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# Panicle surface area as a selection criterion for grain yield in pearl millet (*Pennisetum glaucum*)

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ABSTRACT

In an experiment 24 experimental varieties of 3 composites, viz 'EC 87', 'EC 91' and 'HHVBC', were evaluated during rainy season of 1996 and 1997 in 11 environments at 3 locations for the effect of selection for panicle surface area on grain yield and its components in pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]. Singificant variation was observed among experimental varieties for all the traits. The actual gain in 'PCV 5' (with maximum panicle surface area) over the original population was 8.7% for grain yield/m$^2$ and 7% for grains/m$^2$ across the composites. Breeder selection was effective in improving grains/m$^2$ by an average of 4% in 3 composites, but it was effective in improving grain yield/m$^2$ over the original population by 3% in 'EC 91' only. The net increase in grain yield/m$^2$ was almost similar to the prediction (+8.7% vs prediction of 10%). Also the selection for large panicle surface area, ie 'PCV 5', was more effective than breeder selection for grain yield/m$^2$ by an average of 9% in the 3 composites. The panicle surface area showed positive correlation with grain number/m$^2$, grain size and grain yield/m$^2$ among experimental varieties ('PCV 1' to 'PCV 5') in 3 populations.

**Key words:** Pearl millet, Panicle surface area, Grain number, Grain size, Grain yield

Differences in grain yield among cereals are more often related to differences in grain number per unit area than to differences in grain size. Direct selection for grain number per unit area, however, is not a practical approach to breed for increased grain yield potential because (*i*) its high cost of measurement on large numbers of progeny rows and (*ii*) probable lack of relevance when measured in spaced plants. But due to indirect selection for pancicle surface area we can increase grain number/panicle or per unit area in pearl millet [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz]. Therefore, indirect selection for panicle surface area is a practical approach for increased grain yield with grain yield in pearl millet. Panicle surface area shows positive correlation with grain yield in pearl millet (Mahadevappa and Ponnaiya 1967, ICRISAT, Patancheru 1986, Rattunde *et al.* 1989).

Panicles with large surface area had a different grain number-grain size relationship than panicles with a small surface area (Bidinger *et al.* 1993). Individual grain size was greater for a given grain number in large surface area type of panciles than in small panicle surface area, leading to 20% increase in grain yield in former types. The objectives of this study were (*i*) to determine the effect of panicle suface area on grain number, grain size and grain yield in pearl millet and (*ii*) to predict and measure gain in grain yield improvement from selection based on panicle surface area.

## MATERIALS AND METHODS

Three pearl millet composites, Early Composite 1987 (EC 87), Early Composite 1991 (EC 91), and High Head Volume B Composite (HHVBC) were chosen for the present study. The composites exhibited a wide range in their panicle surface area (panicle length×panicle diameter×$\pi$, assuming the panicle to be a perfect cylinder). The EC 87

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Table 1 Location, condition, season, year and environment for the evaluation of experimental varieties

| Location | Condition | Season | Year | Environment |
|---|---|---|---|---|
| Hisar (Haryana) | Irrigated | Rainy | 1996, 1997 | E 1, E 7 |
| Rohtak (Haryana) | Irrigated | Rainy | 1996, 1997 | E 2, E 8 |
| Patancheru (Andhra Pradesh) | Irrigated | Summer | 1997 | E 6 |
| | Low fertility | Rainy | 1996, 1997 | E 3, E 9 |
| | High fertility | Rainy | 1996, 1997 | E 4, E 10 |
| | Extended day-length | Rainy | 1996, 1997 | E 5, E 11 |

was constituted by random mating Early Composite II (ECII CI), 2 Bold Seeded Early Composite (BSEC) varieties ('ICMV 87901 and 'ICMV 87902') and a variety ('ICMV 87119') from Early Composite (EC). The 'EC 91' was developed by random mating 'Early Composite II' ('ECII CI') and 'Early Smut Resistant Composite II' ('ESRCII CO'). The 'HHVBC' was bred from crosses of elite breeding lines and selected germplasm accessions having long and thick panicles.

Approximately 1 000 plants spaced 75 cm ×75 cm from each of the 3 composites were grown in 1993 rainy season (June–September) at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India. The main panicle of each plant was left for open pollination to measure panicle surface area and tiller panicles were selfed to produce $S_1$ seed. The $S_0$ plants of each population ranked by panicle surface area were divided into 5 classes as :

PCV1<[mean–1.75 (s.d.)]

PCV2>[mean–1.25 (s.d.)], <[mean–0.75 (s.d.)]

PCV3>[mean–0.25 (s.d.)], <[mean+0.25 (s.d.)]

PCV4>[mean–0.75 (s.d.)], <[mean+1.25 (s.d.)]

PCV5>[mean+1.75 (s.d.)]

As per description given above 22 $S_0$ plants were selected from each class at random and then $S_1$ progenies were used to make PCV1 (with minimum panicle surface area) to PCV5 (with maximum panicle surface area ) for each population. Equal number of $S_1$ progenies were also selected at random from the entire set of $S_1$ progenies of each population for recombination to make random control experimental variety (RNDV). The highest ranked 22 $S_0$ plants as selected by the breeder from each population were also recombined to make a breeder selection control (BRDV). In addition, a bulk of the original populations were also planted for seed increase, to represent a fresh seed source from the same seed production environment as of the experimental varieties.

A total of 22 $S_1$ progenies selected to make each experimental variety, viz PCV1, PCV2, PCV3, PCV4, PCV5, RNDV, BRDV along with a mixture of 22 selected $S_1$ progenies of each variety from each population were grown in summer 1996 at Patancheru. Each $S_1$ progeny was sown in a row and mixture of the progenies in 6 rows of 5 m length. The pollen-grains from the mixture of the progenies were collected and used to pollinate each progeny in each variety in 3 composites. Equal quantity of seed from 22 $S_1$ progenies were mixed in each variety in all the 3 composites to constitute 24 experimental varieties, viz EC 87 PCV1, EC 87 PCV2, EC 87 PCV 3, EC 87 PCV 4, EC 87 PCV 5, EC 87 RNDV, EC 87 BRDV, EC 87 ORIG, EC 91 PCV1, EC 91 PCV 2, EC 91 PCV 3, EC 91 PCV 4, EC 91 PCV 5, EC 91 RNDV, EC 91 BRDV, EC 91 ORIG, HHVBC PCV 1, HHVBC PCV 2, HHVBC PCV 3, HHVBC PCV 4, HHVBC PCV 5, HHVBC RNDV, HHVBC BRDV and HHVBC ORIG.

The 24 experimental varieties were evaluated in completely randomized block design (CRBD) with 4 replications in 11 environments at Hisar (29$^0$ N, 75$^0$ E and an altitude 215.2 m), Rohtak (28$^0$ N, 76$^0$ E and an altutude 219.8 m) and Patancheru (18$^0$ N, 78$^0$ E and an altitude 545 m) during the rainy season of 1996 and the summer and rainy seasons of 1997 (Table 1). The plot size was 4 rows of 4.0 m length with row-to-row and plant-to-plant distance 45 cm and 10 cm respectively at Hisar and Rohtak, whereas the inter-row spacing was 75 cm at Patancheru. Harvest area was 2 central rows of 3.0 m length at all locations Traits measured on 24 experimental varieties of pearl millet and their method of measurement are presented in Table 2. Traits were measured on plot basis in each experimental variety in all the 4 replications at all locations. The statistical analysis was based on plot means. Pooled analysis involving 11 environments was carried out using Genstat package. Genetic correlations were computed as per the formula of Johnson *et al.* (1955).

## RESULTS AND DISCUSSION

Significant variation among genotypes was observed for all plot traits. Effects due to base population, selection and

Table 2 Traits measured on 24 experimental varieties of pearl millet on plot basis and method of measurement

| Trait | Method of measurement or calculation |
|---|---|
| Panicle number/m$^2$ | Number of panicles/net harvested area |
| Grains/panicle | [(Grain yield/panicle)(1 000-grain weight)] × 1 000 |
| Grain number/m$^2$ | [(Grain/yield/m$^2$) (1 000 grain weight)] × 1 000 |
| 1 000-grain weight | 100 grain counts were made on 3 randomly selected samples, averaged and multiply by 10 |
| Grain yield/panicle | Grain weight / panicle number |
| Grain yield/m$^2$ | Grain weight / net harvested area |

Table 3 Mean squares obtained from the analysis of variance in 11 environments for panicle number/m², grain number, 1 000-grain weight, grain yield/panicle and grain yield/m² in 24 experimental varieties of 3 millet composites

| Source | $df_1$ | Panicle number/ $m^2$ | Grain number/ ($m^2 \times 10^7$) | 1 000-grain weight (g) | Grain number/ panicle ($\times 10^5$) | Grain yield/ panicle (g) | Grain yield/$m^2$ ($\times 10^3$ g) |
|---|---|---|---|---|---|---|---|
| Environment | 10 | 550.84** | 309.00** | 1 40.22** | 75.50** | 1 774.77** | 307.22** |
| Replication in environment | 33 | 13.0 | 10.80 | 2.21 | 3.38 | 21.05 | 4.44 |
| Genotype | 23 | 42.29** | 12.90** | 5.64** | 6.73** | 84.29** | 11.00** |
| Population | 2 | 353.04** | 78.00** | 25.50** | 2.05** | 127.72** | 66.46** |
| Selection | 7 | 40.79** | 9.39** | 5.95** | 13.0** | 201.49** | 14.85** |
| Population×selection | 14 | 12.93** | 5.31** | 2.23** | 4.27** | 19.50** | 1.16** |
| Genotype × environment | 230 | 6.99** | 3.64** | 1.57** | 2.09** | 14.19** | 1.99** |
| Population × environment | 20 | 19.20** | 4.46** | 4.79** | 2.59** | 43.67** | 5.48** |
| Selection × environment | 70 | 8.56** | 4.29** | 1.46** | 2.74** | 16.85** | 2.22** |
| Population × selection environment | 140 | 4.46** | 3.20** | 1.17** | 1.70** | 8.64** | 1.38** |
| Pooled error | 759 | 2.67 | 2.01 | 0.86 | 1.31 | 7.41 | 1.02 |

**$P$=0.01

Table 4 Mean performance of 24 experimental varieties of 3 pearl millet composites for 6 plot traits averaged over 11 environments

| Composite | Experimental variety | Panicle number/ $m^2$ | Grain number/ $m^2$ | 1 000-grain weight (g) | Grain number/ panicle | Grain yield/ panicle (g) | Grain yield/$m^2$ (g) |
|---|---|---|---|---|---|---|---|
| EC 87 | PCV 1 | 14.9 | 27 237 | 9.17 | 1 881 | 17.1 | 247.0 |
| | PCV 2 | 14.2 | 29 071 | 9.24 | 2 071 | 19.2 | 266.7 |
| | PCV 3 | 13.9 | 30 422 | 9.16 | 2 206 | 20.3 | 277.6 |
| | PCV 4 | 13.2 | 29 913 | 9.47 | 2 267 | 21.5 | 279.2 |
| | PCV 5 | 13.8 | 30 156 | 9.89 | 2 218 | 21.7 | 292.1 |
| | RNDV | 13.0 | 27 290 | 9.58 | 2 130 | 20.4 | 259.8 |
| | BRDV | 12.7 | 28 695 | 9.47 | 2 285 | 21.3 | 263.6 |
| | ORIG | 14.1 | 27 606 | 9.75 | 1 977 | 19.2 | 266.5 |
| EC 91 | PCV 1 | 15.2 | 29 700 | 8.50 | 1 967 | 16.7 | 251.2 |
| | PCV 2 | 15.3 | 30 608 | 8.62 | 2 040 | 17.6 | 263.1 |
| | PCV 3 | 13.6 | 29 010 | 9.13 | 2 172 | 19.7 | 262.3 |
| | PCV 4 | 13.6 | 27 533 | 9.43 | 2 061 | 19.5 | 259.3 |
| | PCV 5 | 13.2 | 31 892 | 8.77 | 2 442 | 21.3 | 275.0 |
| | RNDV | 12.7 | 28 100 | 8.88 | 2 222 | 19.7 | 242.4 |
| | BRDV | 13.9 | 29 077 | 8.93 | 2 127 | 19.1 | 258.3 |
| | ORIG | 13.2 | 27 968 | 9.04 | 2 150 | 19.5 | 250.2 |
| HHVBC | PCV 1 | 12.5 | 25 743 | 9.00 | 2 105 | 18.8 | 226.9 |
| | PCV 2 | 12.7 | 25 391 | 9.21 | 2 027 | 19.0 | 235.4 |
| | PCV 3 | 12.4 | 26 662 | 9.33 | 2 169 | 20.3 | 243.8 |
| | PCV 4 | 12.6 | 27 894 | 9.29 | 2 226 | 20.5 | 250.8 |
| | PCV 5 | 12.3 | 26 870 | 9.80 | 2 223 | 21.8 | 259.4 |
| | RNDV | 12.3 | 25 885 | 9.22 | 2 130 | 19.5 | 233.9 |
| | BRDV | 11.9 | 27 159 | 8.96 | 2 292 | 20.6 | 239.8 |
| | ORIG | 11.9 | 26 129 | 9.59 | 2 251 | 21.3 | 243.5 |

pupulation × selection interaction within the genotype source of variation were also significant for all the traits (Table 3). Interaction of genotype and environment were significant for all traits. The significant interaction of population × selection indicated that the effects of selection for panicle surface area were not consistent across the populations and it was changed from one population to another.

The response to selection in PCV 5 (with maximum panicle surface area) over PCV 1 (with minimum panicle surface area) ranged from 4 to 11% for grain number/m$^2$, 3 to 9% for grain size and 10 to18% for grain yield/m$^2$ in the 3 composites (Table 4). Breeder selection was effective in improving grain yield/m$^2$ over the original population by 3% in EC 91 whereas it was ineffective in EC 87 and HHVBC for the same trait. Breeder selection was also effective in improving grain number/m$^2$ by an average of 4% across the populations. There was no change in grain size due to breeder selection in any of the 3 populations. The selection for increased panicle surface area, i e PCV 5, was more effective than breeder selection for grain yield/m$^2$ in all 3 populations and for grain number/m$^2$ in EC 87 and EC 91. Breeder selection was more effective thatn PCV 5 for grain number/m$^2$ in HHVBC. There was not so much difference in random check and original population for most of the traits in the 3 populations. Hence there was no effect of making the $S_1$s *per se* or a random-mated random sample did not differ from the original population.

Actual gain on the basis of panicle surface area was more effective (3 times)in increasing grain number/m$^2$ than predicted gain,but much less effective (4 times)in increasing grain size than predicted grain (Table 5). The net increase in grain yield/m$^2$ was almost similar to the prediction (+8.7% vs prediction of 10%).Panicle surface area was highly genetically correlated to grain yield/m$^2$ in EC 87 and EC 91 ($S_1$ data). That was the reason predicted gain in grain yield/m$^2$ was more in EC 87 and EC 91than HHVBC. The actual gain is still good of considerable magnitude for grain yield and it was more than the realized gain for grain yield (4%) per cycle of mass selection reported by Rattunde (1988).

Panicle surface area was positively correlated with grain number/m$^2$, grain size and grain yield/m$^2$ among 5 experimental varieties (PCV 1 to PCV 5) selected on the basis of panicle surface area in the 3 populations. For example, an increase of 29% in panicle surface area resulted in a corresponding increase of 7% in grain number/m$^2$, 7% in grain size and 14% in grain yield/m$^2$ with a decrease of 7% in panicle number/m$^2$ across 3 populations (Table 4). The positive correlation between panicle surface area and gain yield/m$^2$ is in agreement with the results of Bidinger *et al.* (1993). Singh and Ahluwalia (1970) reported positive correlation between panicle surface area and grain size.

Table 5 Estimated and actual gains in grain yield/m$^2$ and its components

| Trait | Composite | Estimated gain (%) | Actual gain (%) |
|---|---|---|---|
| Grain number/m$^2$ | EC 87 | 2.8 | 9.2 |
| | EC 91 | 4.5 | 14.0 |
| | HHVBC | 1.3 | 2.8 |
| 1 000-grain weight | EC 87 | 10.8 | 1.4 |
| | EC 91 | 18.1 | 4.1 |
| | HHVBC | 4.4 | 2.1 |
| Grain yield/m$^2$ | EC 87 | 12.5 | 9.6 |
| | EC 91 | 12.2 | 9.9 |
| | HHVBC | 5.3 | 6.5 |

Table 6 Genetic correlation coefficients between panicle surface area (measured on sample of 10 panicles) and 9 plot traits in 8 experimental varieties of EC 87, EC 91 and HHVBC pearl millet composites (averaged over 11 environments)

| Panicle surface area with | EC 87 | EC 91 | HHVBC |
|---|---|---|---|
| Panicle number/m$^2$ | –0.74 | –0.90 | –0.70 |
| Grain number/m$^2$ | 0.89 | –0.13 | 1.00 |
| 1 000-grain weight | 0.69 | 0.74 | 0.59 |
| Grain number/panicle | 0.88 | 0.83 | 1.00 |
| Grain yield/panicle | 1.00 | 1.00 | 0.94 |
| Grain yield/m$^2$ | 0.89 | 0.38 | 0.93 |

Coefficients with an absolute value 0.70 or 0.83 are significant at $P$=0.05 and $P$=0.01 respectively

Panicle surface area however, was negatively correlated with panicle number/m$^2$ (Table 6). Navale and Harinarayana (1992) and Navale *at al.* (1995) reported negative association of panicle length and diameter with panicle number. The negative correlation between panicle surface area and panicle number/m$^2$ offset a part of the grain size in individual panicle productivity on grain yield. Results obtained here supported that selection for large panicle surface area needs to be combined with selection for higher tiller number to be effective in increasing grain yield. Normally increasing grain number by conventional selection results in a decrease in grain size (Alagarswamy and Bidinger 1985). Here, increasing panicle surface area resulted in an equal increase in grain number/m$^2$ and grain size. Substantial increase ingrain yield in this experiment due to 1 cycle of mass selection has been because of a significant increase (7%) in grain number/m$^2$ and grain size.

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