Pearl Millet. II. Vigor Evaluation and Selection for Improved Seedling Vigor[1]

R.K. Maiti[*], *P.S. Raju*[**], *F.R. Bidinger*[**]

ABSTRACT

Evaluation of seedling vigor of a number of pearl millet cultivars has been assessed using the visual scoring method and direct measurement under field conditions. Visual evaluation of seedling size, using a relative scale based on the extremes of vigor in the material being evaluated, was found to be nearly as effective as direct measurement of seedling size for evaluating genotype difference, and much simpler to use. Statistically significant differences among genotypes could be obtained using this method. Direct selection for seedling vigor under field conditions was combined with selection for agronomic traits and was useful in producing inbred lines combining both good seedling vigor and plant type. The yielding ability of a synthetic variety found by intermating nine of these inbred lines was equal to that of the open pollinated checks in three trials. Improvement in seedling vigor, as defined by seedling size, therefore seems to be feasible by combining a larger grain size with direct selection for seedling size in field conditions. Both types of selection should be simple to include in a breeding program without major additional effort.

COMPENDIO

Se evaluó el vigor de las plántulas de un cierto número de variedades de mijo perla usando el método de estimación visual y medidas directas en condiciones de campo. Para la estimación visual del tamaño de las plántulas se empleó una escala relativa basada en los extremos del vigor del material evaluado, encontrando que este método fue casi tan efectivo como la medición directa del tamaño de las plantas al estimar diferencias genotípicas y más simple de usar. El método permitió detectar diferencias estadísticamente significativas entre genótipos. La selección directa por vigor de las plántulas en condiciones de campo, fue combinada con la selección de otras características agronómicas, útil en la producción de líneas puras que reúnen tanto el vigor de las plántulas como el tipo de planta. La productividad de una variedad sintética, formada por el cruce de nueve de estas líneas puras, fue igual a la de los testigos producidos por polinización abierta en tres pruebas. El mejoramiento en el vigor de las plántulas, definido como el tamaño de la plántula, parece ser posible si se combina un tamaño de grano más grande con la selección directa del tamaño de las plántulas, en condiciones de campo. Los dos tipos de selección son sencillos como para ser incluidos en un programa de mejoramiento sin mucho problema.

INTRODUCTION

Differences among millet lines in early seedling growth are clearly visible in the field, and a visual rating of vigor, if sufficiently reproducible, would be adequate for most breeding requirements. Visual ratings of seedling vigor have been used in breeding for this characteristic in grasses (1,2,6) and in sorghum which is found to be highly efficient. After some experimentation it was found that the use of a relative scale, with its extremes adjusted to the extremes of vigor present in the material being scored, was the most satisfactory.

[1] Received for publication 18 February 1988.

[*] Current address: Profesor in Botany, División de Post/Grado, Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León, Ciudad Universitaria, Apartado Postal 2790, Monterrey, N.L., México.

[**] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru P.O.; Andhra Pradesh 502324, India.

MATERIALS AND METHODS

Direct measurement (seedling vigor)

A set of 80 breeding lines plus two hybrid checks was evaluated for seedling vigor in a field trial in

1976. Fifteen days after emergence the height of 10 seedlings per entry was measured; these were cut at ground level and the dry weight of the above ground parts determined. The experiment was replicated four times.

Visual evaluation

Simple scales of either 1 - 4 or 1 - 5 were used, following the technique of Maiti *et al.* (3), with 1 being assigned to the most vigorous lines and 4 or 5 to the least vigorous. The following criteria are considered in the visual evaluation of seedling vigor: height and spread of leaf canopy, diameter of the pseudostem (leaf sheathes), and the length and breadth of individual leaves. The method involves an initial survey of the material to be scored to determine the degree of variation in seedling size and the selection of individual rows or plots to serve as reference points for the extremes (or all points) of the scale. These reference plots may be referred to during the course of the scoring if necessary.

The relationship of visual score and measured plant growth was tested in a replicated field experiment in 1977 with 27 selected millet lines representing a range in seedling vigor. Scoring was undertaken on a 1 - 4 scale at 14 d after emergence and 10 representative plants per plot were harvested at 15 d for measurement of seedling leaf area and dry weight.

Selection for improved seedling vigor

From the previous experiment (5) and from the measurement of seedling dry weight of lines from the working collection (a sample of germplasm and breeding materials chosen to represent the useful genetic variation in pearl millet), a number of lines with good seedling size were identified. Many of these however were poorly adapted to Indian conditions — primarily in that they were too tall and too late to flower — and consequently not directly useful to the breeding program, despite their seedling vigor. It was therefore decided to develop a set of high seedling vigor lines with improved agronomic characteristics.

A partial diallel cross was made in the dry season of 1977 among nine lines from the above set, selected for better agronomic type and seedling vigor. Progeny from these crosses were subjected to pedigree selection for seedling size by visual evaluation, and for panicle size, grain size and reduced non-productive tillering. Yield tests of 35 F_5 and F_6 lines in comparison were carried out in 1980 using two F_1 hybrids as checks.

RESULTS AND DISCUSSION

Direct measurement (seedling vigor)

There were significant differences among lines in both height ($P<.01$) and dry weight ($P<.05$). The range among entries for dry weight was far greater than that for height, but the experimental variation was also greater (Table 1). Either measurement however, was satisfactory to distinguish the more vigorous from the less vigorous seedings. The main conclusion drawn from the experiment was, however, that the effort involved in the direct measurement of seedling dry weight would be excessive if the method were to be used on a large scale. In addition, the destructive sampling necessitated either the sowing of separate experiments or the sacrificing of portions of other tests for the measurement of seedling vigor.

Table 1. Comparison of seedling vigor of breeding lines of pearl millet by direct measurement of seedling height and dry weight at 15 days after emergence (breeding lines trial 1976).

	Height (cm)	Weight (g/plant)
Mean	9.1	0.27
Range	6.2 - 11.7	0.10 - 0.82
F ratio (genotype)	3.03**	1.67*
SE	0.67	0.083
CV (%)	7.4	30.9

** $P < .01$; * $P < .05$; n = 82

Visual evaluation

Correlation of visual score to both measured parameters were strong (coefficients of determination of .70 and .73 for leaf area and dry weight respectively). There was some deviation from linearity in these relationships, but the best lines, as determined by measured growth, were clearly identified by the visual evaluation.

Visual scoring was carried out on a number of replicated breeding trials in 1977 to determine how effective the method was in distinguishing statistical differences among lines. Results from two of these, presented in Table 2, show highly significant differences (P<.01) for visual score among entries in both trials.

Table 2. Analyses of variance of visual score for seedling vigor in All Indian Coordinated Millet Improvement Project (AICMIP) advanced hybrid trial and in the intervarietal composits S1 progeny trial (breeding trials evaluation 1977).

	AICMIP trial	S1 progeny trial
No. of entries	22	315
Replications	3	2
Scale used	1–5	1–5
Mean score (trial)	2.6	2.8
Range in entry means	1.7–3.7	1.0–5.0
F ratio (entry)	2.44**	2.66**
SE	0.34	0.53
CV (%)	22	19

** P < 0.1

The use of a relative rather than an absolute scale resulted in a full range of scores, which are usually normally distributed allowing direct statistical analysis (avoiding the need for transformation of data). The scores are also usually sufficiently repeatable to allow statistical differentiation of entries, even with cultivars in the range of 20 percent. For most estimates of seedling vigor (where large seedling size is the objective) visual assessment using a relative scale should be adequate. A similar conclusion has been reported for sorghum.

Selection for improved seedling vigor

Most of the lines had acceptable maturity, head size and grain size (Table 3). The better lines had a seedling size comparable to the hybrid check MBH 110 (a large-seeded cultivar which produces very vigorous seedlings) and several had grain yield approaching those of the checks (Table 4). Considering that the seedling vigor lines were highly inbred, these results were very promising.

Yields of ICMS 8153 at both locations were similar to those of the standard, open-pollinated check varieties WC-C75 and ICMS 7703 (Table 5) (although there may be some loss of yield with additional inter mating as the component lines were highly inbred and the first generation synthetics undoubtedly benefit from some degree of hybrid vigor).

The results of the selection exercise indicate that it is possible to combine selection for high seedling vigor with selection for agronomic performance and that simple visual scoring at approximately two weeks after emergence is effective in identifying individuals with good seedling vigor. The effort required to incorporate this selection into a breeding program is not great. In early generations, superior seedlings can be easily identified (by tagging for example) for

Table 3. Summary of results of yield test of seedling vigor inbred lines (field trial 1980).

Variable	Mean	Range	F ratio (entry)	S.E.	CV (%)
Visual score for seedling vigor	2.6	1–4	2.91**	0.31	13
Dry wt. at 15 days (g/plant)	0.72	0.54–1.05	1.71*	0.086	13
Days to flowering	41	36–45	5.47**	0.8	2
Panicle length (cm)	25	18–28	3.48**	1.0	5
1000 grain wt. (g)	8.3	6.8–11.8	5.96**	0.33	4
Grain yield (kg/ha)	2 170	1 250-3 360	4.40**	220	11

** P < .01; * P < .05; n = 37

Table 4. Seedling vigor and grain yield of the highest seedling vigor inbred lines, best yielding inbred lines, and check hybrids (inbred yield trial 1980).

Cross/cultivar	Vigor score	Seedling t. (g/plant)	Grain yield (kg/ha)	100 seed wt. (g)
	Best vigor lines			
(700594xK-560-11) x 13033	1.5	0.35	2 190	0.98
(700594xK-560-11) x [SD2 ExB-2(D-1005-3-2)]	1.5	0.89	3 160	0.95
(700594xK-560-11) x 66A	1.7	0.94	2 830	0.90
(700594xK-560-11) x 66A	2.2	0.75	2 280	0.92
(700440x700651-2-1) x (SD2xExB-2(ESD-1003-1)	2.2	0.90	1 920	0.81
	High yielding lines			
(700594xK-560-11) x [SD2xExB-2(D-1005-3-2)]	1.5	0.89	3 160	0.95
(700594xK-560-11) x 66A	1.7	0.94	2 830	0.90
66A x (J-25-1x700797-12-1)	3.0	0.67	2 740	0.95
(SD2xExB-2(ESD-1003-1)x(700440x700651-2-1)	2.7	0.66	2 700	0.85
(700594xK-560-11) x (SD2xExB-2(ESD-1003-1)	2.5	0.69	2 610	0.72
	Check lines			
MBH 110	1.0	1.05	3 360	1.18
BK 560	2.2	0.64	3 280	0.90

Table 5. Comparison of grain yields of the seedling vigor synthetic ICMS 8153 with those of check cultivars WC-C75 and ICMS 7703 (field trials 1981)*.

	Grain yield (kg/ha)		
Trial location	ICMS 8153	WC-C75	ICMS 7703
Patancheru (low fertility)	1 880	2 430	1 970
Patancheru (high fertility)	3 630	3 600	3 670
Hissar	3 500	3 200	3 360
Mean	3 000	3 080	3 000

* Data courtesy of Dr. K.N. Rai, ICRISAT.

subsequent evaluation at flowering and at maturity. In later generations, evaluation for seedling vigor can be carried out on a progeny row basis which is both rapid and simple.

LITERATURE CITED

1. KNEEBONE, W.R; CREMER, C.L. 1955. The relationship of seed size to seedling vigor in some native grass species. Agronomy Journal 47:472-477.
2. KNEEBONE, W.R. 1956. Breeding for seedling vigor in sand bluestem (*Andropogon hollii* Hack.) and other native grasses. Agronomy Journal 48:37-40.
3. MAITI, R.K; RAJU, P.S.; BIDINGER, F.R. 1981. Evaluation of visual scoring for seedling vigor in sorghum. Seed Science and Technology 9:613-622.
4. MAITI, R.K. 1986. Morfología, crecimiento y desarrollo del sorgo. México, Universidad Autónoma de Nuevo León, Facultad de Agronomía. 419 p.
5. MAITI, R.K.; RAJU, P.S.; BIDINGER, F.R. 1990. Seedling vigor in pearl millet. I. Role of seed size. Turrialba 40:353-355.
6. TOSSELL, W.E. 1960. Early seedling vigor and seed weight in relation to breeding in smooth bromegrass *Bromus intermis* Lyss. Canadian Journal of Plant Science 40:268-280.