PATH ANALYSIS IN RICE (*Oryza sativa* Linn.)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled 'Path Analysis in Rice (Oryza sativa Linn.)', is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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Vellayani,
27th July, 1978.

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INTRODUCTION

INTRODUCTION

Biometrical studies have proved themselves to be of immense worth to the breeder of plants and animals, because they help in the clear understanding of the absolute criteria, on the basis of which, inherently and economically superior and desirable types and varieties could be evolved. The present investigation was carried out in this line, so as to help the scientific rice breeder perform his duty more satisfactorily and effectively.

Remarkable break through has become possible in the case of rice in enhancing grain production with the better understanding of the concept of the ideal plant type, and the evolution of the novel high yielding varieties. However, the requirements that are needed for such a variety differ from place to place, and also in consideration with the widely fluctuating agroclimatic ecological conditions that generally prevail in the usual rice growing tracts. The most appropriate solution to this problem could be resolved only by a scientifically knowledgeable rice breeder.

The prime job of the breeder is to identify the superior, and more desirable type in a community exhibiting variability. For this, he must be equipped with adequate scientific knowledge, particularly on the criteria, on which he could depend, for carrying out effectively the selection procedure.

Informations in the aspects, already mentioned to as above, are available, but not adequately. Yield of grain, is the main objective as far as the rice breeder is concerned. This character is often subject to environmental influence, that alone is capable of imparting wide range of variability. Apart from the environment, the genetic make up also does contribute its own might in the varied manifestation of the character. The genetic system involved is by itself enough complex. Yield is a highly complex character, whose inheritance is dependant upon the functioning of an intricately organised polygenic system. Further, the character is influenced by other variables as well. The number of such variables is generally large, and each variable is found to influence the character in a different fashion and in differing magnitude. The object of the practical breeder is, therefore, to identify the more important components from the others, and direct selection, preferably, on the basis of such criteria alone.

Two entirely new, but different, and at the same time interrelated lines of biometrical approach need special mention in this context.

The first, following the identification of the components, involves the analysis of their interrelationship. Genotypic correlation is estimated as a routine in this regard. Further, an understanding of the attributes of the components, such as Heritability, Genetic Advance and Genetic Gain under different intensities of selection, and which could be statistically estimated, helps in the confirmation of the relative importance of the components.

Secondly, mere identification of the correlated variables, and the estimation of the degree of their association, by themselves, are often felt to be inadequate, because these factors exert their influence directly, as well as indirectly through other variables. Further, the interference of the residual element is often liable to induce unwanted obliterations in the final causation of the effect. Wright (1921, 1934, 1954), devised a technique, widely known as the path co-efficient analysis. This method of analysis, in combination with the information obtained from the correlation studies as already mentioned, helps the breeder to make himself aware of the more reliable and important criteria upon which the selection should be based.

The present investigation on rice (<u>Oryza</u> <u>sativa</u> L. race <u>indica</u>) was carried out in the premises of the College of

Agriculture at Vellayani under the Kerala Agricultural University, with a view to furnish the practical rice breeder with the required information, so as to enable him identify the potentially high grain yielder from the less desirable types, and to exercise selection procedure in a relatively more accurate and dependable manner.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

As has already been pointed out in the introduction, two lines of biometrical study have been conducted, during the course of the present investigation in rice, at the College of Agriculture, Vellayani under the Kerala Agricultural University during June - September, 1977.

The first, relates to the understanding of the correlated components of yield of grains and their relative importance on the basis of the statistically computed parameters - Heritability, and Genetic Advance and Genetic Gain at different intensities of selection.

The second, involves the assessment of the magnitude of the relative direct and indirect influence of these variables, and also that of the residual factor, on yield of grains. Here, the theory of causation and effect is made applicable and the path co-efficient analysis method was resorted to.

Certain authors have already carried out similar lines of study in rice. Further, it was conducted in several other crop species as well.

This review confines only to reports made in rice.

1) Correlation of variables

Galton (1889), conceived the idea of correlation of variables for the first instance.

Fisher (1918, 1954), developed the method of applying the theory of correlation of variables, in the understanding of their influence in biologic systems.

Snedecor and Cochran (1967), improvised the mathematical computation of the co-efficient of correlation.

The expression of inherited characters is often influenced by the genotype, the environment and the genotypic - environmental interaction.

Burton (1952), introduced a convenient procedure for the calculation of the phenotypic and genotypic co-efficients of correlations.

Genetic parameters like heritability and genetic advance and genetic gain under different probability levels of selection have been often found to be of great use for assessing the relative importance of these inherited and correlated variables.

Hanson et al., (1956), proposed the mathematical relationship of various estimates on computation of heritability. This attribute is generally expressed as the percentage, and in the broad sense it refers to the proportion of variance due to genotype over the variance due to the phenotype.

Johnson et al., (1955), introduced a methodology for partitioning the total variance into that due to genotype, phenotype and error, in the analysis of variance. Error, in this context refers to genotypic-environmental interaction.

Lush (1949), and Johnson et al., (1955), devised an accurate and easily manageable procedure for the calculation of the genetic advance under specified intensity of selection.

Johnson et al., (1955), further, substantiated the advantage of computing the genetic gain under selection and its usefulness in relative comparison of variables.

These two parameters, genetic advance and genetic gain, are of great value to the plant breeder in understanding to what extent they could be possessed, and made advantage of, in respect of certain desired polygenic characters under specified probability levels of discrimination to particular genotypes during selection.

Vibar (1920), reported the positive association of yield with duration, height and length of panicle.

Bhide and Rao (1927), observed high positive correlation of yield with number of ear bearing tillers and low correlation with length of main panicle.

Mahalanobis (1934), while studying the various characters in 147 rice varieties, found that mean yield was correlated with number of tillers per plant and length of leaf. Further, he observed that grain size, plant height and duration as independent characters.

Rao (1937), obtained high correlation of yield with number of tillers, length of panicle and number of grains per ear.

Chakravarthy (1940), found no significant relationship of yield with length and breadth of flag leaf, and thickness of grain.

Ganguly and Sen (1941), reported the positive association of height of tiller, length of panicle, and number of grain per panicle, with yield.

Ramaiah (1953), while reviewing the experimental results obtained at various rice research stations, stated that yield was positively correlated and with mean yield and number of tillers per plant. Further, he observed relatively weaker positive association of yield, with height, ear length and mean number of grains per ear.

Eikichi (1954), obtained high positive correlation between yield and tillering, weight of ear, length of ear and number of grains per ear.

Ghose et al., (1956), based on their studies on correlations at intervarietal level, reported positive correlation of yield with length and number of panicle. Further, they observed that the contribution of height towards yield was only negligible.

Sayed and Krishnamoorthy (1956), conducted a biometrical study in rice planted at different spacings and found high positive association of number of ear bearing tillers and length of ear head.

Ghose et al., (1960), recorded strong association of yield with plant height, number of tillers, panicle length, panicle weight and number of grains.

Chandramohan (1964), recorded close association of number of ear bearing tillers, number of grains per plant and the yield of straw with yield of grains in rice.

Guevarra and Chang (1965), reported positive correlation between culm length and the mean length of elongated internodes and high correlation between number of days to heading and the average number of leaves, in 62 rice varieties and lines.

Sastry et al., (1967), made correlation studies in eleven short statured high yielding rice varieties, and found highly significant positive association of yield with number of ear bearing tillers, plant height and number of sterile grains per plant.

Ganesan et al., (1968), observed moderate correlation between the length of grain and grain weight in 30 rice varieties, comprising of three maturity groups, ten in each.

Roychoudhury (1968), conducted correlation studies in 30 rice varieties for 3 years and reported positive correlation of grain yield with plant height.

Lin (1969), recorded significant positive association between panicle length and heading date, and between leaf area and panicle length, in a progeny of high tillering variety of rice.

Sarathe et al., (1969), conducted a study involving 5 rice varieties, and observed significant positive association of yield with panicle length, number of tillers per plant, and 1000-grain weight under low fertility level, but the associations were found to be insignificant under high fertility level.

Rao (1970), noticed significant positive correlation between grain yield per plant and panicle length, and observed positive correlation between panicle length and number of grains per panicle, in the progenies of T(N)1 x TKM 6 and T(N)1 x Basumathi.

Rao and Goud (1971), while studying rice under three environmental conditions, recognised the high correlation of number of effective tillers and grains per panicle with grain yield.

Chandrasekharan and Karivaratharaju (1973), recorded positive correlations between grain yield and the photosynthetic surface areas of the flag leaf, glume, rachis and peduncle.

Chandramohan and Narayanasamy (1973), with their correlation studies involving 20 tall and dwarf *indica* rice recorded positive association of yield with panicle number and straw weight in most of the varieties, while grain number per panicle and 1000-grain weight association with yield was only in few varieties.

Cheng *et al.*, (1973), reported positive correlation of height with period from planting to heading and with panicle length in F_2 rice progeny of 4 parent cross.

El'tsov (1973), obtained high correlation between grain weight per panicle and the sum of the areas of the middle and upper leaves.

Fuchs (1973), reported high positive correlation of yield with number of panicles per plant and grain number per panicle and very weak association with 1000-grain weight on single plant basis in rice. Further, he observed positive association between panicle length and plant height, both on single plant basis as well as on varietal basis, and slight negative correlation between grain number per panicle and panicle number per plant.

Govindaswami _et al._, (1973), reported highly significant positive association of ear bearing tillers with grain yield and negative correlation with plant height, in rice progeny of a cross.

Lenka and Misra (1973), reported high positive correlation between grain yield and fertile grains in four rice varieties.

Mishra _et al._, (1973), recorded a significant, negative correlation between the number of ear-bearing tillers and both grain number per panicle and 100-grain weight.

Rao *et al.*, (1973), found highly significant positive correlation of yield with number of ear bearing tillers and panicle weight in 37 rice varieties.

Sivasubramanian and Menon (1973), reported moderate genotypic correlation between grain yield with number of grains and panicle weight in the F_2 population in an intervarietal rice hybrid.

Sreerangasamy and Murugesan (1973), recorded high correlations between plant height and leaf length, plant height and tillers and leaf length, leaf length and panicle length in diploid rice while it was very low or negligible in autotetraploids.

Subramanian and Menon (1973), recorded positive correlation of yield with plant height, number of ear bearing tillers, length of panicle, number of grains in the primary ear, shape of grain and 100-grain weight in the progenies of a tall rice varieties. Further, they observed significant association of plant height, number of ear bearing tillers and panicle length with yield in progenies of tall x dwarf rice varieties, and in the case of tall x tall progenies there was positive correlation between panicle length and grain yield, whereas in tall x dwarf progeny there was positive association of grain yield with panicle length and number of grains in the primary ear. The correlation pattern stress the need for greater emphasis on the panicle length and number of grains in the primary ear in the selection of desirable recombinants with high yield of grains.

Venkateshwarlu et al., (1973), recorded positive genotypic association of grain yield with number of ear bearing tillers, ear length, 100-grain weight and grain number per panicle.

Rao et al., (1974), in the correlation studies they conducted in high yielding rice varieties, noticed significant positive association of grain yield with leaf area index, panicles per square metre and test weight.

Srivastava et al., (1974), reported positive and highly significant correlation co-efficients, in T141 rice variety, between the number of spikelets on a panicle and three of its component characters, namely, the mean number of secondary branches per primary branch, the number of primary branches in a panicle and the mean length per primary branch.

Das and Borthakur (1975), reported that significant association between height and days to flower in a cross of short and long duration varieties.

Majumder *et al.*, (1975), showed negative association of the seasonal difference in duration with amylose activity and width of the mesophyll layer.

Saini and Gagneja (1975), reported the association of height, days to heading and other characters with yield.

Singh and Nanda (1975), with their phenotypic and genotypic correlation studies in rice, observed that both sets of correlations were in near agreement indicating that genetic variability with common effects was more important than the environmental variability with common effects. They further noticed the negative correlation of incidence of *Xanthomonas oryzae* with yield and its components.

Brar and Saini (1976), reported significant association of grain yield with ear bearing tillers, spikelets per panicle, 100-grain weight in segregating population of two crosses between tall and dwarf varieties of rice. They further observed negative genotypic correlation of plant height with yield and spikelets per panicle in 'B. 370 x T(N)1' cross and in B. 370 x IR 8 cross there was negative association of spikelets per panicle with sterility, and 100-grain weight and sterility with yield.

Dzuba (1976), calculated the co-efficients of correlation between 15 characters in 126 varieties. The highest of these involved grain weight per panicle, which was closely correlated with number of spikelets per panicle and the compactness of the panicle.

Eunus *et al.*, (1976), found that grain yield was correlated negatively with plant height and flag leaf angle, but positively with flag leaf length, second leaf length, number of panicles per unit area, number of filled grains per panicle and number of filled grains per unit area. The highest grain yield was obtained from dwarf plants which had the maximum number of panicles and filled grains per panicle and longer leaves with a more or less acute flag leaf angle.

Rai and Murthy (1977), during their correlation studies with eight rice cultivars under two fertility levels, obtained significant positive correlation of yield with grains per panicle and total dry weight.

Agrawal *et al.*, (1978), conducted correlation studies involving 80 semi dwarf rice varieties and recorded highest positive correlation of panicle bearing tillers and plant height with grain yield, followed by 100-grain weight and number of spikelets. Further, they observed low negative association of days to 50% flowering with grain yield.

2) Path co-efficient analysis

Since the correlated variables exert their influence, both directly and indirectly through other variables, and since the residual factor also gets involved, for the proper understanding of the role of causation on the ultimate effect, a different procedure of analysis has to be depended upon.

Wright (1921, 1923, 1934), introduced the path co-efficient analysis and the method has been found to be useful in solving the problems mentioned above. In this method, the theory of causation and effect is made applicable. The ultimate dependant variable is referred to as the "effect", and the components, which by themselves may or may not be dependent on other variables as the "causes".

Niles (1922, 1923), Tukey (1954), and Dewey and Lu (1959), recommended the application of the path co-efficient analysis as a potent method for resolving the accurate and dependable criteria in selection procedures in the breeding of plants and animals.

Durate and Adams (1972), emphasised the identification and the classification of the components (causes) to different orders (First, Second, Third and etcetera), and the vital importance of the formulation of the causal scheme in path analysis studies. The recommendation too have been followed with success by various authors in different crop species.

Following is a review of findings of different authors who used this analytical method in rice.

Rao and Goud (1971), who conducted path co-efficient analysis with eight varieties of rice, reported that the number of effective tillers and number of grains per panicle exhibited significant direct effect on grain yield. They recommended that these two yield components should be given preferential weightage over others in selection programmes.

Sharma and Srivastava (1971), studied the components of panicle morphology in rice and recorded that the total number of spikelets borne on a panicle was mainly determined by the number of primary and secondary branches in a panicle. Further, they observed that the secondary branches have higher influence on the number of spikelets in a panicle, than the primary branches.

Chandramohan and Narayanasamy (1973), while studying yield components and other metric traits in 20 tall and dwarf *indica* rice varieties identified that the number of panicles per clump, grain number per panicle, 1000-grain weight and panicle length, as the yield components.

Kumar and Saini (1973), showed that the panicle bearing tillers and plant height directly contributed to grain yield in short statured rice varieties.

Lenka and Misra (1973), with their path co-efficient studies in IR 8, T(N)1, Bala and Ptb. 10 rice varieties, found that the number of panicles per plant and of grains per panicle in Ptb. 10 and 1000-grain weight in T(N)1 as the important determinants of grain yield.

Mishra *et al.*, (1973), studied 49 dwarf rice strains, and reported that the number of grains per panicle, grain weight and number of ear bearing tillers have direct influence on grain yield. Further, they observed that grains per panicle having the largest direct effect, but its indirect effect via number of ear bearing tillers is as the indirect effect of 100-grain weight via the number of effective tillers. The effect of the number of ear bearing tillers through grains per panicle has high and through grain weight low negative effects. The grain weight exhibited the lowest direct effect, and through other components relative lower indirect effects which were also negative. They concluded that the number of grains per panicle, grain weight and number of ear bearing tillers as the important yield contributing components in rice.

Sivasubramanian and Menon (1973), analysed the data collected on F2 population of a diallel cross involving 4 rice varieties and along with parents, observed very high positive direct influence of plant height and panicle weight and a lesser influence of flowering duration on grain yield. Further, they observed negative influence for most of the traits through other characters on ultimate yield of grains and the influence of plant height on grain yield was mostly direct and had a negative effects through all other characters.

Sreerangasamy and Murugesan (1973), conducted path analysis in diploid and autotetraploid rice and observed that the leaf length, productive tillers and plant height directly influenced the grain yield in diploid rice, whereas in autotetraploids the leaf length showed the highest direct effect, followed by panicle length and productive tillers. Further, they observed that there was very high positive indirect effect via all other characters in diploid rice, and in contrast such indirect effects were of low magnitude in autotetraploids.

Venkateshwarlu et al., (1973), based on results from path analysis studies in 16 advanced rice strains, diverse in geographic and genetic origin, and grain yield, recorded that ear bearing tiller number and grains per panicle as those having high positive direct effect on grain yield, and that 100-grain weight has a positive indirect effect through all other variables except grains per panicle. And further, they emphasized that the ear bearing tiller number is the most important character on which selection indices are to be formulated.

Nancharaiah et al., (1974), while studying genetics of yield and yield components in dwarf rice, stated that the yield components were panicle number, grain number per panicle and grain weight.

Srivastava et al., (1974), while measuring the direct and indirect effects of 4 components influencing the total number of spikelets in a panicle recorded that the direct effect of the length of the panicle axis on the number of spikelets in a panicle was negative. The direct effect of the mean length of a primary branch and the number of primary branches on spikelet number were low and positive, and the direct contribution of the number of secondary branches per primary branch to spikelet number in a panicle was maximum. They concluded that of all the panicle components number of secondary branches per primary branch has played a pivotal role in increasing the total number of spikelets in a panicle of T141 rice variety.

Majumder <u>et al</u>., (1975), while applying path co-efficient analysis as an aid to selection for low temperature tolerance in rice observed that all characters except seasonal differences to the 5th leaf stage, days to germination and number of bulliform cells had negative direct effects on seasonal differences in heading duration. They, further, suggested that the characters such as amylose activity and mesophyll width be considered in selecting for cold tolerance.

Saini and Gagneja (1975), while examining yield and its variables by applying path analysis involving 40 semi dwarf rice varieties that had been derived from 18 crosses, claimed that the number of spikelets per panicle had the greatest direct effect on yield followed by the number of ear bearing tillers per plant, 1000-grain weight, panicle length, and days to heading.

Singh and Nanda (1975), found that the panicle number, panicle length and grains per panicle have more influence on grain yield than grain weight, while working on correlation, path analysis of yield and its components, and incidence of bacterial blight in rice. Further, they recorded that incidence of Xanthomonas oryzae was negatively correlated with yield and yield components.

Stephen et al., (1975) reported that the total dry weight as the largest direct effect on yield while attempting studies in photosensitive and photoinsensitive rice cultivars under normal and waterlogged conditions.

Singh and Nanda (1976), while examining the inheritance of yield and yield contributing characters observed that in rice, grain weight, spikelets per panicle, panicle length and panicles per plant directly influence the grain yield.

Brar and Saini (1976), while testing the segregating population of two crosses between tall and dwarf rice varieties by using path analysis affirmed strongly that the number of ear bearing tillers, plant height, sterility and 100-grain weight had the important influence on yield, and in one cross number of days to heading also played important role by influencing grain yield.

Banerjee and Sinha (1977), while measuring 11 variables in 74 rice strains by subjecting to path analysis stressed that the number of ear bearing tillers had the largest positive and direct contribution to grain yield followed by number of grains per panicle, length:breadth ratio and 100-grain weight. Most of the secondary characters expressed their indirect influence on grain yield via these traits. Although plant height contributed directly to yield, it did not exert $\overset{an}{on}$ indirect influence through the length:breadth ratio or 100-grain weight. They concluded that inclusion of shorter height as a breeding objective would not jeopardize breeding for improvement of ear bearing tillers and number of grains per panicle.

Agrawal <u>et al</u>., (1978), recorded, while studying 80 semi dwarf cultures derived from different cross combinations, that the panicle bearing tillers and plant height directly contribute towards grain yield. Further, they observed that $\overset{an}{on}$ increase in panicle bearing tillers should be reflected in an increase in grain yield and they suggested that selection for high productivity should be made on the basis of performance per se, and that plant height should be towards higher side of range (60.2 to 91.0 cm) coupled with fairly large number of panicles per plant.

MATERIALS AND METHODS

MATERIALS AND METHODS

Material

Forty cultivars of <u>indica</u> rice, exhibiting distinct diversity in morphology and performance, and representing ecogeographically different environmental adaptation, constituted the material for the study. The varieties were selected and obtained from the germplasm collection maintained at the Rice Research Station, Pattambi. Table 1 gives particulars of these varieties, which were given identification numbers V_1 . . . . . V_{40}.

Methods

The experiment was conducted under field condition at the College of Agriculture, Vellayani during June - September, 1977.

Experimental Design and Layout.

The experiment, consisting of forty treatments, was laid out in a Randomised Block Design with four replications. The size of the plot was 1.0 M x 1.4 M. Each replication (block) consisted of forty such plots (treatments) and the total number of plots in all the replications were one hundred and sixty.

Table - 1. Particulars of the forty varieties of rice (*Oryza sativa* L.) used in the study.

Variety	State	Parentage	Treatment number
Annapurna	Kerala	Ptb. 10 x T(N)1	V_1
Arobindo	West Bengal	**	V_2
Aswathi	Kerala	Ptb. 10 x $D_g V_g$	V_3
Bala	Cuttack	N 22 x T(N)1	V_4
Basumathi	Punjab	Pure-line selection	V_5
Bharathi	Kerala	Ptb. 10 x IR 8	V_6
Cauvery	AICRIP, A.P.	T(N)1 x TKM 6	V_7
Dee-gee-woo-gen	Taiwan	Natural mutant	V_8
Hamsa	A.P.	HR 12 x T(N)1	V_9
Jamuna	AICRIP, A.P.	**	V_{10}
Jyothi	Kerala	Ptb. 10 x IR 8	V_{11}
Kalinga-I	Orissa	Dunghansali x IR 8	V_{12}
Kalinga-II	Orissa	Dunghansali x IR 8	V_{13}
Kanchi	Tamil Nadu	T(N)1 x CO 29	V_{14}
Kannagi	Tamil Nadu	IR 8 x TKM 6	V_{15}
Karuna	Tamil Nadu	IR 8 x ADT 27	V_{16}
Krishna	Cuttack	GEB 24 x T(N)1	V_{17}
Kumar	Orissa	T 90 x IR 8	V_{18}
Madhu	Karnataka	T(N)1 x TKM 6	V_{19}
Mala	Bangala Desh	**	V_{20}

Contd . . . 2

Table - 1 Contd.

Variety	State	Parentage		Treatment number
Padma	Cuttack	T 141	x T(N)1	V_{21}
Pennai	Tamil Nadu	T(N)1	x ASD 1	V_{22}
Pusa-33	IARI., New Delhi	Sabarmathi	x Ratna	V_{23}
Ratna	Cuttack	TKM 6	x IR 8	V_{24}
Rohini	Kerala	Ptb. 10	x IR 8	V_{25}
Sabari	Kerala	IR 8/2	x Annapurna	V_{26}
Suhasini	Maharastra	BG 79	x IR 8	V_{27}
Suma	Karnataka	T(N)1	x TKM 6	V_{28}
Supriya	Orissa	IR 8	x (GEB 24 x T(N)1)	V_{29}
Triveni	Kerala	Annapurna	x Ptb. 15	V_{30}
IET 1444	AICRIP, A.P.	T(N)1	x CO 29	V_{31}
IR 22	IRRI., Manila	IR 8	x Tadukan	V_{32}
IR 26	IRRI., Manila	IR 24	x TKM 6	V_{33}
IR 28	IRRI., Manila	IR 833	x IR 2042	V_{34}
IR 30	IRRI., Manila	IR 26	x IR 2147	V_{35}
IR 32	IRRI., Manila	IR 20	x *Oryza nivara* x CR 94-13	V_{36}
IR 34	IRRI., Manila	**		V_{37}
T(N)1	Taiwan	Ti-chio-wu-chien (Low-Black pointed)	x Tsai-Yuan-chon	V_{38}
Culture-4	Kerala	Ptb. 10	x IR 8	V_{39}
Culture-1180	Kerala	Ptb. 10	x IR 8	V_{40}

**Information not available.

Raising the crop.

Twentyone day old healthy seedlings were transplanted in the plots with 20 cm x 20 cm spacing. Thus each plot representing a treatment, was planted with twentyeight seedlings arranged in four rows of seven plants in each.

The crop was given management care as recommended in the package of practices of the Kerala Agricultural University (1977).

Collection of data.

For each treatment in a replication, data was collected from a sample of ten plants and the remaining eighteen constituted the border.

The following observations were made and recorded.

1. Yield of grains per plant.

   Grains harvested from each plant was weighed after normal drying, and the weight was expressed in grams.

2. Number of panicles per plant.

   The total number of panicles in each plant was counted.

3. Number of grains per panicle.

The primary panicle carried filled as well as unfilled grains. They were separated from each other and counted. The total number of grains was also calculated and used for computing the percentage of filled grains.

4. Test weight of grains.

Thousand filled grains were selected at random for each treatment in the four replications and weighed accurately on the analytical balance and the value was expressed in grams.

5. Duration of the variety.

All plants, constituting the sample in each plot, were harvested on the same day. This variable was recorded as number of days taken by the plants for harvest from the date of sowing.

6. Length of panicle.

The measurement was made in centimeters.

7. Number of branches per panicle.

The primary branches alone were counted in this context.

8. Percentage of filled grains per panicle.

This was computed using the following relationship.

$$\text{Percentage of filled grains} = \frac{\text{Number of filled grains}}{\text{Total number of grains}} \times 100$$

9. Height of plant.

The height of the primary tiller was measured at the time of harvest and recorded in centimeters.

Statistical Analysis.

The data collected in respect of the metric traits, as mentioned above, was tabulated and subjected to statistical analysis.

For the estimation of mean and for the analysis of variance, the proceedures proposed by Panse and Sukhatme (1957) were used.

Analysis of variance

Source of variation	Degrees of freedom	S.S.	M.S.	F-ratio
Replications	$(r - 1)$	SS_R	s^2_R	$\frac{s^2_R}{s^2_E}$
Treatments	$(v - 1)$	SS_V	s^2_V	$\frac{s^2_V}{s^2_E}$
Error	$(r - 1)(v - 1)$	SS_{VR}	s^2_E	

Where

r = the number of replications

v = the number of varieties

SS_R = replication sum of squares

SS_V = varietal sum of squares

SS_{VR} = error sum of squares

s^2_R = replication mean square

s^2_V = varietal mean square

s^2_E = error mean square

The significance of the computed values for 'F' was tested with reference to the 'F' table (Panse and Sukhatme, 1957).

Phenotypic Variance (Johnson et al., 1955)

$$V_p = \frac{V}{N}$$

Where

V_p = phenotypic variance

V = type mean square

N = number of replications

Genotypic Variance (Johnson *et al.*, 1955)

$$V_g = \frac{V-E}{N}$$

Where

V_g = genotypic variance

E = error mean square

Phenotypic Co-efficient of Variation (Burton, 1952)

$$\text{pcv} = \frac{V_p}{\text{Mean}} \times 100$$

Where

pcv = phenotypic co-efficient of variation

V_p = phenotypic variance

Genotypic Co-efficient of Variation (Burton, 1952)

$$\text{gcv} = \frac{V_g}{\text{Mean}} \times 100$$

Where

gcv = genotypic co-efficient of variation

V_g = genotypic variance

Heritability in broad sense (Hanson et al., 1956)

$$h^2 = \frac{V_g}{V_p} \times 100$$

Where

h^2 = heritability expressed in percentage

V_g = genotypic variance

V_p = phenotypic variance

Expected Genetic Advance under selection (Lush, 1949 and Johnson *et al.*, 1955)

$$GA = \frac{V_g}{V_p} \times \sqrt{V_p} \times K$$

Where

GA = genetic advance

V_g = genotypic variance

V_p = phenotypic variance

K = selection differential expressed in Phenotypic standard deviation

K = 2.06 in the case of 5% selection in large samples (Miller *et al.*, 1958 and Allard, 1960)

Expected Genetic Gain under selection (Johnson *et al.*, 1955)

$$GG = \frac{GA}{\bar{x}} \times 100$$

Where

GG = genetic gain

GA = genetic advance

$\bar{x}$ = mean

Correlation co-efficients (Snedecor and Cochran, 1967)

$$r = \frac{SP_{xy}}{\sqrt{SS_x \times SS_y}}$$

Where

r = correlation co-efficient

x and y = variables under study

SP_{xy} = sum of products of xy

SS_x = sum of square of x

SS_y = sum of square of y

Simple correlations between yield of grain and each one of the eight components as listed earlier, and the mutual correlations among the components were worked out.

Genotypic correlations (Al-jibouri *et al.*, 1958)

$$r_g = \frac{V_{g12}}{\sqrt{V_{g1} \times V_{g2}}}$$

Where

r_g = genotypic correlations co-efficient

V_{g12} = genotypic covariance of variables 1 and 2

V_{g1} = genotypic variance of variable 1

V_{g2} = genotypic variance of variable 2

The significance of r_g is tested using 't' test.

Path co-efficient Analysis (Wright, 1921, 1923, 1934, 1954 and Dewey and Lu, 1959).

The path co-efficient methodology was used to explicit the cause-effect relationship in the systems of correlated variables under study.

Y, and X_1, X_2, X_3, X_4, X_5, X_6, X_7 and X_8 were identified as the effect and causes respectively.

A causal scheme as represented in Fig. 1 was formulated.

The variable X_4 (duration) and X_7 (Percentage of filled grains per panicle) are eliminated as X_4 is found to have very little influence on yield and X_7 is of similar nature to that of X_2 (Number of grains per panicle).

Y formed the effect, X_1, X_2 and X_3 formed the first, X_5 and X_6, the second, and X_8 the third order variables in Fig. 1. X_4 and X_7 were not included in this part of the analysis for reasons already pointed out.

For calculating the path-coefficients the

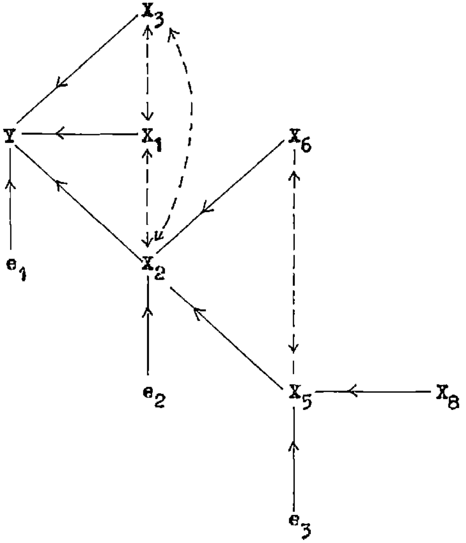


Fig. 1. Diagrammatic representation of the causal scheme in rice for effect (Y) and six causes (X_1, X_2, X_3, X_5, X_6 and X_8) belonging to three orders.

equations evolved by Dewey and Lu,(1959) were used. Accordingly,

$$Y = a_1 x_1 + a_2 x_2 + a_3 x_3 + e_1$$

$$X_2 = a_5 x_5 + a_6 x_6 + e_2$$

$$X_5 = a_8 x_8 + e_3$$

RESULTS

RESULTS

The results of the analysis of data collected during the course of the experiment are presented in the tables and diagrams appended in this section.

For the sake of convenience the following symbols are used to characterise each observation.

Character	Symbol
1. Yield of grains per plant	Y
2. Number of panicles per plant	X_1
3. Number of grains per panicle	X_2
4. 1000-grain weight	X_3
5. Duration	X_4
6. Length of panicle	X_5
7. Number of primary branches per panicle	X_6
8. Percentage of filled grains per panicle	X_7
9. Height of the plant	X_8

The mean values computed for yield and the components mentioned above are shown in Table 2.

Presented in Table 3 are the range, and the mean for the nine characters, when all the forty varieties included in the study were considered together.

Table - 2. Mean value for yield and eight other characters in forty different varieties of rice.

Varieties	Characters								
	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
V_1	12.150	6.820	114.200	22.105	124.000	24.870	10.700	63.290	85.270
V_2	15.600	8.250	110.500	19.160	127.000	23.870	10.370	82.770	81.070
V_3	13.975	7.420	86.500	28.925	131.000	24.850	11.500	59.450	85.950
V_4	11.050	6.250	103.200	20.095	122.000	19.550	7.870	77.340	77.270
V_5	6.925	5.670	73.200	20.310	125.000	28.350	9.350	63.970	129.000
V_6	13.625	6.450	110.500	27.955	124.000	22.750	9.970	81.250	85.300
V_7	13.675	9.770	75.000	22.927	116.000	22.370	7.920	79.570	83.170
V_8	12.325	8.420	85.500	25.302	125.000	23.850	11.200	68.950	89.270
V_9	11.725	6.870	98.700	20.695	124.000	24.270	9.900	72.740	81.220
V_{10}	12.500	9.200	72.200	22.777	125.000	22.620	7.770	74.670	82.120

Contd . . . 2

Table - 2 Contd.

Varieties	Characters								
	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
V_{11}	15.950	8.550	94.000	27.332	124.000	21.720	8.750	81.730	78.920
V_{12}	13.400	10.100	59.000	26.172	114.000	21.850	7.200	78.140	78.770
V_{13}	13.050	10.020	68.500	21.945	117.000	21.770	7.470	86.430	78.500
V_{14}	12.450	7.970	89.700	22.162	117.000	21.600	8.520	80.700	80.370
V_{15}	17.250	9.470	103.000	22.802	114.000	20.570	9.120	85.470	74.400
V_{16}	10.800	7.100	104.500	16.735	117.000	19.970	7.620	89.890	63.450
V_{17}	13.600	11.600	88.700	18.677	128.000	22.300	8.470	81.230	70.870
V_{18}	18.000	11.450	112.500	17.620	124.000	22.320	9.520	75.880	81.150
V_{19}	11.975	7.550	102.500	20.795	121.000	24.470	10.070	79.760	84.200
V_{20}	14.100	6.920	126.200	24.225	124.000	21.500	9.870	63.760	92.850

Contd . . . 3

Table - 1 Contd.

Varieties	Characters								
	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
V_{21}	12.925	8.470	105.000	19.352	125.000	21.300	9.050	80.610	72.550
V_{22}	11.750	8.370	87.500	20.227	122.000	21.850	7.770	90.900	81.800
V_{23}	14.675	8.970	80.700	24.470	114.000	21.400	7.250	78.780	78.400
V_{24}	17.100	10.070	113.000	21.322	125.000	25.150	10.170	77.260	81.220
V_{25}	14.250	7.070	93.700	27.812	114.000	21.300	8.320	85.810	74.450
V_{26}	12.300	7.850	67.200	29.177	129.000	23.370	9.720	63.890	81.220
V_{27}	14.800	9.320	78.500	27.982	128.000	21.920	8.470	74.760	75.750
V_{28}	14.250	10.920	84.700	20.195	117.000	23.270	9.450	78.290	86.100
V_{29}	12.125	7.620	78.000	28.837	124.000	22.800	8.920	73.060	78.200
V_{30}	14.525	7.150	106.000	24.157	119.000	23.570	10.550	80.600	80.700

Contd . . . 4

Table - 1 Contd.

Varieties	Characters								
	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
V_{31}	14.200	8.720	92.500	23.085	121.000	21.770	8.670	87.880	82.600
V_{32}	12.075	9.200	93.000	22.090	130.000	22.950	9.600	74.690	86.670
V_{33}	19.375	11.700	111.200	20.622	137.000	22.770	9.950	74.780	83.050
V_{34}	11.800	8.000	85.000	23.762	117.000	22.200	7.150	84.360	80.700
V_{35}	14.000	7.670	103.200	21.382	119.000	23.420	9.770	80.190	78.570
V_{36}	16.475	10.700	96.500	21.810	122.000	23.320	8.660	84.460	79.270
V_{37}	14.425	9.870	78.500	24.445	119.000	22.020	7.120	83.510	80.000
V_{38}	11.700	8.370	99.700	23.797	123.000	23.050	10.950	82.780	80.970
V_{39}	15.400	7.620	96.200	27.995	126.000	23.150	9.100	85.550	81.520
V_{40}	15.950	7.870	91.700	28.995	124.000	21.600	9.770	77.910	84.670

Table - 3. The range and the mean value for nine characters in rice.

Character	Range	Mean
Y	6.925 - 19.375	13.705
X_1	5.700 - 11.700	8.550
X_2	59.000 - 126.200	93.010
X_3	16.735 - 29.177	23.256
X_4	114.000 - 131.000	122.130
X_5	19.550 - 28.350	22.692
X_6	7.120 - 11.500	9.084
X_7	59.450 - 90.900	78.348
X_8	63.500 - 129.000	81.790

It is apparent from the Table that the magnitude of the range between the minimum and maximum values recorded in respect of each of the characters as compared against the mean, varied to different degrees from variable to variable. The relative magnitude was assessed on the basis of the following relationship.

$$\text{magnitude } (\%) = \frac{\text{Range}}{\text{Mean}} \times 100$$

For each character the following represent the percentage thus computed.

Y	90.84
X_1	70.18
X_2	72.25
X_3	53.50
X_4	13.92
X_5	38.78
X_6	48.24
X_7	40.15
X_8	80.08

The relationship, therefore, seems to suggest that the magnitude of range is maximum for yield of grains per plant (Y) and minimum for duration (X_4). In the descending order of this criterion, characters could be ranked as Y, X_8, X_2, X_1, X_3, X_6, X_7, X_5 and X_4.

The analysis of variance for the nine characters studied in the forty varieties of rice grown in a Randomised Block Design with four replications was worked out and the result is presented in Table 4.

Table - 4. Anova for yield and its components in rice.

Source of variation	df	Mean squares								
		Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Block	3	26.583	4.618	119.490	0.446	53.183	0.846	0.167	37.137	67.304
Treatment	39	20.474**	9.204**	911.005**	46.458**	91.987**	8.431**	5.498**	224.458**	337.983**
Error	117	8.645	2.393	128.575	0.174	10.512	1.149	0.419	47.838	15.165

**Indicates 'F' value significant at 1% level.
(The significance for treatment alone is marked)

From the Table it is evident that the varieties differed significantly from each other for all the nine characters studied.

The variance in respect of the different characters were further subjected to statistical manipulation to determine the variance due to phenotype (V_p), variance due to genotype (V_g), co-efficient of variation due to phenotype (pcv), co-efficient of variation due to genotype (gcv), heritability in the broad sense (h^2), genetic advance (GA) and genetic gain (GG) under 5% probability of selection. The results are presented in Table 5.

Once the yield and its components were identified, the association between yield and each one of the components and among the components were investigated into. The results obtained in this regard, expressed as co-efficient of genotypic correlation, are given in Table 6.

The genotypic relationship between yield and its components are diagramatically represented in Fig. 2.

It is evident from Fig. 2 and Table 6, that six components, when indicated a positive relationship (X_1, X_2, X_3, X_4, X_6 and X_7) against Y, two suggested a negative trend (X_5 & X_8).

Table - 5. Components of variance, phenotypic coefficient of variation, genotypic coefficient of variation, heritability, genetic advance, genetic gain for yield and other variables in rice.

Variable	Variance		Coefficient of variation		Heritability h^2 (%)	Genetic advance (at 5% intensity of selection)	Genetic gain
	Phenotypic (V_p)	Genotypic (V_g)	Phenotypic (pcv)	Genotypic (gcv)			
Y	5.119	2.957	16.508	12.547	57.770	2.693	19.640
X_1	2.301	1.703	17.738	15.260	74.000	2.312	27.010
X_2	227.751	195.608	16.226	15.037	85.890	27.700	29.780
X_3	11.615	11.571	14.654	14.627	99.620	6.994	30.060
X_4	22.997	20.369	3.926	3.695	88.570	8.750	7.150
X_5	2.108	1.821	6.397	5.946	86.380	2.542	11.190
X_6	1.374	1.270	12.905	12.404	92.380	2.231	24.550
X_7	56.115	14.155	9.561	8.481	76.690	12.340	16.000
X_8	84.496	80.705	11.239	10.984	95.510	18.090	22.110

Table - 6. Genotypic correlations among yield and eight components in rice.

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
X_1	..	-0.2917**	-0.3138**	+0.0396	-0.2967**	-0.2955**	+0.3634**	-0.4219**
X_2	..	..	-0.3678**	+0.2439**	-0.0903	+0.5283**	-0.1815*	-0.1431
X_3	..	..	..	+0.1122	-0.0130	+0.0959	-0.2695**	+0.0345
X_4	..	..	..	..	+0.5043**	+0.6008**	-0.6008**	+0.2846**
X_5	..	..	..	..	..	+0.6251**	-0.6599**	+0.8106**
X_6	..	..	..	..	..	..	-0.5521**	+0.2943**
X_7	..	..	..	..	..	..	..	-0.5824**
X_8	..	..	..	..	..	..	..	..
Y	+0.5461**	+0.2975**	+0.1252	+0.0585	-0.4725**	+0.0829	+0.2803**	-0.5702**

**Indicates significance at 0.10 level probability.

Figure - 2

Y = Yield of grains per plant

X_1 = Number of panicles per plant

X_2 = Number of grains per panicle

X_3 = 1000-grain weight

X_4 = Duration

X_5 = Length of panicle

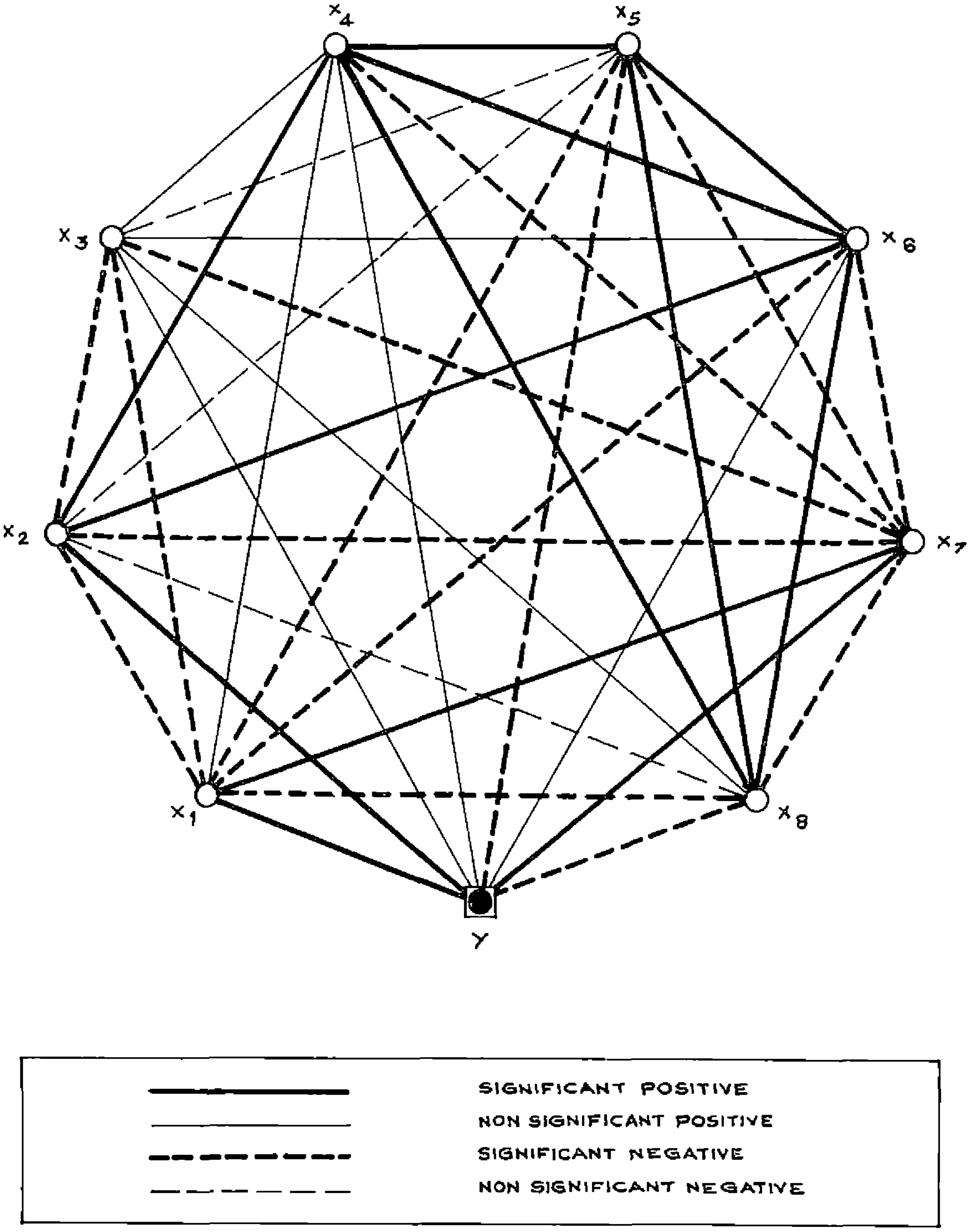
X_6 = Number of primary branches per panicle

X_7 = Percentage of filled grains

X_8 = Height of plant

FIG 2

CORRELATION DIAGRAM OF YIELD AND ITS COMPONENTS IN RICE



━━━━	SIGNIFICANT POSITIVE
────	NON SIGNIFICANT POSITIVE
▬ ▬ ▬ ▬	SIGNIFICANT NEGATIVE
— — — —	NON SIGNIFICANT NEGATIVE

Further, studies on mutual correlation, incorporating Y and X_1 . . . . . . X_8, reveal additional information and the results obtained during the course of study are represented diagramatically in Fig. 2.

Since a study involving simple correlations alone is felt to be inadequate for assessing the absolute contribution of each component towards yield, as an alternative the path analysis was also done. For this, as the preliminary step, the components were identified to belong to the first, second and third orders of causes. The findings of this analysis are diagramatically presented in Fig. 3 in which the causal scheme with the values for the path co-efficient and correlation co-efficient are illustrated.

For the understanding of the cause-effect relationship, the particulars of direct and indirect effects of the components belonging to each of the different orders, as presented in Tables 7 and 8 are made use of in the study.

It is seen from Table 7 that components X_1, X_2 and X_3 caused direct effect on yield, that of X_1 was maximum followed by X_2 and X_3. At the same time these 3 causes produced indirect effects as well. When X_1 has indirect

Figure - 3

Y = Yield of grains per plant

X_1 = Number of panicles per plant

X_2 = Number of grains per panicle

X_3 = 1000-grain weight

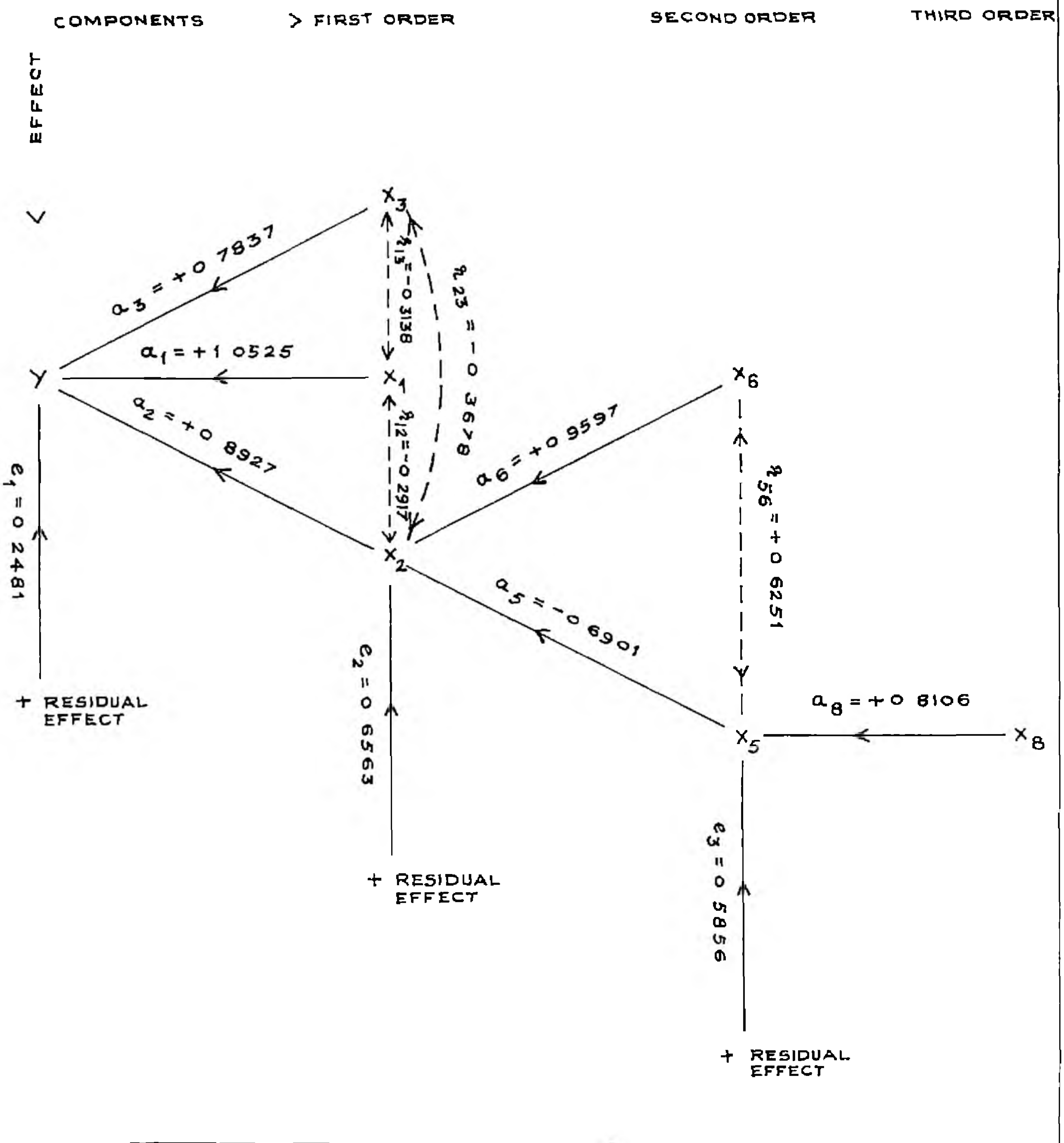
X_5 = Length of panicle

X_6 = Number of primary branches per panicle

X_8 = Height of plant

FIG 3

PATH DIAGRAM OF YIELD AND ITS COMPONENTS IN RICE



UNIDIRECTIONAL ARROWS INDICATE THE DIRECT PATH COEFFICIENTS AND THE BI-DIRECTIONAL ARROWS INDICATE THE CORRELATION COEFFICIENTS

Table - 7. Direct and indirect effects of the first order components on yield in rice.

	X_1	X_2	X_3	Total correlation
X_1	+1.0525	-0.2604	-0.2458	+0.5461
X_2	-0.3070	+0.8927	-0.2882	+0.2975
X_3	-0.3302	-0.3284	+0.7837	+0.1251

(The underlined figures represent the direct effects)

Table - 8. Direct and indirect effects of the second order components on number of grains per panicle (X_2) in rice.

	X_5	X_6	Total correlation
X_5	-0.6901	+0.5998	-0.0903
X_6	-0.4314	+0.9597	+0.5283

(The underlined figures represent the direct effects) effect through X_2 and X_3, X_2 has effects through X_1 and X_3, and X_3 through X_1 and X_2.

As is illustrated in Table 8, X_5 and X_6, which are the second order components influence only X_2 belonging to the first order. Both these variables (X_5 and X_6) contributed direct as well as indirect influence on X_2,the indirect effect of X_5 was through X_6 and that of X_6 was through X_5. Further, the direct effect of X_5 appears to be negative and that of X_6 positive.

The third order component (X_8) has influence only on one of the two second order components (X_5). Here the direct effect alone has relevance.

DISCUSSION

DISCUSSION

The results of the present investigation are discussed henceforth.

Forty distinct varieties of indica rice constituted the material for the study.

It is apparent, in the light of the analysis of variance (Table 4), that the varieties differed significantly from each other in respect of the following nine quantitative characters.

1. Yield of grains per plant (Y)
2. Number of panicles per plant (X_1)
3. Number of grains per panicle (X_2)
4. 1000-grain weight (X_3)
5. Duration (X_4)
6. Length of panicle (X_5)
7. Number of primary branches per panicle (X_6)
8. Percentage of filled grains per panicle (X_7) and
9. Height of plant (X_8)

Yield of grain is the most important character as far as the crop of the present study is concerned.

Further, this character, which is under the control of a polygenic system, is dependant upon several other variables, including the eight that are already enumerated, and the interrelationship of these variables is sufficiently complex. Under the circumstance, one has to identify yield, which is the dependant character, as the 'effect', and the other variables as the components or the 'causes' of the 'effect'.

The mean value for each variable, in the forty varieties were worked out separately and the results are presented in Table 2. Further, the mean was computed for the varieties considered as a whole (Table 3). These observations seem to suggest certain interesting trends.

The relative magnitude of the range for the varieties when expressed as percentage over the general mean, varied from variable to variable, the maximum was recorded against yield (Y), followed by height of plant (X_8), number of grains per panicle (X_2), number of panicles per plant (X_1), 1000-grain weight (X_3), number of primary branches per panicle (X_6), percentage of filled grains per panicle (X_7), and length of panicle (X_5), and the minimum against duration (X_4). It seems to suggest that the varieties exhibit significant difference in yield which in turn, is dependant on all the other variables individually, as well as in combination, and all these characters being polygenically inherited, was also influenced by the environment in varying magnitude.

The overall variation, in general, is recognized as the sum total of variation due to genetic causes, environmental effect, and the gene-environment interaction. Further, the alleles in the polygenic system are also not totally free from mutual interaction among themselves. In order to assess accurately the aspects projecting out from this perspective, an attempt was also made to study the variation caused by the genotype. As is evident from Table 5, the pattern of variation due to genotype for the nine variables exhibit almost similar trend as that exhibited by the phenotype. The computation of the percentage value for heritability, in the broad sense, from the values for the partitioned variance, indicate another important feature. The value for the estimate is maximum for 1000-grain weight (X_3), followed by height of the plant (X_8), number of primary branches per panicle (X_6), duration (X_4), length of panicle (X_5), number of filled grains per panicle (X_2), percentage of filled grains per panicle (X_7), and number of panicles per plant

(X_1), and the minimum for grain yield (Y). It seems, that yield, the character that is being given top priority importance in the present study, when exhibited wide range of variability at the intervarietal level, records the minimum value for heritability. This confirms that the manifestation of this character is of a highly complex nature, which involve influence of several other conditions created by both genic and non-genic causes.

Two more parameters, which are of paramount importance in selection procedure - Genetic Advance, and Genetic Gain under selection at specified intensities, have also been estimated (Table 5).

Yield, as is seen from the Table, eventhough does not promise the maximum advantage in terms of Genetic Advance and Genetic Gain, should not be under any circumstance overlooked, because as has already been discussed, its manifestation is far from the results of simple causes alone. Therefore, yield of grain in rice is an important quantitative character which has by nature a highly complex system of expression, changes in which is equally subject to environment fluctuations.

For a better understanding of the interrelationship of yield and its components, genotypic correlation co-efficients have been calculated, and the results of the analysis are presented in Table 6. The outstanding feature, that is evident from the above Table, is that yield bears a significantly positive association with number of panicles per plant (X_1), number of grains per panicle (X_2) and percentage of filled grains per panicle (X_7). However, its association with length of panicle (X_5) and height of the plant (X_8), though significant is negative. Thus, of the eight components only five bear significant association to yield. The negative association of height of plant to yield is already observed by rice breeders as is apparent from the concept of the ideal plant type for maximum yield potential, which prescribe a relatively short, or medium stature as the most important and essential requirement for a potentially high grain yielder. Similar association had been observed by Goud et al., (1969), and Eunus et al., (1976). However, results contrary to what has been just pointed out, were reported by Vibar (1920), Ramaiah (1953), Sastry et al., (1967), Roychoudhury (1968), Chang et al., (1973), Govindaswami (1973), Sivasubramanian and Menon (1973), Sreerangasamy and Murugesan (1973), Paramasivan (1977), and Agrawal et al., (1978). It must be remembered, in this context, that thirtynine out of the forty varieties made use of in the present investigation, were of the ideal high yielding plant type, which is associated with a relatively short plant height. Probably, the results indicating positive trend of plant height with grain yield, reported by several authors, might have involved the different material for their study.

The second component, that suggest a negative trend in association with yield, is length of panicle. Naturally, a long statured plant can have only a relatively long panicle. But since, in such types the nodes are widely spaced, one can anticipate only a sparse distribution of grains and consequently, a low yield. But in the higher yielding varieties though much of importance is not given to individual length of panicles, probably, the increase in number of grains per panicle is given more weightage.

Further, these two negatively correlated variables, length of panicle (X_5), and number of primary branches per panicle (X_6), are also significantly associated between themselves and the value for the co-efficient is high, and at the same time positive, thus confirming the negative influence of these two variables on yield.

Length of panicle (X_5), bears significant relationship with number of panicles (X_1), duration (X_4), number of primary branches per panicle (X_6), percentage of filled grains per panicle (X_7), and height of plant (X_8), and the sign of association are negative, positive, positive, negative, and positive respectively.

Similarly, height of plant (X_8), also bears significant relationship with number of panicles per plant (X_1), duration (X_4), length of panicle (X_5), number of primary branches per panicle (X_6), percentage of filled grains per panicle (X_7), and the signs are negative, positive, positive, positive and negative respectively.

Thus, these two variables, length of panicle (X_5), and height of plant (X_8), exhibit negative correlation with number of panicles per plant (X_1), and positive with duration (X_4), of which (X_1) is positively correlated to yield, and X_4 does not exhibit any significant relationship with yield, but seems to indicate a positive trend in the relationship.

The positive relationship of length of primary panicle (X_5) and the number of primary branches per panicle (X_6), and height of plant (X_8), and the number of primary branches per panicle (X_6), further, confirms the negative influence of these two components on yield. Similarly, the relationship of these two variables on percentage of filled grains per panicle (X_7) also indicate an identical trend of association on yield.

Number of panicles per plant (X_1), number of grains per primary panicle (X_2), and percentage of filled grains per panicle (X_7), bear significantly positive correlation with yield (Y), the values obtained for the co-efficient are in the descending order of magnitude. At the same time, number of panicles per plant (X_1), and number of grains per primary panicle (X_2), are also correlated significantly but the association is negative. Apparently, this is the reason why the values show some difference.

Further, number of panicles per plant (X_1), when it is positively correlated to yield, is also positively correlated to percentage of filled grains per panicle (X_7), which, in turn bears a similar relationship with yield (Y), as that of number of panicles per plant (X_1).

The negative, and at the same time moderately significant value for correlation co-efficient for number of grains per primary panicle (X_2), and percentage of filled grains per panicle (X_7), is probably the cause for the slight difference in the correlation values for number of grains per panicle (X_2), and percentage of filled grains per panicle (X_7).

Mere identification of the components of yield and the analysis of their interrelationship is often observed to be inadequate for the wholesome understanding of the expression of the effect. The path analysis method introduced by Wright (1921), further, helps us not only in revealing in absolute terms the relationship in this context, but also helps in estimating more or less accurately, the direct effect of each of the causes and the indirect effect that each of them contribute through other components in the final causation of the effect.

On the basis of the direct relevance, or the expression of the effect, the three causes, number of panicles per plant (X_1), number of grains per primary panicle (X_2) and 1000-grain weight (X_3), in this study have been assigned to the group of first order components.

Further, length of panicle (X_5), and number of primary branches per panicle (X_6), are grouped under the second order components. Only one cause, height of plant (X_8), is identified to be of the third order and this variable is presumed to be influencing the second order component, length of panicle (X_5) only.

With this, the causal scheme was made (Fig. 1). The causes of each order is believed to be responsible for the causation of other variables of the preceding order. However, the contribution of the residual effect (e_1, e_2, and e_3) has not been overlooked, and the estimated values have been represented in Fig. 3.

In this study the cause-effect path relationship between grain yield per plant (Y), and duration (X_4), has not been depicted in the causal scheme because only a negligible part of the total variation in terms of effect has been observed to be due to this cause.

The very object of cause-effect relationship is to reduce the number of causes as far as possible and also to give emphatic preference to those of the components, which are relatively more effective. This was borne in mind for making the causal scheme. On the contrary, it is felt, that if more the number of causes are included, the possibility of complicating the understanding is more, and thus the selection procedure could not be exercised with convenience.

The relationship of the effect and the first order components seems to suggest the following trends. Of the three first order components, number of panicles per plant (X_1), number of grains per panicle (X_2), and 1000-grain weight (X_3), the direct effect is always positive and the magnitude is maximum for number of effective tillers per plant (X_1), followed by number of filled grains per panicle (X_2) and 1000-grain weight (X_3). Almost similar results were recorded by Rao and Goud (1971), Lenka and Misra (1973), Mishra <u>et al</u>., (1973), Sreerangasamy and Murugesan (1973), Venkateshwarlu <u>et al</u>., (1973), Saini and Gagneja (1975), Singh and Nanda (1975), Brar and Saini (1976), Banerjee and Sinha (1977), and Agrawal <u>et al</u>., (1978).

Further number of panicles per plant (X_1), has indirect effects, one through number of filled grains per primary panicle (X_2), and the other through 1000-grain weight (X_3), both being of a negative nature.

Similarly, a comparative scrutiny of the direct and indirect effects of number of filled grains per panicle (X_2) and 1000-grain weight (X_3), also is indicative of a similar trend as has been already discussed for number of panicles per plant (X_1), number of grains per panicles (X_2) has indirect effects through number of panicles per plant (X_1), and 1000-grain weight (X_3). 1000-grain weight (X_3) has indirect effect through number of panicles per plant (X_1) and number of grains per panicle (X_2).

It is seen from Table 7 that the indirect effect X_1 X_2, and X_1 X_3, are of relatively lesser magnitude than that of X_2 X_1, and X_3 X_1, though both categories mark the negative sign.

Further, the indirect effect X_2 X_3 is also found to be recording a relatively lower value than that for X_3 X_1. Here again the signs are negative.

With regards to 1000-grain weight (X_3), the indirect effects X_3 X_1, and X_3 X_2, recorded relatively higher magnitude than that of X_1 X_3, and X_2 X_3 and the sign remained in all the cases negative.

Considering the relationship of the two second order, components, length of panicle (X_5), and number of primary branches per panicle (X_6), on the first order component, number of grains per panicle, the following observation came to light.

The direct effects of length of primary panicle (X_5), number of grains per panicle (X_2), are negative, and recorded a comparatively higher value than their indirect effect through number of primary branches per panicle (X_6) which is found to be positive, thus leading to a total negative correlation value which is very much low. The direct effect of number of primary branches per panicle (X_6), on number of grains per panicle (X_2), is positive but the indirect effect through length of panicle (X_5), is negative, thus leading to a diminution in the total correlation value. Plant height (X_8) in this case is presumed to have only direct effect, and if at all any indirect effect is involved, that is not considered.

The observations could be summarised as follows:

	Component	Direct effect	Total effect
First order	X_1 (on Y)	+1.0525	+0.5461
	X_2 (on Y)	+0.8927	+0.2975
	X_3 (on Y)	+0.7837	+0.1251
Second order	X_5 (on X_2)	-0.6901	-0.0903
	X_6 (on X_2)	+0.9597	+0.5283
Third order	X_8 (on X_5)	+0.8106	+0.8106

The above figures lead to the following features in the cause-effect relationship in rice.

1) Yield is more governed by

(a) number of panicles per plant	(X_1)
(b) number of grains per panicle	(X_2)
(c) 1000-grain weight	(X_3) and
(d) duration	(X_4)

The gross influence of number of panicles (X_1), is maximum followed by that of number of grains per panicle (X_2), and 1000-grain weight (X_3). The effect of duration (X_4) is very much negligible. Therefore, one has to give preference to more number of panicles (X_1), for selecting a potentially high yielder. The component next in order is number of grains per panicle (X_2), followed by 1000-grain weight (X_3). Almost similar reports were made by Rao and Goud (1971), Chandramohan and Narayanasamy (1973), Kumar and Saini (1973), Lenka and Misra (1973), Mishra <u>et</u> <u>al</u>., (1973), Venkateshwarlu <u>et</u> <u>al</u>., (1973), Nancharaiah <u>et</u> <u>al</u>., (1974), Saini and Gagneja (1975), Singh and Nanda (1975), Banerjee and Sinha (1976), Brar and Saini (1976), and Agrawal <u>et</u> <u>al</u>., (1978).

Further, the direct effect of number of panicles per plant (X_1), on grain yield per plant (Y) is more, but gets less in magnitude because of its negative indirect effects i.e., more the number of effective tillers (X_1), less will be the number of grains per panicle (X_2), and also 1000-grain weight (X_3). For selecting the type with high grain yield potential, therefore, one has to exercise certain amount of compromise among the relative expression of these three characters mentioned above. However, the fact that number of grains per panicle (X_2), 1000-grain weight (X_3), has their influence on the effect (Y) directly, should not be overlooked.

Length of panicle (X_5), and number of primary branches per panicle (X_6), are found in this particular causation study to be bearing more relevant relationship on number of grains per panicle (X_2), and are of the top priority components, that are being recommended for consideration in selection for high grain yield.

Number of primary branches per panicle (X_6), is positively correlated to grain yield per plant (Y), whereas overall length of panicle (X_5), bears a negative relationship. When taking into consideration, the direct influence of these 2 components on number of grains per panicle (X_2), the value is positive and high for number of primary branches per panicle (X_6), whose indirect effect through length of panicle (X_5), is negative and moderate, and that for length of panicle (X_5), is negative and at the same time its indirect effect is positive, and the ultimate result of the direct and indirect effects leads in respect of these two components, to a relatively lower value. That is the direct and indirect effects bear opposite signs as has already been noticed in the relationship of the first order components (X_1 , X_2 and X_3) and the effect (Y).

Therefore, between the second order components, for selection, emphasis should be attributed to number of primary branches per panicle (X_6).

Height of plant (X_8), is highly correlated to grain yield per plant~~s~~ (Y) but inversely (Table 6). On the basis of the values presented in the same Table, the components could be arranged in the diminishing order of values for genotypic correlation ignoring their respective signs as follows:

i)	Height of plant	(X_8)
ii)	Number of panicles per plant	(X_1)
iii)	Length of panicle	(X_5)
iv)	Number of grains per panicle	(X_2)
v)	Percentage of filled grains per panicle	(X_7)

1000-grain weight (X_3), however, does not come in this picture, but its significant negative relationship with number of panicles per plant (X_1) and number of grains per panicle (X_2) has been taken as the reason for its being included in the causal scheme.

Therefore, it is recommended on the basis of the present investigation carried out in rice at the College of Agriculture, Vellayani, that for selection of a type with high grain yield potential the following characters should be given importance.

(a) Height of plant

It is preferable to have a dwarf or medium statured plant. This recommendation is in accordance with that prescribed for the ideal plant type for the High Yielding Varieties.

(b) Number of panicles per plant

This could be realised only if the plant itself bears an inherant capacity to produce more tillers.

(c) Length of individual panicle

Plants with relatively short panicles are to be preferred over long. Incidently, a taller plant is likely to have larger panicles, but the former character has already been observed to be, generally, not very much desirable, unless specific objectives like breeding for varieties suited for cultivation in areas where there is chance for enundation of water, and where there is more demand for bulk of straw.

(d) Number of grains per panicle

A panicle with more number of grains has been identified as another important criterion for selection.

(e) 1000-grain weight

A variety recording a high value for this attribute should be preferred.

Therefore, the concept of a relatively short statured plant with high tillering capacity and moderately short panicles with more number of heavier grains per panicle, should be the criterion for selection of rice varieties superior in terms of yield.

Rice is a plant which has a relatively short span of life, is cultivated mainly for its grains. For maximum productivity, its function should be incessant, and necessarily directed towards synthetic activities. In a photosynthetically functioning organization like the plants, if the material that is synthesised during the period of growth and development is more utilized for the production of economically less important parts like the vegetative organs, naturally, the material that is available for the production of grains will be inadequate for the required recovery of grains. In the case of a relatively tall plant, the probability of having more number of tillers will be less, and consequently, the number of panicles will also be less. Further, the length of panicle, in such cases also tend to be more. This will, eventually, cut short the diversion of the synthesised material towards the production of grains. The very necessity of having more number of relatively heavier grains, that is essential for the ultimate realization of high yield, under such circumstances, will not be achieved. Therefore, the norm should be that the plant must be able to synthesise the required materials in abundance and at the same time should not unnecessarily direct them for producing more of vegetative parts that will be of low economic value.

SUMMARY

SUMMARY

1. The object of the biometrical study on forty divergent *indica* rice varieties, carried out at the College of Agriculture, Vellayani under the Kerala Agricultural University, during June - September 1977, is to furnish the practical rice breeder with information on certain accurate and dependable criteria for selecting the potentially high grain yielders.

2. The experiment was laid out with the forty varieties (treatments) in a randomised block design with four replications. A sample of ten plants was drawn from each plot which were planted with twentyone day old seedlings 20 cm x 20 cm apart in four rows of seven plants in each, in which eighteen plants constituted the border.

3. Collection of data was confined to the ten plants in each sample and the following variables were measured.

a) Grain yield per plant
b) Number of panicles per plant
c) Number of grains per panicle
d) 1000-grain weight
e) Duration
f) Length of panicle
g) Number of primary branches per panicle

h) Percentage of filled grains per panicle, and

i) Height of the plant.

4. The data collected, was tabulated, and subjected to the following statistical analysis.

a) Calculation of mean for each treatment separately and for all treatments together

b) Analysis of variance in respect of the nine variables.

5. It was observed that the forty varieties exhibited significant difference for all the nine variables mentioned above.

6. Co-efficient genotypic correlation was calculated and also the genetic parameters - Heritability and, Genetic Advance, and Genetic Gain under different intensities of selection, with a view to assess the relative importance of the variable in the final expression of yield of grain.

7. The path co-efficient analysis was carried out after identifying the more important of the components, and assigning them to the first, second and third orders, based on their relative merit. For the accurate and dependable application of the theory of causation and effect, an appropriate causal scheme was formulated and from the values for the path co-efficient, and the relative magnitude

and sign (positive or negative) for the direct and indirect influence of each of the variable and that of the residual effect, conclusions were drawn. It has been found that some of the components included in the study were of relatively greater importance than others.

8. In the light of the results and their critical scrutiny, it has been found that a relatively short statured plant with more number of effective tillers, bearing more number of heavier grains on shorter panicles, preferably with a few primary branches are most ideal for realising high yield of grains in rice.

9. The implications of the conclusion drawn from the study are also discussed.

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PATH ANALYSIS IN RICE (*Oryza sativa* Linn.)

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ABSTRACT OF THESIS

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ABSTRACT

When biometrical studies on forty divergent varieties of *indica* rice (*Oryza sativa* L.) were conducted at the College of Agriculture, Vellayani under the Kerala Agricultural University during June - September 1977, the estimates for genotypic correlation of yield and eight components, and path co-efficient of yield and the first, second and third orders of components revealed that relatively short statured plants having more number of panicle bearing tillers, and more number of heavier grains on relatively shorter panicles, preferably with a few primary branches, have been found to be ideal for a type having high grain yield potential. Therefore, it is recommended that selection for high grain yielders in this crop should be based on these criteria.