Diversity and Stability of Barley in Nepal

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ABSTRACT

Barley is an important food and cash crop grown by small farmers in the mountains of Nepal. Great diversity exists in Nepalese barley land races, and in the genotypes within land races. There is corresponding diversity in the environments and in the cropping systems in which the crop is grown. A review of the performance of barleys tested in the Nepal National Barley Improvement Program revealed that the best introduced entries performed better than local varieties in the lowland plains areas. In contrast, local landrace selections produced higher grain yields when tested in the hills and mountains. The use of local germplasm is likely to lead to most rapid improvement of barley in Nepal, in the future. Selection for stripe rust *(Puccinia striiformis)* resistance and utilization of population buffering in improved varieties is likely to improve their stability.

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INTRODUCTION

Traditional mountain farming systems are characterized by diversity. In the hills of Nepal for example, a farmer may grow three crops a year on a valley bottom under tropical conditions, and a single, cold tolerant crop under cool temperate conditions near the top of the same hillside. Similarly, great diversity exists in the variety and number of crops grown, in the landraces of a crop species, and in the genotypes within a landrace. Such biological diversity is a feature of adaptation across diverse agro-ecological environments, but perhaps more important is the stability conferred by such diversity, which helps to insure a consistent level of production from one year to the next. This stability reduces the risk of crop failure and famine for small, subsistence hillside farmers.

Single genotypes of a crop also differ in stability, and methods for evaluating and selecting stable genotypes in a crop improvement program have been developed by many workers, including Eberhart and Russell (1966) and Binswanger and Barah (1980). Crop improvement programs for such mountain areas must ensure that new, more productive crop varieties, and other new production technology can sustain the productive base for the hill farmers. New technology must be at least as stable as traditional systems.

This paper will briefly describe agricultural systems in Nepal with particular reference to barley. Past research to improve barley will be reviewed, and the stability of local and introduced genotypes of barley will be compared.

AGRICULTURAL SYSTEMS IN NEPAL. Agriculture in Nepal directly sustains 90% of its population of 18 million people. Subsistence agriculture predominates, and reported per capita income is among the lowest for any country in the world.

Nepal can be divided into three physiographic areas with agricultural importance. The terai or lowland which lies to the south, is an extension of the Indogangetic plain. Rapid increase in agricultural production in the terai, due to forest clearing for agriculture, increased irrigation and cropping intensity, has produced a modest food surplus in the area.

The majority of the population live in the other two regions namely the hills and mountains, where farming is carried out on steep, terraced hillsides and valley bottoms. Lower terraces, known as khet lands, generally have access to some irrigation and are planted in rice-based cropping systems. Rainfed terraces higher on the hillslopes, known as bari lands are often planted with maize-based cropping systems. Wheat is the major winter crop. Other hill crops include finger millet *(Eleucine coracana)*, barley, buckwheat and amaranthus which can be major staple food crops. Up to 150 different crops can be grown in a single village (Hawtin and Mateo, 1986) with a single farm often growing 30 or more, in a great variety of mixed, relayed and rotational systems (Riley *et al*, 1989).

Traditional hill farming systems (Figure 1) rely on livestock and forest areas to provide the compost necessary for sustained crop production. Relatively high levels of 20 to 40 tons per hectare per season of compost are applied under traditional systems. Due to a 2.6% annual population increase, traditional systems are coming under increasing stress. Forests are being cleared for agriculture, and less fodder is available for livestock. Reduced availability of compost has likely contributed to the reported steady decline in crop yields over the past decade (Thapa, 1989). Chemical fertilizer (mainly urea) is now used to a limited extent to supplement compost. However widescale replacement of organic with chemical fertilizer is considered unfeasible due to high transport costs in mountain areas.

BARLEY IN NEPAL. Barley is grown from the terai, up to an elevation of 4000 m in Nepal, but is a staple food crop mainly in the hills and mountains in the west of the country (Figure 2). Although reported barley production in the terai has declined in the past decade from 6000 to 3000 tons per year, production in the hills over the same period has increased from 9000 to 12,000 tons, and from 8000 to 10,000 tons in the mountains (Baniya, 1989). Barley is valued by farmers in these areas because it can be grown as a winter crop, maturing approximately one month earlier than wheat, thus allowing time to plant a summer crop such as maize, rice or buckwheat after barley (Figure 3). At the highest elevations, which experience an alpine climate, barley is grown as a spring planted crop, taking up to ten months to mature. Barley straw is preferred as a livestock feed, and its value is equal to that of the grain in areas where livestock feed is limiting (Riley *et al*, 1989). Barley grain is most commonly prepared as roti (bread) or champa (porridge), but is also important as a cash crop, traditionally traded for salt from Tibet.

Factors other than altitude can greatly affect the environment in which barley grows. Annual rainfall can vary from 5000 mm in a barley area near Lumle in Mid-Western Nepal, to just 500 mm in another major barley area, around Marpha, just 30 km away which is in a rainshadow area behind the Annapurna mountain range. South facing slopes are warmer and dryer than north facing slopes. Barley on south facing slopes at Jumla (2300 m) in Western Nepal matures approximately three weeks earlier than on north facing slopes (Whiteman, 1979a). Barley growing close to an inner terrace wall receives more radiated warmth and matures one to two weeks earlier than barley near the outer edge of the terrace. Year-to-year variation can be equally pronounced. At Jumla barley can vary in maturity by as much as a month depending on how quickly spring temperatures rise, while a late frost can occasionally cause severe damage to a crop in flower. Farmers report that epidemics of stripe rust (*Puccinia striiformis* f. sp. *hordei*) can occur during years with humid weather (Upreti *et al*, 1989).

High variation may exist in farmers' yields. In irrigated barley areas in western Nepal, reported yields range from 2.5 to 5 tons per ha (Riley *et al , 1989; Whiteman 1979b),* far higher than the national average reported for barley of 0.9 tons per ha (Baniya, 1989).

Nepal is a centre of diversity for barley (Witcombe 1975), and many studies (Takahashi *et al*, 1968; Witcombe and Gilani, 1979; and Konishi 1986) have described and classified this variation. We have observed that farmers in the mountains of both Eastern and North Western Nepal generally grow only one land race of hulless barley (uwa) and one of hulled barley (jau) which they regard as two separate crops. Hulless barley in Eastern Nepal is generally hooded, or has reduced awns and is very early, but less frost tolerant, and more susceptible to powdery mildew and covered smut than is the hulled land race from the same area. In Western Nepal, both hulless and covered forms are fully awned, but the covered forms are 2-3 weeks earlier to mature than the hulless land races. In highest elevation areas (4000 m) a long maturing blue or black seeded hulled land race with good winter hardiness, known as Pawe, is grown. In lower elevation areas in mid-hills and terai, hulled land races are exclusively grown.

Genetic variation within land races has been found to increase with altitude (Konishi, 1986) with greatest within land race variation from areas where barley is most important. Such variation likely confers an increased stability through population buffering.

BARLEY IMPROVEMENT IN NEPAL. In 1988, the International Development Research Centre (IDRC) provided support for a newly created Hill Crops Improvement Program under the Ministry of Agriculture, His Majesty's Goverment, Nepal. However, barley improvement in Nepal started as early as 1971. Annual barley reports, systematically collected by Mr. K. M. Singh, have enabled the progress of this work to be reviewed (Lohani 1973 a, b, c; 1974, 1975, Anonymous 1978; Singhand Mathema 1976, Malla and Singh 1978, Regmi *et al* 1988).

METHODOLOGY

The review compared the performance of land race selections with introductions and the local check.

Records for grain yield existed for six sites in low hills, mid hills and mountains over years for four genotypes tested in Initial Evaluation Trial (IET), Preliminary Variety Trial (PVT), and Coordinated Variety Trial (CVT). These were compared in a stability analysis as generated by the MSTAT microcomputer software program. NB 1003-11, and NB 1003-37 are single plant selections from the same land race from Solukhumbu (Eastern Nepal), Bonus is a stripe rust-resistant two-row introduction from Sweden, while the local check is considered as a genotype even though it may have varied from year to year. At each location, grain yields of the genotypes were regressed over the trial means across years which were considered the environment index. Grain yields of other genotypes, tested for only 1-3 years were plotted directly, but were not subjected to stability analysis. A genotype is said to be stable if it has a high mean yield, a low slope or b value less than one (Eberhart and Russell, 1966). The coefficient of determination (R^2) indicates the proportion of genotype variation which is accounted for by linear regression. Least significant differences (P .05) at each location were computed using genotype means from each trial, as grain yields from each replication were not included in the reports. Therefore LSD values may be higher than had individual observations been used. For the same reason, it was not possible to compute site variances, so variances among environments assumed to be equal in the combined analyses.

RESULTS

Initial rapid progress was reported from testing introduced barley varieties under terai and low hill environments. Table 1 presents the performance of the best introduced barley varieties which possess improved grain yield, and stripe rust resistance as compared to the local check. Five introductions had been released by 1975, but did not prove popular in the terai where barley acreage was declining. Bonus, which possesses resistance to Race 57, the prevalent race of barley stripe rust (C. B. Karki, personal communication), is the only variety presently recommended for the hills of Nepal.

A program was also started aimed at the improvement of local land races for disease and lodging resistance and grain yield. Several hundred single plant selections were evaluated first at Khunaltar (1350 m) in the low hills, then at other mid hill and mountain environments. Table 2 presents the evaluation of a number of lines developed from selections within a single land race. The derived lines vary significantly for grain yield, and several have produced slightly higher yields than Bonus. Variation also exists for stripe rust resistance, plant height and heading days. Two selections from this landrace: NB 1003-11 and NB 1003-37 are among the most promising entries, but have not yet been released because they are not resistant to stripe rust.

Stability anaylses carried out over years at six locations in the hills and mountains indicate varying genotype response across locations. Figure 4a compares genotype response at Khumaltar. Bonus performed well at this location, with a slightly higher mean grain yield and lower b value than local selections. Bonus was also equal in maturity to the local check, and fully resistant to stripe rust. Some introductions (WI 2231 x Magnif 102, 14th IBON 96, and PRO 40A x DI 70), and a derivative from a local by exotic cross (NB 4402 x LSB 2-22) have performed very well when tested for two years at Khumaltar. NB 1054 is a very early hulless landrace which yielded less than the local check.

At Kabre (Figure 4b) which is the major testing site for the Eastern Nepal hills, genotype response is very different from that at Khumaltar. Mean yield of Bonus is less than half that of local selections. All other introductions tested for 1 to 2 years have also performed very poorly. At Kabre, most introductions suffer from sterility or embryo abortion, possibly related to the low soil pH, while locals generally fill seed well. The local by exotic cross was marginally lower yielding than the local check, while the very early hulless barley yielded slightly more in the year tested.

At Pakhribas (Figure 4c) and at Lumle (Figure 4d) where rainfall is higher, the long maturing introduction CI 7117-9 x Deiralla has produced high grain yield. However this variety is too long in maturity to fit into a maize-barley rotation. At both locations mean yield of Bonus were similar to those of the local selections. At Kabre, Lumle and Pakhribas, the three mid-hill locations, Bonus produced a b value less than 1 while that of NB 1003-37 was greater than 1. At Lumle, the 1987/88 barley crop was unusually free of stripe rust (Sthapit, 1988). This could explain the improved grain yield in local selections over Bonus during this season, in contrast to previous seasons when the rust resistance in Bonus may have conferred a yield advantage over locals.

At higher elevation sites, at Jumla (2300 m) (Figure 4e) and Kakani (2030 m) (Figure 4f), NB 1003-37 has again produced slightly higher mean grain yields, while the maturity of Bonus is markedly later than that of the local genotypes. At Jumla, early maturity is important to enable rice to be planted after barley. Thus, the introduced entries are too late to be accepted by farmers in the Jumla area.

A combined analysis over 44 environments from six locations (Figure 5) reveals that NB 1003-37 produced significantly higher mean grain yields than either Bonus or the local check. Maturity of Bonus was three days later than local check and six days later than NB 1003-11. In locations where early maturity is important, NB 1003-11 may have an advantage over the local. Bonus, the recommended variety, has been accepted only in low and mid hill areas where its longer maturity is not so pronounced and where stripe rust can be a constraint.

DISCUSSION

Barley lines developed from single plant selections from adapted local populations produced higher grain yields than either the local check or the recommended variety, Bonus, in mid hill and mountain locations in Nepal. The higher b value produced at several sites by NB 1003-37 in stability analyses across years, may be caused by a loss of population buffering in this genotype derived from a local land race selection, while the more consistent yield observed in Bonus when tested over years may be due to its stripe rust resistance. In other regions of the world where large local land race diversity exists, most rapid improvement may be achieved through utilization of local material. Single head progenies derived from barley land races collected along the Fertile Crescent in Syria and Jordan have been identified with higher grain yields, improved agronomic traits and greater disease resistance compared with the original populations (Ceccarelli *et al*, 1987).

It is suggested that greater resources be devoted to the identification and utilization of local barley selections in Nepal, possessing improved grain and straw yields, disease resistance, early maturity and lodging resistance. Careful recombination of a number of improved selections may be necessary to ensure that the improved variety is as stable across years as the land race which it replaces.

The different responses of genotypes at the different sites suggest that more decentralized initial testing of material needs to be carried out at mid hill and mountain locations.

Since 1980, the Nepal barley program has devoted most of its limited resources to testing introduced material provided by International Agricultural Research Centres, and directly from other countries. Although emphasis on such testing should be reduced, testing of pre-selected introductions can be useful. For example, two Canadian hulless barley lines, *SB 85216* and *SB 85219* when tested in an oberservation nursery at Khumaltar in *1988-89* were free of stripe rust, and produced 77 and 47% higher yields than the adjacent Bonus check. In the longer term, derivatives from hybridization between local and introduced parents can be expected to result in even greater improvement.

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Table 1:

Evaluation of Introduced Barley Varieties at Khumaltar (low hills) and Parwanipur (terai) from 1972 to 1974

Variety	Origin	Mean Yield (kg/ha)	Maturity Days Parwanipur	Stripe Rust	
HBL 56	India	2557	114	10	MS
CI 10448	Colombia	2268	114	5	S
Galt	USA	2276	114	10	S
Bonus	Sweden	2288	112	–	R
Ketch	Australia	2006	106	20	S
Local Check	Nepal	1713	116	70	S
LSD (.05)		250			

Table 2:

Variation in Local Barley Lines Originating from a Single Land Race Tested in IET at Khumaltar 1975-1976

Entry	Grain Yield (kg/ha)	Heading Days	Plant Height (cm)	Stripe Rust
NB 1003-3	1382	105	85	HS
NB 1003-7	1664	105	79	MR
NB 1003-8	1931	106	84	S
NB 1003-11	1945	104	84	MS
NB 1003-47	1432	102	81	HS
NB 1003-53	1751	101	82	MS
NB 1003-59	1675	102	72	MS
NB 1003-64	1396	104	77	HS
NB 1003-68	1996	104	88	MR
NB 1003-85	1795	103	76	MS
NB 1003-86	1666	104	97	S
NB 1003-88	2182	102	77	MR
NB 1003-91	1882	105	92	MS
NB 1003-108	1605	103	71	MS
NB 1003-109	1764	104	77	MR
Bonus Check	1733	104	63	R

LSD (.05)	506
CV	22.4%

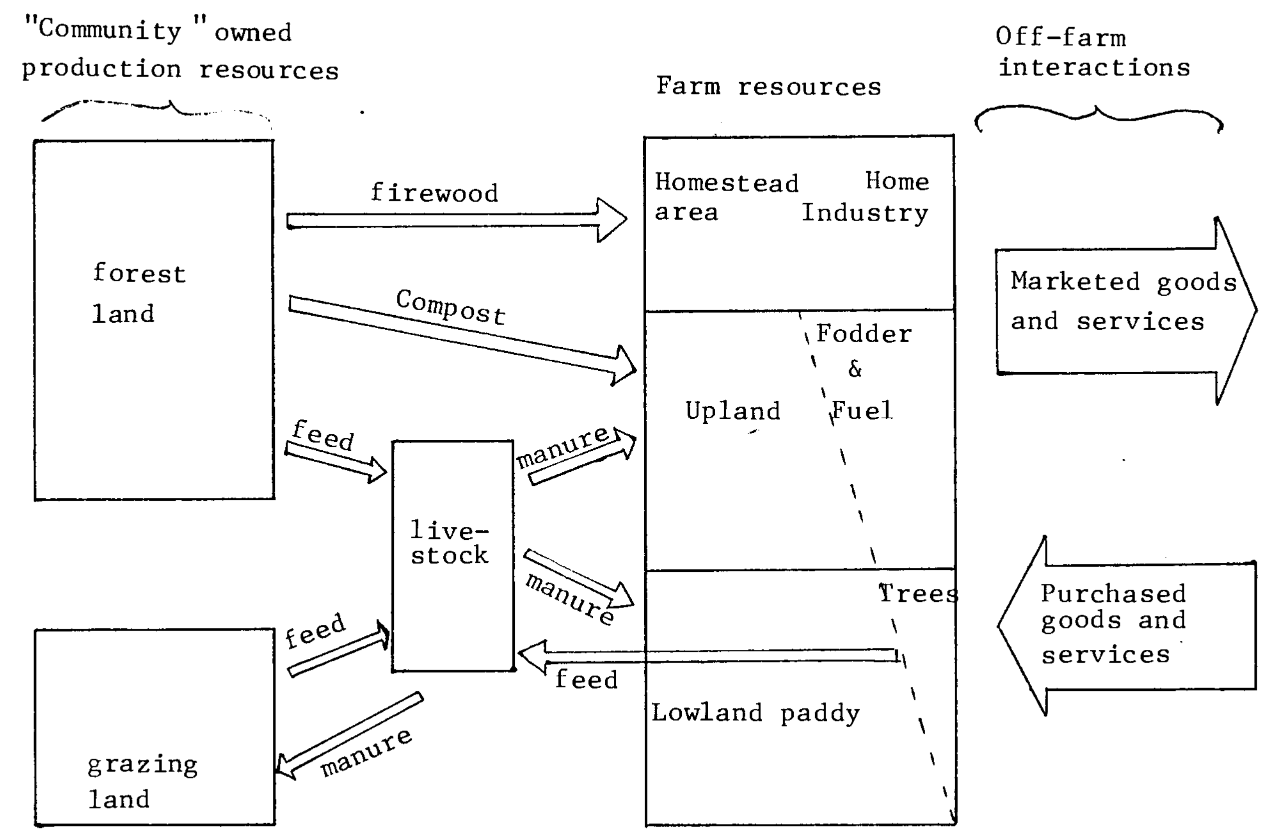


Figure 1   Conceptual model of the production system of a Nepalese hill farm.

From Harwood, R. 1979. Small Farm Development

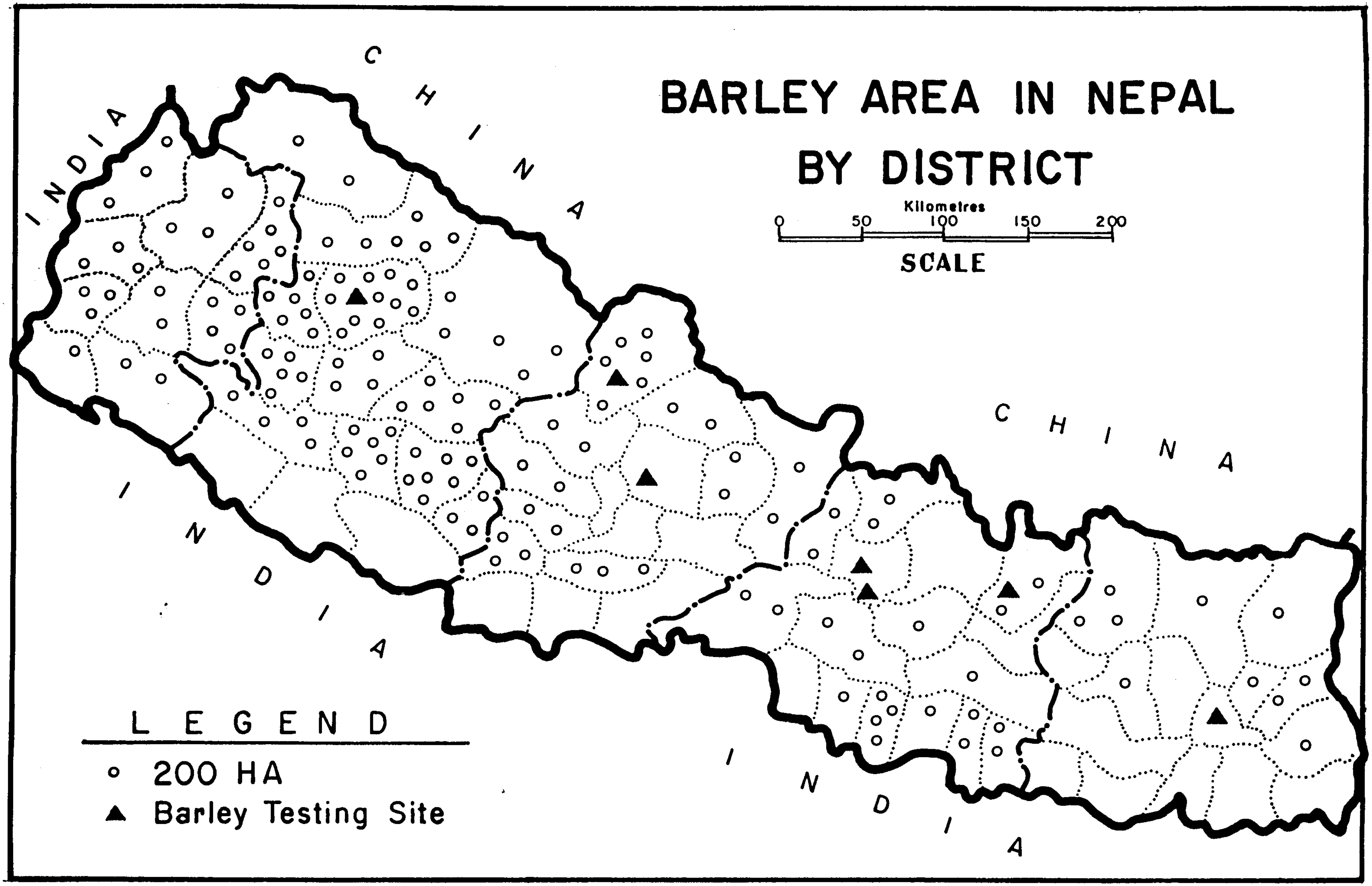


Figure 2 Barley area in Nepal, by district

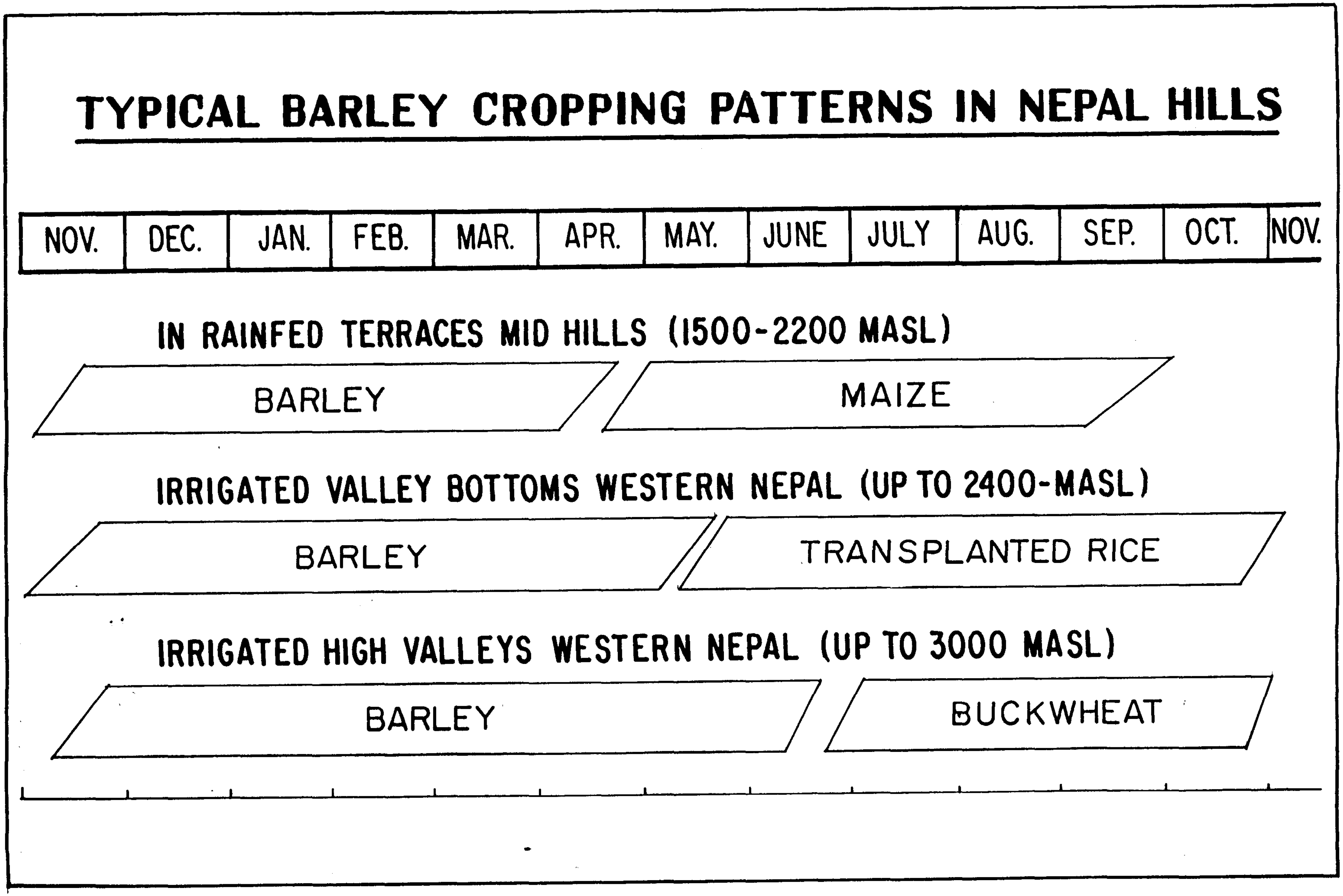


Figure 3 Some cropping patterns with barley in Nepal hills and mountains

KHUMALTAR 1975-88

ELEV. 1350 M.A.S.L.
RAIN FALL 1300 MM
SOIL PH 5.5 - 6.5

VARIETY	MAT. DAYS	STRIPE RUST	YIELD MEAN	YIELD b	YIELD R^2
LOCAL CHECK	166	S	2224	0.83	.79
BONUS	164	R	2395	0.92	.69
NB 1003-37	165	MS	2190	1.18	.81
NB 1003-11	163	MS	2235	1.13	.78
LSD (.05)			232		
NB 4402 X LS8 2-22	174	—	3624	2 Environments	
NB 1054	141	HS	1878	,,	,,
WI 2231/MAGNIF.-102	152	—	3127	,,	,,
PRO 40 AX DI 70	157	—	2883	,,	,,
CI 7117-9 X DEIR ALLA -106	174	—	1488	,,	,,
14 TH IBON 96	159	O	3683	one	,,

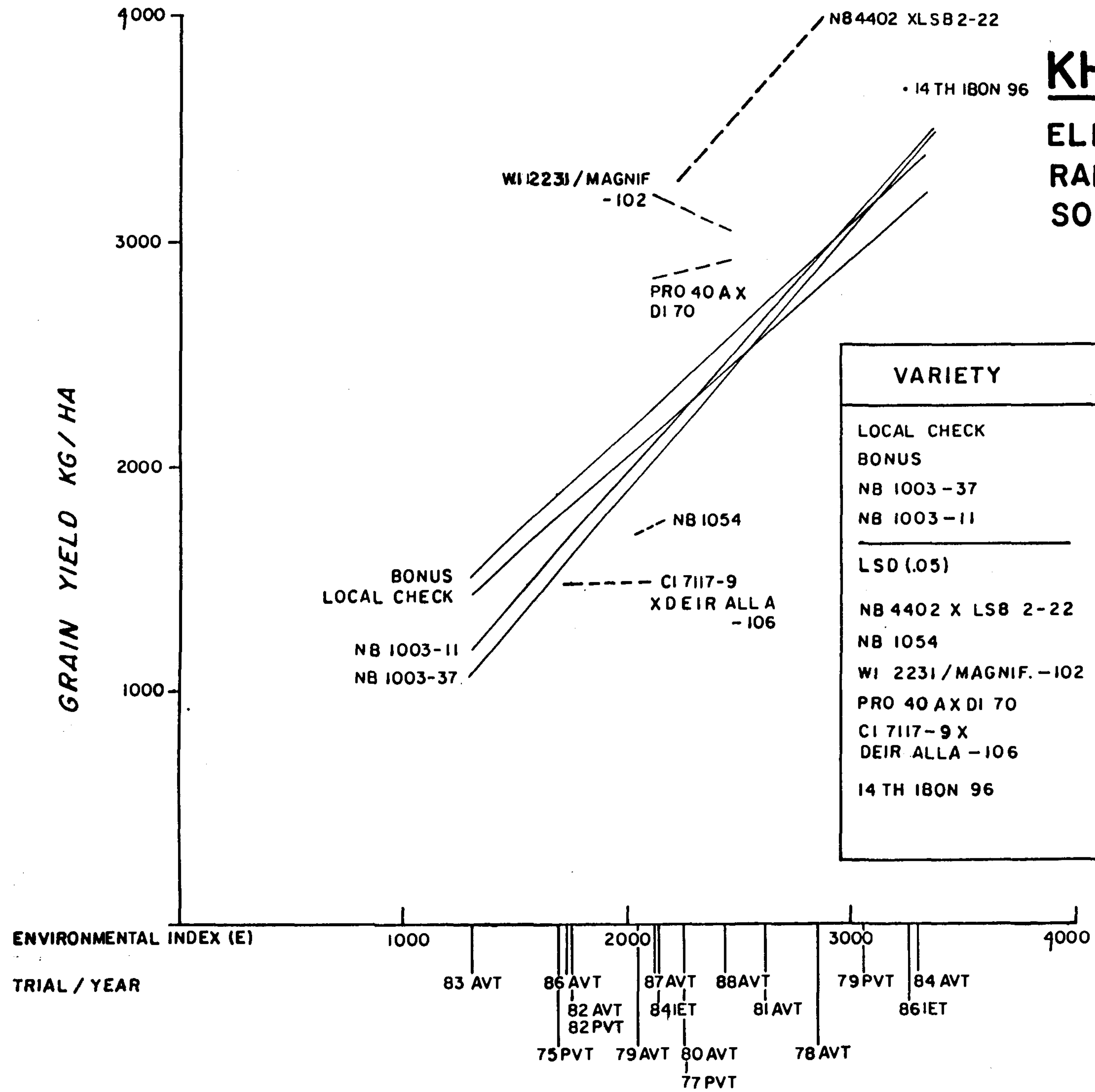
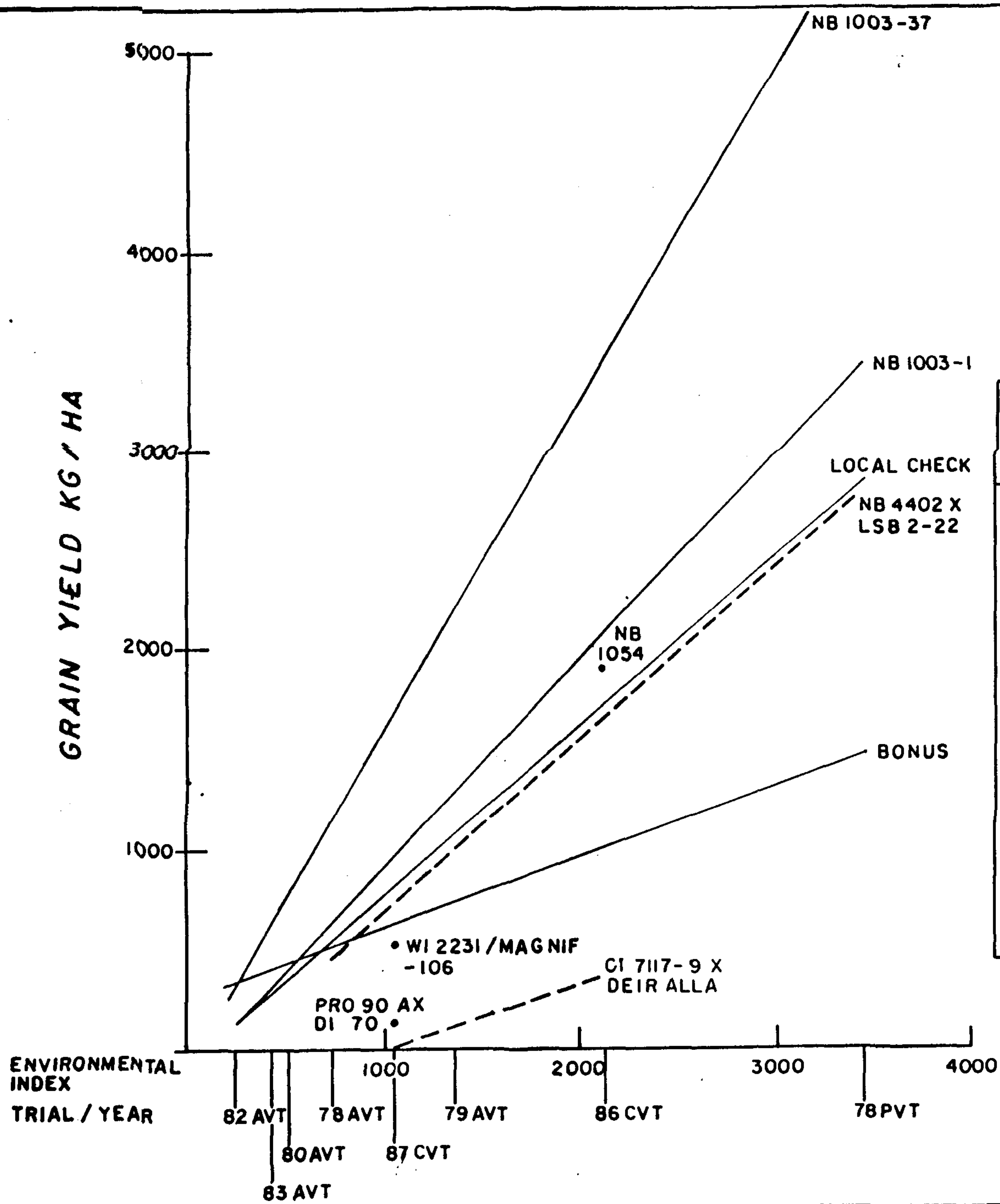


Figure 4a Stability of barley genotypes at Khumaltar

KABRE 1978-1988

ELEV. 1740 M.A.S.L.
RAIN FALL 1900 MM
SOIL PH 4.7-5

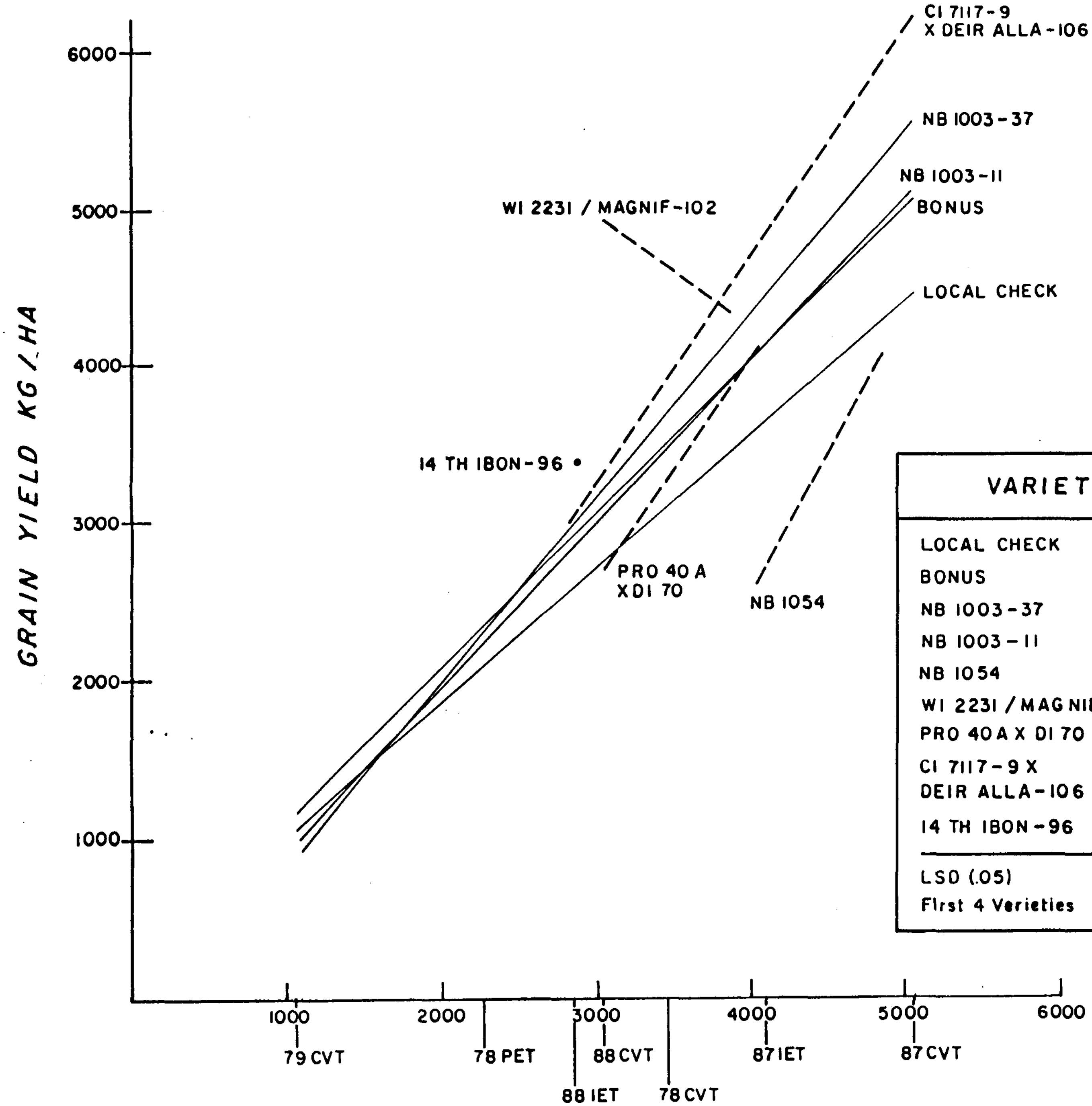


VARIETY	MAT. DAYS	STRIPE RUST (1988)	YIELD MEAN	YIELD b	YIELD R^2
LOCAL CHECK	152	100S	984	0.84	.97
BONUS	161	20MR	680	0.36	.25
NB 1003-37	159	100S	1988	1.60	.93
NB 1003-11	159	100S	1584	1.35	.88
NB 4402 X LSB 2-22	162	MS	1541	2 Environments	
NB 1054	152	100S	1794	1 "	"
WI 2231/MAGNIF	150	60S	565	" "	"
PRO 90 A X DI 70	155	80S	142	" "	"
CL 7117-9 X DEIR ALLA	152	60S	335	2 "	"
14 TH IBON-96	158	5R	000	1 "	"
LSD (.05) (First 4 Verieties)			791		

Figure 4b Stability of barley genotypes at Kabre

PAKHRIB 1978-88

ELEV. 1760 M.A.S.L.
RAIN FALL 2250 MM

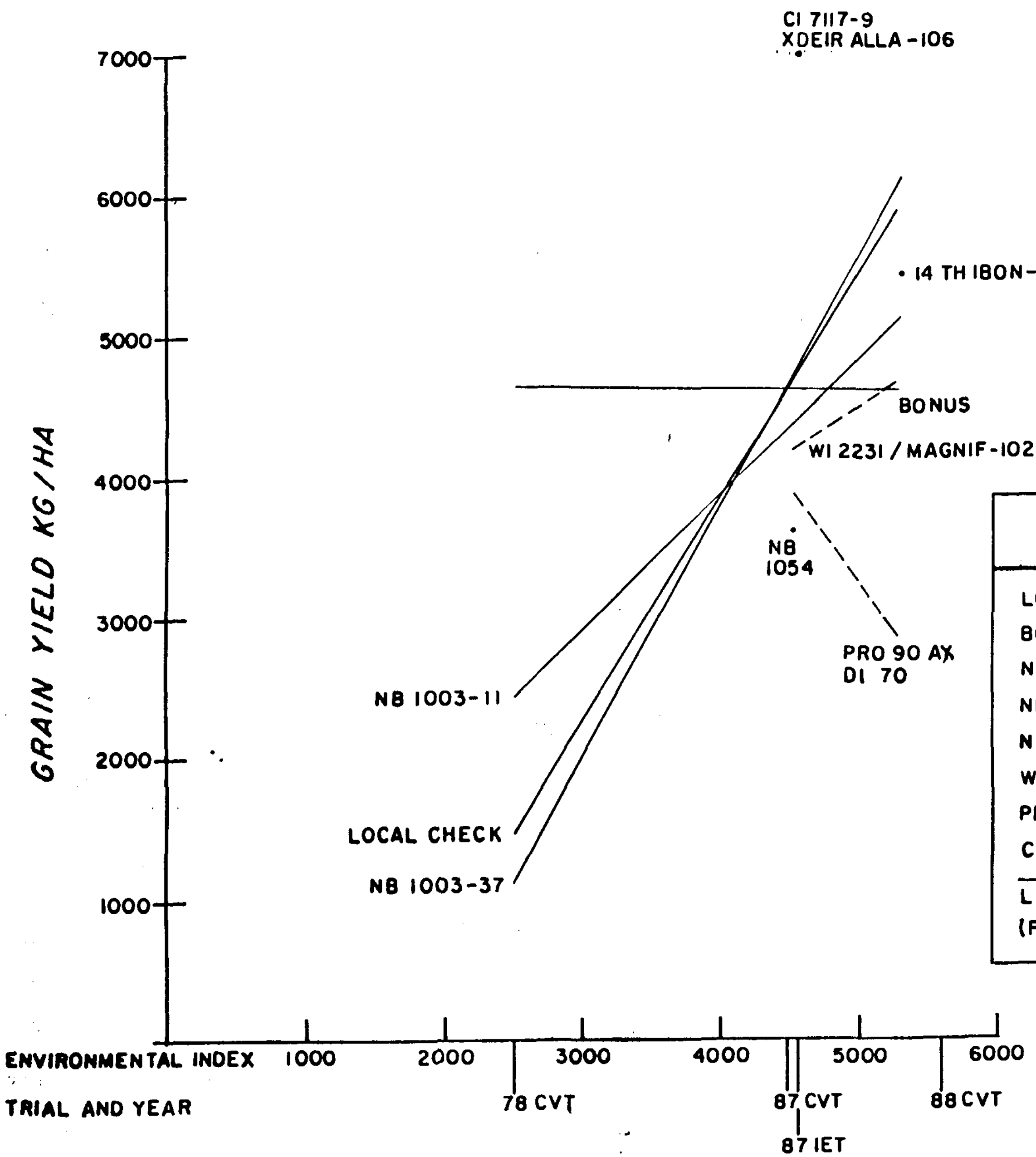


VARIETY	MAT. DAYS		YIELD MEAN	b	R^2
LOCAL CHECK	172		2740	0.85	.80
BONUS	174		3105	0.98	.88
NB 1003-37	165		3215	1.17	.94
NB 1003-11	163		3016	1.02	.97
NB 1054	158		3336	2 Environments	
WI 2231 / MAGNIF-102	170		4636	"	"
PRO 40 A X DI 70	172		3416	"	"
CI 7117-9 X DEIR ALLA-106	179		4585	"	"
14 TH IBON-96	170		3560	1 Environment	
LSD (.05) First 4 Varieties			NS		

Figure 4c Stability of barley genotypes at Pakribas

LUMLE 1978-1988

ELEV. 1670 M.A.S.L.
RAIN FALL 5100 MM

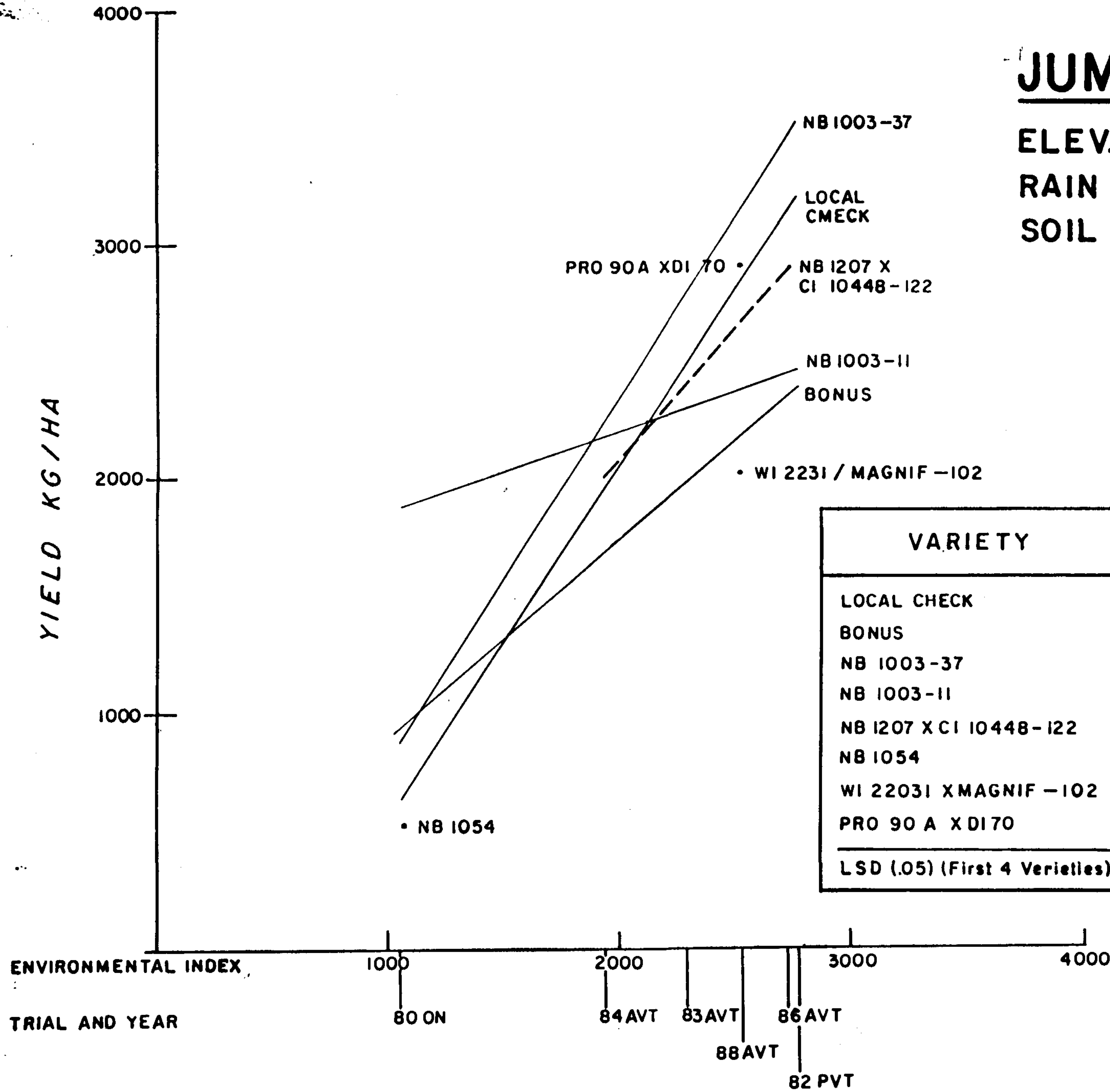


VARIETY	MAT. DAYS		YIELD MEAN	b	R^2
LOCAL CHECK	167		4248	1.64	.99
BONUS	163		4629	0.02	.99
NB 1003-37	163		4306	1.81	.99
NB 1003-11	164		4133	0.98	.96
NB 1054	159		3607	1 Environment	
WI 2231 / MAGNIF - 102	167		4428	2 Environments	
PRO 90 AXDI 70	164		3994	1 "	"
CI 7117-9X DEIR ALLA-106	185		7039	1 "	"
LSD (.05) (First 4 Verieties)			NS		

Figure 4d Stability of barley genotypes at Lumle

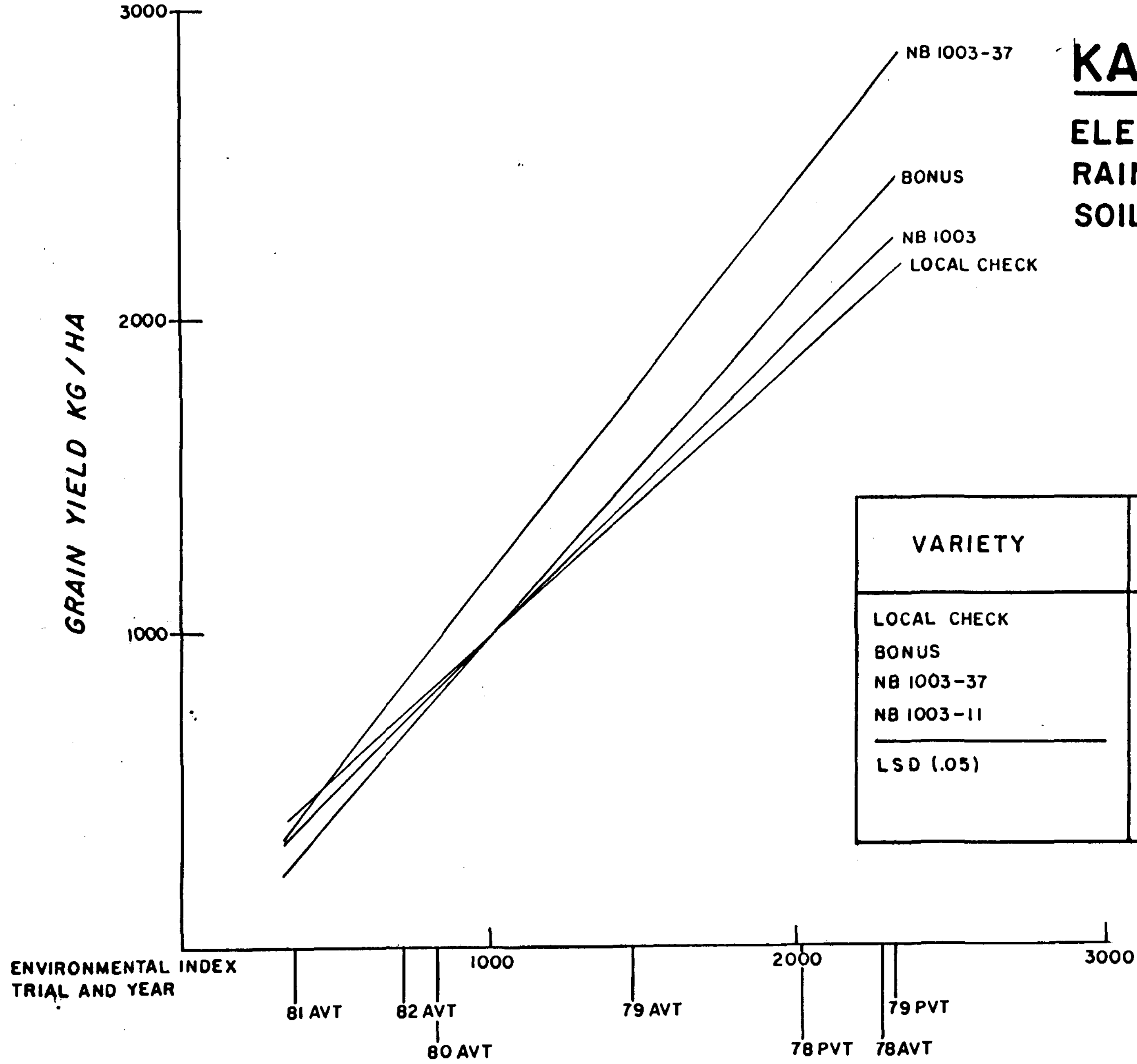
JUMLA 1980-1986

ELEV. 2390 M.A.S.L.
RAIN FALL 970 MM
SOIL PH 7-8



VARIETY	MAT		YIELD		
	DAYS		MEAN	b	R^2
LOCAL CHECK	178		2372	1.49	.89
BONUS	188		1921	0.84	.56
NB 1003-37	182		2423	1.44	.76
NB 1003-11	182		2271	0.32	.35
NB 1207 X CI 10448-122	188		2530	3 Environments	
NB 1054	179		560	1 Environment	
WI 22031 X MAGNIF -102	183		2052	"	"
PRO 90 A X DI 70	188		2912	"	"
LSD (.05) (First 4 Verieties)			NS		

Figure 4e Stability of barley genotypes at Jumla

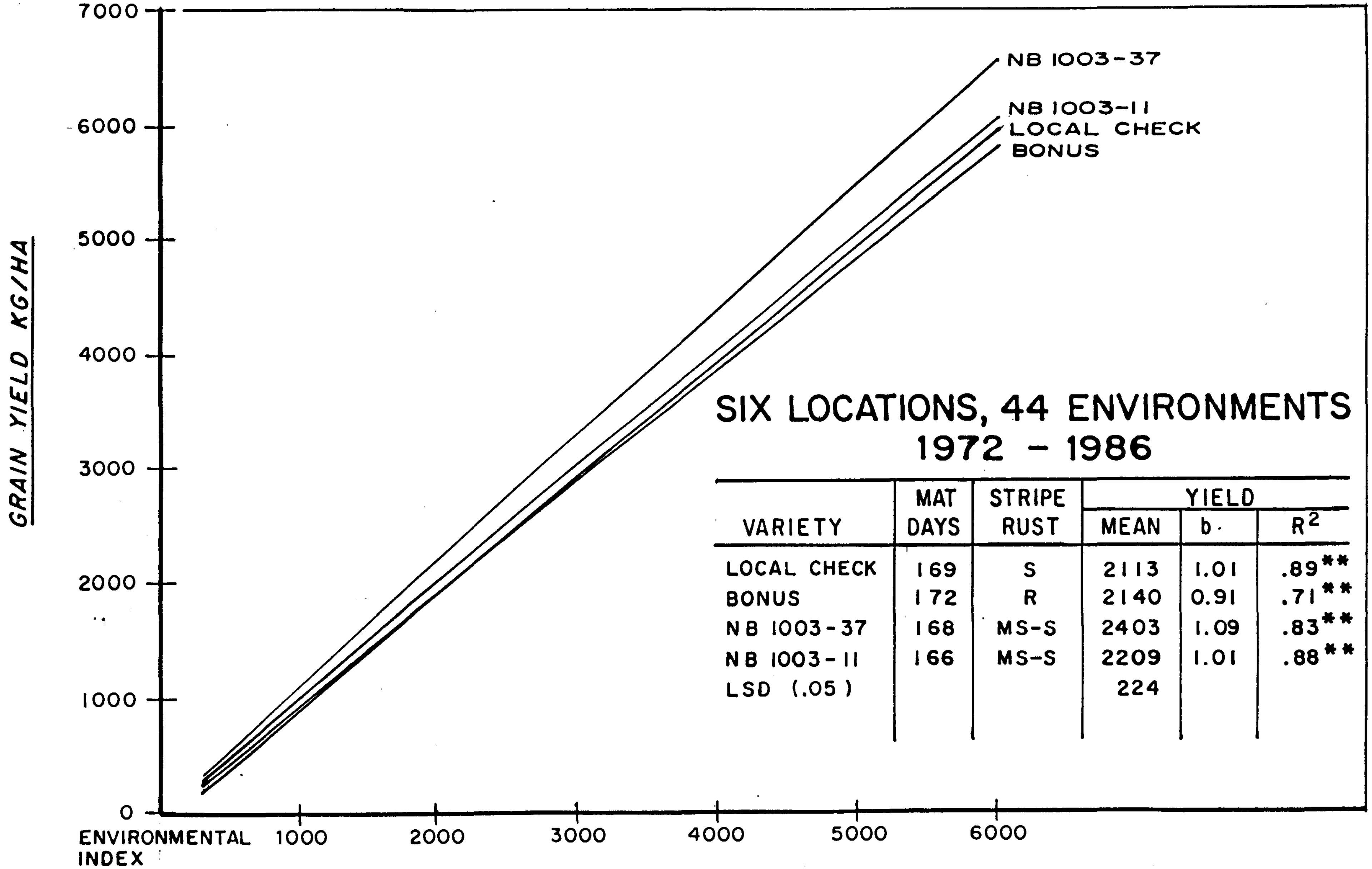


KAKANI 1978-1982

ELEV. 2030 M.A.S.L.
RAIN FALL 2400 MM
SOIL PH 4-5

VARIETY	MAT DAYS	STRIPE RUST (1978)		YIELD MEAN	YIELD b	YIELD R^2
LOCAL CHECK	179	S		1363	0.88	.84
BONUS	183	—		1477	1.12	.96
NB 1003-37	175	S		1722	1.28	.93
NB 1003-11	172	HS		1381	0.97	.71
LSD (.05)				NS		

Figure 4f Stability of barley genotypes at Kakani



SIX LOCATIONS, 44 ENVIRONMENTS 1972 - 1986

VARIETY	MAT DAYS	STRIPE RUST	YIELD		
			MEAN	b.	R^2
LOCAL CHECK	169	S	2113	1.01	.89**
BONUS	172	R	2140	0.91	.71**
NB 1003-37	168	MS-S	2403	1.09	.83**
NB 1003-11	166	MS-S	2209	1.01	.88**
LSD (.05)			224		

Figure: 5 Stability of Grain Yield in Four Genotypes of Barley Across Six Locations in Nepal.