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A Pavani
Department of Genetics and Plant Breeding, Acharya N.G Ranga Agricultural University Bapatla, Andhra Pradesh, India

D Ratna Babu
Department of Genetics and Plant Breeding, Acharya N.G Ranga Agricultural University Bapatla, Andhra Pradesh, India

Corresponding Author:
A Pavani
Department of Genetics and Plant Breeding, Acharya N.G Ranga Agricultural University Bapatla, Andhra Pradesh, India

Restriction selection Indices in foxtail millet [*Setaria italica* (L.) Beauv.] using equal economic weights and inverse of means

A Pavani and D Ratna Babu

Abstract
Restricted selection was used for calculating the genetic advance of yield and nutritional components *viz.*, days to 50% flowering, plant height, panicle length, productive tillers per plant, days to maturity, test weight, protein, carbohydrate, calcium, iron, zinc, copper, manganese, phosphorus and grain yield per plant. The genetic advance of all fifteen characters studied was calculated by assigning equal economic weights to all of them as well as by using the inverse of means as their economic weights. In 11 of the 15 cases, the trait plant height showed the highest estimate of genetic advance in both cases. The key finding of this analysis is that identical trend exists in both cases *i.e.*, by assigning equal economic weights and when inverse of means of respective characters are used as economic weights. This indicates that both methods of assigning weights were equally effective and will result in similar conclusions.

Keywords: restricted selection, genetic advance, economic weights, foxtail millet

1. Introduction
Foxtail millet, with chromosome number 2n=18, is a self-pollinating crop with reported out crossing rates of up to 1.4 % (Li *et al.*, 1935) [6]. It belongs to the Poaceae family and subfamily Panicoideae. The naming of this taxon evolved as the millet having panicles resembling a foxtail in appearance *i.e.*, long panicle with soft long and erect hairs. The foxtail millet is thought to have been domesticated in Central China for the first time. Taxonomically, foxtail millet comprised two sub species: *Setaria italica* sub sp. *italica* and subsp. *viridis*. The sub species *viridis* is considered as the progenitor of the cultivated type (Upadhyaya *et al.*, 2008) [14]. Italian millet, German millet, Chinese millet, Hungarian millet are all other names of foxtail millet. It is referred as "Korra" in Andhra Pradesh. It is thought to have been domesticated and cultivated over 4000 years ago (Chang, 1973; Ho, 1975) [1, 3]. It has high nutritional value as it contains β-carotene, protein (12.3%), fat (4.7%), carbohydrate (60.6%) and ash (3.2%) as well as minerals (Fe, Zn, K, Ca, Mg), antioxidants, dietary fibre, phytochemicals, vitamins (thiamine, riboflavin, niacin) and has low glycemic index (Rai, 2002) [8]. Various breeding programmes based on various types of selection techniques are available to improve yield levels. In some circumstances, the breeder may wish to effect change in means of certain characters while leaving the means of other characters unchanged. Kempthrone and Nordskog (1959) [5] introduced the concept of 'restricted selection indices" to facilitate this type of selection. The indices enable us to restrict change in only some characters without affecting the development in other characters.

2. Materials and Methods
A total of sixty genotypes of foxtail millet for this study was laid out in a Augmented Randomised Complete Block Design (Federer, 1956) [2] with four checks *viz.*, Suryanandi, Prasad, Co 7 and Krishnadevaraya in each block. During *kharif*, 2018-19, the trial was carried out at RARS, Lam, Guntur, Andhra Pradesh, which is located at 16.10^0 N latitude, 28.29^0 E longitude and 31.5 m altitude. Each genotype was grown in a two rows of 4 m length with a row spacing of 22.5 cm and plant spacing of 10 cm. Data on Plant height, panicle length, productive tillers per plant and grain yield per plant were collected on five randomly selected plants per treatment. However, data on days to 50% flowering, days to maturity, test weight, protein, carbohydrate, calcium, iron, zinc, copper, manganese and phosphorus were recorded on plot basis. Seed protein was estimated using Micro kjeldhal Distillation Method (Sadasivam and Manickam, 1996) [9]. Carbohydrate content was estimated using the procedure given by

Sadasivam and Manickam (1997) [10]. Iron, Zinc, Copper and Manganese was estimated with the help of Atomic Absorption Spectrophotometer (AAS) as per Tandon (1999) [13]. Similarly, phosphorus content was also estimated as per procedure given by Tandon (1999) [13]. While calcium content was estimated using Versanate titration method (Jackson, 1967) [4]. Among the fifteen characters taken for present study, selection was restricted to only fourteen characters at a time without changing the mean of remaining fifteenth character. All such fifteen possible cases were worked out according to Singh and Chaudhary (2010) [11] and the genetic advances for the fourteen characters subjected to selection in each of the fifteen cases were estimated.

3. Results and Discussion

Table 1 shows the estimates of genetic advances of all the fourteen characters subjected to selection in each of the fifteen cases, when equal economic weights were assigned.

Plant height (11.940) followed by carbohydrate (4.642) and grain yield per plant (3.921) had highest estimate of genetic advance while the least estimate was observed for copper (-0.112) in the first case, when selection was restricted to fourteen characters without affecting the mean of days to 50% flowering.

Days to 50% flowering (6.696) followed by days to maturity (5.423) and carbohydrate (3.597) had highest estimate of genetic advance while the least estimate was recorded for zinc (-0.111) in the second case, when selection was restricted to fourteen characters without affecting the mean of plant height.

The highest estimate of genetic advance was recorded by days to 50% flowering (7.458) followed by days to maturity (6.334) and plant height (3.036) while the least value was recorded by copper (-0.091) in the third case, when selection was not applied on panicle length but on all other fourteen traits, selection was applied.

The highest estimate of genetic advance was recorded by days to 50% flowering (5.221) followed by plant height (4.446) and days to maturity (4.368) while the least value was observed for copper (-0.071) in the fourth case where productive tillers per plant was left out and selection was done for other fourteen traits.

In the fifth case when selection was restricted to fourteen characters leaving days to maturity, the highest estimate of genetic advance was recorded by plant height (11.789) followed by carbohydrate (4.745) and panicle length (3.268) while the least value was recorded by days to 50% flowering (-0.384).

Plant height (5.926) had the highest estimate of genetic advance followed by days to 50% flowering (5.588) and days to maturity (4.696) and least value was observed for iron (-0.087) in sixth case where test weight was not considered for selection and selection was done for other fourteen traits.

In the seventh case, highest estimate of genetic advance was recorded by plant height (9.726) followed by carbohydrate (3.980) and days to 50% flowering (3.464) while least value was copper (-0.106) when selection was restricted to fourteen characters without affecting the mean of protein.

In the eight case when selection was imposed on the combination of fourteen characters which does not include carbohydrate, highest estimate of genetic advance was recorded by plant height (8.621) followed by days to 50% flowering (4.992) and days to maturity (4.493) and least value was observed for copper (-0.078).

Plant height (9.682) followed by carbohydrate (3.916) and days to 50% flowering (3.581) had highest estimate of genetic advance and the least value was observed for copper (-0.102) in ninth case, when selection was restricted to the combination of fourteen characters which does not include calcium.

Plant height (9.334) had highest estimate of genetic advance followed by carbohydrate (3.983) and days to 50% flowering (3.689) and the least value recorded by copper (-0.110) in tenth case, when selection was restricted to the combination of fourteen characters which does not include iron.

In the eleventh case when selection was not applied on zinc, highest estimate of genetic advance was recorded by plant height (9.471) followed by carbohydrate (3.762) and days to 50% flowering (3.744) and least value was observed for copper (-0.101).

The highest estimate of genetic advance was recorded by plant height (9.178) followed by carbohydrate (3.758) and days to 50% flowering (3.706) and the least value was observed for iron (-0.056) in the twelfth case where copper was left out and selection was done for other fourteen traits.

Plant height (9.143) had recorded highest estimate of genetic advance followed by carbohydrate (4.113) and grain yield per plant (3.671) and least value was recorded by copper (-0.096) in thirteenth case where manganese was not considered for selection.

The highest estimate of genetic advance was recorded by plant height (9.310) followed by carbohydrate (3.988) and days to 50% flowering (3.699) and least value was observed for copper (-0.110) in the fourteenth case where selection was not applied on phosphorus.

In the fifteenth case when selection was restricted to the combination of fourteen characters which does not include grain yield per plant, highest estimate of genetic advance was recorded by days to 50% flowering (6.113) followed by days to maturity (5.399) and plant height (3.784) and least value was observed by zinc (-0.021).

Plant height recorded maximum estimates of genetic advance in eleven of the fifteen cases of restricted selection, namely case 1, case 5, case 6, case 7, case 8, case 9, case 10, case 11, case 12, case 13 and case 14 (Table 1).

Similarly, the estimates of genetic advances of all the fourteen characters in each of the fifteen cases, when inverse of means were used as economic weights are presented in the table 2.

In first case, when selection was restricted to fourteen characters without affecting the mean of days to 50% flowering, highest estimate of genetic advance was recorded in plant height (8.803) followed by grain yield per plant (3.738) and carbohydrate (3.721) while the least estimate was found for days to maturity (-0.180).

Days to 50% flowering (3.739) followed by carbohydrate (2.932) and grain yield per plant (2.500) had recorded highest estimate of genetic advance in second case when selection was restricted to fourteen characters without affecting the mean of plant height and least value was observed for copper (0.013).

In the third case when selection was not applied on panicle length, the highest estimate of genetic advance was recorded by days to 50% flowering (5.254) followed by days to maturity (3.539) and grain yield per plant (1.297) and least value was observed for carbohydrate (-0.077).

Days to 50% flowering (2.625) followed by plant height (2.196) and carbohydrate (1.513) had recorded highest estimate of genetic advance among the remaining fourteen characters in the fourth case where productive tillers per plant

were not subjected to selection, while phosphorus (0.036) had the least value.

In the fifth case when selection was restricted to fourteen characters leaving days to maturity, the highest estimate of genetic advance was recorded by plant height (8.325) followed by grain yield per plant (3.678) and carbohydrate (3.640) while least value was observed for copper (-0.007).

Plant height (3.528) followed by days to 50% flowering (3.221) and days to maturity (1.702) had the highest estimate of genetic advance among the remaining fourteen characters in sixth case where test weight was not considered for selection and protein (0.005) had lowest value.

Highest estimate of genetic advance was recorded by plant height (7.950) followed by grain yield per plant (3.610) and carbohydrate (3.495) and copper (-0.015) had least value in the seventh case, when selection was restricted to fourteen characters without affecting protein.

Plant height (6.688) had highest estimate of genetic advance, followed by days to 50% flowering (2.690) and grain yield per plant (2.590) and phosphorus (0.024) had least value in the eight case when selection was imposed on the combination of fourteen characters which does not include carbohydrate.

Highest estimate of genetic advance was recorded by plant height (8.115) followed by grain yield per plant (3.675) and carbohydrate (3.429) and the least value was recorded by copper (-0.009) in ninth case when selection was restricted to the combination of fourteen characters which does not include calcium.

Plant height (8.739) had highest estimate of genetic advance followed by grain yield per plant (3.716) and carbohydrate (3.655) while the least value was recorded by copper (-0.003) in the tenth case when selection was restricted to the combination of fourteen characters excluding iron.

Highest estimate of genetic advance was recorded by plant height (7.760) followed by carbohydrate (3.772) and grain yield per plant (3.701) and the least value was observed for copper (-0.027) in the eleventh case when selection was excised on the combination of fourteen characters which does not include zinc.

Highest estimate of genetic advance was recorded by plant height (7.707) followed by grain yield per plant (3.560) and carbohydrate (3.448) and the least value was observed for phosphorus (0.019) in the twelfth case when selection was imposed on the combination of fourteen characters which does not include copper.

Plant height (7.548) recorded highest estimate of genetic advance followed by grain yield per plant (3.878) and carbohydrate (3.698) and least was recorded by copper (0.005) in the thirteenth case where manganese was not considered for selection.

Plant height (7.505) followed by grain yield per plant (3.756) and carbohydrate (3.653) had recorded highest estimate of genetic advance while least value was observed for copper (-0.021) in the fourteenth case when selection was not applied on phosphorus.

In the fifteenth case when selection was restricted to the combination of fourteen characters which does not include grain yield per plant, highest estimate of genetic advance was recorded by days to 50% flowering (3.559) followed by days to maturity (2.173) and plant height (1.029) while least value was observed for test weight (-0.005).

It was evident that when both equal economic weights (Table 1) and inverse of means (Table 2) are used as economic weights, plant height registered maximum estimates of genetic advance in the similar cases (*i.e.*, case 1, case 5, case 6, case 7, case 8, case 9, case 10, case 11, case 12, case 13 and case 14). This shows that both the methods of assigning economic weights are equally efficient. Similar equal efficiency of both ways of assigning economic weights was also reported by Srilaksmi and Babu (2016) [12] in finger millet and Priya and Babu (2017) [7] in rice.

Table 1: Genetic advance estimates (ΔG_i) in 15 cases of restricted selections for 60 genotypes of foxtail millet [*Setaria italica* (L.) Beauv.] when equal economic weights are assigned.

Case	Traits	Days to 50% flowering	Plant height	Panicle length	Prod. tillers per plant	Days to maturity	Test wt	Protein	Carbohydrate	Calcium	Iron	Zinc	Copper	Manganese	Phosphorus	Grain Yield/ plant
1	Days to 50% flowering	0.000	11.940	3.197	0.827	0.638	0.363	-0.046	4.642	0.280	-0.062	-0.085	-0.112	0.044	0.005	3.921
2	Plant height	6.696	0.000	1.121	0.483	5.423	0.236	0.793	3.597	0.878	0.164	-0.111	-0.099	0.063	-0.008	2.228
3	Panicle length	7.458	3.036	0.000	0.311	6.334	0.101	0.449	0.724	0.453	0.017	0.045	-0.091	0.103	-0.006	1.218
4	Prod. tillers per plant	5.221	4.446	0.748	0.000	4.368	0.076	0.485	2.207	0.303	0.202	0.059	-0.071	0.091	0.010	0.740
5	Days to maturity	-0.384	11.789	3.268	0.815	0.000	0.360	0.004	4.745	0.244	-0.016	-0.065	-0.093	0.045	0.008	3.982
6	Test wt	5.588	5.926	0.574	0.211	4.696	0.000	0.187	0.937	0.582	-0.087	0.043	-0.005	0.114	-0.001	0.573
7	Protein	3.464	9.726	2.533	0.772	3.329	0.324	0.000	3.980	0.424	0.001	-0.062	-0.106	0.080	0.002	3.507
8	Carbohydrate	4.992	8.621	1.268	0.583	4.493	0.190	0.234	0.000	0.255	-0.005	0.053	-0.078	0.087	0.004	2.373
9	Calcium	3.581	9.682	2.507	0.758	3.361	0.328	0.256	3.916	0.000	-0.001	-0.051	-0.102	0.060	0.002	3.569
10	Iron	3.689	9.334	2.502	0.763	3.455	0.325	0.235	3.983	0.404	0.000	-0.067	-0.110	0.073	0.002	3.518
11	Zinc	3.744	9.471	2.425	0.741	3.447	0.316	0.210	3.762	0.334	0.028	0.000	-0.101	0.077	0.002	3.480
12	Copper	3.706	9.178	2.442	0.734	3.300	0.293	0.168	3.758	0.287	-0.056	-0.037	0.000	0.064	0.002	3.241
13	Manganese	3.126	9.143	2.599	0.775	3.078	0.341	0.415	4.113	0.107	-0.073	-0.090	-0.096	0.000	-0.001	3.671
14	Phosphorus	3.699	9.310	2.497	0.765	3.473	0.325	0.236	3.988	0.406	-0.011	-0.068	-0.110	0.073	0.000	3.520
15	Grain Yield/plant	6.113	3.784	0.279	0.072	5.399	-0.007	0.195	1.124	0.777	-0.079	-0.021	-0.011	0.123	0.006	0.000

Table 2: Genetic advance estimates (ΔG_i) in 15 cases of restricted selections for 60 genotypes of foxtail millet [*Setaria italica* (L.) Beauv.] when inverse of means are assigned

Case	Traits	Days to 50% flowering	Plant height	Panicle length	Prod. tillers per plant	Days to maturity	Test wt	Protein	Carbohydrate	Calcium	Iron	Zinc	Copper	Manganese	Phosphorus	Grain Yield/ plant
1	Days to 50% flowering	0.000	8.803	2.855	0.768	-0.180	0.347	-0.035	3.721	0.346	0.362	0.065	-0.013	0.078	0.021	3.738
2	Plant height	3.739	0.000	1.421	0.505	2.286	0.256	0.500	2.932	0.757	0.580	0.065	0.013	0.086	0.015	2.500
3	Panicle length	5.254	0.601	0.000	0.286	3.539	0.110	0.290	-0.077	0.480	0.571	0.246	0.040	0.135	0.019	1.297
4	Prod. tillers per plant	2.625	2.196	0.870	0.000	1.237	0.096	0.298	1.513	0.321	0.763	0.257	0.065	0.120	0.036	0.933
5	Days to maturity	0.392	8.325	2.763	0.749	0.000	0.339	0.023	3.640	0.349	0.383	0.074	-0.007	0.082	0.022	3.678
6	Test wt	3.221	3.528	0.590	0.174	1.702	0.000	0.005	0.076	0.625	0.491	0.257	0.140	0.150	0.026	0.592
7	Protein	1.851	7.950	2.581	0.758	1.289	0.335	0.000	3.495	0.426	0.383	0.072	-0.015	0.097	0.019	3.610
8	Carbohydrate	2.690	6.688	1.485	0.583	1.805	0.217	0.087	0.000	0.284	0.441	0.193	0.026	0.107	0.024	2.590
9	Calcium	1.841	8.115	2.575	0.749	1.241	0.339	0.134	3.429	0.000	0.389	0.087	-0.009	0.080	0.020	3.675
10	Iron	1.822	8.739	2.697	0.828	1.391	0.343	0.163	3.655	0.469	0.000	0.029	-0.003	0.083	0.017	3.716
11	Zinc	1.940	7.760	2.680	0.787	1.394	0.349	0.143	3.772	0.495	0.345	0.000	-0.027	0.090	0.019	3.701
12	Copper	1.948	7.707	2.548	0.746	1.314	0.330	0.103	3.448	0.398	0.372	0.074	0.000	0.092	0.019	3.560
13	Manganese	1.177	7.548	2.734	0.780	0.781	0.362	0.345	3.698	0.034	0.317	0.047	0.005	0.000	0.018	3.878
14	Phosphorus	2.194	7.505	2.555	0.797	1.626	0.342	0.117	3.653	0.443	0.347	0.068	-0.021	0.090	0.000	3.756
15	Grain Yield/plant	3.559	1.029	0.289	0.025	2.173	-0.005	-0.003	0.220	0.839	0.556	0.208	0.147	0.162	0.035	0.000

4. Conclusion

Restricted selection was carried out by restricting the selection for only fourteen out of fifteen characters while leaving the fifteenth character unchanged. The trait, plant height recorded the maximum estimate of genetic advance in 11 out of 15 possible restriction selections. This phenomenon was observed in both cases *i.e.*, when equal economic weights are used as well as when inverse of means are used as economic weights of the respective characters.

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