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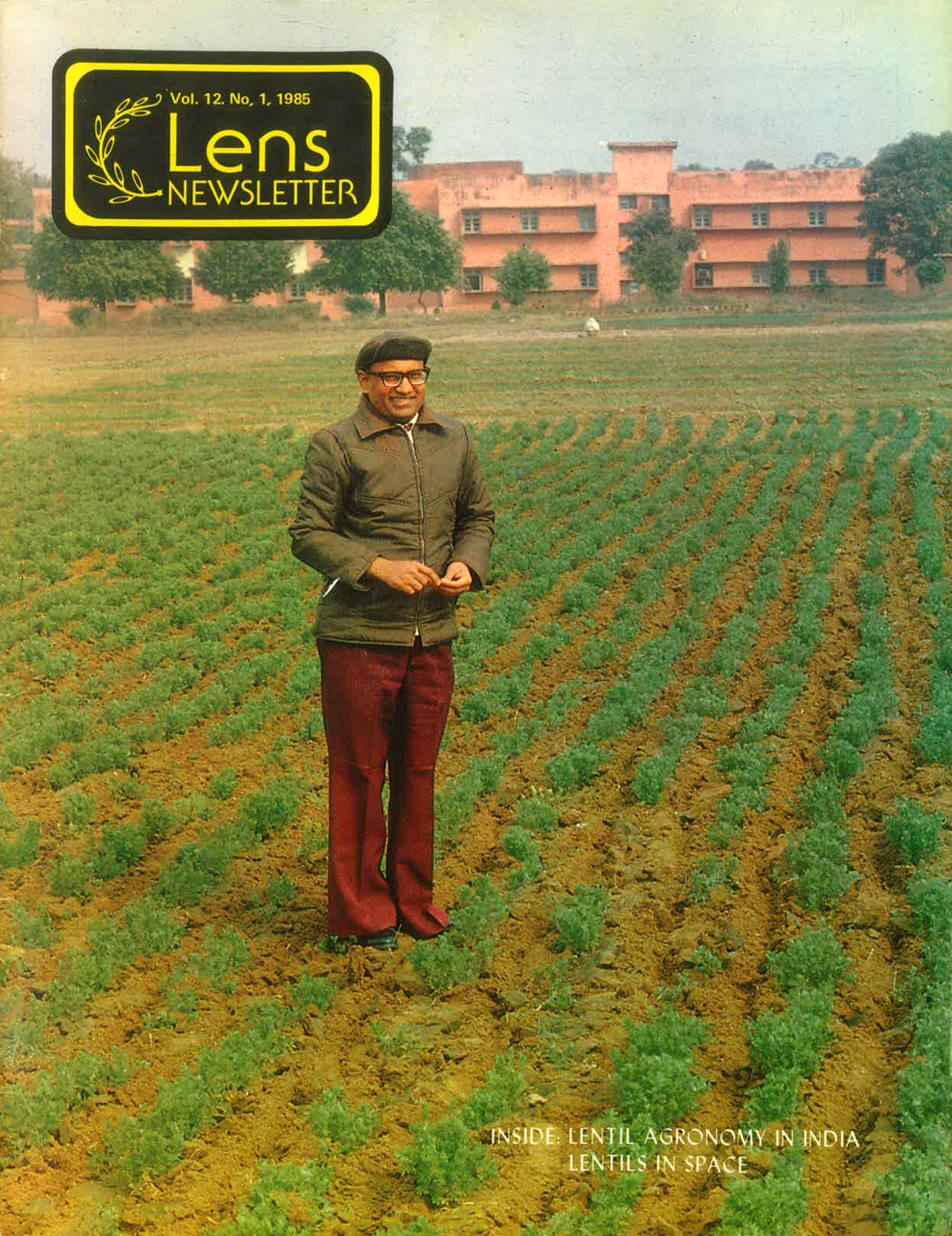

INSIDE: LENTIL AGRONOMY IN INDIA
LENTILS IN SPACE

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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 Centre (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 Experimental News Service provides information on lentil research free of charge through a question and answer service, photocopies, and searches of a lentil document collection.

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SUBSCRIPTIONS: LENS Newsletter is available free to lentil researchers under an IDRC grant. To subscribe, write: LENS/Documentation Unit/ICARDA/P.O.Box 5466/Aleppo, Syria.

COVER PHOTO: Dr. C.S. Saraf, agronomist at the Indian Agricultural Research Institute, New Delhi, surveys his field of *macrosperma* lentils (cultivar ILL-4605-Precoz). Dr. Saraf is the author of the review of lentil agronomy in this issue of LENS.

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Vol. 12, No. 1, 1985

Lens NEWSLETTER

CONTENTS

REVIEW ARTICLE

A decade of agronomic research on lentil in India – A critical review

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Abstract

This review highlights constraints to lentil production in India, the world's major lentil producer. It also summarizes research of the last decade on aspects of agronomy, spanning cultivar development, sowing date, plant density, seed treatment, *Rhizobium* inoculation and nutrient management, micronutrients, water management, weed management, and salt tolerance.

Introduction

Food legumes, including lentils, occupy a very significant place in Indian farming as a source of minerals, vitamin-rich vegetables, protein-nutritious fodder, and soil-enriching green fodder. The importance of legumes in the country's agriculture has increased in recent years with the shortage of chemical fertilizers and energy. India produces more lentils than any other country (Webb and Hawtin 1980). Most of the crop is grown in the northern, eastern, and central parts of the country up to Maharashta, on an area of about 0.8926 million hectares, with total production at about 0.436 million metric tonnes. Average yield is 465 kg/ha.

India's low yields of pulses in general and lentils in particular are primarily due to lack of proper management, high-yielding varieties, and proper plant protection measures. Pulses are mainly grown on land too low in fertility and soil moisture to sustain cereal crops. The lack of improved pulse production coupled with rising demand underscores the need for better pulse production technology.

This paper reviews lentil research in India during the past decade, constraints on production, and research approaches to future work.

Major constraints on production

The per capita availability of food legumes is rapidly decreasing and malnutrition increasing, due to stagnation of production, increasing population, and lack of major technological breakthroughs. Production has not kept pace with demand because of a number of constraints:

I. *Technological constraints*

A. Lack of high yielding varieties: The traditional lentil varieties generally have low yield potential. They are susceptible to various pests and diseases, have unstable yields, and are unsuited to different production systems, all of which must be overcome with better varieties.

B. Lack of quality seed: Poor quality seeds suffer from low levels of germination, seed-borne diseases, and contamination, all of which appear to be managerial rather than technological problems.

C. Input management: Lentil farmers do not apply fertilizers, *Rhizobium,* irrigation, or weed control measures – all of which constitute the major reason for unstable lentil yields.

D. Storage pests and diseases: Suitable control measures for pests and diseases, both in the field and during storage, must be developed, in conjunction with tolerant or resistant varieties.

II. *Other constraints*

A. Scarce and expensive labor: Lentils and other food legumes are crops of farmers with small holdings. During peak work hours, scarce and costly labor significantly constrains production by delaying important field operations and reducing efficiency. The solution is to develop small machines and implements to improve yield and efficiency.

B. Expensive chemicals: Costly agricultural chemicals such as fertilizers, fungicides, insecticides, and herbicides should be subsidized, and farmers instructed in their use.

C. Poor practices: A potentially high-yielding variety may give low yields without adequate fertilizer and plant protection measures. Packages of recommended practices should be prepared for each legume crop, and farmers trained in their use.

D. Lack of efficient cropping system: Pulses are generally grown as intercrops, mainly to ensure against failure of one crop and to produce enough for consumption. More efficient cropping systems must be developed to obtain the highest economic benefits.

Agronomy of lentils

The agronomic requirements of lentil vary from one region to another, depending on climate and cropping system.

I. *Cultivars*

Yield stability of lentil cultivars was analyzed by Singh *et al.* (1975) at Kanpur and Jhansi. They reported that cultivars L9-12 and TT-3 gave the highest average yields of 1.53 and 1.56 t/ha^{-1}, respectively. Cultivars Pusa 4, L 9-12, and Bombay 18 recorded high mean yields and had regression coefficients of about unity with least deviation, indicating that these cultivars are highly adaptable to all environments. Although cultivars PL-5, PL-8, Pusa-6, TT-2, and TT-3 produced high mean yields, they showed regression coefficients above unity and greater variation, suggesting that they are adapted only to more favorable environments. Cultivars B-77, NP-11, and Pusa 1, however, were suitable to unfavorable environments. Out of several varieties tested by Singh and Mehra (1976), T-36 was the most widely-adapted variety, followed by PL-8 and Bombay-18. Ojha *et al.* (1977) and Shrivastava (1979) observed that L9-12, Pant L-406, Pant L-209, and BR-25 yielded high under Bihar conditions. Pandya *et al.* (1980) identified Pant L-406 as a rust and wilt-resistant variety for the sub-Himalayan region, while Sen (1981) recommended S-256 (Ranjan) for West Bengal.

On the basis of varietal testing in different agro-climatic zones, the following varieties are recommended for general cultivation:

- Northwest plain zone: L 9-12, Bombay-18, Pusa-4, Pant L-406, Type-36, Pusa-1, Pant-639, Pant L-638, and Pusa-6.
- Northeast plain zone: T-36, Pusa-4, Pant L-406, BR-25, B-77, S-256 (Ranjan), and BR-12.
- North hill zone: LG-7, LG-8, LL-3, LL-5, and NP-11.
- Central zone: PKV-1, JLS-1, JLS-2, JLS-4, Sehore-34, PL-5, PL-8, JL-80, JL-85, and T-8.

II. *Sowing time*

Optimum time of sowing and plant density are the major determinants of full yield potential of improved varieties. The optimum sowing time varies in different agro-ecological conditions, depending on climatological parameters. Indian farmers normally use broadcast sowing, a primitive method that results in a poor plant stand because seeding depth is uneven and weed control difficult. Various genotypes behave differently on different sowing dates, and several studies in India have indicated that mid-October to mid-November is the optimum sowing time in the plains of north and central India. Yadav and Saxena (1973), Kannaiyan and Nene (1975), Pandey *et al.* (1981), and Singh and Saxena (1982) observed that sowing lentil on Oct 30 gave the highest grain yield (1.5 t/ha) in the sub-Himalayan region. As sowing is progressively delayed, yields gradually decrease. In the eastern part of India, Upadhaya and Sahariya (1977) recorded the highest lentil yield (1.06 t/ha) with sowing in mid-November. Delayed sowing significantly reduced yield possibly due to the shorter period of crop growth. Saraf and Baitha (1979) obtained significantly higher yields under Delhi conditions of North India, when lentil was sown between the end of October and mid-November. A shorter growing period might result in less dry matter accumulation and fewer pods and nodules/plant, which reduces grain yield. The protein in grains, however, increased with delayed sowing (Table 1). Shrivastava (1979) reported mid-November as the optimum sowing time (1.95 t/ha) under Bihar conditions. Kannaiyan and Nene (1975) observed decreased disease intensity with delayed sowing.

Table 1. *Influence of date of sowing on grain yield (t/ha) and protein percentage in lentil.*

Date of sowing	Grain yield (t/ha)	Protein (%)
Oct 25	1.98	23.6
Nov 16	1.97	23.8
Dec 7	1.09	24.1
CD 5%	0.15	0.3

III. *Plant density*

The response to plant density (seed rates) varies with different sowing dates. Significant interactions in most of the research trials in India showed that with early sowing in the end of October, a wider row spacing of 30 cm (1.48 t/ha) is best, while delayed sowing results in a higher yield (1.32 t/ha) with narrowly-spaced (15 cm) rows (Saxena and Yadav 1976; Saraf *et al.* 1975). Different genotypes and growing conditions are largely responsible for variations in growth and yield. With delayed sowing, higher plant density results in increased crop canopy, higher incident solar radiation, and higher yields.

Climate affects lentil yields in India, since the response to row spacing is definitely related to the amount of rainfall in the preceding monsoon (rainy) season, especially with cultivation under rainfed conditions.

IV. *Seed treatment*

Agrawal *et al.* (1976) and Vishunavat and Shukla (1981) observed that seed treatment with Bavistin was most effective in increasing emergence, plant density, and seed yield. Treatment with Thiram and Captan were next most effective.

V. *Rhizobium inoculation and nutrient management*

Lentil responds to balanced fertilizer application as well as inoculation with efficient *rhizobium* strains, since a lentil crop yielding about 1.6 t/ha removes about 75-80 kg N/ha, 22 kg P_2O_5/ha, and 60-64 kg K_2O/ha. Ojha *et al.* (1977), Panwar *et al.* (1977), Sekhon *et al.* (1978), Bisen *et al.* (1980), and Sanoria and Mallik (1981) observed at different locations in north India that inoculation with an efficient *rhizobium* strain increased lentil yields by 10-17%, depending on location. Response to phosphorus was variable. Singh and Marok (1981) reported the critical level of available P for lentil as 15 kg P_2O_5/ha. Chowdhury *et al.* (1974), Sinha (1977), Rizk (1979), Singh *et al.* (1979), and Saraf and Baitha (1982) observed 40-50 kg P_2O_5/ha as the optimum dose for lentil.

Significant response to potassium was not observed, probably due to its higher initial status in the soils. Sharma (1970) obtained a significant increase in lentil yield with 22 kg K_2O/ha on sandy loam soils at Gurdaspur (Punjab) in two out of three years. However, no response to K was obtained at other locations in India (Saxena and Yadav 1976; Panwar 1978).

VI. *Micronutrients*

Research on micronutrients in lentil has been very meager in India. As cropping intensity has increased, the soils show deficiency in zinc, molybdenum, and boron. Shukursha (1976) reported from Pantnagar that zinc application at 5 ppm markedly increased the number and weight of nodules and their leghaemoglobin contents. Nodulation, dry matter accumulation, and biological nitrogen fixation were highest in zinc-treated plots. At the same location, Chandra and Bangwar (1977) observed acute zinc deficiency in lentil followed by rice. They also noted that the critical limit for available zinc extracted by different extractants ranged between 1.81-0.34 ppm zinc extracted by 0.05 N HCl + 0.025 N H_2SO_4.

VII. *Water management*

Lentil requires as much water as wheat or barley; however, more than 90% of Indian lentil farmers cultivate lentil on conserved soil moisture or residual soil moisture left after paddy, resulting in low yields. Optimum soil moisture in the profile at critical growth stages of the crop helps to increase the yield of rabi pulses (Saraf *et al.* 1968). Dastane *et al.* (1971) and Singh (1976) reported that the 4-6 leaf stage was the most critical for irrigation of lentil grown on sandy loam soils of Delhi.

It was further reported from IARI, New Delhi that three irrigations applied at 3, 10, and 15 weeks after sowing resulted in highest yield in sandy loam soils. Under limited irrigation, two irrigations at 3 and 10 weeks after sowing produced significantly higher yield than a single irrigation (IARI 1973). Singh (1973) reported significant improvement in yield (56% $>$control) at Hissar with irrigations at 6 and 10 weeks. Panwar and Paliwal (1975) at Kanpur reported a significant effect with late sowing of a pre-sowing irrigation plus two later irrigations, one at 45 and a second at 75 or 105 days after sowing, resulting in a yield of 1966 kg/ha^{-1}, compared to the control yield of 435 kg/ha^{-1}. Ojha *et al.* (1977) observed in Bihar that only one irrigation at either pre-flowering or post-flowering stage produced the highest yield (21.4 q/ha^{-1}). Increased irrigations at all stages significantly reduced yield (16.49 q/ha^{-1}). However, at IARI, New Delhi, Saraf and Baitha (1979) observed significant response for up to three irrigations. The water requirement ranged from 155 mm with one irrigation to 214 mm with four irrigations for a lentil crop timely sown. About 67% of the total soil moisture depletion occurred in the upper 30 cm of soil, with another 25% in the second 30 cm.

Hamoudi (1979), Rizk (1979) at IARI, Singh *et al.* (1979) at Hissar, and Verma and Kalra (1981) at Meerut observed that lentil responded significantly to two irrigations, one at pre-flowering and one at pod-filling stage. Murari (1982) studied the response of lentil to mulching and kaolin spray under various soil moisture regimes at IARI, New Delhi. He reported that mulch application reduced water loss and increased yield by about 15%. Tension of 1.5 bar in 0-22.5 cm depth was optimum for irrigation in lentil.

In summary, when lentil is grown on conserved soil moisture, response to irrigation depends upon the amount of soil moisture conserved, which in turn depends upon the preceding season's rainfall as well as soil depth and texture. Significant responses to irrigation have been obtained on sandy loam soils, mainly because of their lower water-holding capacity. Pre-flowering (peak vegetative phase) and pod-filling appear to be the critical stages for water requirement.

VIII. *Weed management*

Since lentil is mainly grown on conserved soil moisture in low-lying areas, weeds have not been a major problem before, but as more irrigated lentils are grown, they may become one. Uncontrolled weeds may reduce yield up to 90%. Weeds in lentils are more commonly controlled mechanically than by chemicals. Studies have indicated that weed control is most critical for lentil during the first 6-8 weeks after sowing.

Singh (1973), Ahlawat *et al.* (1981), and Faroda and Singh (1981) reported that mechanical weeding at 20-25 days after sowing increased lentil yield by about 115%. Singh and Mani (1981) at IARI studied the residual effect of atrazine and alachlor, applied at different doses to maize, on weed management in lentil. No toxic residual effect was observed on the following lentil crop and few weeds appeared. Ahlawat *et al.* (1979) at IARI compared various herbicide treatments with mechanical methods of weed control. Weed competition reduced lentil yields up to 50% in different years. Among the chemicals, alachlor 1.5 kg/ha (pre-emergence) and prometryne 0.25-0.50 kg/ha^{-1} (pre-emergence) recorded significantly better yields than with no herbicide. Weed management clearly shows promise for increasing lentil yield.

IX. *Salt tolerance*

Rai (1983) studied the salt tolerance of *rhizobium* strains and lentil genotypes in Bihar, India. He observed variation in different strains and cultivars. The cultivars Pant L-406, Pant L-639, and BR-25 tolerated 1.0-1.25% sodium chloride. Only cultivar Pant L-639 resisted high salinity, up to a level of 3%. Such cultivars should be used in breeding programs.

Conclusion

This review demonstrates great scope for improving lentil production in India, although the development of improved cultivars proceeds slowly. The major constraint to increasing yield is the lack of agronomic management technology suited to the varied conditions under which the crop is grown. Input management, furthermore, is almost unknown to Indian lentil farmers. As recent studies show, however, lentil yields can be increased substantially with the appropriate inputs and practices discussed here.

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Effects of gravity on lentil root growth

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Abstract

An experiment is planned in space (SPACELAB) to study the effects of microgravity on lentil root growth and on root curvature. It should shed light on the role of the endoplasmic reticulum-amyloplast complex in the geosensing cells. At the same time, the interaction between the mechanism of perception of gravity, mitotic activity, and cell differentiation will be investigated. As background to this experiment, recent work on geotropic response of roots is reviewed.

Introduction

Gravity greatly influences the direction of growth in plants (Larsen 1962a and b). Primary roots and stems grow in the direction of gravity (orthogeotropism), whereas secondary roots and lateral branches grow obliquely to it (plagiotropism).

Any change in the orientation of the main axis of a plant causes curvature of its primary root (as well as other organs). This results in the reorientation of the root's tip in the direction of gravity, due to the growth asymmetry of the upper and lower sides of the root. This phenomenon results from accelerated differentiation of the upper part of the meristem and the elongation zone. Thus, the structure and growth of the root are disturbed by a gravitational stimulus and are partly controlled by a system which allows the root to orient itself relative to gravity.

The organs that respond to gravity have special cells (statocytes) with voluminous amyloplasts that are able to move under the action of gravity (Audus 1962, 1979). These cells are involved in the perception of gravity and the orientation of the plant organs (Iversen and Larsen 1973; Juniper 1976, 1977; Sievers and Volkmann 1972; Perbal and Perbal 1976; Volkmann and Sievers 1979). Gravity can also play a role in the distribution of growth regulators (Gibbons and Wilkins 1970, Pilet 1971, 1973, 1976, 1981; Shaw and Wilkins 1973). Thus, gravity is necessary for normal development of vascular plants. Plant physiologists have tried to simulate weightlessness to determine all the effects of gravity on plant morphology, using clinostats to prevent the geotropic reaction of primary roots and stems by rotating the plantlets around a horizontal axis (Shen-Miller *et al.* 1968; Shen-Miller 1970). However, the mechanism of action of this apparatus is still unclear and will not be elucidated until plants grown on a clinostat can be compared to plants grown in microgravity. It is, therefore, proposed to study root growth and cell differentiation in lentil seedlings in microgravity as a part of the BIORACK project (D1 mission of SPACELAB, Nov 1985). This paper describes the details of this experiment. As background to the proposed experiment, the current understanding of the effect of gravity on root growth and development is reviewed here.

1. *The effect of gravity on root growth and development*

1.1. *Root structure.* Many studies have dealt with the structure of the tip of primary roots (Lance-Nougarede and Pilet 1965; Pilet and Lance-Nougarede 1965; Barlow 1975; Clowes 1976; Harkes 1976). The structure and function of the root tip is relatively similar in different species of plants. The root tip is composed of the cap, the meristem, and the elongation zone (Fig. 1). The cap has four parts: the axial and lateral meristems which produce, respectively, the statocytes and the peripheral cells (Perbal 1974). The root meristem is composed of three functional

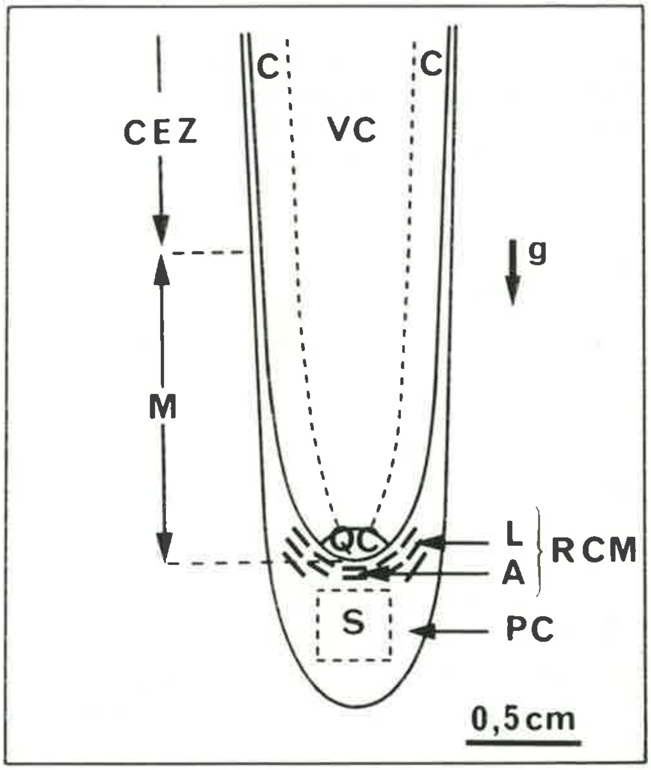


Fig. 1. *Structure of the lentil root tip. C, cortex; CEZ, cell elongation zone; g, direction of gravity; M, meristem; PC, peripheral cells; QC, quiescent center; RCM-A, axial root cap meristem; RCM-L, lateral root cap meristem; S, statocytes; VC, vascular cylinder.*

zones: the quiescent center, the proximal meristem (where the plane of division is random), and the distal meristem (where the plane of division is perpendicular to the root axis).

The cells cease to divide and begin to differentiate rapidly beyond the meristematic zone. The text that follows deals mainly with the cortical cells which are most important in the root's response to gravity (Pilet *et al.* 1969; Pilet and Lance-Nougarede 1974).

1.2. *Modifications of root growth during geotropic stimulation.* When the primary root of a lentil grows in the direction of gravity, the proximal and distal meristems extend from the quiescent center to 2 mm from the root extremity, and the cell elongation zone extends from the second to the sixth mm.

When the root is placed horizontally for 2 hrs, it bends (Fig. 2) and reorients its tip. The zone of curvature stretches from the 1st to the 3rd mm; i.e., where the distal meristem and the zone of the very beginning of cell differentiation are normally located.

The average growth of the lower part of roots placed in a horizontal position (i.e. stimulated for 2 hrs (0.87 ± 0.23 mm)) is similar to that of vertically-orientated roots (0.88 ± 0.15 mm). In contrast, the upper side of stimulated roots grows more rapidly (1.49 ± 0.20 mm) than that of vertical roots (Darbelley and Perbal 1984).

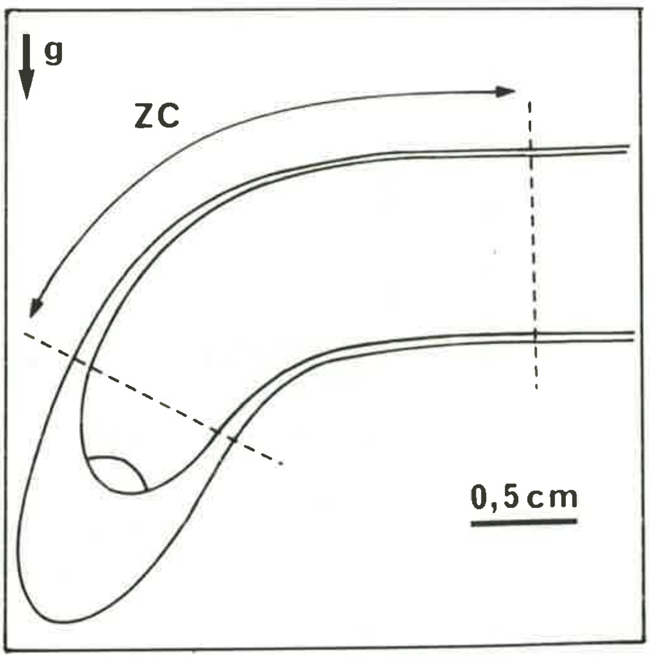
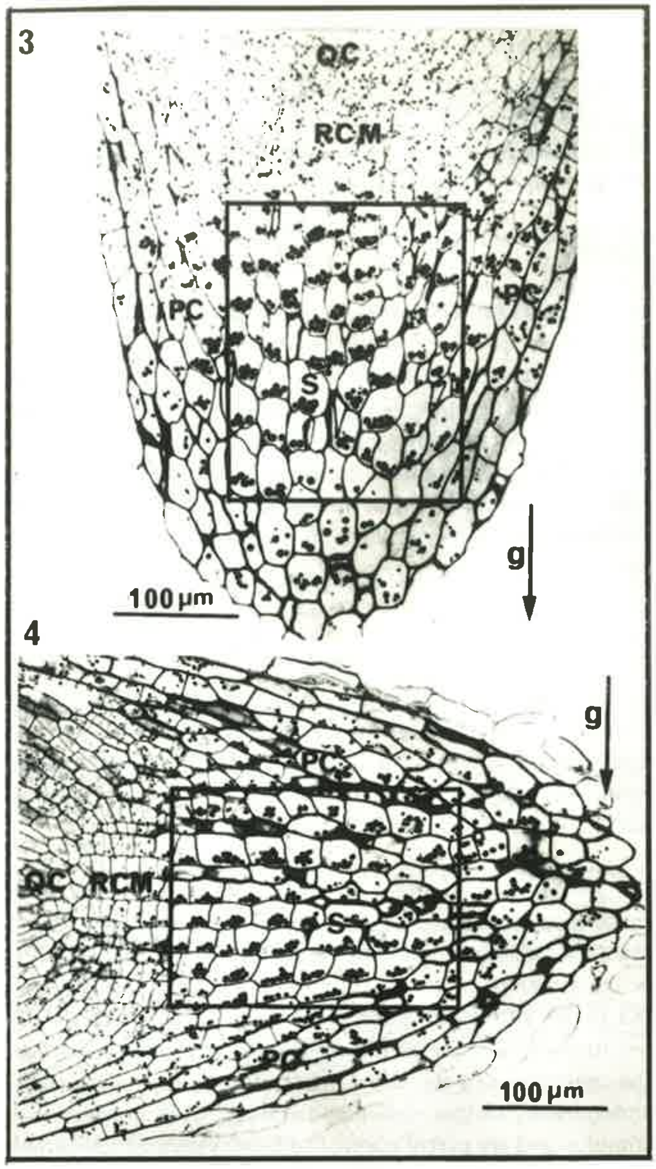


Fig. 2. *Location of the zone of curvature (ZC) of a lentil root stimulated for 2 hrs; g, direction of gravity.*



Figs. 3 and 4. *Thick-thin sections of lentil roots placed vertically (3) and horizontally (4). g, direction of gravity; PC, peripheral cells; QC, quiescent center; RCM, root cap meristem; S, statocytes. Sections stained with PAS.*

Physiological studies have shown that the curvature results from the redistribution (toward the lower half of the root) of a growth inhibitor produced by the cap (Gibbons and Wilkins 1970; Pilet 1971, 1973, 1976; Shaw and Wilkins 1973) and simultaneously of a growth factor arising from the older part of the root (Pilet 1981).

1.3. *Perception of gravity.* The cells responsible for the perception of gravity (statocytes) are located in the center of the root cap (Fig. 1). The statocytes contain voluminous amyloplasts (statoliths) capable of moving in the direction of gravity. Figures 3 and 4 show longitudinal axial sections of lentil roots placed in vertical or horizontal positions. In both positions, the sedimentation of the amyloplasts in response to gravity is clearly observed. Sedimentation results from the starch grains in the amyloplasts, which are much denser than the surrounding cytoplasm.

When the starch of the plastids is removed by a hormonal treatment (gibberellic acid, with or without kinetin), these organelles do not move in response to gravity (Iversen 1969). Similarly, decreasing the volume of the amyloplasts by etiolation of seedlings reduces the geotropic reaction in the roots (Perbal and Riviere 1976).

The ultrastructural study of these geosensing cells in roots grown in their normal position (Fig. 5) shows that statoliths are sedimented on the distal wall. On the other hand, in roots stimulated for 20 min, the amyloplasts do not reach the plasmalemma lining the longitudinal wall (Fig. 6), and large aggregates of endoplasmic reticulum (ER) are located along the distal wall. The role of the association between amyloplasts and aggregates of ER is not yet well understood. According to Sievers and Volkmann (1972), the ER-amyloplasts complex should be responsible for inducing geotropic stimulation. In contrast, Iversen and Larsen (1971, 1973) and Perbal (1977, 1978) have hypothesized that this complex should represent a mode of regulation of the curvature; i.e., it should terminate the stimulation. In effect, the stimulus should result from the pressure, contact, and movement of the amyloplasts on the cytoplasm lining the plasmalemma (Perbal and Perbal 1976).

The role of the endoplasmic reticulum in the perception of gravity by roots thus remains to be determined. The BIORACK project gives us the opportunity to analyze the role of the endoplasmic reticulum by disturbing the polarization of the ER-amyloplasts complex in microgravity.

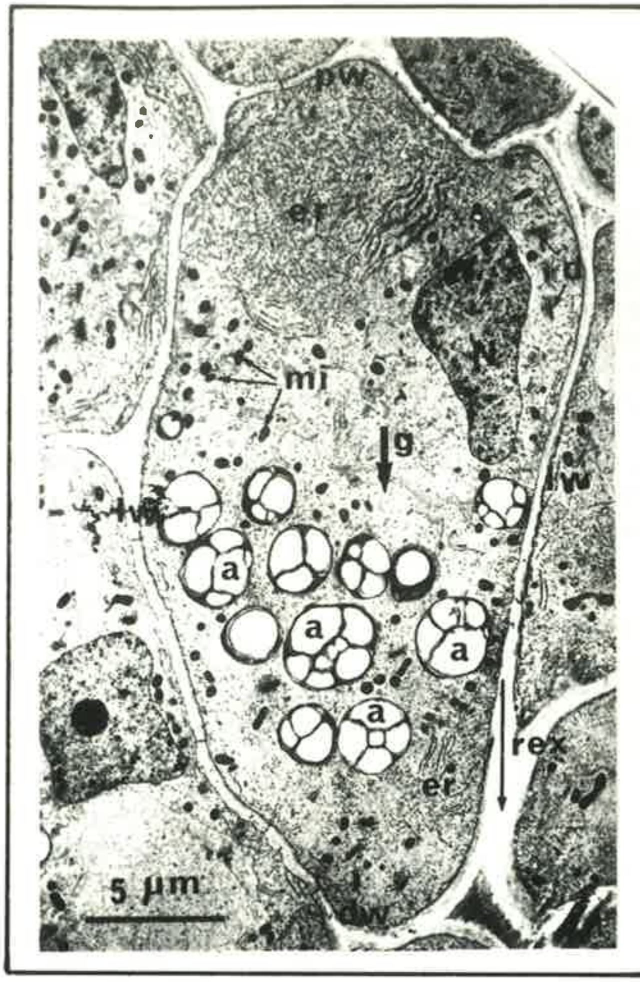


Fig. 5. *Statocyte of a lentil root cap in the vertical position (see legend below).*

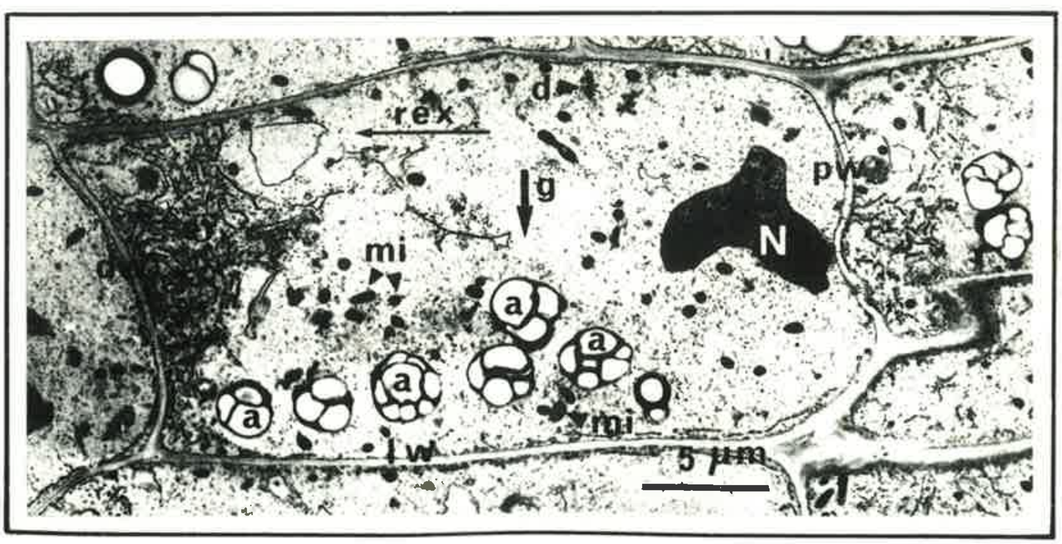


Fig. 6. *Statocyte of a lentil root cap after a 20 min stimulation in a horizontal position.*

Legend to Figs. 5 and 6. *a, amyloplast; d, dictyosome; dw, distal wall; er, endoplasmic reticulum; g, direction of gravity; lw, longitudinal wall; mi, mitochondria; N, nucleus; pw, proximal wall; rex, root extremity.*

2. *Space experiment*

Three conditions of growth are planned for the space experiment (Fig. 7). Some seedlings will be grown in microgravity. Other seedlings will be cultivated on the 1 g centrifuge so that their roots grow in the direction of centrifugal acceleration. Still other seedlings will be cultivated in 0 g and then placed on the centrifuge for 3 hrs in two different positions, to determine if they are still able to respond to an acceleration of 1 g. During the flight, seeds will be hydrated to permit root development and also photographed, and roots will be chemically fixed. After landing, the following aspects will be analyzed: root orientation, root growth, mitotic activity in root cells, cell differentiation, and ultrastructure of statocytes and of the ER-amyloplast complex.

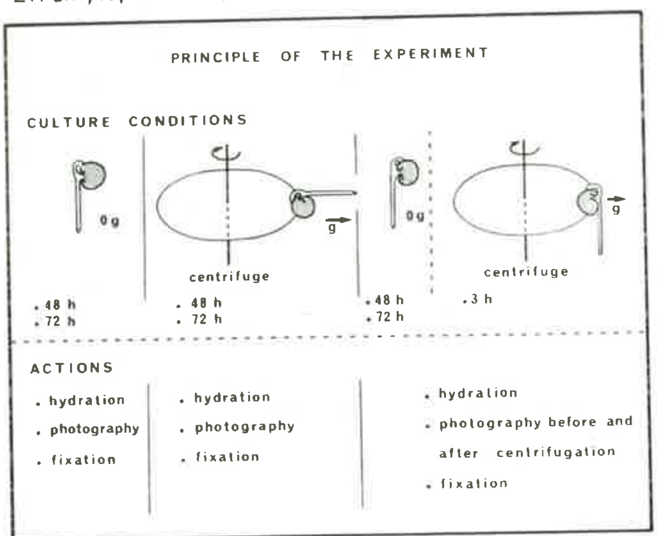


Fig. 7. *Principle of the experiment, culture conditions, and operations to be done during flight.*

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RESEARCH ARTICLES

Breeding and Genetics

Association among economic traits in lentil

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Abstract

Correlations among economic traits—time to flower, time to maturity, seeds/pod, 1000-grain weight, grain yield, dry matter production, and harvest index—were studied in 19 promising Indian cultivars. Large variation was recorded for all these characters except for time to maturity. Seed size had a highly significant negative correlation with seeds/pod (r = – 0.79). A significant negative correlation between time to flower and 1000-grain weight (r = – 0.68) indicates that most of the bold-seeded Indian lentils are early flowering. Longer periods of flowering and maturity produced more dry matter. The traits of seeds/pod and total dry matter increased grain yield the most. Harvest index was negatively correlated with earliness, while a harvest index of 40-50% was best for high yield. Total dry matter was also significantly and positively correlated with grain yield.

Introduction

The average lentil yields in India are very low (465 kg/ha). Although yield increase is the ultimate objective of a breeding program, identification of important yield components increases breeding efficiency. Therefore, to determine which characters have the greatest effect on yield, this study used character association to identify lentil traits that can be used, in isolation or combination, as selection criteria.

Materials and Methods

All 19 varieties tested in the All India Coordinated Variety Trial in the 1981/82 season were used in this study. These varieties were developed at different centers and represent a fairly wide range of genetic variability among Indian lentils. The varieties were sown in a randomized complete block design with four replications on 24 Nov, 1981. Net plot area was 11.25 m^2. Rows were spaced 22.5 cm apart and plants within rows were spaced 3 cm apart. Observations were recorded on time to 50% flowering (days), time to 50% maturity (days), seed number/pod, 1000-grain weight, total dry matter, and grain yield. The harvest index (HI) was calculated in percentage on a plot basis. Simple correlations were calculated for all possible character pairs.

Results and Discussion

Genetic variability

The range of variability given in Table 1 shows that the material has sufficient variation for all characters except time to maturity. More or less uniform maturity occurs under Indian conditions, irrespective of very conspicuous differences in flowering time, because the sharp temperature rise in late spring induces forced maturity.

Table 1. *Range, mean, and standard error of economic traits of 19 lentil cultivars tested at Delhi, 1982.*

Character	Range	Mean	S.E.
Time to 50% flowering	68 - 95	80.5	8.55
Time to 50% maturity	129 - 139.5	134.9	10.04
Number of seeds/pod	1.3 - 1.9	1.12	0.14
1000-grain weight (g)	14.88 - 32.69	21.98	5.54
Dry matter yield (kg/ha)	3556 - 6878	5081	980
Grain yield (kg/ha)	1256 - 2489	1849	347
Harvest Index (HI %)	26.6 - 45.0	36.8	5.73

Character association

The correlation studies (Table 2) show that time to flower has a significant negative correlation with 1000-grain weight (r = – 0.68) and harvest index (r = – 0.64). Flowering

Table 2. *Correlations between important economic characters.*

Character	Time to 50% maturity	Seeds/ pod	1000- grain weight	Dry matter yield	Grain yield	Harvest Index (HI)
Time to 50% flowering	0.32	0.48*	– 0.68**	0.46*	0.10	– 0.64**
Time to 50% maturity		– 0.04	0.01	0.32	– 0.42	– 0.12
Seeds/pod			– 0.79**	0.43	0.46*	0.10
1000-grain weight				– 0.40	– 0.23	0.18
Dry matter yield					0.62**	– 0.41
Grain yield						0.46*

*Significant at P = 0.05
**Significant at P = 0.01

time, however, shows a mild and non-significant positive correlation with grain yield (r = 0.10), while delayed maturity has a much stronger negative relationship with grain yield (r = – 0.42). Negative correlation between maturity and yield has also been reported by Muehlbauer (1974) and Singh and Singh (1970). It is evident that a longer growth period, as indicated by late flowering, may help to increase yield somewhat, but excessively delayed maturity under Indian conditions always lowers yield by significantly reducing seed size (r = – 0.68). The negative correlations of time to flower and maturity with harvest index indicates simply that prolonged vegetative growth produces more vegetative matter, which is further confirmed by the strong positive dependence of dry matter yield on time to flower (r = 0.46) and maturity (r = 0.32).

Delayed maturity within the range studied significantly increased seed number/pod (r = 0.48). Therefore, late maturity, up to certain limit, can increase yield by increasing seeds/pod and dry matter accumulation, since yield is dependent on seeds/pod (r = 0.46) as well as on total dry matter.

Seed size decreased seed number/pod (r = – 0.79), a correlation observed before in many crops, including lentil (Sarwar *et al.* 1972; Wilson 1977). Nevertheless, seed size may not ultimately be a major block to breeding for yield, because its negative correlations with dry matter accumulation (r = – 0.40) and grain yield (r = – 0.23) are non-significant. Grain weight showed a mild positive correlation with HI (r = 0.18) in the 19 varieties, which might be improved through further breeding work. Therefore, it should be possible to combine grain size with yield potential, since HI has a high positive correlation with grain yield (r = 0.46).

Macrosperma lentils introduced from abroad have not succeeded in India, mainly because these strains mature extremely late and yield poorly. However, this study indicates that large seeds may not be solely responsible for low yields of *macrosperma*, and that larger seeds could raise yield potential, provided that breeding addresses other growth requirements.

Harvest index as a selection criterion

HI is generally low (30-40%) in most pulse crops (Jain 1971). Many workers regard HI as a dependable parameter of yield potential, and this study confirms a positive association between HI and yield (r = 0.46). At the same time, dry matter accumulation has still greater impact on yield, as shown by one of the highest correlation coefficient values for this character pair (0.62) obtained in this study (Table 2). Simultaneous increase in total dry matter and HI mean that additional biomass accumulated in the form of grain—the ideal situation for improving yield potential. We have also found that delayed flowering and maturity favor total dry matter accumulation (r = 0.46 and 0.32), but not grain yield (r = 0.10 and – 0.42) or HI (r = – 0.64 and – 0.12).

Although HI generally provides a good indicator of yield potential, this study reveals some exceptions. The variety Sehore 74-3, with 48.08% HI, yielded 2189 kg/ha, whereas the highest-yielding cultivar, Pant L 639, with 38.55% HI, yielded 2489 kg/ha (Table 3). Although Table 3 shows that the genotypes with low HI (26.62-32.99%) gave low yields (1322-2056 kg/ha), and those with high HI (38.55-48.08%) yielded higher (mostly above 2000 kg/ha), there was a substantial overlapping of yield potential between the various HI groups, with frequent exceptional combinations of yield and HI. In spite of a positive HI-yield correlation obtained in this study and reported earlier (Singh 1977), it is clear that optimum vegetative matter production as well as a good HI are essential for high yield. The reason for the high HI frequently reported in established varieties and promising breeding materials is that these genotypes are already selected for yield, with HI calculated later.

Table 3. *Harvest index and grain yield of best new Indian lentil cultivars in All-India Coordinated Variety Trial.*

Variety	Harvest index (%)	Yield (kg/ha)	Variety	Harvest index	Yield (kg/ha)
LL-153	26.6	1600	K76	36.9	1311
PL-79-8	29.4	2022	Pant L-639	38.5	2489
LG-120	30.3	2056	RAU-101	40.2	2044
LL-56	31.6	1733	Sehore 74-7	40.8	1578
Sehore-34	32.2	1322	Pant L-406	41.4	2078
PL-77-2	33.0	1833	Lens-1268	42.6	2222
LG-112	34.1	1256	Lens-1304	42.6	2250
LL-147	34.6	1700	VL-1	45.0	1967
PL-77-12	35.4	1878	Sehore-74-3	48.1	2189
LL-78	36.5	1589			

It appears that yield potential can be increased greatly, without an extremely high HI. This study suggests that an HI in the upper range (40-50%) is optimum.

Acknowledgements

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Agronomy and Mechanization

Water use patterns and water requirement of lentil planted on different dates

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Abstract

The effects of planting date, irrigation regime, and phosphate application on lentil yields and water use patterns were studied during the 1973/74 season in North India. Two irrigations increased seed yield from 952 kg/ha with no irrigation to 1557 kg/ha and gave a net profit of 2702 Rs/ha. More irrigation (3 and 4) doubled yields above the control and resulted in net profits of more than 4300 Rs/ha.

Introduction

Lentil (*Lens culinaris* Med.) is cultivated mostly in pure stands, unmixed with other crops, in the northern part of India up to an altitude of 500 m. It occupies an area of about 0.926 million hectares with a production of about 0.436 metric tonnes. However, yields are poor, only 465 kg/ha, and fluctuate. One important reason is that lentil is mostly grown under low moisture conditions with almost no inputs, and management is not as intensive as for cereals.

Approximately one third of the world's acreage under pulses is in India. Most of this area is rainfed and gives low yields. It is possible to augment pulse production by irrigating more area, using improved cultivars, and introducing agronomic management technology. The optimum soil moisture in the profile at the critical growth stage or stages of the crop increases the yield of winter pulses (Dastane *et al.* 1971; Saraf *et al.* 1968). Irrigation increases lentil yields (Saraf and Baitha 1979; Yusuf *et al.* 1979; Saxena and Wassimi 1980; Verma and Kalra 1981; Murari 1982).

Information is still lacking on optimum soil moisture regimes for different growth stages, consumptive use of water requirement, and water use efficiency in lentil sown on different dates. This study investigates water requirements and water use of lentil planted on different dates.

Materials and Methods

A field study was carried out at the farm of the Indian Agricultural Research Institute, New Delhi, during the winter season of 1973/74 on sandy loam soil with medium fertility and a pH of 8.1. Single value physical constants were determined for different soil layers (Table 1).

Table 1. *Some single value physical constants of the soil of experimental field.*

Soil depth from surface (cm)	Field capacity (%)	Permanent wilting point (%)	Bulk density (gm/cc)
0-15	17.33	6.79	1.52
15-30	17.54	6.54	1.49
30-45	17.54	6.66	1.48
45-60	17.34	6.69	1.48
60-90	17.08	6.64	1.50
90-120	17.79	6.61	1.54
Method employed:	Field method	Pressure membrane apparatus	Core sampler
Reference:	(Coleman 1944)	(Richards 1947)	(Piper 1950)

Depth to water table

Fig. 1 shows the mean values of depth to water table during the crop season. The water table ranged from 2.6 m at sowing time to 3.0 m at harvest, indicating that the water table did not contribute to the water required by the crop.

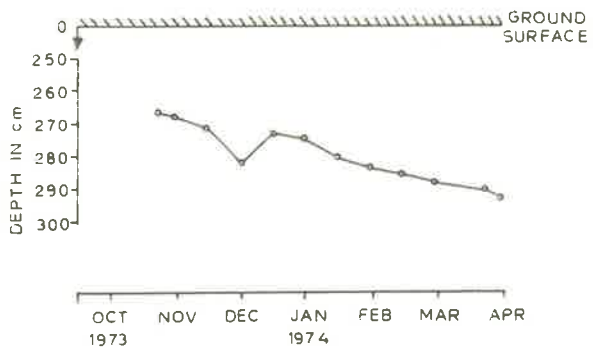

Fig. 1. *Depth to water table from ground level.*

The experiments were sown on three dates: end of October (D1), mid-November (D2), and beginning of December (D3). Five different soil moisture regimes were maintained: I_1, 0.0-2.0 atm tension during crop growth; I_2, 0.0-2.0 atm tension in vegetative phase and 0.0-4.0 atm tension during reproductive phase; I_3, 0.0-4.0 atm tension in vegetative phase and 0.0-2.0 atm tension in the reproductive phase; I_4, 0.0-4.0 atm tension throughout the crop growth period; and I_5, control. The gypsum blocks were embedded at 30 cm soil depth. Phosphorus was applied at three levels: 0, 60, and 120 kg P_2O_5/ha. The experiments were carried out in a split plot design with a combination of dates and irrigation in main plots and levels of phosphorus in sub-plots.

Results and Discussion

Data were recorded on soil moisture changes in different treatments during crop growth. Information was obtained on consumptive use of water, depletion patterns, and water requirement. Soil moisture was determined before irrigation at depths of 0-15, 15-30, 30-45, 45-60, 60-90, and 90-120 cm. Data on soil moisture use were used to work out the factors that follow.

Soil moisture changes and depletion patterns

This was determined from different layers in each soil moisture regime. Data taken before each irrigation in different treatments are graphically shown in Fig. 2. A series of troughs represent pre-irrigation soil moisture levels, and the peak represents the post-irrigation values. The trough represents the frequency of differential irrigation in each soil moisture regime on different dates.

The troughs in I_1 soil moisture regime were shallower than those in other soil moisture regimes on all dates, indicating that the intervals between successive irrigations were shortest in that regime. Further, the irrigation intervals shortened as the season advanced, showing the increased rate of soil moisture losses with the onset of the warmer season.

Cumulative depletion of soil moisture from different layers down to 120 cm (Fig. 3) indicates that the depletion in lower layers was always less than in upper layers in each soil moisture regime.

Water requirement and irrigation requirements

Data on total water requirement and irrigation requirement (Table 2) revealed that the total water use by lentil ranged between 115.23 and 228.43 mm for different dates of sowing in I_1, I_2, I_3, and I_4 regimes.

Relative economic efficiency of water use

To find out the economic efficiency of water use, the cost and net profits of differential irrigations were compared (Table 3).

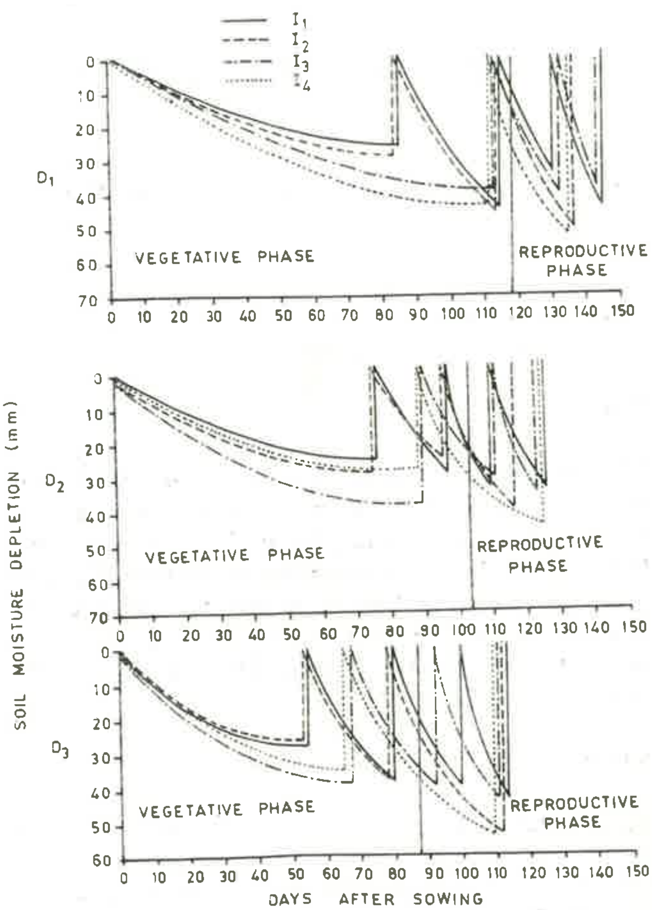

Fig. 2. *Soil moisture changes in different regimes.*

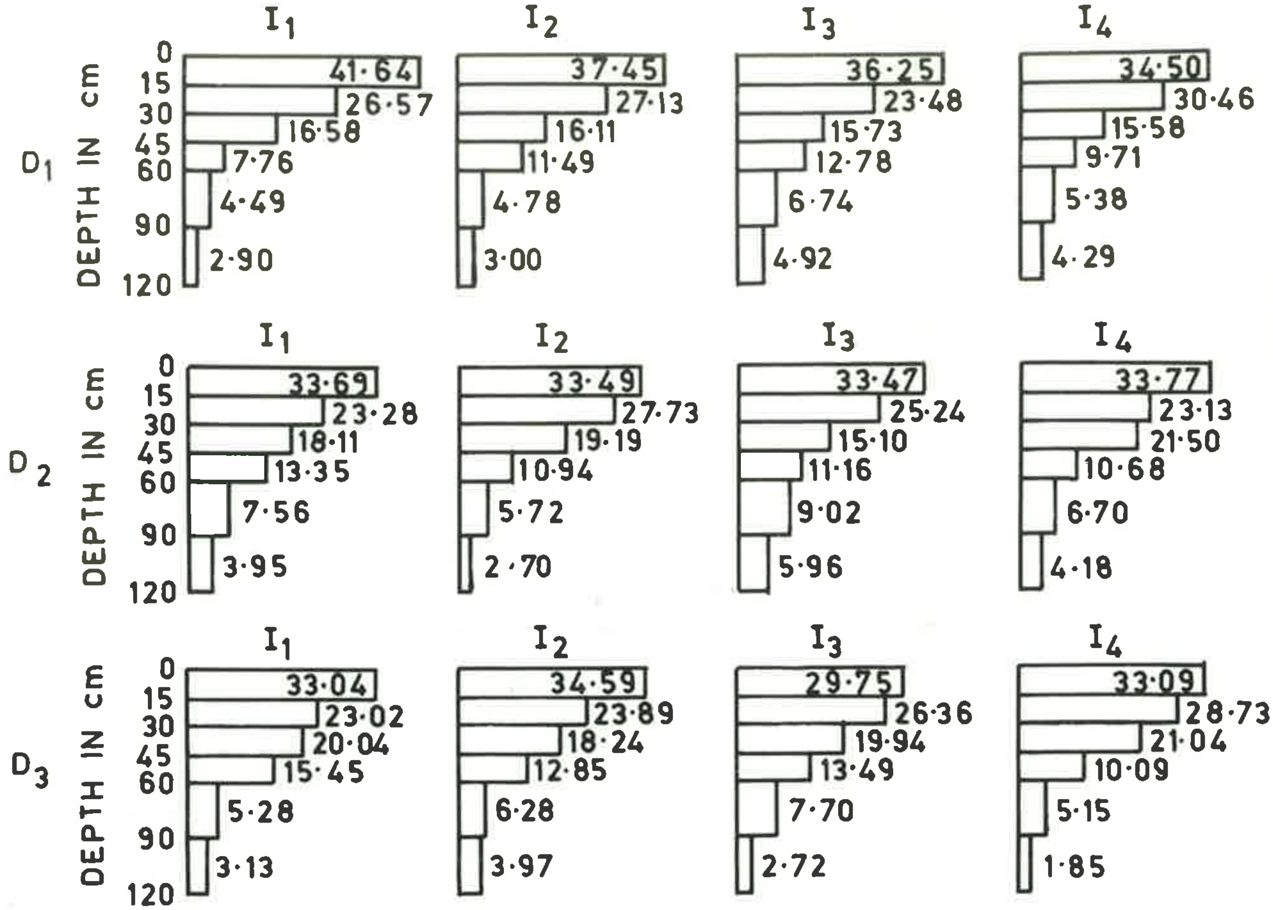

Fig. 3. *Moisture extraction in percentage in different treatments in lentil during the season.*

Table 2. *Water and irrigation requirement in different soil moisture regimes of lentils planted on different dates.*

Soil moisture regimes (dates)	Number of irrigations	Depth of soil moisture (mm)	Differential moisture (mm)	Effective rainfall (mm)	Irrigation requirement (mm)	Water requirement (mm)
(1)	(2)	(3)	(4)	(5)	(4+5)	(3+4+5)
$D_1 I_1$	4	27.73	186.9	Nil	186.9	214.6
$D_1 I_2$	3	27.73	165.0	Nil	165.0	192.8
$D_1 I_3$	3	27.73	161.1	Nil	161.1	188.8
$D_1 I_4$	2	27.73	127.2	Nil	127.2	154.9
$D_2 I_1$	4	24.26	179.1	Nil	179.1	204.2
$D_2 I_2$	3	24.26	137.3	Nil	137.3	161.5
$D_2 I_3$	3	24.26	141.7	Nil	141.7	169.1
$D_2 I_4$	2	24.26	90.1	Nil	90.1	115.2
$D_3 I_1$	4	26.01	202.4	Nil	202.4	228.4
$D_3 I_2$	3	26.01	162.5	Nil	162.5	188.5
$D_3 I_3$	3	26.01	162.5	Nil	162.5	188.5
$D_3 I_4$	2	26.01	122.6	Nil	122.6	148.5

Table 3 shows that irrigation of lentil is profitable. Data on comparative performance of different crops under limited irrigation have shown that food legumes are more profitable and economical considering the high cost of produce. Further, the fact that fertilizers are expensive and scarce should favor food legumes over cereals, since legumes require a lower level of inputs.

In conclusion, yield potential and input management of lentil should be improved so that lentil can compete favorably with high yielding cereals. This would improve lentil yields, increase acreage, and use irrigation potential more efficiently. The water requirement values in this study should guide the release of canal water for irrigation.

Table 3. *Relative economics of irrigation treatments.*

Irrigation treatments	Grain yield (kg/ha)	Number of irrigations	Cost of irrigation (Rs 40/ha) + application charges (Rs 10/ha)	Cost of produce (Rs 450/ 100 kg)	Net profit over control (Rs/ha)
I_1	1963	4	200	8833.50	4349.50
I_2	1970	3	150	8865.00	4431.00
I_3	1953	3	150	8788.50	4354.50
I_4	1557	2	100	7086.50	2702.50
I_5	952	0	0	4284.00	

(LS$ = Rs 12.75 approximately)

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Economics of cultivating lentils after rice or cotton in Kafr El-Sheikh Governorate, Egypt, 1983/84 season

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Abstract

The yield and net income from lentils were compared in two different crop rotations–lentils after rice and lentils after cotton–in Kafr El-Sheikh Governorate, Egypt. A survey of 40 farmers, 20 using each rotation, showed that seed yield, gross returns, and net returns were larger from lentils grown after rice. The gross return/variable cost ratio averaged 2.2 after cotton and 2.7 after rice, rated against the ratio of 1.5-2 considered reasonable for irrigated agriculture when all household inputs are counted as costs, as in this study.

Introduction

In the past, most Egyptian lentils were produced in Upper Egypt, with Assiut as the leading governorate. During the last few years, farmers began growing lentils in the Delta region, with encouraging results to date. Lentil specialists in the Delta noticed that yields of lentils cultivated after rice tended to be higher than when planted after cotton. This study, undertaken in the Kafr El-Sheikh governorate, a leading rice-growing area, had two objectives:

- To determine whether differences in lentil yields and net income under the two crop rotation were statistically significant.
- To analyze the economic profitability of growing lentils under the two crop rotations.

Data Collection

Sampling

In Kafr El-Sheikh governorate, lentils were grown only in the Biala and Sedisalim districts during the 1983/84 season. This study was conducted in the Biala district, where most lentils are grown. Data provided by the Department of Statistics, Ag-Management, Biala district showed that El-Shorafa village had 28% of the total lentil area in the district, with 17% in the village with the next largest area. To avoid location effects on the economic variables, all input and output prices, including labor wages, relate to El-Shorafa village and all sample farmers reside in that village. The total lentil area in this village was 228.48 ha (544 feddans) in the 1983/84 season.

A list of farmers growing lentils in this village in 1983/84 did not indicate the crop grown previously. Based on past economic studies in Egypt, a sample of 20 farmers in each of two groups was believed adequate. Hence, the first 20 farmers on the list growing lentils after cotton comprised the first sample, and the first 20 farmers growing lentils after rice comprised the second sample. All farmers in the samples had fairly small holdings, with the largest holdings in each group being 1.68 ha.

Field enumeration

Data were gathered with a questionnaire similar to that used in other production economics studies conducted by EMCIP in Egypt (Deuson *et al.* 1984a). Throughout the growing season, fields were visited periodically by production economics research unit enumerators and agricultural extension staff of the village. The enumeration procedures followed two guidelines: whenever possible, data were collected by direct field observation; if not, enumerators relied on information provided by the farmer during visits soon after major field operations or transactions occurred.

Economic Analysis Methods

Computation of variable costs

Variable costs were computed as follows:

- Hired labor costs are the products of the number of MDEs times a weighted average wage. One MDE equals one man-day and is assumed equivalent to 1.5 women-days or 2 child-days.
- Family labor costs are the products of MDEs and a weighted average wage.
- Equipment costs are estimated by multiplying the custom rental rate/hectare by the number of hectares on which equipment was used. The custom rate is also applied in the computation of owned equipment costs.
- Variable costs of seed and chemical fertilizers are computed by multiplying quantities provided by their unit-price in the market where purchased; i.e., the cooperative market or the free market.

Computation of gross returns

- Output price data are collected both at the government delivery price and on the open market.
- Gross field income from seed is calculated by adding the money value of the quantity delivered to the cooperative at the fixed government price to the money value of the quantity sold in the free market at the free-market price.
- The straw income is computed by multiplying the quantity produced by the prevailing price/unit.
- Total gross return equals the gross field income from seed plus the gross field income from straw.

Partial budgets

The purpose of using partial budgets is to compare the changes in returns with the changes in costs that are due to some adopted practice. The practices in this study are to cultivate lentils after cotton or after rice. Following Perrin *et al.* (1976), partial budgeting may be carried out in three major steps (for details, see El-Gamassy *et al.* 1983):

- Calculate average net return/unit area for each treatment.
- Choose a recommended treatment using dominance and marginal analysis as applicable.
- Use minimum return analysis and sensitivity analysis to check the suitability of the recommendation related to yield and price variability.

For this study, however, the comparison is based only on the first step.

Statistical Results

Analysis of variance was first used to determine which factors under the two alternative practices show statistically significant differences. Five variables were tested (Table 1). Scientists normally require that differences be significant at P = 0.05 or less. However, Perrin *et al.* (1976) argued that for economic analyses, significance at P = 0.10 or less should be accepted for making recommendations to farmers. Based on this guideline, seed yield, gross returns, and net returns were significantly larger for lentils planted after rice than for lentils planted after cotton. Differences in straw yield and variable costs, however, were not statistically significant.

The higher seed yield after rice may reflect a reduction in weeds since the large amount of irrigation water used with rice tends to kill many weeds before they can go to seed. Another possible cause is that the large amount of water used on rice washes the accumulated salts away from the root zone, possibly encouraging nodulation on the lentil crop that follows.

Table 1. *ANOVA results for five variables based on planting lentils after cotton or rice, 1983/84.*

Variable	Unit	Level after Cotton	Level after Rice	Probability*
Seed yield	Ardabs	3.96	4.84	0.07
Straw yield	Loads	2.70	2.90	0.26 NS
Gross return	LE	400.00	489.00	0.07
Variable cost	LE	181.00	180.00	0.92 NS
Net return	LE	219.00	309.00	0.05

*NS = Not significant.

Economic Results

Partial budget

Table 2 shows the average gross returns, variable costs by major operations, and net returns for growth of lentils following cotton and following rice. These are based on one irrigation in each case. Harvest costs dominate total variable costs, making up over half of the total in each case. Tractor costs for land preparation averaged about half as much after rice than after cotton, but the ranges overlapped. The range after cotton was LE 8.3-26.2 (US$ = LE 1.20 approximately) and after rice was LE 9.5-23.8. Seeding rates, however, tended to be higher after rice. The range after cotton was 83.3-126.2 kg/ha with 95.2 kg as the most frequent amount. After rice, the range was 95.2-126.2 kg/ha, with 114-119 kg as the most frequent. Other costs averaged nearly the same for the two rotations.

The gross return/variable cost ratio averaged 2.2 after cotton and 2.7 after rice. This compares with the 1.6-1.7 average for soybean in Menya Governorate in 1982 (Deuson *et al.* 1984b). A ratio of 1.5-2 is considered reasonable for irrigated agriculture when all household inputs are considered as costs.

Table 2. *Partial budgets based on planting lentils after cotton or rice, in LE/ha, in 1983/84.*

Item	Level after Cotton (LE/ha)	Level after Rice (LE/ha)
Gross returns:		
Seed	905.2	1115.0
Straw	47.6	49.0
Total	952.8	1164.0
Variable costs:		
Land preparation (tractor)	25.7	10.7
Seeding		
Seed and inoculation	61.4	71.0
Tractor	21.4	24.5
All labor	5.0	5.0
Total	87.8	100.5
Fertilization:		
Fertilizer	22.9	22.6
Manure hauling	0.7	0.0
All labor	6.7	5.4
Total	30.3	27.0
Weed control (labor)	34.8	29.0
Irrigation:		
Pump	10.5	8.6
All labor	6.7	9.0
Total	17.2	17.6
Harvesting and threshing:		
Machinery	60.5	64.3
All labor	174.8	179.5
Total	235.3	243.8
Total variable costs	431.1	428.6
Net return	521.7	735.4
	Ratio	
Gross returns/ variable costs	2.2	2.7

(US$ = LE 1.20 approximately)

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Influence of soil moisture regimes, straw mulching, and kaolin spray on yield-attributing characters, and correlation between yield and yield attributes in lentils

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Abstract

The effects of different soil moisture regimes, a soil mulch, and different spray regimes of kaolin were studied on lentils grown in two seasons (1978/79 and 1979/80) in North India. Irrigation increased both seed yield and straw yield, but the straw mulch and kaolin spray did not affect lentil productivity.

Introduction

Lentils are an important winter pulse grown in India. Cultivation is confined to marginal and sub-marginal lands coupled with low levels of production technology. Lentil production can be increased by applying proper management practices such as irrigation, straw mulching, and kaolin spray. Data indicate that lentils respond favorably to water supply based on time interval or depth of water; however, further investigation is still required on the effect of soil water potential on lentil performance. The use of straw mulch and a spray of kaolin suspension are advocated to reduce water loss from the soil surface and to check excessive transpiration from plants for yield increase in other crops. However, there is little information on the effect of straw mulching and kaolin spray on the productivity of lentils. Therefore, field studies were conducted to assess the effect of soil moisture regimes, straw mulch, and kaolin spray on the productivity of lentil plants.

Materials and Methods

A field trial was conducted during the winter seasons of 1978-80. Lentil variety Pusa 4 was grown in a split plot design with four replications at the Water Technology Centre, Indian Agricultural Research Institute, New Delhi. Treatments included three soil moisture regimes (no irrigation, and irrigation at 0.5 bar and 1.5 bar tension); two levels of mulch (no mulch and straw mulch at 4 t/ha); and four levels of 6% kaolin suspension (no spray, two sprays at pre-flowering stage + two sprays at post-flowering stage, two sprays at pre-flowering stage, and two sprays at post-flowering stage). Combinations of soil moisture regimes and mulch were assigned to main plots and kaolin spray to sub-plots. The sub-plots measured 5 x 3 m. Sowing was done in rows spaced 25 cm apart on 2 Nov 1978 and 31 Oct 1979. Harvesting dates were 5 Apr 1979 and 3 Apr 1980, respectively. A basal dose of 20 kg N, 60 kg P_2O_5, and 40 kg K_2O/ha was applied in both years. Seed rate was 40 kg/ha. Mulch was applied immediately after crop establishment. Measurement of 0.5 and 1.5 bar tension was made by installing a mercury manometer type tensiometer and pre-calibrated gypsum blocks, respectively. Tensiometers and gypsum blocks were installed at 20 cm soil depth. Surface -120 cm soil layers had field capacity between 16.1% and 17.8% , permanent wilting point between 4.1 and 7.7% , and bulk density between 1.51 and 1.57 g/cc. Soil had 20.6 and 30.9 kg P_2O_5/ha in the years 1978 and 1979, respectively. The respective values of K_2O were 102.0 and 105.6 kg/ha and those of nitrogen were 0.034 and 0.033% . Groundwater table fluctuated from 318.0 to 366.0 cm from ground surface in 1978/79 and from 381.5 to 468.5 cm in 1979/80. Simple correlation coefficients were computed between yield and various characters following standard procedure.

Results and Discussion

Yield attributes: Plant height increased significantly from no irrigation to irrigation at 0.5 bar tension in both years (Table 1). The numbers of branches and pods were the same at 1.5 and 0.5 bar tensions in 1979/80. But both these treatments produced more branches and pods than did the unirrigated control. Increased availability of soil moisture at 0.5 and 1.5 bar tensions showed no effect on these characters in 1978/79 because of the good rainfall distribution (162.2 mm). Grain weight and seeds/plant

Table 1. *Influence of soil moisture regimes, mulch, and kaolin spray treatments on yield attributes of lentil during 1978-80.*

Treatment	Height (cm/plant)		Branches/ plant		Pods/ plant		Grain weight (g/plant)		Straw weight (g/plant)		Grains/ plant		1000-grain weight (g)	
	1978/79	1979/80	1978/79	1979/80	1978/79	1979/80	1978/79	1979/80	1978/79	1979/80	1978/79	1979/80	1978/79	1979/80
Soil moisture regimes														
No irrigation	34.2	28.1	10.4	10.4	83.0	47.7	2.2	1.3	2.5	1.9	128.7	69.7	18.3	18.0
Irrigation at 0.5 bar tension	43.7	37.3	11.4	13.7	105.3	92.8	2.7	2.3	4.0	2.4	165.1	146.3	20.9	18.5
Irrigation at 1.5 bar tension	37.7	32.2	11.3	12.7	98.6	88.2	2.7	2.6	3.7	2.8	151.4	139.7	20.9	18.9
C.D. 5%	2.4	3.0	NS	2.1	NS	12.4	NS	0.4	0.6	0.4	27.4	21.4	NS	NS
Mulch treatment														
No mulch	38.1	31.9	10.5	11.6	87.3	63.9	2.4	1.9	3.2	2.3	140.1	97.7	19.5	18.5
Mulch	39.0	33.2	11.6	12.8	103.9	68.6	2.6	2.0	3.4	2.5	156.7	106.1	20.6	18.4
C.D. 5%	NS	NS	NS	NS	16.3	NS	NS	NS	NS	NS	NS	NS	NS	NS
Kaolin spray														
No spray	38.3	32.7	12.2	12.3	94.8	63.0	2.5	1.9	3.3	2.3	152.3	96.3	19.6	18.5
Two sprays at pre-flowering + two sprays at post-flowering	38.5	32.4	10.4	11.9	96.3	68.9	2.6	2.0	3.4	2.6	148.4	108.5	20.7	18.5
Two sprays at pre-flowering	39.4	33.1	10.3	12.6	90.6	73.0	2.4	2.1	3.0	2.4	135.4	109.3	20.0	19.0
Two sprays at post-flowering	38.0	31.9	11.3	12.2	100.8	60.1	2.6	1.9	3.5	2.3	157.6	93.4	19.9	17.9
C.D. 5%	NS	NS	1.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.5

NS = Not significant.

differed significantly in 1979/80 due to the levels of irrigation. Tensions of 0.5 and 1.5 bar were superior to no irrigation. There was no difference between the irrigated treatments. Soil moisture regimes had no effect on 1000-grain weight (Table 1). Dry weight and straw weight/plant were considerably lower under no irrigation than under irrigated plots at 0.5 and 1.5 bar tensions. Improved plant characters under 0.5 and 1.5 bar tensions were attributable to adequate supply of moisture, which promoted growth by increasing turgidity. These results confirm those obtained by Rizk (1979) and Singh (1980).

Application of straw mulch increased values of yield attributes, but not enough to cause significant variation except in number of pods/plant in 1978/79, for which straw mulch proved superior to no mulch. Similar results have been obtained elsewhere (Kumar *et al.* 1973).

Two sprays of kaolin during pre-flowering stage and four sprays during crop growth suppressed branching in 1978/79. The 1000-grain weight increased significantly under two pre-flowering kaolin sprays in 1979/80. Other plant characters were unaffected by different spray treatments. Whitening of plants with kaolin spray is generally adopted for improved productivity, through reduced leaf temperature and decreased stomatal conductance for reduced transpiration and higher leaf water potential. It appears from the present investigation that whitening the leaves was not beneficial to lentil, possibly because of reduction in CO_2 uptake and other associated factors (Stanhill *et al.* 1976; Moreshet *et al.* 1977). Moreshet *et al.* (1979) found a similar lack of response to kaolin in cotton.

Table 2. *Simple correlation coefficients (r) between total biological yield/ha and grain yield/ha and important plant characters.*

Plant characters	Total biological yield		Grain yield	
	1978/79	1979/80	1978/79	1979/80
Height (cm/ plant)	0.794*	0.749*	0.716*	0.687*
Number of branches/plant	0.168	0.648*	0.217*	0.648*
Total weight (g/plant)	0.510*	0.428*	0.525*	0.468*
Grain weight (g/plant)	0.336*	0.448*	0.399*	0.495*
Straw weight (g/plant)	0.599*	0.357*	0.578*	0.384*
Number of pods/ plant	0.352*	0.410*	0.419*	0.457*
Number of grains/ plant	0.378*	0.434*	0.446*	0.490*
1000-grain weight (g)	0.335*	0.226*	0.327*	0.241*

* Significant at 5%.

Correlation: Simple correlation coefficients (r) presented in Table 2 show that total produce was positively and significantly correlated with the yield-attributing characters of plant height, total weight/plant, grain weight/plant, straw weight/plant, pod and grain number/ plant, and 1000-grain weight in both years. Number of branches was strongly correlated with total yield in 1979/80. Grain yield was positively and significantly correlated with plant height, number of branches/plant, grain and straw weight/plant, pod and grain number/plant, and 1000-grain weight. The 1000-seed weight differences were not significant.

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Productivity of lentil in relation to N-availability and population density

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Abstract

In an experiment conducted on lentil cultivar L9-12, different population densities (80, 160, and 240 plants/m^2) and rates (0, 15, 30, and 45 kg/ha) of urea did not significantly affect yield. Population pressure within rows was compensated for mainly by number of branches. NO_3^- influx to the site of nitrate reduction was not limiting; rather, efficiency of nitrate reduction was very low. Soluble protein, chlorophyll, and chlorophyll a/b ratio were not significantly affected by the treatments. N supplement and accurate manipulation of plant density in a row were not important factors for lentil yield. Highest nodulation, recorded at flowering, was not affected by N treatments. Soil moisture, plant moisture, and relative growth rate declined during the early growth stage. The results suggested that nitrate-N supplement may not remarkably improve lentil yield, and that manipulation of water supply is necessary for optimum yield.

Introduction

The value of N fertilization to leguminous crops is well established. The responses of different legumes to N fertilizer have been reported (France *et al.* 1979; Podder and Habibullah 1982; Rahman *et al.* 1982). Reports on lentil N response, however have been inconsistent (Anam and Elahi 1981; HRS 1972; HRS 1975; HRS 1976; HRS 1977). ICARDA studies of symbiotic N_2-fixation with the N^{15} technique have shown that 86% of total nitrogen of lentil comes from dinitrogen fixation (ICARDA 1982). The remaining 14% of total N may come from soil, either through NO_3^- assimilation and/or through NH_4^+ assimilation. However, the major form of combined N in soil is in the form of NO_3^- (France *et al.* 1979). Therefore, the primary unknown component of lentil response to nitrogen fertilizer is the capacity of the lentil plants for NO_3^- assimilation. The key enzyme for the committed step of NO_3^- assimilation is nitrate reductase (NR) which was reported to be the rate-limiting enzyme for most of the crops (Dutta 1980; Dutta *et al.* 1980; Dutta *et al.* 1982; Beevers and Hageman 1969). NR is an inducible enzyme whose induction depends on substrate (NO_2^-) and energy supply (Beevers and Hageman 1969), and the influx of NO_3^- to the site of induction is the main factor regulating NR levels under conditions suitable for the induction of the enzyme (Meeker *et al.* 1974; Neyra and Hageman 1976; Shaner and Boyer 1976). Thus, this study sought to determine the level of NR at different N levels and incident light intensity.

Materials and Methods

Plant culture condition

The experiment was conducted at the Institute of Nuclear Agriculture (INA) farm in winter. The experimental cultivar L 9-12 was grown in a randomized block design with four replications and a plot size of 11 m^2. Four levels of nitrogen (0, 15, 30, and 45 kg/ha) from urea and three levels of population (D_1 = 80, D_2 = 160, and D_3 = 240 plants/m^2) in rows 25 cm apart were used. Urea was applied to the soil and mixed before seed sowing. Phosphorus and potash were applied to soil and mixed during land preparation as P_2O_5 and K_2O from triple super phosphate and mureate of potash at a rate of 50 and 25 kg/ha, respectively. The seeds were sown by dibbling. Thinning was done after emergence to maintain the desired population, and weeding was done when required.

Plant and soil sampling

Soil moisture data were collected at 15-day intervals starting 20 days after sowing. Soil samples were collected from up to 30 cm depth and mixed thoroughly; 100 gms of this soil was oven-dried for 48 hours at 72°C. Percentage of moisture was calculated from the difference between wet and dry weight.

Plant moisture and total dry weight were determined at 10-day intervals, starting 30 days after seedling emergence. Relative growth rates of plants were determined every 10 days starting from 30 days after seedling emergence. Nitrate reductase activity (NRA), chlorophyll content (Chl), and soluble protein were determined at full flowering. Data on plant height, number of branches, and pods/plant were taken at harvest.

Biochemical assay

Nitrate reductase activity (NRA) was determined *in vivo* according to the method described by Neyra and Hageman (1974). At seedling stage, NRA was determined in plus and minus substrate (NO_3^-) assay medium to find out the availability of NO_3^- at the site of induction. Chlorophyll was extracted in 80% acetone and the quantities of total chlorophyll (Chl), Chl a, and Chl b, were determined using the specific absorption coefficients of Arnon (1949). Soluble protein was extracted in phosphate buffer pH 7.0 and color was determined with Folin and Ciocaltev's phenol reagent according to Lowry *et al.* (1951).

Results and Discussion

Yield and yield attributes

The mean seed yield of the experiment was 676 kg/ha. Data showed no significant effect of N and population on seed yield and plant height, which had a mean of 33.1 cm. Number of branches/plant increased significantly as plant population decreased, and an increase in pods/plant was apparent in lower population treatments. Thus, the yield in lower population treatments was compensated for by increased number of branches giving more pods/plant. The result indicated that branch number in lentil is a genetically labile character susceptible to environmental fluctuations, and also that lentil yield may not be improved remarkably by population manipulations. Attempts to base lentil selection on higher branch number may therefore be futile.

Soil-plant-water relationship

Soil moisture declined at a very fast rate during early growth causing slight decline in moisture content of leaves, but the relative growth rate decreased suddenly (Fig. 1). After 45 days, the plants received a mild shower and quickly regained the higher relative growth rate along with leaf moisture status, indicating that just prior to these showers the plant was under severe water stress, which might have limited growth processes. After 60 days, the moisture content and RGR (Relative Growth Rate) of plants declined rapidly, although soil moisture gradually increased. The decline of RGR with ontogenetic development is normal, but the sudden decrease and increase indicated the influence of other factors. Clearly, adequate water supply is needed during early plant growth under Bangladesh conditions.

Nitrate assimilation

Measured as the activity of enzyme nitrate reductase (NR), the nitrate assimilation was not affected by levels of nitrogen fertilizer and plant population. The mean NR-activity was measured as 1.07 μ mol. NO_2^-/g fresh weight/hr. Clearly, the NR-profile in lentil was much lower than in many other legumes and cereals (Dutta *et al* 1980; Scott and Neyra 1979; Nicholas *et al.* 1976) and the activity was not induced by increasing the nitrogen fertilizer. Nitrate assimilation is therefore apparently a very insignificant pathway of nitrogen assimilation in lentil. Perhaps the NH_4^+ assimilation might be more dominant, which may explain why Anam and Elahi (1982) obtained significant yield increase with urea application on lentils in different soils in Bangladesh.

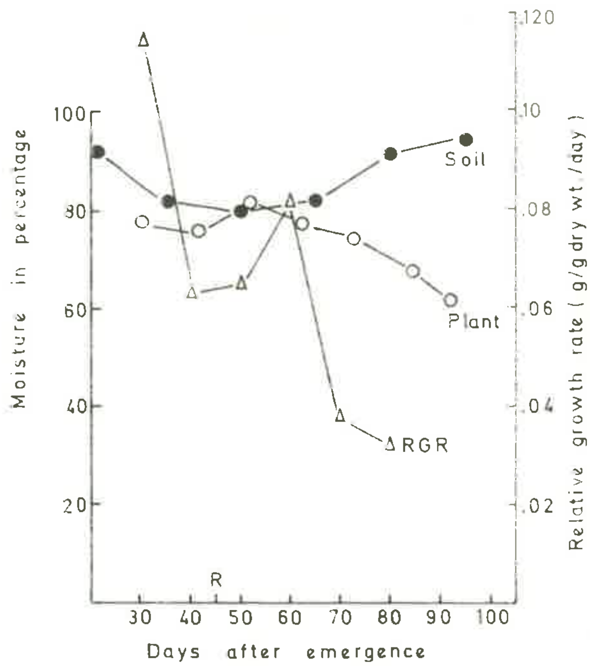

Fig. 1. *Soil moisture, plant moisture, and relative growth rate during ontogenetic development of lentil (R denotes rainfall).*

Nodulation and N_2 fixation

Data on number of nodules/plant in different treatments at flowering (Table 1) and the average number at various stages of growth (Fig. 2) showed that nodulation can freely occur without rhizobial inoculation. Nodulation was not affected by high N treatments of 45 kg N/ha (Table 1). Nodulation reached its peak at flowering and dropped thereafter because of degeneration of nodules (Fig. 2). The leghaemoglobin status of the remaining nodules also degenerated. Thus, symbiotic nitrogen fixation in the post-flowering period must have decreased to a very low level. Genetic improvement for improved nodulation in the post-flowering period should be possible and might be a way to improve lentil yields.

Photosynthetic components

Chlorophyll: Total chlorophyll content was not affected by N or population treatments. The mean values for total chlorophyll, Chl a, and Chl b were 2.91, 1.6, and 1.37 mg/g fresh wt, respectively. But the chlorophyll a/b ratio was poor and was not affected by any of the treatments. The chlorophyll a/b ratio is fixed in a species for a certain set of environments and plays a vital ecological role for the plant community. In cereal crops and other legumes, the value is quite high. The significance of the chlorophyll a/b

Table 1. *Effect of N and population density (D) on lentil yield and yield attributes.*

Treatment	Seed yield (kg/ha)	Number of branches/plant	Number of pods/plant	Height (cm)	Number of nodules at flowering/plant
N_0	633	27.7	67.3	35.2	84.9
N_{15}	664	26.8	62.1	31.5	92.5
N_{30}	738	25.3	57.5	31.8	75.8
N_{45}	668	25.8	62.0	33.8	74.1
D_1	592	31.5 a	72.4	33.9	71.4
D_2	687	28.8 a	60.6	31.3	82.2
D_3	750	18.9 b	55.6	34.0	91.8
N	NS	NS	NS	NS	NS
D	NS	(2.71)	NS	NS	NS
N x D	NS	NS	NS	NS	NS

Means followed by different letters are significantly different.
NS indicates that differences between treatments were non-significant at 5%.
Value in parentheses is standard error of difference between two means.

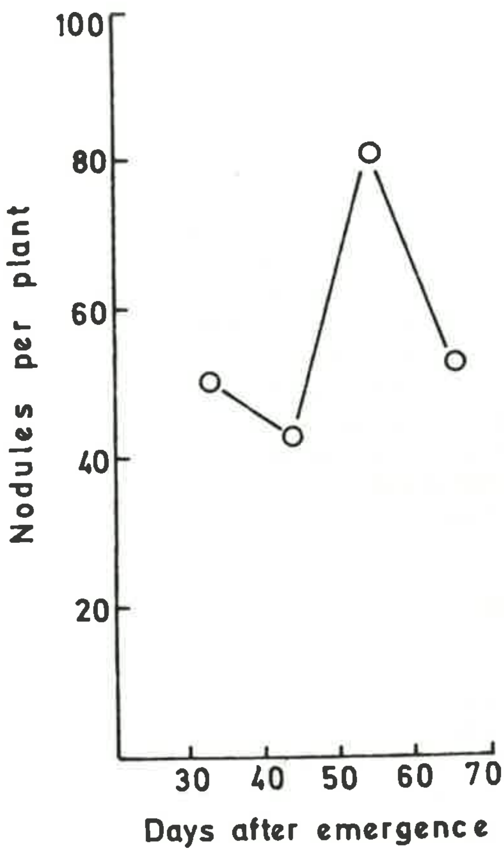

Fig. 2. *Nodule growth during ontogenetic development of lentil.*

ratio lies in the fact that Chl a is the ultimate molecule to harvest photon to the reaction center of photosynthesis, and that Chl b acts as intermediate accepter and shade adapter. The relative abundance of the Chl a molecule over Chl b indicates the relative efficiency of photoharvest (Boardman and Anderson 1964). The low Chl a/b ratio provides scope for genetic manipulation of this trait for developing more productive plants.

Soluble protein

The soluble protein in leaves was not significantly affected by N or population treatment. The value obtained for soluble protein was generally quite high with a mean of 27.1 mg/g fresh wt. The quantity of soluble protein does not reflect the efficiency of enzymes for CO_2 fixation although 50% of the soluble proteins might be composed of RuBP Carboxylase. Higher quantity of a soluble protein, however, may be utilized by plants for pod filling by remobilization. This is observed in lentil as evidenced by the total drying of the leaves during pod maturation.

Conclusion

To summarize, lentil is a crop with many physiological constraints; e.g., limitation of NO_3^- assimilation, photoharvest efficiency, short duration of N_2 fixation, and susceptibility to water stress. The results of this study suggest a need for genetic manipulation of these physiological characters for developing better plant types.

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Physiology and Microbiology

Plant regeneration of lentil *in vitro*

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Abstract

A technique of plant regeneration is described in which lentil hypocotyls and epicotyls were cultured. Developing shoots were isolated from calli and grown through to maturity in pots.

Plant regeneration is a primary requisite for the application of biotechnology to crop improvement. To develop a superior field crop, fertile plants must be produced from the genetically modified cell line. Legumes, in general, are moderately difficult to manipulate *in vitro,* with control of regeneration particularly difficult. This is especially true of pulses, where there are few examples of successful and reliable regeneration of plants from non-organized cells in culture.

We devised a simple protocol for reliable regeneration of plants from callus cells in each of three tested lentil genotypes. Hypocotyls and epicotyls of Laird, Eston, and NEL-481 seedlings were cultured in Murashige and Skoog basal medium with 3% sucrose, 10 mg/l kinetin, and 1 or 0.1 mg/l gibberellic acid. The medium was solidified with 0.8% agar and the sealed plates, containing their aseptically transferred explants, were placed in a dark cabinet at room temperature. After four weeks, the cultures were moved to an incubator set at 21^{O}C with a 16 hs daylight regime. Shoots appeared spontaneously on the surface of the calli on many of the cultures within about two weeks. To promote germination, healthy growing shoots were isolated from the callus and grown in their own culture vials containing basal medium. When shoots reached about 5 cm in height, they were transferred to a standard mist chamber for two weeks to develop roots and acclimatize. Finally, the plantlets were transferred to potting soil in pots in the greenhouse where maturation, flowering, and seed set took place in a normal fashion.

Pests and Diseases

Reaction of lentil varieties and exotic germplasm to rust *(Uromyces fabae)*

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Abstract

A total of 110 lentil varieties and germplasm accessions were screened in Madhya Pradesh, India for reaction to rust, a major lentil pathogen. Using a nine point scale with the score 1 as no infection, all the lines scored either 3 or above. There were 25 lines, comprising 4 varieties and 21 germplasm accessions, showing a reaction of 3.

Lentil *(Lens culinaris)* is an important pulse crop in India. It is widely grown in Madhya Pradesh on an area of about 0.3 million hectares. The crop is badly infected with rust (*Uromyces viciae fabae* Shroet) which has also been reported in the past on lentil, pea, and lathyrus in and around Jabalpur (Nema and Agrawal 1960; Mishra 1969). It was more severe under humid conditions. Lentil rust has been appearing almost every year in farmers' fields as well as in the experimental fields of the All India Coordinated Varietal Trials of lentil, and in exotic germplasm collections from Iran and other countries grown at the university farm. To identify sources of resistance, varieties and germplasm collections were screened under natural conditions of disease incidence over two seasons.

Twenty five plants of each variety/germplasm collection were randomly selected for recording observations on rust reaction. These were classified with a nine point scale adapted from Singh *et al.* (1981) for *Ascochyta* blight.

1. No pustules visible.
3. Few scattered pustules, usually seen after careful searching.
5. Pustules common on leaves and easily observed, but causing no apparent damage.
7. Pustules very common and damaging but not observed on petioles and stems.
9. Pustules extensive on all plants; seen on leaves, petioles, and stems, and killing leaves and other plant parts.

The rust reactions of different entries are shown in Table 1. In this investigation, lentil varieties C 31, HY1-1,

Table 1. *Rust reactions of different entries of lentil.*

Rating	Entry
1	
3	C-31, HY 1-1, NP47, T-36, 10446, 10465, 10006, 10051, 10052, 10110, 10472, 10475, 10478, 10485, 10488, 10492, 10495, 10502, 10506, 10507, 10511, 10517, 10526, 10527, and 10535.
5	TT-3, BR25, L9-12, 10447, 10450, 10454, 10463, 10464, 10031, 10066, 10109, 10467, 10095, 10469, 10078, 10083, 10092, 10481, 10482, 10483, 10487, 10493, 10496, 10498, 10505, 10509, 10512, 10513, 10515, 10516, 10518, 10520, 10528, 10534, 10536, 10537, 10538, 10539, 10542, and 10547.
7	Bom 18, 10451, 10547, 10460, 10050, 10063, 10001, 10106, 10033, 10111, 10096, 10084, 10470, 10477, 10479, 10480, 10484, 10499, 10514, 10523, 10524, 10525, 10530, 10532, 10540, 10541, 10544, and 10545.
9	NP 11, B 77, T 8, Jabalpur local, 10452, 10458, 10459, 10467, 10054, 10076, 10099, 10101, 10080, 10486, 10516, 10533, 10543, and 10546.

NP 47, and T 36 were rated as 3 for rust reaction. Eight out of 21 germplasm collections, rated 3 for rust reaction, were earlier reported as highly resistant and resistant to powdery mildew (Mishra 1973). These eight germplasm collections are Nos. 10511, 10526, 10465, 10475, 10495, 10502, 10506, and 10507.

Varieties TT 3, BR 25, L 9-12 and 37 collections were rated as 5 to rust. But out of these, collections 10528, 10536, 10537, 10463, 10066, 10496, 10498, 10509, 10518, 10520, and 10534 tested as resistant to rust (rating 3), were also earlier classed as highly resistant and resistant to powdery mildew (Mishra 1973). Nine collections—10447, 10454, 10031, 10469, 10092, 10481, 10505, 10516, and 10542— out of 37 collections graded as semi-resistant to rust (Rating 5) were also reported by Mishra (1973) as semi-resistant to powdery mildew.

Varieties Bom 18 and 27 collections were graded as 7. NP 11, B 77, T 8, and Jabalpur local, including 14 collections, were graded as 9 to rust. None of the varieties or exotic collections were free from rust and so could not be rated as 1.

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Effect of seed treatment on lentil rust *(Uromyces fabae)* development

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Abstract

Six fungicides — Bavistin, Bayleton, Bayton, Plantvax, Vigil, and Vitavax — were tested for control of lentil rust *(Uromyces fabae)* in lentil seeds. The disease did not appear in Vigil-treated seeds under artificial inoculation even 60 days after sowing. Bayleton gave light disease reaction after 50 days of sowing, whereas in the control, disease intensity was high from the first day of inoculation and severe 35 days after sowing.

Introduction

Lentil rust causes heavy losses to lentil, to the extent that the entire crop can be lost. Prasada and Verma (1948) reported the seed-borne nature of the disease and its inoculum, which is associated with the inert matter. The present study investigated the efficacy of systemic fungicides in checking the primary inoculum on the seed and, hence, rust development.

Materials and Methods

The seeds of lentil variety L 1278, susceptible to lentil rust, were treated with six fungicides: Bavistin (0.25%) Bayleton (0.25%), Bayton (0.25%), Plantvax (0.25%), Vigil (0.1%), and Vitavax (0.25%). Ten to fifteen seeds were sown in 15 cm clay pots. After 30 days of sowing, the plants were inoculated once with uredospores (20-25 spores/microscopic field 10x) with different treatments at 24-hour intervals for five days and after 10, 20, 30, 40, and 60 days in the glasshouse. The inoculated plants were covered with polythene bags for 48 hours and pots were irrigated regularly. A control without seed treatment was

Table 1. *Intensity of rust * after seed treatment with fungicides and after different times of inoculation.*

Fungicide	Concentration (%)	Days after sowing of inoculation									
		31	32	33	34	35	40	50	60	70	80
Bavistin	0.25	+	+++	+++	+++	++++	++++	++++	++++	++++	++++
Bayleton	0.25	—	—	—	—	—	—	+	++	++	+++
Bayton	0.25	+	+	+	++	++	++	+++	+++	+++	++++
Plantvax	0.25	+	+	+++	+++	+++	+++	+++	+++	+++	+++
Vigil	0.1	—	—	—	—	—	—	—	—	+	++
Vitavax	0.25	+	+	+++	+++	+++	+++	+++	+++	+++	++++
Control		+++	+++	+++	+++	++++	++++	++++	++++	++++	++++

* Rust intensity: — = Free; + = Light; ++ = Moderate; +++ = High; ++++ = Severe.

kept for each treatment. Four replications were done for each treatment. The disease intensity on a scale of free to severe was recorded 15 days after inoculation.

Results and Discussion

Table 1 shows that the disease only appeared 70 days after sowing in Vigil (0.1%) treated seeds. Inoculation after 60 days gave moderate reaction. Bayleton (0.25%) gave light disease intensity following inoculation 50 days after sowing and moderate intensity after 60 days. Bayton (0.25%) exhibited light disease intensity from inoculation up to 33 days after sowing and moderate reaction after 34 days of sowing; afterwards, the disease intensity increased from high to severe. Plantvax (0.25%) and Vitavax (0.25%) gave light disease intensity from inoculation 32 days after sowing; later, the reaction increased to severe. In the control, the disease intensity was high from the first day of inoculation (31 days after sowing) and severe 35 days after sowing. Bavistin (0.25%) gave similar results, except for a light reaction 31 days after sowing.

Since the crop has a long growing period (about 180 days), there is a need for fungicidal protection until maturity. In the absence of such fungicides, spraying the crop when the disease appears is essential for high yield.

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Prasada, R. and Verma, U.N. 1948. Studies on lentil rust *(Uromyces fabae* (Pers.) de Bary) in India. Indian Phytopathology 1(2): 142-146.

Host-suitability of lentil for eight stored product insects

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Abstract

Host-suitability of lentil flour was evaluated for the development of eight stored product insects. ***Latheticus oryzae, Cryptolestes pusillus,*** **and** ***Corcyra cephalonica*** **failed to develop. In comparison with development in wheat flour,** ***Trogoderma granarium*** **took four times longer in lentil flour. Similarly,** ***Tribolium castaneum, Lasioderma serricorne,*** **and** ***Stegobium paniceum*** **developed about twice as slowly on lentil flour as on wheat.** ***Cadra cautella*** **developed slowly on lentils, requiring 1.5-1.75 times the duration it took on wheat. Anti-nutritional factors delayed development of the insects.**

Introduction

Lentil (*Lens culinaris* Med.) is an important legume crop in India, accounting for up to 3.8% of total pulse production. During storage, it is damaged mainly by pulse beetles *Callosobruchus chinensis* (Linn.) and *C. analis* (Fab.). A few reports have dealt with the inhibition of the development of *Trogoderma granarium* (Events) on lentil (Singh and Pant 1955; Pant and Dang 1969; Bhattacharya and Pant 1970). This study evaluates the suitability of lentil flour as host for eight stored product insects.

Materials and Methods

Fresh and uninfested wheat grain and lentil seeds were washed, dried at 40^{o}C, and milled for flour in a domestic electrical grinder up to 40 mesh size. The flour was conditioned for a week at 65% R.H. and at 27 ± 1^{o}C. Test insects were used from laboratory strains maintained in the Stored Product Laboratory, Division of Entomology, IARI. Ten newly-hatched larvae of *Tribolium castaneum* (Herbst.), *Latheticus oryzae* (Waterhouse), *Trogoderma granarium* (Events), *Cadra cautella* (Walker), and *Corcyra cephalonica* (Staint) were released in separate glass vials (2.5 x 7.5 cm). Three pairs of fresh adults–*Lasioderma serricorne* (Fab.), *Stegobium paniceum* (Linn), and *Cryptolestes pusillus*–were released. One g of flour was put in each vial for testing all species except for *C. cautella* and *C. cephalonica,* for which 2 g flour was used. The vials were plugged with cotton wool and transferred to desiccators maintaining 65% R.H. All tests were carried out at 27 ± 1^{o}C, except for *T. granarium,* for which a higher temperature of 32 ± 1^{o}C was maintained. The emergence of adults was observed after four weeks. After first emergence, daily observations were recorded. Data on adult emergence and range of developmental period were calculated (Table 1).

Results and Discussion

Among eight insects tested for their host suitability on lentil, *L. oryzae, C. pusillus* and *C. cephalonica* totally failed to develop. The development of the other five insects was considerably delayed. *T. granarium* was most delayed in development; it took four times as long on lentil (130-180 days) as on wheat flour (42-48 days). *T. castaneum* required about twice the time on lentil as on wheat. Both the insects showed only 13.3% emergence on lentil. *L. serricorne* and *S. paniceum* needed about 1.5 times longer to complete 12.6 and 9.6% emergence. Percent emergence in *C. cautella* was not affected but took 1.75 times longer.

The results of the test showed the presence of antinutritional factors in lentil for eight common stored product insects. Singh and Pant (1955) and Punj (1968) also found lentil to be the worst food among different pulses for some stored product insects. Bhattacharya and Pant (1970) reported heat labile trypsin inhibitor and LIT, a lentil inhibitor, as factors delaying larval development of *T. granarium.* Yadav (1983) reported that *C. maculatus,* a very prominent species of pulse beetle, did not infest lentil, although two other species, *C. chinensis* and *C. analis,* are serious pests.

Table 1. *Developmental period and percent emergence of different stored product insects on wheat and lentil.*

	Range of development period (days)		Emergence of adult (%)	
Insect	Wheat	Lentil	Wheat	Lentil
T. castaneum	28-37	56-62	70.0	13.3
L. oryzae	37-43	N.D.	36.6	N.D.
T. granarium	42-48	130-180	60.0	13.3
L. serricorne	40-48	52-60	100.0	12.6
S. paniceum	44-56	60-65	100.0	9.3
C. pusillus	45-55	N.D.	100.0	N.D.
C. cautella	28-33	47-51	70.0	73.3
C. cephalonica	32-35	N.D.	56.6	N.D.

N.D. : No development.

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Seed Quality and Nutrition

Proteinase inhibitor activities and electrophoretic inhibitor patterns of lentils

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Abstract

Thirty-eight lentil samples (commercial cultivars and accessions from various lentil collections) were tested for inhibitor activities against bovine trypsin and chymotrypsin. A larger group with low inhibitor content (0.6-1.1 mg trypsin and 0.4-0.9 mg ∝ -chymotrypsin inhibited/g of seed meal) and a number of samples with higher inhibitor content (up to 2.5 mg trypsin or 2.4 mg ∝ -chymotrypsin inhibited/g) were demonstrated. Inhibition of human trypsin fell in the same range as that of bovine trypsin (80-100%), while human chymotrypsin was inhibited more effectively than the bovine enzyme (150-260%). Four isoinhibitors were demonstrated electrophoretically in all the samples, which are grouped into three genetically-controlled inhibitor pattern types: type A, with the most basic inhibitor predominating; type B, with the most basic and the most acidic inhibitor occurring in equal amounts; and type C, with the most acidic inhibitor predominating. Genetic similarity seems to be more responsible for both inhibitor content and inhibitor pattern type than does geographical provenance.

Introduction

Extracts from lentil (*Lens culinaris* Medik.) seeds have been shown to inhibit human chymotrypsin more effectively than the bovine enzyme; in contrast, both human and bovine trypsin were inhibited to the same extent (Belitz *et al.* 1982). The principal *L. culinaris* inhibitor (LCI-4) has been isolated from a commercial cultivar and partially characterized (Weder *et al.* 1983). To clarify the reasons for the different action against human and bovine chymotrypsin, the remaining three inhibitors from lentils shall be isolated to investigate the molecular structure of the lentil inhibitors. Because of the predominance of LCI-4 in the cultivar investigated, we screened 38 lentil samples from different parts of the world for both inhibitor activities and electrophoretic inhibitor patterns to find a sample suitable for the isolation of the other three inhibitors. The results of this study are presented here and discussed in relation to their use by plant breeders and agronomists.

Materials and Methods

Lentil (*Lens culinaris* Medik.) seeds were received from collections in different parts of the world or purchased from local markets (Table 1). Trypsin (E.C. 3.4.24.4., bovine, cryst., 3.5 units/mg, 24579) and ∝ -chymotrypsin (E.C. 3.4.24.1., bovine, cryst. lyophil., 45 m units/mg, 2307) were biochemical grade reagents obtained from Merck. Inhibition of human enzymes was tested using the juice from the human small intestine obtained from a Munich hospital. The sources of the other reagents were as given previously (Weder and Murray 1981; Belitz *et al.* 1982; Weder *et al.* 1983).

Seed extracts were prepared as described earlier (Weder 1978) and diluted according to their inhibitor activities. Inhibition of human trypsins and chymotrypsins was determined with synthetic substrates as given previously (Belitz *et al.* 1982); inhibition of the bovine enzymes was measured with synthetic substrates (Belitz *et al.* 1982) and/or with casein as a substrate (Weder 1978). Inhibitor patterns were obtained by disc electrophoresis of the extracts (glycine - tris pH 8.3, 7.5% acrylamide, anodic) and specific staining for trypsin inhibitors (Weder and Murray 1981).

Results and Discussion

Designations and origin of the 38 lentil samples investigated are listed in Table 1. Samples 340-358 were grown repeatedly in Australia and the origin is given in parentheses. Color and mean seed weight of the samples are included in Table 1; the color is mostly light brown ranging from clay (5D5) and camel (6D4) to golden brown (5D7) and sienna (6D7), respectively; the average seed weight varies from 19 to 81 mg.

Inhibition of bovine trypsin and chymotrypsin determined with a protein (casein) as substrate is also given in Table 1. Bovine trypsin-inhibitor activities ($BTIA_c$, column 5) lie between 0.6 and 2.5 mg trypsin inhibited/g seed meal; bovine chymotrypsin-inhibitor activities ($BCTIA_c$, column 6) range from 0.4 to 2.4 mg ∝ -chymotrypsin inhibited/g seed meal. These values lead to mean inhibitor activities of 1.2 and 0.9 mg/g for $BTIA_c$ and $BCTIA_c$, respectively. Representatives showing these activities are scarcely found

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among the samples investigated. However, the samples can be arranged into a group showing lower inhibitor activities (23 samples) and exhibiting a nearly Gaussian distribution and a group of samples (15) with higher inhibitor activities. Representatives of the first group ($BTIA_c$ 0.6-1.1 mg/g, mean value 0.9 mg/g, $BCTIA_c$ 0.4-0.9 mg/g, and mean value 0.6 mg/g) should be preferable for breeding or introduction as new cultivars in order to reduce possible digestive troubles if the lentils are not heated sufficiently before consumption. Among these samples are some with large seeds (especially # 327, but also # 336, 347, 352, 353, and 358) that should be particularly promising. Of course, yields must also be taken into consideration. It is interesting to note that most of the representatives of the lentil subspecies *macrosperma* belong to the group with low inhibitor activity (14 out of 18 samples), while the *microsperma* lentils are equally distributed in the two groups (9 and 11 samples with low and high inhibitor activity, respectively), if a seed mass of 45 mg is used as the junction point between the two lentil subspecies (W. Erskine, 1984, ICARDA, personal communication). Among the samples commercially available or to be introduced some are of high inhibitor activity (# 320-323, 359), and all samples from the USA (# 336-338) and that from New Zealand (# 339) are of low inhibitor activity.

Inhibition of human and bovine proteinases determined with synthetic substrates is given in Table 2 ($HTIA_s$, human trypsin-inhibitor activity; $BTIA_s$, bovine trypsin-inhibitor activity; $HCTIA_s$, human chymotrypsininhibitor activity; $BCTIA_s$, bovine chymotrypsin-inhibitor activity, all determined with synthetic substrates). Compared with the corresponding inhibitor activities determined with casein as a substrate (Table 1), higher inhibitor activities were found with synthetic substrates: $BTIA_s/BTIA_c$, about 2-3, and $BCTIA_s/BCTIA_c$, 0.8-1.8. The differences are probably due to differences in Michaelis constants of synthetic and natural substrates on the one hand and between the two enzymes on the other hand. Also, other constituents present in the crude seed extracts may interact with both the enzymes and the substrates in different ways. With pure inhibitor preparations, these differences lessen, but inhibitor activities determined with proteins were always smaller than those determined with synthetic substrates (Weder and Mueller, unpublished work).

Comparing the inhibition of human and bovine trypsin, $HTIA_s$ and $BTIA_s$ (Table 2, columns 1 and 2), about the same inhibition was found with the samples investigated, showing ratios of 0.8-1.0 (column 5). In contrast, human chymotrypsins ($HCTIA_s$, column 3) were inhibited more effectively than the bovine enzyme ($BCTIA_s$, column 4) by all samples, resulting in ratios of 1.5-2.6 (column 6). These

Table 2. *Proteinase inhibitor activities and activity ratios of some lentil samples.*

No.[a]	$HTIA_s$[b]	$BTIA_s$[c]	$HCTIA_s$[d]	$BCTIA_s$[e]	$HTIA_s/BTIA_s$[f]	$HCTIA_s/BCTIA_s$[g]
320	2.6	2.7	2.3	1.1	1.0	2.2
321	4.9	5.5	3.6	1.8	0.9	2.0
322	5.2	5.2	3.4	2.1	1.0	1.7
323	4.3	5.0	3.3	2.2	0.9	1.5
324	5.1	5.4	3.7	2.2	0.9	1.7
325	3.0	3.2	2.8	1.3	0.9	2.1
326	4.3	5.4	3.7	1.8	0.8	2.1
327	2.4	2.7	2.0	0.8	0.9	2.6

a: Internal sample number (Table 1); b: $HTIA_s$, human trypsin-inhibitor activity with BAPA (N α—benzoyl-DL-arginine 4-nitroanilide) as a substrate (Table 1); c: $BTIA_s$, bovine trypsin-inhibitor activity with BAPA as a substrate; d: $HCTIA_s$, human chymotrypsin-inhibitor activity with GLUPHEPA (glutaryl-L-phenylalanine 4-nitroanilide) as a substrate; e: $BCTIA_s$, bovine α-chymotrypsin-inhibitor activity with GLUPHEPA as a substrate; f: ratio of the two trypsin inhibitor activities determined with a synthetic substrate; g: ratio of the two corresponding chymotrypsin inhibitor activities.

results could be verified with two pure inhibitors from lentil seeds, $HTIA_s$ being 0.7 times $BTIA_s$ and $HCTIA_s$ being 2.7 times $BCTIA_s$ (Weder and Mueller, unpublished work). From this it follows that human trypsins are generally inhibited to the same extent by lentils as discussed above for bovine trypsin and the various samples investigated, while human chymotrypsins are affected about two and a half times as much as the bovine enzyme. In total, 100 g of lentils, if absorbed quantitatively unchanged, are able to inhibit 22-45% of the daily production of human trypsins and chymotrypsins (about 1 g each), if not suitably processed. In this respect, lentils are similar to *Pisum sativum* L. and *Vicia faba* L. and about one fifth to one tenth as effective as *Phaseolus vulgaris* L. or *Glycine max* (L.) Merr. (Belitz *et al.* 1982).

Disc electrophoresis of the lentil seed extracts and staining for trypsin inhibitors showed the presence of four inhibitors, denoted LCI-1 to -4 according to their electrophoretic mobility, in all the samples investigated. As proven with some of the samples, these four inhibitors also inhibited chymotrypsin. However, these four inhibitors are present in different amounts in the individual lentil sample, leading to three (or four) different inhibitor pattern types (Fig. 1). Type A, with LCI-4 predominating, followed by LCI-1 and only traces of LCI-2 and -3, was found in most of the samples (Table 1; inhibitor pattern types in final column). Type A, which ranks second in frequency, differs

Table 1. *Proteinase inhibitor activities and electrophoretic inhibitor patterns of lentil samples.*

No.[a]	Designation[b]	Origin[c]	Color[d]	Weight (mg)	$BTIA_c^e$	$BCTIA_c^f$	Type[g]
320	Lentil	Unknown[h]	6E6: B	53	1.3	0.7	A
321	Lentil	Unknown[i]	5D7: LB	69	2.5	2.4	A'
322	Lentil	Italy[j]	7E7: B	29	2.2	1.6	B
323	Red lentil	Turkey[k]	6A8: O[l]	28	2.2	1.6	A'
324	ILL 4354	Jordan[m]	4C6/5D7: GY/LB	42	1.7	1.4	A'
325	ILL 4401 (local small)	Syria[m]	6D4: LB	27	1.6	0.8	C
326	ILL 784	Egypt[m]	6D4: LB	36	1.9	1.6	A'
327	ILL 4400 (local large)	Syria[m]	5D6: LB	81	1.0	0.9	A
329	Red lentil	Australia[n]	6D7: LB	56	0.8	0.7	A
330	SA 12102	Australia[n]	6F6: DB	34	0.6	0.5	A
331	SA 14697	Australia[n]	7E5: B	33	0.6	0.4	A
332	NEL 155	Australia, (Turkey)[n]	6E4: B	23	0.9	0.6	A
333	NEL 710	Australia, (Afghanistan)[n]	6D4: LB	19	1.4	1.1	A
334	NEL 784	Australia (Egypt)[n]	6E5: B	19	1.1	0.9	A'
336	Brewer lentil	USA[o]	4D4/5D5: OLB/LB	61	0.7	0.6	A
337	Chilean lentil	USA[o]	4D5/6C5: OLB/BO	47	1.0	0.7	A
338	Tekoa lentil	USA[o]	4D5/6D5: OLB/LB	44	0.9	0.6	A'
339	Brown Chilean	New Zealand[p]	6D6: LB	57	0.8	0.6	A
340	WWL 1	Australia 1982[p]	6D6: LB	43	0.7	0.6	A
341	WWL 2	Australia 1982[p]	6D5: LB	58	0.7	0.4	A
342	WWL 3	Australia 1982[p]	6E5: B	31	1.0	0.7	A'
343	WWL 4	Australia 1982[p]	6D5: LB	31	1.4	0.9	A'
344	WWL 5	Australia 1981[p]	6D5: LB	43	1.1	0.7	A
345	WWL 6	Australia 1981[p]	6D5: LB	30	1.4	1.1	B
346	ILL 8	Australia 1982 (Jordan)[p]	6D6: LB	50	1.6	1.2	B
347	CPI 31019	Australia 1981 (Yugoslavia)[p]	5D6: LB	61	1.0	0.6	A
348	CPI 30997/B	Australia 1982 (Yugoslavia)[p]	6D6: LB	30	1.2	1.0	C
349	CPI 30995/A	Australia 1982 (Yugoslavia)[p]	6D5: LB	31	1.0	0.6	B
350	CPI 30982	Australia 1981 (Germany)[p]	6D5: LB	48	1.0	0.8	A
351	ILL 15	Australia 1982 (Jordan)[p]	6D4: LB	57	0.8	0.6	C
352	ILL 30	Australia 1982 (Syria)[p]	6D4: LB	65	0.8	0.6	A
353	ILL 193	Australia 1982 (Syria)[p]	6D4: LB	60	0.9	0.6	A
354	ILL 254	Australia 1982 (Greece)[p]	6D4: LB	53	1.0	0.7	A'
355	ILL 915	Australia 1982 (Spain)[p]	6D5: LB	47	1.0	0.7	A'
356	ILL 983	Australia 1982 (Chile)[p]	6D5: LB	46	1.5	1.3	B
357	ILL 1042	Australia 1982 (Iran)[p]	6D5: LB	42	1.4	1.0	A
358	ILL 4400	Australia 1982 (Syria)[p]	6D4: LB	62	0.9	0.7	A
359	Red lentil	Sudan 1983[q]	6B7: O[l]	26	1.6	1.1	B

a: Internal sample number; b: ILL, International Legume Lentil (ICARDA number), NEL, Near East Lentil (old ICARDA designation), WWL, Wagga Wagga Lentil, CPI, Commonwealth (of Australia) Plant Introduction; c: country where the accession was grown (where it originated); d: color code according to Kornerup and Wanscher (1975), observation under daylight lamp (6500 K9), after colon: simplified code; B: brown, BO: brownish orange, DB: dark brown, GY: grayish yellow, LB: light brown, O: orange, OLB: olive brown; e: $BTIA_c$, bovine trypsin-inhibitor activity with casein as a substrate (all inhibitor activities expressed as mg active enzyme 100% inhibited/g of seed meal); f: $BCTIA_c$, bovine —chymotrypsin-inhibitor activity with casein as a substrate; g: type of electrophoretic inhibitor pattern according to Fig.1; h: Munich shop (producer, Fa. Neuss and Wilke, Gelsenkirchen, FRG); i: Munich shop (producer, Fa. Forum-Handels-GmbH, Hamburg, FRG); j: Lebascha, health food (Munich, FRG); k: Turkish shop (Munich, FRG); l: shelled; m: ICARDA (Aleppo, Syria); n: Northfield Research Laboratories and Research Centre (Adelaide, S.A., Australia); o: Washington State University (Pullman, WA, USA); p: Agricultural Research Institute (Wagga Wagga, N.S.W., Australia); q: market (Kosti, Sudan).

by displaying higher amounts of LCI-1, but LCI-4 still predominates, while type B (found in six samples) exhibits equal amounts of LCI-1 and LCI-4 and, generally, larger amounts of LCI-2 and -3. In contrast, type C, which was found only in three samples, contains larger amounts of LCI-1, only small amounts of LCI-4, and traces of LCI-2 and -3. While type A inhibitor patterns are usually found in samples with low inhibitor contents, types B and C are mainly found in samples with high inhibitor contents. With regard to the aim of the screening experiments, samples 325 and 348 are well suited for isolating LCI-1, while # 322, 345, 346, 356, and 359 are better for isolating LCI-2 and -3 together with LCI-1 and -4, considering both an adequate inhibitor activity and the right inhibitor pattern type.

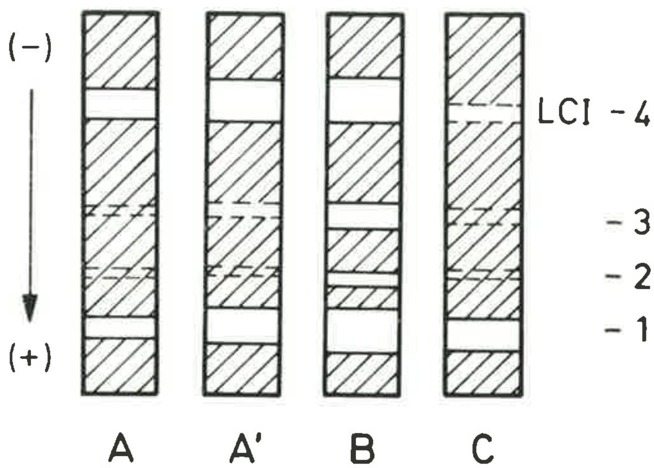

Fig. 1. *Electrophoretic trypsin inhibitor pattern types of Lens culinaris: A - sample # 320 (Table 1), A'- # 323, B - # 322, and C - # 325. Samples of 0.2 ml (35 mg seed meal/ml) electrophorized at pH 8.3, incubated with trypsin solution (0.1 mg/ml) and then with N-acetyl-DL-phenylalanine B-naphthyl ester and Fast blue B salt.*

Because four isoinhibitors have been demonstrated in all the samples studied, the isoinhibitors are probably genetically controlled by different loci which are not inherited independently of each other, or at least are not affected by the breeding experiments conducted. Differences in electrophoretic inhibitor pattern type, however, indicate that these loci are not located on the same chromosome. Genetic similarity seems to be more responsible for both inhibitor amount and pattern type than is geographical provenance, as seen with ILL 4400 grown in Syria (# 327) and in Australia (# 358), the two accessions showing low inhibitor contents and inhibitor pattern type A. The same is true of Chilean lentils grown in the USA (# 337), Brown Chilean from New Zealand (# 339), and Tekoa lentils (# 338), which are selected from Chilean (Hawtin *et al.* 1980).

Acknowledgements

We gratefully thank Mr. David G. Georg, South Australian Department of Agriculture, Northfield Research Laboratories and Research Centre, Adelaide, Australia; Mr. Edward J. Knights, New South Wales Department of Agriculture, Agricultural Research Institute, Wagga Wagga, Australia; Dr. Kenneth J. Morrison, Cooperative Extension Service, USDA, Washington State University, Pullman, USA; and Dr. Mohan C. Saxena, ICARDA, Aleppo, Syria for providing us with the lentil samples. We are also grateful to Dr. P. D. Lehnert, Gastroenterologische Labor der Medizinischen Klinik Innenstadt der Universitaet Munchen, for collecting and supplying the small intestinal juice. We thank the Deutsche Forschungsgemeinschaft for supporting this work and Mrs. Maria Valeria Bokor for technical assistance.

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Hard seed in lentils

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Abstract

The effect of storage period following harvest on the germination and hard seed percentages was studied in three lentil varieties. The % hard seed decreased from 64% a week after harvest to about 25% at sowing time (224 days after harvest). There were no genetic differences observed.

In many pulses, the trait of hard seededness, mainly due to an impermeable seed coat, is a problem for both cooking quality and germination.

Hard seed % varies from one variety to another. To study the effect of storage period on this character, three varieties – BR 25, No. 26, and Pant L 639 – were tested for germination on the 7th, 140th, 224th, and 320th day after harvest. Seeds were stored in cloth bags under ambient conditions and care was taken to avoid infestation with storage pests. Four hundred seeds of each variety were divided into four groups to make four replications. Seeds were put onto germination paper and placed in a germinator at 25°C. Germination and hard seed count were done five days later. Different categories were set up: germinated seed, hard seed (no water absorbed), imbibed ungerminated seed, abnormal seedlings (odd radicle or pumule growth), and dead seeds (absorbed water and then started rotting).

Percentages of hard seed and of germination are given in Table 1. Percentage of hard seed decreased with storage, but hard seed % among different varieties was almost equal on each date tested.

Hard seededness affects % germination. The third observation (Day 224 in Table 1) was recorded in the last week of November, which is the lentil sowing period in the region. This observation showed about 25% hard seeds which germinated slowly or not at all, which would give an uneven plant stand. Breeders should attempt to develop a variety with almost negligible hard seededness at sowing time to produce a uniform stand.

At 320 days after harvest, hard seed % was less than one in all varieties. By induced ageing hard seed % can be reduced, an observation also made by Sami and Gupta (1980) for six lentil varieties in which hard seeds had heavier testa.

Reference

Sami, Mohammad and Gupta, P.C. 1980. Seed dormancy studies in lentil during storage. Legume Research 3: 71-77.

Table 1. *Germination (G) and hard seed (HS) percentages in lentil varieties.*

Length of storage after harvest (days)	BR 25		No. 26		Pant L 639	
	(G)	(HS)	(G)	(HS)	(G)	(HS)
7	33.25	61.50	33.50	63.25	29.00	66.25
140	57.25	33.25	53.50	35.50	52.25	36.00
224	62.25	25.50	56.50	26.75	67.00	25.50
320	90.50	0.75	90.50	0.25	83.50	0.50

Abnormal seedlings and dead seeds are not included in either G or HS percentages.

LENTIL INFORMATION

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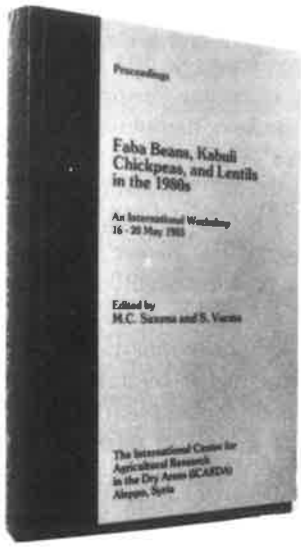

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PROCEEDINGS FABA BEANS, KABULI CHICKPEAS, AND LENTILS IN THE 1980's AN INTERNATIONAL WORKSHOP 16-20 MAY 1983

Edited by M.C. Saxena and S. Varma

ICARDA presents a 395 page book designed for all food legume researchers. This volume reflects the contributions of participants from 24 countries, including those from institutions with which ICARDA collaborates on more basic research.

This book is the proceedings of an international workshop on food legumes—faba beans, kabuli chickpeas, and lentils—held at ICARDA, Aleppo in 1983. The workshop aimed to assess the progress made in collaborative work on the improvement of these legumes in the last five years. The meeting also examined the research and training plans of the Food Legume Improvement Program at ICARDA and then formulated recommendations for future research directions.

The papers cover many aspects of food legume research, including germplasm, breeding, disease control by host-plant resistance, insect pests, weed and nematode control, and the physiology, agronomy, and nitrogen fixing capacity of food legumes. Other subjects include food legume quality and anti-nutritional factors, seed production, mechanization, on-farm trials on food legumes, training and communications, and ICARDA's cooperative food legume testing program. The papers also review recent food legume research in the Nile Valley, North Africa, the Americas, and India.

The proceedings reflect the contributions of participants from 24 countries, including those from advanced institutions and from developing countries. Included also is the discussion which followed the conference presentations and the recommendations.

Copies of the proceedings are available from ICARDA, FLIP, P.O. Box 5466, Aleppo, Syria.

Allen, D.J. 1983. **The Pathology of Tropical Food Legumes. Disease Resistance in Crop Improvement.** John Wiley and Sons Ltd., Chichester, USA. 413 pp. ISBN 0-47110-232-6.

This book gives a critical review of the pathology of the legume crops grown for food in the tropics. The crops covered are those widely grown in the tropics: groundnut, soybean, bean, cowpea, pigeonpea, and chickpea. The foreword of the book is written by Dr. A.H. Bunting, an authority on the international agricultural research system and on the subject of agricultural research and development needs of the developing countries. The author has been closely associated with the activities of the international agricultural research centers in the tropics and has devoted a number of years to research on the diseases of food legumes in many parts of the tropics.

The opening chapter deals with the tropical environment, the evolutionary diversity of legumes, and the complex cropping systems in which they are grown. Following is a discussion of crop-pathogen evolution, the stability of cropping systems, germplasm exchange, and new encounters between the hosts and parasites.

Chapters two and three discuss the pathogens themselves. The subsequent six chapters deal with the diseases of individual crops, and the final chapter covers the subject of resistance breeding and disease management. The book has an extensive list of references and an index.

As the author notes in the preface, "this book has been written principally for those actively engaged in the improvement of the legume crops, particularly plant breeders, plant pathologists, and entomologists." It would be of value to those who are involved in resistance breeding in tropical legumes, and even to those working on other crops.

Halevy, A.H. (ed.). 1984. **Handbook of flowering.** CRC Press Inc., 2000 Corporate Blvd., N.W. Boca Raton, Florida 33431, USA. 624 pp.

All aspects of the flowering process are discussed by international scientists in these volumes. Relevant data are included on field crops, fruits, vegetables, ornamental and commercial plants, and on forest trees of temperate and tropical climates. Information is presented in encyclopedic form, much of it published for the first time. The first volume contains general information on various major plant groups and chapters on individual plants beginning with the letter A. Individual plants are described from the standpoint of juvenility and maturation, morphology, induction, and morphogenesis to anthesis.

Key Lentil Abstracts

Bhatty, R.S. 1984. **Relationship between physical and chemical characters and cooking quality in lentil.** *Journal of Agricultural and Food Chemistry* 32(5): 1161. University of Saskatchewan, Crop Development Center, Department of Crop Science and Plant Ecology, Saskatoon, Saskatchewan, Canada.

The cooking quality (shear force) of 101 samples of three cultivars of lentil grown at several locations in 1980 and 1981 was related to their protein, hardness, phosphorus (P), Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, $(Na^{+} + K^{+})/P$, and $(Ca^{2+} + Mg^{2+})/P$ contents. The major significant correlation obtained was between cooking quality and $(Ca^{2+} + Mg^{2+})/P$ ratio, suggesting some role of these mineral elements in the cooking quality of the lentil. The cooking quality of 10 samples of lentil, having extreme values for shear force, was not related to seed size, hardness, or amylose content. The good-cooking lentil had significantly higher hydration coefficients (water uptake) than the poor-cooking lentil. However, the rate of water uptake was similar in both the good- and poor-cooking lentil samples. Scanning electron microscopy showed similar starch granules in both good- and poor-cooking lentil; nor were there any consistent differences in the differential scanning calorimetry properties of the starches. However, viscoamylograms of the lentil meals showed consistently higher peak and set-back viscosities for the good-cooking lentil samples.

Bhatty, R.S. and Christison, G.I. 1984. **Composition and nutritional quality of pea (*Pisum sativum* L.), faba bean (*Vicia faba* L. spp. minor) and lentil (*Lens culinaris* Medik) meals, protein concentrates and isolates.** *Qualitas Plantarum, Foods for Human Nutrition* 34(1): 41-51. University of Saskatchewan, Crop Development Centre, Department of Crop Science and Plant Ecology, Saskatoon, Saskatchewan, Canada.

Pea (*Pisum sativum* L.), faba bean (*Vicia faba* L., spp. minor), and lentil (*Lens culinaris* Medik.) meals, protein concentrates and isolates were analyzed for proximate composition, oligosaccharides, and amino acid composition. Protein quality was evaluated using a mouse bio-assay. The concentrates contained 59.2 to 70.6% and the isolates 86.7 to 90.8% protein (N x 6.25) on moisture-free basis. Glucose, sucrose, raffinose, stachyose and verbascose were present in the highest concentrations in the protein concentrates (7.1 - 11.1%), the pea protein concentrate contained 8.7% sugars and faba bean and lentil protein concentrates 7.1% and 6.6%, respectively. The protein isolates were almost free (containing less than 0.79%) of the sugars. Amino acid composition of the meals, concentrates and isolates showed, as expected, sulfur-amino acid deficiency (about two thirds of the rat requirement), which was probably largely responsible for the low protein efficiency ratios (0.75 - 1.18), and net protein ratios (0.25 - 0.73) of the three products, compared to values of 2.56 and 2.18, respectively, obtained for casein. The protein digestibilities of the meals, concentrates and isolates (81 - 90%) were similar to that of casein (87%). The poor growth-promoting abilities of the meals, concentrates and isolates were possibly also due to growth-depressing factors such as tannins, trypsin inhibitors and hemagglutinins present, particularly in faba bean and lentil.

Erskine, W. 1985. **Selection for pod retention and pod indehiscence in lentils.** *Euphytica* 34: 105-112. ICARDA, P.O. Box 5466, Aleppo, Syria.

The genetic variation for seed yield losses and the response to selection for reduction of such losses was studied by a six-week delay in the timing of harvest in various segregating populations from four lentil crosses. The bulk segregating populations had previously been subjected to different numbers of selection by means of a delayed harvest. The loss in seed yield from a delayed harvest in the two seasons 1981/82 and 1982/83 accounted for 551 and 105 kg/ha seed, representing 34 and 11% of the yield from a correctly timed harvest, respectively. Pod drop accounted for 65% of this loss, whereas dehiscence gave 35% of the loss in both seasons. The parents of cross 4 differed significantly for pod dehiscence, with genotype 74TA 550 showing relative indehiscence. Selection by means of a delayed harvest of bulk populations decreased pod dehiscence; but correlated effects of the selection included a reduction in both mean seed weight and bulk mean yield.

Ladizinsky, G., Braun, D., Goshen, D. and Muehlbauer, F.J. 1984. **The biological species of the genus *Lens* L.** *Botanical Gazette* 145(2): 253-261. U.S. Department of Agriculture, Agricultural Research Service, Washington State University, Pullman, Washington 99164, USA.

According to crossability relations and fertility of hybrids, the various members of the genus *Lens* were grouped in two biological species, *L. culinaris* and *L. nigricans.* Members of different species are cross incompatible because hybrid embryos abort ca. 2 wk after pollination. Hybrid seeds, which are rarely produced, are albino and die shortly after germination. When a mature plant is obtained, it is sterile as a result of irregular chromosome associations at meiosis. Within species, considerable chromosome repatterning occurs, but as a rule, F_1 hybrids are easily obtained and are fertile or partially fertile. Three subspecies were defined in *L. culinaris:* ssp. *culinaris,* which encompasses the cultivated lentils; ssp. *orientalis,* which represents the wild lentils with lanceolate stipules (cytogenetically, some accessions of this subspecies are closely related to ssp. *culinaris*), and ssp. *odemensis,* characterized by semi-hastate stipules that form horizontal positions on the stem. In conventional taxonomic treatments of the genus, ssp. *odemensis* is considered as *L. nigricans. L. nigricans* is composed of two subspecies: ssp. *nigricans* has stipules that are considerably semi-hastate and dentate at their base and pointed upward in a parallel position to the stem; and ssp. *ervoides* has semi-hastate or lanceolate stipules and is distinguished by its smaller leaves, calyx teeth, pods, and seeds. The two subspecies rarely form mixed stands in nature, but their hybrids are partially fertile.

Nozzolillo, C. and de Bezada, M. 1984. **Browning of lentil seeds, concomitant loss of viability, and the possible role of soluble tannins in both phenomena.** *Canadian Journal of Plant Science* 64: 815-824. University of Ottawa, Department of Biology, Ottawa, Ontario K1N 6N5, Canada.

Under normal storage conditions, lentil seeds, *Lens culinaris* Medic. (Fabaceae), were observed to discolor gradually over a 2-yr period from the olive green of freshly harvested seeds to a light yellow and finally a deep brown. Browning was experimentally accelerated by exposure to a warm, humid environment and conversely, retarded by exposure to a cold or dry atmosphere. Browned seeds were judged less viable than green seeds on the basis of (1) a fainter reaction to the tetrazolium test, (2) lower percent germination, and (3) a higher electrical conductivity of the imbibition medium indicative of a loss of membrane integrity and resultant loss of cell solutes. Coats of both green and browned seeds contained a high amount of proanthocyanidins (condensed tannins), both procyanidin and prodelphinidin, but browned seeds exuded much lower amounts of low molecular weight proanthocyanidins (soluble tannins) into the imbibition medium than did green seeds. It is concluded that (1) browning was a result of polymerization of soluble tannins to brown-colored high MW polymers (condensed tannins), and (2) under experimentally provided storage conditions of high relative humidity, embryo death was hastened in the presence of the seed coat, possibly by the interaction of soluble tannins or their precursors with embryo membranes.

Sharma, S.N. and Prasad, R. 1984. **Effect of soil moisture regimes on the yield and water use of lentil (*Lens culinaris* Medic).** *Irrigation Science* 5(4): 285-293. Indian Agricultural Research Institute, Water Technology Centre, New Delhi-110012, India.

The effect of soil moisture regimes on the grain and straw yield, consumptive water use (Cu) and its relation with evaporation from free water surface (Eo), water use efficiency and soil moisture extraction pattern of lentil was studied in a field experiment conducted at the Indian Agricultural Research Institute, New Delhi during the fall-spring season of the crop years 1979/80 and 1980/81. The grain and straw yield, consumptive water use rate, Cu/Eo ratio and water use efficiency increased with an increase in irrigation frequency. Consumptive water use rate increased as the crop season advanced and reached its peak value during flowering and grain filling stage. The Cu/Eo ratio attained its minimum values 35 and 105 days after sowing at branching and grain filling stages. Depletion of soil moisture was most from the top 0-30 cm soil layer followed by 30-60 cm soil layer and was least from 90-120 cm soil layer. The pattern of soil moisture depletion was also influenced by soil moisture regime. During the vegetative and flowering stage the percent contribution from the top 0-30 cm soil layer decreased and that from the lower soil layers (30-60, 60-90, and 90-120 cm) increased with an increase in the soil moisture tension. However, the actual amount of moisture depleted from all the soil layers was always higher under low soil moisture tension regime than under high soil moisture tension regime. During the grain development stage the soil moisture treatment had no significant effect on the relative contribution from different soil layers under low and high soil moisture tension as the crop was irrigated at the same time under both these treatments. However, with no irrigation, the percent contribution from top soil layer continued to decrease, and from lower soil layers continued to increase, as the crop advanced from flowering stage to grain development stage.

Sindhu, J. S., Slinkard, A. E. and Scoles, G. J. 1984. **Karyotypic analysis of *Lens orientalis* (Boiss.) handle-mazetti.** *Cytologia* 49: 151-155. University of Saskatchewan, Crop Development Centre, Saskatoon, Saskatchewan, Canada.

Karyotype analysis was performed in 11 lines of *Lens orientalis*. There were no differences in chromosome morphology of different accessions. The diploid chromosome number was 14 and the average chromosome length was 4.34 μ. The karyotype comprised one metacentric, three submetacentric and three acrocentric chromosome pairs. The fourth longest chromosome pair (a submetacentric) was characterized by a conspicuous secondary constriction. A karyogram and an idiogram were prepared and the karyotypic formula developed.

Zamir, D. and Ladizinsky, G. 1984. **Genetics of allozyme variants and linkage groups in lentil.** *Euphytica* 33: 329-336.

The genetics of eight electrophoretically detectable enzymes in lentil was examined. The enzyme systems glutamicoxaloacetic transaminase, malic enzyme, phosphoglucomutase, alcohol dehydrogenase, 6-phosphogluconate dehydrogenase, shikimic dehydrogenase, and isocitrate dehydrogenase were assayed. The allozymes at each of the studied loci behaved in a codominant manner and segregated in the expected Mendelian fashion. Linkage tests between these loci and an additional morphological trait revealed two linkage groups that involved five loci; the rest were independent of each other.

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Lens News Service

FORTHCOMING CONFERENCES — 1985

October

Arid Lands: Today and Tomorrow. An International Arid Lands Research and Development Conference
Tucson, Arizona, USA, 21-25 Oct
Contact: Dr. G. P. Nabham, University of Arizona, Office of Arid Lands Studies, Tucson, Arizona 85721, USA

1986

June

II International Legume Conference
St. Louis, Missouri, USA, 23-27 June
Contact: Dr. J. L. Zarucchi, Legume Conference Coordinator, Missouri Botanical Garden, P.O. Box 299, St. Louis, Missouri 63166, USA

July

The International Food Legume Research Conference on Pea *(Pisum sativum)*, **Lentil** *(Lens culinaris)*, **Faba bean** *(Vicia faba)*, **and Chickpea** *(Cicer arietinum)*
Spokane, Washington, USA, 6-11, July

The conference theme is the assessment of research on cool-season food legumes and the development of strategies for their improvement. Invited papers will focus on topics in both the basic and applied sciences. The conference is designed to address world-wide multidisciplinary research interests and to develop strategies for the exploitation of cool-season food legumes in the diverse systems in which they are grown.
Contact: Dr. R. H. Lockerman, Chairman, International Food Legume Research Conference, Plant and Soil Science Department, Montana State University, Bozeman, Montana 59717, USA

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International Board for Plant Genetic Resources (IBPGR) Crop Ecology and Genetic Resources Unit Food and Agriculture Organization of the United Nations Via delle Terme de Caracalla 00100 Rome, Italy	Collection, conservation, documentation, and use of plant germplasm.
International Center for Agricultural Research in the Dry Areas (ICARDA) P.O. Box 5466 Aleppo, Syria	Lentil, chickpea, and faba bean.
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru P.O. Andhra Pradesh 502 324, India	Chickpea, pigeonpea, and groundnut, peanut.
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The aim of LENS Newsletter is to publish quickly the results of recent research on lentils. Articles should normally be brief, confined to a single subject, good quality, and of primary interest to research, extension, and production workers, and administrators and policy makers.

Style

Articles should have an abstract (maximum 250 words) and whenever possible the following sections: introduction, materials and methods, and results and discussion. Authors should refer to recent issues of LENS for guidance on format. Articles will be edited to maintain uniform style but substantial editing will be referred to the author for his/her approval; occasionally, papers may be returned for revision.

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The views expressed and the results presented in the newsletter are those of the author(s) and not the responsibility of ICARDA or the University of Saskatchewan. Similarly, the use of trade names does not constitute endorsement of or discrimination against any product by ICARDA.

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Manuscript

Articles should be typed double-spaced on one side of the page only. The original and two other legible copies should be submitted. The contributor should include his name and initials, title, program or department, institute, postal address, and telex number if available. Figures should be drawn in India ink; send original artwork, not photocopies. Define in footnotes or legends any unusual abbreviations or symbols used in a figure or table. Good quality black and white photographs are acceptable for publication. Photographs and figures should preferably be 8.5 cm or 17.4 cm wide.

Units of measurement are to be in the metric system; e.g. t/ha, kg, g, m, km, ml (= mililiter), m^2.

The numbers one to nine should be written as words except in combination with units of measure; all other numbers should be written as numerals; e.g., nine plants, 10 leaves, 9 g, ninth, 10th, 0700 hr.

Examples of common expressions and abbreviations

3 g; 18 mm; 300 m^2; 4 Mar 1983; 27%; 50 five-day old plants; 1.6 million; 23 u g; 5^oC; 1980/81 season; 1980-82; Fig.; No.; FAO; USA. Fertilizers: 1 kg N or P_2O_5 or K_2O/ha.
Mon, Tues, Wed, Thurs, Fri, Sat, Sun; Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec. versus = vs, least significant difference = LSD, standard error = SE ±, coefficient(s) of variation = CV(s). Probability: Use asterisks to denote probability * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Botanical: Include the authority name at the first mention of scientific names. Cultivar(s) = cv(s), variety = var(s), species = sp./spp., subspecies = subsp., subgenus = subg., forma = f., forma specialis = f.sp.

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Submission of articles

Contributions should be sent to LENS, Documentation Unit, ICARDA, P.O. Box 5466, Aleppo, Syria.

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