Yield stability of some groundnut accessions in northern Ghana

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SUMMARY

Yield stability of 12 groundnut accessions mainly developed by ICRISAT and two check varieties were tested in multilocational trials covering four locations in northern Ghana during the 1994, 1996, and 1997 cropping seasons. The trial for each year was arranged in a randomized complete block design with four replications and analyzed following a factorial design of 14 genotypes × 3 years × 4 locations. Significant differences were obtained ($\alpha \leq 0.05$) for the main effects of genotypes, years, and locations as well as the first and second order interactions; 33 per cent of the variability in kernel yield was accounted for by genotype × year × location interaction whilst 26 per cent by genotype × location interaction. Proportions of the total variance due to yield differences between genotypes and genotype × year interaction were negligible. Yield stability as indicated by the regression coefficient, among-location variance, and the value of mean yield suggested that JL 24, an early-maturing variety, was the most adapted to marginal environments whereas the check variety, F-mix, maintained its superiority in adapting to favourable environments.

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RÉSUMÉ

MARFO, K. O. & PADI, F. K.: *La stabilité de rendement de quelques accessions d' arachide au nord du Ghana.* La stabilité de rendement de 12 accessions d'arachide principalement développées par ICRISAT et 2 variétés de vérification étaient mises à l'essai dans les essais de multi-emplacement recouvrant 4 emplacements au nord du Ghana pendant la culture des saisons de 1994, 1996 et 1997. L'essai de chaque année était arrangé en modéle de bloc complet choisi au hasard avec 4 replications et analysé suivant un modèle factoriel de 14 génotypes × 3 ans × 4 emplacements. Des différences considérables étaient obtenues (μ ³ 0.05) pour les effets majeurs des génotypes, des années et des emplacements ainsi que les interactions d'ordre premier et second; 33 pour cent de la variabilité du rendement d'amande était le résultat de génotype × année × intéraction d'emplacement alors que 26 pour cent était le résultat de génotype × l'intéraction d'emplacement. Les proportions de la variance totale dû aux différences de rendement entre les génotypes et les génotypes × l'interaction d'année étaient négligeables. La stabilité de rendement indiquée par le coefficient de régression, la variance parmi les emplacements et la valeur du rendement moyen suggéraient que JL 24, une variété de la maturation tôt, était la ligne la plus adaptée aux environnements marginaux alors que la variété de vérification, F-mix, gardait sa superiorité dans l'adaptation aux environnements favorables.

Introduction

Yield of crop cultivars respond differently as climatic conditions change. Consequently, relative rankings of varieties for their yield performance can shift significantly between years and locations. These shifts are conditioned by traits that allow a cultivar to counteract limiting factors and use favourable environmental factors. As environmental factors vary in time and space, selecting materials suitable for commercial production requires establishing a network of comparative yield trials in which prospective varieties are tested against standard cultivars in different agro-ecological regions for several years. These trials show an insight into the performance of genotypes in an array of environmental and agricultural production conditions.

In estimating yield stability of crop genotypes, two important indices specific to each genotype are the genotype's mean yield across enivronments and the regression coefficient determined by regressing the mean yield of a variety over the mean yield of all varieties in each location (Finlay & Wilkinson, 1963). A generalized relationship of variety response to environment is determined by plotting a variety's regression coefficient against mean yield. The position of the variety indicates its response to (or interaction with) the environment. Besides the mean value of yield and the regression coefficient, Eberhart & Russel (1966) noted that a stable variety should have a minimum deviation from regression. Lin, Binns & Lefkovitch (1986), in a review of stability analysis, noted that a cultivar may be regarded stable if (i) its among-environment variance is small, (ii) its response to environment is parallel to the mean response of all genotypes in the trial, and (iii) the residual mean square from a regression model on the environmental index is small. The ultimate aim of any of the above approaches is to efficiently exploit a positive variety × environment interaction and counteract any negative interaction in the target production zones.

This study reports a 3-year evaluation of some groundnut accessions in northern Ghana aimed at selecting suitable cultivars for commercial production.

Materials and methods

Experimental procedures

Twelve groundnut accessions received from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were tested against two check varieties at four locations in northern Ghana in the 1994, 1996, and 1997 cropping seasons. The locations included Nyankpala, Damongo, and Wa in the Guinea savanna zone, and Manga in the Sudan savanna zone. For each year, each plot measured 4 m long with 5-row plants spaced at 50 cm between rows and 20 cm within rows. Two seeds were planted per hill. The experiments were arranged in a randomized complete block design with four replications. Data were collected on the two inner rows.

Choice of varieties

The varieties, belonging to three different maturity groups, were selected from among the best performing lines in earlier field evaluations including the following:

1. RLRS 11, Chinese, ICG (FDRS) - 20, JL 24, ICGS 66, and TS-32-1 belonging to the early-maturing group with mean maturity periods ranging between 85 and 95 days.
2. ICG (FDRS)-32, ICGV 87160, NCACC 17090 and ICGV 86558 belonging to the medium-maturity group with mean maturity periods ranging between 100 and 108 days.
3. F-mix, CS 49, CS 6, and ICGV-SM 87723 belonging to the late-maturity group with mean maturity periods over 115 days.

Statistical procedures

A factorial treatment arrangement of 14 genotypes × 3 years × 4 locations was used in the analysis following a randomized complete block design. Table 1 presents the form of ANOVA. Treatment means were considered to be significantly different at $\alpha \leq 0.05$ and were separated by the least significant difference (LSD)

TABLE 1

Form of the Analysis of Variance for Obtaining Variance Components of Genotype, Locations and Years

Source of variation	*Degrees of freedom*	*Mean squares*	*F-test*
Replications	r-1		
Years (Y)	y-1		
Locations (L)	l-1		
Y × L	(y-1) (l-1)		
Genotypes (G)	g-1	M_1	
G × Y	(g-1) (y-1)	M_2	
G × L	(g-1) (l-1)	M_3	
G × Y × L	(g-1) (y-1) (l-1)	M_4	
Error	(g-1) (r-1) ly	M_5	

test.

The values of the components of variance were calculated from the linear functions of the mean squares as follows:

Plot error variance (σ^2_e) = M_5

Variance for genotype × location × years (σ^2_{gly}) = $(M_4 - M_5)/r$

Variance for genotype × location (σ^2_{gl}) = $(M_3 - M_4)/ry$

Variance for genotype × years (σ^2_{gy}) = $(M_2 - M_4)/rl$

Variance for genotypes (σ^2_g) = $(M_1 - M_2 - M_3 + M_4)/rly$

where *r, l, y* and *g* are the numbers of replications, locations, years, and genotypes, respectively.

M_1 = mean square for genotypes
M_2 = mean square for genotype × year
M_3 = mean square for genotype × location
M_4 = mean square for genotype × year × location
M_5 = error mean square

In estimating phenotypic stability, kernel yields were regressed on the environmental index, determined from the mean yield of all genotypes at a location minus the mean yield of all genotypes at all locations. The interpretation of stability was according to the suggestion of Finlay & Wilkinson (1963).

Results and discussion

The difference in kernel yield between years could partly be explained with the rainfall amounts during the reproductive periods (Table 6). In 1994 and 1997, adequate rainfall was received throughout the growth period whereas in 1996, rain was poorly distributed with the last 20 days receiving no rains at Manga and Wa. Thus, the least favourable year for groundnut kernel yield was 1996. For the locations, the most important cause for yield differences is the poor soils at Manga (in the Sudan savanna ecology) compared with the other locations.

Table 2 presents the analysis of variance for the 14 groundnut genotypes tested at four locations in each of 3 years. The analysis also shows the variances resulting from the variability of the years, locations, and their interactions.

The differences between varieties were significant. The F-test and the variance due to varieties were low, indicating that yield differences between varieties were small. Across locations and years, the highest kernel yield was produced by F-mix, followed by JL 24 and the least by ICGV-SM 87723 (Table 3). These small differences in kernel yield are expected, since the varieties were selected from the best-performing lines in different maturity groups. Significant differences were observed between years, locations, and the interactions between genotypes and locations as well as genotypes and years. The most favourable year, as shown by the kernel yields, was 1994 followed by 1997 and then 1996 (Table 3). The most favourable location for kernel yield was Damongo, followed by Nyankpala, Wa and then Manga. In spite of the large differences between years for kernel yield, differences in genotype

TABLE 2

Analysis of Variance for 14 Groundnut Varieties Tested over 3 Years at Four Locations in Northern Ghana

Source of variation	*Degrees of freedom*	*Mean squares*	*F-test*	*Components of variance* σ^2	*%*
Replications	3	0.083			
Years (Y)	2	13.031	388.449*		
Locations (L)	3	14.527	432.989*		
Y × L	6	1.265	37.708*		
Genotypes (G)	13	0.322	9.604*	-0.001	0.00
G × Y	26	0.094	2.811*	-0.003	0.00
G × L	39	0.395	11.762*	0.021	25.61
G × Y × L	78	0.143	4.263*	0.027	32.93
Error	501	0.034		0.034	41.46
Total	671			0.082[1]	100.00

CV = 19.32 %

[1] Negative values omitted in calculating the total

*Significant at $\alpha \leq 0.05$

TABLE 3

Interaction Genotype × Year for Kernel Yield (t/ha) for 14 Genotypes Tested over a 3-Year Period in Northern Ghana

Genotype	*1994*	*1996*	*1997*	*Mean*
RLRS 11	1.109	0.662	0.927	0.899
Chinese	1.073	0.555	0.981	0.869
ICG (FDRS) 20	1.151	0.665	0.969	0.928
JL 24	1.221	0.748	1.118	1.029
ICGS 66	1.222	0.722	0.892	0.945
TS-32-1	1.178	0.589	1.055	0.941
ICG (FDRS)-32	1.116	0.718	1.066	0.967
ICGV 87160	1.228	0.708	0.981	0.972
NCACC 17090	1.227	0.748	0.884	0.953
ICGV 86558	1.169	0.632	0.968	0.923
F-mix	1.409	0.897	1.212	1.173
CS 49	1.058	0.627	1.020	0.901
CS 6	1.126	0.634	1.100	0.953
ICGV SM 87723	0.827	0.634	0.987	0.816
Mean	1.151	0.681	1.012	0.948

LSD at $P = 0.05$ for genotypes: 0.074; for years: 0.034 for genotypes × years: 0.128

response to years were small as indicated by the size of the F-test and the variance. On the other hand, a significant proportion of the variance (25.61 per cent) was due to genotype × location interaction, a consequence of a high yield variability per location. Except for ICGV-SM 87723 which recorded its highest mean yield in 1997, all the other varieties had their highest mean yields in 1994, followed by 1997 and least in 1996 (Table 3). Genotype × location interaction could be separated by maturity groups (Table 5). All the late-maturing genotypes had their highest yields at Damongo, followed by Nyankpala, Wa and least at Manga. In the medium-maturity group, except for ICG (FDRS)-32, the highest mean yields were at Damongo, followed by Wa, Nyankpala and least at Manga. For the early-maturity group, all genotypes (except RLRS 11) had their highest mean yields at Nyankpala, followed by Damongo, Wa and least at Manga. Only RLRS 11 showed no significant difference between the mean yields at Wa and Manga, and produced the second highest yield at Manga (Table 4).

The magnitude of interaction of genotype × year usually exceeds that of interaction of genotype × location (Allard & Bradshaw, 1964). This, however, depends on the area covered by the trial and how climatically diverse the area is. Borojevic (1990), in an analysis of genotype × environment interaction effects on yield of wheat, found that in a 3-year period, interaction of genotype × location was greater than interaction of genotype × year, and in another 3-year period, this pattern was reversed.

The interaction of the second order, genotype × year × location was also significant. Although the F-test for the genotype × location interaction was greater than that of the interaction of genotype × year × location, 32.93 per cent of the variability in yield was accounted for by the latter with only 25.61 per cent by interaction of genotype × location. The high variability among years and locations was due to the environmental diversity

TABLE 4

Interaction Genotype × Location for Kernel Yield (t/ha) for 14 Genotypes Tested at Four Locations in Northern Ghana

Genotype	*Damongo*	*Manga*	*Nyankpala*	*Wa*	*Variance*
RLRS 11	1.037	0.768	1.063	0.728	0.031
Chinese	0.969	0.547	1.077	0.885	0.052
ICG (FDRS) 20	1.047	0.581	1.367	0.719	0.124
JL 24	1.015	0.799	1.387	0.915	0.065
ICGS 66	1.005	0.680	1.272	0.825	0.065
TS-3 2-1	0.957	0.537	1.312	0.956	0.100
ICG (FDRS)-32	1.179	0.664	1.058	0.966	0.048
ICGV 87160	1.200	0.543	0.961	1.186	0.094
NCACC 17090	1.300	0.352	0.899	1.261	0.193
ICGV 86558	1.277	0.454	0.935	1.027	0.119
F-mix	1.586	0.567	1.480	1.058	0.215
CS 49	1.417	0.359	0.996	0.834	0.211
CS 6	1.456	0.324	1.088	0.946	0.222
ICGV SM 87723	1.049	0.314	1.021	0.880	0.118
Mean	1.178	0.535	1.137	0.942	0.118

LSD at $P = 0.05$ for location: 0.040 for genotypes × location: 0.148

TABLE 5

Ranking of Locations for Mean Kernel Yield of 14 Genotypes for the 3-Year Trial

	Early-maturing group						*Medium-maturing group*				*Late-maturing group*			
Location	*RLRS 11*	*Chinese*	*ICG (FDRS)20*	*JL 24*	*ICGS 66*	*TS-32-1*	*ICG (FDRS)32*	*ICGV 87160*	*NCACC 17090*	*ICGV 86558*	*F-mix*	*CS 49*	*CS 6*	*ICGV-SM 87723*
Damongo	2	2	2	2	2	2	1	1	1	1	1	1	1	1
Manga	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Nyankpala	1	1	1	1	1	1	2	3	3	3	2	2	2	2
Wa	4	3	3	3	3	3	3	2	2	2	3	3	3	3

1 = highest yield 4 = lowest yield

TABLE 6

Total Rainfall Received during the Reproductive Periods at the Various Locations for Each Year

Reproductive	*Nyankpala*			*Damongo*			*Manga*			*Wa*		
duration (days)	*1994*	*1996*	*1997*	*1994*	*1996*	*1997*	*1994*	*1996*	*1997*	*1994*	*1996*	*1997**
1-10	64.0	24.3	81.9	25.1	29.2	11.4	20.3	86.9	75.7	47.1	47.8	
11-20	8.6	3.9	59.4	6.9	44.2	99.2	147.6	80.9	59.0	24.7	79.0	
21-30	9.4	73.7	51.4	2.7	65.3	65.5	58.3	123.6	145.8	26.2	107.7	
31-40	93.2	62.4	82.0	120.7	121.6	7.1	121.4	60.1	13.3	75.9	51.1	
41-50	117.8	38.5	109.5	64.5	47.7	51.9	76.9	90.6	39.6	76.3	40.7	
51-60	62.8	57.6	61.2	39.3	87.3	13.5	129.5	61.8	32.5	73.9	58.3	
61-70	57.4	72.6	40.2	198.9	32.1	30.2	43.3	14.2	9.7	88.0	8.5	
71-80	52.1	24.0	10.4	50.3	13.1	10.2	61.3	0.0	2.5	24.0	0.0	
81-90	45.7	0.0	0.0	52.1	0.0	0.1	10.2	0.0	0.0	62.8	0.0	

*Not available

of the different locations, resulting in a high interaction between years and locations which in turn affected the genotype × year × location interaction. This signifies that it would be difficult to develop a variety for general cultivation across the various ecological zones of northern Ghana. Hence, cultivars with narrow or specific adaptability would be more suitable for specific ecologies.

Fig. 1, 2 and 3 show the relationship between the regression coefficients (b) and the mean yields for each year. In general, genotypes differed widely in their relative rankings between years. Broadly, three groups can be identified:

1. Those varieties with *b* values consistently greater than 1; including F-mix, CS 49, CS 6, and NCACC 17090.
2. Those varieties with *b* values consistently less than 1; including JL 24, RLRS 11, ICGS 66 and Chinese.
3. Varieties that differed in their *b* values between years; including ICGV-SM 87723, ICGV 86558, ICG (FDRS)-32, ICG (FDRS)-20, TS-32-1, and ICGV 87160.

The relationship between the regression coefficient and mean kernel yield, averaged over all locations and years (Fig. 4), shows a similar pattern for genotypes. All varieties in Category 1, except NCACC 17090, belong to the late-maturity group while those in Category 2 belong to the early-maturity group. It generally follows that the late-maturing varieties are more adapted to favourable environments and the early-maturing types to marginal environments.

In deciding on variety adaptability to specific environments, the values of mean yield of prospective cultivars need to be compared with those of the commercial cultivars besides the *b*

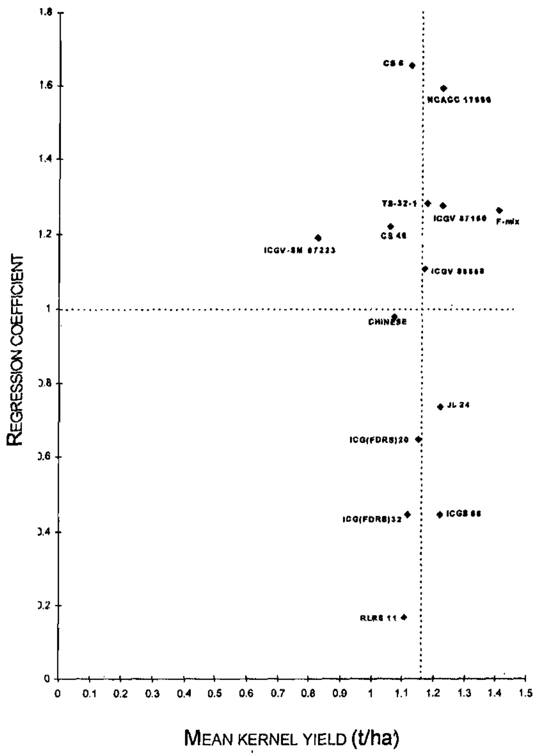

Fig. 1. The relationship of regression coefficient and mean kernel yield for 14 groundnut genotypes grown in 1994.

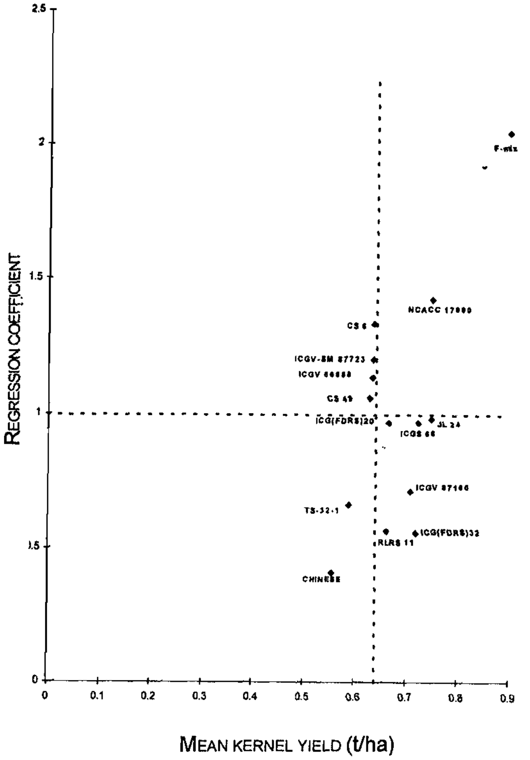

Fig. 2. The relationship of regression coefficient and mean kernel yield for 14 groundnut genotypes grown in 1996.

values (Borojevic, 1990). In this evaluation, the yield of all varieties exceeded that of Chinese, the check variety for the early- and medium-maturity groups, whereas the yield of F-mix, the check variety of the late-maturity group, was the highest for each of the 3 years. The trial mean for each year is, therefore, chosen as the threshold yield for accepting a variety's mean yield. The results clearly indicate that for the favourable environments (Damongo and Nyankpala), F-mix maintained its superiority over all available genotypes. In these ecologies, the high rainfall and relative humidity favour a high incidence of leaf spot diseases. The resistance of F-mix to these biotic stresses (NAES, 1991) could be an important trait adapting it to these environments. For marginal environments in which climate changes greatly from season to season, the ideal variety would be one which is unresponsive to the climatic changes in expressing its genetic yield potential. Such a variety would have a small among-environment variance (Lin *et al.,* 1986), a regression coefficient less than one (Finlay & Wilkinson, 1963), and a high mean yield. Judging by these parameters, JL 24 is most adapted to marginal environments. In the least favourable year (1996), the regression coefficient of this variety was close to unity (Fig. 2), indicating broad adaptability to all marginal environments.

No significant correlations between regression coefficients and variety mean yields were found for any of the years. This is corroborated by earlier studies of Matsuo (1975) who observed that genes

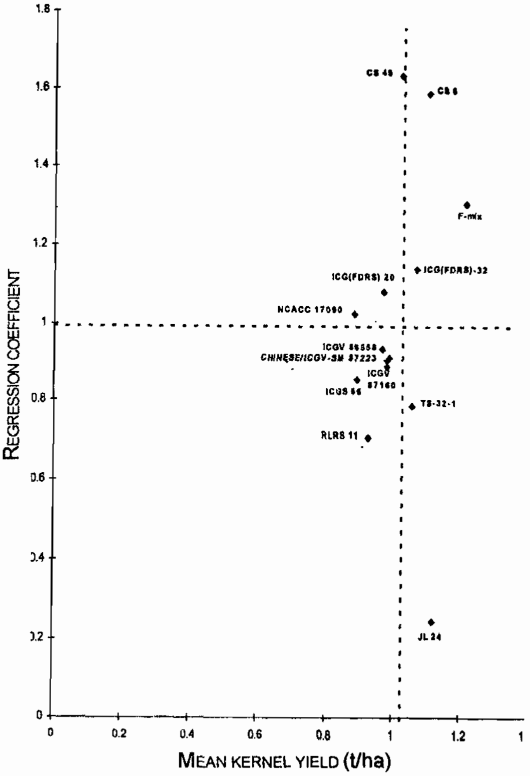

Fig. 3. The relationship of regression coefficient and mean kernel yield for 14 groundnut genotypes grown in 1997.

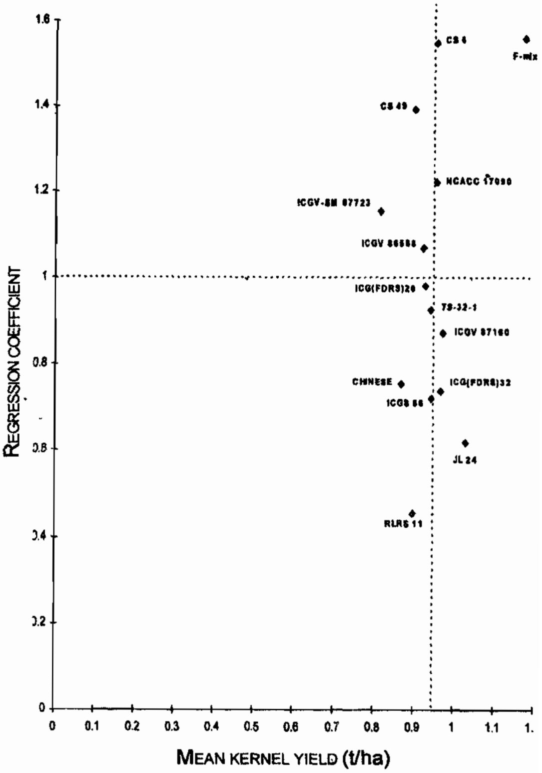

Fig. 4. The relationship of regression coefficient and mean kernel yield for 14 groundnut genotypes grown in 3 years at 4 locations.

controlling productivity are different from those controlling yield stability, indicating the possibility of developing varieties high in stability and yield.

Conclusion

The analysis of variance of kernel yield for the 14 groundnut genotypes indicated that yield variation was predominantly due to interaction between genotypes and environmental factors – 58.54 per cent (genotype × location and genotype × year × location), than by the random and undefined environmental factors (41.46 per cent). The variations due to differences in the genetic yield potential of the varieties and the interaction between genotype and years were negligible. The different locations and years were unequal in their effects on the genotypes. Because of these small differences between varieties and the high location effect on them, large changes in the relative ranking of genotype performance between years are common. Thus, it becomes difficult choosing truly superior-yielding varieties for general cultivation. In spite of the large differences in climatic conditions between the years (reflected in yield differences between years), yield performance of JL 24 and F-mix were stable across the 3 years as indicated by the regression - mean yield plots, proving their suitability to marginal and favourable environments, respectively.

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