16 ICRISAT Presentation: Yield Variability in Sorghum and Millet

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The objective of this summary is limited. Only the main findings in the four ICRISAT papers are highlighted (Workshop Papers 17, 30, 31, and 35). Additionally, we report the results of collaborative research between the All India Coordinated Sorghum Improvement Project and ICRISAT on yield variability in improved and local sorghum genotypes. We do not attempt to make a comprehensive assessment of past ICRISAT or national program research on yield variability in sorghum and millet in the semiarid tropics.

PEARL MILLET YIELD VARIABILITY IN SOUTH ASIA

The International Pearl Millet Adaptation Trial (IPMAT), which has both hybrids and varieties as entries, has been grown multilocationally in India and Pakistan. The data for grain yield over five years were analyzed in a number of ways to examine the stability of the entries.

A regression analysis shows that the hybrids were generally higher yielding than the varieties but were less stable (Table 16.1).

Table 16.1--Millet yield in the International Millet Pearl Trials, 1979-84

Year[a]	Mean Grain Yield		Adjusted Mean Square Error[b]		Mean Slope	
	Hybrids	Varieties	Hybrids	Varieties	Hybrids	Varieties
			(kilograms per hectare)			
1979	2,300	2,237	163,533	61,222	1.02	0.98
1980	2,096	1,974	62,791	33,085	1.01	0.99
1981	2,236	2,262	117,970	33,189	1.04	0.97
1983	2,068	2,109	157,951	50,968	0.97	1.02
1984	2,028	1,773	62,228	40,166	1.07	0.96

[a] Trial not held in 1982.

[b] Adjusted following the method of Eberhart and Russell (1966).

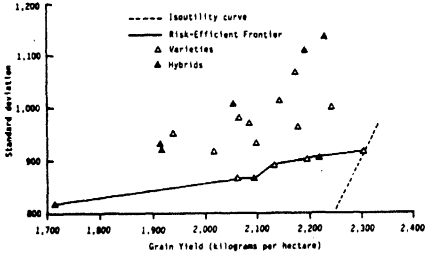
The most important source of genotype x environment interaction in the regression analysis was due to the deviation from the regressions (S^2d values) rather than to variation between the regressions. The varieties were superior to the hybrids in this respect, having lower than average S^2d values.

Although regression analyses are helpful in testing selection procedure, it is an inescapable conclusion that to obtain an overall picture of how stability and mean yield are to be traded off, other analyses are required. A mean-variance analysis (Binswanger and Barah 1980) shows that the highest yielding genotype was always preferred among the risk efficient entries (Figure 16.1). Similarly, a first-degree stochastic efficiency analysis (Anderson et al. 1977) indicates that the hybrids, despite their inferior stability in a regression analysis, were more risk efficient than the varieties.

The analyses demonstrated that the breeders' procedure of selecting among the highest yielding entries across environments is satisfactory. Such an emphasis will usually select entries that perform well in poor environments and that would be chosen by risk-averse farmers.

One variety from an advanced cycle composite, ICMV 81111, combined both high yield and stability. A variety both high yielding and stable is a desirable alternative to a hybrid, particularly in view of the simpler seed multiplication procedures and the reduced susceptibility of varieties to ergot and smut. Moreover, as discussed in Walker (Workshop Paper 30), individual hybrids in India have proven to be most unstable in yield from year to year due to their rapid increase in susceptibility to downy mildew. There is every reason to expect that the more genetically diverse variety would become susceptible in a less rapid and spectacular manner.

Figure 16.1. Millet yield in the international pearl millet trial, 1979 to 1984[a]



[a]Trial not held in 1982.

SORGHUM YIELD VARIABILITY IN INDIA

A mean-variance analysis was used to measure stability (intertemporal) and adaptability (over space) components of variance with multilocational, multiyear, yield data for sorghum in India (Barah et al. 1981). Adaptability and stability were highly correlated. Only the stability component is relevant for farmers in their adoption decision. Measures of farmers' risk aversion were used to rank genotypes according to preferences that take account of both yield and stability. Since yield differences were large and risk aversion moderate, preference-based ranking did not differ markedly from yield-based rankings.

These results are comforting to sorghum breeders in India and perhaps elsewhere as well. Rankings based on yield and risk preference were very closely related, entirely agreeing with the results obtained for pearl millet. However, further analyses of sorghum are required to see whether this is also the case with less fertilizer or plant protection. Furthermore, adaptability and stability are highly related, supporting a multilocational breeding and testing approach in the pursuit of both low risk and high yields.

PEARL MILLET YIELD VARIABILITY IN NIGER

To examine yield variation and variability with traditional and improved technologies in West Africa's Sahel, a series of tests were managed by farmers in western Niger in 1982 and 1983 in four villages, with a total sample size of about 100 farmers. Each farmer had one plot of three treatments: T1 -- local millet without chemical fertilizer; T2 -- local millet with 30 units of nitrogen (urea) and 18 units of phosphate, and T3 -- improved millet with the same fertilizer dose as T2.

Fertilizer with both local and improved cultivars (T2 and T3) significantly increased mean yield; however, planting an improved genotype (T3) had no significant effect on yield (Table 16.2). Based on mean data for the village by year combinations, the mean standard deviation increased from T1 to T2 to T3. Treatment 3, with a lower mean yield and a higher standard deviation, was stochastically inefficient compared to T2. Compared to T1, the increased yield of T2 amply compensated for additional risk. Fertilizer increased yield of the local variety fourfold, for a unit change in standard deviation. All but the most extremely risk-averse farmers would prefer T2 to T1.

These results support the emerging story on millet production in West Africa that, up to the present, improved genotypes have not consistently yielded appreciably more than local cultivars and that moderate doses of fertilizer, particularly phosphate, can be profitably applied with little or no increase in risk.

SORGHUM AND PEARL MILLET YIELD VARIABILITY IN INDIA

Hybrids released in the late 1960s account for about 40 percent of sorghum and 60 percent of pearl millet planted area in India.

Table 16.2--Millet grain yields in Western Niger by treatment, four villages

Treatment	Village 1 1982	Village 1 1983	Village 2 1983	Village 3 1982	Village 3 1983	Village 4 1983	Mean
Treatment 1[a]							
Mean yield (kg/he)	168	277	355	195	173	298	244
Standard deviation	115	143	134	96	133	176	133
Treatment 2[b]							
Mean yield (kg/he)	277	428	572	413	404	412	418
Standard deviation	125	170	171	195	163	238	177
Treatment 3[c]							
Mean yield (kg/he)	330	543	501	356	417	341	415
Standard deviation	165	197	242	140	204	199	191

[a] Local millet without chemical fertilizer.
[b] Local millet with 30 units of nitrogen (urea) and 18 units of phosphate.
[c] Improved millet with same fertilizer as treatment 2.

Usually they are sown in rainfed fields, where small doses of fertilizers are applied. To what extent have improved hybrid technologies been responsible for increased variability in sorghum and pearl millet production?

We analyzed data on grain production in 48 and 40 major producing districts in India for sorghum and pearl millet, respectively. We used a statistical decomposition method developed by Hazell (1982). Two 12-year periods (1956/57 to 1967/68 and 1968/69 to 1970/80), corresponding to before and after the release of the sorghum and pearl millet hybrids, were selected to represent the eras before and after the green revolution.

Instability in sorghum and pearl millet production increased in terms of both total variance and coefficient of variation (cv) from the first 12-year period to the second. For sorghum, the cv of linearly detrended production increased from 8 percent to 16 percent and the F ratio of the variances was 40.2. For pearl millet the cv increased from 11 percent to 34 percent, and the F ratio was 16.6.

Increased production variance stemmed overwhelmingly from increased production covariances among major producing regions for both sorghum and pearl millet. More than 90 percent of the increase in production variance for both crops was attributed to changes in interdistrict production covariances. What was surprising was the strength of yield covariances in conditioning those changes (Table 16.3).

Why have sorghum and pearl millet yields become increasingly covariate over time and across districts? For sorghum, changes in yield covariance between the first and second period for each district pair were positively and significantly linked to the level of hybrid adoption, changes in rainfall covariance, and extent of

Table 16.3--Sources of increase in the variance of sorghum and pearl millet production in India, 1956/57 to 1967/68 and 1968/69 to 1979/80.

Source of Change	Sorghum	Pearl Millet
	(percent)	
Within-district production variances	5	8
Interdistrict production covariances		
Yield	84	52
Other	11	38
Total	95	92

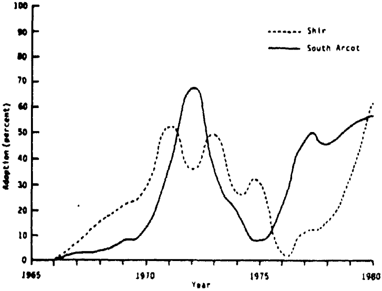
irrigated area. For pearl millet, the level of hybrid diffusion and irrigated area was positively and significantly associated with changes in yield covariance.

In other words, the production and genetic environments are becoming more similar over time, and it is this growing similarity that is mainly responsible for increasing production variability at the national level for these crops. Increased yield covariances are to be expected, because hybrids have a narrow genetic background. For example, the bulk of hybrid sorghum area in India is planted to four hybrids, CSH1, CSH5, CSH6, and CSH9. The latter three have the same male parent, CS3541. Most of the commercially available pearl millet hybrids in the period under study were produced from the same seed parent.

The first-generation pearl millet hybrids, HB1, HB3, and HB4, became extremely susceptible to downy mildew, resulting in significant economic losses in the early 1970s after inoculum had built up in farmers' fields. In response to those losses, farmers in several major producing regions reverted to local types. Hybrid adoption rates plummeted. In the middle and late 1970s, hybrid adoption again picked up as farmers accepted the second-generation hybrids, which at that time were much less susceptible to downy mildew. Similar, atypical adoption patterns in producing regions as far distant as Tamil Nadu and Maharashtra bear ample testimony to the problem of increasing production covariances caused by the release of supersusceptible cultivars (Figure 16.2).

Judicious varietal release strategy and sound trade and storage policies can cost-effectively offset most, if not all, the instability costs arising from increasing yield covariance. However, in the absence of such efficient policies, investing in crop research to maintain and enhance resistance to yield reducers and to broaden genetic variation will have stability benefits at the national level over and above returns to increased production. In any case, more covariate regional yields and the resulting increased production variability were a small price to pay for productivity growth attributed to the sorghum and pearl millet hybrids.

Figure 16.2. Adoption of pearl millet hybrids in Shir (Maharashtra) and South Arcot (Tamil Nadu), 1966-80



HOUSEHOLD INCOME VARIABILITY IN INDIA'S SEMIARID TROPICS

Much of the investment in breeding, pathology, entomology, and physiology at the centers of the Consultative Group on International Agricultural Research is aimed at developing higher yielding and more stable yielding varietal technologies, which increase output and improve equity and nutrition. Could these technologies also enhance the welfare of farm households by reducing variability in household income and consumption? The answer to that question hinges on the nexus between variability in crop yield and fluctuations in household income. We examined that relationship for resource-poor farm households in India's semiarid tropics (SAT).

We relied on household panel data from three ICRISAT study villages representative of three soil, climate, and cropping regions of India's SAT. Income data from the "continuous" cultivator households (those that remained in the panel from 1975/76 to 1983/84) were analyzed. For these 81 households, information on fluctuations in income was summarized by the cv of net household income. A cv was estimated for each household based on nine years of income data deflated by a village-specific consumer price index.

Risk benefits were estimated under a scenario of perfect yield stabilization for the common crops in each village. Although the mean household income cvs for the producers of these crops varied from 33 percent to 47 percent, the risk benefits from perfect stabilization of commodity yield ranged from modest to negligible (Table 16.4).

Ironically, risk benefits were largest in irrigated paddy, the crop with the lowest yield cv. Removing variability from the yield

Table 16.4--Risk benefits from simulated perfect crop yield stabilization

Crop and Village	Number of Farms	Coefficient of Variation of Household Income	Mean Reduction in Household Income Variability	Mean Proportional Risk Premium
			(percent)	
Irrigated paddy in Aurepalle	9	46.6	15.4	2.9
Castor in Aurepalle	23	44.8	4.4	1.3
Local sorghum in Aurepalle	21	34.4	1.0	0.2
Local sorghum in Shirapur	21	34.0	-3.9	-0.2
Desi cotton in Kanzara	26	33.0	0.8	0.2
Hybrid sorghum in Kanzara	18	34.4	0.6	0.3

of only one crop was simply not an effective way to reduce income variability for the vast majority of farm households in the study villages. For the rainfed crop with the largest risk benefits, perfect yield stabilization would only reduce household income variability by about 5 percent. Such a modest change would be worth less than 2 percent of mean household income. Stabilizing the yield of one crop taps at most 25 percent of the potential risk benefits from perfect crop income stabilization.

Perfect crop yield stabilization does not buy much in the way of risk benefits, because most farm households rely on multiple income sources, particularly earnings in the local labor market. Diversified cropping patterns are also the norm in dryland agriculture in India's SAT; hence farm households are not overly dependent on revenue from a single dominant crop. Furthermore, area vulnerability in dryland agriculture severely erodes the effectiveness of policies or technologies that work through yield to reduce variability in household income and consumption. Mean area variability exceeded mean yield variability for each of the common crops.

These results support the notion that little if any economic value should be attached to the supposed risk reducing attributes of improved varietal technologies for resource-poor households in India's SAT. Such technologies should be evaluated with regard to their effect on mean yield or output levels, equity, and nutrition. Risk benefits derived from supposed reductions in variability in household income and consumption are likely to be too small in practice to be measurable. More generally, focusing on crop yield stability to diminish variability in household income and consumption for small farm households in India's SAT is a misguided means to an

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end. Likewise, we should not be overly concerned that the improved varietal technologies adopted by farmers may have accentuated yield variability. Increased yield variability is unlikely to manifest itself in markedly heightened household income variability.

Risk benefits from technologies that dampen yield variability may be more substantial in Africa's SAT because resource-poor households may rely more heavily on crop income than similar households in India's SAT. Also, those households are most likely to have fewer effective private and institutional means to compensate for shortfalls in current income. More research on household risk benefits is needed in Africa's SAT.

CONCLUSION

What emerges from all these papers is a common theme: yield stability is not an overriding or even an important objective for research on sorghum and millet improvement. Mean yield and profitability should remain front and center on the agenda of objectives. Economic gains from research by breeders, pathologists, entomologists, and physiologists will be manifested in the form of higher m[illegible] yields.

In those regions where sorghum and millet hybrids have been adopted, maintenance research and a sound varietal release and testing policy are fundamental to protect farmers against the dynamic risk of increasing disease and pest susceptibility. That is one source of yield variability that sorghum and millet scientists clearly can do something about.