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Variation in Wheat and Barley Landraces from Nepal and The Yemen Arab Republic

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With 7 tables

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Abstract

Sixteen landraces each of hexaploid wheats (*Triticum aestivum* L.) and six-rowed barleys (*Hordeum vulgare* L.) from Nepal and an equal number of tetraploid wheats (*T. turgidum* L.) and two-rowed barleys (*H. distichum* L.) from the Yemen Arab Republic were evaluated for morphological variation and days to heading. Landraces from four different areas in each country with four collection sites each at varying altitudes were selected to determine the distribution patterns of this variation. The plant material was grown at an experimental station 110 km NW of Bari, Southern Italy, and quantitative and qualitative data were recorded for 17 wheat and 18 barley characters on 50 plants selected at random from each landrace. There were significant differences in variation among regions in the Yemen and river valleys in Nepal, as well as among landraces in the same regions or river valleys. There was considerable overlap in quantitative variation patterns among landraces. Polymorphisms were common and in most cases only two or three character states were sufficient to describe the variation. It is concluded that in order to study cereal variation patterns in a secondary centre of diversity, data on quantitative as well as qualitative characters of a sufficiently large number of plants and landraces must be recorded to obtain accurate and significant results. A study such as this provides plant breeders with valuable information on important sources of germplasm.

Key words: *Triticum* spec. — *Hordeum* spec. — landraces — morphological variation — heading date — evaluation of germplasm — genetic resources — polymorphism pattern

In recent years it has been suggested that the accumulation of diversity in certain areas may be due to the spread of human migrations across ecological and climatic zones until a barrier is reached which cannot be traversed.

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It is at these extremities of cultivation that one may find considerable diversity, sometimes referred to as "peripheral diversity" (YAMASHITA 1979). According to VAVILOV (1951), Ethiopia is a centre of diversity for tetraploid wheats and two-rowed hulled barleys, and Central Asia (the Hindu-Kush area) for hexaploid wheats and six-rowed hulled barleys. These crop plants must have been brought to Ethiopia and the Hindu-Kush already well adapted to cultivation by man as both these areas are devoid of wild forms of *Triticum* or *Hordeum* (SCHIEMANN 1951, HARLAN 1975); consequently these areas should be considered as secondary centres of diversity. The selection of germplasm for this study from Nepal and the Yemen Arab Republic (hereafter referred to as the Yemen) is appropriate because of their proximity to the secondary centres of diversity for hexaploid wheats and six-rowed barleys and tetraploid wheats and two-rowed barleys, respectively; hence they may hold interesting gene combinations for use in future breeding programmes.

Landraces collected from various countries within the centres of diversity have been evaluated in previous studies, including Ethiopian barleys (QUALSET 1975), *durum* wheats (PORCEDDU 1976, ADARY 1978), *turgidum* wheats (JAIN et al. 1975) and *aestivum* wheats and six-rowed barleys (WITCOMBE 1975, GILANI 1977, WITCOMBE and GILANI 1979). The variation found in landraces for disease resistance as well as quantitative and qualitative morphological characteristics has been described, but further studies are needed for a fuller exploitation of this valuable germplasm in order to gain better knowledge of evolutionary pathways, the distribution pattern of characters and their frequencies, and associations between characters in different areas.

Much of the genetic improvement in wheat and barley has come through "pure lines", which are highly uniform in morphology, heading time, disease resistance and quality factors associated with marketability (ALLARD 1961). There is some evidence that mixtures of varieties and landraces may yield better and more consistently than stocks in which variability has been kept to the minimum (HARLAN 1951, DORST 1957, WIEBE 1975). Evidence to date shows that landraces have been fragmented by human activities, and different cultural practices keep them apart (MANGELSDORF 1952, WITCOMBE 1977). Landraces have evolved adapted to particular ecological niches and geographical regions. Appropriate sampling and evaluation of landraces can provide valuable information regarding genetic variance and heritability leading to genetic advance in plant breeding. Breeders have always been interested in studying the inherent variation in agronomic characters within their germplasm before initiating a breeding programme (MARSHALL and BROWN 1975), in order to maximise the efficiency of their efforts.

Materials and Methods

Sixteen landraces each of wheat and barley collected by expeditions sponsored by the International Board for Plant Genetic Resources (IBPGR) in Nepal (ERSKINE et al. 1979) and the Yemen (AYAD and CROSTON 1980) were utilized in this study. These 64 randraces were collected from diverse altitudes ranging from as low as 780 m to 2800 m above mean sea-level. The origin and exact location of the collecting sites are given in *Tables 1* and *2* respectively. All Nepalese wheat landraces were hexaploid *Triticum aestivum* L. whereas those from the Yemen were tetraploid *T. turgidum* L. The Nepalese barley landraces were six-rowed *Hordeum vulgare* L. whereas those from the Yemen were *H. distichum* L.

Tab. 1 Provenances of wheat and barley landraces from Nepal

Valley	Village	Lat. (N)	Long. (E)	Alt. (M)	Crop W=Wheat B=Barley
Bheri	Kalagaon	28°36′	81°35′	780	W,B
	Dailekh	28°50′	81°43′	1410	W,B
	Channa	28°55′	81°45′	1960	W,B
	Bhavassaini	28°58′	81°46′	2400	W,B
Karnali	Tulkana	28°57′	82°17′	1710	W,B
	Chirana	29°11′	81°53′	1950	W
	Rachuli	29°10′	81°52′	1960	B
	Bahivanka	29°14′	82°02′	2145	W
	Dillikot	29°04′	81°45′	2245	W,B
	Dhaulapani	29°14′	82°05′	2250	B
Dhaulagiri	Armadi	28°13′	83°40′	800	B
	Beni	28°20′	83°33′	980	W
	Taka	28°29′	83°22′	1680	W,B
	Malkabang	28°22′	83°27′	2000	W,B
	Lomsom	28°30′	83°14′	2170	W,B
Gandak-Bagmati	Jitpur	27°43′	85°45′	1200	W,B
	Sunakothi	27°37′	85°22′	1300	B
	Thecholele	27°35′	85°18′	1350	W,B
	Godavri	27°36′	85°22′	1400	W,B
	Kakani	27°49′	85°16′	2200	W

The landraces were sown in a completely randomized block design at Gaudiano (41°6′N, 15°52′E), an agricultural community in the heart of the cereal growing area of southern Italy, in December 1980 and harvested in June 1981. After emergence, 50 plants from each landrace were selected at random and tagged. Data on 17 morphological characters and the number of days to heading of these 50 plants were recorded; the characters are listed below:

- Flag-leaf length (cm)
- Flag-leaf width (cm)
- Plant height (cm)
- Uppermost inter-node length (cm)
- Number of spikes per plant
- Spike length (cm)
- Number of spikelets per spike
- Spike colour
- Presence or absence of awns
- Awn colour
- Awn length (cm)
- Awn surface (barbed or smooth)
- Seed colour
- Number of seeds per spike
- Weight of seeds per spike (g)
- 1000-grain weight (g)
- Spike density
- Number of days to heading

The awn length of wheat plants was not measured as there were many landraces among the Nepalese material which had awned as well as awnless plants.

Statistical Analysis System (SAS) was used to perform several analyses on the quantitative as well as qualitative data, including analysis of variance, discriminant analysis and frequencies, between and within landraces and between regions and valleys.

Tab. 2 Provenances of wheat and barley landraces from the Yemen Arab Republic

Region	Village	Lat. (N)	Long. (E)	Alt. (M)	Crop W=Wheat B=Barley
Al Baida	Al Souma'a	14°15′	44°55′	1950	W,B
	Al Mashair	14°15′	45°30′	2600	W
	Maswakin	14°10′	45°32′	2650	B
	Al Okla	14°12′	45°35′	2700	B
	Al Barria	14°17′	45°35′	2700	W
	Jubair	14°15′	44°55′	2700	W,B
Ibb	Jabal Al Khadra	13°52′	44°12′	2100	W,B
	Irian	14°15′	44°15′	2150	B
	Robat Al Gala'a	14°15′	44°20′	2400	W
	Bait Yehia Obad	14°10′	44°17′	2500	W,B
	Al Dubarin	13°50′	44°10′	2550	W,B
Dhamar	25km N of Dhamar	14°40′	44°20′	2200	W
	Dhamar	14°50′	44°15′	2300	W,B
	Qarn Dhamar	14°20′	44°20′	2350	W,B
	Koman	14°20′	44°25′	2350	W,B
	Yerim	14°15′	44°15′	2500	B
Sana'a	Shibam Al Kharas	15°10′	44°15′	2200	W
	Wadi Dhar	15°21′	44°10′	2400	B
	Rabo'o	15°20′	44°12′	2450	W,B
	Bani Mattar	15°15′	44°50′	2500	W,B
	Bait Mahdam	15°15′	44°10′	2800	W,B

Results and Discussion

Wheat

Although the two types of wheats were of different ploidy there were certain general patterns of variation which make it possible to compare the situation in the two countries. Among the twelve quantitative characters observed the greatest differences between mean values were seen mainly in four characters: flag-leaf length, plant height, number of seeds per spike and 1000-grain weight (*Table 3*). These differences can be attributed to the morphology of the *aestivum* and *turgidum* wheats rather than to geographical distribution or cultural practices. Although the tetraploid wheats from the Yemen had fewer grains, these were heavier than grains from the hexaploid wheats. There was greater variation in the quantitative characters between regions in the Yemen than between river valleys in Nepal, even though the altitudinal variation of the collection sites was greater in Nepal than in the Yemen (*Table 4*). There were significant differences in flag-leaf length, spike length and spike density between the regions in the Yemen, whereas in Nepal only differences in spike density were significant.

The variation between landraces themselves was greater in the Yemeni material than in Nepalese germplasm for all quantitative characters except

Tab. 3 Means and coefficients of variation (C.V.%) for wheat and barley characters based on 50 plants per landrace from Nepal and the Yemen Arab Republic

Character	Wheat				Barley			
	Mean		CV		Mean		CV	
	Nepal	Yemen	Nepal	Yemen	Nepal	Yemen	Nepal	Yemen
Flag-leaf length (cm)	23.7	27.0	15.3	12.7	17.6	20.9	18.2	18.2
Flag-leaf width (cm)	1.6	1.6	13.0	11.2	1.5	1.2	13.6	14.6
Plant height (cm)	112.5	89.9	6.7	8.1	103.4	85.3	7.4	9.4
Uppermost internode length (cm)	42.3	39.3	11.6	13.4	37.5	34.9	13.2	15.3
No. spikes/plant	34.8	33.7	33.3	29.9	27.1	38.1	35.5	31.5
Spike length (cm)	12.1	11.3	9.5	9.9	9.7	10.9	11.4	11.4
No. spikelets/spike	19.9	18.2	8.9	11.5	25.5	23.2	11.9	12.8
No. seeds/spike	65.4	38.9	18.4	19.8	63.3	21.2	16.9	17.7
Weight seeds/spike (g)	2.3	2.0	24.0	24.0	3.0	1.5	22.6	26.5
1000-grain weight (g)	35.0	52.4	16.2	15.6	47.8	70.3	13.0	18.4
Spike density	16.7	16.3	9.7	9.9	26.9	21.4	12.5	8.8
Awn length (cm)	–	–	–	–	11.6	14.8	18.5	12.3
Days to heading	122.2	123.3	3.4	3.3	115.7	106.7	8.2	6.5

spike length where the reverse was true. There was significant variation for all characters in both countries between landraces, indicating considerable variation among landraces in the same region or valley.

However, the variation within landraces was more or less similar in both countries, except in the case of characters such as number of spikes per plant, number of seeds per spike, and the 1000-grain weight (*Table 5*). WITCOMBE and GILANI (1979) came to a similar conclusion while working on bread

Tab. 4 Mean squares for variation in wheat landraces from Nepal and the Yemen Arab Republic on a geographical basis

Character	Nepal			Yemen		
	Between valleys d.f.=3	Within valleys d.f.=12	Error d.f.=780	Between regions d.f.=3	Within regions d.f.=12	Error d.f.=782
Flag-leaf length	314	203*	13	1049**	218*	12
Flag-leaf width	1	1*	< 1	4	2*	< 1
Plant height	4460	2190*	57	14930	4550*	54
Uppermost internode length	412	378*	24	1223	664*	28
No. spikes/plant	735	464*	134	113	717*	102
Spike length	119	42*	1	142**	32*	1
No. spikelets/spike	33	25*	3	924	395*	4
No. seeds/spike	1670	867*	145	7970	6241*	59
Weight seeds/spike	3	2*	< 1	8	8*	< 1
1000-grain weight	1970	1074*	32	4086	2022*	67
Spike density	203**	49*	3	1836**	383*	3
Days to heading	592	301*	17	2912	857*	16

* = significant variation between landraces in the same valley/region, p = 0.001 %
** = significant variation between valleys/regions, p = 0.001 %

Tab. 5 Mean squares for variation between and within wheat and barley landraces from Nepal and the Yemen Arab Republic

Character	Wheat				Barley			
	Nepal		Yemen		Nepal		Yemen	
	Between land-races d.f.=15	Within land-races d.f.=780	Between land-races d.f.=15	Within land-races d.f.=782	Between land-races d.f.=15	Within land-races d.f.=782	Between land-races d.f.=15	Within land-races d.f.=783
Flag-leaf length	225	13	384	12	205	10	314	14
Flag-leaf width	< 1	< 1	2	< 1	3	< 1	< 1	< 1
Plant height	2643	58	6626	54	1530	58	524	64
Uppermost internode length	385	24	776	28	381	25	152	29
No. spikes/plant	518	134	597	102	1262	93	919	145
Spike length	58	1	54	1	88	1	19	2
No. spikelets/ spike	26	3	501	4	269	9	168	9
No. seeds/spike	1028	145	6587	59	1921	115	134	14
Weight seeds/ spike	2	< 1	8	< 1	19	< 1	2	< 1
1000-grain weight	1253	32	2435	67	2076	44	114	4
Spike density	80	3	674	3	885	11	66	4
Awn length	—	—	—	—	272	5	34	3
Days to heading	359	17	1268	16	4557	91	—	—

wheats from Nepal and Pakistan. They recorded data on nine quantitative characters and found that the means, variances and coefficients of variation were more or less identical in both countries for this crop.

The variation in landraces from the Yemen was significantly correlated with altitude of the collection site for three quantitative characters, namely flag-leaf width, number of spikes per plant and weight of seeds per spike. In contrast, this relationship was not seen among the landraces from Nepal (*Table 6*). In another study (GILANI 1977) it was observed that Nepalese wheat characteristics were correlated with altitude, and this correlation could be attributed to genetic differences. Nevertheless, the effect of altitude on landraces is variable for different crops as well as diverse environmental situations. For instance, it was found that an increase in altitude by 1000 m had a marked increase in yields of *T. aestivum* in Rhodesia (CACKETT and WALL 1971), whereas in soybeans an increase in altitude from 1394 m to 1636 m was sufficient to depress yields in the Sikkim Himalaya (BASNET et al. 1974).

Wheats from the Yemen were generally heterogeneous for spike colour, but they were more or less homogeneous for seed colour. Among the wheat landraces from Nepal the reverse was true. There was also more variation for the presence or absence and awn length in landraces from Nepal than in those from the Yemen where all landraces except one were awned. WITCOMBE (1975) reported anthocyanin pigmentation among wheats from eastern Nepal resulting in maroon coloured spikes, and in extreme cases of anthocyanin concentration, even purple or black. However, no spikes of these colours were observed in the Nepali material in this study. No definite conclusions as

Tab. 6 Correlation coefficients between character means and altitude of collection site for wheat and barley landraces from Nepal and the Yemen Arab Republic (* correlations are significant at P = 0.001)

Character	Wheat		Barley	
	Nepal	Yemen	Nepal	Yemen
Flag-leaf length	+0.17	+0.20	+0.32	+0.12
Flag-leaf width	+0.02	-0.44*	+0.40*	+0.34
Plant height	+0.04	-0.01	+0.22	+0.07
Uppermost internode length	+0.33	+0.16	+0.07	0
No. spikes/plant	-0.16	+0.42*	+0.20	+0.16
Spike length	+0.07	-0.18	-0.64*	+0.24
No. spikelets/spike	-0.01	-0.10	+0.08	+0.02
No. seeds/spike	+0.20	-0.17	+0.43*	-0.10
Weight of seeds/spike	+0.13	+0.44*	+0.61*	-0.12
1000-grain weight	-0.02	+0.06	+0.62*	+0.04
Spike density	-0.05	+0.04	+0.60*	-0.17
Awn length	—	—	-0.53*	-0.02
Days to heading	+0.04	+0.14	+0.01	+0.07

regards distribution of variation can be drawn on such qualitative characters alone and a thorough study of quantitative character differences in crops is needed for adequately describing the variation pattern.

Barley

The two types of barley landraces studied differed from each other in many agronomical characteristics. The two-rowed barleys from the Yemen headed, on average, nine days earlier than the six-rowed material from Nepal (*Table 3*). These traits could be of much use in barley breeding especially in areas of marginal agriculture where drought and flooding are major threats.

The analysis of variance based on thirteen quantitative characters showed that the regions in the Yemen were not significantly different from each other with respect to all the landrace characters. In the landraces from Nepal, flag-leaf width, spike length, and awn length were significantly different on a river valley basis (*Table 7*). However, all characters in both countries were significantly variable between landraces from the same valley or region. The mean squares between the landraces from Nepal were highest for number of days to heading (*Table 5*). It is interesting to note that there was almost no variation in spike lengths within landraces, as was also the case of the weight of seeds per spike. This observation indicates that both barleys had fairly stable yield characteristics.

Several characters among the landraces from Nepal were significantly correlated with the altitude of the site of collection, in contrast to the situation in the Nepalese wheats, but among the Yemen material none of the characters had any significant correlation with altitude (*Table 6*). The mean flag-leaf length was greater among the two-rowed barleys but the six-rowed ones had a

Tab. 7 Mean squares for variation in barley landraces from Nepal and the Yemen Arab Republic on a geographical basis

Character	NEPAL			YEMEN		
	Between valleys d.f.=3	Within valleys d.f.=12	Error d.f.=782	Between regions d.f.=3	Within regions d.f.=12	Error d.f.=783
Flag-leaf length	445	144*	10	542	235*	15
Flag-leaf width	10**	1*	< 1	< 1	1*	< 1
Plant height	2431	1304*	58	609	3901*	116
Uppermost internode length	634	318*	24	540	2611*	93
No. spikes/plant	613	1425*	92	847	1013*	145
Spike length	296**	36*	1	21	20*	2
No. spikelets/ spike	306	260*	9	234	209*	9
Awn length	770**	147*	4	91	27*	3
No. seeds/spike	1169	2109*	114	273	187*	14
Weight seeds/ spike	21	19*	1	3	2*	< 1
1000-grain weight	3048	1833*	44	2238	2602*	178
Spike density	2010	603*	11	50	129*	4
Days to heading	4590	4548*	90	—	—	—

* = significant variation between landraces in the same valley/region, p = 0.001%
** = significant variation between valleys/regions, p = 0.001%

wider flag-leaf (*Table 3*) and this character was positively correlated with altitude (*Table 6*). Since yield components such as number of seeds per spike, weight of seeds per spike and spike density were all positively correlated with altitude in the Nepalese barleys it may also be concluded that an increase in altitude led to broader flag-leaves as well as higher yields. In another study on Canadian barley cultivars, however, FEJER et al. (1979) found that increased flag-leaf dimensions severely depressed grain yields. Recent experimental evidence clearly shows that variation in flag-leaf area after anthesis does not explain variation in grain yields (THORNE 1973). Nevertheless, many physiological studies have indicated that the green parts above and including the flag-leaf make a sizeable contribution to grain yield in cereals and consequently selection for greater photosynthetic area appears to be a promising means of establishing higher yields (YAP and HARVEY 1972).

The length of the awns was greater among the Yemeni landraces than the Nepalese ones. The importance of the awns as a photosynthetic structure in cereals has been particularly stressed by several workers. It is known that awn length is positively correlated with seed size and hence contributes directly towards greater yields (QUALSET et al. 1965, SCHALLER et al. 1972), which may be due to the greater photosynthetic surface close to the seed which aids grain filling. However, long awns can be also disadvantageous to the plant under wet conditions, because the greater amount of water retained by the spike can make the spike heavier and cause considerable lodging (FARIS 1974). Nevertheless, Walpole and Morgan (1972) have suggested that plant breeders should concentrate on increasing awn length with a view to maximising yields.

The polymorphism among the five qualitative characters was not considerable, and only two or three character states were sufficient to describe fully the variation in these characters. This may be due to the fact that qualitative traits in general are controlled by major genes which are less susceptible to change under diverse geographical and environmental conditions (Witcombe 1975). For instance, there was no substantial variation for spike colour in material from both countries, cream being the dominant colour present in nearly 80 % of the spikes. However, in the Nepalese material this predominance was not as great due to the presence of brown spikes.

An interesting phenomenon observed in certain landraces collected in the Dhaulagiri river valley in Nepal was the shattering of awns near maturity. It is known that brittleness in spikes and awns is a characteristic associated with wild forms and it was interesting to find this trait in a cultivated barley landrace. However, six-rowed barley weed races have been reported from Israel (Harlan 1965) and from the Himalaya (Witcombe 1978). Since both these forms have a brittle rachis the possibility cannot be excluded that the cultivated six-rowed landraces may have exchanged genes at some stage with weedy forms which normally exist at the borders of cultivated fields and periodically inject portions of their own gene-pool into the cultivated forms through introgressive hybridisation. Murphy et al. (1982) crossed the brittle *H. agriocrithon* with cultivated six-rowed types and found that some of the progenies had spikes as brittle as one of their parents whereas others were as tough as the spikes of the cultivated types.

The "non-heading" character in which the spike fails to emerge from the flag-leaf even at maturity is another interesting feature revealed in this study. Some plants among certain *H. distichum* landraces from the Yemen had spikes which remained enveloped in the flag-leaf up to maturity. This character was always associated with a low plant height when compared to the normally heading plants. However, from the plant breeder's point of view it may be a desirable character, since it not only protects the spike from fungal spores which may be present in the atmosphere but also restricts plant height which may prove useful to prevent lodging.

In conclusion it can be said that landrace variation within these two secondary centres of diversity could not be fully evaluated without growing the plant material in the field under conditions similar to those of its original habitat, as found in Southern Italy, although an initial impression of the extent of landrace variation can be obtained through the application of polyacrylamide gel electrophoresis of seed proteins (Damania et al. 1983). Data should also be recorded on a sufficiently large sample in order to draw correct statistical inference from qualitative as well as quantitative characters. The polymorphism for qualitative characters was not as much as one would expect in an area of diversity and hence predictions of variability based solely on a few qualitative traits and an inadequate number of plants or landraces should be avoided. The significant differences in performances for all characters between landraces observed show ample evidence of variation (in contrast to cultivars or varieties) because each plant behaves as an individual line.

Zusammenfassung

Genetische Variation in Landsorten von Weizen und Gerste aus Nepal und Jemen

Je sechzehn Landsorten von hexaploidem Weizen (*Triticum aestivum* L.) und sechszeiligen Gersten (*Hordeum vulgare* L.) aus Nepal und von tetraploidem Weizen (*T. turgidum* L.) und zweizeiligen Gersten (*H. distichum* L.) aus der arabischen Republik Jemen wurden auf Variationen hinsichtlich morphologischer Merkmale und der Eigenschaft „Tage zum Schossen" untersucht. Landsorten von vier verschiedenen Standorten in jedem der Länder, mit unterschiedlicher Höhe über dem Meeresspiegel, wurden ausgewählt, um das Verteilungsmuster dieser Variation zu bestimmen. Das Untersuchungsmaterial wurde an einer Versuchsstation, 110 km von Bari, Süd-Italien, angebaut. Daten quantitativer und qualitativer Merkmale wurden für 17 Weizen- und 18 Gerstenmerkmale an einer Stichprobe von je 50 Pflanzen jeder Art ermittelt.

Statistisch signifikante Unterschiede wurden für die Variation in den Gebieten des Jemen und den Flußtälern Nepals sowie zwischen den Landsorten derselben Gebiete und der Flußtäler festgestellt. Für quantitative Eigenschaften überschnitten sich die Verteilungen der Landsorten. Polymorphismen traten häufig auf, und in den meisten Fällen reichten zwei oder drei Merkmale aus, um die Variation zu beschreiben.

Daraus wird geschlossen, daß an einer genügend großen Anzahl von Pflanzen und Landsorten Messungen an quantitativen und qualitativen Eigenschaften durchgeführt werden müssen, um die Variationen in einem sekundären Mannigfaltigkeitszentrum zureichend sicher abschätzen zu können. Eine solche Untersuchung gibt dem Pflanzenzüchter nützliche Auskunft über wichtige Keimplasma-Quellen.

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