higher returns from the crops (Ali et al. 1981; Singh and Marok 1981).

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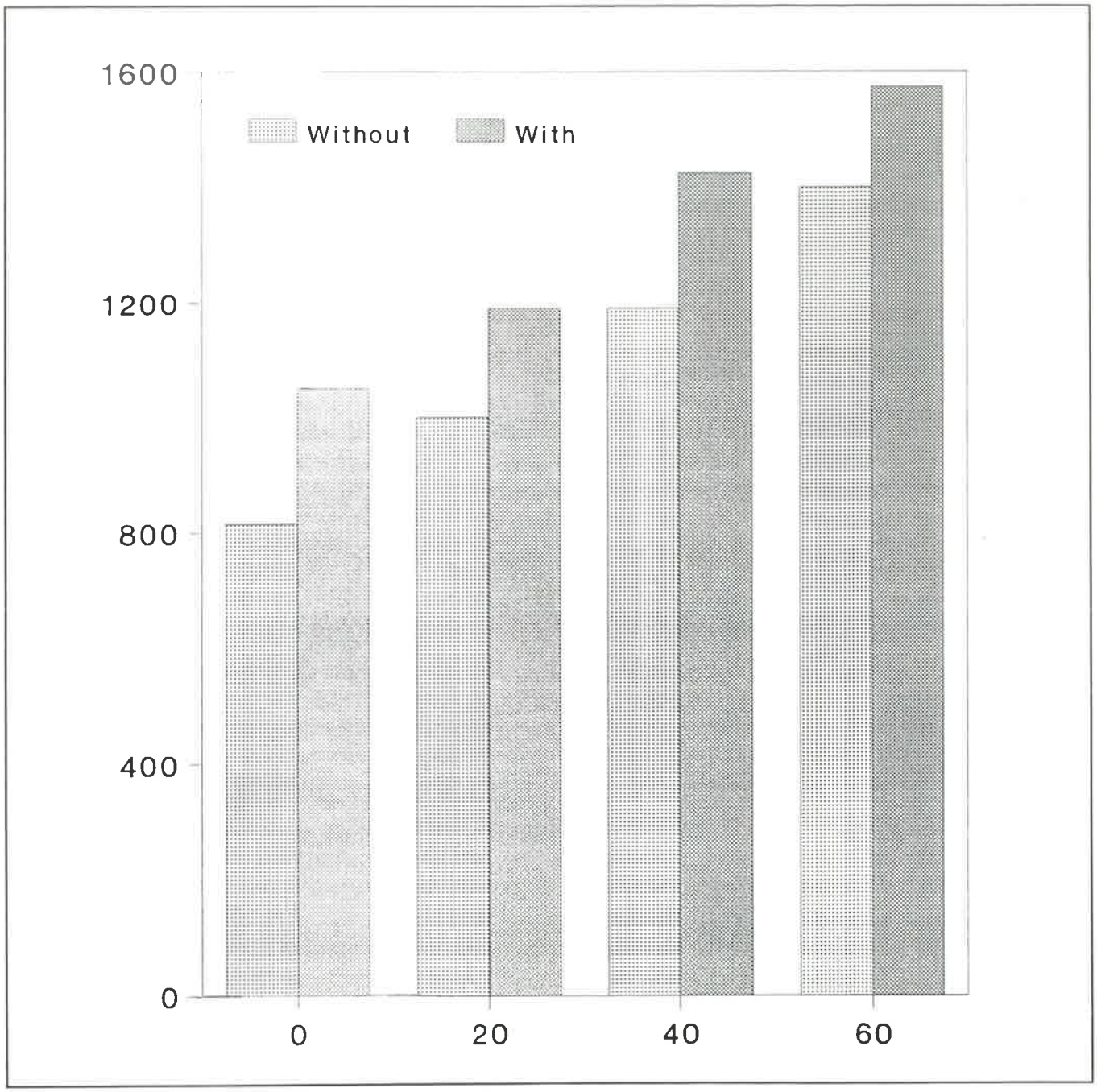

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استجابة غلة العدس الحبية للفوسفور والتلقيح بالريزوبيا

الملخص

ضمن ثلاثة مواقع في إقليم غورداسبور بالبنجاب في الهند دُرست خلال الموسم 87/1986 الاستجابة للتسميد الفوسفوري (0، 20، 40، و 60 كغ P2O5/هـ) والتلقيح بالريزوبيا في صنف العدس L9-12. وبصرف النظر عن التلقيح الريزوبي تفوّقت الغلال الحبية للعدس معنويا عند جميع مستويات التسميد الفوسفوري على الشاهد، إلا أن الاستجابة للتسميد بالنسبة للشاهد تناقصت مع زيادة محتوى التربة الفوسفوري. وكانت هناك زيادة في الغلة الحبية متوافقة مع استعمال المعلّق الريزوبي في جميع مستويات التسميد بالفوسفور. وسُجّل أعلى معدل في الغلة الحبية مقداره 1562 كغ/هـ من المعاملة بإضافة 60 كغ P2O5/هـ إلى عدس ملقح بالريزوبيا، والتي أعطت 13 كغ غلة حبية/كغ فوسفور مضاف، بعائد قدره 13 روبية مستثمرة في التسميد.

Pilot Study for Lentil Yield Maximization in Rubatab Area in the Arid Northern Region of Sudan

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Abstract

A pilot study for maximizing lentil yield was conducted at Rubatab area in the northern region of Sudan for three seasons (1983–84, 1984–85, and 1988–89). The objectives of the study were to identify the practical difficulties encountered when lentil is grown in a large area using a package of suggested cultural practices for maximizing lentil yield; to demonstrate to farmers the best technology for lentil production; to explore the possibility of decortication using the flour mill; and to estimate production costs.

Results indicated seasonal variation in lentil yields. The lowest grain yield (661 kg/ha) was recorded in the 1984–85 season, while the highest yield (3021 kg/ha) was obtained in 1988–89. The grain yield realized in the 1983–84 season (1524 kg/ha) was intermediate. The high grain yield obtained in 1988–89 was associated with an increased number of pods per plant and seeds per pod. The seasonal variation in lentil yields was attributed to the variation in duration of the growing season and the temperatures prevailing during the winter season.

Hand sowing, weed control, bird scaring, and harvest were found to be the most laborious and expensive operations. It is suggested that the mechanization of sowing and harvest, and the identification of appropriate herbicides will markedly reduce lentil production costs. It is anticipated that when large areas are grown with lentil the damage by birds may be reduced through a dilution effect. Until then, chemical control appears to be an immediate solution for this urgent problem.

Lentil processing is by far the main constraint to lentil expansion in Sudan. While results of decortication studies suggest the possibility of using the traditional flour mill, lentil hulling by the flour mill results in high weight loss and poor quality. The quality of locally processed lentils may be improved by selecting large-seeded varieties; adopting cultural practices which increase seed size; and cleaning, grading, and washing prior to hulling to improve the efficiency of the flour mill. Until these changes can be implemented, importation of proper hulling machines appears to be a necessity for the expansion of lentil production in Sudan.

Introduction

Lentil is an important food legume in Sudan. Traditionally, the crop was grown after the flood recessions in the northern province (Dongla-old Wadi Halfa area), with the bulk grown in the Selaim basin. In the early 1960s, production of lentil in the northern province was stopped because of competition with other cash crops (e.g., faba beans, wheat, and spices) and low yields due to bird damage. In the early seventies, lentil

production was reactivated by some farmers in Rubatab area in the Nile province where the crop was successfully grown under pump irrigation (El-Sarrag and Nourai 1983).

Since the area grown with lentil in Sudan is very small, the country imports all required lentils from abroad. Table 1 shows Sudanese lentil imports and their value for the period 1960–September 1989. The quantity of lentils imported in the period 1980–September 1989 (9.75 years) was higher than the quantity imported in the period 1960–1979 (20 years), indicating an increased lentil consumption. However, the price of lentil has shown a substantial increase; the cost per metric ton increased from an average of 92 Sudanese pounds (LS) (over the two periods, 1960–69 and 1970–79) paid for imports of the period 1960–79, to 1,248 LS per metric ton paid for lentil imported in the period 1980–September 1989.

Table 1. Sudan lentil imports for the period 1960–September 1989 (Department of Statistics and Sudan Bank).

Period	Quantity (metric tons)	Total value (LS 000's)	Average imports (metric tons)/year	Price per metric ton (LS)
1960–69	33523	2003	3352	60
1970–79	37241	4610	3724	124
1980–Sep 89	73131	91272	7501	1248

In recent years the Sudanese government started an intensive program to promote the production of lentils and to increase the area under the crop with the ultimate goal of self-sufficiency. This study was undertaken to investigate the effects of a package of improved cultural practices developed at Hudeiba Research Station on yields of lentil grown in farmers' fields; in particular, to assess the benefits of using the traditional flour mill for decortication, in terms of loss in and quality of decorticated lentil. Further objectives of the study were:

- Identifying difficulties encountered when lentil is grown in a large area using a package of suggested cultural practices for maximizing lentil yields
- Demonstrating to farmers the best management practices identified by research scientists
- Estimating production costs

Materials and Methods

The study was conducted for three seasons (1983–84, 1984–85, and 1988–89) at Rubatab area in the Nile province. In the first two seasons the plots were grown at Abu Hasheim in the eastern bank of the Nile while during the third season the study was conducted at El-Kudig in the western bank of the Nile. The package of improved cultural practices tested included:

- early sowing (first–second week of November);
- a seed rate of 142.9 kg/ha using the local Selaim variety in the 1983–84 and 1984–85 seasons, and Giza 9 in the 1988–89 season;
- application of nitrogen fertilizer in the form of urea at the rate of 43 kg N/ha;
- frequent irrigation (every 10 days); and
- weed and pest control.

The data pertaining to the net area planted in each season and the cultural practices adopted are presented in Table 2.

The number of pods per plant was determined from 50 plants taken at random from the planted area while the 1000-seed weight was determined from 10 random samples. The straw yield was determined from 20 plots (plot area = 18 n^2) selected at random from the planted area.

Lentil harvesting was done by hand. Plants were cut with a special sickle (mongal) and collected in heaps to dry in the field. After completely drying, the plants were threshed by hand using sticks, followed by winnowing to separate straw and pod walls from lentil seeds.

Decortication study was conducted using the traditional flour mill, which is the only available facility for decortication of lentils in Sudan. In each season, one lot of ungraded dry lentil seeds (75 kg) was decorticated by the traditional flour mill after the adjustment of the clearance. After thorough winnowing of the decorticated lentils, samples were taken to assess the quality of decorticated lentils where the weight of pure hulled seeds, unhulled and partially hulled seeds, broken seeds, and impurities was expressed as a percentage of the original sample's weight.

Results and Discussion

Table 3 shows that there were seasonal differences in lentil yields. The lowest grain yield (661 kg/ha) was recorded in the 1984–85 season, while the highest yield (3021 kg/ha) was realized in the 1988–89 season. The grain yield obtained in 1983–84 was intermediate. A similar trend of variation with seasons was observed in straw yield and harvest index. The high grain yields recorded in the 1988–90 season were associated with an increased number of pods per plant and seeds per pod (Table 3).

Table 2. Cultural practices of lentil grown at Rubatab.

Practices	Season		
	1983–84	1984–85	1988–89
Plot net area (ha)	0.29	0.36	0.42
Sowing date	16–18 Nov. 1983	10–11 Nov. 1984	13 Nov. 1988
Planting method	Flat planting in rows 30 cm apart	Flat planting in rows 30 cm apart	Hand broadcasting and ridging by oxen
Date of N fertilizer application	3 Jan 1984	13 Dec 1984	5 Dec 1988
Number of hand weedings	2	2	2
Insect pest control	—	One spray with Nurelle-dursban at the rate of 2.4 l/ha on 10 Dec 1984 against *Spodoptera exigua*	Three sprays with Folimat 80% at the rate of 2.62 L/ha on 22 Dec 1988 against white flies, and on 8 Jan and 1 Feb 1989 against *S. exigua*
Total number of irrigations	11	10	10
Days from sowing to harvest	107–108 days	105 days	117–120 days

Table 3. Yield and yield components of lentils grown at Rubatab.

Season	Yield (kg/ha)		Harvest index (%)	Number of pods/plant	Number of seeds/pod	1000-seeds weight (g)
	Grain	Straw				
1983–84	1524	3681	31.3	32.8	1.1	22.4
1984–85	661	2772	19.3	28.3	1.0	25.9
1988–89	3021	5350	37.2	38.6	1.4	24.9
Mean	1735	3934	29.3	33.2	1.2	24.4

The seasonal variation in lentil yields may have been a reflection of the variation in the duration of the growing season and the temperatures prevailing during the winter season. Table 4 shows the maximum and minimum temperatures recorded at Abu Hamad Meteorological Station, situated 75 km north of the test sites. The highest yields, realized in the 1988–89 season, may have been due to the relatively longer and cooler winter season, particularly during January and February (Table 4).

Studies on lentil decortication by the traditional flour mill for three seasons indicated that of the original 75 kg of lentil seeds used for decortication, the average weight of decorticated lentil seeds retained after the removal of seed coat and powder by winnowing was 64.0 kg (Table 5). The average percent by weight of seeds retained after

Table 4. Mean maximum and minimum temperatures prevailing in the period between seed sowing and harvest (Abu Hamad Meteorological Station).

Season	Temp†	Month				
		Nov	Dec	Jan	Feb	Mar
1983–84	Max	34.2	30.5	27.9	33.1	36.7
	Min	18.8	15.4	12.3	15.1	18.8
1984–85	Max	32.5	29.6	31.4	28.8	36.5
	Min	18.0	14.9	15.6	12.2	18.9
1988–89	Max	32.9	30.7	24.7	26.8	33.0
	Min	17.6	15.9	9.7	11.1	16.1

† Temperature in °C.

Table 5. Lentil decortication by the traditional flour mill†.

Season	Seed weight before decortication (kg)	Seed weight after decortication (kg)	% by weight of seeds retained after decortication	% by weight of seed coat and powder
1983–84	75.0	64.6	86.1	13.9
1984–85	75.0	62.6	83.5	16.5
1988–89	75.0	64.7	86.3	13.7
Mean	75.0	64.0	85.3	14.7

† A Denish mill with vertically placed stones (50 cm diameter) was used for hulling after the adjustment of the clearance.

decortication was 85.3 with an average loss in weight (seed coat and powder) of 14.7% (Table 5).

Examination of the composition of lentils decorticated by the traditional flour mill indicated that the percent by weight of pure hulled seeds ranged between 43.8 and 68.6, while the percent by weight of broken seeds varied between 7.8 and 18.9 (Table 6). The lowest weight of unhulled and partially hulled seeds was recorded in the 1983–84 season (18.3%), while the highest (37.2%) was recorded in the 1988–89 season.

The proportion of unhulled and partially hulled seeds is a major factor affecting the quality of lentils decorticated by the traditional flour mill. The presence of unhulled and partially hulled seeds results in a slight color change of cooked lentils from yellow to brownish yellow. However, the proportion of unhulled and partially hulled seeds could be reduced by soaking lentils for a short period and then pressing the seed by hand to remove the seed coat prior to cooking. Generally the lentil decorticated by the flour mill is acceptable, and the locally processed lentil is of good quality as it needs a shorter time for cooking and it tastes better than the imported lentils. The presence of unhulled and partially hulled seeds in lentils decorticated by the flour mill was mainly due to the fact that the varieties adapted to Sudan's growing conditions are small-seeded varieties. Moreover, the decorticated lentil was not subjected to grading and washing operations.

Table 6. The composition of lentils decorticated by the traditional flour mill.

Season	Pure hulled seeds (%)	Hulled broken seeds (%)	Unhulled and partially hulled seeds (%)	Impurities (%)
1983–84	68.6	10.2	18.3	2.9
1984–85	62.1	7.8	24.4	5.7
1988–89	43.8	18.9	37.2	0.1
Mean	58.2	12.3	26.6	2.9

Problems

The problems encountered during the study included:

- **Sowing.** In the first two seasons lentil was raised in flat plots. This method of planting necessitates that after preparation of a fine seed bed, continuous lines 30 cm apart should be marked on each plot. Seeds were then hand-sown in these lines and covered with a thin layer of soil. Hand sowing of lentil is a laborious, time-consuming, and expensive operation. In the third season, this method of planting was changed to broadcasting and ridging by oxen, which is a cheaper method of planting. The introduction of seed drills suitable for lentil will facilitate the planting of large areas in a short time with minimum cost.
- **Weed control.** Lentil is known to be sensitive to weed infestation. Lentil yields are markedly reduced if the crop is unweeded or weeding operation is delayed (El-Badawi and Nourai 1984). In Sudan weeding is done by hand, which is a very expensive operation due to a scarcity of laborers and high wages. Implementation of chemical weed control in lentil will reduce the cost of production, and research is underway to identify the best herbicides in lentils.
- **Bird control.** Birds appear to be a problem in Rubatab area. Great losses in the crop could be encountered due to bird damage and the period of bird scaring depends upon the winter season (in this study, it varied from 30 to 50 days). It is anticipated that when large areas are grown with lentils the damage by birds may be reduced by dilution. However, to enhance immediate expansion of the lentil crop, chemical control of birds at Rubatab area during the period of pod formation to crop maturity by the Plant Protection Department appears to be important.

- **Lentil Harvesting.** In this study lentil cutting, threshing, and winnowing was done by hand. However, in a recent pilot study, a Turkish thresher was used, which resulted in a marked reduction in harvest cost. The mechanization of lentil harvest is important but this necessitates breeding to select erect and nonlodging varieties suitable for mechanical harvesting.
- **Processing.** Lentil varieties adapted to Sudanese growing conditions are characterized by their small seeds. Studies on the decortication of lentils by the traditional flour mill indicated that high losses (seed coat and powder) could be encountered. In the present study an average loss of 14.7% was realized due to hulling by the flour mill. This loss is very high as it has been reported that the lentil seed has three main components: the seed coat, cotyledons, and embryo (including the radicle, plumule, and embryonic axis), forming 8%, 90%, and 2%, respectively, of the seed weight (Singh et al. 1968). Additionally, a large proportion of lentils decorticated by the flour mill is either broken, unhulled, or only partially hulled. The improvement of the quality of locally processed lentils requires selection of large-seeded varieties, and the adoption of management practices which increase seed size and give better seed filling.

Summary

Lentil is consumed in a processed (decorticated) form in Sudan. The lack of proper decorticating machines is one of the major problems facing lentil crop expansion. The importation of proper decorticating machines will improve the quality of decorticated lentils, minimize the losses of decortication, and encourage farmers to grow lentils. Meanwhile, until proper decorticating machines are imported, cleaning, grading, and washing should be carried out to improved the efficiency of the traditional flour mill.

The results of the economic evaluation of the package indicated that lentil cultivation at Rubatab area is profitable. Detailed results of the economic evaluation are to be published in a separate paper (Faki and Nourai, forthcoming).

Acknowledgements

This study was generously supported by ICARDA/IFAD Nile Valley Project on Faba Beans in 1983–84 and 1984–85 Seasons, and the Nile Valley Regional Program on Cool-season Food Legumes in 1988–89 Season. The financial support by these two projects is highly acknowledged. Thanks are also due to Drs M. C. Saxena and W. Erskine of Food Legume Improvement Program, ICARDA, Syria, for their interest in and support of lentil research in Sudan.

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دراسة رائدة للحصول على أعلى غلة من العدس بمنطقة الرباطاب في الإقليم الشمالي الجاف من السودان

الملخص

أجريت على مدى ثلاثة مواسم 84/1983 و 85/1984 و 89/1988 دراسة رائدة للحصول على أعلى غلة من العدس بمنطقة الرباطاب بشمالي السودان. تجلّت أغراض الدراسة في تحديد الصعوبات العملية التي تحول دون زراعة العدس على مساحات واسعة باتباع مجموعة المعاملات الزراعية الموصى بها لزيادة الغلة، وإرشاد الزراع إلى أفضل تقنية لإنتاج العدس، وبحث إمكانية تقشير العدس باستعمال مطحنة الدقيق، وتقدير تكاليف الإنتاج.

أشارت النتائج إلى وجود تباين موسمي في غلال العدس؛ إذ سُجلت أدنى غلة حبية (661 كغ/هـ) في موسم 85/1984 ، وأعلاها (3021 كغ/هـ) في موسم 89/1988، وأوسطها (1524 كغ/هـ) في موسم 84/1983. وترافقت الغلة الحبية الوفيرة في الموسم 89/1988 بزيادة عدد القرون/النبات، وعدد البذور/القرن. وقد عُزي تباين غلال العدس من موسم لآخر إلى اختلاف طول موسم النمو، والحرارة السائدة خلال فصل الشتاء.

إن الزراعة اليدوية ومكافحة الأعشاب وطرد الطيور والحصاد من أكثر العمليات الزراعية تطلّبا للجهد، والمال. وهناك اقتراح مفاده أن تكاليف إنتاج العدس ستقل إلى حد كبير بمكننة الزراعة والحصاد، وتحديد مبيدات الأعشاب المناسبة. ويُتوقع أنه مع زراعة مساحات واسعة بالعدس فإن ضرر الطيور قد يقل من جراء تخفيف تأثيرها. وحتى ذلك الوقت فإن المكافحة الكيماوية ستبقى على ما يبدو الحل المباشر لهذه المعضلة الملحة.

تُعتبَر عملية تجهيز العدس، وإلى حد بعيد، المعوق الرئيسي للتوسع

واتباع معاملات زراعية تؤدي إلى زيادة حجم الحبة، وتنظيف وتدريج وغسيل العدس قبل تقشيره لتحسين كفاءة مطحنة الدقيق. وريثما يتم تحقيق هذه الأمور فإن استيراد آلات مناسبة لتقشير العدس هو من الأهمية بمكان للتوسّع بزراعة العدس في السودان.

بزراعة العدس في السودان. وبينما تظهر نتائج الدراسات إمكانية استعمال مطحنة الدقيق التقليدية في تقشير العدس، إلا أن ذلك يؤدي إلى ضياع كبير في الوزن، ونوعية عدس متدنية. غير أنه يمكن تحسين نوعية العدس المُجهّز محليا عن طريق انتخاب أصناف كبيرة الحبة،

Effect of Mixed Cropping Lentil with Barley at Different Seeding Rates

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Abstract

In a mixed cropping experiment, three combinations of lentil (*Lens culinaris* Medik.) and barley (*Hordeum vulgare* L.) were compared to corresponding sole crops. Normal seed rate of lentil (24 kg/ha) was sown with 10%, 30%, and 50% of the normal (100 kg/ha) barley seed. Barley seed sown at 30% had no significant adverse effect on lentil yield and an additional 930 kg/ha of barley grain was obtained. The highest land equivalent ratio and monetary returns were recorded in this 100% lentil + 30% barley combination.

Introduction

Lentil is the second pulse crop of Bangladesh, ranking next to chickling both in acreage and in production (Anonymous 1989). As a mixed crop, it is often grown with mustard, linseed, sugarcane, wheat, and barley. In intercropping experiments of several pulses with sugarcane Hossain (1981) found lentil to be the most suitable. Rahman and Shamsuddin (1981) obtained 45% yield advantage from mixed cropping of lentil and wheat (100:30 ratio) over normally seeded lentil.

Mixed cropping is practiced by the farmers of Bangladesh to some extent but there have been few investigations into the advantages and disadvantages of this practice over monoculture. Additionally, mixed cropping is, in general, practiced with no particular seeding ratio of the two crops. Hence the present experiment was conducted to determine a suitable seeding ratio for lentil and barley sown in a random mixture.

Materials and Methods

The experiment was conducted under rainfed conditions at the Regional Agricultural Research Station farm, Ishurdi, Pabna, Bangladesh from November 1989 to March 1990. The texture of the soil was silty loam with pH 7.8. The treatments consisted of three combinations of lentil and barley (100:10, 100:30, and 100:50) plus the monocultures of the two crops as checks. The design was randomized complete block with five replications. Plot size was 5 × 3 m. The seed rates of monoculture lentil (cv. Utfola) and monoculture barley (cv. Centinila) were 24 kg/ha and 100 kg/ha, respectively. Sowing was done on 20 November 1989. Monoculture lentil received 20, 40, and 20 kg/ha of N, P_2O_5, and K_2O, respectively. Sole barley and mixed crop treatments received 60, 40, and 40 kg/ha of N, P_2O_5, and K_2O, respectively. All the fertilizers were applied basally. One hand weeding was done 20 days after sowing. Harvesting of lentil was done on 25 February 1990 and that of barley on 7 March 1990. Data on different yield parameters were collected from 10 randomly selected plants in each plot; grain yield was recorded from the whole plot. Collected data were analyzed statistically and mean values were adjudged by Duncan's Multiple Range Test. Land equivalent ratio (LER), cost, and return analysis were also computed.

Results and Discussion

Yields of mixed crops and monocultures differed due to changes in yield/plant or changes in plant populations or both. Differences in yield between mixed crop and monoculture indicated the effects of competition in the mixture.

Effect of barley on lentil

The results (Table 1) revealed that yield and yield parameters of lentil were lower in mixture with 50% barley than in monoculture. Grain yield, plant populations/m^2, number of pods/plant, number of seeds/pod, and 1000-seed weight of lentil in mixed cropping were statistically identical to sole lentil (1.05 t/ha) up to addition of 30% barley seeds. Due to higher

Table 1. Effect of mixed cropping on grain yield and yield components of lentil.

Seeding ratio	Plant populations/m^2	Plant height (cm)	Number of pods/plant	Number of seeds/pod	1000-seeds weight (g)	Grain yield (t/ha)
100% lentil	126.0 a†	32.2 b	72.2 a	1.90 a	14.1 a	1.05 a
100% lentil + 10% barley	124.8 a	37.5 b	70.1 a	1.87 a	14.0 a	1.00 a
100% lentil + 30% barley	120.5 ab	40.4 ab	68.5 a	1.81 a	13.8 ab	0.98 a
100% lentil + 50% barley	100.0 b	44.1 a	25.0 b	1.10 b	13.2 b	0.45 b
100% barley	—	—	—	—	—	—

† Values followed by the same letter(s) in a column are statistically similar at 5% level according to Duncan's Multiple Range Test.

competition of nutrients, moisture, space, and light, the number of pods/plant, number of seeds/pod, and seed size, i.e., yield/plant of lentil were reduced. Zaman (1989) reported that yield/plant of lentil was decreased in lentil and wheat mixed cropping.

Effect of lentil on barley

Grain yield and number of spike/m^2 of barley differed significantly mainly due to different amount of seeds used in the combinations (Table 2). Sole barley produced highest grain yield (2.58 t/ha) and the highest number of spikes/m^2. In mixed cropping, the yield/plant of barley was significantly higher over sole barley, as were the yield components, i.e., number of spikes/plant, number of grains/spike, and 1000-grain weight. The increase in yield/plant might be for beneficial effect of lentil on barley. Rahman (1984) obtained more wheat yield/plant from lentil and wheat mixed cropping than wheat monocultures.

Relative yields of barley showed that barley yields were higher than the expected yields (on the basis of seeding percentage) in the mixtures (Table 3). That is 10%, 30%, and 50% barley seeds produced 11%, 36%, and 51% yield of monoculture, respectively.

Table 2. Effect of mixed cropping on grain yield and yield components of barley.

Seeding ratio	Number of spikes/m^2	Plant height (cm)	Number of spikes/plant	Number of grains/spike	1000-grain weight (g)	Grain yield (t/ha)
100% lentil	—	—	—	—	—	—
100% lentil + 10% barley	27.2 d†	83.1 a	4.5 a	37.9 a	43.0 a	0.28 d
100% lentil + 30% barley	88.7 c	82.0 a	4.0 b	37.1 a	43.0 a	0.93 c
100% lentil + 50% barley	120.0 b	81.2 a	3.4 c	36.9 a	42.7 a	1.32 b
100% barley	225.9 a	80.0 a	3.0 d	30.8 b	40.5 b	2.58 a

† Values followed by the same letter(s) in a column are statistically similar at 5% level according to Duncan's Multiple Range Test.

Table 3. Relative yields, LER, and cost and return analysis of different seeding ratios.

Seeding ratio	Relative Yield		LER	Gross return ($/ha)†	Total variable cost ($/ha)	Gross margin ($/ha)	Benefit cost ratio
	Lentil	Barley					
100% lentil	1.00	—	1.00	420.0	96	324.0	4.38
100% lentil + 10% barley	0.95	0.11	1.06	430.0	101	329.0	4.26
100% lentil + 30% barley	0.93	0.36	1.29	491.5	106	385.5	4.64
100% lentil + 50% barley	0.43	0.51	0.94	321.2	112	209.2	3.76
100% barley	—	1.00	1.00	276.1	102	174.1	2.71

† Market price: Lentil $0.400/kg; Barley $0.107/kg.

From the above results, it may be observed that 30% barley seed did not reduce lentil yield significantly, producing highest LER of 1.29. Highest monetary return was also obtained from the same combination. Similar findings were also reported by Rahman and Shamsuddin (1981) for lentil and wheat mixture.

In conclusion, it may be inferred that 30% barley seeds can be mixed in normal lentil without substantial yield loss and with high monetary return in Ishurdi region.

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تأثير الزراعة المختلطة : عدس وشعير عند معدلات بذار مختلفة

الملخص

عُقدت في تجربة على الزراعة المختلطة مقارنة بين ثلاثة تواليف من العدس (*Lens culinaris* Medik) والشعير (*Hordeum vulgare* L.) مع زراعة المحصولين كل منهما لوحده. زُرع العدس بمعدل بذار طبيعي (24 كغ/هـ) مع 10 ٪، و 30 ٪، و 50 ٪ من معدل بذار طبيعي (100 كغ/هـ) من الشعير. لم تظهر بذور الشعير المزروعة بمعدل 30 ٪ تأثيرا معنويا معاكسا لغلة العدس، إذ تم الحصول على كمية إضافية تعادل 930 كغ/هـ من حبوب الشعير. وسجل التوليف 100 ٪ عدس + 30 ٪ شعير أعلى نسبة من مكافىء الأرض: والعوائد المالية.

Physiology and Microbiology

Influence of Drought at Different Growth Stages on Yield of Lentils

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Abstract

A pot experiment was carried out to study the effect of drought applied at different growth stages on seed yield of lentils. Five treatments were applied: (A) control, without drought; (B) drought at the juvenile stage; (C) drought at flowering; (D) drought at beginning of pod set; and (E) drought at pod filling. Plants were arranged in a complete randomized design. Drought was imposed at the phenological stage by withholding water. Leaf water potential at the end of drought period was similar for all treatments. Drought at juvenile stage, flowering, and pod set (treatments B, C, and D) significantly reduced seed yield. However, drought during pod filling (treatment E) did not differ in respect to the control. The reduction of yield in B, C, and D was due to a lower pod number per plant. There were no statistical differences among treatments in other yield components. Treatments A and E had the highest water use efficiency.

Introduction

Lentil is a relatively new crop in Argentina, the cultivation of which began six decades ago, mostly for export. Recently, INTA (Inst. Nac. de Tecnologia Agropecuaria) proposed some irrigated valleys, where higher yields and better quality have been demonstrated, for use to enhance lentil production (INTA 1984).

Water is one of the most important limiting factors to crop yield in many areas of the world (Kramer 1982). Water stress adversely influences many aspects of plant growth which ultimately affect crop production and yield (Hsiao 1973, Hsiao and Acevedo 1974); use of supplemental irrigation has produced beneficial results (Nema et al. 1984, Saraf and Baitha 1985, Murari and Pandey 1985, McKenzie et al. 1986).

In addition, many papers have pointed out the differential sensitivity of plants to water stress at different growth stages (Salter and Goode 1967, Lis et al. 1964, 1967, 1968). However, few papers have investigated the relationship between water stress and phenology of this crop (Nema et al. 1984, Saraf and Baitha 1985).

Lentils would be an irrigated crop in the valleys proposed by INTA; therefore, it is important to know what irrigation schedules combine maximum lentil yield and water-use efficiency. For this reason, a pot experiment was carried out to determine yield responses to water stress at different stages of growth.

Materials and Methods

The experiment took place in the Experimental Field of CRICYT Mendoza, Argentina (33° 53′ S, 68° 51′ W, 827 m above sea level).

Seeds of *Lens culinaris* M. cv. Precoz were sown in 10-l capacity pots without drainage. A loam-sandy soil with a pot capacity of 0.16 $g^{g^{-1}}$, wilting point of 0.078 $g.g^{-1}$, AEC of 900 micromhos, and pH of 7.82 was used.

Five treatments were applied:

A. Control, without drought
B. Drought at juvenile stage
C. Drought at flowering
D. Drought at pod set
E. Drought at pod filling

Pots were arranged in a completely randomized design, with 15 replications for B, C, and D; 8 for E; and 22 for the control. The experiment was conducted under field conditions. A N15-P15-K15 fertilizer was applied at a rate equivalent to 600 kg/ha.

Each drought treatment was initiated by withholding water when the respective vegetative stage became apparent and was finished when the plants showed yellowish and folding leaves. Wilting was not observed.

At the end of each drought period, leaf water potential was measured by the pressure chamber technique (Scholander 1965). Soil water content was determined by the gravimetric method at the same time.

When the soil moisture lessened to 30% of the soil water capacity, the pots were irrigated. The amount of water used for each pot was measured gravimetrically.

Values of water added to each treatment are expressed in mm.

At harvest time, seed weight per plant, seed number per plant, 1000-seed weight, pod number per plant, harvest index, water use efficiency, and germination percentage were determined for each treatment.

Harvest index (HI) was calculated as grams of seeds per gram of aboveground dry matter. Water use efficiency (WUE) is expressed as mg of aboveground dry matter over grams of water consumed. Analysis of variance and Tukey test, corrected for the number of repetitions, were used to test differences among treatments.

Results

The total amount of water received, stage at which drought was imposed, and the duration of the drought period for each treatment are shown in Table 1. The control received 318.6 mm of water in its entire growth cycle. Treatment B (drought at juvenile stage) received the least amount of water (193 mm) and it had the longest period of drought (71 days). Treatment E (drought at pod filling) received 5 and 25 mm less of water than treatments C and D respectively.

Table 1. Growth stage, period without irrigation, and total water received for each treatment.

Treatment	Growth stage during water stress	Drought period (days)	Total water received (mm)
A	Control, without stress	—	319
B	Juvenile stage	71	193
C	Bloom	42	231
D	Pod set	20	251
E	Pod filling	26	226

The extended period without irrigation of treatment B (juvenile stage) was due to the reduced evaporative demand of the season. The other treatments needed progressively less time to achieve the wilting point.

At the end of the drought periods leaf water potential showed no statistical differences between treatments (Table 2). Thus, the stress intensity was the same for all of them. On the other hand, soil water content of the treatments at that time differed, but a higher value was shown for treatment B.

Table 2. Leaf water potential and soil water content for different treatments at the end of drought period.

Drought treatment	Leaf water potential (MPa)	Control	Soil water content g. g^{-1}
B	-2.10 (0.30†) a‡	-1.02 (0.20) b	0.069 a‡
C	-1.58 (0.17) a	-0.51 (0.04) b	0.045 b
D	-1.72 (0.19) a	-0.64 (0.04) b	0.054 b

† Values in parentheses are S.E. of the mean.
‡ Values with the same letter are not different at $P < 0.05$.

Drought at juvenile stage, flowering, and pod set significantly ($P < 0.01$) affected seed yield compared with the control and drought at pod filling (Table 3). Pod number was the yield component primarily affected by water stress, ranging from 46.3 pods per plant in the control to only 5.6 in treatment B. Drought did not influence either seed number per pod or seed weight.

Harvest indexes of the control and treatment E were about 0.57, while drought applied at juvenile stage and pod set significantly lowered this parameter to 0.48 and 0.45, respectively.

Water use efficiency was maximum in treatment E (0.94) and control (0.79), which were significantly higher

Table 3. Seed yield, yield components, harvest index, and water use efficiency for different treatments.

Treatment	Seed yield g/plant	Pods/plant	Seeds/pod	1000-seed weight	Harvest index	WUE
A	3.17 a†	46.3 a	1.31 a	51.9 a	0.57 a	0.79 a
B	0.37 b	5.6 c	1.28 a	53.5 a	0.48 b	0.17 c
C	1.06 b	16.3 bc	1.30 a	52.0 a	0.52 ab	0.38 bc
D	1.20 b	20.0 b	1.42 a	48.5 a	0.45 b	0.52 b
E	2.88 a	35.5 a	1.38 a	59.2 a	0.58 a	0.94 a

† Treatments with the same letter are not different at $P < 0.05$.

than the rest. The lowest value corresponded to treatment B (0.17).

Seed quality of all treatments was excellent—spotless and of good size. Germination percentage was not different among treatments (data not shown).

Discussion

The results of this study have shown that drought at juvenile stage, flowering, and pod set substantially reduced grain yield compared with the control. In contrast, drought during pod filling did not affect yield. It is important to consider that this treatment received less water than treatments A, C, and D. Therefore, it would appear that yield was not determined by the total amount of water received, but by the moment when drought occurred.

There was a close association between seed yield and pod number of each treatment. In fact, the yield component most sensitive to water stress was the number of pods per plant. Seed weight was not affected. These results are coincident with those obtained by Murari and Pandey (1985) in an experiment with different soil moisture regimes.

Considering that the intensity of drought was similar for all treatments (Table 2), the harm to yield and growth could have been due to the length of the drought period and the time when it happened. Drought during juvenile stage the most harmful for lentil yield and growth. It is important to note that the greatest stress occurred at preflowering stage and lentil seems to be very responsive to irrigation in this period (Nema et al. 1984).

The result obtained with treatment E (drought at pod filling) has implications for irrigation management; because high yields manifested with low water consumption, it may be possible to stop watering at this growth stage without yield loss.

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تأثير الجفاف خلال مختلف أطوار النمو في غلة العدس

الملخص

نُفذت تجربة أصص لدراسة تأثير الجفاف الذي أحدث خلال مختلف أطوار النمو في الغلة البذرية للعدس. طُبق في التجربة 5 معاملات، هي (أ) شاهد بدون جفاف، (ب) جفاف في الطور الفتي للنبات، (ج) جفاف عند الإزهار، (د) جفاف في بداية تشكّل القرون، و (هـ) جفاف عند امتلاء القرون. ورُتّبت النباتات بالتصميم العشوائي الكامل. وأحدث الجفاف في طور النمو المظهري للنبات بقطع الماء عنه، وكان إجهاد الماء في الأوراق عند نهاية فترة الجفاف متشابها في جميع المعاملات. وأدى الجفاف في الطور الفتي وعند الإزهار وعقد القرون (المعاملات ب، ج، د) إلى تدني الغلة البذرية بدرجة معنوية. ومع ذلك فإن الجفاف خلال طور امتلاء القرون (المعاملة هـ) لم يختلف فيما يتعلق بالشاهد. ويعود تدني الغلة في المعاملات ب، ج، د إلى قلة عدد القرون/النبات. ولم تظهر فروق إحصائية بين المعاملات في المكوّنات الأخرى للغلة. وتمتعت المعاملتان: آ، هـ بأعلى كفاءة على استعمال الماء.

Isolation, Culture, and Callus Regeneration of Lentil Protoplasts from Leaf Tissue

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Abstract

Protoplasts of lentil (*Lens culinaris* var Eston) were prepared, purified, and cultured. Leaves from 14- to 21-day old in vitro–grown seedlings were incubated overnight in a mixture of 2% Cellulase "Onozuka" RS and 0.5% Macerozyme R10 dissolved in 0.5 M mannitol with Pental salts (mg/l: 27.2 KH_2PO_4, 101 KNO_3, 1480 $CaCl_2$ $2H_2O$, 246 $MgSO_4$ $7H_2O$, 0.16 KI and 0.025 $CuSO_4$ $5H_2O$) and antibiotics (mg/l: 400 ampicillin, 10 gentamycin, and 10 tetracycline). Protoplasts were purified by density gradient centrifugation and cultured in osmotically adjusted media. Protoplasts in liquid K3 medium (0.5 M mannitol) with 2.0 mg/l naphthaleneacetic acid and 0.5 mg/l benzylaminopurine, layered on the identical medium solidified with 0.2% Gelrite[R], produced microcalli within 30 days. These masses were transferred to callus induction-regeneration medium, but attempts to regenerate plantlets were unsuccessful.

Introduction

Lentils are a major food source in many parts of the world and an important economic component of USA Pacific Northwest agriculture. However, many crops are lost yearly to weed competition and diseases. Genetic manipulation of several different lentil cultivars may lead to cultivars resistant to pathogens and herbicides (Mroginski and Kartha 1983).

Protoplasts can be manipulated through electroporation, microinjection, fusion, and mutation and therefore may prove useful for genetically improving lentils (Stiff et al. 1986; Webb 1988; Rozwadowski et al. 1990). This paper describes methods to prepare, purify, and culture lentil leaf protoplasts and to regenerate callus.

Materials and Methods

Leaves of in vitro-cultured seedlings were used for all experiments. Fifty seeds of the lentil variety 'Eston' (obtained from Fred Muehlbauer, USDA/ARS, Washington State University, Pullman) were surface sterilized in 100 ml of 0.525% sodium hypochlorite containing a few drops of Tween 80 (Sigma Chemical Co., St. Louis, MO.) for 10 minutes. Seeds were rinsed in sterile distilled water, swirled in 70% ethanol for 30 seconds, and rinsed three to six times in sterile, distilled water. Eight to 10 seeds were placed in 50 ml of 0.7% Difco Bacto agar in distilled water in the bottom of square 750 ml glass jars capped with cotton plugs. (Vessels and media were previously autoclaved for 15 minutes at 121°C at 1.06 $kg^{-1}cm^{-2}$). Seeds were germinated in the jars under fluorescent lights (80 $\mu Em^{-2}sec^{-1}$) with a 16-hour light/8-hour dark cycle at ambient temperature (20°–25°C) and grown for 14–21 days. Leaves (1.5–3.0 g) were aseptically removed from the seedlings, weighed, and placed in a petri dish containing 25 ml of an enzyme solution. The enzyme solution consisted of: 2% Cellulase RS, 0.5% Macerozyme R10 (Yakult Honsho Co., Ltd., Nishinomiya, Japan), Pental et al. (1982) salts (mg/l: 27.2 KH_2PO_4, 101 KNO_3, 1480 $CaCl_2$ $2H_2O$, 246 $MgSO_4$ $7H_2O$, 0.16 KI and 0.025 $CuSO_4$ $5H_2O$), antibiotics (mg/l: 400 ampicillin, 10

gentamicin, and 10 tetracycline), and 9% (0.5 M) mannitol. The enzyme solution was stirred slowly in the cold to dissolve the enzymes, and the pH was adjusted to 6.0. The solution was centrifuged at 12,000 g for 10 minutes and filter sterilized through a 0.45 μm filter (Millipore, Bedford, MA). The petri dish containing the leaves and enzyme solution was sealed with parafilm, covered to keep out light, and placed on a rotary shaker at 80 rpm at room temperature for 16 hours. The digested solution was filtered through a 61 μm stainless steel filter. The protoplast/enzyme suspension was poured into a sterile 15 ml polystyrene centrifuge tube, centrifuged at 100 g for three minutes, and the supernatant discarded.

Protoplasts were purified using the methods of Edwards et al. (1979) and a modification by Loescher (unpublished). The pellet was brought to 3 ml volume with a solution (pH 7.5) of 0.5 M sucrose, 5% dextran (35,000–50,000 MW), 25 mM Hepes-KOH, and 0.1% BSA. This was overlayered (covered) with 3 ml of the same solution without dextran. Three ml of a third solution (pH 7.5) consisting of 0.5 M sorbitol, 25 mM Hepes-KOH, and 0.1% BSA, was layered over this. Following centrifugation at 300 g for 7 minutes, protoplasts were collected at the sorbitol-sucrose (top) interface. Debris from the digestion that formed a pellet in the bottom of the tube and damaged protoplasts that collected at a lower interface were discarded. The protoplast solution was diluted by an equal volume of the sorbitol/Hepes-KOH/BSA solution and centrifuged at 300 g for 7 minutes. The supernatant was discarded and the pellet was resuspended in 1 ml of 0.5 M mannitol, counted, and diluted to 6×10^4 protoplasts/ml.

Aliquots of the protoplast suspension were stained with fluorescein diacetate (Sigma Co., St. Louis, Mo.) and examined with a fluorescent microscope to determine viability (Bottino 1981). Protoplasts were also stained with Cellufluor (Polysciences, Warrington, PA) to determine complete removal of the cell walls (Bottino 1981).

Two basal media [Murashige and Skoog (1962) medium and Nagy and Maliga K3 medium (1976)], both containing 0.5 M mannitol and no sucrose, were tested with two different plant growth regulator combinations using three different culturing techniques: liquid, agarose-embedded, and liquid-over-solid medium. Plant growth regulator combinations tested were: 2 mg/l NAA and 0.5 mg/l BAP or 0.5 mg/l picloram with 0.2 mg/l each of BAP, zeatin, and kinetin. Protoplasts were cultured at a density of 6.0×10^4 protoplasts/ml in 6- and 12-multi-well polystyrene plates (Nunc Co., Naperville, IL) in liquid media or in agarose-containing media (0.4% low temperature gelling agarose) using 1 ml/well (12-well plate) or 2 ml/well (6-well plate). The protoplast/medium solutions were also dispensed into wells coated with the identical medium solidified with 0.2% Gelrite^R (Chemical Dynamics Corp., South Plainfield, NJ). The Gelrite-solidified medium was dispensed at 2 ml/well (6-well plate) or 1 ml/well (12-well plate) and cooled overnight. Protoplast suspensions were then dispensed at 500 μ l/well (6-well plate) or 250 μ l/well (12-well plate). All plates were sealed with parafilm, placed in a sealed plastic container with damp paper towels to ensure high relative humidity, and placed in an incubator with 16-hour light (80 $\mu Em^{-2}sec^{-1}$) and 8-hour dark at 26°C. Aliquots of protoplast suspensions were stained with Cellufluor after 72 hours and examined microscopically to determine if cell wall synthesis had been initiated.

After seven days a volume of medium equal to 20% of the original protoplast volume was added to each well. This medium was identical to the original medium except that 3% sucrose was included. The multiwell plates were removed from the humidity chamber and placed directly on the incubator shelf. After 14 days in culture, most of the old medium was aspirated off the cells and fresh medium was added. After 21 days mannitol was omitted from the feeding medium, and this formulation was used weekly for an additional four weeks.

Seven weeks after the initial protoplast isolation, the developing microcalli were transferred to agar- or Gelrite^R solidified B5 (Gamborg et al. 1968) medium with added ammonium nitrate (500 mg/l) containing either 1 mg/12,4-D or 1.0 mg/l BAP and 0.25 mg/l IAA. This medium was used to induce callus growth in lentil embryos (Saxena and King 1987). Four weeks later, healthy callus was transferred to both liquid and Gelrite-solidified (0.2%) B5 hormone-free medium containing the added ammonium nitrate and 70 mg/12 glutamine. Saxena and King (1987) found that glutamine aided the formation and growth of somatic embryos.

Results and Discussion

The use of in vitro–cultured seedlings eliminated both contamination and erratic reproducibility problems that had been experienced in the past. Cotton plug closures on the glass jars proved superior for the growth of vigorous seedlings compared to other closures tested (e.g., foil, screw caps), possibly due to improved gas exchange.

The isolation procedure produced an average of 4.0×10^6 protoplasts per g of tissue. Fluorescein diacetate staining showed that 75% of these protoplasts were viable.

The spherical shape of the newly isolated protoplasts plus the lack of staining from Cellufluor fluorescent stain showed complete removal of the cell wall.

After 72 hours in culture, some protoplasts synthesized cell walls as evidenced by their nonspherical form and their response to Cellufluor staining. Cell elongation and/or division was evident three to five days after isolation.

Embedding the protoplasts in agarose was ineffective, and protoplasts lysed rapidly. This observation is in contrast to Rozwadowski et al. (1990) who found agarose supplemented media to be beneficial. Some microcalli formed from protoplasts in liquid medium but these turned brown and died within a month. Protoplast survival and cell division occurred in treatments where a pad of Gelrite-solidified media protected the protoplasts form direct contact with the plastic of the multiwell plates.

K3 medium, containing BAP and NAA, proved to be superior to MS medium for the culture of lentil protoplasts, and protoplasts growing on that medium remained green and produced microcalli. Protoplasts growing in the picloram and BAP/zeatin/kinetin mixture lost their green color rapidly in both the MS and K3 media. Protoplasts growing in MS medium tended to aggregate, and few formed cell walls and microcalli.

The microcalli transferred to B5 medium continued to develop. Transfer of portions of callus from these media to glutamine-containing medium did not produce any organogenic or embryogenic structures. Callus on all B5 media were subcultured twice before the experiments were terminated.

This is the first report of callus regeneration from leaf-derived lentil protoplasts. Callus regeneration from epicotyl-derived lentil protoplasts was recently reported (Rozwadowski et al. 1990); however, these researchers used a different protocol and other growth media. Incorporation of these new methods into our procedure could be beneficial. Research must continue to determine the requirements for plantlet regeneration from callus. This will enable lentil breeders to utilize techniques of protoplast fusion, microinjection, and electroporation to transfer useful traits into currently cultivated lentil varieties.

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عزل واستنبات وتجدّد الكالوس في جبلات أولية لنسج ورقية من العدس

الملخص

جرى تجهيز وتنقية وزراعة جبلات أولية protoplasts من العدس (*Lens culinaris* var *Eston*)، ثم حُضّنت أوراق عمرها 14 – 21 يوما من بادرات نامية ضمن أنابيب اختبار لمدة ليلة واحدة على مزيج من السلولاز 2 ٪ "أونوزوكا" RS، وماسيروزيم 0.5 ٪ R 10 محلول في م– مانيتول مع أملاح بِنْتال (مغ/ل: KH2PO4 27.2، KNO3 101، CaCl2 H2O 1480، MgSO4 7H2O 246، KI 0.16، و CuSO4 5H2O 0.025) ومضادات حيوية (مغ/ل: 400 أمبيسيللين، 10 جنتامايسين، و 10 تتراسيكلين). جرت تنقية الجبلات الأولية بالطرد بتدرّج الكثافة، ثم زُرعت على بيئة مُعدّلة أوسموزيا (تناضحيا). أنتجت الجبلات على البيئة السائلة K3 (0.5 مانيتول) مع 2.0 مغ/ل نفتالين حمض الخل و 0.5 مغ/ل بنزيل أمينوبيورين – التي انفصلت إلى طبقات على بيئة مماثلة تم تجميدها بإضافة جيليريت 0.2 ٪ – نسجَ كالوسٍ دقيقةً خلال 30 يوما. ونُقلت هذه الكتل إلى بيئة لحث توليد الكالوس، لكن محاولات إكثارها إلى نبيتات باءت بالفشل.

Pests and Diseases

Performance of Lentil Varieties/ Germplasm Lines against Blight

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Abstract

Under natural epiphytotic conditions 105 lentil genotypes were evaluated for resistance against blight (*Ascochyta fabae* f. sp. *lentis*) during podding; none were resistant. Two genotypes, SS-159 and L-3328, were moderately resistant. The remaining genotypes showed susceptible to highly susceptible reactions. Highest disease incidence was recorded on LG-198, LG-265, L-3323, L-4152, and L-4206. LL-4163 developed maximum blight lesions/pod.

Lentil (*Lens culinaris* Medik.), one of man's oldest protein-rich food legume crop, has replaced chickpea cultivation in Himachal Pradesh to a considerable extent. One of the major factors limiting successful lentil cultivation in this Indian state is the prevalence of several serious diseases. In this study the development of blight (*Ascochyta fabae* f. sp. *lentis*) was studied on 105 lines/ varieties of lentil under natural epiphytotic conditions.

Each variety/line of lentil was grown in 2-m long rows, replicated three times in randomized block design. There was sufficient natural inoculum at the experiment site and weather conditions were highly favorable for disease development. Data on blight incidence were recorded before harvesting by counting the number of blighted pods/100 pods taken randomly in each replication, and lesions on the blighted pods and blight lesions/pod were determined.

Results (Table 1) showed that blight incidence on different lentil genotypes ranged from 7% to 60%, being the maximum on LG-198, LG-265, L-3323, L-4152, and L-4206. The lowest incidence of 7% occurred on L-3328.

The maximum blight lesions/pod were recorded on Vipasa, JL-171, LL-4163, LG-4128, L-9-12, EC-158885, EC-158905, L-2117, L-2961, L-3315, L-3316, and L-155905. The maximum incidence (2.5/pod) was on LL-4163. On the basis of blight incidence, ranges of 0%-5%, 6%-10%, 11%-40%, and above 40%, the lentil genotypes were categorized into resistant, moderately resistant, susceptible, and highly susceptible, respectively (Table 2). Accordingly, out of 105 genotypes evaluated, SS-159 and L-3328 were found moderately resistant to Ascochyta blight. The majority of varieties/lines were susceptible to highly susceptible and none of the varieties/lines were resistant to the blight pathogen. The results presented clearly indicate a need to screen more lentil germplasm to identify sources of resistance/tolerance to the disease.

Table 1. Natural incidence of Ascochyta blight on different genotypes of lentil.

Genotype	Incidence (%)†	Blight lesions/pod	Genotype	Incidence (%)	Blight lesions/pod
Precoz	50	1.5	LG-195	43	1.1
Vipasa	50	2.1	LG-198	60	1.7
JL-1	20	1.3	LG-217	30	1.2
JL-82-6	27	1.4	LG-239	37	1.5
JL-171	45	2.0	LG-264	40	1.3
DPL-IA	33	1.6	LG-265	60	1.0
DPL-3	30	1.1	LG-295	50	1.3
HPL-4	13	1.0	LG-4128	43	2.0
LL-145	23	1.3	PL-81-3	30	1.0
LL-4163	53	2.5	PL-170	37	1.4
LH-15	20	1.6	PL-1265	50	1.2
LH-82	20	1.4	PL-1268	27	1.5
LH-81-8	37	1.2	PL-12156	45	1.4
K-303	20	1.2	PL-43137	27	1.1
SS-158	25	1.2	GL-81-3	35	1.3
SS-159	10	1.0	PI-19	25	1.0
SKL-259	33	1.3	L-9-12	35	2.1
LG-24	20	1.0	L-9-18	20	1.6
LG-111	30	1.0	L-82-3	27	1.0
LG-171	33	1.0	L-3991-11	50	1.2
LG-189	37	1.6	L-3991-24	25	1.0

† Average of three replications.

(Table 1 continued on following page.)

Table 1. (Continued).

Genotype	Incidence (%)	Blight lesions/pod	Genotype	Incidence (%)	Blight lesions/pod
L-3991-25	25	1.0	L-3293	50	1.0
L-3991-29	20	1.0	L-3304	53	1.6
L-3991-30	33	1.3	L-3315	20	2.0
EC 158884	47	1.4	L-3316	15	2.0
EC 158885	45	2.0	L-3323	60	1.0
EC 158887	50	1.0	L-3328	7	1.0
EC 158892	23	1.0	L-3335	17	1.5
EC 158898	47	1.0	L-3904	40	1.3
EC 158905	15	2.0	L-4026	20	1.0
EC 165446	35	1.3	L-4047	53	1.0
L-178	23	1.5	L-4048	23	1.5
L-199	47	1.0	L-4076	53	1.3
L-259	37	1.5	L-4120	30	1.0
L-406	47	1.5	L-4122	30	1.3
L-416	27	1.2	L-4123	50	1.2
L-452	50	1.4	L-4125	40	1.0
L-639	17	1.1	L-4126	30	1.6
L-830	27	1.5	L-4142	33	1.7
L-1633	23	1.1	L-4152	60	1.8
L-1644	30	1.3	L-4163	27	1.4
L-1646	43	1.5	L-4206	60	1.9
L-2114	23	1.3	L-4224	33	1.0
L-2117	13	2.0	L-4228	27	1.2
L-2297	30	1.2	L-4266	35	1.7
L-2961	43	2.0	L-4463	30	1.3
L-2979	20	1.0	L-155905	50	2.0
L-3034	33	1.5	L-24118	30	1.3
L-3038	30	1.5	L-24123	20	1.0
L-3046	47	1.0	L-41161	47	1.0
L-3284	30	1.0	L-41282	30	1.2
L-3285	57	1.1	L-46161	30	1.8
L-3286	20	1.0			

Table 2. Reaction of lentil lines against *Ascochyta fabae* f. sp. *lentis*.

Blight (%)	Category	Germplasm lines
0-5	Resistant	Nil
6-10	Moderately resistant	SS-159, L-3328
11-40	Susceptible	JL-1, JL-82-6, DPL-IA, DPL-3, HPL-4, LL-145, LH-15, LH-82, LH-81-8, K-303, SS-158, SKL-259, LG-24, LG-111, LG-171, LG-189, LG-217, LG-239, LG-264, PL-81-3, PL-170, PL-1268, PL-43137, GL-81-3, PI-19, EC-158892, EC-158905, EC-165446
		L-9-12, L-9-18, L-82-3, L-3991-24, L-3991-25, L-3991-29, L-3991-30, L-178, L-259, L-416, L-639, L-830, L-1633, L-1644, L-2114, L-2117, L-2297, L-2979, L-3034, L-3038, L-3284, L-3286, L-3315, L-3316, L-3335, L-3904, L-4026, L-4048, L-4120, L-4122, L-4125, L-4126, L-4142, L-4163, L-4224, L-4228, L-4266, L-4663, L-24118, L-24123, L-41282, and L-46161.
> 40	Highly susceptible	Precoz, Vipasa, JL-171, LL-4163, LG-195, LG-198, LG-265, LG-295, LG-4128, PL-1265, PL-12156, L-3993-11, EC 158884, EC 158885, EC 158887, EC 158898, L-199, L-406, L-452, L-1646, L-2961, L-3046, L-3285, L-3293, L-3304, L-3323, L-4047, L-4076, L-4123, L-4152, L-4206, L-155905, and L-41161.

كفاءة أصناف/أو سلالات أصول وراثية من العدس ضد اللفحة

الملخص

جرى تحت ظروف عدوى وبائية طبيعية تقييم 105 طرز وراثية من العدس لمقاومة لفحة الأسكوكيتا (*Ascochyta fabae* f. sp. *Lentis*)، خلال طور تشكّل القرون. لم يكن أي منها مقاوِما، باستثناء طرازين (SS-159, L-3328) أظهرا مقاومة متوسطة، في حين كانت سائر الطرز الوراثية الأخرى ما بين الحساسة والشديدة الحساسية للمرض. وسُجّلت أعلى نسبة حدوث إصابة بالمرض على: LG-198, LG-265, L-3323, L-4152, L-4206، وتطوّرت على قرون الطراز الوراثي LL-4163 أعلى نسبة بقع إصابة.

Results of Seed Tests. VII. - Occurrence of *Fusarium* Species and *Trichotecium roseum* Link. on Stored Seeds of Lentil

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Abstract

In the course of routine germination tests performed on 16 lentil seed lots stored for nine years, *Fusarium equiseti* (Corda) Saccardo and *Fusarium oxysporum* Schlecht. were isolated from one lot each; and *Trichotecium roseum* Link. from two seed lots. Artificial inoculations of lentil seeds with pure cultures of the isolated fungi caused seed rot and seedling decay.

Introduction

To preserve the genetic diversity for plant breeders and agricultural scientists, germplasm banks for long-term storage of seed have been established (Ng and Williams 1979). However, some seed microflora retained pathogenicity and viability well during the storage (Hewett 1987). Numerous fungi found on different seed were recorded in the Hungarian gene bank established at the Research Centre for Agrobotany (village Tápiószele) (Simay 1986, 1987a, 1987b, 1988, 1989, 1990a, 1990b, 1990c; Simay and Horváth 1990), but no information was available on occurrence of *Fusaria* and *T. roseum* on seeds of lentil (*Lens culinaris* Medik.).

Materials and Methods

Laboratory germination tests of 16 lentil seed lots stored for nine years with 6%–8% moisture content in hermetically sealed containers at 0°–4° C were carried out under standard ISTA conditions (ISTA 1985), considered acceptable for gene banks. Four lots had a contamination level above 10%. These four lots were processed further to determine the fungi causing seed rots.

Pure cultures were obtained on potato-dextrose-agar (PDA) and 2% malt-extract-agar (MEA) media. The identification of the isolated species was based on Booth (1971) and Domsch et al. (1980).

The pathogenicity tests of the isolated fungi for germinating seeds was investigated by soaking surface-sterilized (70% ethanol) lentil seeds for four hours in a spore suspension (5.10^5 spore/ml). Soaked seeds were then sown into heat-sterilized perlite in two replicates, each with 100 seeds. Seedling emergence was registered two weeks after sowing and the symptoms on seedlings and the unemerged seeds recuperated from perlite were recorded.

Fusarium equiseti (Corda) Saccardo and *F. oxysporum* Schlecht. were identified in one seed lot each, while *Trichotecium roseum* Link. was recorded on two lots. Infected seeds failed to germinate, were overgrown by fungal mycelia, and had pinkish mold growth which could spread to the surrounding healthy seeds.

F. equiseti was fast-growing, reaching 5.5-6 cm diameter on PDA and MEA within four days. Its mycelium was abundant, peach to buff, and later turned brown. Macro-conidia (30-48 x 4.2-5.4 μm) were poorly developed, and had 3-5 septa; distinct pedicellate basal cells were observed.

Fusarium oxysporum Schlecht. were also rather fast-growing on the two media, with colonies reaching 4.8–6.2 cm diameter within four days. The aerial mycelium was always well sporulated but only sometimes present. Single-celled micro-conidia (5.4-10.8 μm) were dominant. Chlamydospores were also often produced (Figure 1).

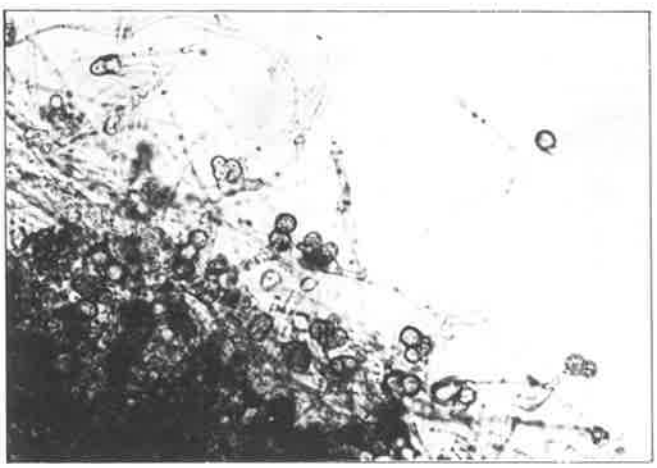

Figure 1. Chlamydospores of *Fusarium oxysporum*.

Trichotecium roseum Link. produced pinkish, dusty colonies, with erect, unbranched conidiophores, on both MEA and PDA media (Figure 2). the conidiophores bore basipetal, zig-zag chains of two-celled conidia with truncate bases. The conidia were 12.4-24 x 7.8-10.4 μm.

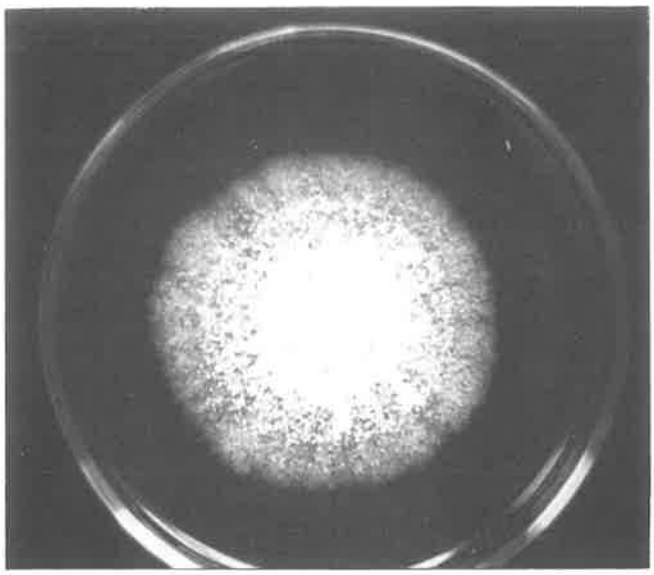

Figure 2. Colony of *Trichotecium roseum* on MEA.

The above-mentioned fungi are well known. Constitutents of the seed microflora of different plants (Agarwal and Sinclair 1987; Neergaard 1979), they were also reported on lentil seeds (Prasad and Chaudhary 1987; Rádulescu and Negru 1971), but no data on their occurrence on long-term stored lentil seeds was available.

In the pathogenicity tests, the three fungi caused a retardation in the emergence of seedlings. The rate of emergence of uninoculated seedlings was 97.5%, while this was 83.5%, 45.5%, and 46% in cases of seeds inoculated with *F. equiseti, F. oxysporum,* and *T. roseum,* respectively. The recuperated nongerminated seeds were overgrown by mycelium. In some cases, germination started normally, but the emerging seedlings, especially those developed from seeds inoculated with *F. oxysporum,* decayed later. These seedlings showed root and shoot discoloration (Figure 3).

These results reflect the importance of the pathogens occurring on stored seeds; further investigations on stored lentil seeds are continuing in the Hungarian gene bank.

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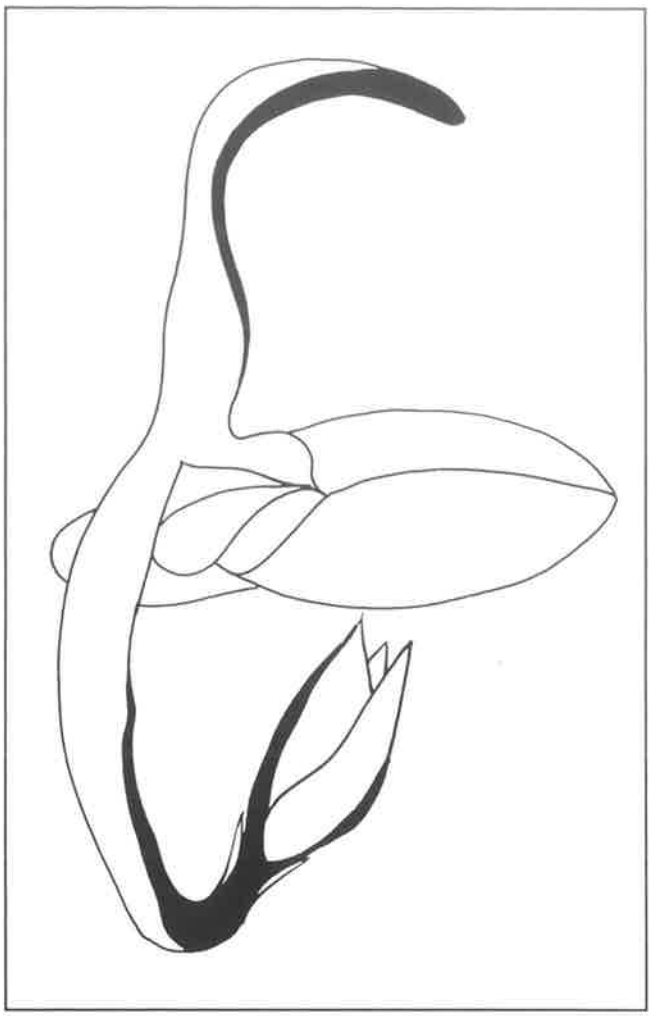

Figure 3. Discoloration and rotting of lentil seedling emerged from seed inoculated with *F. oxysporum.*

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نتائج اختبارات البذور. VII – الإصابة بأنواع *Fusarium* والفطر *Trichotecium roseum* Link. على بذور العدس المخزونة

الملخص

في سياق اختبارات الإنبات المعتادة التي خضعت لها 16 مجموعة من بذور العدس المخزونة لمدة 9 سنوات تم عزل الفطرين *Fusarium equiseti* (Corda) Saccardo و *Fusarium oxysporum* Schlecht. كل من مجموعة واحدة، والفطر *Trichotecium roseum* Link. من مجموعتين. وسبّبت عدوى اصطناعية لبذور العدس بمستنبتات نقية من الفطور التي جرى عزلها عفن البذور، وانحلال أو تفسّخ البادرات.

Lentil Information

Visuals

ICARDA has recently released three slide-tape modules dealing with legume hybridization techniques. The three programs, *Hybridization Techniques in Chickpea, Hybridization Techniques in Lentil,* and *Hybridization Techniques in Faba Bean,* discuss the morphology of the flowers, crossing block layout, and emasculation and pollination techniques. The programs are designed as introductory material for junior scientists.

To purchase the modules send a check for US $50 payable to ICARDA for each program to the Training Coordination Unit. Each slide set includes 80 slides, a cassette tape, and an accompanying resource book.

On the Bookshelf...

The ICARDA library has recently acquired an original of *Lentils of the USSR and of other countries.* Helena Barulina. Supplement 40 to the *Bulletin of Applied Botany, Genetics and Plant Breeding.* Leningrad. 304 pp.

This book was written in 1930 by the wife of Vavilov, who distinguished herself as an accomplished and renowned botanist. A classic among lentil literature, it was part of a series of monographs published by the Bureau of Applied Botany of the State Institute of Experimental Agronomy and the Institute of Applied Botany. The English summary comprises the last 39 pages of this 304-page monograph. In it are covered (by chapter) "History of the cultivation of the lentil"; "The geography of the crop and the limits of its cultivation"; "The chemical composition and the cooking properties of lentil seeds"; "The genus *Lens*, its history and geography"; System of hereditary variation of the lentil (*L. esculenta*); description of separate characters"; "Classification of *L. esculenta*. Key to the determination of varieties"; Treats on the French lentil (*Vicia Ervilia* Willd.) and the Oneflowered lentil (*Vicia monanthos* Desf.); "The lentil of USSR"; "The lentil of Asia"; "The lentil of Africa"; "The lentil of Europe"; The ecological types of the lentil in regard to earliness, amount of green mass, drought-resistance, and immunity; The principal centers of the origin of *L. esculenta*"; "On the vetch as a weed in lentils (mimicry in plants)"; and the anatomical characteristics of the lentil (*Lens esculenta*).

***Legume Genetic Resources for Semi-arid Temperate Environments.* Proceedings of an International Workshop Cairo, Egypt, 19–24 June 1987. Alan Smith and Larry Robertson (eds). ICARDA 512 pp.**

The food, pasture, and forage legumes are of crucial importance in maintaining sustainable cropping systems. This is a collection of the papers presented at an international workshop held to identify areas for further research and support, and to develop future activities related to the genetic resources of legumes. This book should be of importance to researchers concerned with the collection, conservation, evaluation, and documentation of the germplasm of these crops.

Key Lentil Abstracts

Ansari, S. A., Samillah, M. M. R. K. Afridi, and N. A. Khan. 1990. Response of field-grown lentil to pre-sowing seed enrichment with pyridoxine. *Field Crops Res.* 23(1)45–54.

Field-grown lentil (cv. T-36) responded significantly to presowing seed treatment for 12 hours with 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% aqueous pyridoxine solutions in comparison with unsoaked and water-soaked controls. In general, the treated plants showed better growth at 60, 90, and 120 days after sowing (DAS). Treatment also resulted in the highest dry-weight, root nodule number, leaf area, leaf nitrate-reductase activity and leaf N, P, and K contents at all stages, net assimilation rate for the periods 60–90 and 90–120 DAS, pod number per plant, seed number per pod, seed yield, and seed protein content at harvest. Results indicate not only improved seedling establishment, growth, and development but also enhanced N, P, and K uptake in the treated plants. This in turn led to higher seed yield and protein content.

Bremer, E., and C. van Kessel. 1990. Appraisal of the nitrogen-15 natural abundance method for quantifying dinitrogen fixation. *Soil Sci. Soc. Am. J.* 54(2):404–11.

Several investigators have questioned the use of the ^{15}N natural-abundance method of estimating N_2 fixation because of variability in soil $\delta^{15}N$ and small differences between the $\delta^{15}N$ of soil N and atmospheric N.

Investigations were conducted to compare the ^{15}N natural-abundance and ^{15}N-isotope-dilution methods for estimating N_2 fixation of field-grown pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medik.). Spatial variability was assessed at three sites by determining the $\delta^{15}N$ of non-N_2-fixing plants. Seasonal variation in $\delta^{15}N$ for spring and winter wheat (*Triticum aestivum* L.), flax (*Linum usitatissimum* L.), barley (*Hordeum vulgare* L.), rape (*Brassica napus* L.), and lentil was determined at one site. Comparisons between $\delta^{15}N$ and ^{15}N-enriched isotope-dilution methods for estimating N_2 fixation by lentil were conducted at several sites over a three-year period. Variability in $\delta^{15}N$ of the reference plant was site dependent: the $\delta^{15}N$ ranged from 2.8 to 9.3 at the first site, 3.4 to 8.8 at the second site, and 3.5 to 6.2 at the third site. The average $\delta^{15}N$ of four of the five non-N_2-fixing plants increased from 5.4 at 42 days after planting, and its $\delta^{15}N$ value declined from 8.1 at 42 days after planting to 7.3 at the final harvest. The $\delta^{15}N$ values for lentil were similar at 42 and 63 days after planting to the $\delta^{15}N$ values of the four reference plants, but did not increase after 63 days. Estimates of N_2 fixation were not significantly different in 18 out of 21 comparisons; in two comparisons the $\delta^{15}N$ method and in one comparison the ^{15}N-enriched method provided higher estimates of N_2 fixation. Overall, both methods appeared to provide equally reliable estimates of N_2 fixation for lentil.

Cessna, Allan. 1990. Diquat residues in lentil following preharvest treatment. *Can. J. Plant Sci.* 71:413–18.

In a two-year study, residues of diquat were spectrophotometrically determined in lentil (*Lens culinaris* Medik.) seed and straw/chaff following preharvest treatment using 0.56 kg ha^{-1} at three crop growth stages. Diquat residues ranged from 12.9 to 17.3 mg kg^{-1} in the lentil straw/chaff one day after application and decreased to 1.1 to 6.0 mg kg^{-1} two weeks later. Diquat residues in the seed were in the order of 0.05 mg kg^{-1} or less regardless of time of sampling after spraying or growth stage of the crop at application. The limit of quantification of the analytical method was 0.04 mg kg^{-1}, and recoveries of diquat from fortified seed and straw were in the order of 70%.

Erskine, W., R. H. Ellis, R. J. Summerfield, E. H. Roberts, and A. Hussain. 1990. Characterization of responses to temperature and photoperiod for time to flowering in a world lentil collection. *Theor. Appl. Genet.* 80:193–99.

The times from sowing to first flowering (f) of 231 accessions of lentil (*Lens culinaris* Medik.), comprising germplasm from eight countries and breeding lines from ICARDA in Syria, were recorded in four glasshouse environments; two photoperiods (16 and 13 h/day) combined with warmer (24°/13°C) and cooler (18°/9°C) day/night temperatures. The linear model $1/f = a + b\,T + c\,P$ (where T is mean diurnal temperature and P is photoperiod) provided an average fit over the 21 accessions of $r^2 = 0.852$. Since there is not interaction term in this linear model, the flowering responses of an accession to temperature and photoperiod are independent. The values of the constants b and c indicate relative responsiveness of rate of progress towards flowering ($1/f$) to temperature and photoperiod, respectively. Comparison among the 231 accessions showed a weak, but significant, negative correlation between the values of b and c ($r = -0.291$, $P < 0.01$). Since the proportion of the variance of b not attributed to its linear regression on c was > 0.91, we conclude that these phenological responses are under separate control and that there is considerable scope for selection of any combination of sensitivities to temperature and photoperiod in lentil. Just as a large proportion of the variation among accessions in mean time to first flowering was attributed to country of origin, so also was variability in the values of the constants a, b, and c. In particular, sensitivity to photoperiod (i.e., the value of constant c) was dependent upon latitude of origin. Breeding lines from ICARDA were equally variable in a, b, and c as were germplasm accessions from elsewhere, while the mean values were similar to those of accessions from neighboring Jordan. A single accession of wild lentil (*L. culinaris* subsp. *orientalis*) from Turkey showed flowering responses to T and P similar to the mean value of accessions of cultivated lentil from that country. Results from diverse environments for the Argentinian cv. Precoz show that the use of this linear model facilitates predictions of time to flowering in any environments (within wide limits) of known mean temperature and photoperiod. The model, then, minimizes the need for multisite evaluations of phenology, since predictions of preflowering duration in any environment, and characterization of flowering responses to photoperiod and temperature, can now be achieved by screening germplasm in a few, carefully selected locations.

Erskine, W., J. Isawi, and K. Masoud. 1990. Single plant selection for yield in lentil. *Euphytica* 48(2):113–16.

Individual plant selection for yield in lentil is problematic at a commercial crop density primarily because of inter-plant entanglement by tendrils. Visual plant selection for yield was compared with random selection in the F_5 at three plant densities (66, 133, and 200 seeds/m^2) by an

evaluation of F_7 progeny yields over two seasons in two populations of lentil. Random plant sampling was as effective as visual plant selection in isolating high-yielding F_7 lines. The plant density of the selection environment did not affect the response to selection. The correlations between the seed number of selected F_5 plants and the mean yield of their F_7 progenies were r = + -0.26 and -0.06 in two populations, indicating the lack of positive response to plant selection for seed number. The results show that (1) random sampling is the most economic of the methods tested of plant selection for yield and (2) the plant density of the environment for plant selection can be low enough to avoid interplant entanglement by tendrils, allowing a focus in plant selection on characters, other than yield, of importance to the breeding program and with a higher heritability than yield.

Erskine, W., and F. J. Muehlbauer. 1990. Effects of climatic variations on crop genetic resources and plant breeding aims in West Asia and North Africa. In *Climatic Change and Plant Genetic Resources,* ed. M. Jackson, V. B. Ford-Lloyd, and M. L. Parry, 148–57. London, UK: Belhaven Press.

This paper addresses topics, such as breeding for drought tolerance; effects of drought on crop genetic resources; and exploitation of genetic resources for drought tolerance. This attempts to delineate some of the approaches to breeding for drought tolerance as frequency of drought in the semiarid regions may increase with global warming.

Keatinge, J. D. H., and N. Chapanian. 1991. The effect of improved management on the yield and nitrogen content of legume hay/barley crop rotations in West Asia. *J. Agronomy and Crop Science* 167:61–69.

In the light of growing governmental support in West Asia and North Africa for policies which either discourage cereal monoculture or encourage fallow replacement by farmers, two experiments were conducted in northern Syria. These were designed to evaluate and quantify the effect of agronomic interventions on the productivity and nitrogen content of legume hays, and the subsequent residual effects of these interventions on the yield and nitrogen content of a following barley crop. Quantitative estimates of the residual effects of legume hays, when grown under rainfed conditions, on the N uptake of barley are rarely available for the region at large.

The major management effects on the productivity of legume hays were the addition of phosphate fertilizer and a reduction in row spacing. Positive residual effects on the yields of following barley crops were shown to be small but not insignificant. They could be considered to be important influences in the sustained production of barley in legume hay-barley crop rotations.

It is suggested that the results give further positive evidence that farmers in West Asia will not resist the introduction of improved crop rotations including legumes in place of their current fallow-barley or continuous crop sequences.

McKenzie, B. A., and G. D. Hill. 1990. Growth, yield, and water use of lentils (*Lens culinaris*) in Canterbury, New Zealand. *J. Agric. Sci.* 114:309–20.

Lentils (*Lens culinaris* Medik.) were sown on eight sowing dates from April to November in two seasons in Canterbury, New Zealand. In 1984–85, six sowing dates were combined with two lentil cultivars (Olympic and Titore) and two irrigation treatments. In 1985–86, Titore was sown on two dates, with four irrigation treatments. An additional experiment grown under rain shelters examined the response of Titore to four irrigation regimes. The 1984–85 season was dry and rainfall was only 70% of the longterm mean. In this season, seed yield was high, 3.3 t/ha from the may sowing. The 1985–86 seasons was wetter than average and seed yields were lower, ranging from 0.6 to 1.5 t/ha. Under rain shelters, seed yield ranged from the equivalent of 0.32 to 2.5 t/ha.

Sowing date had the most marked effect on seed yield. In the 1984–85 season, all autumn and winter sowings yielded 2.4–3.3 t/ha, whereas the spring sowings yielded 0.5–1.5 t/ha. In 1985–86, unirrigated plots from the May sowing yielded 1.5 t/ha, whereas all other plots yielded *c.* 0.8 t/ha.

Generally, the small-seeded cultivar Titore outyielded Olympic. Dry matter (DM) accumulation followed similar trends to seed yield. Seasons DM accumulation followed a sigmoidal curve. Functional growth analysis indicated that plants from autumn/winter sowings had a weighted mean absolute growth rate of 110–171 kg/ha per day, whereas spring-sown plants grew at 96–137 kg/ha per day. The maximum crop growth rate was 230 kg/ha per day in the July 1984 sowing.

There was little positive response to irrigation in both seasons. Under rain shelters, there was a linear increase in both dry matter and seed production with increased total water. Fully irrigated plants produced 1.27 g DM and 0.72 g seed/m^2 per mm of water received.

In the field experiments there was no relationship between maximum potential soil moisture deficit (D) and yield. Under rain shelters, however, there was a linear relationship which indicated a limiting deficit of *c.* 130 mm. The relationship showed that, for each millimeter increase in D above D_l, 0.39% of the maximum yield was lost.

Under the rain shelters, there was a strong relationship between yield and actual evapotranspiration (ET). Water-use efficiency (WUE) ranged from 2.81 g DM/m^2 per mm ET in unirrigated plots to 0.69 g seed/m^2 per mm ET.

The results showed that lentil growers in Canterbury, and presumably in similar environments, are unlikely to benefit from irrigating their crops. In such environments, lentils appear to be an ideal dryland crop.

Muehlbauer, N. F. Weeden, and D. L. Hoffman. 1989. Inheritance and linkage relationships of morphological and isozyme loci in lentil (*Lens* Miller). J. Heredity 80(4):298–303.

Allozyme polymorphisms for 18 loci are described and their monogenic inheritance is demonstrated. We investigated linkage relationships among the 18 isozyme loci as well as four genes controlling morphological traits. Six small linkage groups were identified, containing 14 of the loci analyzed. Several of these groups appear to be conserved between *Lens* and *Pisum*, indicating that this intergeneric comparison may expedite genetic studies and breeding programs in both crops.

Munoz, Alejandro Matus. 1991. Agronomic Evaluation of Zero Tannin Lentil. Thesis. University of Saskatchewan. College of Graduate Studies and Research Saskatoon.

The seed coat of lentil contains tannin precursors which can discolor seed from the normal olive green to deep brown on prolonged storage due to an oxidative polymerization of soluble condensed tannins reacting with themselves and with others compounds, such as aurones. Discolored lentil seed is unacceptable to the consumer.

The Crop Development Centre of the University of Saskatchewan developed some zero tannin (ZT) lentil lines that, due to the absence of tannin, do not discolor during storage. Seed increase of those lines has been a problem, probably because of a high incidence of seed rot (emergence rarely exceeds 5% without fungicide seed treatment), poor seed quality and vulnerability to mechanical damage due to a much thinner seed coat.

The effect of fungicide on seedling emergence of zero tannin lentil lines was investigated by using a split-plot design replicated three times for two years. The main effect was lentil lines and the split effect was untreated seed vs. seed treated with the fungicide metalaxyl.

An evaluation of 102 zero tannin lentil lines for the agronomic traits: seedling emergence, days to flower, days to mature, plant height, seed yield and seed weight was conducted in three 6 × 6 lattices with three replications. The lentil cultivars Eston and Laird were included in order to determine the potential for commercial production of zero tannin lentil lines in Western Canada.

The susceptibility of zero tannin lentil lines to mechanical damage was investigated by seeding 29 ZT lentil lines, Laird and Eston in a randomized complete block design with four replications. Lentil were threshed and cleaned by hand in order to minimize damage to the seed. The seed was tested for mechanical damage in the Stein Breakage Tester using 10 g samples of lentil at 14% moisture running for 60 seconds at 1725 rpm.

The following conclusions can be made from these studies.

1. Seedling emergence of ZT lentil lines was greatly improved following fungicidal seed treatment with metalaxyl.
2. Fungicidal seed treatment had no effect on agronomic traits of ZT lentil lines, other than seedling emergence and seed yield.
3. The most promising ZT lentil lines for cultivation in Western Canada are ZT-4, V8-91, and VLT-20.
4. ZT lentil lines are more susceptible to mechanical damage than tannin-containing lentil cultivars such as Eston.
5. Susceptibility to mechanical damage of lentil cultivars increased as seed size increased, but differences in seed size only explained 20% of the difference in resistance to mechanical damage.
6. Commercial production of ZT lentil lines must involve fungicidal seed treatment with metalaxyl and special precautions during seeding, harvesting and cleaning to minimize mechanical damage to the seeds.
7. A second cycle of selection following hybridization of the better ZT lines to adapted lines would increase the frequency of acceptable ZT lentil lines available for testing.

Silim, S. N., M. C. Saxena, and W. Erskine. 1990. Seeding density and row spacing for lentil in rainfed Mediterranean environments. *Agron. J.* 82(5):927–30.

Lentil (*Lens culinaris* Med.) is largely sown by hand broadcasting at around 400 seeds m^{-2} in West Asia. Rising labor costs for hand harvest are forcing farmers to consider machine harvesting, which is economically feasible only on mechanically drilled, flat seedbeds. Seeding experiments were conducted at three sites between 1979 and 1986 to determine the effect of seeding densities (100–400 seeds m^{-2}) and row spacing (0.2, 0.3, 0.4, and 0.5 m) on the seed yield, biological yield, and economic return of rainfed lentil. The main site, Tel Hadya (Syria), had a mean annual rainfall of 315 mm over five seasons; Terbol (Lebanon) was wetter with 520 mm over two seasons; and Breda (Syria) was dryer with 244 mm over two seasons. Seed yield and total biological yield were greater at the two wetter sites, but yields were significantly affected by seeding density within each site. The relationship between yield and seed density was best described by a quadratic curve. At the wetter sites (Tel Hadya and Terbol), seeding densities for maximum seed yield were 267 ± 33 seeds m^{-2}, considerably lower than the 334 ± 4 at the drier Breda site. For maximum total biological yield, the seeding densities were 276 ± 22 for Tel Hadya, 298 ± 16 for Terbol, and 346 ± 4 seeds m^{-2} at Breda. The results indicated that using a seed drill, the optimum density for gross economic return minus seed cost was 280 seeds m^{-2} at Tel Hadya and Terbol and 320 seeds m^{-2} at Breda. These rates represent a potential saving in seed costs of 20%–30% over hand broadcasting. Yields were less responsive to row spacing than to seeding density. Narrowest row spacing (0.2 m) generally gave the greatest seed yields, which decreased linearly with increased row spacing.

Tahir, Muhammad. 1990. Use of Isozyme Polymorphisms in Lentil for Gene Mapping and Detection of Quantitative Trait Loci. Thesis. Washington State University, USA.

Polymorphisms at isozyme loci were used to locate the genomic regions which influence the development of economically important traits in lentil (*L. culinaris* Medik). Associations of seven quantitative traits with 10 isozyme loci were determined in backcross inbred lines, as indicated by the differential expression of the quantitative trait at the marker locus classes. Five of the 10 marker loci (*Ga1-1, Ga1-2, Pgm-c, Pgm-p,* and *Lap-1*) showed significant associations with one or more quantitative traits. At least one locus was detected as affecting variation in days to flower, days to maturity, and plant height. Two to three effective loci were detected for biomass, seed yield, harvest index, and seed weight. The detected quantitative trait loci appeared to be positioned on linkage groups 1, 4, 5, and 7 as determined by the known position of the isozyme loci in various linkage groups.

Inheritance and linkage relationships of isozyme and morphological loci were examined in homozygous recombinant lines of lentil. Random single-seed-descent-derived lines, developed from eight interspecific crosses, were assayed for parental alleles at two to eight isozyme and four morphological trait loci. Significant deviations from the expected 1:1 ratio were observed for most marker loci, with the cultivated parent (*L. culinaris*) allele being more frequent than the wild parent (*L. orientalis*) allele. Six linkage groups were identified which included previously reported linkages (*Gs:Aat-p, Pi:Ga1-1, Yc:Pgm-p, Aat-c:Me-2, Aat-mb:Skdh,* and *Fk:Pgd-p)*, and four previously unreported linkages (*Gh:Ga1-1, Ga1-2:Aat-mb:Skdh, Skdh:Aldo:Naq*).

Random, single-seed-descent-derived lines of eight interspecific *Lens* hybrids were used to determine the associations of isozyme loci with the expression of quantitative traits. The loci affecting variation in seven quantitative traits (days to flowering, days to maturity, plant height, biomass, seed yield, harvest index, and seed weight) were identified by their association with 14 isozyme markers (*Aat-c, Aat-m, Aat-p, Adh-1, Fk, Ga1-1, Ga1-2, Lap-1, Lap-2, Pgd-p, Pgi, Pgm-c, Pgm-p,* and *Skdh*). The known positions of 10 of the 14 isozyme loci on lentil genetic maps were used to mark the genomic regions for location of associated quantitative trait loci. Regions of the genome represented by linkage groups 1, 5, and 7 appeared to affect a greater number of traits than other genomic regions represented by linkage groups 2, 3, and 4.

Vandenberg, A., and A. E. Slinkard. 1989. Inheritance of four new qualitative genes in lentil. *J. Hered.* 80(4):320–22.

Single-gene inheritance was observed for four qualitative traits in lentil, *Lens culinaris* spp. *culinaris* (Medik.) Williams. Glabrous pod (*glp*) was determined by a single gene recessive to pubescent pod (*Glp*). Green pod color (*grp*) was inherited as a single gene recessive to red pod color (*Grp*). Tendrilless leaf (*tnl*) was determined by a single gene recessive to tendriled leaf (*Tnl*). A chlorina chlorophyll mutant (*chl*) was determined by a single gene recessive to its normal dominant allele (*Chl*).

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Raziuddin, H. Ahmed, C. M. Altaf, and F. Hanan. 1990. Investigation on the karyotype of lentil *Lens culinaris* Medik. *Sarhad J. Agric.* 6(3):261–64.

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Forthcoming Conferences and Events

1992

***3rd International Legume Conference*, Kew, UK, 1992.** Contact: The Royal Botanic Gardens Kew, Richmond, Surrey TW9 3AB, UK.

***International Food Legume Research Conference*, Cairo, Egypt, 12–16 April 1992.** Contact: A. L. Slinkard (306) 966-4978.

***1st European Conference on Grain Legumes*, Angers, France, 1–3 June 1992.** Contact: Secretariat, UNIP, 12 Avenue George V, 75008 Paris, France.

***First International Crop Science Congress*, Ames, Iowa, USA, 14–22 July 1992.** The program will consist of plenary sessions, symposia, and voluntary poster papers and professional tours organized so as (a) to present knowledge pertinent to crop scientists from all regions of the world, (b) to emphasize integration of knowledge from crop science to solve global and regional problems and issues, and (c) to focus on global research needs. Opportunities for work group sessions will be provided on the congress program. Contact: K. Frey, International Crop Science Congress, c/o Agronomy Department, Iowa State University, Ames, IA 50011, USA.

1993

***15th Congress on Irrigation and Drainage*, The Hague, The Netherlands, 30 August–12 September 1993.** Contact: ICID, 48 Nyaya Marg, Chanakyapuri, New Delhi 110021, India.

Second International Food Legume Research Conference 12–16 April 1992, Cairo, Egypt

The First International Food Legume Research Conference (IFLRC-I) on pea (*Pisum sativum*), lentil (*Lens culinaris*), and chickpea (*Cicer arietinum*) was held at Spokane, Washington, U.S.A in 1986. It was a resounding success with over 500 registrants from 50 countries. The program consisted of 91 papers coauthored by 202 contributors from 40 countries. The Conference Proceedings were published as Summerfield, R. J. (ed.). *World Crops: Cool Season Food Legumes, 1988.* Kluwer Academic Publishers, Dordrecht, The Netherlands.

The success of IFLRC-I has promoted development of the Second International Food Legume Research Conference (IFLRC-II), which will be held 12–16 April 1992 in Cairo, Egypt. Recent success in development of low neurotoxin lines of grass pea (*Lathyrus sativus*) has resulted in the addition of this promising cool season food legume to the list of species covered.

The objectives of IFLRC-II are to (1) review and assess recent results from national and international research programs on cool season food legumes and (2) develop strategies for increasing production per unit area and increasing use of these cool season food legumes in various cropping systems. Both basic and applied research will be addressed and multidisciplinary research efforts will be emphasized.

For further information please contact:

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