Euphytica 35 (1986) 695–700

VARIATION BETWEEN AND WITHIN LENTIL LANDRACES FROM YEMEN ARAB REPUBLIC

W. ERSKINE and M. A. CHOUDHARY[1]

International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria

Received 3 March 1986

INDEX WORDS

Lens culinaris, lentil, landrace, population, variation.

SUMMARY

The variation in 31 landraces of lentil collected from Yemen Arab Republic was partitioned to estimate the variation between populations and the variation between families within populations by studying a total of 568 progenies of randomly selected plants. There was significant variation between populations and between families within populations in seedling pigmentation, time to flower, time to maturity and plant height, but the predominant source of variation was between populations. This variation was unrelated to altitude of collection. The landraces were equally variable across characters. The implications of this analysis of variation on lentil breeding and germplasm collection are discussed.

INTRODUCTION

Landraces comprise the major domesticated genetic resource for plant breeders of food legumes, in which there are few released cultivars. Extensive collections have been made to conserve this genetic diversity, and the differences between accessions collected in various geographical areas have been thoroughly studied since the work of Vavilov and his colleagues (e.g. BARULINA, 1930; MURATOVA, 1931). There is, however, little information on the variation within individual legume landraces because no partition has been made between environmental variance and the variance between families within populations (ERSKINE & KHAN, 1981). Plant breeders should be aware of the population structure of the landraces they are trying to replace. The information is also important in planning collection, maintenance and exploitation of genetic resources.

In lentils (*Lens culinaris* MED.) research on the population structure of landrace accessions has revealed an outcrossing level of around 1% from an analysis of the level of heterozygosity at a polymorphic aspartate amino-transferase locus (SKIBINSKI et al., 1984). It remains to partition the variation between and within landraces for a range of morphological characters in this autogamous crop.

[1] Present address: Directorate of Pulses, Ayub Agricultural Research Station, Faisalabad, Pakistan.

MATERIALS AND METHODS

We studied landraces of lentil collected in the Yemen Arab Republic by a mission of the International Board of Plant Genetic Resources (AYAD et al., 1980). The samples had been grown on mountain terraces between 1700 and 2800 metres above sea level. Samples were collected from farmers' stores and some markets where the stallholders reported them as 'local' (Table 1). In the villages Maris and Qabil the samples were from two farmers, while in Bani Mah'dam the samples were from one farmer who had two known varieties of lentil. No lentil varieties have been released to farmers in the country.

The 31 landraces were grown at ICARDA Tel Hadya Farm, N. Syria (36°40'N.) in the 1980–81 season and 20 plants were selected at random from each population. The single-plant progenies were multiplied in rows in 1981–82 at Tel Hadya. Seed was available from 568 progeny rows for planting in December, 1982 at Tel Hadya

Table 1. Origin of collections.

Sample	Province	Village	Latitude (°N)	Longitude (°E)	Altitude (m)	Status of sample
1	Radaa	Mawr	14.25	44.73	2000	Store
2	Radaa	Al Sharaf	14.23	44.72	2500	Store
3	Radaa	Al Hajar	14.10	44.67	2630	Store
4	Radaa	Al Khabbar	14.30	44.83	2040	Store
5	Radaa	Agaba	14.25	44.78	2560	Store
6	Radaa	Al Hassan	14.23	44.77	2530	Store
7	Radaa	Bait al Souraini	14.17	44.77	2500	Store
8	Radaa	Jubair	14.19	44.78	2700	Store
9	Sana'a	Sana'a				Market
10	Taiz, Jebel Sabir	Zumrain Sabir Al Mawadem	13.53	44.00	2300	Store
11	Ibb/Yareem	Al Quaibah				Market
12	Ibb	Jebel al Khudra	14.10	44.10	2500	Store
13	Ibb	Al Housain	14.10	44.15	1700	Store
14	Ibb	Irian	14.25	44.25	2150	Store
15	Ibb	Maris	14.28	44.47	2200	Store
16	Ibb	Maris	14.28	44.47	2200	Store
17	Ibb	Yarim	14.30	44.38		Market
18	Dhamar	Koman	14.28	44.42	2350	Store
19	Dhamar	Dhumara	14.42	44.45	2200	Store
20	Dhamar	Quarn Dhamar	14.50	44.40	2200	Store
21	Dhamar	Al Gra'aman	14.63	44.32	2200	Store
22	Dhamar	Hamam Ali	14.67	44.15		Market
23	Dhamar	Dhamar	14	44		Market
24	Sana'a	Qabil	15.45	44.13	2400	Store
25	Sana'a	Qabil	15.45	44.13	2400	Store
26	Sana'a	Rabo'o	15.40	44.17	2400	Store
27	Sana'a	Bani Mah'dam	15.17	44.00	2800	Store
28	Sana'a	Bani Ma'dam	15.17	44.00	2800	Store
29	Sana'a	Shibam al Kharas	15.33	44.48	2200	Store
30	Sana'a	Al Anbar	15.47	44.42	2200	Store
31	Sana'a	45 km S. of Sana'a	15.98	44.25	2400	Store

in a randomized block experiment with two replications and progenies sown in one meter long rows. The distance between rows was 25 cm and there were 40 seeds/row. Phosphate was applied at the rate of 50 kg P_2O_5/ha prior to sowing.

The following characters, known to have a relatively high heritability, were measured on each row: 1) Seedling leaf pigmentation (presence or absence); 2) Time from first rain following sowing to when 50% of the plants in a row started flowering (days); 3) Time from first rain following sowing to when 90% of pods in a row were golden-brown (days); 4) Average plant height of three plants per row from the ground to the tip of the extended foliage (cms); 5) Average number of seeds per pod in 30 randomly selected pods per row; 6) 100-seed weight calculated from the number and weight of seeds in the above 30 pods (g).

For the quantitative characters (2–6), an analysis of variance of the randomized block design was undertaken. Thereafter the genetic variance was paritioned into two sources namely variance between populations and variance between families within populations.

RESULTS

The only qualitative trait is leaf pigmentation at the seedling stage, for which all 31 populations were polymorphic. The frequency of pigmental morphs varied from 0.33 in the sample No. 6 from Al'Hassan, Radaa Province to 0.98 with an overall mean frequency of 0.67 (Table 2).

The overall mean for time to flower was 97 days. The earliest population (No. 27) flowered after a mean of 94.4 days, whereas the latest population (No. 9) came into flower after 104.7 days giving a spread of 10 days between the landraces. There was highly significant genetic variation both between populations and between families within populations (Table 3). But the predominant source of variance was between landraces, because the variance ratio (F value) of the test of between populations against between families within populations was 48.8 and significant at $P < 0.001$.

Time to maturity followed flowering by an average of 41 days, a mean of 138 days after sowing. As with time to flowering, there was significant variation both between populations and between families within populations for time to maturity. The major source of variance was between populations because the F value of the mean square of between populations versus between families within populations was 5.9 and significant at $P < 0.001$. The range between land races for time to maturity was only 2 days from 136.6–138.8 days. The brevity of the period reflects the water and temperature stress during pod filling, which severly reduced the life cycle of the plants in North Syria.

The average height of plants was 22.2 cm. There was significant variation both between populations and between families within populations. The F value of the mean square between populations versus between families within populations was 3.0 and highly significant. The range in mean landrace height was 2.8 cm from 21.2 to 24.0 cm.

The overall mean for 100 seed weight was 2.77 g. The variation between families within populations was non-significant for 100 seed weight, whereas there was significant variation between populations, ranging from 2.51 – 3.11 g/100 seeds.

Table 2. The mean and standard deviation of populations for plant height (cm), time to flower (days) time to maturity (days), and 100 seed weight (g), together with the frequency of pigmented morphs.

Sample number	Freq. of pigmented morphs	Plant height		Time of flower		Time of maturity		100 Seed weight	
		mean	S.D.	mean	S.D.	mean	S.D.	mean	S.D.
1	0.76	21.9	1.59	95.4	1.14	137.0	1.06	2.90	0.09
2	0.50	23.0	1.68	95.6	2.03	137.6	2.64	2.91	0.11
3	0.65	22.6	1.18	95.4	1.11	137.1	0.91	2.88	0.09
4	0.58	21.4	1.42	95.3	0.89	136.8	0.51	2.82	0.11
5	0.76	21.7	1.41	95.7	1.07	136.9	0.69	2.98	0.09
6	0.33	21.7	2.07	95.2	1.38	136.6	0.68	2.61	0.18
7	0.58	22.1	2.05	95.6	1.31	137.1	0.39	2.71	0.17
8	0.68	22.9	2.62	95.9	0.83	137.2	1.01	2.77	0.16
9	0.95	23.8	1.82	104.7	1.57	138.4	1.01	3.00	0.11
10	0.70	22.7	1.40	95.1	1.16	137.0	0.54	2.72	0.14
11	0.74	21.2	2.63	96.4	2.25	137.6	1.08	2.63	0.09
12	0.98	23.2	1.45	104.5	1.65	138.4	1.24	2.72	0.13
13	0.72	21.6	1.68	95.0	0.94	137.3	0.66	2.65	0.11
14	0.82	23.0	1.74	96.2	1.02	136.9	0.69	2.75	0.10
15	0.75	22.2	1.38	96.5	1.30	137.0	0.47	2.62	0.16
16	0.95	23.7	1.72	99.0	2.09	137.7	1.00	2.98	0.15
17	0.68	22.6	1.19	95.9	1.08	136.8	0.38	2.72	0.12
18	0.38	22.3	2.27	95.5	1.47	137.2	0.65	2.79	0.12
19	0.50	21.4	1.81	96.0	1.20	136.9	0.94	2.55	0.14
20	0.64	22.1	2.26	95.4	0.90	136.7	0.56	2.80	0.10
21	0.82	21.6	2.69	95.5	1.33	136.9	0.73	2.55	0.13
22	0.78	21.7	1.85	95.4	1.17	137.1	1.29	2.51	0.16
23	0.64	22.4	1.71	95.3	0.88	136.9	0.46	2.68	0.17
24	0.53	21.4	1.92	96.0	1.92	137.1	0.51	2.77	0.08
25	0.63	22.0	2.00	95.7	1.64	136.9	0.63	2.62	0.16
26	0.60	21.6	1.70	95.8	1.09	137.1	0.59	2.89	0.11
27	0.53	21.3	1.88	94.4	0.97	137.1	1.48	2.64	0.20
28	0.95	24.0	1.44	104.2	1.69	138.8	1.04	3.11	0.10
29	0.61	21.9	1.81	95.2	1.21	137.1	0.41	2.64	0.12
30	0.67	22.1	2.35	95.2	0.92	137.1	0.31	2.89	0.14
31	0.74	21.8	2.22	95.5	1.14	136.8	0.55	2.81	0.11

Table 3. F values from the analyses of variance of different characters.

	Time to flower	Time to maturity	Plant height	Seeds per pod	100 seed weight
Populations v. Error[1]	125.3***	8.98***	4.56***	1.33	1.52*
Fam. within pops v. Error	1.68***	1.51***	1.51***	1.16	1.08
Pops v. Fam. within pops	48.76***	5.94***	3.02***		

[1] Degrees of freedom for populations = 30; families within populations = 537; and error = 567.
*$P<0.05$ and >0.01; ***$P<0.001$.

Table 4. Correlations coefficients between plant characters and altitude of collection.

	Plant height	Time to flower	Time to maturity	100 seed weight	Altitude
Freq. pigmented morphs	0.567**	0.646**	0.547**	0.346	–0.091
Plant height		0.685**	0.728**	0.519**	0.288
Time to flower			0.515**	0.195	0.183
Time to maturity				0.464*	0.304
100 seed weight					0.253

* $P < 0.5$ and > 0.01; ** $P < 0.01$.

The average number of seeds per pod was 1.39. The differences between populations was significant only at $P = 0.1$.

The variation across characters of landraces was compared using the coefficients of variation of the characters plant height, time of flower and maturity and 100 seed weight in a two-way analysis of variance. The individual landraces were found to be equally variable over these characters because the difference between landraces in the mean coefficient of variation was non-significant.

In order to explore the relationship between plant morphology and altitude of collection correlations were made between altitude and the means of plant characters. Market samples were excluded from this analysis. The correlations with altitude were non-significant and hence there was no systematic regional or clinal differentiation in the material (Table 4). Correlations amongst the characters revealed that the populations with the highest frequency of pigmented morphs were tall and late to flowering and maturity.

DISCUSSION

Extensive study of the variation among lentil landraces from around the world has emphasized regional differences and local adaptation (BARULINA, 1930; ESRKINE & WITCOMBE, 1984). Barulina described the lentils of Yemen within grex *aethiopicae* m., var. *abyssinica* (HOCHST.) *Al.* because of the elongated pod apex, the light-brown colour of mature pods, and the seeds with diameter 3–5 mm and orange cotyledons. The material under study all conformed to type; and additionally the plants were very sensitive to frost, flowered early with blue flowers in a mean of 97 days, and were short with an average plant height of 22 cm.

Before this expedition there were only six accessions from Yemen in the world lentil germplasm collection at ICARDA. The new landraces are particularly valuable, because in December 1983 a devastating earthquake destroyed large areas of farming communities in the Dhamer and Sana'a regions whence nearly half of the landraces originate (DAMANIA et al., 1985).

Turning from macro-geographic variation to the micro-geographic level, the study showed that although the predominant source of variation within the Yemeni germplasm was between populations rather than between families within populations, there was also highly significant variation between families within populations. This pattern of variation in the landraces has implications for future lentil collection in the absence

of other information. For example, as many different areas as possible should be sampled within a target region to maximise the sampling of between population variation. Within collection sites sufficient plants/seed must be collected to ensure an adequate sample of the variation between families within populations and to allow a sharing of the seed for storage. Since the populations were found equally variable a similar quantity of seed may be collected at each site.

The landraces under study are the product of many cycles of selection in farmers' fields in Yemen. Their population structure and, in particular, the variation within populations is instructive to plant breeders wishing to replace them. Homogeneous and homozygous lines are the usual end-product of breeding programs of autogamous food legumes. To this end, pure line selection is required for the direct exploitation of germplasm.

In view of the evidence that heterogeneous populations tend to be more stable than homogeneous populations (summarized in SIMMONDS, 1979) the breeding program at ICARDA is producing advanced generation bulk lines each with limited heterogeneity. They are formed by bulking the progeny of single plant selections made at the F_4 or F_5 generation (AUCKLAND, 1967). Continued segregation in later generations at the remaining heterozygous alleles will produce a low level of heterogeneity within bulked lines, parallel to that within landraces.

ACKNOWLEDGEMENTS

The authors wish to express gratitude to Miss L. Khoury, Messrs U. Obaji and A. Ismail for their technical assistance, and to Drs M. C. Saxena, R. S. Malhotra and L. Holly for their helpful comments on the script.

REFERENCES

AUCKLAND, A. K., 1967. Soyabeans in Tanzania. 2. Seasonal variation and homeostasis in soyabeans. J. Agric. Sci. (Camb.) 69: 455–464.

AYAD, W. G., R. P. CROSTON & A. A. KHAWLANI, 1980. Collecting in the YAR. II. Plant Genet. Res. Newsl. 43: 25–27.

BARULINA, H., 1930. Lentils of the USSR and of other countries. Bull. of Appl. Bot., Gen. and Pl. Breed., Supplement 40. Leningrad (English Summary).

DAMANIA, A. B., M. T. JACKSON & E. PORCEDDU, 1983. Variation in wheat and barley landraces from Nepal and the Yemen Arab Republic. Z. Pflanzenzüchtg 94: 13–24.

ERSKINE, W. & T. N. KHAN, 1981. Variation within and between landraces of winged bean (*Psophocarpus tetragonolobus* (L.) D.C.). Field Crops Res. 3: 359–364.

ERSKINE, W. & J. R. WITCOMBE, 1984. Lentil germplasm catalog. ICARDA, Aleppo, Syria.

MURATOVA, V., 1931. Common beans (*Vicia faba*). Bull. of Appl. Bot., Gen. and Pl. Breed., Supplement 50. Leningrad (English Summary).

SIMMONDS, N. W., 1979. Principles of crop improvement. Longman, London and New York.

SKIBINSKI, D. O. F., D. RASOOL & W. ERSKINE, 1984. Aspartate amino-transferase allozyme variation in a germplasm collection of the domesticated lentil (*Lens culinaris*). Theor. Appl. Genetics 68: 441–448.