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rural population is worth the high purpose of a whole host of public servants and none among them will equal an agricultural graduate in initial equipment. To us, therefore, it looks as if there is a tragic element in the enforced idleness of this class of men, when each of them could be made a centre of dynamic strength. A comprehensive plan of absorbing all agricultural graduates with a view to permeating the service to make it as it were rural minded, strikes us as the only solution to this unemployment of educated youth and their utilisation in agencies for schemes of rural reconstruction. We have not written this in any opportunist mood born of current distress, but with the high purpose of tackling this fundamental problem right at its bottom. We hope that our appeal will fall on responsive ears.

Cattle Breeding. With reference to our note on Cattle Breeding in the December issue of the journal, we are glad to learn from the Director of Agriculture, that work on Ongoles was not given up, but that "the select breed of Chintaldevi was transferred to Guntur, to form a nucleus."

The Late Dewan Bahadur K. Rangachariar. It is with feelings of deep sorrow that we have to announce the death of Dewan Bahadur K. Rangachariar on the 10th of May at his village, Lakshmipuram, near Kuppam. He had been ailing for sometime but none suspected that the end was so near. It is sad to face the fact that only ten years have elapsed since he was a pensioner. Attuned to very active habits, these years were to him a period of continued work, until he broke down under its strain. Simple in habits, warm in his emotions and encyclopaedic in his equipment, his was a great soul. In his death, India has lost a Botanist of repute. To his many students and to us at the Agricultural College and Research Institute, it will be many years before the memory of his genial presence and incessant activity fades away. We offer to Mrs. Rangachariar and other members of the family our sincere and heart-felt condolences.

ENVIRONMENTAL AND GENETIC INFLUENCES ON THE SORGHUM CROP AT NANDYAL

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Introduction. The area under sorghum in the Nandyal tract is fairly extensive and comprises the whole of the Kurnool district, parts of Cuddapah, Anantapur and Nellore districts and portions of the Nizam's dominions. The whole of this area is under one variety—a compact-headed yellow type called '*Patcha jonna*'. Early trial of other types such as the famous white or *Tella jonna* of Bellary and some red sorghums were not found useful at the Nandyal Station. Further work was therefore more or less confined to the *Patcha jonna*

and covers a wide field of agricultural experiments on the varietal, manurial and cultural side. A few aspects of this work are presented in this paper as throwing light on some fundamental problems associated with agricultural improvements and the methods adopted to attain them.

Variability in yields. A fact of common interest in all agricultural work is the large variation in crop yields. Two aspects of this variation are of profound interest in agricultural studies namely the annual variation and the field variation. When improvements whether varietal or manurial are to spread over several thousands of acres, a wide range of soils and other conditions are to be encountered, and it is desirable that the extent of improvement likely to be effected is perceptible beyond the range of variation. In the sorghum crop, for example, seasonal as well as field variations are high On an average, for the past 25 years, over an area of 80 acres at Nandyal Farm, the effects of these causes can be quantitatively expressed thus:—

	Per acre. lbs.	Per cent of total variance.
Seasonal variation.	135	49%
Differential field variation.	150	51%

Expressed in terms of the average acre yield of unmanured land, which is 370 lbs. per acre, these are respectively an annual variation of 37% and a field variation of 41%. Of these two factors the percentage of variance attributable to seasonal factors in the several experiments is as follows:-

	Percentage of variance.	Period.
Comparative trials	79%	15 years.
Manurial trials.	57%	8 years.

These figures are very high indeed and their extent has to be borne in mind as factors over which we have no control but with the working of which we are indirectly connected.

Variation due to agronomic factors. The next step in our enquiry will be to determine how far the variations induced by the several channels of agricultural improvements compare with these annual variations. For this purpose the data of the several agricultural experiments were analysed by the methods of variance of Fisher. The experiments were conducted from 1912 onwards and except for the restriction that the random arrangement of plots has not been followed, have been conducted over a large number of years with a fair number of repetitions to ensure statistical accuracy. Subject to the original designs, each of the manurial, cultural and varietal trials was conducted separately so that the effects of these are not strictly comparable. But by comparing each of these factors with the annual variations and the experimental error, over several years, the effects of the several factors can be expressed approximately on a common basis as follows :—

	Standard deviation in pounds per acre.	Period.
Seasonal variation	174	15 years.
Varietal "	118	" "
Manurial " (artificials)	176	3 "
" " (Cattle manure)	122	8 "
Block " "	105	15 "
Experimental error	45	15 "

From the figures given, it will be seen that the variability due to 'artificial manuring' is the largest of the agronomic influences, followed by 'cattle manure' and 'varieties'. In general, it can be said that the larger the variability of a factor the greater the measure of improvement that can be effected. To understand more fully the influence of each, it will be necessary to know the actual increases obtained.

The extent of the different agricultural improvements on sorghum. From results of the several agronomic experiments the following table gives the increases in pounds per acre due to the several factors :—

Table I. Increases in pounds per acre due to the several agronomic factors.

Nature of factor.	Nature of control.	Value of control		Increase over control		Percentage increase		Remarks.
		Grain	Straw	Grain	Straw	Grain %	Straw %	
Manures.								
Cattle manure, super 1 cwt. & am. sulphate 2 cwt.	No manure.	370	1440	315	800	85	56	New Series.
Artificials only.	do.	do.	do.	250	700	68	49	(The immediate effect of manures applied to Sorghum appearing in alternate years in the rotation).
Cattle manure only (5 cartloads).	do.	do.	do.	97	230	26	16	
Cattle manure (continuous 8 years).	do.	433	1000	390	536	90	54	Old Series (single plots)
Poudrette (continuous 4 years).	do.	450	1510	406	920	90	61	do.
Varieties.								
N 23/10	T_6	557	1953	88	272	16	14	New Series
T_1	Local	410	1800	40	- 220	10	- 12	Old Series
T_6	do.	410	1800	20	- 100	5	- 6	do.
Spacings.								
28" Drill	10½"	464	1681	- 27	- 337	- 6	- 20	Old Series
16" do.	do.	do.	do.	- 40	- 200	- 9	- 12	do.
24" do.	do.	390	1502	39	- 443	10	- 29	New Series
20" do.	do.	do.	do.	- 15	- 418	4	- 28	
16" do.	do.	do.	do.	52	- 182	13	- 12	
24" do. Thinned to ½ as control.	24" Drill	429	1060	4	- 175	1	17	
20" do.	do.	375	1084	66	- 68	17	6	
16" do.	do.	442	1320	- 37	- 284	- 8	22	
10½" do.	do.	390	1502	23	- 330	- 6	4	

(a) *Manures.* From the figures given in Table 1, it will be seen that artificial manuring gives by far the largest increase on the crop. The effect of the cattle manure is variable. In the first series of experiments (1913—24) it gave so high an increase as 400 lbs. per acre applied continuously over eight years in doses of 10 cart-loads per acre. This includes the accumulated residual effects. Recent trials have however not been so encouraging, the immediate increase being as small as 80 to 100 lbs per acre when applied alone or over artificials. Part of the difference is due to the smaller dose (5 cartloads), but it should be mentioned that there are residual effects. Although the extent of increase due to artificials is fairly high, their application is unfortunately not an economic proposition even when two years' residual effects on the succeeding cotton and *jonna* are considered. In the case of cattle manure, the profits depend more or less on cost, but considering the limited quantity of cattle manure available and the great demand for it in paddy lands, the area that can be covered is necessarily restricted. The results would also indicate that unless when applied in doses of 10 cartloads and more per acre the effect will not be appreciable. We are therefore left to conclude that although manuring is a marked channel of increasing sorghum yields, economic considerations prevent its utilisation to the full extent. Among other sources of manure that have been experimented with on the farm, mention may be made of the preparation of composts and poudrette [1]. Our present experience is that these can be made but the profits depend on the way in which the labour cost is calculated. One fact may be mentioned in this connection, and that is the high conserving value of poudrette. Results at the Nandyal Agricultural Station show that in four years of application of poudrette, the land has increased in fertility at the rate of 332 lbs per acre, per year, while, with cattle manure the increase has been only 78 lbs per acre for the same period. This would indicate the large possibilities of poudrette.

(b) *Varietal improvement.* Although this represents the easiest channel of crop improvement the magnitude of increase due to this cause is small, being within 100 lbs. per acre as can be seen from table 1. Considering that these figures refer to the highest increase from 17 years of comparative trials, with as many as 37 strains, they can be taken to be sufficiently indicative. Unfortunately, the fullest use cannot be taken of these increases, as the high-yielders have generally poor quality of grain. Popular opinion among ryots, however, seems definitely to favour a bold type of grain even at the sacrifice of yield. For instance, a bold-grained type such as T. 6 has been popular with the ryots for the past 15 years although with a small-grained strain, N. 23/10, we are not able to advance very much inspite of it being definitely higher in yield. Recent trials at the Nandyal station show

1. Manure prepared from nightsoil.

that considerable genetic variations exist in the size of the grain and that much improvement can be effected by choice of a suitable type. The quality of the straw is also another factor of varietal improvement. In Nandyal, two types of sorghum exist, one with sweet stalk and dull midrib and another with pithy stalk and white midrib. The two combinations were found inseparable for a long time but we have recently isolated the two types, of which the one with a white midrib and a sweet stalk has economic possibilities. Another channel of improvement on the genetic side is the percentage of grain to earhead, a character which is not affected significantly by such environmental influences as manuring. Although the magnitude of the varietal improvement is relatively moderate, it is still of importance on account of the above three characters.

(c) *Spacing experiments.*—An examination of Table I will show that under conditions of Nandyal the acre yields of grain are not significantly affected by different spacings. Closer spacings give more straw yields and are therefore preferable.

Environmental and genetic variations on the characters of the plant. From the point of view of the scientific investigator, it is not sufficient to know the quantity of the improvement; it is also useful to know the channels through which the variation is caused so that improvement can be effected through all sources. The sorghum crop especially, is very sensitive to environmental influences and the characters on which these effect are most marked, are also those in which varietal differences exist. The relative importance of these two factors can be understood by the following data from 22 varieties giving the influence of a border position in a plot on the several characters.

Table II. Analysis of variance. Border effect.

Variance due to freedom		Mean sqaure variance in character.		
		Weight of head (grms.)	Length of head (c.m.)	Number of grains per head.
Varieties	21	495	113	364490
Border effect	1	27805	129	1188990
Differential response	21	212	36	180505
Random	88	87	67	50417

It will be seen that the effects due to varieties as well as the border position are very significant, the differences being very pronounced for weight of head and number of grains per head. In the case of weight of grain, it was found that there was a significant and progressive decrease in the character from the top of the head towards the bottom, as shown below :

"able III. Mean weight of 1000 grains along the earhead from top to bottom (grms.)

Average of	1st quarter (Bottom)	2nd quarter	3rd quarter	4th quarter (Top)
Centre heads	28·3	28·9	29·1	29·6
Border „	30·9	31·1	31·2	31·3

The analysis of variance for this character is as follows:

	Freedom.	Mean square.
Varieties.	21	87·8
Position along head.	3	146·1
Interaction of variety & position.	63	3·2
Border effect.	1	8525·4
Interaction of border and variety.	21	20·0
Random	418	6·8

The figures give very clear evidence, as to how large an influence is exerted on the earhead characters of the sorghum crop by such a purely environmental variation as border effect, ascompared to the varietal factor.

The weight of the earhead. As a next step in the enquiry, the influence of the different environmental and genetic factors on the weight of the earhead was investigated from the several agronomic experiments, this character being very important for yield. The results are as below:—

Table IV. Influence of th different agronomic factors on the weight of earheads and the number of earheads per plot.

Nature of factor.	Nature of control.	Weight of earheads (gms).		Number of earheads perplot of 2 cents.	
		Increase over control.	Value of control.	Increase over control.	Value of control.
Border influence.	Centre heads	28·9	17·5	...	...
Varieties.					
(Maximum effect).	Local	4·7	12·8	—45	478
				20	478
Manuring.					
Artificial & cattle manure.	No manure	8·4	15·3	21	465
Cattle mauring.	„	2·6	15·3	—33	465
Artificials.	„	3·5	15·3	78	465
Spacing.					
24" drill.	10½ drill	6·9	9·1	—169	498
20" „	„	4·7	9·1	—174	498
16" „	„	1·6	9·1	— 43	496
Thinned to half as control. 24	24"	5·9	16·0	— 80	329
20"	20"	5·9	13·8	— 51	324
16"	16"	2·9	10·7	—122	455
10½"	10½"	2·7	9·1	— 94	498

Leaving out of consideration the border influence which is very high due to the limited sphere of its action and taking as the basis of comparison the maximum values as representing the possible increase due to each factor, it is seen that the influences of manuring and spacing on the earhead weight are to higher than that of the varieties. As these figures are obtained from large samples made from bulk fields, the result can be of wide application. For purposes of yield studies, however, the earhead weight is not the sole factor influencing the result. Recent studies have shown that this character is profoundly affected by changes in population. In the spacing experiments, for example, every increase of spacing whether between lines by use of drill or within lines by thinning, produced a pronounced and statistically significant increase in the size of the earhead, as given below, although the acre yield is not affected.

Table V. Spacing experiments—Analysis of variance.

Variance due to.	Freedom	Mean variance in the characters.			
		Yield of grain.	Yield of straw.	Average wt. of grain per earhead.	Number of earheads per plot.
Drill spacings.	3	230·6	63·4	·0581	36819
Thinnings (wide & narrow).	1	181·6	97·5	·0700	47633
Interactions.	3	137·7	7·2	·0047	2313
Blocks.	2	3355·2	122·7	·0039	17096
Random.	14	298·6	10·7	·0078	3810
Significance of spacing effects.		Not significant.	Significant.	Significant.	Significant.

This high response of earhead weight to population seen above, makes any improvement in earhead weight alone of practically no value. What is wanted is an increase of population as well as earhead weight. From an examination of Table IV, it will be seen that the plots manured with artificials alone or combined with cattle manure, satisfy both these conditions. We are not in a position to state why cattle manure gives a lower number of earheads per plot than the artificials, although in both cases the same seed rate and conditions of sowing were employed. If mere increase of the yield is the problem on hand, the application of artificials and the use of a moderate seed rate appears to be the best method from the farm data for both grain and straw. As already mentioned, considerations of cost do not justify the use of artificials at present.

Rainfall, 'trend' and date of sowing influences. We have already mentioned that the influences of the several agronomic factors are superimposed on the already existing variations of soil and season. At the Nandyal Agricultural Station no work has been done yet on the nature of the soil influences and the effect of tilth on yields, but as

mentioned in a previous section the nature of the influence is sufficiently high (S. D. 150 lbs per acre) to warrant intensive study. In regard to the seasonal variation, it will be interesting to know the nature of influences at work. Part of these changes is due to a cyclic influence or 'slow trend' which takes place independently of the weather. The nature of this influence is given in Fig. (1) from which it will be seen that the yield of sorghum exhibits a tendency to high and low yields once in seven years. The magnitude of this influence is however moderate being less than 15 % of the total variance. With regard to weather elements, we have data of rainfall and yields for the past 25 years. from which we find that the nature of the rainfall influence on the jonna crop is limited, the average effect due to every inch of additional rainfall in pounds per acre at different periods of the year being as in Fig. II (Fisher's method of multiple regression by polynomials. Phil. Tran B. 213, 1925). The percentage effect of rainfall on yield is however small and the effect is not statistically significant ($R = 0{\cdot}4$ $P > {\cdot}05$) We can therefore conclude that the existing variations in the amount or distribution of rainfall at Nandyal does not materially affect yields. In a similar manner, the date of sowing, and changes due to variations in rainfall—incidence, which ranged from the middle of September to the middle of October, had no significant effect on yield ($r = 0{\cdot}289 \pm {\cdot}121$). It was also found that the effect due to soil deterioration was practically nil (less than 1%). That the soils have been maintaining their fertility may be due to the better tilth on farm lands and to the effect of improved varieties. It is seen, however, that no significant increase in fertility on cropping power has occurred during the past twenty five years, probably because the quantity of manure applied (3 or 4 cartloads per acre once in four years) is hardly enough to add to fertility. An examination of all of the above factors shows that more than 60% of the seasonal variation is due to causes other than those above mentioned. Although this variation is high, the analysis of the several agronomic experiments show that the effects of manuring, varieties etc. take place independently of the annual variation, and are statistically significant in most cases. The extent to which they contribute to the acre yield have already been discussed in a previous section.

Effect of size of the earhead and quality of grain on the succeeding crops.—As channels of increasing yields, mention may be made of the effect of grading grain which is being employed in Bombay ; and in our own Province the studies of the cropping power of seed in relation to manurial practice have been undertaken by Viswanath and Suryanarayana. In Nandyal we have got only one year's trial of grading the seeds and the results are not consistent or statistically significant. With regard to the other aspect, we have been experimenting on the effect of sowing grain obtained from different sizes of earheads in our row yields. We have found that in all the

Fig II. AVERAGE EFFECT IN POUNDS PER ACRE OF EVERY INCH OF ADDITIONAL RAINFALL ON THE SORGHUM CROP AT NANDYAL

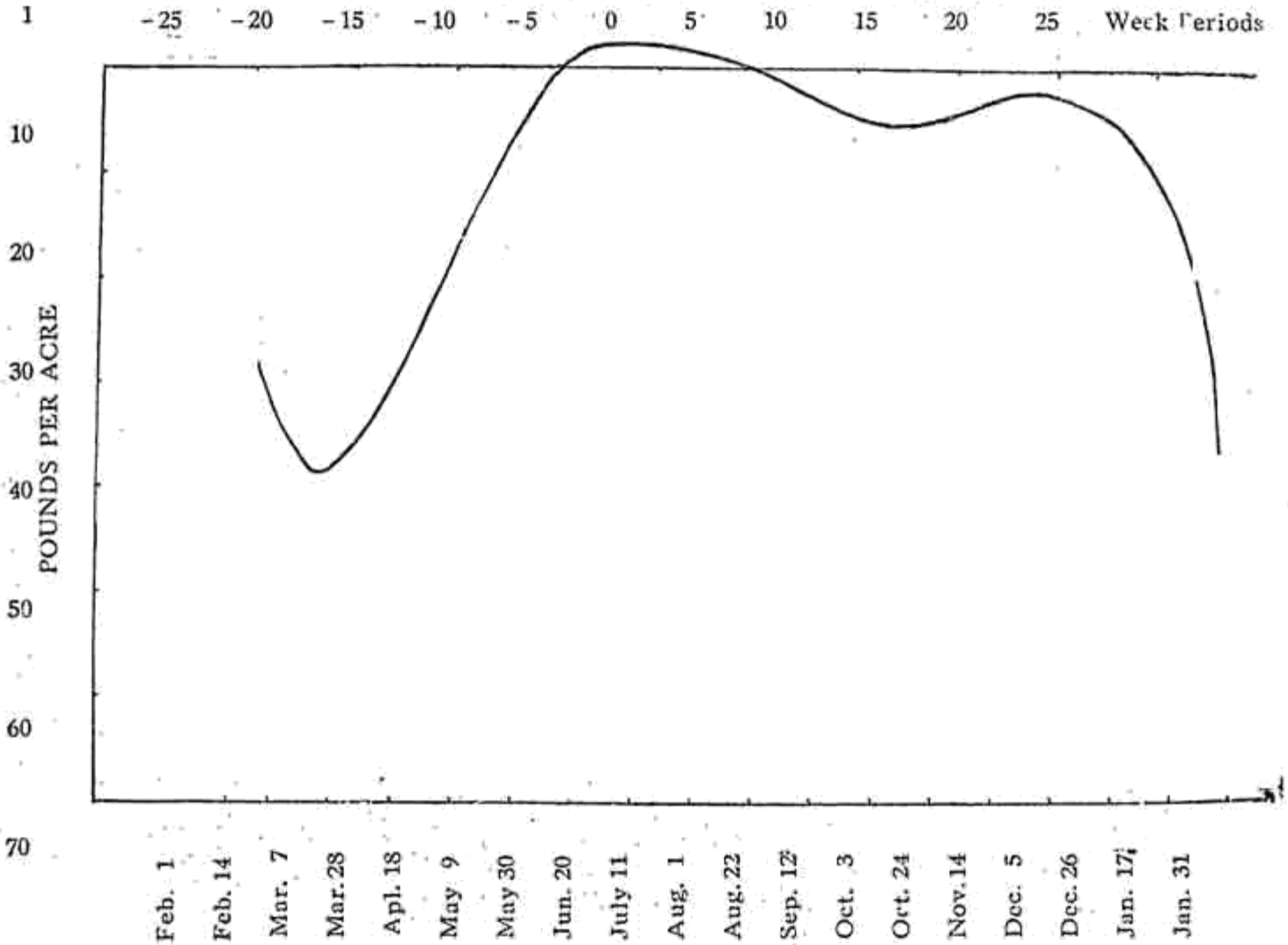
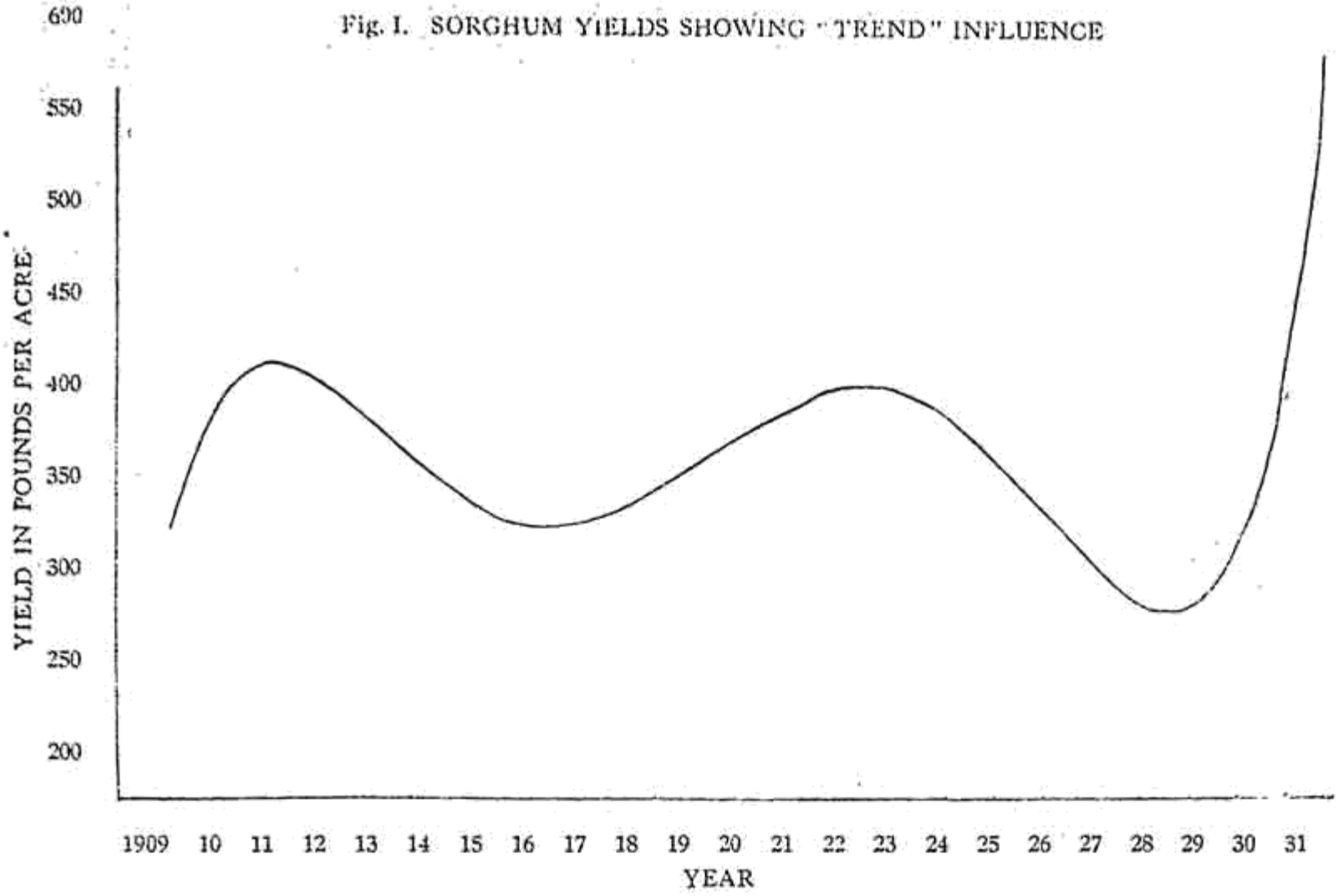


Fig. I. SORGHUM YIELDS SHOWING "TREND" INFLUENCE



characters—weight, length and circumference of head—the correlations between parent and offspring were invariably negative as follows:

Table VI. Correlation of parent and offspring in sorghum characters

Strain No.	Weight of earhead.	Length of head.	Circumference of head.	Height of plant.
25/102	—·701	—·530	—·610	—·203
26/15	—·324	—·272	—·133	—·338
26/116	—·644	—·365	—·418	—·421
28/3	—·854	—·282	—·577	—·212
29/68	—·728	—·755	—·276	—·743
Mean value of 'r'.	—·650±0·059	—·441±·061	—·403±·060	—·383±·066

Although the correlations are significant in the large majority of cases, there is no relation between the weight of the head sown and the yield of the progeny row ($r = 0{\cdot}145 \pm {\cdot}104$) and only a slight one between the number of earheads per plot and the yield ($r = {\cdot}310 \pm {\cdot}093$). There is however significant correlation between the weight of the earheads sown and the number of plants in the row ($r = 0{\cdot}649 \pm {\cdot}062$). The inference is probable from this that the greater weight of earhead has produced a larger number of plants which persisted in spite of thinning and that these have responded to closer spacing by a smaller size of earhead as in the spacing experiments discussed in a previous section. The results indicate the importance of keeping the number of plants constant in such studies although the authors recognise the practical difficulties in handling sorghum. There is, however, nothing in these results at variance with Viswanath's findings as the seeds he used were obtained from manured land, and were therefore different.

Conclusions.—We have so far endeavoured to show the possible limits of different agricultural improvements on the sorghum crop, and the relative importance of genetic and environmental influences increasing its yield. Manurial improvements have been found to have relatively higher intensity than varietal forces but application of artificials is however, excluded by cost considerations. The value of poudrette as a manure appears very promising and our present efforts are concentrated on the making of this and other organic composts on a large scale. The sorghum crop is shown to be very sensitive to environmental influences and responds significantly to even small variations in spacing and very considerably to manuring or border effect. A wide variation in soil is indicated in the tract and the possibilities of more intensive tillage are still to be investigated. Methods of grading the seed towards increase of yield are under study. Although seasonal variation is very high in the crop, some of the environmental, influences such as manuring, compare favourably with such variations and the possibilities of maintaining a moderately high yield irrespective of the season by intensive methods, are indicated.