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LENS NEWSLETTER

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UNIVERSITY OF SASKATCHEWAN

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COVER: Screening lentil for FBNYV resistance, highly resistant (ILL 6198, left) and highly susceptible (Crimson, right) genotypes (see pp. 41–43).

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Research Articles

Breeding and Genetics

Effect of Genetic and Non-genetic Factors on Crossability in Lentil

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Abstract

The effect of varietal group, day length, growing conditions and temperature on crossability in lentils (*Lens culinaris* Medik.) was investigated. The highest pod and seed set either in the greenhouse or in the field in winter was observed in the minimum–maximum temperature regime of 10–21°C. Pod and seed set were higher in the greenhouse than in the field both in *microsperma* × *macrosperma* and reciprocal crosses. The use of *microsperma* as female parent in winter and *macrosperma* as female parent in summer produced substantially higher pod and seed set than their reciprocals. The effect of varietal group, day length, temperature and growing conditions is important and should be taken into consideration when planning hybridization programs in lentil.

Key words: *Lens culinaris*; lentils; hybridization; genetics; varieties; temperature; duration; fruit; seeds; India.

تأثير العوامل الوراثية وغير الوراثية في قابلية التهجين في العدس

الملخص

دُرست تأثيرات مجموعة من الأصناف، طول النهار، ظروف النمو ودرجات الحرارة على قابلية التهجين في العدس (*Lens culinaris* Medik.). وقد لوحظت أعلى نسب عقد القرون والبذور ضمن نظام درجات حرارة دنيا – عظمى 10–21 مْ، سواء في الدفيئة أو في الحقل تحت النهارات القصيرة. وكان عقد القرون والبذور أعلى في الدفيئة منه في الحقل في التهجينات الصغيرة الحبة x الكبيرة الحبة والتهجينات العكسية معاً. إن استخدام صنف صغير الحبة كأم تحت النهارات القصيرة وصنف كبير الحبة كأم تحت النهارات الطويلة انتج عقد قرون وبذور أعلى بدرجة كبيرة من تهجيناتها العكسية. وتعتبر تأثيرات مجموعة من الأصناف، طول النهار، درجات الحرارة وظروف النمو على جانب كبير من الأهمية مما يحتم أخذها بعين الاعتبار عند التخطيط لبرامج تهجين في العدس.

Introduction

Lentil comprises two subspecies, gene complexes or varietal groups, namely small-seeded (*microsperma*) and large-seeded (*macrosperma*). The genetic restructuring of lentils in India involves *microsperma* –*macrosperma* introgression. Crossing in lentil is difficult due to the small, fragile and cleistogamous nature of the flowers. *Microsperma* × *macrosperma* hybridization programs are normally undertaken during short days in winter. However, certain exotic *macrosperma* types do not flower under these conditions and require artificially lengthened days in the greenhouse, or growing in the Summer Himalayan Nursery. It is, therefore, imperative to know the effect of genetic (varietal group) and non-genetic factors, such as growing conditions, day length and temperature, on crossability in lentil gene complexes in order to help geneticists and breeders plan *microsperma* × *macrosperma* hybridization programs efficiently.

Materials and Methods

The experimental material comprised four *microsperma* varieties (PL 406, PL 639, L 830 and L 9-12), recommended for cultivation in northern India, and two *macrosperma* introductions (HPL 4 and Precoz). These were grown during winter (October 1986 to May 1987) both in the field and in the greenhouse at Palampur (32°6′ N, 76°3′ E, 1290 m), located in the mid-hills of the north-western Himalayas. These genotypes were also grown during summer (May–September 1987) at Kukumseri (2426 m) in the Lahoul valley, which lies between latitudes 30°42′ and 32°60′ N and longitudes 76°47′ and

78°41′ in the dry, temperate, high hills of the north-western Himalayas. *Microsperma* × *macrosperma* hybridization was undertaken at Palampur for four weeks during winter (14 February to 15 March) and at Kukumseri for four weeks during summer (14 July to 13 August). All the genotypes flowered during this period. The maximum and minimum temperatures, number of cross-pollinations attempted, pods and seeds set were recorded during the crossing period and afterwards. The percentage of pods and seeds set per cross-pollination and seeds per crossed pod were calculated.

Results and Discussion

The pod and the seed set following *microsperma* × *macrosperma* crosses in the greenhouse were 17.5 and 24.5%, respectively, during week 1, having average maximum/minimum day temperature of 19.8/ 9.2°C (Table 1). The highest pod and seed set (25.5 and 30.2%) occurred during week 2 (21.3/10.2°C). The pod and seed set decreased linearly during weeks 3 and 4 following linear increase in the average maximum temperature (Figs. 1 and 2).

Table 1. Cross-pollinations attempted, pods and seeds set, and seeds/crossed pod in greenhouse (G) and field (F) during different weeks in lentil gene complexes in winter.

Week	Average air temperature (°C)		Growing conditions	Cross-pollinations attempted	Pods set	Seeds set	Seeds/ crossed pod
	Maximum	Minimum					
			microsperma × *macrosperma*				
I	19.8 ± 2.3	9.2 ± 1.8	G	355	62 (17.5)†	87 (24.5)	1.40
	14.9 ± 1.2	5.0 ± 1.7	F	289	22 (7.6)	30 (10.4)	1.36
II	21.3 ± 2.0	5.0 ± 1.7	G	388	99 (25.5)	117 (30.2)	1.18
	16.1 ± 2.1	5.6 ± 1.2	F	301	35 (11.6)	49 (16.3)	1.40
III	26.3 ± 1.9	16.7 ± 1.5	G	339	80 (23.6)	90 (26.6)	1.13
	20.2 ± 0.6	9.1 ± 1.2	F	277	45 (16.2)	58 (20.9)	1.29
IV	27.2 ± 1.5	16.6 ± 2.7	G	300	65 (21.7)	70 (23.3)	1.08
	21.9 ± 3.2	10.5 ± 1.9	F	356	66 (18.5)	90 (25.9)	1.36
			macrosperma × *microsperma*				
I			G	118	12 (10.2)	13 (11.0)	1.08
			F	81	6 (7.4)	6 (7.4)	1.00
II			G	99	12 (12.1)	23 (23.2)	1.92
			F	92	5 (5.4)	5 (5.4)	1.00
III			G	125	14 (11.2)	23 (18.4)	1.64
			F	75	8 (10.7)	13 (17.3)	1.63
IV			G	110	12 (10.9)	13 (11.8)	1.08
			F	130	8 (6.2)	13 (10.0)	1.63

† Percentage of cross-pollinations attempted in parentheses.

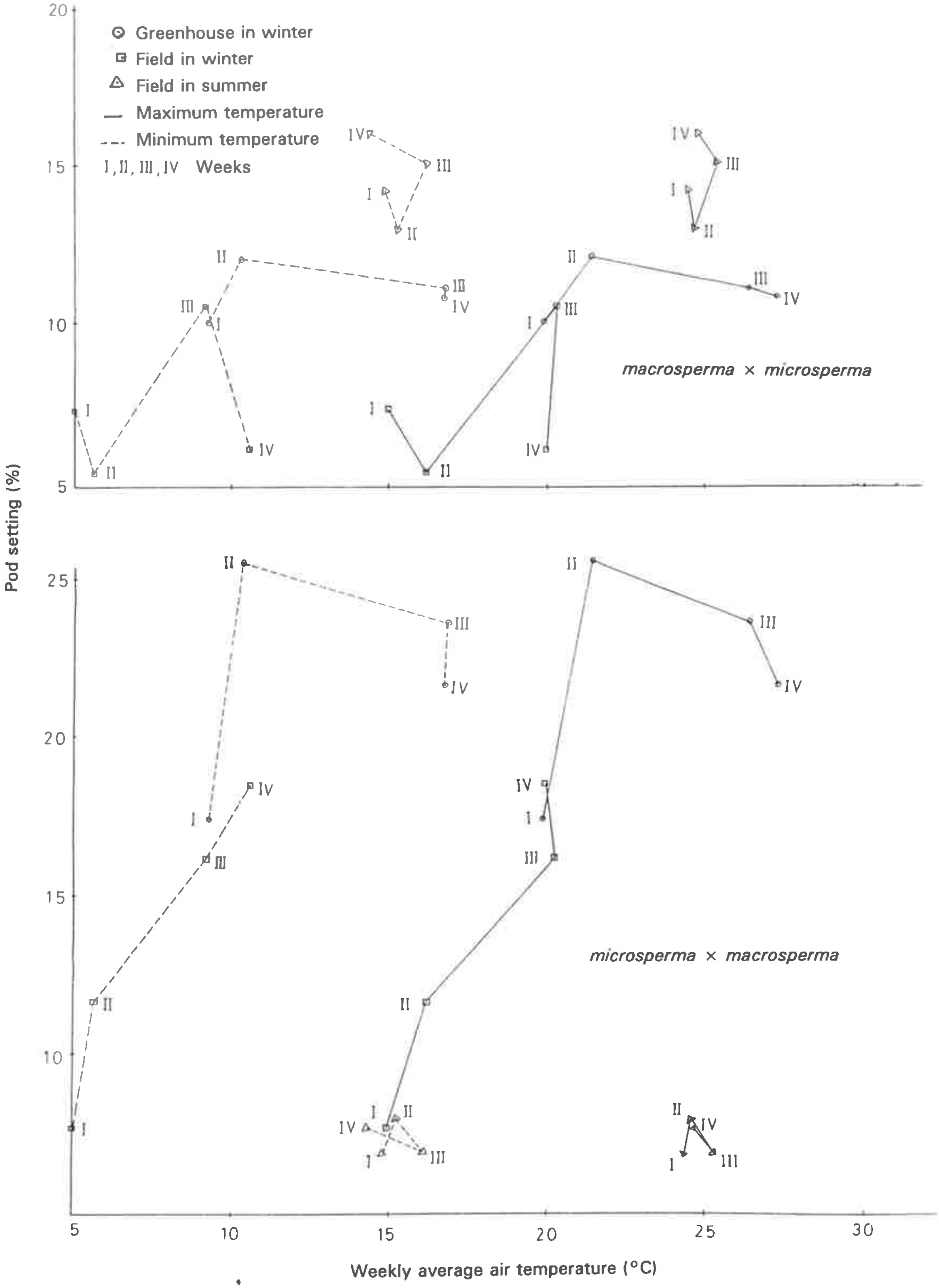

Fig. 1. Effect of temperature and growing conditions on pod setting in *microsperma* × *macrosperma* and reciprocal crosses of lentil.

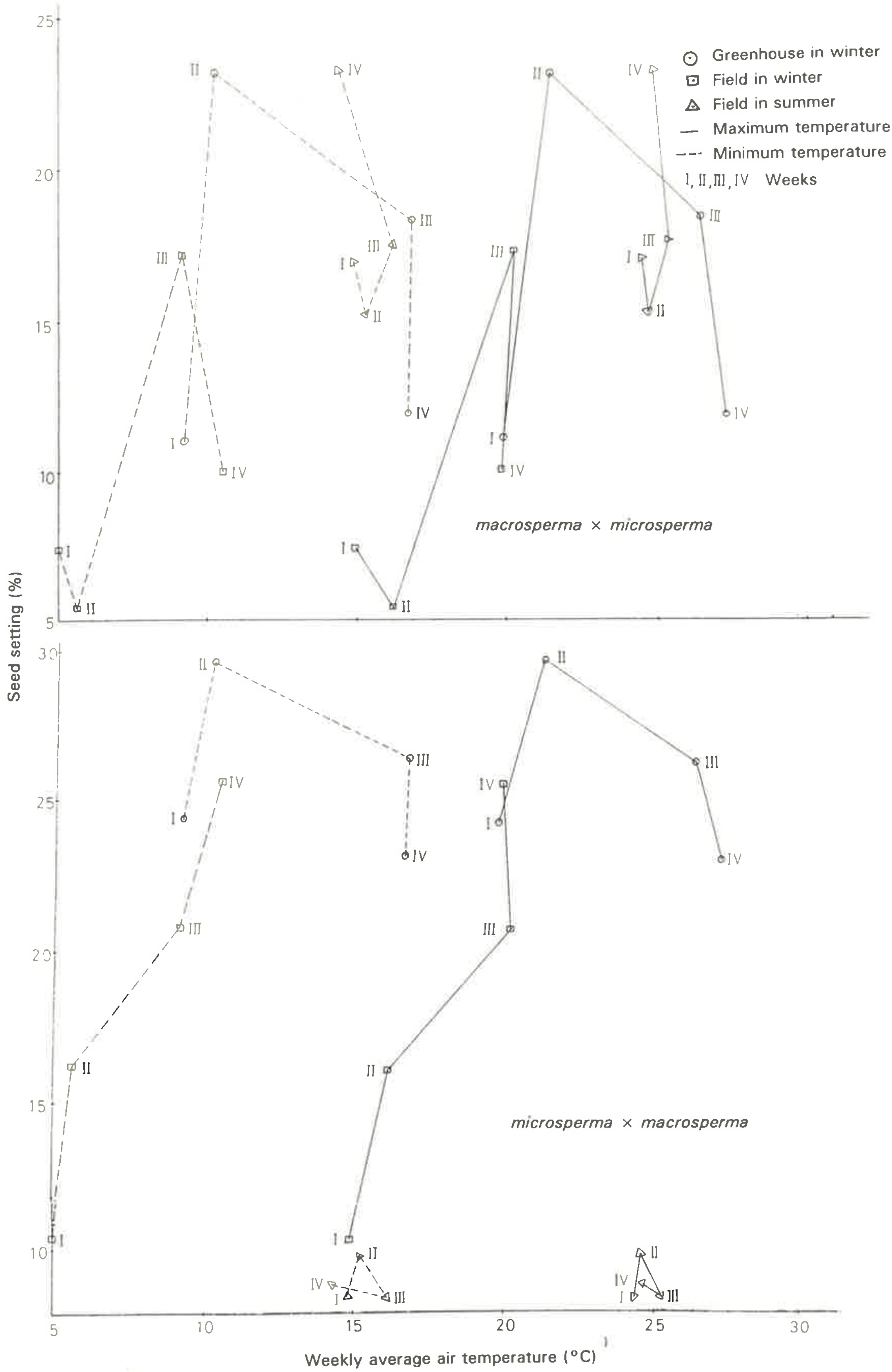

Fig. 2. Effect of temperature and growing conditions on seed setting in *microsperma* × *macrosperma* and reciprocal crosses of lentil.

Under field conditions, however, pod and seed set were 7.6 and 10.4% in week 1 (14.9/5.0°C). They increased linearly during weeks 2 and 3 following an increase in temperature, and were highest during week 4 (18.5 and 25.2%, at 21.9/10.5°C), though this was less than the pod and seed set observed in the greenhouse during week 2.

In reciprocal crosses (*macrosperma* × *microsperma*) attempted in the greenhouse, the highest pod and seed sets of 12.1 and 23.2% were during week 2 (21.3/10.2°C; Table 1). Pod and seed set decreased during weeks 3 and 4 following further increase in temperature (Figs 1 and 2). In the field, pod and seed set of 7.4 and 7.4% respectively during week 1, and 5.43 and 5.43% during week 2 were recorded (Table 1). They were highest (10.7 and 17.3%) during week 3 (20.2/9.1°C; Figs 1 and 2). They declined during week 4 with the further increase in temperature. Seeds per crossed pod decreased in the greenhouse (1.40–1.08) from week 1 to 4 with the linear increase in temperature in *microsperma* × *macrosperma* crosses (Table 1). However, this character remained unaltered in the field (1.29–1.40). Unlike in reciprocal crosses, seeds per crossed pod did not indicate any relationship with the increase in temperature either in greenhouse or field from week 1 to week 4.

These observations lead us to conclude that temperature has a important role in altering pod and seed set. The highest pod and seed set either in the greenhouse or field were observed in the minimum/maximum temperature regime of 10/21°C. Pod and seed set were higher in the greenhouse than the field in both *microsperma* × *macrosperma* and reciprocal crosses. This could be due to protection from factors such as rain, frost, sleet and wind, which are experienced in the field. In a study on technique for crossing lentils, Wilson (1972) also reports the success of manual crossing in the greenhouse during the winter, when temperatures were maintained at 18–24°C, whereas it was unsuccessful in the field.

At Kukumseri under field conditions, there was little variation in the average maximum/minimum temperature (24.4 to 25.3°C/14.3 to 16.1°C) during four weeks (Table 2). Accordingly there was no significant variation in pod and seed set and the number of seeds/pod between these weeks in *microsperma* × *macrosperma* cross combinations (Figs 1 and 2). Likewise, in reciprocal crosses, there was no substantial variation in pod (13.0–15.2%) and seed set (15.2–17.6%) during weeks 1 to 3. However, pods set (16.1%) remained unchanged, while seeds set (23.4%) improved during week 4. Seeds per crossed pod remained

Table 2. Cross-pollinations attempted, pods and seeds set during different weeks under long days in lentil gene complexes at Kukumseri.

Week	Average air temperature (°C)		Cross-pollinations attempted	Pods set	Seeds set	Seeds/crossed pod
	Maximum	Minimum				
			microsperma × *macrosperma*			
1	24.4 ± 0.3	14.8 ± 0.4	292	20 (6.85)†	25 (8.56)†	1.25
2	24.6 ± 0.4	15.2 ± 0.5	303	24 (7.92)	30 (9.90)	1.25
3	25.3 ± 0.4	16.1 ± 0.3	305	21 (6.68)	26 (8.52)	1.24
4	24.7 ± 0.3	14.3 ± 0.4	325	25 (7.69)	29 (8.92)	1.16
			macrosperma × *microsperma*			
I			147	21 (14.29)	25 (17.00)	1.19
II			138	18 (13.0)	21 (15.2)	1.17
III			165	25 (15.15)	29 (17.57)	1.16
IV			137	22 (16.05)	32 (23.35)	1.45

† Percentage of cross-pollinations attempted in parentheses.

unchanged (1.16–1.19) during weeks 1 to 3, whereas it increased (1.45) during week 4. These observations give further credence to the idea that temperature has an important role in altering pod and seed set. However, with the results available, it was not possible to decide an optimum maximum/minimum temperature for pod and seed set under long days. It also gives no indication about the extent of pod and seed set at the optimum temperature combination, which yields the highest pod and seed set under short days.

The two varietal groups behaved differently as female parents under the different day lengths prevailing in summer and winter. The use as female parents of *microsperma* in winter and *macrosperma* in summer, produced substantially higher pod and seed set than the reciprocals because of their differential adaption to photoperiod (Tables 1 and 2; Figs 1 and 2). The adaptability of the female parent to a particular day length is more important than the pollen parent in planning *microsperma* × *macrosperma* hybridization programs. Erskine et al. (1990) also report the independent role of temperature and day length in determining the onset of ontogenesis in lentils.

A very high degree of association was observed between pod and seed set (%) both in the greenhouse and in the field under long and short days involving *microsperma* × *macrosperma* or reciprocal crosses (Table 3). Pod and seed set per cross-pollination attempted were affected concomitantly by day length, varietal group, growing conditions and temperature. Pod set and seeds per crossed pod had positive association in the field conditions under long days in *microsperma* × *macrosperma* and short days in reciprocal cross-combinations. Seeds set per cross-pollination under field conditions was also related with seeds per crossed pod in lentil crosses under both day lengths. The findings of the present investigation revealed the role of day length, temperature, growing conditions and varietal group on crossability in lentil and should be taken into consideration in planning hybridization in this crop.

Table 3. Interrelationships of pod (x) and seed set (y) with seed/crossed pod (z) obtained in greenhouse (G) and field (F) under different day lengths in lentil gene complexes.

Photo-period	Growing condition	Correlation		
		xy	xz	zy
		microsperma × *macrosperma*		
S	G	0.99*	–0.48	–0.35
	F	0.96*	0.50	0.72
L	F	0.99*	0.97*	0.99*
		macrosperma × *microsperma*		
S	G	0.98*	0.12	0.17
	F	0.99*	0.76*	0.76*
L	F	0.98*	0.66	0.74*

S= Short days; L= Long days.

* Significant at 5% level.

Acknowledgements

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Heterosis in Lentil[1]

قوة الهجين في العدس

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Abstract

Heterosis over better and standard parent was estimated for yield and its components in 30 hybrid lentils (*Lens culinaris* Medik.) derived by crossing three well-adapted varieties as testers and 10 eco-geographically diverse genotypes as lines. The range of heterosis over better parent (in percentage) was –10.1 to 49.9 for days to initial flowering, –16.6 to 33.7 for plant height, –17.1 to 21.0 for primary branches/plant, –16.7 to 42.7 for secondary branches/plant, –24.7 to 81.7 for pods/plant, –11.1 to 15.8 for seeds/pod, –48.8 to 19.6 for 100-seed weight and –23.5 to 106.4 for yield/plant. The majority of crosses exhibited negative heterosis over better parent for 100-seed weight. The heterosis observed for yield was mainly attained through major yield components, pods/plant and secondary branches/plant. The hybrid Pusa 4 × Pant L-234 exhibited maximum better and standard parent heterosis for yield/plant, and also showed highest better parent heterosis for pods/plant along with high heterosis for seeds/pod and 100-seed weight.

Key words: *Lens culinaris*; lentils; heterosis; hybridization; varieties; genotypes; yield components; India.

الملخص

قُدرت قوة الهجين الخاصة بأب أفضل وقياسي من حيث الغلة ومكوناتها في 30 هجيناً من العدس (*Lens culinaris* Medik.) مستمدة من تهجين ثلاثة أصناف شائعة الاستخدام، كأدوات اختبار و 10 طرز وراثية متنوعة جغرافياً - بيئياً كسلالات. وقد تراوحت مدى قوة الهجين على أب أفضل (كنسبة مئوية) ما بين 10.1 - إلى 49.9 بالنسبة لعدد الأيام حتى الإزهار الأولي، 16.6 - إلى 33.7 بالنسبة لطول النبات، 17.1 - إلى 21.0 للفروع الأساسية/النبات، 16.7 - إلى 42.7 للفروع الثانوية/النبات، 24.7 - إلى 81.7 للقرون/النبات، 11.1 - إلى 15.8 للبذور/القرن، 48.8 - إلى 19.6 لوزن المئة بذرة و23.5 - إلى 106.4 للغلة/النبات. أظهرت غالبية الهجن قوة هجين سلبية عبر أب أفضل من حيث وزن المئة بذرة. تم التوصل إلى قوة الهجين من حيث الغلة عن طريق مكونات الغلة الأساسية بصورة رئيسية، القرون/النبات والفروع الثانوية/النبات. وقد أظهر الهجين Pant L - 234 x Pusa 4 قوة هجين قصوى لأب أفضل وقياسي من حيث الغلة/النبات. كما أظهر قوة هجين أعلى لأب أفضل من حيث القرون/النبات إلى جانب قوة هجين عالية بالنسبة للبذور/القرن ووزن المئة بذرة.

Introduction

Lentil is a highly self-pollinated crop. The full exploitation of heterosis through development of hybrid varieties will not be possible in the near future. However, the development of pure lines from segregating populations is very important for producing high-yielding varieties. Crosses exhibiting good heterotic expression in F_1 are likely to give better segregants in later generations. Little attempt has been made to obtain information about the magnitude of heterosis involving *microsperma* and *macrosperma* subspecies (Sharma 1991). Therefore, the present investigation was undertaken to specify the magnitude of heterosis in 30 F_1 hybrids involving *microsperma* and *macrosperma* types.

Materials and Methods

Ten eco-geographically diverse lines were used as as female parents: six *microsperma* type (NDL 1, Ranjan, Pusa 4, IC 784013, K 78415 and 1363) and four *macrosperma* types (Precoz, EC 151015, E 153 and E 258). These were crossed with three well-adapted and released varieties (Pant L 234, Pant L 406 and H 75: all *microsperma* types) as pollinators in a line × tester design to generate 30 hybrids. The material was sown during *rabi* (winter) 1991/92 in a randomized block design with

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Table 1. Heterosis (%) over better parent (BP) and standard variety (SV) in 30 hybrids for different characters.

Hybrid		Days to flowering	Plant height (cm)	Primary branches/plant	Secondary branches/plant	Pods/plant	Seeds/pod	100-seed weight (g)	Yield/ plant (g)
NDL 1 × Pant L 234	BP	3.2	-9.2	12.8	19.2	27.9	-9.9	-0.9	24.5
	SV	7.7**	9.1	10.8	24.9	18.6	7.9	5.4	25.4
NDL 1 × Pant L 406	BP	1.5	-5.9	3.6	21.8	22.1	-7.7	7.3	48.6*
	SV	1.5	6.1	3.6	21.8	22.1	10.5	12.3	49.7*
NDL 1 × H 75	BP	1.6	3.4	11.0	29.9*	39.0*	-3.3	8.5	29.1
	SV	3.5	16.6	2.7	31.0*	37.6*	15.8	13.6	30.1
Ranjan × Pant L 234	BP	9.1**	-10.4	-3.7	2.5	21.3	1.2	-18.6**	30.2
	SV	2.2	7.8	-5.4	7.4	-6.3	10.5	23.4*	19.3
Ranjan × Pant L 406	BP	3.2	3.7	0.0	17.5	25.6	2.4	-11.1	57.1**
	SV	-3.3	9.7	0.0	17.5	25.6	11.8	34.2**	57.0**
Ranjan × K 75	BP	0.1	6.0	14.0	18.2	14.7	1.2	-15.5	50.7
	SV	-6.2*	12.2	2.7	19.2	13.5	10.5	27.5**	38.2
Precoz × Pant L 234	BP	49.9**	13.8	-10.1	33.3*	67.9**	-6.9	-36.4**	32.9
	SV	30.9**	36.8**	-11.7	39.7**	26.1	-6.6	52.2	17.4
Precoz × Pant L 406	BP	41.8**	23.5*	-17.1	12.7	6.2	-8.1	-41.3**	-1.5
	SV	23.9**	23.6*	-17.1	12.7	6.2	5.3	40.5**	-1.5
Precoz × K 75	BP	47.2**	33.7**	6.0	32.0*	26.0	-9.2	-43.0**	33.4
	SV	28.6**	36.7**	-4.5	33.2*	24.7	4.0	36.4**	16.8
Pusa 4 × Pant L 234	BP	2.9	-2.1	14.7	42.7**	59.2**	5.4	0.0	106.4**
	SV	2.5	17.7	12.6	49.6**	19.6	15.1*	51.3**	82.2**
Pusa 4 × Pant L 406	BP	-3.1	6.8	-0.9	25.3	54.2**	15.8*	14.2*	67.6**
	SV	-3.5	13.9	-0.9	25.3	54.2**	15.8*	29.7**	67.6**
Pusa 4 × K 75	BP	-2.6	-2.1	5.0	-0.4	2.1	10.0	-10.9	36.6
	SV	-3.0	4.4	-5.4	0.4	1.0	15.8*	34.8**	19.6
IC 784013 × Pant L 234	BP	10.6**	-15.4	-12.8	12.5	15.7	-7.2	-11.6	-7.4
	SV	6.8*	1.7	-14.4	17.9	-13.0	1.3	-6.0	-18.2
IC 784013 × Pant L 406	BP	-4.6	8.0	2.7	8.7	3.2	11.8	19.6	10.6
	SV	-7.9**	8.0	2.7	8.7	3.2	11.8	19.6	10.6

IC 784013 × K 75	BP	-1.4	14.9	21.0*	23.9	12.6	0.0	4.9	30.9
	SV	-4.4	17.5	9.0	21.9	11.4	5.3	9.2	14.6
EC 151015 × Pant L 234	BP	5.0	-14.8	0.0	12.5	81.7**	-2.4	-32.4**	11.8
	SV	8.5**	2.5	-1.8	17.9	36.5*	6.6	-5.4	-1.3
EC 151015 × Pant L 406	BP	-2.5	1.0	-12.6	-11.8	-5.0	4.8	-10.2	4.9
	SV	-2.5	9.4	-12.6	-11.8	-5.0	14.5*	25.6	4.9
EC 151015 × K 75	BP	-10.1**	1.8	5.0	4.9	17.7	7.5	-0.9	67.0**
	SV	-8.4**	10.3	-5.4	5.2	16.5	13.2	38.6*	46.3*
IC 78415 × Pant L 234	BP	2.8	-13.8	-4.6	7.5	43.4	4.8	-7.4	9.8
	SV	7.9**	3.6	-5.4	12.2	7.8	14.5*	14.2	-20.3
IC 78415 × Pant L 406	BP	-9.4**	-6.9	-5.4	-9.2	-24.7	-11.1	12.3	21.1
	SV	-9.4**	5.5	-5.4	-9.2	-24.7	-5.3	12.3	21.1
IC 78415 × K 75	BP	-2.4	-16.6	8.0	7.4	-15.6	0.0	-4.3	-18.6
	SV	-0.6	-5.5	-2.7	8.3	-16.5	5.3	-0.3	-28.7
E153 × Pant L234	BP	1.8	-5.1	-12.8	3.8	33.2	-2.4	1.6	28.2
	SV	7.9**	14.1	-14.4	8.7	0.1	6.6	39.6**	13.3
E 153 × Pant L 406	BP	3.9	10.5	-5.4	11.4	4.4	10.4	3.8	23.3
	SV	3.9	10.5	-5.4	11.4	4.4	11.8	36.4	23.3
E 153 × K 75	BP	6.3*	14.4	4.0	4.3	0.4	5.0	4.5	39.5
	SV	8.3**	16.9	-6.3	5.2	-1.5	10.5	48.1**	22.2
E 258 × Pant L 234	BP	18.0**	0.8	-7.1	10.4	30.7	-3.6	-41.7**	11.7
	SV	25.2**	21.2*	-8.8	15.7	-1.8	5.3	70.9**	-1.4
EC 258 × Pant L 406	BP	18.9**	12.8	0.9	38.9**	27.6	-1.3	-40.8**	34.5
	SV	18.9**	22.4*	0.9	38.9**	25.6	-1.3	74.1	34.5
E 258 × K 75	BP	15.6**	-6.6	4.9	-16.7	-24.6	-1.3	-48.8**	-23.5
	SV	17.7**	1.5	-18.3	-16.0	-25.4	4.0	50.0	-33.0
1363 × Pant L234	BP	6.5*	-3.2	11.7	22.4	69.3**	1.2	3.5	72.1**
	SV	13.0**	16.3	11.7	33.6*	53.3**	10.5	2.5	52.0*
1363 × Pant L 406	BP	9.2**	4.0	4.5	7.6	26.5	1.2	3.8	22.9
	SV	9.2**	14.4	4.5	17.5	26.5	9.2	3.8	22.9
1363 × K 75	BP	12.7**	-6.6	-0.9	8.8	25.8	4.9	-0.6	27.7
	SV	14.8**	2.8	-0.9	18.8	24.5	13.2	3.5	11.9

*,** Significant at P = 0.05 and P = 0.01, respectively.

two replications. Plots were single rows, 3 m long with 30 cm between rows and 5 cm between plants within rows. The parents and F_1s were nested within crosses and randomized. Observations were recorded on five randomly selected plants from each of the F_1s and parents for eight characters. Heterosis was measured in percentage over the better parent of the cross and the standard parent, which was Pant L 406.

Results and Discussion

There was a high heterosis for yield/plant, which reached significance over better parent in six crosses and ranged from 48.6 to 106.2% (Table 1). These six cross-combinations also significantly out-yielded the standard variety, by 46.2 to 82.2%. Heterosis for yield/plant was not strictly proportional to the heterosis observed for yield components. In the majority of crosses, heterosis in two or three components coincided with heterosis for yield/plant. The crosses showing standard heterosis for yield/plant also expressed desirable standard heterosis for four to six other characters, with the exception of NDL 1 × Pant L 406. The cross Pusa 4 × Pant L 234 showed positive heterosis for secondary branches/plant, and Pusa 4 × Pant L 406 did so for pods/plant. Both of these crosses also had positive standard heterosis for seeds/pod and 100-seed weight along with yield/plant.

Among 12 hybrids involving *microsperma* × *macrosperma*, only one (EC 151015 × K 75) exhibited significant positive heterosis for yield/plant over both better and standard parents along with significant desirable heterosis for days to flowering (over both parents) and significant positive heterosis for 100-seed weight (over standard).

Besides yield, considerable heterosis was observed for other characters, but its degree varied considerably depending upon the character concerned. The best crosses for various characters were EC 151015 × K 75 for days to flowering; Precoz × K 75 for plant height; IC 784013 × K 75 for primary branches/plant; Pusa 4 × Pant L 234 for secondary branches/plant; Pusa 4 × Pant L 406 for pods/plant and seeds/plant. All of which showed significant heterosis in desirable direction over both better and standard parents. For 100-seed weight, more than half of the F_1s exhibited desirable heterosis over standard variety; however, none of the crosses showed desirable heterosis over the better parent. Several other workers report high degrees of heterosis for yield and its components in the F_1s of various grain legumes (Singh 1991).

Secondary branches/plant, pods/plant, seeds/pod and 100-seed weight appeared important yield components associated with manifestation of heterosis for yield. This confirms the view that heterosis for yield is due to heterosis in individual yield components.

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Agronomy and Mechanization

Cultivation of Lentil in Pakistan: A Survey of Major Lentil-growing Areas

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Abstract

To obtain data on the causes of low yield in lentil (*Lens culinaris* Medik.), 44 farmers were interviewed in Punjab and NWFP – an area representing about 50% of Pakistan's lentil area. Lack of soil moisture at the time of planting due to untimely rains was the most serious problem identified in all but one of the districts surveyed. Additional serious constraints were: plant diseases (Bajaur and Narowal Districts); expense of inputs (Swat and Attock Districts); wild boar (Gujrat District); small size of land holdings (Narowal District), and storage pests (Rawalpindi District).

Key words: *Lens culinaris*; lentils; cultivation; surveys; crop loss; soil moisture; plant diseases; rain; costs; stored products pests; small farms; boars; Pakistan.

زراعة العدس في الباكستان : مسح لمناطق زراعة العدس الرئيسية

الملخص

للحصول على بيانات حول أسباب الفاقد في غلة العدس (*Lens culinaris* Medik.)، تمت مقابلة 44 مزارعاً في البنجاب و NWFP – وهي منطقة تمثل حوالي 50٪ من مناطق زراعة العدس في الباكستان. تبين أن افتقار رطوبة التربة في موعد الزراعة الناجم عن هطول الأمطار في أوقات غير مناسبة، يجسد أكثر المشاكل خطورة في جميع الأقاليم التي تم مسحها باستثناء إقليم واحد. كما كانت هناك معوقات جدية أخرى تجلت في : أمراض النبات (في إقليمَي Bajaur و Narowal)، تكاليف مستلزمات الإنتاج (في إقليمَي Swat و Attock) وجود الخنازير البرية (في إقليم Gujrat)، الحيازات الصغيرة من الأرض (إقليم Narowal) وآفات التخزين (إقليم Rawalpindi).

Introduction

Lentil is a valuable legume crop of Pakistan in human nutrition and in dryland cropping systems. However, the production of lentil in the country is insufficient to meet consumer requirements. Therefore, the Government has to spend foreign exchange to import lentils. According to a recent report by the Ministry of Finance, more than 32,000 tonnes of lentils were imported by the Government during the five years 1987–92, which cost about 246 million rupees.

The average yield of lentil in the country is about 408 kg/ha which is very low as compared with the world average of 812 kg/ha (FAO 1992). The blame for poor yield is generally placed on biotic (insects, diseases, etc.) and abiotic (cultivation on marginal land, seed distribution, etc.) stresses. Generalizations about these stresses have been made from individual observations and interviews with farmers, but not based on data to indicate their range and intensity. Presently, no data are available which identify the potential threats to lentil cultivation in various growing areas. Therefore, a survey of major growing areas was conducted to identify the potential factors (biotic and abiotic) responsible for low lentil yields in farmers' fields in Pakistan.

Procedural Outline

Of the total area sown for lentils in the country, 75% (67,900 ha) lies in the province of Punjab while another three provinces – NWFP, Sind and Balochistan – contribute 14%, 11% and 1%, respectively. The present survey was confined to the major lentil-growing areas of Punjab and NWFP. Table 1 lists the number of farmers interviewed and the areas surveyed, which constituted about 50% of the total lentil area.

Table 1. Areas surveyed and number of farmers questioned in each.

Target area	Sample size
Rawalpindi Division	18
Gujaranwala Division	17
Swat and Bajaur (NWFP/FATA)	9
Total	44

Observations/Results

Land holding and land tenure

The maximum land-holding size of 5.26 ha was recorded in Bajaur Agency, with the minimum of 2.83 ha in Gujaranwala Division (Fig. 1). Similarly, area allocated to lentil crop was maximum (nearly 0.8 ha) in Bajaur and least (0.5 ha) in Gujaranwala Division. The area of lentil is drastically decreasing, particularly in Gujaranwala Division, owing to land fragmentation. Land-tenure system was governed by owner, owner-cum-tenant and tenant, and the relative share was 77, 15 and 8%, respectively (Fig. 2), in all production zones.

Cropping pattern of different production zones

Table 2 shows the *rabi* (winter) and *kharif* (summer) crops commonly grown in the lentil-growing areas of Pakistan. The growing pattern of rotation of these crops is presented in Table 3.

Lentil, being a *rabi* crop,is generally grown after the harvest of *kharif* cereals and largely competes with wheat. However, in Bajaur area lentil was grown on *kharif* fallow lands as mixed crop with mustard (*Brassica*). A new pattern of rains (showers in March –April), particularly in Gujaranwala Division, has proved favorable for wheat while supporting various diseases and causing lodging in lentil. Lack of soil moisture at sowing was the main reason for fluctuation in the area of lentil crop from year to year. The area under lentil in Bajaur was increasing owing to Government policies to eradicate poppy.

Planting lentil as a sole crop was the dominant practice only in Rawalpindi Division (Fig. 3). However, lentil was sown as mixed crop in Bajaur and Gujaranwala Division on 89 and 76% of the area, respectively. Mixed cropping of lentil and mustard is a common practice in Bajaur, whereas in *barani* (dryland, rain-fed) areas of Gujaranwala Division, chickpea and linseed are grown as mixed crops with lentil.

Production practices adopted by farmers

Land preparation

Two plowings for land preparation is common practice in rain-fed areas of Gujaranwala Division and also in Rawalpindi Division (Fig. 4). However, in Bajaur Agency, lentil is grown on fairly well prepared soils and most of the farmers plow their fields three times before planting.

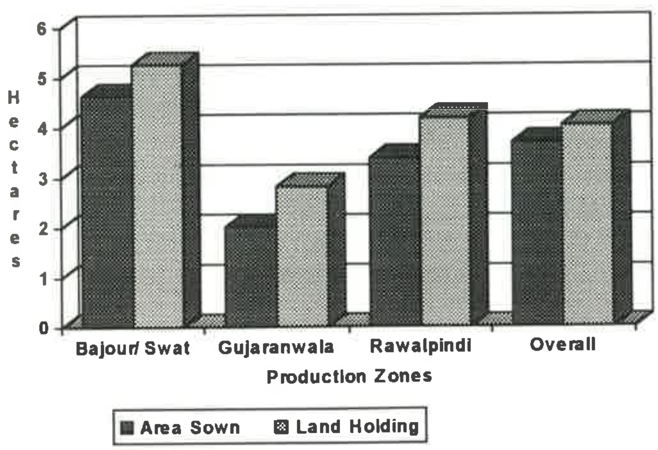

Fig. 1. Average land holding and area allocated to lentil in different production zones.

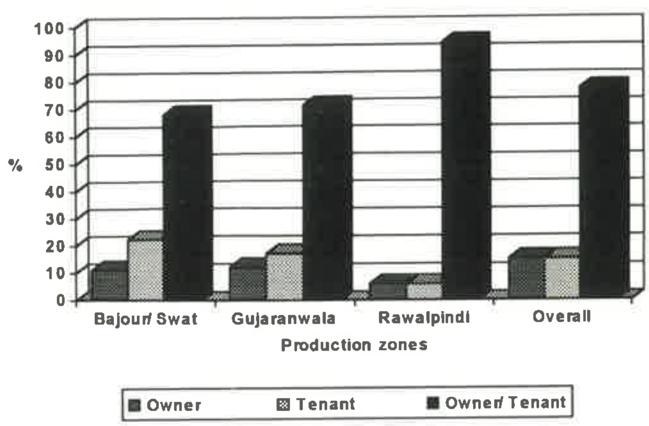

Fig. 2. Land tenure in different production zones of lentil.

Table 2. *Rabi* and *kharif* crops most commonly grown in lentil-growing areas.

Zone	District	*Rabi* crops	*Kharif* crops
Bajaur/Swat	Bajaur	Barley, lentil, poppy, mustard, wheat	Maize, sorghum
	Swat	Barley, lentil, onions, peas, wheat	Maize, mung, urd bean, tomato
	Dir	Barley, lentil, mustard, wheat	Maize, sorghum
Gujaranwala	Gujrat	Chickpea, lentil, sesame, wheat	Millet, mung, urd bean, moth bean, sorghum
	Narowal	Barseem, chickpea, lentil, wheat	Millet, maize, urd bean, moth bean, rice, sorghum, sugarcane, rape seed
	Sialkot	Chickpea, lentil, wheat	Rice, urd bean, sunflower
Rawalpindi	Attock	Barley, lentil, mustard, wheat	Mung, urd bean, maize, mustard, sesame
	Chakwal	Chickpea, lentil, mustard, wheat	Millet, groundnut, maize, sorghum
	Rawalpindi	Barley, lentil, mustard, wheat	Millet, groundnut, maize, mung, urd bean, muskmelon

Table 3. Crop rotations commonly practiced by lentil growers in different production zones.

Zone	District	Common crop rotations
Bajaur/Swat	Bajaur	(i) Fallow–lentil–maize–wheat/barley (ii) Fallow–lentil–fallow–wheat/barley
	Swat	(i) Maize–lentil–maize–tomato/peas/wheat (ii) Tomato–lentil–watermelon/maize–wheat (iii) Fallow–lentil–fallow–wheat
Gujaranwala	Gujrat	(i) Millet–lentil–fallow–wheat (ii) Maize–lentil–fallow–wheat
	Narowal	(i) Millet–lentil–millet–wheat (ii) Urd bean–lentil–sorghum–wheat/lentil (iii) Fallow–lentil–millet–wheat (iv) Rice–lentil–rice–wheat (v) Flooded–lentil–flooded–wheat/lentil
	Sialkot	(i) Millet–lentil–fallow–wheat (ii) Rice–lentil–*kharif* fodder–wheat
Rawalpindi	Attock	(i) Maize/millet/sorghum–lentil–fallow–wheat
	Chakwal	(i) Lentil–urd bean–fallow–wheat (ii) Lentil–sorghum/groundnut–wheat
	Rawalpindi	(i) Lentil–fallow/sorghum–wheat (ii) Sorghum–lentil–fallow–wheat (iii) Lentil–mung/sorghum–lentil

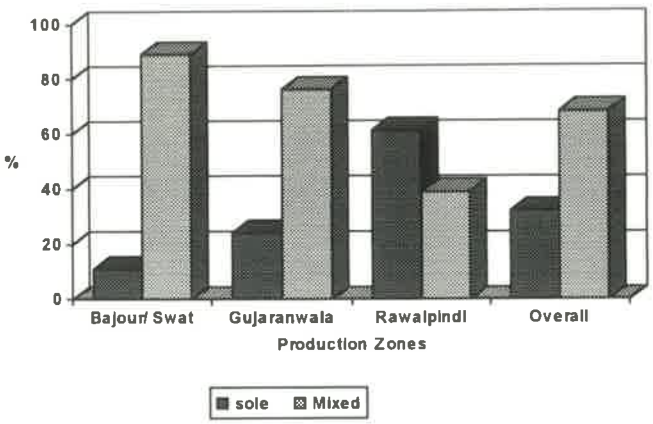

Fig. 3. Cropping pattern of different production zones.

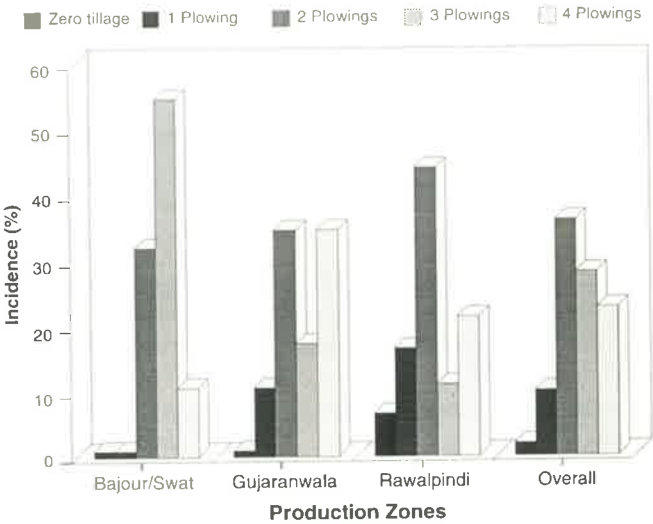

Fig. 4. Land preparation for lentil cultivation in different production zones.

Sowing

Broadcast sowing was the exclusive practice for planting lentil in all the areas surveyed. However, the seed rate used varied from farmer to farmer, ranging from 12 to 37 kg/ha. Farmers in Bajaur were using a comparatively high seed rate (35 kg/ha) compared to the 22 and 30 kg seed/ha used by farmers in Rawalpindi and Gujaranwala Divisions, respectively (Fig. 5).

Planting time of lentil in Bajaur area was mid-September, while in Gujaranwala and Rawalpindi Divisions it ranged from mid-October to early November depending upon the rains (Table 4). Farmers of Bajaur area seemed to be very particular about lentil planting time. They have set the sowing time according to the rise and movement of a group of stars locally called "Khhat". According to them, late sowing reduces the number of grains/pod and grain size, which then affect the economic yield. Day-length is correlated with rising of these particular stars.

Fertilizer application

Fertilizer application was not a common practice among the growers in any of the regions. However, some farmers applied fertilizer without any recommendation (Table 5). Most of the growers claimed that fertilizer is very expensive and the most popular fertilizer (diammonium phosphate) is often not available in the market. Black marketing also discourages the poor growers to apply fertilizer to this "risky crop".

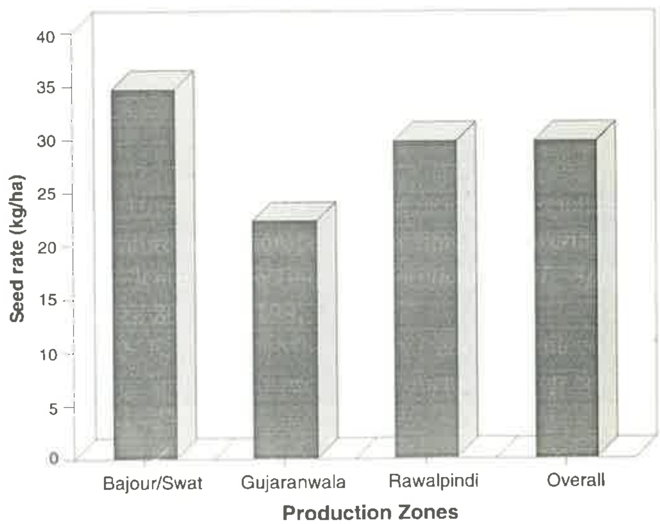

Fig. 5. Seed rate used for lentil planting in different production zones.

Table 4. Sowing and harvesting time of lentil in different production zones.

Zone	District	Sowing date	Harvest date
Bajaur/Swat	Bajaur	Mid-September	Mid-May
	Swat	Mid-October	End May
Gujaranwala	Gujrat	Early November	End April
	Narowal	End October	Mid-April
	Sialkot	Early November	End April
Rawalpindi	Attock	Mid-October	End April
	Chakwal	Mid-October	Mid-April
	Rawalpindi	Early November	Mid-April

Table 5. Fertilizer application by lentil growers in different production zones.

Zone	District	Fertilizer application
Bajaur/Swat	Bajaur	(i) Nitrophos @ 124 kg/ha (ii) Ammonium sulfate @ 124 kg/ha
	Swat	(i) DAP @ 248 kg/ha
Gujaranwala	Gujrat	(i) DAP @ 124 kg/ha (ii) Urea @ 124 kg/ha (iii) Farmyard manure @ 5 trolleys/ha
	Narowal	(i) Urea @ 40 kg/ha
	Sialkot	Not common practice
Rawalpindi	Attock	(i) Urea @ 79 kg/ha (ii) Urea + DAP @ 124 kg/ha each
	Chakwal	(i) Urea @ 40 kg/ha
	Rawalpindi	(i) Urea @ 82 kg/ha (ii) Urea + DAP @ 62 kg/ha each

DAP = diammonium phosphate.

Weeding practices

Weeding practice in the lentil crop as well as the purpose of weeding varied according to the needs and resources of the farmers in different production zones (Figs 6 and 7). Scarcity of fodder is very common in all the rain-fed areas, so weeding has dual purpose: besides protecting the crop, farmers get green fodder for livestock (Fig. 7). This practice ultimately decreases grain yield, because in most of the fields weeding is practised after the critical time. Common weed species observed in lentil fields are listed in Table 6.

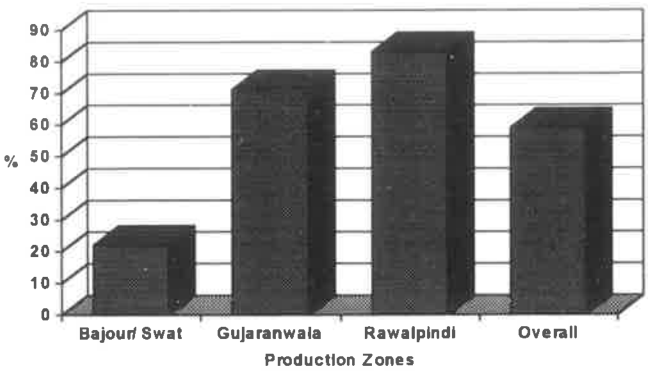

Fig. 6. Percentage of farmers practising weeding in different production zones.

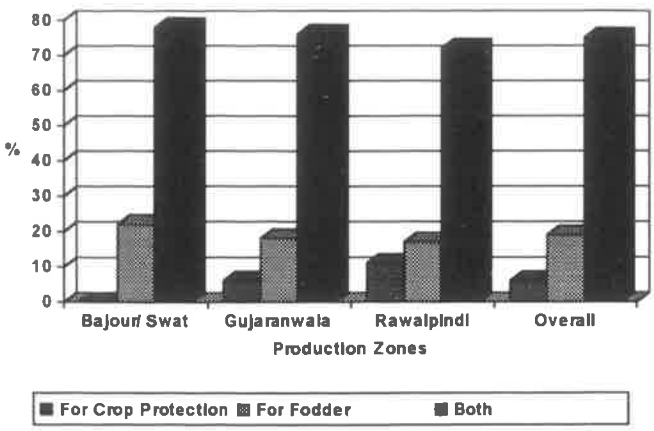

Fig. 7. Purpose of weeding in different production zones.

Table 6. Common weeds† of lentil in different production zones.

Zone	District	Weeds†
Bajaur/Swat	Bajaur	Maina, Billi Booti, Dumbi Grass
	Swat	Not a serious problem
Gujaranwala	Gujrat	Maina, Billi Booti, Wild Vetch, Pohli
	Narowal	Maina, Billi Booti, Bathu, Piazi, Wild Vetch
	Sialkot	Pohli
Rawalpindi	Attock	Wild Oat, Pohli, Laili, Wild Vetch, Billi Booti
	Chakwal	Papra, Pohli, Piazi
	Rawalpindi	Maina, Pohli, Billi Booti, Piazi, Dodhak

† Bathu = *Chenopodium album* L.; Billi Booti = *Anagallis arvensis* L.; Dodhak = *Euphorbia helioscopia* L.; Dumbi Grass = *Phalaris minor* Retz.; Laili = *Convolvulus arvensis* L.; Maina = *Medicago polymorpha* L.; Papra = *Fumaria parviflora* Lam.; Piazi = *Asphodelus tenuifolius* Cav.; Pohli = *Carthamus oxycantha* Bieb.; Wild Oat = *Avena fatua* L.; Wild Vetch = *Vicia sativa* L.

Diseases and insects

Diseases and insects observed in surveyed areas are presented in Table 7. Most fields in Bajaur and Swat area were disease-free, but ascochyta blight and botrytis were present in traces. In Gujaranwala Division, an unidentified disorder causing burning of crop along with rotting of roots was observed after torrential rains, usually at the time of pod formation. This was noted as a serious threat to the crop for several years. Devastation of the lentil crop in Narowal Tehsil resulted in a drastic decrease in production area. Similarly, ascochyta blight was recorded as an important disease in Rawalpindi Division, causing severe damage every year. Among insects, pod borer causes minor problems in Swat and Gujaranwala area. Bruchid, a stored grain pest, is a problem in Rawalpindi Division, therefore marketing of the produce just after threshing is a common practice.

Table 7. Common diseases and insects of lentil crop in different production zones.

Zone	District	Diseases†	Insects†
Bajaur/Swat	Bajaur	Botrytis; Blight	None
	Swat	Botrytis; Blight; Chlorosis	Pod Borer
Gujaranwala	Gujrat	Blight	None
	Narowal	Blight; Root Rot; Rust; Unknown Disorder	White Ant; Pod Borer
	Sialkot	Blight; Root Rot	None
Rawalpindi	Attock	Blight	None
	Chakwal	Blight	None
	Rawalpindi	Blight; Stem Rot	Bruchid

† Blight = *Aschochyta lentis* Bond & Vassill.; Botrytis = *Botrytis cinerea* Pers. ex Fr.; Root Rot = *Rhizoctonia solani* Kühn; Rust = *Uromyces fabae* (Pers.) de Bary; Pod Borer = *Etiella zinkenalla* Treitschke; Unknown Disorder = Burning of plants coupled with rotting of roots due to unidentified organism.

Production potential and economics

Grain yield, cost of cultivation and net return

Average grain yield of lentil by zone is presented in Fig. 8. Lentil yields were generally higher in Bajaur area (1420 kg/ha) compared with Gujaranwala and Rawalpindi Divisions (857 and 892 kg/ha, respectively). Higher grain yield in Bajaur was due to weed-free fields, minor problems of disease, insect and other pests, planting on *kharif* fallow lands and comparatively long growing season. Moreover, farmers in Bajaur area grew lentil as a cash crop and most of the produce was sold in the market; farmers in Gujaranwala Division grew lentil mainly for domestic consumption. The trend of the growers in Rawalpindi Division was also toward marketing because they used the lentil mostly in the form of *dal*.

In Bajaur Agency and Gujaranwala Division, 67 and 71% of the growers disposed of their produce at the farm gate, whereas 72% of growers of Rawalpindi Division sold their produce in the nearest market (Fig. 9). Highest cultivation cost was recorded in Bajaur Agency (Rs. 1421/ha; Fig. 10) and lowest in Rawalpindi Division (Rs. 954/ha). There was much variation in net income among the growers interviewed, but average net return was highest in Bajaur (Rs. 11,532/ha), followed by Gujaranwala Division (Rs. 4922/ha).

Use of lentil straw

Lentil straw is considered a poor feed for cattle because of its adverse effects on health. Therefore, it is mixed with wheat straw and used as feed for livestock other than milk animals. Generally, lentil straw was used as donkey feed or as a kitchen fuel. Data show that in Bajaur area lentil straw is mostly used for livestock (Fig. 11), whereas 56% of the farmers of Rawalpindi Division reported that they did not use lentil straw at all.

Growers' awareness of improved varieties

The technical knowledge of the lentil growers regarding improved production technology, particularly improved varieties, was poor. None of the growers in Gujaranwala Division knew anything about improved varieties of lentil (Fig. 12). In Rawalpindi Division, some 22%, mostly belonging to the Farming System Research (FSR) target area of Fatehjang, knew about Mansehra-89 (Precoz), a bold-seeded variety. However, the same growers pointed out difficulties in marketing the produce of Mansehra-89. No other improved variety was observed in the fields in the FSR target area, and no improved varieties were grown elsewhere. Either local landraces or mixtures were grown throughout the lentil-production zones surveyed.

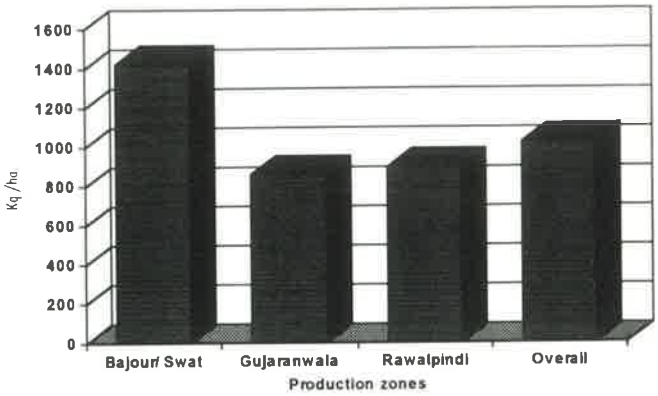

Fig. 8. Average grain yield of lentil in different production zones.

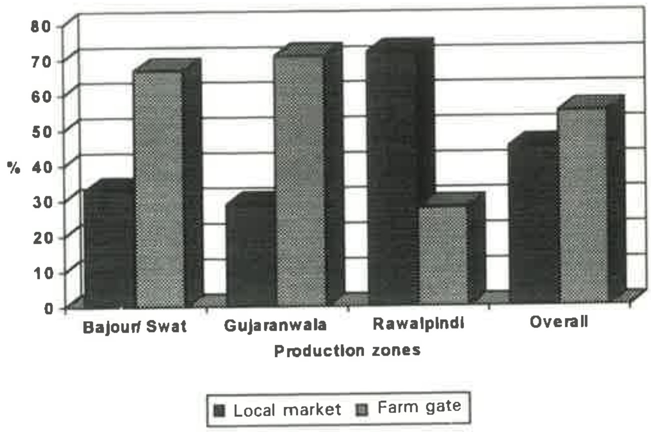

Fig. 9. Marketing pattern of lentil produce in different production zones.

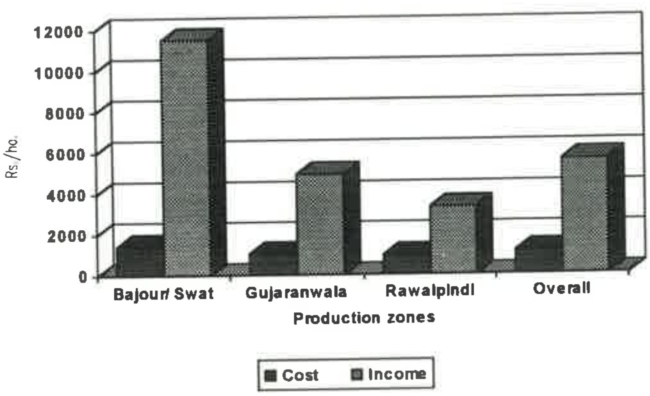

Fig. 10. Cost and net benefit of growing lentils in different production zones. (Rs 30 = US$ 1.)

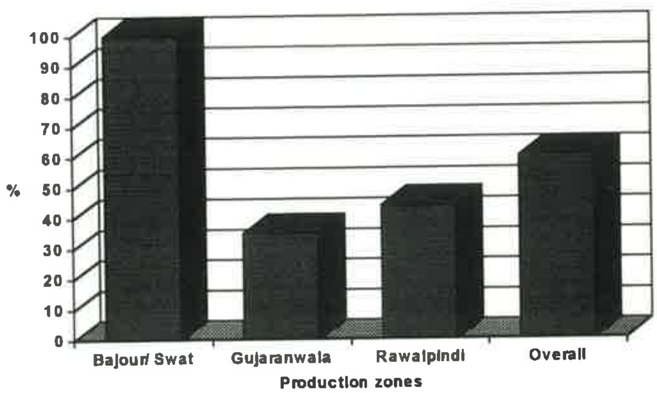

Fig. 11. Usage of lentil straw as cattle feed in different production zones.

Technical support from Agriculture Department

Of the lentil growers in Gujaranwala and Rawalpindi Divisions, 94 and 78%, respectively, were never approached by the Agriculture Department (Fig. 13). This can be attributed to Government policies which give more emphasis to major crops like wheat, rice and maize. The other drawback was that none of the production inputs (fertilizer, seed, machinery and credit) are controlled by the Extension Department, which has the mandate to contact the farmers and transfer improved production technology. Some on-farm research activities are carried out exclusively by the Research Department. We recommend that on-farm research activities should always be conducted in collaboration with other relevant agencies such as Agriculture Extension.

Overall Assessment

The most important constraints to lentil production in each area surveyed are listed in Table 8.

Reference

FAO. 1992. FAO Production Yearbook 1992. Food and Agriculture Organization, Rome, Italy.

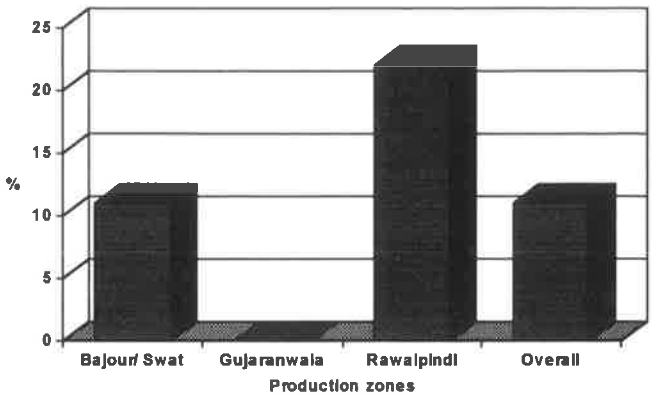

Fig. 12. Farmers' awareness about the improved lentil variety in different production zones.

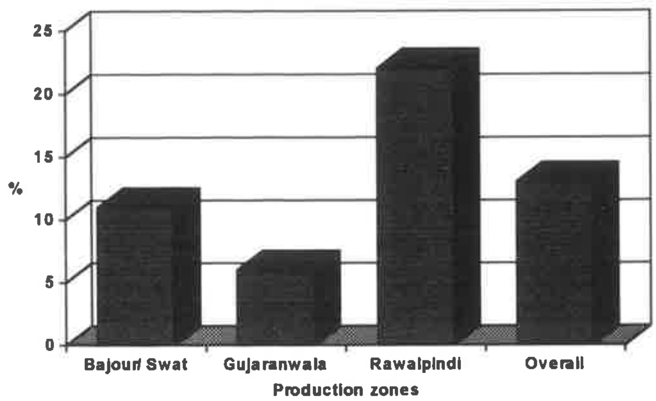

Fig. 13. Availability of technical support to farmers in different production zones.

Table 8. Most important problems identified by lentil growers in different production zones.

Zone	District	Common problems
Bajaur/Swat	Bajaur	Lack of soil moisture at the time of planting due to untimely rains. Local varieties susceptible to diseases with low yield potential.
	Swat	Lack of soil moisture at the time of planting due to untimely rains. Expensive inputs.
Gujaranwala	Gujrat	Lack of soil moisture at the time of planting due to untimely rains. Wild boar.
	Narowal	Diseases of lentil particularly unknown disorder Small land holding size.
	Sialkot	Lack of soil moisture at the time of planting due to untimely rains.
Rawalpindi	Attock	Lack of soil moisture at the time of planting due to untimely rains. Expensive inputs.
	Chakwal	Lack of soil moisture at the time of planting due to untimely rains.
	Rawalpindi	Lack of soil moisture at the time of planting due to untimely rains. Stored grain pests.

Effect of Date of Sowing and Seed-rate on Growth and Yield of Lentil

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Abstract

Field experiments comparing sowing dates, seed rates and cultivars of lentil (*Lens culinaris* Medik.) were conducted during 1987–93 winter seasons on loamy sand soil and under irrigated conditions in Punjab, India. Sowing on 25 Oct. produced significantly higher yields than sowing on 20 Nov.: 29.9, 22.6 and 41.2% higher grain yield in 1987/88 to 1989/90, respectively. For small-seeded lentils (1.7 g/100 grains) a seed-rate of 22.5 kg/ha was optimum for 25 Oct. sowing, whereas 37.5 kg seed/ha was needed for 20 Nov. sowing. The grain yield tended to decrease when a higher seed-rate of 37.5 kg/ha was used on 25 Oct. However, for medium-sized lentils (2.8 g/100 grains) under normal planting (end Oct.), 60 kg seed/ha was needed to achieve higher productivity. The use of 75 kg seed/ha showed decrease in yield.

Key words: *Lens culinaris*; lentils; sowing date; seeding rates; varieties; yields; India.

تأثير موعد الزراعة ومعدل البذار في نمو وغلة العدس

الملخص

نُفذت تجارب حقلية لمقارنة مواعيد الزراعة ومعدلات البذار وأصناف من العدس، (*Lens culinaris* Medik.) خلال المواسم الشتوية من 1987 - 1993، على تربة رملية طفالية (غرينية) وتحت ظروف الري في البنجاب بالهند. فلقد أعطت الزراعة في 25 تشرين الأول/اكتوبر غلة أعلى بكثير من الزراعة في 20 تشرين الثاني/نوفمبر : 29.9، 22.6 و 41.2٪ زيادة في الغلة الحبية خلال المواسم 88/1987 وحتى 90/1989 على التوالي. أما بالنسبة للعدس الصغير البذرة (1.7 غ/100 حبة) فقد كان معدل البذار البالغ 22.5 كغ/هـ مثالياً لموعد الزراعة في 25 تشرين الأول/اكتوبر، في حين كان معدل البذار البالغ 37.5 كغ من البذور/هـ ضرورياً لموعد الزراعة في 20 تشرين الثاني/نوفمبر. ومالت الغلة الحبية إلى التناقص عندما استخدم معدل بذار أعلى قدره 37.5 كغ/هـ في 25 تشرين الأول/اكتوبر. غير أن معدل البذار المثالي للعدس المتوسط البذرة (2.8غ/100 حبة)، تحت موعد الزراعة الطبيعي (نهاية تشرين الأول/اكتوبر)، كان 60 كغ بذار/هـ وإن استخدام 75 كغ بذار/هـ قد أدى إلى تناقص في الغلة.

Introduction

In India, lentil is an important winter pulse crop. Time of sowing is an important non-monetary factor to exploit its potential grain yield as it affects plant growth and development due to environmental change. Moreover, it is important to study the seed-rate responses to sowing dates since plant population is also a major factor affecting productivity. Higher plant population may cause severe competition between plants and lanky growth leading to lodging of the crop, which can result in poor yields. On the other hand, low plant populations do not use the available natural resources efficiently and yields are generally low. Therefore, there is a need to manipulate the plant population according to time of sowing. Furthermore, new genotypes of lentil with medium-sized grains have recently been developed and information regarding their seed-rate requirement was lacking. The present investigations were undertaken to find out the effect of sowing dates and seed-rates on the growth and yield of lentil.

Materials and Methods

Experiment 1

A field trial was conducted during 1987/88 to 1989/90 on loamy sand soil at the Punjab Agricultural University, Ludhiana, India. The experimental soil had pH 8.3 and was low in organic carbon (0.32%) and available nitrogen (106 kg N/ha), but medium in available phosphorus (17.4 kg P/ha) and potash (235 kg K/ha). Two sowing dates (25 October and 20 November) were used in the main-plots and three seed-rates (22.5, 30 and 37.5 kg/ha) as sub-plots in a split-plot experiment. Small-seeded variety 'LL 147' (100-grain weight about 1.7 g) was sown at a row distance of 22.5 cm.

Experiment 2

A second experiment was conducted on medium-sized lentil having 2.8 g average 100-grain weight during 1991/92 and 1992/93 comparing three/four genotypes (LG

362, LH 84-8, DPL 13 and DPL 30) sown at the seed-rates 45.0, 60.0 and 75.0 kg/ha, in a split-plot design with three replications. The crop was sown on 28 and 30 Oct. during the two consecutive years. A basal dose of 15 kg N and 40 kg P_2O_5/ha was given to the crop.

In both experiments, we recorded grain yield, plant height and the yield attributes number of pods/plant, seeds/pod and 100-seed weight.

Results and Discussion

Grain yield significantly decreased with the delay in sowing (Table 1). There were 29.9, 22.6 and 41.2% increases in grain yield in the 25 Oct. sowing over the 20 Nov. sowing during the three consecutive years. The higher grain yield in 25 Oct. sowing was possibly due to better plant growth and significantly higher values of yield attributes (Table 2). In all years, plants were significantly

Table 1. Grain yield (kg/ha) of lentil as influenced by seed-rate under different sowing dates.

Seed-rate (kg/ha)	Grain yield (kg/ha)								
	1987/88			1988/89			1989/90		
	20 Oct.	20 Nov.	Mean	25 Oct.	20 Nov.	Mean	25 Oct.	20 Nov.	Mean
22.5	1308	855	1081	2034	1548	1194	1493	924	1208
30	1206	943	1074	2020	1626	1249	1493	1050	1271
37.5	1160	1007	1083	1973	1733	1235	1391	1128	1259
Mean	1225	935		2009	1635		1459	1024	

LSD at 5%	1987/88	1988/89	1989/90
Sowing dates	218	195	101
Seed-rate	NS	NS	NS
Interaction	NS	NS	113

Table 2.Effect of sowing date and seed-rate on growth and yield attributes of lentil.

Attribute	Sowing date			Seed-rate (kg/ha)			
	Oct.	Nov.	LSD at 5%	22.5	30	37.5	LSD at 5%
Plant height (cm)							
1987/88	39.3	26.1	2.8	32.3	32.6	33.1	NS
1988/89	41.6	28.1	3.1	34.6	34.9	35.1	NS
1989/90	41.3	29.3	3.5	34.9	35.3	35.7	NS
Number of pods/plant							
1987/88	92.3	68.7	4.1	88.8	81.2	71.4	2.6
1988/89	117.1	88.4	3.8	110.6	103.5	94.1	3.1
1989/90	90.4	67.2	4.6	88.1	84.3	72.9	2.8
Number of seeds/pod							
1987/88	1.7	1.3	0.1	1.5	1.5	1.4	NS
1988/89	1.7	1.4	0.2	1.6	1.5	1.5	NS
1989/90	1.6	1.3	NS	1.5	1.4	1.4	NS
100-seed weight (g)							
1987/88	1.78	1.64	0.09	1.74	1.71	1.68	NS
1988/89	1.80	1.65	0.11	1.75	1.72	1.70	NS
1989/90	1.73	1.58	0.13	1.69	1.84	1.62	NS

taller in the earlier sowing. Similarly, number of pods/plant and number of seeds/pod were reduced with delayed sowing. The test weight was 1.73 g to 1.80 g in the 25 Oct. sowing, while it was 1.58 to 1.65 g in the 20 Nov. sowing. Singh and Saxena (1982) and Singh and Atma Ram (1986) report similar observations regarding the effect of planting date on the seed yield of lentil.

Variation in seed-rate did not influence the plant height, number of seeds/pod or 100-seed weight. However, number of pods was significantly higher in the treatment of 22.5 kg seed/ha than in the 30.0 and 37.5 kg seed-rates. The decrease in number of pods at higher seed-rates (Table 2) was possibly due to increased competition between plants. The mean values for grain yield did not differ significantly across seed-rates, yet the interaction between date of sowing and seed-rate was significant during 1989/90. A seed-rate of 22.5 kg/ha in 25 Oct. sowing produced maximum grain yield (1493 kg/ha), while in 20 Nov. sowing the highest yield (1128 kg/ha) was obtained with 37.5 kg seed/ha. Although during 1987/88 and 1988/89 the interaction effects were non-significant, the trend of grain yield was almost the same as recorded in 1989/90.

Genotypes showed variability in yield (Table 3). In 1992/93, genotype LG 362 was significantly superior to LH 84-8. However, in 1991/92, the differences among genotypes were not significant. In 1992/93, a seed-rate of 60 kg/ha was significantly better than 45 kg seed/ha. Similar results in the grain yield were obtained during 1991/92. The use of 75 kg seed/ha showed decrease in yield.

Table 3. Grain yield (kg/ha) of lentil genotypes (medium-size seeds) as influenced by different seed-rates.

Treatment	1991/92	1992/93	Mean
Genotype			
LG 362	1687	1186	1436
LH 84-8	1895	1067	1481
DPL 13	1864	1126	1495
DPL 30	Nt	1126	–
LSD at 5%	NS	61	
Seed-rate (kg/ha)			
45	1750	1044	1397
60	1886	1195	1540
75	1809	1139	1474
LSD at 5%	NS	71	

Nt Not tested

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Growth Pattern of Lentil under Different Seed Rates, Row Spacings and Fertilizer Levels

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Abstract

A study was undertaken at the A.S. College Lakhaoti (Bulandshahr), U.P., India, during *rabi* (winter) 1982/83 and 1983/84 to investigate the growth pattern

نمط نمو العدس تحت معدلات بذار، ومسافات بين السطور ومستويات تسميد مختلفة

ملخص

أجريت دراسة في معهد أ.س. لاخاوتي (بولاندشاهر) في الهند خلال فصلي شتاء 1982/83 و 1983/84 لدراسة نمط نمو العدس (*Lens culinaris* Medik) بثلاثة معدلات بذار، ومسافتين بين السطور وثمانية مستويات من التسميد منها شاهد واحد (بدون تلقيح وبدون تسميد). كان عدد النباتات/هـ أعلى بكثير في المسافات الضيقة ومعدلات التسميد الأعلى. وكانت النباتات أطول قليلاً، وذات فروع قليلة ومتباعدة مع

of lentil (*Lens culinaris* Medik.) with three seed-rate, two row spacings and eight fertilizer levels including one control (no inoculation and no fertilizer). Number of plants/ha was considerably higher under narrow spacing and higher seed-rate. Plants were slightly taller, sparsely branched with less-spread canopy under higher seed-rates, while they had more spreading canopy, profuse branching and were shorter under wide row spacing. During early stages of growth, higher seed-rates and wide row spacing were associated with high net assimilation rate. In general, plants were taller and more spreading under inoculation + 20 kg N + 50 kg P_2O_5/ha, followed by inoculation alone. A treatment combination of inoculation with 20 kg N + 50 kg P_2O_5/ha, followed by 20 kg N + 50 kg P_2O_5, inoculation + 50 kg P_2O_5, inoculation alone and inoculation + 20 kg N/ha appreciably improved the dry matter accumulation in stem and leaf and total dry matter accumulation, plant height, lateral spread, number of branches and crop growth rate resulting in higher grain yields over control. Highest grain yields were achieved with 60 kg seed/ha, 20 cm row spacing and full fertilizer treatment.

Key words: *Lens culinaris*; lentils; plant habit; seeding rates; spacing; fertilizer application; application rates; canopy; yields; India.

غطاء نباتي أقل انتشاراً تحت ظروف معدلات البذار العالية، في حين كان انتشار غطاؤها النباتي أكبر وعدد فروعها أكثر وأقصر، عند المسافات الواسعة بين السطور. وخلال الأطوار الأولى من النمو، ارتبطت معدلات البذار الأعلى والمسافة الواسعة بين السطور بمعدل مرتفع من التمثيل الصافي. وبشكل عام، كانت النباتات أطول وأكثر انتشاراً تحت ظروف التلقيح + 20 كغ N + 50 كغ P_2O_5/هـ يليه التلقيح وحده. وقد أدت المعاملة التي تجمع بين التلقيح و 20 كغ N + 50 كغ P_2O_5 /هـ يليهما 20 كغ/N + 50 كغ P_2O_5، وتلقيح + 50 كغ P_2O_5، وتلقيح فقط وتلقيح + 20 كغ N/هـ إلى زيادة تراكم المادة الجافة في الساق والأوراق والتراكم الإجمالي للمادة الجافة وطول النبات والانتشار الجانبي وعدد الفروع ومعدل نمو المحصول مما أدى إلى إعطاء غلة حبية أعلى عن الشاهد. وتم الحصول على أعلى غلة حبية في معاملة 60 كغ بذور/هـ والمسافة بين السطور 20سم والتسميد الكامل.

Introduction

Uttar Pradesh (U.P.) is the largest lentil-growing state of India, contributing about 434,000 ha and 209,000 tonnes to the total area and production, respectively. Lentil is considered one of the most nutritious pulses. The mean grain yield in U.P. is low (713 kg/ha). This winter pulse is mainly grown in dryland agriculture. The main constraint to lentil production is poor agricultural management such as inadequate fertilizer application and plant population.

Besides adequate seed inoculation, a knowledge of growth pattern of lentil in relation to application of nitrogen and phosphorus alone and in combination with planting geometry is of prime importance. Both plant population and its geometry are varied by altering inter- and intra-row spacing. Agronomic research on lentil crop is considered to be limited to a particular agro-climatic region. In western plain-zone of U.P., there was insufficient information on the effects of seed-rate, row spacing and fertilizer application on lentil growth. The present study was, therefore, conducted in the 1982/83 and 1983/84 seasons.

Materials and Methods

Field experiments were conducted during *rabi* (winter) 1982/83 and 1983/84 at the Instructional Research Farm of the A.S. College, Lakhaoti (Bulandshahr), U.P. (India), to investigate the growth pattern of lentil under different seeding rates, row spacings and fertilizer levels. Treatments consisted of three seed-rates (20, 40 and 60 kg/ha), two row-spacings (20 and 30 cm) and eight fertilizer levels including control (Table 1). The experiment was laid out in a single split-plot design with three replications of 48 treatment combinations keeping combinations of seed-rates and row spacings as main plots and fertilizer levels in sub-plots. Lentil (cv. Pant L 639) was sown on 29 November 1992 and 30 November 1993, in plots of 6 × 3 m. Net plot size was 5.0 × 1.8 m. The soil of the experimental field was sandy loam in texture and low in nitrogen and phosphorus with pH 7.6 during 1982/83 and pH 7.5 during 1983/84.

Total rainfall (planting to harvesting) was 49 mm during 1982/83 and 70 mm during 1983/84 crop season. Meteorologically, the second season (1983/84) was more favorable for the growth of lentil than the first season.

Table 1. Fertilization of plots.

Fertilizer treatment no.	Inoculation	N (kg/ha)	P_2O_5 (kg/ha)
1 (control)	–	0	0
2	+	0	0
3	–	20	0
4	–	0	50
5	+	20	0
6	+	0	50
7	–	20	50
8	+	20	50

Observations were recorded on five randomly selected, tagged plants in the guarded row of the demarcated 2-m row length in each plot at 30, 60 and 90 days after sowing. For the study of total dry matter accumulation and growth parameters, the plants were sampled from 25-cm row length and data converted into g/m^2.

Results and Discussion

Lower seed-rate (20 kg/ha) had a favorable effect on characters related to plant growth such as number of branches and lateral-spread (Table 2). The lateral spread recorded under 40 kg/ha was equal to that of 20 kg/ha, but higher than that of the 60 kg/ha seed-rate. Donald (1965) reports that this type of response may be regarded as mainly due to plant competition for light, air, soil moisture and nutrients under high seed-rates. It can be inferred that the extent of plant population under 40 kg/ha seed-rate may have been enough to compensate the per-plant advantage accrued to individual plants under the 20 kg/ha seed-rate (Tripathi 1982) and thereby recorded higher grain yield than that of 20 kg/ha and on par with that of 60 kg/ha. The crop growth rate (CGR) and total dry matter accumulation increased significantly up to 60 kg seed/ha. The association of total dry weight with CGR was highly significant and positive at 60–90 day stage (Table 3). Total dry matter accumulation per unit area as well as the dry matter of plant components (leaf and stem) were increased under higher seed-rates (Table 2 and 3). The higher dry matter may be due to greater leaf area in terms of leaf dry weight (Table 3) resulting in higher CGR by way of increased photosynthesis at the 60–90 day stage (Table 3).

A row spacing of 20 cm gave higher dry matter accumulation (Table 2 and 3) which was attributed to efficient arrangement of plants that presented a greater total canopy surface to convert solar energy into chemical energy resulting in higher dry matter production and grain yield (however, the difference in grain yield between 20-cm and 30-cm row spacing was not significant in 1992/93). It could be inferred that inter-plant competition for light and space was also lower with the planting geometry obtained from rows spaced 20 cm apart, resulting in best utilization of available natural resources (Shibles and Weber 1966). CGR was significantly higher and net assimilation rate (NAR) was relatively higher under 20 cm row spacing (Table 3). In general, plants were taller and more spreading under the treatment containing inoculation + 20 kg N + 50 kg P_2O_5/ha, followed by inoculation alone. Highest grain yield was achieved with the treatment inoculation + 20 kg N + 50 kg P_2O_5/ha; however, results from inoculation + 50 kg P_2O_5/ha and 20 kg N + 50 kg P_2O_5/ha were not significantly different from the best treatment. Total dry matter accumulation and CGR were highest under the treatments having inoculation + 20 kg N + 50 kg P_2O_5, 20 kg N + 50 kg P_2O_5, and inoculation + 50 kg P_2O_5/ha. It may be argued that higher nitrogen fixation due to inoculation alone and with application of N and P, simulated nodulation, and root and shoot growth appreciably (Parr and Bose 1944; Saxena and Singh 1976).

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Table 2. Growth parameters at 90-day stage of crop growth as influenced by seed-rates, row spacings and fertilizer levels.

Treatment	Grain yield (kg/ha)		Lateral spread (cm)		Plant height (cm)		No. of branches		TDMA (g/m^2)	
	1982/83	1983/84	1982/83	1983/84	1982/83	1983/84	1982/83	1983/84	1982/83	1983/84
Seed-rate (kg/ha)										
20	1135	1374	22.6	24.5	26.0	26.3	9.4	9.9	193.7	220.4
40	1583	1813	22.2	24.2	26.8	27.1	6.7	8.2	236.0	254.8
60	1619	1855	21.2	23.7	26.5	27.2	6.3	6.5	246.9	274.6
SEm ±	38	34	0.21	0.15	0.44	0.14	0.12	0.05	1.44	1.92
CD at 5%	120	106	0.66	0.47	NS	0.45	0.39	0.17	4.32	6.24
Row spacing (cm)										
20	1494	1728	20.8	24.1	26.7	26.9	7.4	8.0	263.3	299.2
30	1398	1634	23.1	24.2	26.1	26.8	7.5	8.4	200.3	217.1
SEm ±	31	27	0.17	0.12	0.36	0.12	0.10	0.04	1.12	1.60
CD at 5%	NS	87	0.54	NS	NS	NS	NS	0.14	3.52	5.12
Fertilizer level (per ha)										
Control	1137	1225	20.2	21.7	24.0	25.9	6.5	6.5	162.6	160.7
Inoculation	1449	1745	23.2	25.4	27.4	28.8	7.7	7.8	227.3	259.0
N	1317	1570	21.7	25.0	28.1	27.2	7.5	8.8	226.4	258.7
P	1418	1663	20.9	22.7	24.6	25.4	7.0	8.1	222.2	250.6
Inoc. + N	1476	1714	22.7	24.3	26.9	27.6	8.1	9.3	226.2	256.4
Inoc. + P	1559	1815	21.2	23.4	25.8	26.7	7.3	8.2	230.5	265.4
N + P	1533	1785	22.1	23.7	26.0	26.9	7.3	8.6	247.1	267.8
Inoc. + N + P	1677	1929	24.0	26.8	28.6	29.0	8.5	8.4	261.7	280.9
SEm ±	63	47	0.31	0.19	0.71	0.25	0.29	0.13	2.88	3.68
CD at 5%	175	129	0.86	0.53	1.97	0.68	0.81	0.36	7.84	10.24

TDMA = Total dry matter accumulation; N = 20 kg N/ha; P = 50 kg P_2O_5/ha; NS = Not significant.

Table 3. Growth parameters at 90-day stage of crop growth as influenced by seed-rate, row spacing and fertilizer level.

Treatment	Leaf dry weight (g/m^2)		Stem dry weight (g/m^2)		CGR ($g\ m^{-2}\ day^{-1}$)		NAR ($g\ g^{-1}\ day^{-1}$)	
	1982/83	1983/84	1982/83	1983/84	1982/83	1983/84	1982/83	1983/84
Seed-rate (kg/ha)								
20	125.2	144.7	68.5	75.7	5.49	6.29	0.09	0.10
40	149.6	164.5	86.4	89.6	6.66	7.03	0.10	0.09
60	159.2	180.4	89.2	94.2	6.93	7.59	0.10	0.09
SEm ±	1.28	1.44	0.80	1.28	0.032	0.064	0.001	0.001
CD at 5%	4.16	4.64	2.56	4.00	0.128	0.192	0.002	0.003
Row spacing (cm)								
20	161.0	203.1	90.2	96.2	7.47	8.36	0.10	0.09
30	125.8	136.7	74.6	80.0	5.62	6.04	0.10	0.09
SEm ±	1.12	1.12	0.64	1.12	0.032	0.048	0.000	0.001
CD at 5%	3.36	NS	2.08	3.36	0.096	0.144	NS	0.002
Fertilizer level (per ha)								
Control	110.1	104.1	52.5	56.6	4.75	4.58	0.12	0.10
Inoculation	145.4	170.9	81.8	88.1	6.39	7.25	0.10	0.09
N	145.2	170.7	81.2	88.0	6.38	7.23	0.10	0.09
P	144.4	163.3	77.8	87.3	6.22	6.98	0.09	0.09
Inoc. + N	144.9	170.2	81.4	86.1	6.41	6.12	0.10	0.09
Inoc. + P	147.7	172.5	82.7	92.9	6.42	7.34	0.09	0.09
N + P	155.7	175.4	91.5	92.4	6.97	7.47	0.10	0.09
Inoc. + N + P	164.0	178.7	97.7	100.4	7.34	7.81	0.10	0.09
SEm ±	2.40	2.88	1.42	1.76	0.096	0.128	0.001	0.002
CD at 5%	6.88	8.00	4.00	4.96	0.256	0.352	0.002	0.004

CGR = Crop growth rate (days 60–90); NAR = Net assimilation rate (days 60–90); N = 20 kg N/ha; P = 50 kg P_2O_5/ha; NS = Not significant.

Rhizobial Inoculation and Fertilization of Lentil in Bangladesh

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Abstract

An experiment was conducted at Muktagacha site during *rabi* season (winter) of 1993/94 to study the effects of a rhizobial strain in mixture with N, P and K on the growth and yield of lentil (*Lens culinaris* Medik. 'L-5'). Inoculation with *Rhizobium* significantly increased all the yield and growth attributes except the for number of seeds/pod, compared with uninoculated plants receiving no nitrogen fertilizer. That is, the lowest grain yield (583 kg/ha) was obtained from the treatment having no fertilizer or inoculation and the highest yield (1039 kg/ha) was achieved by the inoculated treatment in combination with 30 kg N, 60 kg P_2O_5 and 20 kg K_2O.

Key words: *Lens culinaris*; lentils; *Rhizobium*; inoculation; nitrogen fertilizers; potassium fertilizers; phosphate fertilizers; Bangladesh.

التلقيح الريزوبي والتسميد في بنغلاديش

الملخص

أجريت تجربة في موقع Muktagacha خلال الموسم الشتوي 94/1993 لدراسة تأثيرات سلالة ريزوبية في مزيج من الآزوت والفوسفور والبوتاسيوم في نمو وغلة العدس (*Lens culinaris* Medik.). زاد التلقيح بالريزوبيا جميع خصائص الغلة والنمو بصورة كبيرة باستثناء عدد البذور/القرن، وذلك بالمقارنة مع النباتات غير الملقحة التي لم تسمد بالآزوت. ذلك يعني أنه تم الحصول على أدنى غلة حبية (582.5 كغ/هـ) من المعاملة التي لم تُسمد ولم تُلقح بالريزوبيا، بينما تم تحقيق أعلى غلة (1038.5 كغ/هـ) من المعاملة المُلقحة والمُسمدة بالآزوت والفوسفور والبوتاسيوم.

Introduction

Lentil is one of the important grain legumes in Bangladesh (Alam et al. 1990). It is cultivated under a wide range of agro-ecological conditions in different cropping systems (Kumar et al. 1993). Among the various pulses, lentil has occupied the top position in terms of popularity and has been placed second for area and production in Bangladesh. The land cultivated for lentil in Bangladesh is usually marginal (as are areas for other pulses), and mostly rain-fed, since cereals such as rice and wheat occupy the majority of the productive and irrigated areas. This is one of the main reasons for the low yield and stagnant productivity of lentil in the country. However, there is scope to overcome these constraints through cultivation of modern varieties, fitting them into traditional cropping systems, and the use of seed inoculation with effective *Rhizobium* strains for better nodulation, nitrogen fixation and higher grain yield.

Lentil, like other pulses, has the ability to fix atmospheric nitrogen through symbiotic root-nodule bacteria. This ability of symbiotic fixation may offer an opportunity to improve soil fertility and crop productivity using no or less nitrogenous fertilizers. About 85% or more of the N needs of lentil may be met by symbiotic N fixation through inoculation with effective *Rhizobium* strains in the field and yield may be increased to 2 t/ha through lentil seed inoculation (Bisen et al. 1980).

Lentil is the most important grain legume crop of Mymensingh, but the area of this crop is decreasing owing to continuous rice cultivation; yields are also decreasing. The average yield of lentil hardly exceeds 400–600 kg/ha. Most farmers do not use any fertilizer. As there is great potential to increase yield by exploiting better colonization of their roots and rhizosphere by effective rhizobial inoculation, the present study was undertaken at Muktagacha.

Materials and Methods

The experiment was conducted at the testing site of Muktagacha, Mymensingh district during *rabi* season (winter) of 1993/94 on loamy soil of average fertility. The soil of the experimental plot was moderately fine textured and had a pH of 6.7. The crop variety was L-5. The trial was laid out in a randomized complete block design with four replications. There were five treatments: (i) 0–0–0 kg N–P_2O_5–K_2O/ha (farmers' practice); (ii) 30–0–0 kg N–P_2O_5–K_2O/ha + inoculum; (iii) 0–60–20 kg N–P_2O_5–K_2O/ha + inoculum; (iv) 30–60–20 kg N–P_2O_5–K_2O/ha, and (v) 30–60–20 kg N–P_2O_5–K_2O/ha +

inoculum. The unit plot size was 10 × 5 m. The seed rate was 30 kg/ha. The lentil seeds were coated with inoculant using molasses as adhesive. The coated lentil seeds were broadcast in the field on 20 November 1993. Fertilizer was applied basally. Cultural management was practised as and when necessary. The crop was harvested after 101 days.

Results and Discussion

Data on plant population, plant height, number of primary branches, number of pods/plant, number of seeds/pod, 1000-seed weight and grain yield are presented in Table 1. Number of nodules, nodule weight and shoot weight were also calculated.

Growth attributes

All the characters investigated showed significant differences with treatment, except number of seeds/pod. Growth attributes (number of primary branches, number of nodules/plant, shoot weight (kg/ha), etc.) were significantly increased by inoculation with *Rhizobium*. Vigorous plant growth, significantly taller plants and more branches in the inoculated treatment may be attributed to greater N availability for the crop. A significant effect of 30 kg N, 60 kg P_2O_5 and 20 kg K_2O was observed on plant height, number of nodules and shoot weight/ha. Significant variation in the plant height of N-fertilizer and unfertilized treatments indicated the role of a starter dose of N in promoting effective rhizobial activity for biological N-fixation in later growth stages. However, nodule weight was not significantly affected by the application of nitrogen and inoculation except at the full recommended dose and inoculation. Application of phosphorus at 60 kg/ha with 20 kg potash and inoculation significantly increased plant height, primary branches, number of nodules and nodule weight.

Yield and yield components

Inoculation significantly increased number of pods/plant and 1000-seed weight. Recommended doses of 20 kg N, 60 kg P_2O_5, 20 kg K_2O with inoculation produced the highest grain yield (1039 kg/ha), whereas the farmers' practice treatment (no fertilizer and inoculation) gave the lowest yield (583 kg/ha). The same trend was observed for straw yield. It was also observed that without nitrogen application inoculated treatment with P_2O_5 and K_2O did not give higher yield than the recommended dose of fertilizer (30–60–20 kg N–P_2O_5–K_2O/ha).

It may be concluded that inoculation with complete doses of N–P_2O_5–K_2O may produce better results than other combinations of non-inoculation and less fertilizer.

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Table 1. Effect of inoculation on the growth and yield attributes of lentil

Treatment (kg N–P_2O_5–K_2O/ha)	Plant height (cm)	Plant pop (no./m^2)	No. of primary branches/plant	No. nodules/ plant	Nodule wt/plant (g)	Shoot wt (kg/ha)	No. of pods/ plant	No. of seeds/ pod	1000-seed wt (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
0-0-0 (Farmers' practice)	28.7	70	1.80	6.05	1.40	198	34.7	1.60	15.43	583	1341
30-0-0 + inoculum	30.8	79	1.98	7.4	1.45	209	38.0	1.73	16.30	945	1394
0-60-20 + inoculum	30.7	73	1.88	7.5	1.43	211	41.7	1.78	15.93	980	1390
30-60-20	31.2	75	1.86	7.95	1.60	219	37.6	1.75	15.45	981	1426
30-60-20 + inoculum	33.0	86	2.14	10.1	2.63	235	55.5	2.01	17.43	1039	1628
CV (%)	5.09	6.2	9.06	9.25	44.25	4.2	11.40	10.11	4.58	3.8	4.9
LSD (0.05)	2.45	7.6	0.86	1.12	0.44	14.1	7.35	NS	0.92	54.5	156.6

Physiology and Microbiology

Computer Simulation Model of Lentil Growth and Development

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Abstract

A computer simulation model of lentil (*Lens culinaris* Medik.) crop growth, development and yield has been developed and validated from five years of research in Canterbury, New Zealand. The model is based on the relationship between crop dry matter production and intercepted solar radiation. Submodels determining crop water-use and phenology are based on potential evapotranspiration and on accumulated thermal or photothermal time, respectively. The model has proved accurate for predicting various phenological events in Canterbury. Predicted dates of flowering were within 3 days of actual dates in 7 out of 8 sowing dates. Only in a crop which was severely infected with *Botrytis cinerea* were phenological predictions inaccurate. Crop growth and dry matter accumulation over the growing season were predicted reasonably well. However, actual late spring sowings tended to grow faster than the simulated spring sowings. Total dry matter production was predicted accurately with the predicted values over 8 sowing dates within 15% of the actual values. Analysis showed that the model was very sensitive to changes in the utilization coefficient, but less so to changes in the extinction coefficient and optimum temperature. The model requires more extensive validation, particularly outside Canterbury. However, it is already useful in predicting yields, flowering dates and irrigation requirements of lentils in Canterbury.

Key words: *Lens culinaris*; lentils; computer software; simulation models; growth; plant development; yields; flowering; demand irrigation; forecasting; New Zealand.

نموذج محاكاة حاسوبي لنمو وتطور العدس

الملخص

تم استنباط نموذج محاكاة حاسوبي لنمو محصول العدس وتطوره وغلته واعتمد رسمياً بعد خمس سنوات من الأبحاث في كانتربري بنيوزيلندا. ويعتمد هذا النموذج على العلاقة بين إنتاج المحصول من المادة الجافة والاشعاع الشمسي الذي يتعرض له. وتعتمد النماذج الفرعية (الثانوية) التي تحدد مظهر المحصول واستخدامه للمياه على كفاءة عملية البخر - النتح وعلى الفترة الحرارية أو الضوئية الحرارية المتراكمة على التوالي. وقد أثبت النموذج دقته في التنبؤ بالوقائع - المظهرية المتعددة في كانتربري. إذ كانت مواعيد الإزهار المتنبأ بها خلال 3 أيام من المواعيد الحقيقية في 7 مواعيد زراعة من أصل 8. ولم تكن التنبؤات المظهرية غير دقيقة إلا في المحصول الذي أصيب إصابة شديدة بالعفن الرمادي *(Botrytis cinerea)*. وتم التنبؤ بنمو المحصول وتراكم المادة الجافة على مدى الموسم الزراعي بصورة حسنة إلى حد ما. غير أن الزراعات التي تمت فعلاً في أواخر الربيع كانت تنمو بشكل أسرع من زراعات الربيع التشبيهية. كما تم التنبؤ بإجمالي إنتاج المادة الجافة على نحو دقيق، أما القيم المتنبأ بها على مدى 8 مواعيد زراعية فقد كانت ضمن 15٪ من القيم الفعلية. وأظهر تحليل الحساسية أن النموذج كان حساساً جداً للتغييرات في معامِل الاستفادة ولكنه أقل حساسية للتغييرات في معامِل الانقراض ودرجات الحرارة المثلى. ويتطلب هذا النموذج مزيداً من الدقة والسلامة لاسيما خارج كانتربري، ومع ذلك فهو مفيد في الوقت الحاضر في التنبؤ بغلة العدس ومواعيد إزهاره واحتياجاته من الري في كانتربري.

Introduction

Lentil is a relatively new crop in Canterbury. However, the area sown to lentils is increasing each year (Gerhalter and Hill 1992) because the crop provides a profitable alternative to peas and cereals for farmers on the Canterbury Plains.

Many farmers are interested in growing lentils. However, climate and soils in the area are quite variable. The Canterbury Plains were derived from braided river beds which often gave variable soil depth over relatively small areas. Traditional agronomic field trials are an expensive way to determine suitability of a crop to a particular region. Additionally, it can be difficult to extrapolate results of field trials from one growing season to the next. A different approach to the problem of determining the suitability of a crop to a region involves the production of a mechanistic computer simulation model. Many such models have been produced including: the AFRC (Agriculture and Food Research Council) model to predict yield and leaf area index of wheat in the United Kingdom (Weir et al. 1984); and the CERES (Crop Evaluation Resource Environment Synthesis) models, e.g. CERES-Maize (Ritchie et al. 1989).

A mechanistic model has many advantages over traditional field trials for determining suitability of a crop for an area. If the model is based on sound physical and biological responses to environmental inputs, accurate yield predictions over different sites and seasons are possible.

There are of course some potentially serious problems with the modelling approach. Most models are based on a number of assumptions. These assumptions, if incorrect, can result in inaccurate predictions. Additionally, conditions which are extreme may cause problems for the modeller if these conditions are outside those experienced when the model was developed. Finally, the cost in time and money to develop and then validate a model is high.

The major aim of the research project reported here was the production of a simple computer simulation model of lentil growth and development. The model could then be used by farmers, extension officers and researchers interested in growing lentils in Canterbury. Additionally, with fine tuning and further validation, the model may prove useful overseas.

Materials and Methods

A fully detailed description of materials and methods is presented in McKenzie and Hill (1989), therefore, only a brief account of the materials and methods of the field trials used for model development and validation are presented here.

The computer model was based on data collected from 2 of 6 sowing dates in 1984/85. The other sowing dates in 1984/85 and the two sowing dates in 1985/86 were used for initial validation. In 1984/85, the experiment was a randomized complete block, split-plot factorial design. Six sowing dates ranging from April to November were main plots. Sub-plots consisted of a factorial combination of four treatments: full irrigation or none, and two cultivars, Titore or Olympic.

In 1985/86, the experiment was a randomized complete block factorial combination of two sowing dates and four irrigation levels. Crops were sown on 20 May or 26 August. The four irrigation treatments were full irrigation, two-thirds full irrigation, one-third full irrigation and no irrigation.

Data collected for model development included: accumulated dry matter, leaf area, potential soil moisture deficit, dates of all important phenological stages, seed yield and yield components, solar radiation intercepted and some rudimentary information on rooting.

Data was also collected from experiments conducted in 1989, 1990 and 1991 so that comparisons could be made with simulations run using the same sowing dates as the real experiments.

Model development

The model is based on work by Montieth (1977), where total dry matter (TDM) production is the integral of crop growth rate over time from emergence to physiological maturity. Seed yield is the product of harvest index and TDM.

Crop growth rate (CGR) is dependent upon: the amount of solar radiation (s) intercepted by the crop canopy; the efficiency at which s is converted into dry matter (u); and, a drought factor d_f which stops growth under dry conditions. These factors combine mathematically to describe crop growth in Equation 1.

$$CGR = 0.5 * s * f_i * u * d_f \qquad \text{Equation 1}$$

Where f_i = the fraction of radiation which is absorbed by the crop.

Equation 1 indicates the submodels which are necessary to accurately simulate crop growth, i.e. those needed to calculate f_i and d_f.

The submodel used to determine the amount of radiation intercepted by the crop is based on Gallagher and Biscoe (1978), where:

$$f_i = 1 - \exp(-k * GAI) \qquad \text{Equation 2}$$

Where k = extinction coefficient, an indication of how rapidly light is extinguished as it passes through the canopy, and GAI = green area index.

Green area index, the variate driving Equation 2, was simulated most accurately (though not mechanistically) using a relative leaf area growth rate which was linearly dependent upon daily thermal time (Equation 3). However, upon attaining a GAI of 7 or greater, GAI was not allowed to increase further.

$$\text{Leaf growth rate} = -0.0174 + 0.00892 * tt_d \quad \text{Equation 3}$$

Where tt_d = daily thermal time.

An empirical parabolic function was used to reduce GAI after the crop attained simulated maximum GAI and after physiological maturity.

Though not suggested by Equation 1, all models need a submodel to determine phenological starting and stopping points.

The phenological submodel was necessary to determine crop emergence, flowering, physiological maturity and harvest. All physiological stages, except the period of emergence to flowering, were found to be dependent upon accumulated thermal time above a base of 2°C. The phase emergence to flowering was dependent upon accumulated photothermal time as calculated by Gallagher et al. (1983).

The submodel calculating the drought factor was based on Penman (1971) and Ritchie (1972). The d_f is dependent upon soil water status. When all plant-available soil water is depleted, d_f becomes 0, thus turning off the CGR equation. Any water which becomes available subsequently, either through irrigation or rainfall, is considered fully available for crop growth and d_f is set to 1, and growth continues at the potential rate.

Model Program

The program requires specific input data to run. Data to be entered into a parameter file is listed in Table 1. The data can be entered into an input parameter file and sed when needed. Changes to input parameters can thus be made quickly and easily.

Table 1. Data required to run a computer simulation model of lentil growth.

Input	Definition	Example
loc	Location, 70 characters allowed	Lincoln
experi	Name of researcher, 70 characters	B.A. McKenzie
ysd	Label, 70 characters allowed	May sowing
tbdevel	Base temperature for development	2 °C
tblfgro	Base temperature leaf growth	3 °C
tbgro	Base temperature for grain growth	6 °C
topt	Optimum temperature for growth	25 °C
pb	Base photoperiod	7.4 h
tdemer	Accumulated temperature for emergence	115 °C days
pttflow	Photothermal time to flower	277 °C days
pttmaxg	Photothermal time to maximum GAI	490 °C days
physmat	Thermal time to physiological maturity	546 °C days
ttharv	Thermal time to harvest	270 °C days
hvstin	Harvest index	0.26
u	Utilization coefficient	1.8 g DM/MJ
st1lmt	Stage 1 limit for soil evaporation	5 mm
paw	Plant-available water	240 mm
asmd	Actual soil moisture deficit at sowing	0.0 mm
sday	Sowing day	15
smonth	Sowing month	05
syear	Sowing year	84
k	Extinction coefficient	0.32
#	Number of irrigations	1
	Date and irrigation amount	26 10 84 30

The model also requires a meteorological file to provide the required environmental parameters to drive the model. The required information is outlined in Table 2.

The model is based on a number of assumptions. If these assumptions are not correct, it is unlikely that the model will provide an accurate description of crop growth over the season. The most important critical assumptions are:

1. the crop is disease free;
2. there is no flooding or waterlogging which can kill lentils quickly;
3. the crop is free from pests;
4. soil nutrients are not limiting;
5. harvest index is relatively stable, though changes can be incorporated in the input parameter file;
6. the crop has been sown at a reasonable farm population (anything from 100 to 300 plants/m^2).

Subroutines to account for most of these assumptions could easily be incorporated into the model, but we have not yet done this.

Results and Discussion

The model is reasonably accurate at predicting phenological stages of lentils in Canterbury. Over a number of seasons, with the exception of the 16 April 1984 sowing, predictions of dates of flowering have always been within three days of actual. Table 3 gives the actual and predicted dates of a number of important phenological stages for a few sowing dates.

As can be seen in Table 3, predictions of phenological stages are reasonably accurate, with the exception of physiological maturity in the 26 August 1985 sowing. This sowing was affected by a severe infection of *Botrytis cinerea* which affected the crop in about the middle of December, after persistent November rains.

Predictions of dry matter accumulation over the growing season as shown in Figure 1 are also generally accurate. However, as can be seen in Figure 1, when the crop is in its grand phase of growth in late spring/early summer, simulated growth lags behind actual. There are a number of possible reasons for this. It is possible that the model is using a utilization coefficient that is too low. However, the slower growth is more likely due to a low extinction coefficient which would not cause a large difference in dry matter accumulation early on, but when radiation receipt picks up in late spring/early summer it would have a larger influence. Indeed, sensitivity analysis showed that the model is sensitive to changes in the value of k.

Over a number of sowing dates and seasons, the model has been reasonably accurate at predicting seed yield of lentils (Fig. 2), while the model assumes a stable harvest index (HI). The predictions shown in Figure 2 are based on an HI of about 0.3 for fall and winter sowings, and about 0.2 for spring-sown crops. The assumption of a stable HI is dangerous for grain legumes which can have highly variable HIs. However, under Canterbury conditions, crop HI varies linearly and predictably with sowing date (McKenzie and Hill 1990). A subroutine relating HI to crop duration is being written and will be included in the next version of the model.

Table 2. Weather data required for a computer simulation model of lentil growth.

Year	Month	Day	Max. daily temp. (°C)	Min. daily temp. (°C)	Mean daily temp. (°C)	Total solar rad. (MJ/m^2)	Rain (mm)	Penman ET (mm)	Daily photo-period (h)
84	04	01	15.3	14.0	14.7	7.0	1.7	1.0	12.6

Table 3. Actual and predicted dates for three phenological stages at four sowing dates over 2 seasons for lentils in Canterbury, New Zealand.

Sowing date	Emergence		Flowering		Physiological maturity	
	Actual	Predicted	Actual	Predicted	Actual	Predicted
16 April 84	28/4	28/4	22/10	15/10	4/12	3/12
26 July 84	19/8	15/8	9/11	8/11	21/12	21/12
15 October 84	25/10	27/10	8/12	11/12	14/1	18/1
26 August 85	9/9	9/9	20/11	20/11	13/1	3/1

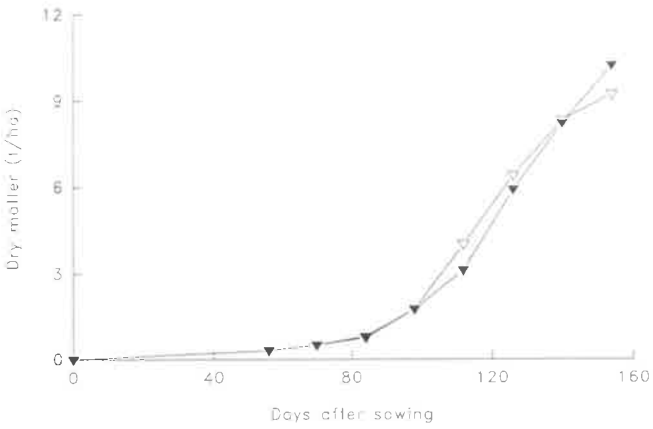

Fig. 1. Actual (▿) and predicted (▾) dry matter accumulation of lentils sown in July in Canterbury, New Zealand.

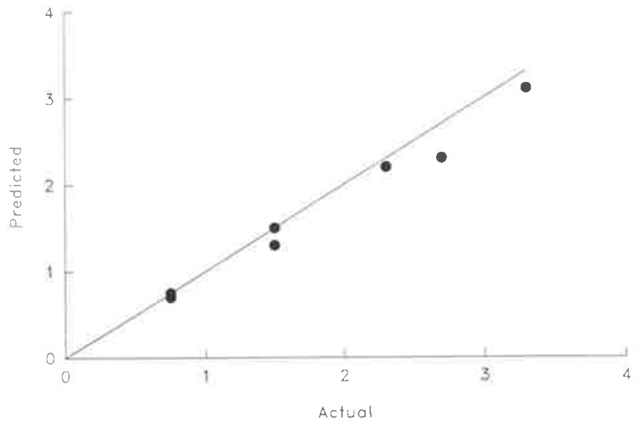

Fig. 2. The relationship between actual and predicted lentil seed yields (t/ha) in Canterbury, New Zealand. Line is x = y.

A simple sensitivity analysis was conducted using the model. As expected, the model is highly sensitive to changes in utilization coefficient (which models both changes in photosynthetic rate and respiration rate, though neither can be separated out in this model). The least sensitive parameter measured was optimum temperature.

Conclusions

Lenmod is a simple model of lentil growth and development which can make relatively accurate predictions of lentil yields in Canterbury. However, further validation outside Canterbury is needed. The model has a number of weaknesses, due primarily to the assumptions made in its development. Despite these drawbacks the model, the model has proved useful for teaching purposes, for predicting flowering dates of lentil crops and for irrigation-scheduling.

The authors would appreciate receiving complete weather data sets from any interested researchers. Also, copies of the model are available free of charge by writing to the senior author.

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Lentil Yield in Relation to *Rhizobium leguminosarum* Inoculation in Eastern Anatolia

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Abstract

Seed yield of lentil (*Lens culinaris* Medik.) was investigated in relation to *Rhizobium leguminosarum* inoculation under dry and irrigated conditions during 1988–93 in Erzurum, Turkey. Under dry conditions, seed yield of cv. Kislik Kirmizi-51 after inoculation, 20 kg N/ha application and inoculation + 20 kg N/ha was increased by 6, 12 and 4%, respectively, compared with the control. Application of P_2O_5 up to 80 kg/ha increased yield by only 4%, but the combination of 20 kg N/ha with 80 kg P_2O_5/ha increased yield by 16% compared with the control. Inoculation + 20 kg N/ha produced the highest protein content. P application enhanced this effect. Under irrigated conditions, among eight pre-selected *R. leguminosarum* strains, F15 produced higher seed yields and strains M90, M9, M11 and M13 gave higher protein content in cv. Erzurum-89 than the control in the presence of indigenous bacteria. In conclusion, because of the presence of indigenous bacteria, *Rhizobium* inoculation may not necessarily give higher yields unless effective local strains are used.

Key words: *Lens culinaris*; lentils; *Rhizobium*; inoculation; yields; Turkey.

Introduction

Lentil is one of the most important pulse crops in the traditional cereal-based farming system in Turkey. Its production and acreage sharply increased during the 1980s (State Institute of Statistics 1990). However, national yields over this period increased only marginally. Proper crop management practices, such as fertilization and *Rhizobium* inoculation, could increase yields. Government agencies provide inoculants and encourage their use in lentil farming.

This study investigated the yield performance of lentil in relation to *Rhizobium* inoculation under dryland and irrigated conditions.

غلة العدس وعلاقتها بالتلقيح بالبكتيريا الجذرية *Rhizobium leguminosarum* في الأناضول الشرقية

الملخص

دُرست غلة بذور العدس (*Lens culinaris* Medik.) وعلاقتها بالتلقيح بـ *leguminosarm Rhizobium* تحت الظروف الجافة والمروية خلال سنوات 1988–93 في أرضروم بتركيا. ففي الظروف الجافة، ازدادت الغلة البذرية للصنف كيسليك كيرميزي – 51 بعد التلقيح ثم بعد إضافة 20 كغ آزوت/هـ ثم بعد التلقيح + 20 كغ آزوت /هـ، بنسبة 6، 12 و4٪ على التوالي مقارنة بالشاهد. إن إضافة P2 O5 حتى 80 كغ/هـ قد أدت إلى زيادة الغلة بنسبة 4٪ فقط. غير أن خلط 20 كغ آزوت/هـ مع 80 كغ P2 O5/هـ زاد الغلة بنسبة 16٪ مقارنة بالشاهد. وقد أعطى التلقيح + 20 كغ آزوت/هـ أعلى محتوى من البروتين. وإن إضافة الفوسفور قد عزز هذا التأثير. أما تحت الظروف المروية، أعطت F15، من بين سلالات *R. leguminosarum* الثمانية التي تم انتخابها سابقاً، غلة بذرية أعلى، كما أن السلالات M 90، M 9، M 11 و M 13 أعطت محتوى من البروتين في الصنف أرضروم – 89 أعلى مما هو في الشاهد في وجود بكتيريا محلية. مما تقدم نستنتج أنه نظراً لوجود بكتيريا محلية فإن التلقيح الريزوبي قد لا يعطي بالضرورة غلة أعلى إلا في حال استخدام سلالات محلية فعالة.

Material and Methods

Two experiments were conducted in order to investigate the effect of *Rhizobium* inoculation on lentil yields at the University of Ataturk farm in Erzurum, Turkey, using two lentil cultivars under dryland and irrigated conditions between 1988 and 1993.

Trial 1

The yield of small-seeded lentil cv. Kislik Kirmizi-51 (1000-grain weight = 29 g) was investigated in relation to sowing density (50, 62, 85 and 125 kg/ha to give 350, 400, 450 and 500 seeds/m^2), phosphorus fertilization (0, 40 and 80 kg P_2O_5/ha) and *Rhizobium* inoculation (control, inoculation only, 20 kg N/ha application, and inoculation plus 20 kg N/ha) in 1988, 1989 and 1990 under dryland conditions.

Rhizobium culture in peat (Central Soil-Fertilizer Research Centre, Ankara) was applied to the seed a day before sowing by wetting and mixing the culture with seeds according to manufacturer's instructions.

Trial 2

Yield of large-seeded lentil cv. Erzurum-89 (1000-grain weight = 54 g) was investigated in relation to eight *Rhizobium* strains in 1992 and 1993 under irrigated conditions. *Rhizobium* strains (M8, M9, M10, M11, M13, F15, M90 and M2426) were previously selected from 18 strains isolated from lentil (M) and common vetch (F) in the region (Kiziloglu 1992). The experiment also included an uninoculated control and control + 40 kg N/ha. *Rhizobium* strains were cultured on yeast mannitol agar at 28°C for 5 days (Vincent 1970) and incorporated into irrigation water in equal volumes (10^7 cells/ml) when seedlings were 2–3 cm high (Kiziloglu 1991). The plots received several light irrigations using furrows until the end of pod-setting stage.

Both trials used 5 × 1.2 m plots containing 6 rows with four completely randomized factorial blocks. P_2O_5 in triple super-phosphate (60 kg/ha in Trial 2) and N in ammonium nitrate were pre-sowing soil-incorporated in spring. Sowing was at a depth of 3–4 cm during 21–26 April (Trial 1) and 4 May (Trial 2). Plants in middle 3.6 m^2 of the plots were harvested at full maturity during 20–25 July (Trial 1) or 27 August and 7 September (Trial 2). Throughout the season, weed control was done manually when required.

The soil was a loamy-sand with pH of 7.5. Average soil contents of $CaCO_3$, P_2O_5 and organic matter were 0.33%, 35–40 kg/ha and 0.75%, respectively. Total N was 0.03%.

Total N content of air-dry seeds was analyzed using Kjeldhal method and protein content was calculated by multiplying total N by 6.25.

Data were subjected to analysis of variance using the MSTATC statistical package.

Results and Discussion

Trial 1

Seed yield under dryland conditions in the treatments of 20 kg N/ha application, inoculation alone, and inoculation plus 20 kg N/ha application were respectively 12, 6 and 4% greater than the control (984 kg/ha) (Table 1). Control plants had equally high numbers of nodules as the inoculated ones, indicating the presence of indigenous rhizobia. In soils where adequate rhizobial populations exist, the beneficial effects of inoculation on lentil depend largely on the effectiveness and competitive ability of the introduced strains (references in Islam 1981) and soil conditions (Sekhon et al. 1978).

In lentils, N_2 fixation declines with increasing soil nitrate levels (Bremer et al. 1990) probably due to inhibition of the root exudation of isoflavonoids that act as regulatory molecules in the initiation of the legume–*Rhizobium* symbiosis (Wojtszek et al. 1992) and a depression of leghemoglobulin concentration and decrease in carbon transport to the nodules (Chamber-Perez and Camacho-Martinez 1992).

Table 1. Mean seed yield and protein content (in brackets) of lentil cv. Kislik Kirmizi-51 in relation to phosphorous application (T1) and *Rhizobium leguminosarum* inoculation (T2), 1988–1990.

Treatment (kg P_2O_5/ha)	Control	20 kg N/ha	Inoculation	Inoculation + 20 kg N/ha	Mean
60	963.3 (21.8)	1076.8 (22.3)	1022.8 (24.6)	1000.7 (27.2)	1015.9 (23.9)
40	986.9 (22.2)	1102.9 (22.7)	1038.4 (25.0)	1016.2 (27.4)	1036.1 (24.3)
80	1001.6 (22.3)	1119.8 (23.0)	1050.1 (25.3)	1030.8 (27.7)	1050.6 (24.6)
Mean	983.9 (22.1)	1099.8 (22.7)	1037.1 (24.9)	1015.9 (27.4)	1034.2 (24.3)
LSD at 0.05	Seed yield: T1=2.67, T2=0.09, T1×T2=5.35		Protein content: T1=0.12, T2=0.10, T1×T2=0.21		

In our trials, inoculation × density × year interaction was significant ($P<0.001$). In 1989 when more adverse conditions prevailed, e.g. higher temperatures (Fig. 1A) and less rainfall (Fig. 1B), yield was lower and the difference between the treatments was less obvious at higher plant densities (data not presented). Greater competition for the limited soil moisture at higher plant densities probably restricted the effectiveness of rhizobial inoculation (Rathore et al. 1992a) and limited the available nitrogen status of the soil (Subedar-Singh and Singh 1986).

Phosphorus application increased seed yield and protein content by only 4 and 0.6%, respectively (Table 1). However, combination of 20 kg N/ha with 80 kg P_2O_5/ha increased seed yield by 16% compared with the control (Table 1). Inoculation × P interaction was not significant.

There is evidence for increased seed yields in lentil with P application (Dhingra et al. 1988) and enhanced nodulation (Rathore et al. 1992b). However, the availability of P also depends on the water state of soil (Rathore et al. 1992a). In our trials, a significant P × sowing density interaction occurred ($P<0.001$). Phosphorus effect disappeared at higher plant densities (Table 2), at which the exhaustion of the limited soil water supply probably decreased the availability of the applied P.

Under irrigated conditions (Trial 2), strain F15 produced higher seed yield (1785.8 kg/ha) than the control (1093.4 kg/ha) (Fig. 2), although yields in this trial, irrespective of inoculation, were higher owing to irrigation and the use of a high-yielding large-seeded cultivar (Eastern Anatolia Agricultural Research Institute 1990). Protein content of seed from strains M13, M11 and M9 was higher (19.7, 18.2, 18.6 and 18.3%, respectively) than the control (12.2%) (Fig. 2). The year × treatment interaction was not significant. Nodulation was observed in all plots (data not presented).

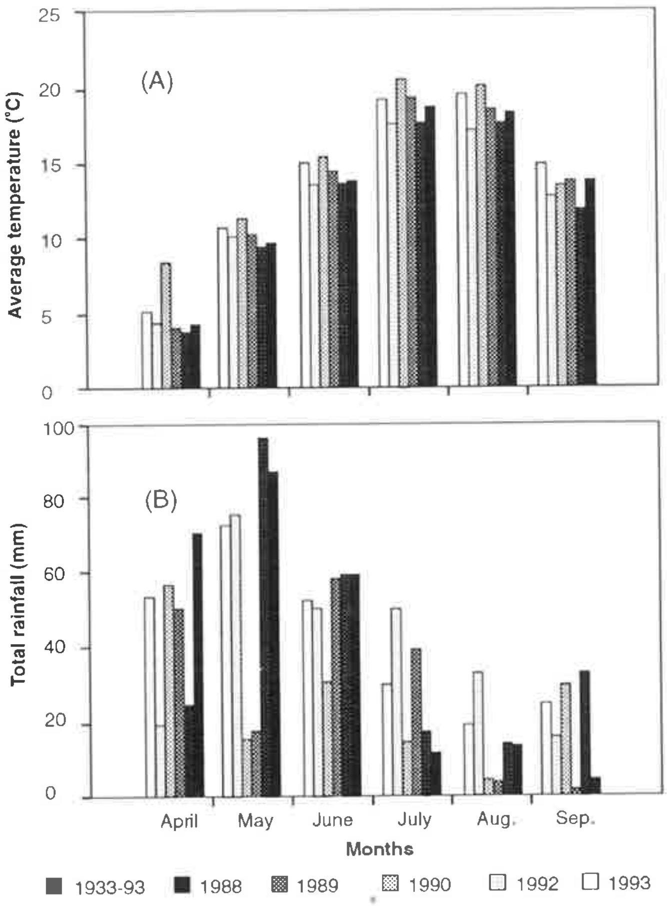

Fig. 1. Average temperature and total rainfall during the growth season at the experimental site.

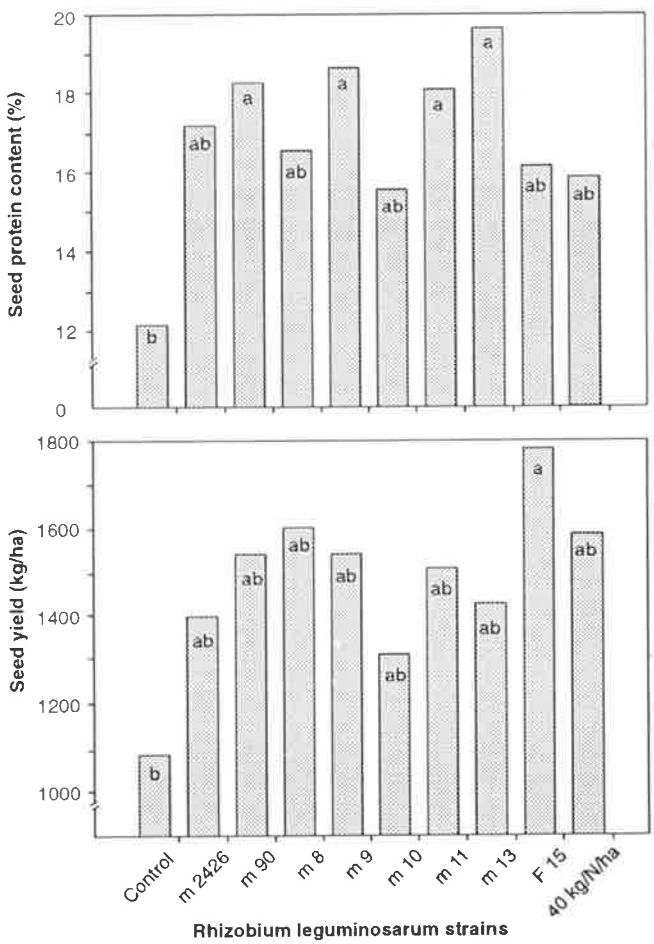

Fig. 2. Seed yield and seed protein content of lentil cv. Erzurum-89 in relation to inoculation with *Rhizobium leguminsarum* strains.

Table 2. Mean seed yield of lentil cv. Kislik Kirmizi-51 in relation to phosphorous application (T1) and sowing density (T2), 1988-1990.

Treatment (kg P_2O_5)	Sowing rate (kg seed/ha)				
	50	65	85	125	Mean
0	897.5	991.2	1065.2	1109.8	1015.9
40	934.4	1003.3	1091.5	1115.3	1036.1
80	960.2	1018.6	1103.5	1120.3	1050.6
Mean	930.7	1004.3	1086.7	1115.2	1034.2
LSD at 0.05	T1=2.67, T2=3.09, T1×T2=5.35				

The data indicate that the use of locally isolated superior *Rhizobium* strains (Kiziloglu 1991) may be a more rational approach for increasing seed yield in the presence of indigenous bacteria, although these strains possibly need to be tested under different locations and soil moisture conditions before any inoculant is produced commercially. In other studies, the use of locally isolated strains increased nitrogen fixation, yield and protein content (Sharma et al. 1982; Bremmer et al. 1990).

Acknowledgement

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Pests and Diseases

Preliminary Screening of Lentil Genotypes for Resistance to Faba Bean Necrotic Yellows Virus

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Abstract

Faba bean necrotic yellows virus (FBNYV) is one of the viruses that affect lentil (*Lens culinaris* Medik.) in Syria. A preliminary screening of 116 lentil genotypes for their resistance to FBNYV was conducted using artificial inoculation by aphids. Two genotypes were highly resistant to the virus with no loss in grain yield due to infection and no virus detected in their leaves by ELISA. In addition, 12 genotypes were resistant with only 10% reduction in grain yield. Moreover, 76 genotypes were highly susceptible to FBNYV, as their grain yield was reduced at least by 50%.

Key words: *Lens culinaris*; lentils; genotypes; selection; plant viruses; disease resistance; Syria.

غربلة أولية لطرز وراثية من العدس لمقاومتها لفيروس اصفرار وموت الفول (FBNYV)

الملخص

يعتبر فيروس اصفرار وموت الفول (FBNYV) من الفيروسات التي تصيب العدس (*Lens culinaris* Medik.) في سورية. أجريت غربلة أولية لـ 116 طرازاً وراثياً لمقاومتها لذلك الفيروس باستخدام التلقيح الاصطناعي بالمن. ظهر أن طرازين وراثيين مقاومان بشكل كبير للفيروس إذ لم تتأثر غلتهما الحبية بسبب الإصابة، ولم يكشف عن وجود الفيروس في أوراقهما عن طريق اختبار إليزا ELISA، كما تبين أن هناك 12 طرازاً وراثياً مقاوماً لم تنخفض غلتها الحبية إلا بنسبة 10٪. علاوة على ذلك، كان هناك 76 طرازاً وراثياً حساساً جداً لـ FBNYV نظراً لانخفاض غلتها الحبية بنسبة لا تقل عن 50٪ .

Introduction

Lentil is the most important legume crop in Syria, and around 100,000 ha were planted to this crop in 1993. Six viruses were reported earlier to infect lentils in Syria (Makkouk et al. 1992), among which faba bean necrotic yellows virus (FBNYV) was the most commonly encountered. FBNYV is known to spread in nature only by aphids; infected lentil plants show yellowing and stunting (Katul et al. 1993). In this study we evaluated 116 lentil genotypes for their reaction to FBNYV using artificial inoculation by aphids.

Materials and Methods

The 116 genotypes used in this study originated from 34 countries and are available as part of the collection held in the Genetic Resources Unit of ICARDA. The origin of the genotypes was Algeria (3), Afghanistan (3), Argentina (3), Bangladesh (3), Canada (3), Chile (3), Colombia (2), Cyprus (2), Czech Republic and Slovakia (3), Egypt (3), Ethiopia (4), France (3), Greece (3), Hungary (3), India (2), Iraq (4), Iran (3), Italy (3), Jordan (5), Lebanon (3), Mexico (3), Morocco (3), Nepal (3), Pakistan (3), Poland (3), Romania (1), Spain (3), Syria (17), Tunisia (2), Turkey (3), Yemen (3), the former Yugoslavia (2), USA (7) and the former USSR (3). Genotypes tested were planted in the field in two replicates each composed of two 1-m rows, with 10 plants/m in two adjacent randomized complete block trials, one inoculated with the virus and the other not. The healthy treatment was maintained virus-free by regular insecticide spray (Supracide = methidathion), once every 15 days, for the duration of the experiment.

Faba bean (*Vicia faba* L.) was planted as a marker between each 10 lentil genotypes to determine the success of inoculation, because of its known susceptibility to the virus. A local FBNYV isolate (SV292-88) was used for artificial inoculation and pea aphid *Acyrthosiphon pisum* was used as the vector. Aphids were kept on infected plants for 48 h to acquire the virus and then transferred to lentil (10–15 aphids/plant) and were permitted one week of inoculation feeding, after which they were killed using an insecticide (Supracide) spray.

Virus disease incidence was recorded 3–6 weeks after inoculation. Virus detection was made by ELISA following the procedure of Clark and Adams (1977). Yield loss was determined after harvest of infected and healthy plants.

Results and Discussion

Disease incidence and yield loss were determined for all the genotypes tested and are presented in Tables 1 and 2. It was possible to divide the genotypes into four categories. (1) Highly resistant genotypes: these genotypes showed no disease symptoms and no virus was detected in the leaves by ELISA; in addition there was no loss in

Table 1. Yield loss categories of lentil genotypes inoculated with FBNYV in inoculated as compared to protected field plots.

Genotype	% Grain yield loss
ILL 75, 86, 204, 291, 292, 5816, 6198, 6245	0
ILL 212, 214, 324, 6193	0.1–5
ILL 203, 4400	5.1–10
ILL 74, 85, 478	10.1–20
ILL 112, 213, 259, 344	20.1–30
ILL 221, 271	30.1–40
ILL 64, 67, 70, 76, 84, 105, 107, 202, 227, 236, 623, 705	40.1–50
ILL 71, 205, 211, 219, 222, 342, 757, Chilean 78	10.1–60
ILL 3, 65, 81, 97, 265, 341, 345, 346, 3485	60.1–70
ILL 2, 50, 96, 98, 226, 258, 260, 336, 347, 707, 921, 3433, 4401, 6229	70.1–80
ILL 1, 24, 25, 31, 49, 54, 57, 68, 79, 104, 269, 339, 711, 716, 855, 920, 1646, 1647, 1855, 1856, 1857, 1922, 3484, 3500, 4408, 4409, 4410, 4411, 4412, 4550, 4605, 4667, 4735, 4736, 4737, 4774, 4803, 5582, 5699, 5700, 5873, 5588, 5994, 6015, 6220, 6226, Palouse, Crimson, Red chief	80.1–100

Table 2. Incidence (%) of FBNYV infection based on visual symptoms after artificial virus inoculation.

Genotype	FBNYV infection (%)
ILL 6198, 6193, 6245	0
ILL 213, 291	1–5
ILL 75, 5816	5.1–10
ILL 86, 226, 227	10.1–20
ILL 85, 292	20.1–30
ILL 74, 204, 214, 344	30.1–40
ILL 70, 203, 478, 757, 4400	40.1–50
ILL 112, 84, 205, 4401	50.1–60
ILL 67, 65, 76, 81, 105, 107, 211, 219, 236, 324, 342, 623, 711, 706	60.1–70
Chilean 78, Red chief, ILL 3, 31, 54, 64, 71, 79, 96, 97, 104, 202, 222, 245,271, 336, 341, 212, 346, 705, 707, 855, 921, 3433, 5700, 5582, 5994, 6220, 6229	70.1–80
ILL 1, 2, 24, 25, 49, 50, 57, 68, 98, 221, 258, 259, 265, 269, 339, 347, 260, 920, 1857, 1646, 1647, 1855, 1856, 1922, 3485, 3484, 3500, 4408, 4409, 4410, 4411, 4412, 4413, 4550, 4605, 4667, 4735, 4737, 4736, 4774, 4803, 5588, 5699, 5700, 5873, 6015, 6226, Palouse, Crimson	80.1–100

grain yield (e.g. ILL 6245 and ILL 6198); (2) resistant genotypes: disease incidence in these genotypes did not exceed 10%, grain yield loss was 0–10% (e.g. ILL 75, 291, 5816 and 6193); (3) tolerant genotypes: disease incidence was high (80%), but the grain yield loss was only about 10% (e.g. ILL 204, 212, 214 and 324), and (4) susceptible and sensitive genotypes: disease incidence in these genotypes was high (reached 100%) and the grain yield loss was also high (reached 100%) (e.g. ILL 4803 and ILL 4774).

The common disease symptoms observed in all genotypes were yellowing and stunting (see photograph on front cover of this issue). Some genotypes showed leaf reddening.

There was no clear association between the best-performing lentil genotypes and the origin of these genotypes. However, among the 14 best-performing genotypes in terms of low disease incidence and low yield loss due to infection, four originated from Syria.

Even though this is a preliminary screening and results need to be confirmed by second- and a third-year trials, it clearly indicates the presence of useful genetic diversity in *Lens culinaris* for FBNYV resistance.

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Variety Release Notice

Rubatab-1 and Aribo-1: Improved Lentil Cultivars in Sudan

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Abstract

Six lentil (*Lens culinaris* Medik.) lines were evaluated for yield and related characters, in comparison to the check 'Selaim', in seasons 1990/91 to 1992/93, under farmers' conditions in Rubatab and Wad Hamid area in northern Sudan and Jebel Marra area in western Sudan. The lines showed significant differences in grain yield at Wad Hamid and Jebel Marra in all seasons, while there were no significant differences at Rubatab. The best grain yield over locations and seasons was given by ILL 818 (2.9 t/ha), followed by ILL 813 (2.8 t/ha) with yield advantage over the check of 11% and 6%, respectively. The results in the three locations justified the recommendation of ILL 813 for release for northern Sudan under the name Rubatab-1 and ILL 818 for Jebel Marra area under the name Aribo-1.

Key words: *Lens culinaris*; lentils; varieties; evaluation; selection; Sudan.

روباتاب -1 وأريبو -1 : صنفان محسنان من العدس في السودان

الملخص

تم تقييم ست سلالات من العدس (*Lens culinaris* Medik.) من حيث الغلة والصفات المرتبطة بها بالمقارنة مع الشاهد (سليام) خلال المواسم الممتدة من 91/1990 إلى 93/1992، وذلك تحت ظروف المزارعين في منطقة روباتاب وواد حميد في شمالي السودان وفي منطقة جبل مارا في غربي السودان. أظهرت السلالات فروقات كبيرة في الغلة الحبية في واد حميد وجبل مارا في جميع المواسم بينما لم تظهر فروقات كبيرة في الروباتاب. وقد أظهرت بيانات الغلة الحبية المأخوذة من المواقع والمواسم أن أفضل سلالة كانت ILL 818 (2.9 طن/هـ)، يليها ILL 813 (2.8 طن/هـ)، وقد تفوقتا في الغلة على الشاهد بنسبة 11٪ و 6٪ على التوالي. إن النتائج المتحصل عليها في المواقع الثلاثة بررت التوصية باستعمال السلالة ILL 813 في شمالي السودان تحت اسم روباتاب 1 والسلالة ILL 818 في منطقة جبل مارا تحت اسم أريبو -1.

Introduction

Lentils are an Old World legume and were probably one of the first plant species to be domesticated. The crop is a cool-season herbaceous annual which originated in the Near East.

Lentils are classified into two races based principally on seed size: the *macrosperma*, having large seeds (6–9 mm diameter), normally yellow cotyledons and little or no pigmentation in the flowers or vegetative structures; and *microsperma*, which have smaller seeds (2–6 mm diameter) with red, orange or yellow cotyledons and more pigmentation on the flowers and vegetative structures (Erskine and Witcombe 1984; Muehlbauer et al. 1985).

Within Sudan the relatively long and cool winter in the north is most favorable for lentil production with germplasm evaluation and cultivation improvement programs concentrated at Hudeiba Research Station since the early 1970s (El-Sarrag and Nourai 1984; Sheikh Mohamed et al. 1989). Recently, the crop has shown good performance at the lower wadis of Jebel Mara area due to the microclimate generated by the effect of the high altitude (300 m).

The objective of this study was to test the performance of some exotic lentil genotypes under farmers' conditions and make recommendations for their growth in Sudan.

Materials and Methods

Lentil germplasm received from Arid Land Agriculture Development/ICARDA and Egypt was evaluated for adaptability in Sudan. In the light of an earlier evaluation at Hudeiba (16°N, 34°E), four *microsperma* lines (ILL 795, ILL 813, ILL 818 and ILL 788) and two *macrosperma* lines (ILL 4605 and ILL 6004) were selected for testing under farmers' conditions. The lines were evaluated for yield and related characters, in comparison to check 'Selaim' at Rubatab area (Kudig, 19°N 32°E), Shendi area (Wad Hamid, 16°N 33°E) and Jebel Mara (Zalengei, 13°N 23°E and Dankuge, 13°N 24°E). At each location, different sites were selected for the trial in three consecutive seasons (1990/91 –1992/93).

The design used was a randomized complete block with four replicates; plot size was 6 × 5 m and net harvested area was 10 m^2. Planting was by drilling seeds on flat plots in rows 30 cm apart with seed rate of 120 kg/ha. Sowing was done in mid-November in each season. Nitrogen fertilizer was added at the rate of 43 kg N/ha, applied as urea at the second irrigation. The crop was irrigated at two-week intervals until maturity; weed and insect pests were kept at a minimum. Characters studies were phenology, grain yield, yield components and grain quality (protein content (% day weight basis) and grain dehulling measured on a Tangential Abrasive Dehulling Device (TADD)).

Results and Discussion

Grain yields of the lines are presented in Tables 1–4. At Rubatab, the best line over seasons and sites was ILL 813, with yield advantage over ILL 795 and Selaim of 2% (Table 1). At Wad Hamid, the best line over seasons and sites was ILL 813, followed by ILL 818 and ILL 795 with yield advantages of 11%, 8% and 4%, respectively, over the check (Table 2). At Jebel Marra, the best line over seasons and sites was ILL 813 (leading in two sites and second in the third), followed by ILL 788 and ILL 4605 with yield advantages of 34%, 27% and 17%, respectively, over the check (Table 3).

Taking the average performance of these lines in grain yield over locations and seasons, the best line was ILL 818, followed by ILL 813 and ILL 795, with yield advantages of 11%, 6% and 4% over the check (Table 4).

Yield superiority was also estimated by taking the mean rank of the lines over environments (locations, sites within locations, and seasons), according to Nachit and Ketata (1986). Line ILL 818 was the highest-yielding genotype, followed by ILL 813 and ILL 4605. ILL 795 was not superior to Selaim (Table 5).

Table 1. Grain yield (kg/ha) of lentil lines at Rubatab, 1990/91 –1992/93.

Line	Season			Mean	Advantage over check (%)
	1990/91	1991/92	1992/93		
ILL 795	1724	1652	2179	1852	0.0
ILL 813	1943	1673	2065	1894	+2.3
ILL 818	1776	1705	1806	1762	-4.9
ILL 6004	1129	1316	1830	1425	-23.1
ILL 4605	1128	1767	2204	1700	-8.2
Selaim (check)	1914	1727	1915	1852	–
Mean	1602	1640	2000	1747	
SE ±	274	158	204		
CV (%)	35	35	23		
Sign. level	NS	NS	NS		

NS = Not significant at P = 0.05.

Table 2. Grain yield (kg/ha) of lentil lines at Wad Hamid, 1991/92–1992/93.

Line	Season		Mean	Advantage over check (%)
	1991/92	1992/93		
ILL 795	5363	3433	4398	+4.3
ILL 813	5813	3550	4682	+11.1
ILL 818	5500	3583	4542	+7.7
ILL 6004	3663	2183	2923	-30.7
ILL 4605	4150	2800	3475	-17.6
Selaim (check)	5431	3000	4216	–
Mean	4986	3091	4039	
SE ±	134	176		
CV (%)	5	11		
Sign. level	**	**		

** Significant difference at P = 0.01.

Table 3. Grain yield (kg/ha) of lentil lines at Jebel Marra, 1990/91–1992/93.

Line	Season			Mean	Advantage over check (%)
	1990/91	1991/92	1992/93		
ILL 788	2310	2690	1950	2317	+27.1
ILL 795	1860	2240	1750	1950	+7.0
ILL 813	1670	2240	1560	1823	0.0
ILL 818	2250	3010	2090	2450	+34.4
ILL 4605	2140	2540	1740	2140	+17.4
Selaim (check)	1940	2050	1480	1823	–
Mean	2030	2460	1760	2053	
SE ±	110	127	113		
CV (%)	16	10	13		
Sign. level	**	**	*		

* Significant differences at P = 0.05; ** Significant difference at P = 0.01.

Table 4. Mean grain yield (kg/ha) of lentil lines over seasons and locations.

Line	Location			Mean	Advantage over check (%)
	Rubatab	Wad Hamid	J. Marra		
ILL 818	1762	4542	2450	2918	+11.0
ILL 813	1894	4682	1823	2800	+6.4
ILL 795	1652	4398	1950	2733	+3.9
ILL 4605	1700	3475	2140	2438	-7.3
Selaim (check)	1852	4216	1630	2630	–

Table 5. Mean grain yield ranking of the lentil lines and superiority estimates over environments.

Line	Location											Mean
	Rubatab				Wad Hamid			Jebel Marra				
	90/91	91/92	92/93	Mean	91/92	92/93	Mean	90/92	91/92	92/93	Mean	
ILL 795	4	5	2	3.67	4	3	3.5	4	3	2	3.00	3.38
ILL 813	1	4	3	2.67	1	2	1.5	5	3	4	4.00	3.88
ILL 818	3	3	5	3.67	2	1	1.5	1	1	1	1.00	2.13
ILL 4605	5	1	1	2.33	5	5	5.0	2	2	3	2.33	3.00
Selaim	2	2	4	2.67	3	4	3.5	3	5	5	4.33	3.50

Yield stability over environments was estimated by relating the yield (t/ha) of each variety to the environmental index (E) by simple linear regression (Eisensmith 1991). The index for each environment is equivalent to the mean yield of the genotypes grown in that environment. Table 6 shows the yield stability statistics of the genotypes over environments and Figure 1 compares the stability regression lines of ILL 813, ILL 818 and Selaim. All genotypes, except ILL 4605, showed high stability over environments with correlation and determination coefficients of more than 0.95. ILL 813 showed best response to favorable environments, as indicated by the slope of the regression line, followed by ILL 818 and ILL 795 (Table 6). ILL 818 also showed high yield in less favorable environments as indicated by the intercept of the regression line and the high mean response.

Grain quality of the lentil genotypes was analyzed at the Food Research Centre, Shambat. The results are shown in Table 7. The protein content of the seed was high in all genotypes: 26–29% at Rubatab and 24–30% at Wad Hamid. Percentage of dehulled grains was acceptable at 86–94. The best line in protein content over locations was ILL 818, followed by ILL 813.

ILL 818, although low in the percentage of dehulled grains (86%), had higher yield, particularly in the less favorable environment (Fig. 1). The high and stable yield together with high protein content makes the line an appropriate candidate for release, particularly for areas where filling the food gap is more important than cosmetic attributes.

Table 6. Yield stability statistics of five lentil genotypes over environments.

Parameter	Genotype				
	ILL 813	ILL 818	ILL 795	ILL 4605	Selaim
Correlation coefficient	0.992	0.982	0.996	0.948	0.985
Determination coefficient	0.984	0.965	0.993	0.900	0.971
Regression line intercept	-0.393	0.091	-0.091	0.550	-0.155
Regression line slope	1.179	1.045	1.042	0.700	1.034
Standard error of slope	0.061	0.082	0.037	0.096	0.073
Student's t value	2.906	0.556	1.147	3.137	0.461
Probability	0.027	1.000	0.295	0.020	1.000
Error mean square	0.040	0.070	0.014	0.096	0.056
Mean response	2.564	2.715	2.525	2.308	2.440

Table 7. Lentil quality analysis.

Location/line	Protein (% DM basis)	Grain dehulling properties (TADD)			Extraction (%)
		Dehulled (%)	Undehulled (%)	Broken (%)	
Rubatab					
ILL 795	26	91.5	8.5	3.0	81.5
ILL 813	29	93.5	6.5	3.0	77.5
ILL 818	28	86.0	14.0	3.5	82.0
ILL 6004	27	96.0	4.0	1.0	82.0
ILL 4605	28	93.5	6.5	1.0	81.5
Selaim (check)	26	90.0	10.0	3.0	75.0
Wad Hamid					
ILL 795	29	82.0	18.0	2.5	78.5
ILL 813	28	94.0	6.0	3.0	77.5
ILL 818	30	86.0	14.0	3.0	79.0
ILL 6004	24	90.5	9.5	1.0	79.5
ILL 4605	29	86.5	13.5	2.0	79.0
Selaim (check)	28	78.0	21.0	2.5	73.5

The performance of the lines in yield-related characters is presented in Table 8. The *microsperma* lines were earlier than the *macrosperma* ones; the seed mass of the *macrosperma* lines was higher then the *microsperma* ones, as expected.

Recommendation

According to the performance of these lines over environments and their relative stability in grain yield, we recommend: (1) line ILL 813 for growth by farmers in northern Sudan, under the name Rubatab-1; and (2) line ILL 818 for growth by farmers in the Jebel Mara area, under the name Aribo-1.

Description

The lines ILL 813 and ILL 818 are selections from the families 130 and 143 introduced from Egypt and received through ALAD/ICARDA in the early 1970s. They have erect growth habit, white flowers, dark seeds and red cotyledons. Other yield-related and quality characters were shown in Tables 7 and 8.

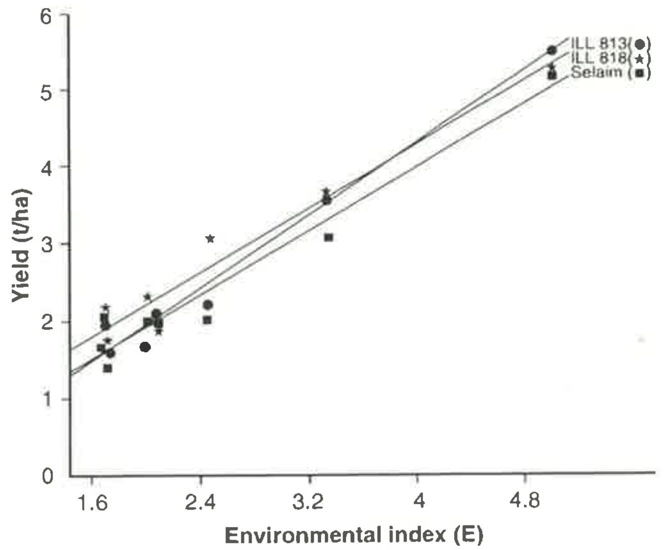

Fig. 1. Stability regression lines of the yield of the genotypes ILL 813, ILL 818 and the check Selaim over environments.

Table 8. Mean performance of lentil genotypes in yield-related characters at Rubatab, Wad Hamid and Jebel Marra.

Location/ line	Days to 50% flowering	Days to maturity	1000-Seed weight (g)
Rubatab			
ILL 795	45	105	46
ILL 813	45	104	50
ILL 818	45	104	45
ILL 6004	62	103	62
ILL 4605	62	104	62
Selaim (check)	50	103	48
Mean	52	104	52
SE ±	0.3**	0.2**	2.0**
Wad Hamid			
ILL 795	45	111	52
ILL 813	46	111	52
ILL 818	46	111	43
ILL 6004	59	113	62
ILL 4605	57	113	62
Selaim (check)	46	111	53
Mean	50	112	54
SE ±	0.3**	0.2**	2.0**
Jebel Marra			
ILL 795	57	104	50
ILL 813	55	102	50
ILL 818	52	103	46
ILL 788	54	104	54
ILL 4605	61	101	58
Selaim (check)	57	100	48
Mean	56	102	51
SE ±	0.3**	0.2**	2.0**

Acknowledgments

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Lentil Information

Editors' notes

Lentil in AGRIS

Recipients are reminded that this title ceased publication after 1989 (vol. 4). You should be aware that recent lentil references are now published in an annual supplement to *LENS Newsletter*.

Variety Release Notices

Commencing with this issue of *LENS Newsletter*, we will publish short articles on released varieties in a separate section: Variety Release Notices. Researchers are invited to contribute to this section by sending brief articles describing newly released varieties. All articles should indicate the pedigrees of varieties, their release date, and include data on agronomic traits.

Recent lentil publications

Breeding for stress tolerance in cool-season food legumes, Ed. K.B. Singh and M.C. Saxena. John Wiley & Sons, Baffins Lane, Chichester, West Sussex PO19 1UD, UK. A Co-Publication with ICARDA and Sayce Publishing (UK). ISBN 0-471-94212-X. 1993, 474 pp.

This book constitutes the proceedings of an international conference on 'Breeding for stress tolerance in cool-season food legumes' held at Ravello, Italy, 10–12 September 1990. The conference was jointly organized by the University of Naples (Italy) and ICARDA. The crops covered are chickpea (*Cicer arietinum* L.), faba bean (*Vicia faba* L.), lentil (*Lens culinaris* Medik.) and pea (*Pisum sativum* L.). Some 24 papers are presented under the following headings: Problems and prospects of stress resistance breeding; Screening for resistance to biotic stresses; Screening for resistance to abiotic stresses; Tools for stress resistance breeding; and, Strategies for stress tolerance breeding. A concluding Summary of the main issues discussed at the conference is also presented.

Expanding the production and use of cool season food legumes. A global perspective of persistent constraints and of opportunities and strategies for further increasing the productivity and use of pea, lentil, faba bean, chickpea and grasspea in different farming systems. Proceedings of the Second International Food Legume Research Conference on pea, lentil, faba bean, chickpea, and grasspea, Cairo, Egypt, 12–16 April 1992, Ed. F.J. Muehlbauer and W.J. Kaiser. Current Plant Science and Biotechnology in Agriculture. Kulwer Academic Publishers, P.O. Box 17, 3300 AA Dordrecht, The Netherlands. ISBN 0-7923-2535-4. 1994, 991 pp.

The principal objectives of the Second International Food Legume Research Conference were to review and assess recent results from national and international research programs on cool-season food legumes and to develop strategies for increasing the productivity, improving the quality and extending the use of these crops in different farming systems. Topics in both basic and applied research were addressed and multidisciplinary research efforts were emphasized. The papers published here are organized according to subject areas: Processing and animal feeds; Climate change and biotic and abiotic stresses; host plant resistance to manage biotic stresses; Policy incentives; Breeding methods and selection indices; Infrastructural support; Cool season food legume breeding; Management to control biotic and abiotic stresses; Biotechnology and gene mapping; Crop physiology and productivity; and Farmers' constraints on on-farm research. Sessions devoted to regional discussion groups and to the continuation of the IFLRC concept are also included. A conference summary is also presented.

Insect pests of pulses. Identification and control manual, by K.S. Chhabra, S. Lal, B.S. Kooner and M.M. Verma. Copublished by Dr K.S. Chhabra and Dr S. Lal on behalf of Punjab Agricultural University, Ludhiana and Directorate of Pulses Research, Kanpur, India. 1993.

This manual covers the major insect pests of the main pulse crops in India: greengram (mung bean), blackgram (urd bean), pigeon pea, chickpea, lentil and field peas. Excellent color photographs show the identification characteristics of each insect as well as symptoms on plant parts or seeds. Since the photographs have been taken under natural conditions, they are of practical diagnostic value. The illustrations are complemented by information on distribution and host range, damage caused, description of pest, its biology and appropriate control measures. This publication provides good information for research workers, extension personnel, farmers and students. As many of the pests are not restricted to India, the manual should receive broad attention and be widely used.

S. Weigand

Conferences

1995

***24th International Seed Testing Association (ISTA) Congress*, Copenhagen, Denmark, 7–16 June.** Contact: Dr Hans Arne Jensen, ISTA Congress Co-ordinator, Plante Directorate, Skovbrynet 20, DK-2800 Lyngby, Denmark [Tel. +45-42-88-33-66; Fax +45-45-93-33-66].

***International Symposium on* Rhizoctonia*: Facts and challenges in Pathology, Taxonomy, Ecology and Disease Control*, Noordwijkerhout, The Netherlands, 28 June–1 July.** Contact: ISR '95 secretariat, Mrs Francien Verwoert, IPO-DLO, P.O. Box 9060, 6700 GW Wageningen, The Netherlands [Tel. +31-8370-76001; Fax +31-8370-10113].

***13th International Plant Protection Congress*, The Hague, The Netherlands, 2–7 July.** Contact: XIII International Plant Protection Congress, c/o Holland Organizing Centre, Lange Voorhout 16, 2514 EE Wageningen, The Netherlands [Tel. +31-365-7850; Fax +31-70-361-4846].

***Improving Production and Utilisation of Grain Legumes – 2nd AEP Conference*, Copenhagen, Denmark, 10–12 July.** Contact: KVL (1995 AEP Conference), 40 Thorvaldsensvej, DK-1871 Frederiksberg C, Copenhagen, Denmark [Tel. 45-35-28-24-32; Fax 45-35-28-20-89]; or AEP, 1995 Conference, 12 avenue George V, 75 008 Paris, France [Tel. +33-1-40-69-49-09; Fax +33-1-47-23-58-72].

***10th biennial Australasian Plant Pathology Society Conference*, Lincoln University, Christchurch, New Zealand, 28–30 August.** Contact: Secretariat, 10th Biennial APPS Conference, Centre for Continuing Education, P.O. Box 84, Lincoln University, New Zealand [Tel. 64-3-325-3819; Fax 64-3-325-3840; E-mail crabbd@lincoln.ac.nz].

1996

***2nd International Weed Control Congress*, Copenhagen, Denmark, 25–28 July 1996.** Contact: ICS, International Conference Services A/S Strandvejen 171, P.O. Box 41, DK-2900 Hellerup, Denmark.

***6th International Parasitic Weed Symposium*, Cordoba, Spain, tentative.** Contact: Dr Maria Teresa Moreno, Centro de Investigacion y Desarrollo Agrario, Apartado 4240, 14080 Cordoba, Spain [Fax +34-57-202721; Telex 76686].

1997

***International Food Legume Research Conference III*, Adelaide, Australia, 22–26 September 1997.** Contact: Dr F.J. Muehlbauer, Chair: IFLRC-III, 303W Johnson Hall, Washington State University, Pulman, WA 99164-6434, USA [Tel. +1-509-335-9521; Fax +1-509-335-8674]; or, Prof. R.J. Summerfield, Program Chairman IFLRC-III, Department of Agriculture, University of Reading, Early Gate, Reading, Berkshire RG6 2AT, UK [Tel. +44-734-318482; Fax +44-734-352421; Telex 847813].

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Manuscript

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All articles must have an abstract (maximum 250 words) and usually the following sections: Introduction, Materials and Methods, Results, Discussion, Conclusions and References. Articles will be edited to maintain uniform style, but substantial editing will be referred to the author(s) for approval. Papers requiring extensive revision will be returned to the author(s) for correction. Authors can refer to a recent issue of *LENS Newsletter* for format. The following guidelines should be followed.

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Present measurements in metric units, e.g. t/ha, kg, g, m, km, ml, L. Where other units are used (e.g. quintal), the metric equivalent should be provided in parentheses.

Define in footnotes or legends any unusual abbreviations or symbols used in the text, tables or figures.

Provide the full name of journals and book titles. Use the following formats for references.

Journal article: Vandenberg, A. and A.E. Slinkard. 1989. Inheritance of four new qualitative genes in lentil. *Journal of Heredity* 80(4): 320–322.

Article in book: Erskine, W. and F.J. Muehlbauer. 1990. Effects of climatic variations on crop genetic resources and plant breeding aims in West Asia and North Africa. Pages 148–157 *in* Climatic Change and Plant Genetic Resources (M. Jackson, B.V. Ford-Lloyd and M.L. Parry, eds). Belhaven Press, London, UK.

Article in proceedings: Montoya, J.L. 1988. The production of seed of leguminous crops in Spain. Pages 136–142 *in* Seed Production in and for Mediterranean Countries. Proceedings of the ICARDA/EC Workshop, 16–18 December 1988, Cairo, Egypt (A.J.G. van Gastel and J.D. Hopkins, eds). ICARDA, Aleppo, Syria.

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