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Discriminant Functions in the Selection of Pearl Millet (*Pennisetum typhoides* Stapf & Hubb.) Populations for Grain Yield[1]

by

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A knowledge of association of quantitative characters especially of yield and its attributes had been of immense practical utility and profound significance in the field of plant breeding. Such an understanding through advanced biometrical methods such as correlation, regression and discriminant function has made it possible to score the given phenotypes very close to their genotypic yield potentialities. The present investigation was undertaken in this context in some of the pearl millet varieties that are being maintained at the Millets Breeding Station, Coimbatore.

Material and methods: From amongst the collection of pearl millet at the Millets Breeding Station, Coimbatore, forty-nine uniform inbred (S_{13}) cultures were chosen and sown in the main season 1963 in a randomised block design replicated four times. The plots had a dimension of 15 × 15 links with three rows of 14 plants in each. The rows were placed two links apart and the plants in rows at one link. The crop was grown irrigated with usual cultural operations. The middle ten plants of the central row were earmarked for recording the data on days to heading, number of internodes, length of peduncle (x_1), diameter of peduncle (x_2), surface area of primary ear (x_3), density of grain (number of grains per square inch) (x_4), Yield of primary ear (x_5), 1000-grain weight, plant height (x_6), tillering capacity (x_7), yield of straw (x_8) and yield of grain (y). Analysis of experimental data, computations of correlation and regression coefficients, fitting up of discriminant functions, tests of significance were done in the way described by Goulden (1959). The expected genetic advance was calculated from the formula $Z/P \sqrt{b_1 g_1 y + b_2 g_2 y + \ldots}$, where Z/P represents intensity of selection and 'b_1' values represent estimated weights corresponding to the theoritical weights and 'g_{1y}' genotypic covariance of the characters concerned. In the case of straight selection the genetic advance was given by $Z/P \frac{g_{11}}{\sqrt{t_{11}}}$, where t_{ii} and

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g_{ii} are phenotypic and genotypic variances respectively. The relative efficiency of the selection index over straight selection as expressed in percentage was calculated by the formula

$$\frac{\text{Genetic advance by selection index method}}{\text{Genetic advance by straight selection}} \times 100$$

Results: In order to evaluate the variability of characters among the 49 cultures, the data were subjected to statistical analysis. The mean values of the characters, and the results of analysis of variance are given in Table 1.

TABLE 1: *Mean values of various characters and results of the analyses*

Inbred line	Date of heading in days	Number of internodes	Length of peduncle (cm)	Diameter of peduncle (cm)	Surface area of primary ear (sq. cm)	Density of grain (no)	Yield of primary ear (gm)	Plant height (cm)	Tillering capacity (no)	Yield of straw (gm)	1000-grain weight (gm)	Yield of grain (gm)
1	2	3	4	5	6	7	8	9	10	11	12	13
K.1-4	64·0	11·0	24·0	0·44	112	8·5	6·5	143·0	2·10	81·0	5·85	7·1
P. T. 819/4	49·7	8·5	24·5	0·43	138	8·0	7·2	162·2	2·20	53·2	6·15	11·9
P. T. 820/6	55·8	9·4	24·5	0·39	134	7·5	5·8	147·2	1·40	75·5	8·47	8·1
P. T. 820/8	40·3	10·2	32·5	0·46	158	9·8	9·7	162·4	2·25	91·8	6·23	19·3
P. T. 825/6	54·1	8·8	26·3	0·33	146	8·2	8·5	141·2	1·65	51·2	9·26	11·3
P. T. 829/3	62·2	9·5	26·5	0·29	124	8·2	6·3	149·2	1·30	75·0	7·29	6·3
P. T. 829/8	59·0	9·1	29·6	0·40	157	8·5	7·6	164·8	2·00	108·5	6·62	12·2
P. T. 830/3	58·9	9·7	29·9	0·41	140	9·2	9·2	163·0	1·25	81·0	7·61	10·8
P. T. 833/7	53·9	9·7	21·6	0·31	127	7·2	5·1	131·2	1·50	44·2	5·74	6·8
P. T. 834/2	54·9	9·6	31·4	0·53	163	8·5	9·1	166·8	1·30	82·8	8·05	12·0
P. T. 834/3	52·8	9·9	28·2	0·45	130	9·2	8·7	154·2	1·30	38·0	7·28	11·5
P. T. 835/3	52·1	9·6	27·6	0·34	138	8·8	7·7	147·2	1·50	51·0	7·09	21·2
P, T. 835/6	55·0	8·8	29·8	0·42	141	10·0	7·9	158·2	1·60	85·8	6·08	10·3
P. T. 835/7	52·5	8·6	27·5	0·36	131	9·8	6·4	137·2	2·18	105·8	6·75	10·7
P. T. 835/8	56·6	10·0	25·3	0·39	140	8·8	8·5	134·8	1·25	52·0	6·84	10·3
P. T. 852/2	59·7	9·4	22·9	0·36	130	9·8	7·7	151·5	2·25	45·8	6·92	18·6
P. T. 853/3	60·3	9·4	25·3	0·28	120	7·5	6·3	148·0	2·40	50·0	6·65	12·6
P. T. 870	52·7	8·9	25·1	0·44	144	8·8	7·1	149·2	1·49	68·8	8·41	8·2
P. T. 873	58·6	11·0	27·4	0·43	185	10·0	9·7	172·5	1·45	84·2	6·78	11·0
P. T. 877	55·9	9·7	25·0	0·43	157	7·8	6·8	153·8	1·50	62·8	6·62	8·8
P. T. 888	55·8	10·3	27·6	0·39	160	7·8	6·3	151·0	2·15	51·2	7·75	7·3
P. T. 928	53·3	9·5	28·7	0·36	116	10·2	7·2	148·0	1.35	48·8	6·45	7·7
P. T. 931	53·3	9·4	24·6	0·42	144	11·2	10·7	143·0	1·30	66·5	7·38	11·4
P. T. 932	45·7	5·9	27·5	0·40	134	12·0	11·0	158·2	1·35	67·5	7·36	12·3
P. T. 934	60·8	9·5	28·3	0·30	142	10·5	9·6	146·0	1·30	69·0	8·02	10·6

TABLE 1 *(Contd.)*

Inbred line	Date of heading in days	Number of internodes	Length of peduncle (cm)	Diameter of peduncle (cm)	Surface area of primary ear (sq. cm.)	Density of grain (no)	Yield of primary ear (gm)	Plant height (cm)	Tillering capacity No.	Yield of straw (gm)	1000-grain weight (gm)	Yield of grain (gm)
1	2	3	4	5	6	7	8	9	10	11	12	13
P. T. 936	60·0	10·6	29·3	0·36	134	12·0	12·1	143 8	1 60	89·0	7 73	15·8
P. T. 940	50·4	8·9	23 0	0·37	109	11 2	6·2	130·2	1·65	44·5	5·25	10·2
P. T. 942	55·9	9·6	28 7	0·40	143	9·5	8·6	157·5	2·05	78·8	7·76	17·8
P. T. 943	49·2	9·7	23·2	0·28	117	9·5	6·4	145·5	1·25	54·5	6·26	7·0
P. T. 944	54·4	8·6	22·6	0·30	93	7·5	5·4	126·2	1·55	44·5	7 62	6·6
P. T. 949	49·3	9·2	26·0	0.25	107	11·8	7·6	139·4	1·45	65·0	5·40	8·9
P. T. 956	56·7	9·9	27·3	0·43	131	12·2	9·5	158·8	2·20	91·2	6·48	18·2
P. T. 963	55·7	9·5	26·4	0·44	139	8·5	7·5	148·2	1·60	71·2	7·24	9·4
P. T. 965	60·5	10·1	29·2	0·42	155	12·2	8·2	163 0	1·10	56·0	7·40	8·6
P. T. 973	58·9	9·6	25·7	0·50	151	10·8	10·6	146·2	1·60	107·2	6·83	14·9
P. T. 1480	57·9	9·7	26·0	0·42	118	6·8	5·5	140·0	1·75	80·0	7·62	8·7
P. T. 1488	56·1	9·6	27·2	0·48	153	6·5	9 4	143·8	1·75	113·5	7·72	15·7
P. T. 1491	55·4	10·7	30·9	0·46	142	7·5	10·4	182·8	1·70	78·0	7·02	14·2
P. T. 1641	56·9	9·8	25·8	0·42	128	7·0	9·5	147·2	2·10	76·2	8·99	14·0
P, T. 1642	58·5	9·4	25·8	0·38	130	8·2	8·2	143 2	1·40	56·5	8·04	8·6
P. T. 1643	49·7	8·1	25·0	0·33	96	7·8	6·1	118·2	1·60	73·8	7·99	8·4
P. T. 1644	53·5	10·2	25·9	0·43	145	8·5	7·4	148·2	1·60	67·5	6·70	9·2
P. T. 1645	54·0	9·1	23·8	0·43	157	8·2	9·3	155·2	1 60	62·5	7·72	11·8
P. T. 1647	55·6	10·2	30·3	0·38	143	8·5	9·4	154·5	1·55	57·5	8·13	12·5
P. T. 1648	55·8	9·6	23·5	0·48	130	11·0	9·1	136·0	1·80	152·5	7·09	17·2
P. T. 1649	56·9	9·1	29·7	0·36	159	8·5	9·2	168 0	2·00	78·5	8·09	13·7
P. T. 1651	52·9	9·9	28·9	0·43	116	8·2	5·9	138·2	2·25	85·7	7·01	8·7
P. T. 1657	52·3	8·7	25·3	0·50	180	8·8	12·3	152·5	2·45	86·8	7·89	21·1
P. T. 1658	51·1	9·4	28·1	0·39	140	8·8	6·6	147·5	1·40	70·0	7·41	9·4
Level of significance	NS	*	*	*	*	*	*	*	*	*	*	*
S. E.	4·27	0·45	3·68	0·03	13·6	0·4	1·50	8·9	0·28	17·1	0·76	1·52
C. D. at 5% level	...	1·24	5·29	0·08	37·8	1·1	4·16	24·6	0·78	47·4	2·11	4·21
C. D. at 1% levsl	...	1·63	6·96	0·11	49·7	1·5	5·46	32·3	1·02	62·3	2·77	5·54

NS: Not significant

*: Significant at 1% level

All the characters, except days to heading, showed significant differences among the cultures studied. Coefficients of variability were moderate in the diameter of peduncle, density of grain, yield of primary ear and yield of straw, whereas it was very high in yield of grain. Heritability was high in diameter of peduncle and moderate in respect of surface area of primary ear, yield of primary ear, plant height, yield of straw and yield of grain.

Simple correlations and regression coefficients at phenotypic, genotypic and environmental levels are presented in table 2. The genotypic correlations

TABLE 2: *Phenotypic, genotypic and error correlation and regression coefficients between grain yield and other variables.*

Characters	Correlation Coefficients			Regression Coefficients		
	Phenotypic	Genotypic	Error	Phenotypic	Genotypic	Error
Date of heading	—0·146*	—0·100	—0·705†	—0·203*	—0·214	—0·258
Number of internodes	0·037	0·001	0·186†	0·340	0·013	0·630†
Length of peduncle	0·282†	0·321†	0·389†	0·631†	1·054†	0·310†
Diameter of peduncle	0·249†	0·269†	0·100	21·130†	24·452†	5·484
Surface area of primary ear	0·271†	0·085	0·477†	0·073†	0·030	0·130
Density of grain	0·189†	0·196†	0·095	0·740†	0·770†	0·365
Yield of primary ear	0·458†	0·524†	0·082	1·465†	2·997†	0·838†
Plant height	0·199†	0·083	0·731†	0·090†	0·058	0·125†
Tillering capacity	0·422†	0·589†	0·535†	7·326†	18·666†	2·934†
Yield of straw	0·326†	0·409†	0·399†	0·086†	0·169†	0·036†
1000—grain weight	0·085	0·040	0·284†	0·556	0·513	0·570†

† Significant at 1% level

* Significant at 5% level

indicated that grain yield is positively correlated with the length of peduncle, diameter of peduncle, density of grain, yield of primary ear, tillering capacity and yield of straw. Days to heading, number of internodes, surface area of primary ear, plant height and 1000-grain weight did not show significant correlation with grain yield. Regression coefficients indicated that all the characters which showed significant association with grain yield had significant influence on grain yield (Fig. 1). As revealed by intercomponental correlations (Table 3), length of peduncle exhibited a positive association with all the characters except density of grain. Diameter of peduncle showed a significant correlation with all the characters except density of grain and tillering. Surface area of primary ear bore a significant association with length of peduncle, diameter of peduncle, plant height and yield of straw. Density of grain exhibited a positive correlation only with yield of primary ear which in turn was closely associated with all the characters excepting surface area of primary ear. Plant height showed a strong negative correlation with tillering capacity, and yield of straw, while with

TABLE 3: *Phenotypic (P), Genotypic (G) and Environmental (E) Correlation Coefficients between different pairs of Characters*

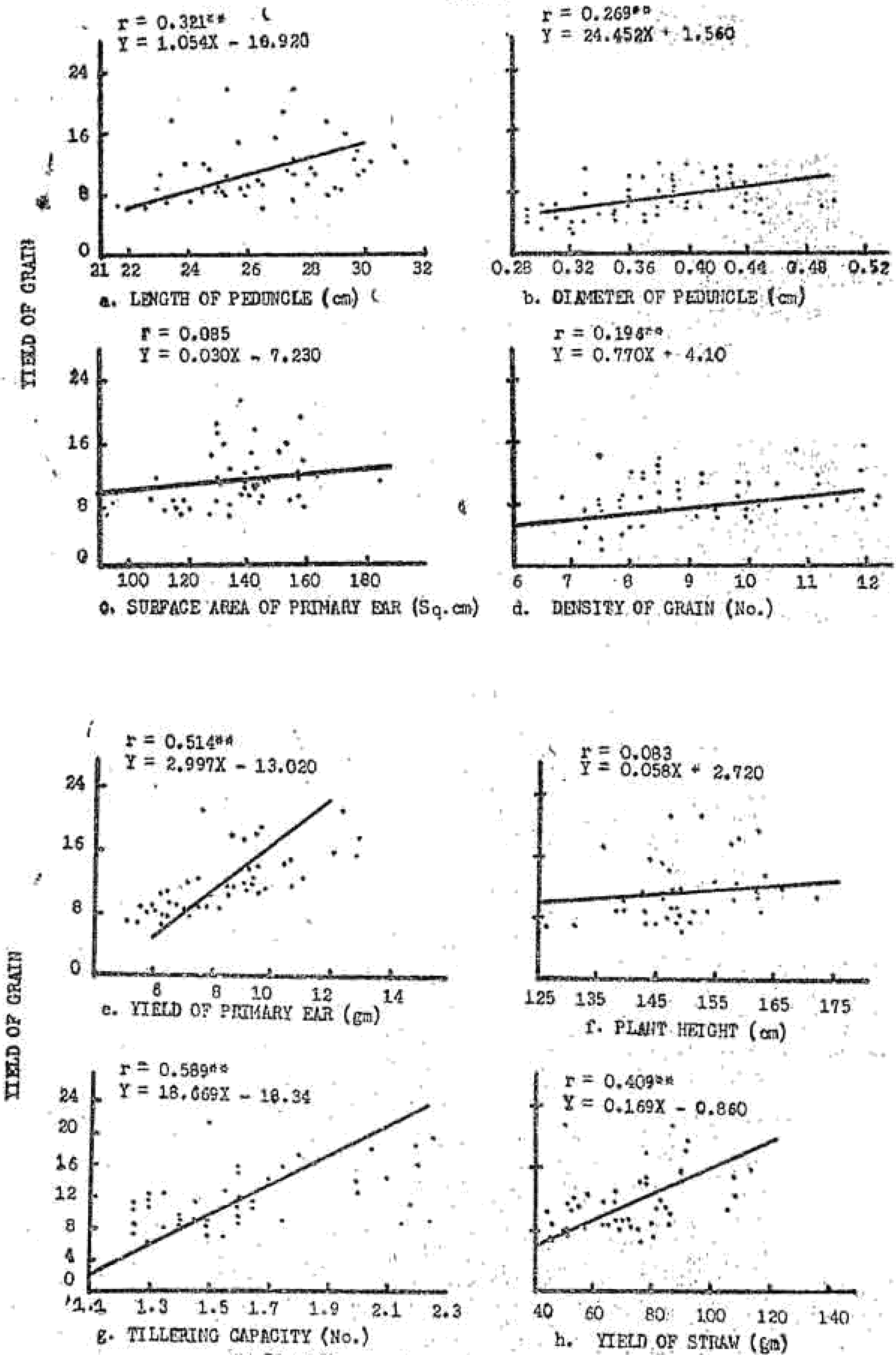
Characters		Diameter of peduncle (x_2)	Surface area of p. ear (x_3)	Density of grain (x_4)	Yield of primary ear (x_5)	Plant height (x_6)	Tillering capacity (x_7)	Yield of straw (x_8)
Length of	P	0·254†	0·395†	0·100	0·477†	0·584†	0·273†	0·254†
peduncle	G	0·257†	0·379†	0·053	0·819†	0·727†	0·682†	0·483†
(x_1)	E	0·318†	0·420†	0·365†	0·295†	0·475†	0·056†	0·140†
Diameter of	P		0·445†	—0·013	0·426†	0·355†	0·160*	0·416†
peduncle	G		0·359†	—0·133	0·453†	0·321†	0·048	0·466†
(x_2)	E		0·723†	0·909†	0·581†	0·514†	0·387†	0·499†
Surface area	P			0·081	0·410†	0·597†	0·143*	0·341†
of primary ear	G			0·104	—0·032	0·566	0·009	0·353†
(x_3)	E			0·030	0·765†	0·639	0·250†	0·313†
Density of	P				0·434†	0·112	—0·015	0·164†
grain	G				0·488†	—0·088	—0·041	0·072
(x_4)	E				0·786†	0·652†	0·452†	0·197†
Yield of	P					0·450†	0·202†	0·329†
pimary ear	G					0·408†	0·181†	0·182†
(x_5)	E					0·482†	0·209†	0·404†
Plant	P						0·578†	0·097
height	G						—0·331†	—0·259†
(x_6)	E						0·275†	0·342†
Tillering	P							0·497†
capacity	G							0·728†
(x_7)	E							0·382†

† Significant at 1% level
* Significant at 5% level

others, except density of grain, it bore a positive correlation. Tillering and yield of straw were strongly and positively correlated. In Fig. 2a the the significant 'r' values between yield and other components as well as between components are represented. Fig. 2b depicts the extent of 'r^2' attributable to each of these characters.

Discriminant functions fitted with varying combinations of characters including grain yield, their genetic advance and efficiency percentage over the straight selection based on yield *per se* are embodied in table 4. It was found in general that functions comprising three or more characters always possessed higher genetic advance and greater efficiency than selection based

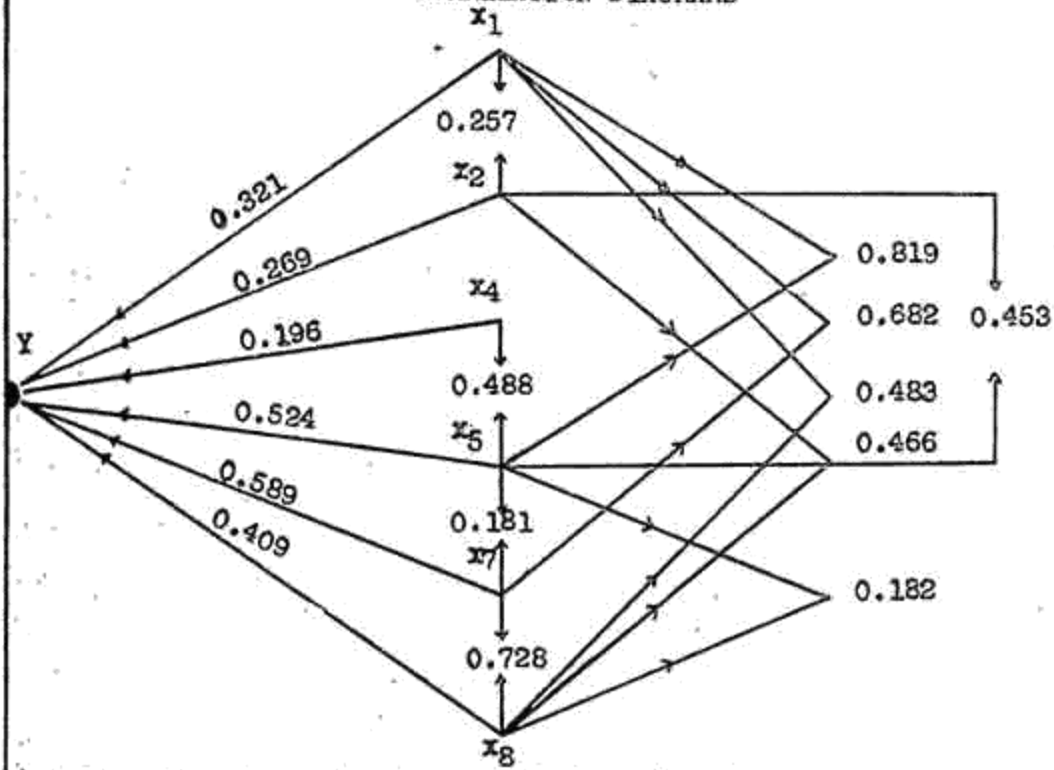
FIG. 1



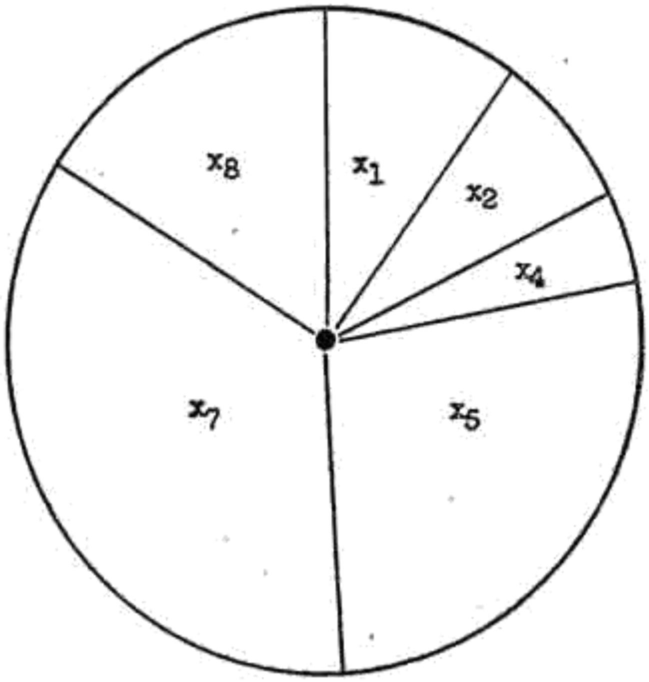
** Significant at one per cent level.

FIG. 2

CORRELATION DIAGRAMS



(a) Significant genotypic correlations (i) between grain yield and components and (ii) intercomponental.



(b) Relative degree of variability in grain yield accounted for by the six components

TABLE 4: *Indices for selection, genetic advance and percentage efficiency*

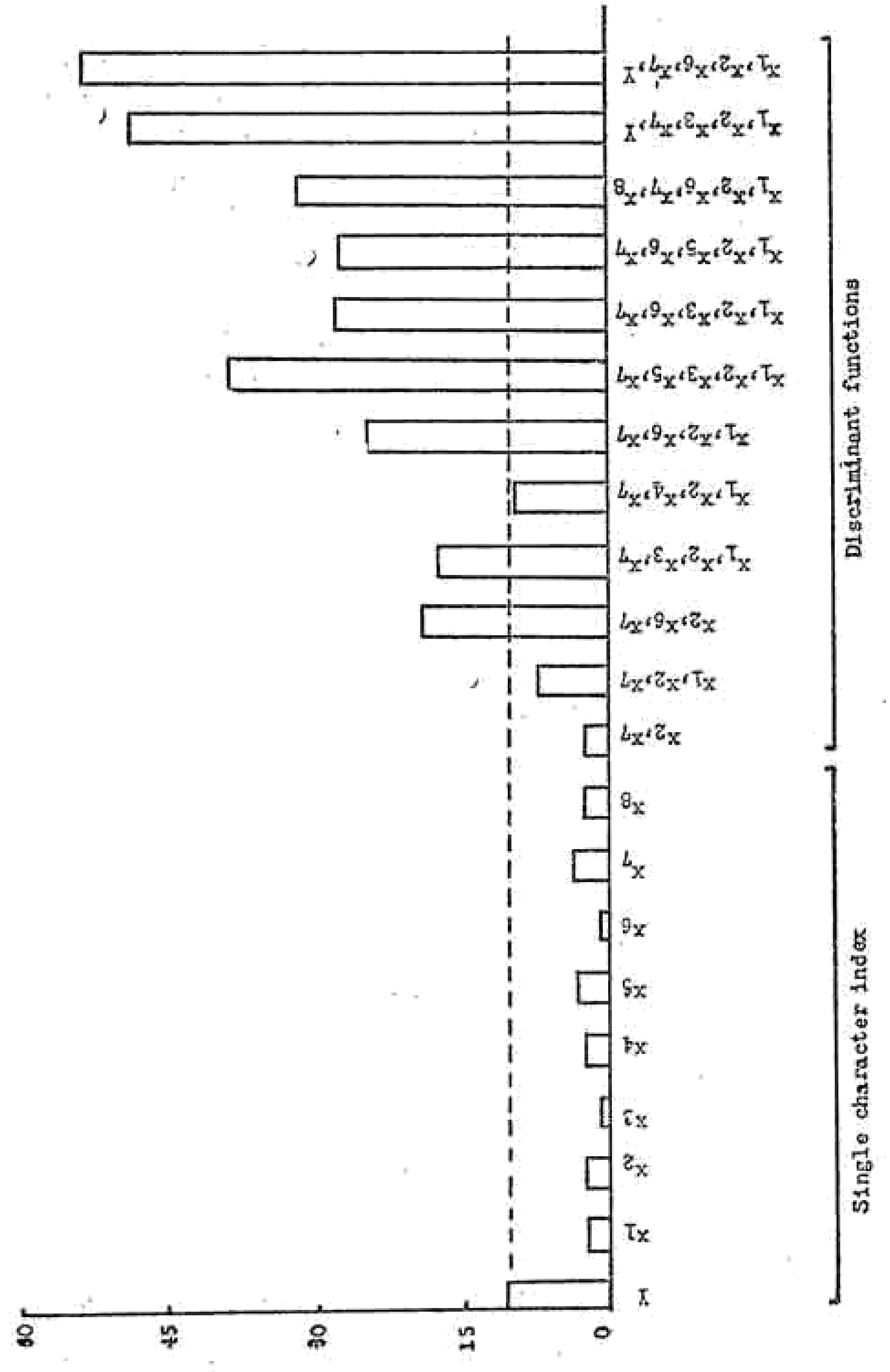
Index		Genetic advance	Efficiency in per cent
Character as index:			
y (Grain yield)	...	10·91	100
x_1 (Length of peduncle)	...	2·32	21
x_2 (Diameter of peduncle)	...	2·68	25
x_3 (Surface area of ear)	...	0·70	6
x_4 (Density of grain)	...	2·08	19
x_5 (Yield of primary ear)	...	3·10	28
x_6 (Plant height)	...	0·60	5
x_7 (Tillering capacity)	...	3·44	32
x_8 Yield of straw)	...	2·76	25
Discriminant functions:			
$3·34\ x_2 + 0·81\ x_7$	...	1·73	16
$1·32\ x_1 + 45·18\ x_2 + 10·13\ x_7$	...	7·38	68
$448·26\ x_2 - 2·57\ x_6 + 107·47\ x_7$	...	19·11	175
$8·03\ x_1 + 291·07\ x_2 + 0·05\ x_3 + 51·65\ x_7$	...	17·79	163
$1·71\ x_1 + 69·70\ x_2 + 3·75\ x_4 + 10·83\ x_7$	...	9·58	88
$19·14\ x_1 + 424·58\ x_2 - 4·80\ x_6 + 125·32\ x_7$	...	24·29	222
$52·17\ x_1 + 2346·30\ x_2 + 0·23\ x_3 - 3·38\ x_5 + 40·11\ x_7$	...	38·21	350
$25·54\ x_1 + 367·37\ x_2 + 2·33\ x_3 - 7·52\ x_6 + 156·42\ x_7$	...	27·28	250
$23·97\ x_1 + 575·47\ x_2 + 4·29\ x_5 - 5·21\ x_6 + 128·96\ x_7$	...	27·41	251
$31·98\ x_1 + 952·35\ x_2 - 9·29\ x_6 + 261·71\ x_7 - 1·45\ x_8$	...	31·62	289
$5·50\ x_1 + 378·25\ x_2 - 0·81\ x_3 + 138·97\ x_7 + 15·57\ y$	...	48·10	445
$40·54\ x_1 + 1144·36\ x_2 - 5·27\ x_6 + 94·28\ x_7 + 14·31\ y$	...	53·40	489

on yield alone. Genetic advance and efficiency percentage were very high wherever yield was also included as a character in the index. Yield in combination with x_1, x_2, x_6, x_7 gave the maximum genetic advance followed in the order of importance by (i) yield with x_1, x_2, x_3, x_7; (ii) x_1, x_2, x_3, x_5, x_7 and (iii) x_1, x_2, x_6, x_7, x_8. Fig. 3 shows the estimated genetic advances for different functions and individual characters when used as basis for selection for grain yield.

Discussion: Yield in crop plants is the ultimate complex expression of interactions between a number of such contributory characters as are governed by gene action and interaction and are also subject to effects of environment and genotype x environment interaction. This character (yield), as interpreted by Grafius (1956) in oats, can be represented by its attributes as the edges of a rectangular parallelepiped wish the yield as volume. The best way of increasing yield would be in increasing the appropriate edge. Ten characters of pearl millet have been examined in this context through correlation, regression and discriminant function techniques.

FIG. 3

Genetic advance for different indices under selection for grain yield



Analysis of variance have indicated a wide range of variability in most of the characteristics of the inbred cultures studied. It was found from the intercomponental correlations, genotypic correlation and regressions between the grain yield and other characters that yield of grain has considerable association with and regression on the length of peduncle, diameter of peduncle, density of grain, yield of primary ear, tillering capacity and yield of straw. Although surface area of primary ear does not bear significant association directly with grain yield, it shows a strong genotypic correlation with other important attributes (length and diameter of peduncle and yield of straw). These findings are in agreement with the reports of Ayyangar *et al.* (1936) and Shankar *et al.* (1963). However, Ayyangar *et al.* (1936) did not find any association between length of peduncle and yield of grain unlike in the present case. Length of peduncle is strongly correlated also with the other important characters. Another deviation from the earlier findings is the negative correlation between these two characters in the present study as against the positive correlation of earlier reports. As far as the inbreds utilised for this study are concerned, this was evident even from the visual observation of the mature plants. Tall plants produced less tillers, thus accounting for the negative correlation of plant height with yield of straw and tillering capacity. Weight of thousand grains does not have any association with grain yield.

At this point, it would be desirable to employ a method of analysis, which will take into account the knowledge about the casual relation between the variables, in addition to that provided on the degree of relationship between the characters by association analysis. While this provides some basis for the observed complexity of yield, as Mather (1949) stressed, the technique of discriminant function developed by Fisher (1936) and applied by Smith (1936) helps to predict the genotypic value of the different varieties in respect of yielding capacity, as distinct from yield itself, from the phenotypic measurement of the component characters. Various combinations of components with or without the complex character itself can be utilised in the way useful for the purpose on hand.

In the present study, discriminant functions computed with varying combinations of attributes have been tested by working out the genetic advance, assuming a constant intensity of selection pressure. The best function has been the one fitted with five characters including yield. In general, it appears as Brim *et al.* (1959) suggest that the more inclusive the index the more efficient selection is. Further, the inclusion of grain yield increases the efficiency of the index considerably. As expected from the negative correlation of plant height with yield, the weight assigned to plant height is consistently little. Shankar *et al.* (1963) also found that the indices formulated by them for grain yield, plant height was to be assigned a small 'b' value. The most efficient index comprised length of peduncle, diameter of peduncle, surface area of primary ear and yield of grain as determinants of the net worth. This is in close agreement with the findings of Shankar *et al.* *(loc. cit.)* in that they also have found an index with length and girth of spike and yield of grain to have shown the maximum efficiency. Therefore, selection of parents with the aid of this function can be expected to give considerable improvement as promising parents of crosses. It needs a mention at this point that, correlations may reflect the system by which a set of lines arose and have little relationships with the associations a breeder may expect to find within a segregating populations.

Summary: Fortynine inbred (S_{13}) pearl millet cultures studied in a field experiment for their variability and association of different characters in relation to grain yield through correlation, regression and discriminant function techniques revealed the following: The cultures varied widely in all their characters except days to heading. Yield of grain had a strong and positive association with length and diameter of pedulcle, density of grain, yield of primary ear; tillering capacity and yield of straw, while it showed negative correlation with plant height and no correlation with surface area of primary ear and 1000-grain weight. Surface area of primary ear, however, showed significant association with other important characters.

In order to assess the grain yielding capacity of various populations, discriminant functions were computed with different sets of characters with and without grain yield and the efficiency of each index compared with direct selection for yield. Of the indices formulated, the ones comprising grain yield were, in general, found to be more efficient in assessing yield potentialities than indices without yield. The most efficient function comprised length and diameter of peduncle, plant height, tillering capacity and yield of grain.

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Studies on Drought Resistance in *Sorghum*—Leaf and Panicle Characters

by

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Introduction: Various investigators have been attempting to find out relatively simple and practical indices for assessing the drought resistance in various crop plants by means of morphological, anatomical and physiological studies. Even though consisderable work on this aspect has been done especially in roots and leaves in cereals like wheat, oats and paddy, much work has not been done in *Sorghum*. In this paper, the results of preliminary studies obtained on the association between morphological characters and drought resistance are presented.

Review of Literature: Miller (1916) believed that a smaller leaf surface together with a larger root system are instrumental in keeping the water supply of the leaf sufficient to retard incipient wilting. Martin (1930) observed that *Sorghum* leaves have a waxy and cutinised epidermis which reduces evaporation. Clements and Kulota (1942) in trying to find out the moisture index in sugarcane observed that drought resistance is characterised by reduced leaf area. Dutt and Rao (1948) (quoted by Argikar 1955)

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