STUDIES ON
INTER-RACIAL AND INTRA-RACIAL F_2 HYBRIDS
OF *Oryza sativa* Linn.

by

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THESIS

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CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bona fide research work carried out by Shri. P.G. Rajendran, under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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INTRODUCTION

The species *Oryza sativa* is divided into two main races, viz. *O. sativa* var. *indica*, *O. sativa* var. *japonica*. The japonicas are characterised by short stature, stiff straw, long panicle, non-lodging habit and possess what is known as ' the response to high fertility The indicas are tall and lodge even under normal doses of manures and are poor responsers to high fertilization. It is generally believed that a large number of gene mutations and gene rearrangements within the chromosomes have accumulated in the japonicas on account of their cultivation in entirely different agro-climatic conditions (Jones and Longley, 1941) which largely accounts for the sterility in the hybrids.

The genetic investigations of rice started with the study of the inheritance of grain colour by Vanderstok (1908) in Java. Since then, the study has been persued in several countries, notably in India, Japan and U.S.A. More than 300 genes affecting 50 plant characters have been identified and their mode of inheritance followed. In the early stage, the studies were mainly confined to the inheritance of qualitative characters and then they have since been extended to quantitative and physiological characters as well. Matsura (1933), Jones (1936) Jodon (1948), Kuang (1951), Nagao (1951) and Ramiah (1953 a) have summarised the genetic work on rice.

The varietal diversity in the cultivated rice species *O. sativa* and the easy crossability among the varieties have led to the development of a large number of improved strains through intervarietal hybridization. Mostly crosses have been limited to types of the same geographical race or sub-species. With a wide range of objectives in breeding, it is considered, that the choice of parents for any hybridization programme need not be limited to any one of the racial groups. In order to combine the useful genes of the two forms, the *japonica* - *indica* rice hybridization programme was launched by the F.A.O at the Central Rice Research Institute, Cuttack, India, and the F_1 hybrid seeds were sent to participating countries and Indian states for study and selection from the first segregating generation onwards. The work on this hybridization has indicated the scope of obtaining suitable varieties with greater response to increased soil fertility.

The study of inheritance of plant characters is of great importance in guiding a plant breeding programme. The plant breeder is conscious that selection capacity of his material depends upon the amount of haritable variability present. It is also necessary to understand the manner in which the variability functions in order to be able to estimate it and use it in breeding.

Therefore, the present study was undertaken with the object of determining the mode of inheritance and evaluating the genetic variation expressed in the F_2 generation of inter-racial and intra-racial hybrids of rice in respect of certain characters.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Geographical Groups of the Species *Oryza sativa* L.

Working with more than 200 varieties, Kato *et al*. (1928, 1930) proposed to classify *O. sativa* into two sub-species, *japonica* and *indica*, on the basis of morphological differences and sexual affinity. The *japonica* group included varieties from Japan, Korea and northern China, whereas the *indica* group consisted of varieties from India, Southern China, Taiwan, Ceylon, Java and other tropical areas. The existence of hybrid sterility between the two groups - 66 - 100% sterility in hybrids in contrast to 16-51% within japonicas and 29 - 31% within indicas- aroused much interest among rice workers. Terao and Mizushima (1939) found that the phenomenon of inter-varietal hybrid sterility was too complicated to allow classification into two distinct groups.

Later on, a third group, *javanica* or *bulu*, was recognized to include varieties showing intermediate characters. The *javanica* varieties showed a very high affinity with japanese varieties and a high to very high affinity with most of the indian varieties tested (Terao and Mizushima 1944). Thus three major variety groups are generally recognized by Japanese workers. Mizushima (1948, 1950) recognized eleven groups on the basis of hybrid sterility, whose affinity varied from one extremity to the other.

The general morphological features of the above three groups as summarised by Terao and Mizushima (1949), are as follows:

indica	*japonica*	*javanica*
1. Broad, light green leaves.	Narrow, deep green leaves.	Broad stiff light green leaves.
2. Slender, somewhat flat grains.	Short, roundish grains.	Broad, thick grains.
3. Profuse tillering.	Medium tillering.	Low tillering.
4. Mostly awnless.	Awnless to awned.	Awnless or long awned.
5. Thin and short hairs on glumes.	Dense and long hairs on glumes.	Long hairs on glumes.
6. Easy shattering.	Low shattering.	Low shattering.

Studies with large collections of varieties showed that the morphological variations within the two variety groups were not discontinuous, (Oka, 1958). Based on the study of character association, Oka divided the cultivated rice varieties into two groups namely 'Continental' and 'Insular', largely corresponding to *indica* and *japonica* types respectively and sub divided the Insular group into two minor groups 'Tropical insular' and 'Temperate insular' according to their geographical distribution.

Unlike the *indicas*, the *japonicas* are adapted to the sub-tropical and warm temperate regions with lesser range of variability. They are characterised by glutinous endosperm, early maturity, response to heavy manuring and non-lodging habit. According to Ramiah (1961) the *indicas* when compared to *japonicas*, possessed greater number of dominant characters and hence *indicas* could be the original form from which the *japonicas* were evolved.

Sterility in hybrids

(a) Inter-racial: In cultivated rice, hybrids between different varieties, particularly those belonging to '*indica*' when crossed with '*japonica*' showed varying degrees of sterility. Ever since the discovery of hybrid sterility in inter-varietal hybrids of rice by Kato (1930), Jenkin (1930), Ramiah (1931) and Oryosi (1940), there has been speculations by various workers concerning the cause of sterility commonly found in these hybrids. Akomine and Hoshika (1941) concluded that the sterility in rice hybrids was due to inter-varietal difference and the effect of climatic factors i.e. air-temperature, humidity and sunshine. The effect of the first factor (air-temperature) was most predominant and the sterility percentage could be predicted from the air-temperature during the growth period. Webstor (1950) while working on rice hybrids agreed with the above statement.

Inter-varietal hybrid sterility has been given three interpretations - Genetic, Chromosomal and cytoplasmic.

(i) Genetic: Hsu (1945) during his investigations, found for the first time that the sterility was genic in nature. He further reported that

F_1 and F_2 of two partially sterile hybrids derived from indica x japonica crosses exhibited a wide range among F_2, plants from complete fertility to plants as sterile as the F_1 and concluded that sterility was due to complementary genes.

Tu (1949) and Kuang (1951) suggested that sterility was caused either by lethal genes or minute structural differences in the chromosomes. Oka (1953, and 1956) arrived at the conclusion from a study of segregating populations of several crosses, that the sterility could be accounted for most logically by sets of duplicate genes in which homozygous recessive combinations led to abortion of spores or gametes. Silow (1954) stated that gene substitution differences in chromosome structure were the cause of sterility.

Oka (1957 b) also postulated a mechanism of dominant lethals to explain the weakness of F_1 plants and another of complementary recessive lethals to account for vegetative break-downs in F_2 plants. Oka (1964) made extensive review of this problem in the light of experimental results obtained by him and his collaborators, over the period from 1953 to 1962 and characterised the intervarietal F_1 sterility by the following features.

The inter-varietal F_1 sterility was haplontic or gametophytic and could be accounted for by assuming sets of duplicate genes which work in the gametes as development maintainers (Gametic development or G.D. genes). A number of such duplicate genes may be concerned with sterility between distantly related varieties.

In the F_2 and later generations of the inter-varietal hybrids, partly sterile or weak segregants were found and from the partly sterile plants, true breeding partly sterile lines could be obtained. This sterility was diplontic or sporophytic and is not correlated with F_1 sterility. This phenomenon which might be considered as a partial break down of hybrids, could be explained by duplicate genes of sporophytic effect.

The origin of duplicate loci might be accounted for by assuming secondary polyploidy.

Genetic consequences of sterility in _japonica_ x _indica_ hybrids have been summarised by Jennings (1966) as follows:

Sterility in the F_1 and F_2 was caused by common chromosomal and/or genic mechanisms. Recombinants and non-recombinants (parental types) were equally fertile, regardless of the degree of hybrid sterility in the population. There was no deficiency of recombinants resulting from hybrid sterility.

Small genic differentiation between the two sub-species _indica_ and _japonica_ which gave rise to highly sterile hybrids, though chromosome behaviour was normal, had been brought to light by Kihara (1966).

(ii) Chromosomal: Jones (1930) working with both Chinese and Japanese varieties of rice, found a higher degree of sterility in the F_1 of certain crosses, from which he deduced the existence of chromosomal incompatibility. Ramanujam and Parthasarathy (1935) found a completely sterile mutant which showed an asynaptic behaviour of chromosomes. Working with a number of varieties representing diverse characters Sethi (1937) detected a positive correlation between meiotic irregularity and sterility.

Terao and Mizushima (1939) expressed the view that eventhough chromosome pairing in the hybrids was apparently normal at metaphase-I, the sterility must be due to small chromosomal differences not detectable at this stage (cryptic structural hybridity).. Jones and Longley (1941) after a study of the gametic tissue of normal and sterile diploid plants, found that the sterile plants were abnormal in meiotic behaviour in spite of their diploid chromosome numbers. It was possible, they thought, that the cultivated rice varieties classified by Kato as <u>O</u>. <u>sativa</u> - <u>japonica</u> and <u>O</u>. <u>sativa</u> - <u>indica</u> represented varieties of the same origin that had been grown under different environmental conditions so long that owing to an accumulation of gene mutations and genic rearrangements within the chromosomes, they became largely incompatible when crossed. Cua (1952) reported that the fertility of partially sterile F_1 hybrids between <u>indica</u> and <u>japonica</u> varieties was improved considerably by artificial doubling of the chromosomes and concluded that the sterility was caused by complex gene mutations and genic rearrangements within the chromosomes.

Mello - Sampayo (1952) discovered decentric bridges and acentric fragments at anaphase-I, in partially sterile hybrids, and concluded that the sterility in that case was caused by paracentric inversions. Sampath and Mohanty (1954) in a study of partially sterile hybrids found that metaphase-I was normal but bridges and fragments were found at anaphase-I in 11 of the 85 hybrids and the sterility was caused by inversions. They also stated that in most hybrids the sterility appeared to have been caused by genic or cytoplasmic factors as the bridges with fragments were not found. Parthasarathy (1954) observed laggards, stretched chromosomes and anaphase bridges with fragments in 33 hybrids and the incidence was more than 10%.

Hsieh (1957) in an extensive study of numerous crosses between _indica_ and _japonica_ varieties observed certain cytological abnormalities, such as stretched chromosomes and bridges but there was scarcely any difference in frequency of occurrence of these aberrations between the parental varieties and their F_1 hybrids. In a further study he concluded that chromosome inversions were an unlikely explanation of sterility in _indica_ x _japonica_ hybrids of rice. Venkataswamy (1957) was the first to indicate that chromosomal differentiation between _indica_ and _japonica_ varieties of rice was due to translocations. Sampath (1957) supported this view and indicated that the origin of duplications and deficiencies in the gametes might account for the sterility in these hybrids.

Yao _et al_. (1958) presented evidence from studies of the pachytene stage of meiosis that chromosome loops characteristic of inversions were present in at least 5 or 7 hybrids under investigations. They also studied that structural differentiation of the parental chromosomes in inter-varietal rice hybrids was even more common than reported by Sampath and Mohanty (1954) and arrived at the conclusion that partial sterility encountered in most such hybrids was probably due to cryptic structural differentiation in the chromosomes arising from included inversions. Hsieh and Oka (1958) reported that bridges accompanied by " small granular fragments " at anaphase-I in 21 of 23 rice varieties, and in 19 of 29 F_1 hybrids studied, were formed. It was further concluded that these did not represent inversion bridges because of their occurrence in homozygous variety and the opinion was that sterility was probably genic in cause, rather than being due to structural difference in chromosomes.

Henderson <u>et al</u>. (1959) showed further evidence of structural differentiation in inter-varietal hybrids of rice. In their investigations they found two types of unusual behaviour, namely, bridges without fragments and bridges accompanied by acentric fragments. Bridges without fragments were noted in some homozygous varieties in the same frequency of hybrids. Bridges accompanied by fragments were found at very low frequency in 9 of 12 hybrids, indicating the presence of paracentric inversions. They strongly suggested that the partial sterility which occurred commonly in inter-varietal hybrids was caused by complex inversions of the included type. Cafey (1959) and Mizushima and Konda (1959) stated that the partial sterility in inter-varietal rice hybrids could be explained on the basis of structural differentiation of the parental chromosomes.

Shastry and Misra (1961) studied the pachytene chromosomes in _japonica_ x _indica_ hybrids and observed three types of aberrations: heteromorphic bivalents, quadrivalents and incomplete chromosome pairing, which are indicative of deletions, translocations and differential segments respectively. A sub-terminal inversion loop was found in bivalent of one hybrid, suggesting a peri-centric inversion. Among the four kinds of abnormalities, loose pairing was by far the most common. The above observations led Shastry and Misra to conclude that _indica_ and _japonica_ groups were differentiated by a series of small structural difference in their chromosome complement and that sterility in the hybrids might be considered as "recombinational" between chromosome segments. However such loop formation was observed both in parents and their hybrids (Wu _et al_.1964) and critical evidence for translocated segments was lacking. On the other hand, Henderson (1964) suggested a possibility in which two inversions with the same chromosome were involved, producing adjacent overlapping and included inversion. This type of included inversion was difficult to detect cytologically, yet it would produce higher sterility than simple paracentric inversions.

In summary most rice workers tend to recognize hybrid sterility as a result of cryptic structural differentiation in chromosomes between the two variety groups (Terao and Mizushima 1939, Jones and Longley 1941, Kuang and Tu 1949 Cua 1952, Yao et al. 1958, Henderson et al. 1959, Sampath 1960, Shastry and Misra 1961).

(iii) Cytoplasmic: Sampath and Mohanty (1954) reported semi-male sterility in direct and reciprocal crosses of Oryza sativa varieties. The occurrence of semi male sterility, when japonica was the female parent, was attributed to chromosomal abnormality (inversions). A statistically significant increase in sterility was apparent in the F_1 hybrids of reciprocal crosses which the authors interpreted as cytoplasmic effect on pollen development when indica cytoplasm and japonica gene were combined.

In a back cross experiment between a Phillipine variety and a Japanese variety, using the latter as the recurrent pollen parent, Kitamura (1962) selected two strains from BC_3 generation. Crossing the two strains with various Japanese varieties, he found that when the japanese varieties were used as maternal parent, all the F_1s were fertile. But some reciprocal F_1s with a Japanese variety as pollen parent, were partially sterile. It seemed that this was an instance of disharmonious interaction between certain genes of the Japanese varieties and the cytoplasm of the Phillipine variety.

Rao (1964) found no major cytoplasmic differences between crosses involving indica and japonica rice varieties. Conducting a back cross experiment between indica and japonica varieties using the latter as the recurrent pollen parent, Oka (1964) observed that repetition of the experiment until BC_6 did not bring about a remarkable improvement in fertility. He also observed that if the partially sterile plants were selfed, the progeny was almost completely fertile. Since a backcross of the reciprocal combination with recurrent parent as the maternal plant did not restore fertility, the sterility appearing in this experiment could not be attributed to cytoplasmic effect. Jenning (1961) found no large reciprocal differences for either pollen or spikelet fertility.

(b) Intra-racial: Members of this race inter-cross readily giving mostly fertile hybrids. However Oka (1956) reported instances of sterility in these hybrids. Richaria _et al_. (1962) recorded a range of zero to 100% sterility in 11 crosses studied by them. Joseph (1962) reported lesser spikelet sterility than pollen sterility in _indica_ x _indica_ combinations.

Inheritance of characters

Plant height: According to the results obtained, Ramiah (1933) suggested that the presence of multiple genes, H_1, H_2 and H_3 controlled the culm height, H_1 and H_2 having a similar action but H_3 was greater than the others. H_1 was fully dominant over H_3 and H_3 over H_2. However, some cases of monogenic segregation with tallness as dominant have also been reported by Ramiah (loc.cit.) and Nandi and Ganguli (1941 b.).

Syakudo *et al.* (1952) found that in the cross between a semi-dwarf form and normal form with 70 and 90 cm in height respectively, the height was controlled by two multiple genes H_2 and H_3 with the combined actions of the gene complex C_1 and the genes for semi-dwarf D_1. The gene D_1 was perfectly dominant over d_1 which determined dwarf stature. This semi-dwarf form and the normal form were designated by $c_1\ h_2\ h_2\ H_3\ H_3\ d_1\ d_1$ and $C_1\ H_2\ H_2\ h_3\ h_3\ D_1\ D_1$ respectively.

Syakudo *et al.* (1954) found that in the hybrid progeny of the crosses between Aikoku, Ginbozy and Kyoto Asahi, the genes which determining the heading periods also affected the culm height by the manner parallel to that observed in the heading period which was governed quantitively by the group of three genes.

A genetic study of the cross Peta x 1.yeo-tze indicated that tallness was partially dominant to shortness and that modifying genes were epistatic to the shortness in genes (Anon. 1964). Both parents and hybrids varied considerably in height.

Chalam and Venkateswarlu (1965) reported that the inheritance of height in many cases was governed by at least 3 genes designated as T_1, T_2 and T_3, each having differential effect in controlling height.

Tillering: Tillering has been shown to be a polygenic character by Bhide (1926). As in other quantitative character, when heavy and light tillering varieties were crossed, a transgressive variation was observed in F_2 with the mean values falling some where between the parental means (Nagai 1926, Jones 1928). Ramiah (1953) observed tillering to be a polygenic character. When the high and low tillering varieties were crossed, Nagai (1959) observed a transgressive variation in the F_2 with the mean value falling between the parental mean. Ghose et.al.(1960) found that genes numbering three to four in some cases and more than four in others, controlled tillering.

Flowering duration: Hoshino (1915) found in a cross between early and late maturing rice that the time of flowering in F_1 was intermediate but nearer to that of the early parent. The F_2 generation equalled the combined range of the parents. The author suggested that three multiple genes would explain the results. Ikeno (1918) reported that in crosses of early and late rices theF_1 was intermediate and segregation in F_2 was complex and apparently due to multiple factors. Hector (1922) found that the F_2 progeny from a cross between an autumn and winter rice segregated into two distinct groups with respect to data of flowering. These two flowering periods were the same as the flowering dates of the two parents with an interval of about three weeks during which time no blooming occurred. The ratio of early to late was 1:3. Nomura et al. (1925) found that the F_1 hybrids were a few days later in shooting than the late parent and in the F_2 segregation it was in the ratio of about 3 late: 1 early with transgressive segregation on both sides. For interpretation, the author drew up a trigenic basis.

Bhide (1926) observed the dominance of lateness in a monogenic ratio in certain crosses while in other crosses, however, such dominance of lateness over earliness was not very evident. Jones (1928) while studying the crosses from various early and late types of rice observed that the F_1 plants might be earlier than the early parent, later than the late parent, or nearer to the early or late parent in time of flowering. The F_2 plants showed transgressive variation and there was a heaping up of plants in the intermediate position in the F_2. He finally observed that two or more genetic factors were involved in the production of earliness in the rice varieties studied.

In crosses between summer and autumn rice Nandi et al. (1940) found the F_2 hybrids to be more or less intermediate, but nearer to the early parent. The F_2 segregation suggested that multiple genes were concerned. In the cross between autumn and winter rice and between summer and winter rice, the F_1 plants were intermediate. The F_2 in the former case, however, showed transgressive segregation on both sides while in the latter the transgression was onesided i.e., towards lateness only. Nandi et al. (1941) found that in a cross between an autumn and winter rice, the F_1 was definitely intermediate and the F_2 had a wide range of variation with transgressive segregation on both sides. Graphically, the F_2 population segregated with a bimodal curve showing clearly a ratio of 3 late: 1 early. In another cross between the summer and the winter rice, the F1 was intermediate and F_2 the transgression was again one sided, i.e., towards the lateness only.

Duration expressed in terms of number of days to heading in rice had been demonstrated as being governed by a large number of multiple genes; but the qualifying values of these genes were not the same (Nagi, 1959). It was shown that a pair of genes determined a wide range of difference. Besides the basic gene, many more genes might determine minor differences. Chalam and Venkateswarlu (1965) found shorter duration to be simple dominant to long duration. In some cases however, lateness was found to be dominant and in some other cases the segregation was polygenic.

Exsertion: According to Ramiah (1932) exsertion of panicle was controlled by a large number of genes. Sethi *et al.* (1937 a) on the other hand, observed an F_2 segregation of 49:3:12 of exserted and partially exserted : tip exserted: enclosed and have expalined their results on a three factor hypothesis with a number of assumption.

Chang and Bardenas (1965) classified panicle exsertion broadly into four groups.

(1) Exserted: Panicle base is clearly above the flag leaf sheath.

(2) Partly exserted: Panicle base appears at the same level as the top of the flag leaf sheath.

(3) Partly enclosed: Panicle is partly enclosed by the flag-leaf sheath.

(4) Enclosed: Panicle is entirely enclosed by the flag-leaf sheath.

Chalan and Venkateswarlu (1965) were of opinion that exsertion was governed by at least three genes.

Length of panicle: Panicle length in rice is a variable character and has definite relationship with yield. Many of the hybrids between short and long ear types demonstrated in F_2, a continuous variation extending over the range of the parents.

A well analysed case could be seen in the cross "Koyabozu " x "ohba" varieties, studied by Takesaki (1925). "Koyabozu" was a variety possessing a medium height with short and dense ear measuring 14.75 cm in length. "Ohba" was medium tall in height with medium long ear, measuring 20.38 cm. The mean ear length in F_2 population was 18.38 cm varying between 12 and 28 cm. He concluded that length is governed by the cumulative action of multiple genes whose qualifying value would be 1.0 cm. Studies made by Bhide (1926) and Ramiah (1930) also showed that this character was governed by polygenes.

Weight of grains: The weight of grain is of economic importance. This varies according to the size and shape of the grain.

Parnell et al. (1922) showed that coarse grains were heavier and that weight was associated with grain colour. Chandraratna et al. (1960) reported that grain weight in receprocal crosses between the pure line varieties Vellai Ilankala Yan 28061 and Pandurani, showed a maternal effect.

Grain characters: There is considerable variation in the size and shape of the rice grains.

Inheritance studies on the length of grain by parnell et al.(1917) showed normal length to be simple dominant over short length. Bhide (1926) reported that grain length was controlled by multiple genes. Chao (1928) found that short was dominant over long. The cross between short (4.13 mm in length) and long (8.81 mm) showed a distinct segregation in F_2, the short kernel was dominant; the observed number gave a fairly good agreement with the segregation expected on the ratio of 3:1. According to Ramiah and Parthasarathy (1933) kernel length was governed by three multiple genes. Hara (1942) found that the length appeared to be controlled by two pairs of genes in the cross between an oval-shaped japonica variety ("Kokuryomiyako") and a long and red kerneled indica variety. In a cross between 'long' (Nioi-ine) and medium ("Tataso"), Morinaga et al. (1943) found that at least five allelomorphs govern the kernal length. Studies at the Central Rice Research Institute showed that length of grain was a quantitive character and was governed by three genes.

According to Ramiah and Parthasarathy (1933) and Mitra and Ganguli (1938), inheritance of the breadth of grain is polygenic. Majid (1939) explained the inheritance of breadth of grain on digenic basis. He has also observed that thickness of grain was controlled by polygenes.

Pollen sterility: Ishikana (1927) interpreted pollen sterility on the basis of a single recessive gene 's'. Ramanujam (1935) has reported that pollen sterility was governed by duplicate recessive genes. Oka (1953 a, 1953 b) found that percentage of pollen abortion in indica x japonica hybrids varied widely among different crosses, ranging from none to 100%. Although a wide range in sterility was also found in segregating populations, he concluded that the sterility was caused by segregation of a few duplicate genes. He further stated that no evidence of irregular chromosome behaviour was found in meiosis. Differences in pollen and seed fertility between reciprocal F_1 hybrids of Indian and Japanese varieties were noted by Sampath and Mohanty (1954). In two series of reciprocal crosses, lower fertility was observed when a japanese variety was used as the female parent. Miller (1959) studied segregation for pollen fertility in the F_2 and F_3 of a cross having 12% pollen fertility in the F_1. F_2 fertility ranged from two to 99 per cent, averaged 80% and showed one mode in the 91 to 99 per cent fertility class. There was no detectable ratio for pollen stainability in the F_2.

Percentage of viable pollen in normally fertile lines could also be lowered by adverse environmental conditions (Misra 1962). He found that some of the known factors are: low air and water temperature, high humidity or excessive rain at flowering, low light intensity, short photoperiod, drought and nitrogen fertilization. Henderson (1964) summarized segregation data from a large number of F_2 plants and lines in a cross. F_2 pollen fertility ranged from one to 98 per cent and averaged 53%. Although there was tendency towards trimodal segregation, many plants were found in each fertility class and it was concluded that the F_2 consisted of an indefinitely large numbers of genetically distinct classes.

Spikelet sterility: Spikelet sterility often exceeded pollen sterility in inter-varietal hybrids and their progenies, (Hsu, 1945). He referred to a trimodal segregation in the F_2 of the two different highly sterile F_1 hybrids. The F_2 populations predominantly were divided into the three seed-set classes of zero to 5 per cent, 45 to 55 per cent and 65 to 75 per cent fertility.

Summarising a large amount of pertinent work by Indian Scientists, Sampath (1959) reported that wide segregation for sterility was found in the F_2 and later generations of _indica_ x _japonica_ hybrids and that plants more sterile than the F_1 parents were present in most F_2 population. Butany _et al._(1961) reported F_2 data from three crosses having widely different levels of F_1 fertility (20, 52 and 75%). On the basis of similar ranges of F_2 segregation and similar Coefficients of variability, they concluded that F_2 and F_3 sterility behaviours were comparable irrespective of the degree of the F_1 sterility.

Phenol reaction: Dark-violet staining of grains and hulls with phenol solution was inherited as a single dominant, Ph. This staining reaction was found in the indica varieties (Nagao 1951).

According to Nagi (1959) certain varieties of _indica_ type possessed the power of oxidising phenolic compounds and hence the colour development.

Oka (1953) recorded the 'continental' forms as phenol positive and 'insular' forms phenol negative. Most of the japanese upland varieties studied by Yamaguchi and Kimura (1958) showed positive phenol reaction in contrast to the irrigated rice.

Jennings (1966) reported that lemmas, paleas and outer glumes of sterile and fertile spikelets of some varieties of rice were stained darkly following soaking for several hours in 1.5% phenol solution. Phenol staining was found monogenic dominant to no staining.

Narayanan Unnithan (1967) has reported that the 'Phenol positive' reaction of the *indica* varieties was found to be dominant over a 'phenol negative 'reaction of the *japonica* varieties.

Cytological: From the prevalence of semi-sterility in the hybrids between *japonica* and *indica* varieties of rice, it has been inferred that the sub-species formation in rice is connected with structural changes in the chromosomes, in addition to gene mutations (Terao and Mizushima 1939 and Gua 1952). However, visible differences between the chromosomes of *indica* and *japonica* varieties have not been found. Sampath and Mohanty (1954) observed a low frequency of 'chromosome bridges' and fragments in the anaphase-I stage of meiosis in *japonica* x *indica* hybrids and concluded that inversions of chromosome segments have played a part in the formation of the *japonica* sub-species.

Venkataswamy (1957) isolated a true breeding semi-sterile culture from F_6 of a *japonica* x *indica* hybrid in which one or two quadrivalents were frequently present in metaphase-I of meiosis. He concluded that translocation of chromosome segments may also have contributed to the formation of *japonica* sub-species.

While studying the chromosome behaviour in meiosis-I in six partially sterile hybrids between varieties of cultivated rice Yao *et al*. (1958) found that diakinesis and metaphase-I were normal in these with no evidence of translocation or absence of pairing to account for the sterility. In two of these hybrids chromosome bridges without fragments occurred at anaphase-I and telophase-I in low but regular frequency. It was concluded that such bridges may be the result of delayed terminalization of chiasmata in pairs of chromosomes which were structurally different at some point. Hsieh and Oka (1958) found that the F_1 plants and parents did not differ significantly as regards the frequency of rarely occurring univalents of 'stretched' chromosomes at metaphase-I and of bridges at anaphase-I. Stretched chromosomes might be due to precocious separation of bivalents. The occurrence of such chromosomes and univalents may be indicative of loose pairing of homologues possibly as a result of formation of an insufficient number of chiasmata per chromosome. They could not be inversion bridges in view of their presence in the parental pure lines, but their nature was unknown.

Detailed study of the chromosome behaviour at anaphase-I in 12 inter-varietal hybrids of cultivated rice was conducted by Henderson <u>et al</u>.(1959). Bridges without fragments and bridges accompanied by acentric fragments were found. Bridges without fragments were also found in each of the three homozygous varieties in approximately the same frequency as in the hybrid. It was concluded that their behaviour was not abnormal and did not indicate the presence of structural differences in chromosomes. Bridges accompanied by fragments were observed at very low frequency indicating the presence of paracentric inversions.

Madhusudhana Rao (1964) analysed 6194 anaphase-I cells of 15 hybrid combinations and found that 19 cells showed bridges without fragments, and

49 cells with laggards. The same type and intensity of abnormality were noticed in parents also. A total of 4219 diplotene cells was examined from the above hybrid combination and 40 cells were found showing unpaired chromosomes. Parents also exhibited about the same per cent of cells showing unpaired chromosomes. He concluded that analysis of diplotene and anaphase-I cells did not give any positive evidence of the structural differentiation of chromosomes.

MATERIALS AND METHODS

MATERIALS AND METHODS

A. Materials

The present investigation is a continuation of the work already started earlier. Inter-varietal crosses of rice (*Oryza sativa* L.) representing *japonica* and *indica* types, in the following four combinations were effected in November, 1966.

Cross No.	♀ parent	♂ parent	Groups
I	Vellayani-1	Tainan-3	*indica* x *japonica*
II	Tainan-3	Vellayani-1	*japonica* x *indica*
III	Vellayani-1	Taichung Native-1	*indica* x *indica*
IV	Taichung Native-1	Vellayani-1	*indica* x *indica*

The behaviour of the first generation hybrids along with the parents was studied during December to March, 1966-1967.

Seeds obtained from 16 F_1 plants representing all the four cross combinations as detailed below, received from the Division of Botany, Agricultural College & Research Institute, Vellayani, were utilized for the present study.

No.	Combination.	F_2 family.	population studied.
I	Vellayani-1 x Tainan-3	1 - 12	270
		1 - 7	64
		1 - 14	57
		1 - 17	21
II	Tainan-3 x Vellayani-1	5 - 9	425
		5 - 1	126
		5 - 5	121
		5 - 7	56
III	Vellayani-1 x Taichung Native-1	2 - 2	224
		2 - 21	38
		2 - 6	33
		2 - 3	26
IV	Taichung Native-1 x Vellayani-1	6 - 12	223
		6 - 16	98
		6 - 7	60
		6 - 14	55

D. Methods

Raising the F_2 generation of plants

All the available seeds of 16 F_1 plants representing the above four crosses along with the three respective parents, were soaked separately in water for 24 hours, drained and kept in a cool dark place for another 24 hours. They were then sown separately in pots. Pot watering was given twice a day for first one week after sowing and there after once daily.

All the available seedlings of the four crosses were planted separately in singles in the main field, 25 days after sowing at a spacing of 30 cm either way, in such a way that seeds obtained from one F_1 plant represented one F_2 family. Hundred plants in each of the three parents were also raised side by side with the hybrids for comparison.

The usual manuring schedule of 40 lb N, 30 lb P_2O_5, and 30 lb K_2O in the form of ammonium sulphate, single superphosphate and muriate of potash, over a basal dose of 1000 lb of green leaf per acre, recommended for paddy was adopted. There was no incidence of disease during the crop period. Mild attack of pests to the crop during its early phase was effectively checked by suitable plant protection measures.

Observations on the following 15 characters were recorded both on the hybrids and on the parents and their pattern of inheritance worked out. Results of four typical families representing all the four cross combinations, are presented in the body of the thesis and the rest in the appendix.

I Plant height

Height was measured in cm from the base of the plant to the tip of the main panicle after the grains attained full maturity. A total number of 2043 plants was studied for this characters.

II Productive tillers

Number of ear-bearing tillers per plant was counted at the time of harvest and the mean number of tillers per plant in both hybrids and parents was calculated. A total number of 2028 plants was studied.

III Non-productive tillers

Number of non-ear bearing tillers per plant was counted at the time of harvest. The mean number of tillers per plant in both hybrids and parents was calculated. This observation was confined to a total of 1907 plants.

IV Flowering duration

Number of days from the date of seeding to the opening of the spikelet in the first emerging panicle was taken as the flowering duration. This was recorded on 2064 plants.

V Exsertion of panicle

Length in cm of the internodal region from the tip of the last leaf-sheath to the neck of the panicle was measured as exsertion.

A total number of 986 plants was studied. This observation was recorded on the main tiller of each plant.

VI Length of panicle

Length of panicle of the main tiller of each plant was measured in cm, the measurement being taken from the neck to the tip of the top most grain. A total number of 993 plants was studied for this character.

VII Grain and straw yields per plant

Single plants were harvested and seeds collected separately. The yield of grain and straw was recorded in grams after drying and the mean yield per plant was worked out, both for grain and straw. A total number of 1447 plants was studied for this.

VIII Length, breadth and thickness of grains

Measurements in mm from 5 branch tip grains per panicle of the main tiller of each plant were made. Mean length, breadth and thickness of grain were calculated for each of the hybrids and the parents. A total number 235 plants was studied for this.

IX Phenol reaction test

The test was conducted in family 1 - 14 under cross I and in family 5 - 7 under cross II comprising of a total population of 56 and 53 plants respectively. Seed samples from all the F_2 plants at the rate of ten seeds per plant were drawn at maturity and were soaked in 1.5%

aqueous phenol solution for six hours, drained and air dried. Hull colour was recorded as phenol negative if unstained and phenol positive if stained to black. Based on this the individuals were grouped into two phenotypic classes - stained and unstained. The agreement of the observed frequencies to the expected ratio was tested by χ^2 test of goodness of fit.

X Pollen sterility

Sterility of pollen grains was estimated both for the parents and the hybrids. Fresh pollen grains were collected at the time of anthesis. They were stained with glycerine - acetocarmine mixture (1:1) and the slides were kept for a few minutes so as to allow the stain to act on the pollen grains. The slides were then examined under the microscope (low power). Well stained pollen grains were counted as fertile and others as sterile ones. Counts were made from 30 microscopic fields selected at random for each plant. The data were tabulated and the percentage of sterility was estimated as shown below:

$$\text{Percentage of pollen sterility} = \frac{\text{No. of sterile grains} \times 100}{\text{Total number of grains.}}$$

The study was conducted on 122 hybrid plants selected at random belonging to four crosses and on 30 parental plants.

XI Spikelet sterility

This was estimated after the grains attained full maturity. The earheads from the main tiller were collected from each of the plants and the total number of well filled grains and chaff was counted separately. The data were tabulated and the percentage of sterility was estimated as shown below:

$$\text{Spikelet sterility} = \frac{\text{Number of chaff} \times 100}{\text{Total number of spikelets}}$$

A total number of 900 plants belonging to the four cross combinations and the parents were studied.

Methods of analysis: Based on the results obtained, the individuals were grouped into frequencies by selecting appropriate class intervals. Then the mean, standard error of mean and coefficient of variation were calculated, both for hybrids and parents. The results are presented in Table I to XIV.

XII Cytological studies

Panicles of the proper stage from 15 plants selected at random in each of the four cross combinations were fixed between 9.30 A.M. and 10.A.M. in three parts ethyl alcohol to one part glacial acetic acid. The material was kept in the fixative over night, washed in rectified spirit and stored in 70% alcohol. Temporary slides with 1% acetocarmine were prepared, gently warmed over the flame and the cells flattened placing the slides on folds of filter paper by applying modest pressure. The slides were examined with the help of an Olympus microscope. Abnormalities in meiosis as observed under the microscope, were recorded.

EXPERIMENTAL RESULTS

RESULTS

The objective of any breeding programme is to obtain individuals possessing maximum number of desirable attributes. A knowledge about the mode of inheritance of characters will be of great help to the breeder in planning his work and also in selecting out such desirable phenotypes from a segregating population. Results obtained from a study of 15 characters in F_2 generation of both inter and intra-racial hybrids of four crosses in rice, are presented below:

Detailed characteristics of the parental types used

Sl.No.	Particulars	Vellayani-1	Taichung Native-1	Tainan-3
1	Type	*Indica*	*Taiwanese indica*	*Japonica*
2	Origin	Selection from a mutant type developed by neutron irradiation in Ptb.10 (Evolved at A.C.& R.I., Vellayani)	Selection from a cross between Dee-Geo-Woo.Gen and Tsai-Yuwan-Chung (Taiwan)	Selection from a cross between Kwan Fu 401 x Gj Unk 38 (Taiwan)
3	Habit of the plant	Tall	Short	Medium tall
4	Tillers	Few and spreading	Many and compact	Many and compact

Sl.No.	Particulars	Vellayani-1	Taichung Native-1	Tainan-3
5	Panicle exsertion	Well exserted	Not exserted	Well exserted
6	Panicle type	Semi compact, partly drooping	Semi-compact drooping	Compact drooping
7	Lemma palea colour	Green	Green	Green
8	Grain size	Medium	Medium bold	Bold
9	Grain colour	Straw	Straw	Straw
10	Awnless	Awnless	Awnless	Awnless
11	Rice	White	White	White
12	Duration	Short (90-100 days)	Medium (120-125 days)	Medium (120-125 days)

I <u>Plant height</u>

The data pertaining to the frequency distribution of individuals of both parents and hybrids based on plant height are presented in Table I.

(TABLE I)

Height of Vellayani-1 and Tainan-3 ranges from 45 to 114 cm and 50 to 104 cm respectively. The F_2 progeny of the cross Vellayani-1 x Tainan-3 shows a wide range of plant height as compared to the parental

TABLE I

Frequency distribution of individuals (parents and F_2) for height (in cm) of plants

Classes particu-lars *	40 44	45 49	50 54	55 59	60 64	65 69	70 74	75 79	80 84	85 89	90 94	95 99	100 104	105 109	110 114	115 119	120 124	125 129	130 134	135 139	Total	$\bar{X}$	S.E	C.V
1	..	1	..	..	1	1	2	3	7	4	15	13	11	3	2	..	..	..	..	..	63	91.8	1.5	12.8
2	..	..	1	..	2	..	3	5	8	18	14	9	2	..	..	..	..	..	..	..	62	86.5	1.2	10.9
3	..	..	..	2	4	6	18	11	11	2	1	..	..	..	..	..	..	..	..	..	55	74.1	1.0	9.9
4	2	..	..	3	5	13	24	33	29	39	28	25	21	15	19	9	5	..	..	..	270	88.9	0.9	17.3
5	7	4	6	11	26	24	48	56	56	54	45	37	23	11	8	4	2	1	1	1	425	82.3	0.8	18.9
6	..	1	4	6	26	20	32	17	20	33	26	8	10	12	..	..	..	..	..	..	215	78.5	1.3	25.2
7	..	4	5	11	21	15	26	22	23	22	32	18	14	7	1	1	1	..	..	..	223	80.6	1.0	19.0

* 1	Vellayani-1	
2	Tainan-3	
3	Taichung Native-1	
4	Vellayani-1 x Tainan-3	(Family 1 - 12)
5	Tainan-3 x Vellayani-1	(,, 5 - 9)
6	Vellayani-1 x Taichung Native-1	(Family 2 - 2)
7	Taichung Native-1 x Vellayani-1	(,, 6- 12)

$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation

lines (vide plate I and II). This is supported by the fact that the coefficient of variation is found to be more in F_2 than in the respective parents. The reciprocal of the above cross also shows almost the same pattern of segregation in F_2 (Fig.1). The highest frequencies of F_2 individuals in both direct and reciprocal crosses are observed to be between 80 - 89 cm and in fact coincides with the mean of the two parental values.

Height of Taichung Native-1 ranges from 55 to 94 cm. The F_2 progeny of the cross between Vellayani-1 x Taichung Native-1 shows a range of variation between 45 - 109 cm, (vide Plate III and IV). The mean of the F_2 is seen to be near to the mean of the two parents. The reciprocal cross also shows similar pattern of segregation with a wider range of variation in F_2 than in the parents (Fig.2).

It is also seen from the table that a few of the F_2 individuals in all the four crosses, resemble the respective parents in plant height. A minor proportion of F_2 population is found to surpass the parental limits in the expression of the character. This transgression is found to be on both sides in the four crosses studied.

No reciprocal difference is seen in the pattern of segregation of plant height in F_2.

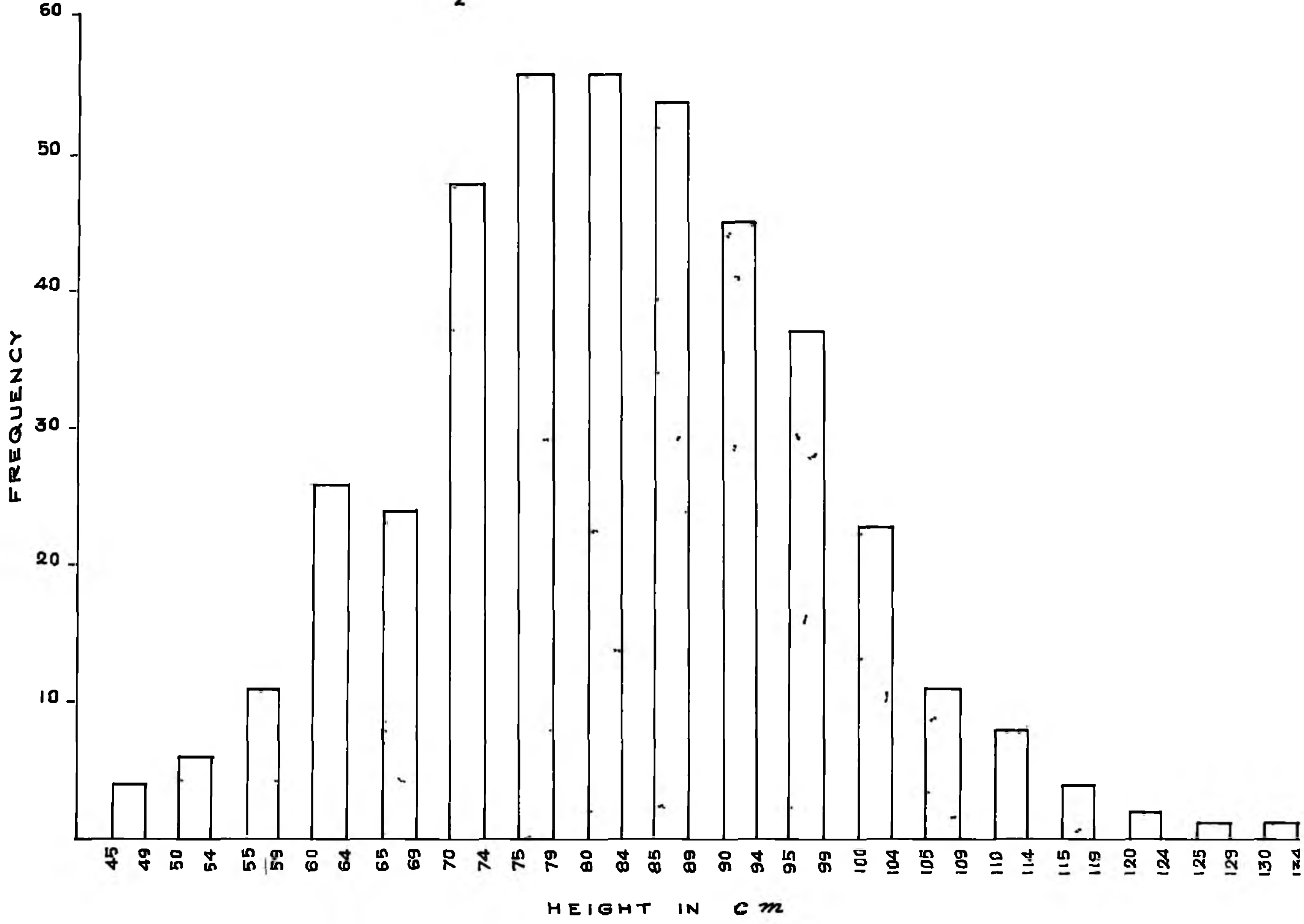
II <u>Productive tillers</u>

The data referring to these of both parents and hybrids are presented in Table II

(TABLE II)

HISTOGRAM REPRESENTING THE FREQUENCY DISTRIBUTION
F_2 INDIVIDUALS FOR PLANT HEIGHT

T 3 × V 1



V 1 × T 3

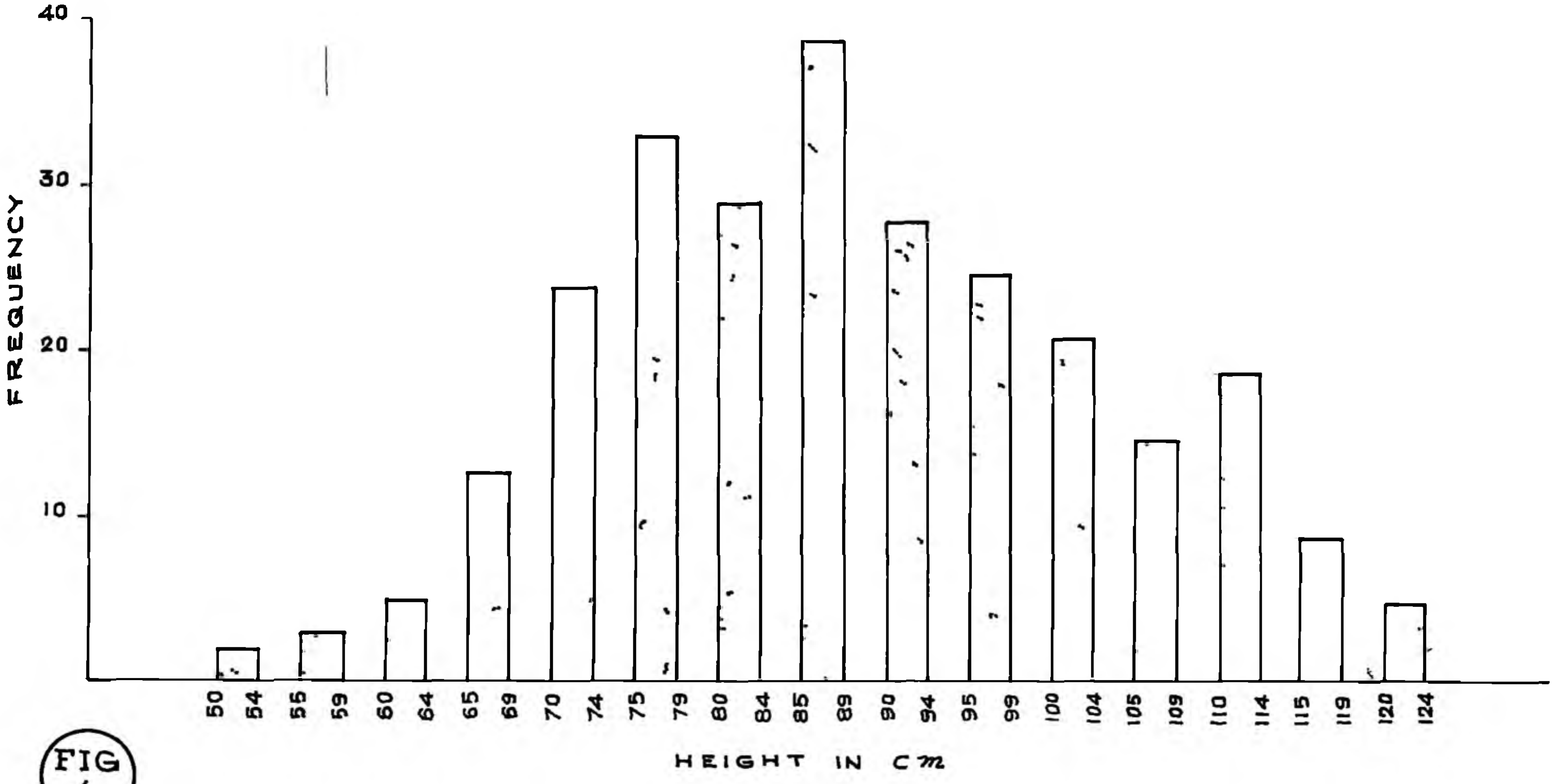
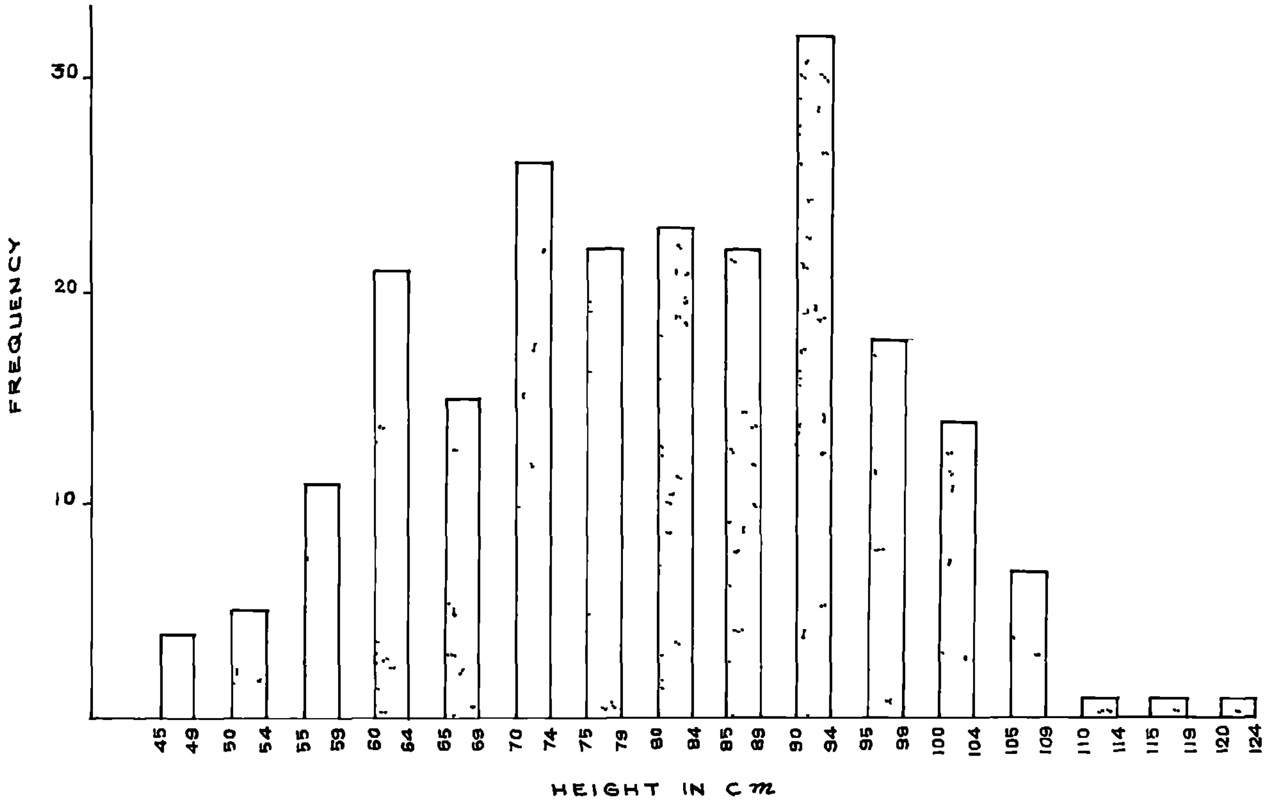


FIG 1

HISTOGRAM REPRESENTING THE FREQUENCY DISTRIBUTION O
F_2 INDIVIDUALS FOR PLANT HEIGHT

TN 1 × V 1



V 1 × TN 1

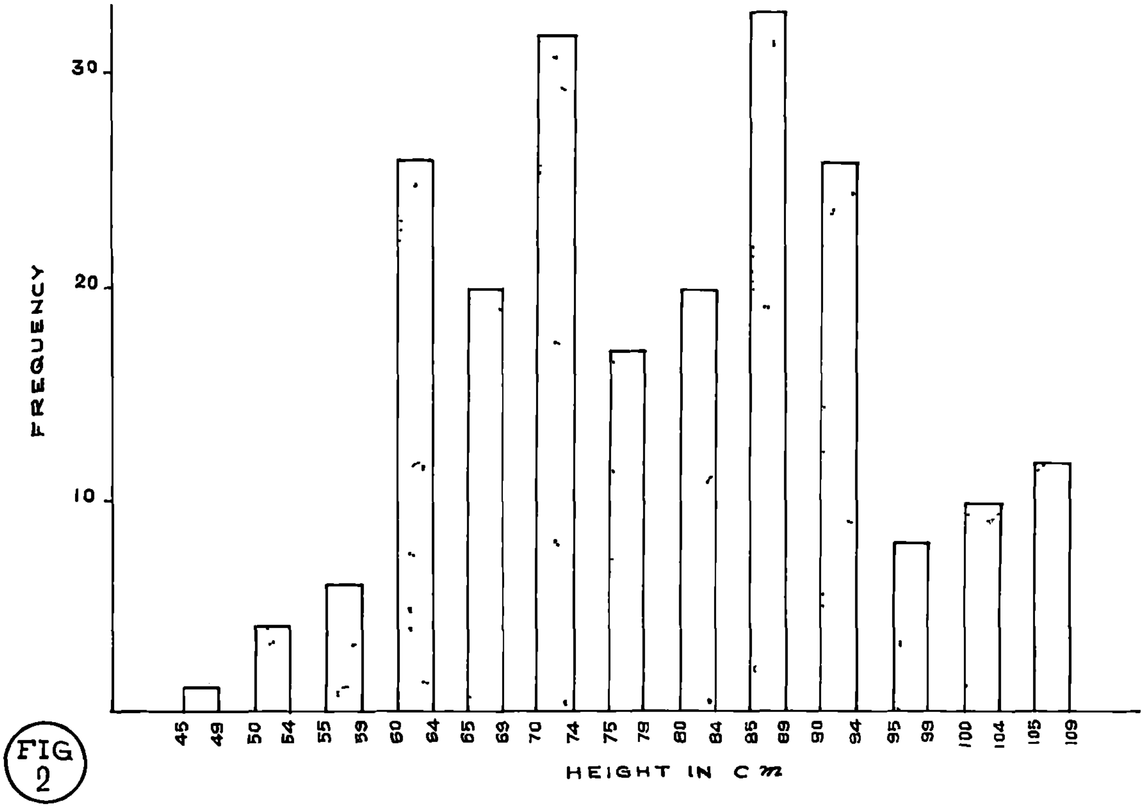


FIG 2

TABLE II

Frequency distribution of individuals (parents and F_2) for the number of productive tillers

Classes particu-lars *	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total	$\bar{X}$	S.E	C.V
1	..	10	16	13	16	3	1	1	..	..	..	..	..	..	..	..	..	60	3.9	0.2	34.8
2	3	12	13	11	8	4	3	3	4	1	..	...	..	..	..	..	..	62	4.3	0.3	53.2
3	..	..	1	1	6	8	5	12	4	7	2	4	2	..	..	1	..	53	7.9	0.5	43.1
4	2	38	40	36	34	22	27	21	15	9	9	3	3	4	2	3	2	270	5.8	0.2	57.4
5	29	79	79	98	49	38	22	14	8	2	2	..	1	..	1	..	..	422	4.0	0.1	52.2
6	2	13	20	31	28	18	34	17	15	8	5	5	6	3	1	6	1	213	6.7	0.3	53.4
7	..	2	8	10	23	22	32	23	23	22	22	13	9	8	1	2	3	223	8.4	0.2	37.0

*	
1	Vellayani-1
2	Tainan-3
3	Taichung Native-1
4	Vellayani-1 x Tainan-3 (Family 1 - 12)
5	Tainan-3 x Vellayani-1 (,, 5 - 9)
6	Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7	Taichung Native-1 x Vellayani-1 (,, 6 -12)

$\bar{X}$ = Mean
S.E = Standard error of mean
C.V. = Coefficient of variation

Number of productive tillers in Vellayani-1 and Tainan-3 ranges from 2 to 8 and 1 to 10 respectively. The F_2 hybrids of these parents are found to exhibit a wide range of variation between 1 and 17, (vide Plate V and VI). The mean number of tillers in cross V1 x T3 and T3 x V1 are 5.8 and 4.0 respectively. These in turn agree with the mean of the two parents.

Taichung Native-1 shows a variation of 3 to 16 with a mean of 7.9 Cross Vellayani-1 x Taichung Native-1 and its reciprocal exhibit a greater range from 1 to 17 and 2 to 17 with mean 6.7 and 8.4 (vide Plate VII and VIII). The means in turn agree with the mean of the two parents.

Individuals having the parental values are found to occur in all the F_2s. A one sided transgression is seen in all the four cases. No reciprocal difference is detected.

III Non-Productive tillers

Frequency of individuals grouped on the basis of number of non-earbearing tillers is shown in Table III.

(TABLE III)

Among the parents, Taichung Native-1 shows the maximum number of non-productive tillers per plant with a mean of 6.0. F_2 progeny of Vellayani-1 x Tainan-3 shows a mean value of 2.6, which is in close agreement with the mean of the two parents. Reciprocal cross also shows

TABLE III

Frequency distribution of individuals (parents and F_2) for the number of non-productive tillers

Classes particulars *	1	2	3	4	5	6	7	8	9	10	11	12	Total	$\bar{X}$	S.E.	C.V
1	15	22	9	2	2	..	..	..	..	..	..	..	50	2.1	0.1	47.8
2	13	32	5	3	2	..	..	..	..	..	..	..	55	2.1	0.1	47.8
3	..	1	7	9	10	10	1	9	3	4	..	1	55	6.0	0.3	38.7
4	36	113	55	32	12	4	1	1	1	..	1	..	256	2.6	0.1	52.1
5	78	159	69	53	14	13	6	..	..	1	..	..	393	2.6	0.1	54.4
6	19	81	50	22	18	6	5	1	2	..	..	..	204	3.0	0.1	51.8
7	20	74	35	43	9	6	8	2	3	2	3	1	206	3.4	0.1	62.6

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 - 12)
5 Tainan-3 x Vellayani-1 (,, 5 - 9)
6 Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7 Taichung Native-1 x Vellayani-1 (Family 6 -12)

$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation

the same pattern of segregation.

The F_2 progeny of the cross between Vellayani-1 x Taichung - Native-1 shows a higher mean of 3.0. The reciprocal cross also shows the same pattern of variation with mean 3.4.

The cross Vellayani-1 x Tainan-3 shows a coefficient of variation of 52.1 and its reciprocal cross a variation of 54.4. This is higher than the variation possessed by the parents i.e. 47.8 each. The same is the case in the second set of crosses.

IV <u>Flowering duration</u>

Data pertaining to this are presented in Table IV.

(TABLE IV)

Vellayani-1 flowers earlier with a mean flowering duration of 78 days. Tainan-3 and Taichung Native-1 have a mean flowering duration of 83.9 and 82.2 days respectively. The F_2 progeny of the cross between Vellayani-1 and Tainan-3 shows transgressive variation with its mean nearing to the mean of the two parents. The reciprocal cross also shows similar results.

In the cross between Vellayani-1 and Taichung Native-1, the range of variation in the F_2 is found to be within the limits of the variation exhibited by the parents. However, the mean of the F_2 is found to agree with the mean of the two parental values. The reciprocal cross does not differ from the direct cross in its pattern of segregation,

TABLE IV

Frequency distribution of individuals (parents and F_2) for flowering duration in days

Classes particulars *	50 52	53 55	56 58	59 61	62 64	65 67	68 70	71 73	74 76	77 79	80 82	83 85	86 88	89 91	92 94	95 97	98 100	101 103	104 106	107 109	Total	$\bar{X}$	S.E.	C.V.
1	..	..	..	..	..	1	3	15	1	16	17	6	1	3	..	..	..	..	..	..	63	78.0	0.7	6.9
2	..	..	..	..	..	..	1	1	1	5	26	7	9	7	1	1	3	..	..	..	62	83.9	0.7	7.0
3	..	..	..	..	..	..	..	1	1	3	38	3	3	4	2	..	..	..	..	..	55	82.2	0.5	4.6
4	1	1	1	15	29	37	43	38	25	39	17	5	6	3	4	1	2	1	1	1	270	72.3	0.4	9.1
5	..	..	..	1	4	21	32	57	115	79	54	11	11	14	10	9	1	2	3	1	425	77.3	0.4	9.6
6	..	..	..	..	..	8	19	60	14	20	68	8	3	6	6	3	..	..	..	..	215	77.2	0.4	8.5
7	..	..	..	..	3	29	18	53	4	26	60	9	6	9	3	2	1	..	..	..	223	76.3	0.7	13.6

*	
1	Vellayani-1
2	Tainan-3
3	Taichung Native-1
4	Vellayani-1 x Tainan-3 (Family 1 - 12)
5	Tainan-3 x Vellayani-1 (,, 5 - 9)
6	Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7	Taichung Native-1 x Vellayani-1 (,, 6 -12)

$\bar{X}$ = Mean
S.E.= Standard error of mean
C.V.= Coefficient of variation

the means of the two being - 77.2 and 76.3, which also agree with the parental mean. In two of the four crosses, there is clear evidence of transgressive segregation.

V Exsertion of panicle

Frequency distribution of both parents and hybrids, on the basis of exsertion of panicle is shown in Table V.

(TABLE V)

Among the parents Taichung Native-1 is not exserted at all. Vellayani-1 and Tainan-3 have a mean exsertion of 3.0 cm and 7.1 cm respectively. The cross between Vellayani-1 and Tainan-3 shows a mean exsertion of 3.7 cm which falls between the two parental means. Reciprocal cross shows the same pattern of segregation with a mean of 3.3 cm which is also very close to the mean of the parents.

In the cross between Vellayani-1 and Taichung Native-1 majority of the F_2 individuals show no exsertion. The same is the result obtaine in reciprocal cross also. The mean of the F_2 progeny agrees with the me of the two parents.

The fact that F_2 has a greater range of variability as compared to parents, is shown by the magnitude of coefficient of variation. This is also seen in Plates IX and X.

TABLE V

Frequency distribution of individuals (parents and F_2) for exsertion of panicle in cm

Classes particulars *	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total	$\bar{X}$	S.E.	C.V.
1	8	1	5	6	3	5	2	2	1	..	..	..	..	..	..	..	..	..	33	3.0	0.4	76.8
2	..	..	..	..	2	2	7	8	8	3	1	1	..	..	..	..	..	..	32	7.1	0.3	21.5
3	47	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	47	0	0	0
4	68	12	16	29	23	19	22	14	12	10	4	3	2	..	..	..	1	1	236	3.7	0.2	93.7
5	73	15	15	21	28	22	16	15	6	7	4	..	3	..	..	..	1	..	226	3.3	0.2	96.6
6	153	14	10	10	6	9	2	2	2	2	..	..	..	..	..	..	..	..	210	0.9	0.1	204.8
7	132	16	16	9	10	7	8	..	2	1	..	..	..	..	..	..	..	..	201	1.1	0.1	173.5

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 - 12)
5 Tainan-3 x Vellayani-1 (,, 5 - 9)
6 Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7 Taichung Native-1 x Vellayani-1 (,, 6 -12)

$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation

VI Length of panicle

Data are presented in Table VI.

(TABLE VI)

From the results presented in Table VI, it is seen that all the parents show the same range of variation of 17 to 26 cm, with means almost nearing to 22 cm. The cross between Vellayani-1 and Tainan-3 exhibits transgressive variation with mean value lying close to the mean value of the two parents. The reciprocal crosses do not show any difference and their means agree with the mean of the respective parents (Fig.3).

The F_2 progeny in all the four crosses are found to have greater range of variation as compared to the respective parents (vide Plates XI and XII). There is a clear case of transgressive variation in all the above four cases (Fig.4).

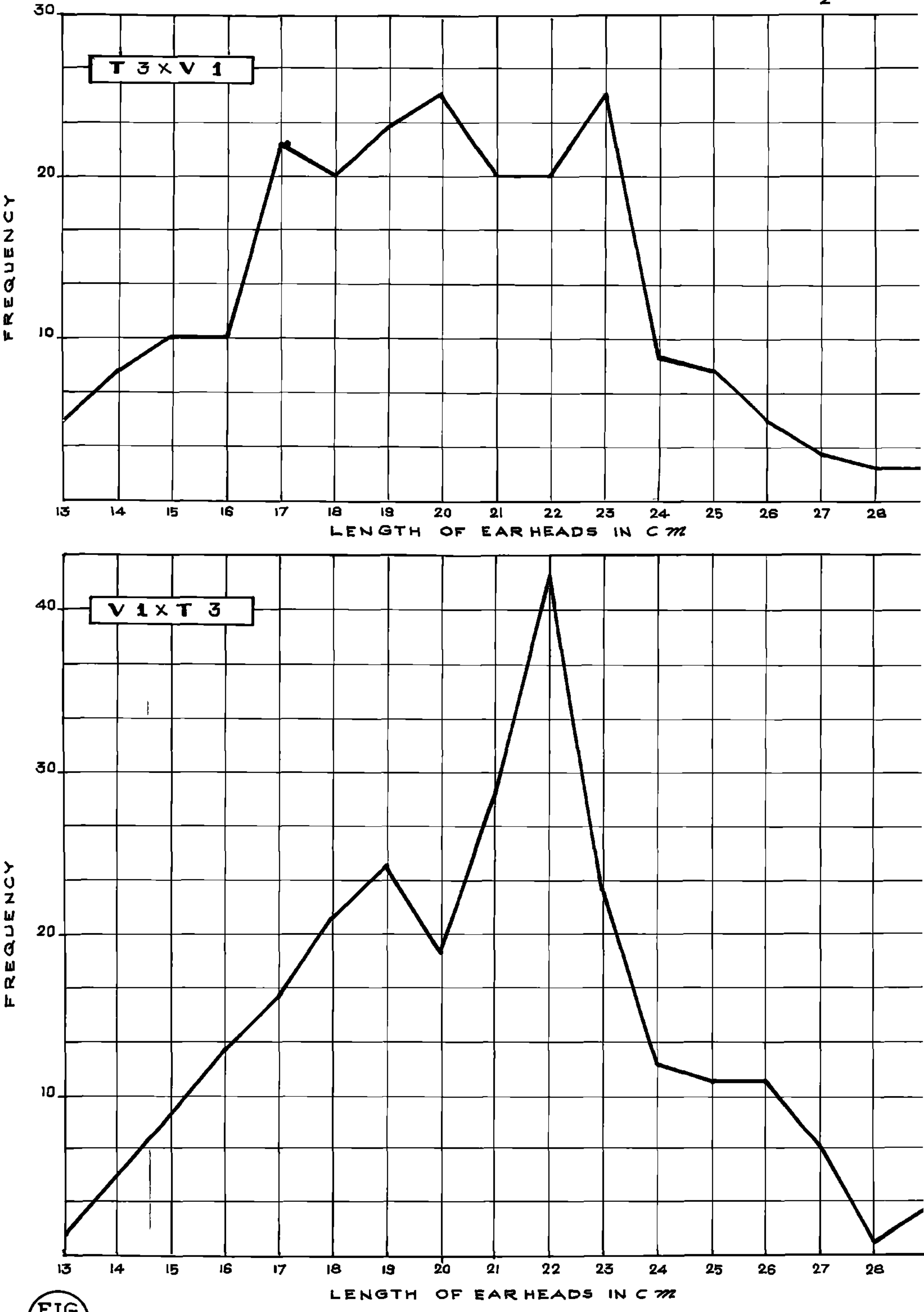
VII Grain yield

Frequency of individuals of both parents and hybrids are presented in Table VII.

(TABLE VII)

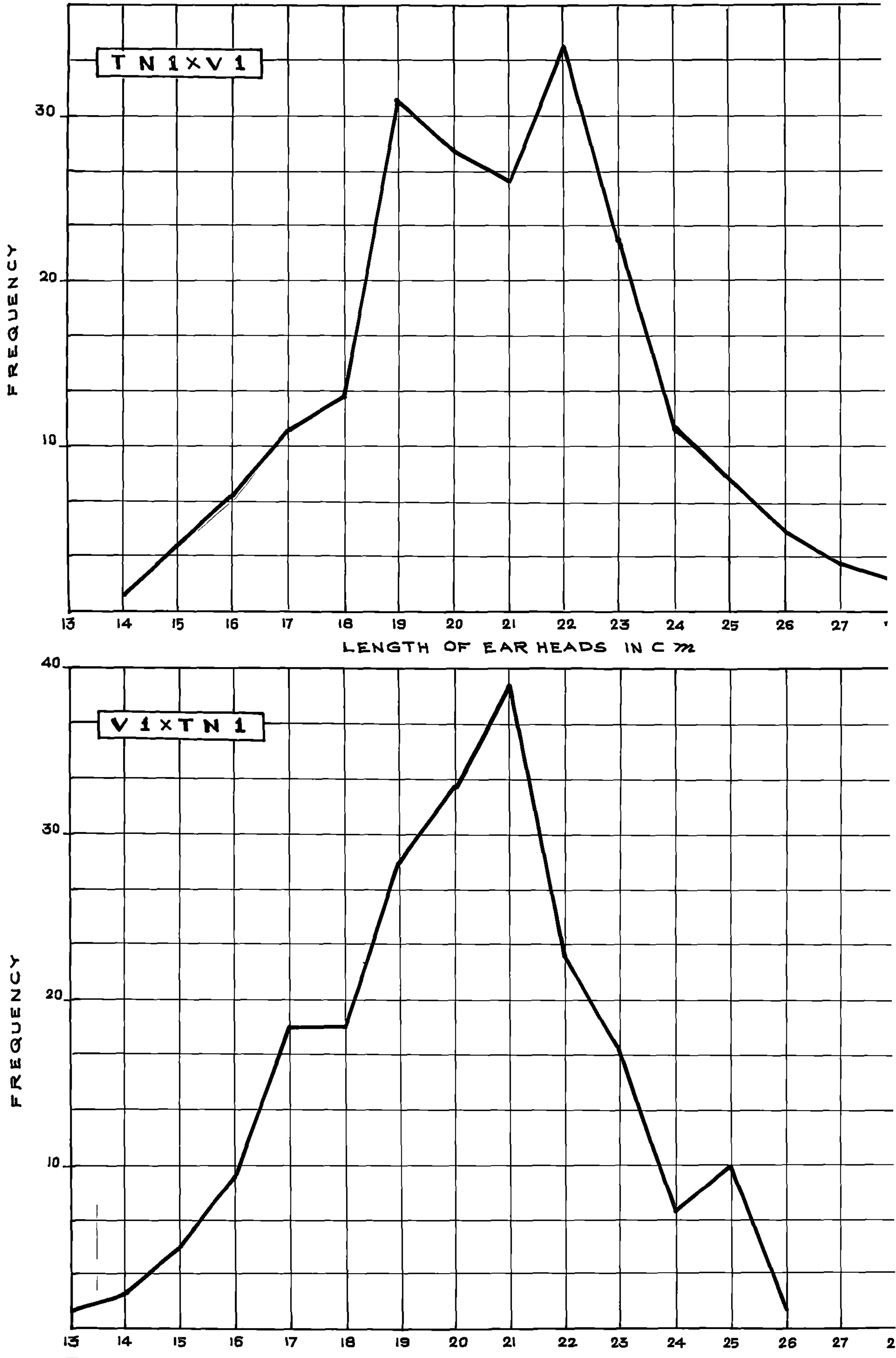
The results show that the cross between Vellayani-1 and Tainan-3 and its reciprocal have recorded mean grain yields lesser than that of either of the parents.

FREQUENCY POLYGON RERRESENTING THE LENGTH OF EARHEADS OF F_2 INDIVI



FIG

FREQUENCY POLYGON REPRESENTING THE LENGTH OF EARHEADS OF F_2 IND



FIG

TABLE VI

Frequency distribution of individuals (parents and F_2) for length of earhead in cm

Classes particulars *	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total	$\bar{X}$	S.E.	C.V.
1	..	..	..	..	1	1	4	2	9	6	6	2	1	1	..	..	..	..	33	21.5	0.3	9.3
2	..	..	..	..	..	..	1	3	4	8	6	8	1	1	..	..	..	..	32	22.5	0.3	7.0
3	..	..	..	..	..	3	3	3	8	7	11	8	3	..	..	..	..	..	46	22.0	0.3	8.7
4	1	5	9	13	16	21	24	19	29	42	23	12	11	11	7	1	3	..	247	20.8	0.2	15.8
5	5	8	10	10	22	20	23	25	20	20	25	9	8	5	3	2	2	1	218	20.0	0.2	18.3
6	1	2	5	9	18	18	28	33	39	23	17	7	10	1	..	..	..	..	211	20.1	0.2	12.7
7	..	1	4	7	11	13	31	28	26	34	22	11	8	5	3	2	..	..	206	20.8	0.2	12.9

*		
1	Vellayani-1	
2	Tainan-3	
3	Taichung Native-1	
4	Vellayani-1 x Tainan-3	(Family 1 - 12)
5	Tainan-3 x Vellayani-1	(,, 5 - 9)
6	Vellayani-1 x Taichung Native-1	(Family 2 - 2)
7	Taichung Native-1 x Vellayani-1	(,, 6 -12)

$\bar{X}$ = Mean
S.E.= Standard error of mean
C.V.= Coefficient of variation

TABLE VII

Frequency distribution of individuals (parents and F_2) for grain yield (in g)

Classes particulars *	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	21 22	23 24	25 26	27 28	29 30	31 32	33 34	35 36	Total	$\bar{X}$	S.E.	C.V.
1	1	7	8	9	2	..	1	1	1	..	..	..	..	..	..	..	..	..	30	6.8	0.6	51.9
2	2	2	10	4	4	4	2	..	1	1	..	..	..	..	..	..	..	..	30	8.1	0.8	51.9
3	1	1	3	6	3	4	4	2	3	..	..	2	..	1	..	..	..	..	30	11.8	1.1	50.9
4	65	50	33	26	11	11	3	3	3	..	..	1	1	..	..	..	..	..	207	5.2	0.3	80.2
5	142	87	40	25	10	6	..	1	1	..	..	..	..	..	..	..	..	..	312	3.6	0.2	73.8
6	24	26	30	37	17	14	3	4	7	9	3	1	3	1	2	1	..	..	182	8.7	0.5	74.6
7	2	8	21	30	20	15	11	23	12	7	4	2	8	4	1	..	..	1	169	12.4	0.5	53.2

* 1	Vellayani-1
2	Tainan-3
3	Taichung Native-1
4	Vellayani-1 x Tainan-3 (Family 1 - 12)
5	Tainan-3 x Vellayani-1 (,, 5 - 9)
6	Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7	Taichung Native-1 x Vellayani-1 (,, 6 -12)

$\bar{X}$ = Mean
S.E = Standard error of mean
C.V. = Coefficient of variation

In the cross between Vellayani-1 and Taichung Native-1, the mean value of the F_2 is found to lie between the parental means. Similar pattern of segregation is found in the reciprocal cross also.

The coefficient of variation is observed to be more in all the four crosses as compared to parents, thereby indicating the wider range of variability in hybrids.

VIII Straw yield

Data pertaining to straw yield are presented in Table VIII

(TABLE VIII)

Results show that the cross between Vellayani-1 and Tainan-3 has recorded a variation in straw yield ranging from 1 to 34 g. Its mean of 10.0 agrees with the mean of the two parents. The reciprocal of the above cross is also seen to have similar results. Same is the case observ in the other set of crosses.

In all the F_2s studied the extent of variability is found to be more as compared to respective parents. There is a clear evidence of transgressive variation on both the sides.

IX Length of grain

Data are presented in Table IX.

(TABLE IX)

TABLE VIII

Frequency distribution of individuals (parents and F_2) for straw yield (in g)

Classes particulars *	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	21 22	23 24	25 26	27 28	29 30	31 32	33 34	35 36	Total	$\overline{X}$	S.E.	C.V.
1	..	3	3	10	7	1	2	2	2	..	..	..	..	..	..	..	..	..	30	9.1	0.7	41.5
2	..	1	3	4	5	7	5	1	2	2	..	..	..	..	..	..	..	..	30	11.2	0.7	36.0
3	..	..	3	6	3	9	2	3	2	2	..	..	..	..	..	..	..	..	30	11.4	0.7	34.8
4	14	22	36	32	29	15	7	18	12	10	4	2	2	2	1	..	1	..	207	10.0	0.4	62.6
5	26	55	56	68	37	19	14	9	11	5	4	5	3	1	..	..	1	..	312	8.2	0.3	66.5
6	2	17	29	40	35	9	4	15	8	9	2	4	3	2	..	1	..	2	182	10.6	0.5	60.6
7	1	1	11	21	19	27	8	31	10	11	10	1	12	..	3	..	1	2	169	14.4	0.5	45.5

* 1	Vellayani-1
2.	Tainan-3
3	Taichung Native-1
4	Vellayani-1 x Tainan-3 (Family 1 - 12)
5	Tainan-3 x Vellayani-1 (,, 5 - 9)
6	Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7	Taichung Native-1 x Vellayani-1 (Family 6 -12)

$\overline{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation.

TABLE IX

Frequency distribution of individuals (parents and F_2) for length of grains (in mm)

Classes particulars *	6.4 6.5	6.6 6.7	6.8 6.9	7.0 7.1	7.2 7.3	7.4 7.5	7.6 7.7	7.8 7.9	8.0 8.1	8.2 8.3	8.4 8.5	8.6 8.7	8.8 8.9	9.0 9.1	Total	$\bar{X}$	S.E.	C.V.
1	..	..	..	..	1	3	1	4	1	..	..	..	..	..	10	7.7	0.08	3.2
2	1	2	5	1	1	..	..	..	..	..	..	..	..	..	10	6.8	0.06	2.9
3	..	..	..	..	2	6	2	..	..	..	..	..	..	..	10	7.5	0.04	1.9
4	1	2	6	7	9	8	10	8	3	2	1	..	..	..	57	7.4	0.06	5.7
5	1	1	4	6	7	9	6	3	1	1	1	..	1	..	41	7.4	0.06	5.2
6	..	1	2	4	6	7	12	7	5	4	3	..	..	1	52	7.6	0.05	4.9
7	..	1	2	4	8	10	10	6	4	8	2	..	..	..	55	7.6	0.06	6.0

*	
1	Vellayani-1
2	Tainan-3
3	Taichung Native-1
4	Vellayani-1 x Tainan-3 (Family 1 - 14)
5	Tainan-3 x Vellayani-1 (,, 5 - 7)
6	Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7	Taichung Native-1 x Vellayani-1 (,, 6 -14)

$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation

The cross between Vellayani-1 and Tainan-3 shows a range of 6.4 to 8.5 mm with a mean of 7.4 mm. The mean is in agreement with the mean of the two parents. Reciprocal cross gives similar results (Fig.5).

The cross between Vellayani-1 and Taichung Native-1 shows a range of variation between 6.6 and 9.1 mm with 7.6 mm as the mean. This is in agreement with the parental mean of 7.6 mm. The reciprocal cross also gives similar results (Fig.6).

The extent of variability exhibited by all the F_2s studied, is found to be more with respect to parents. Transgressive segregation on both the case is seen only in two of the four cases studied.

X <u>Breadth of Grains</u>

Results are presented in Table X.

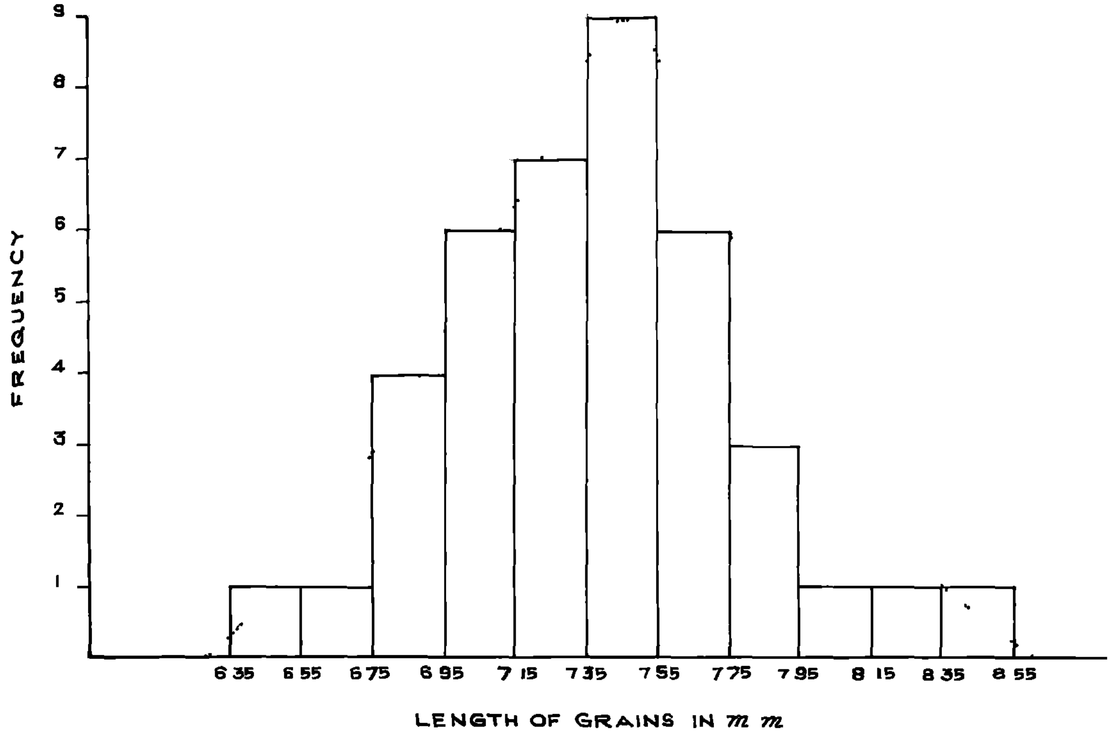
(TABLE X)

Range of variation in the F_2 of the cross between Vellayani-1 a Tainan-3 is seen to be 2.4 to 3.5 mm with mean 3.0 mm. This is in accord with the mean of the two parental values. The reciprocal cross is also f to behave similarly.

In the cross between Vellayani-1 and Taichung Native-1, the ran of variation is found to be from 2.2 to 3.5 mm with mean 2.9 mm. This is in agreement with the mean of the two parents. The reciprocal cross is observed to have a lesser range of variation with a mean 3.0 mm which agree with the mean of the parents.

HISTOGRAM REPRESENTING THE FREQUENCY DISTRIBUTION
F_2 INDIVIDUALS FOR LENGTH OF GRAINS

T 3 × V 1



V 1 × T 3

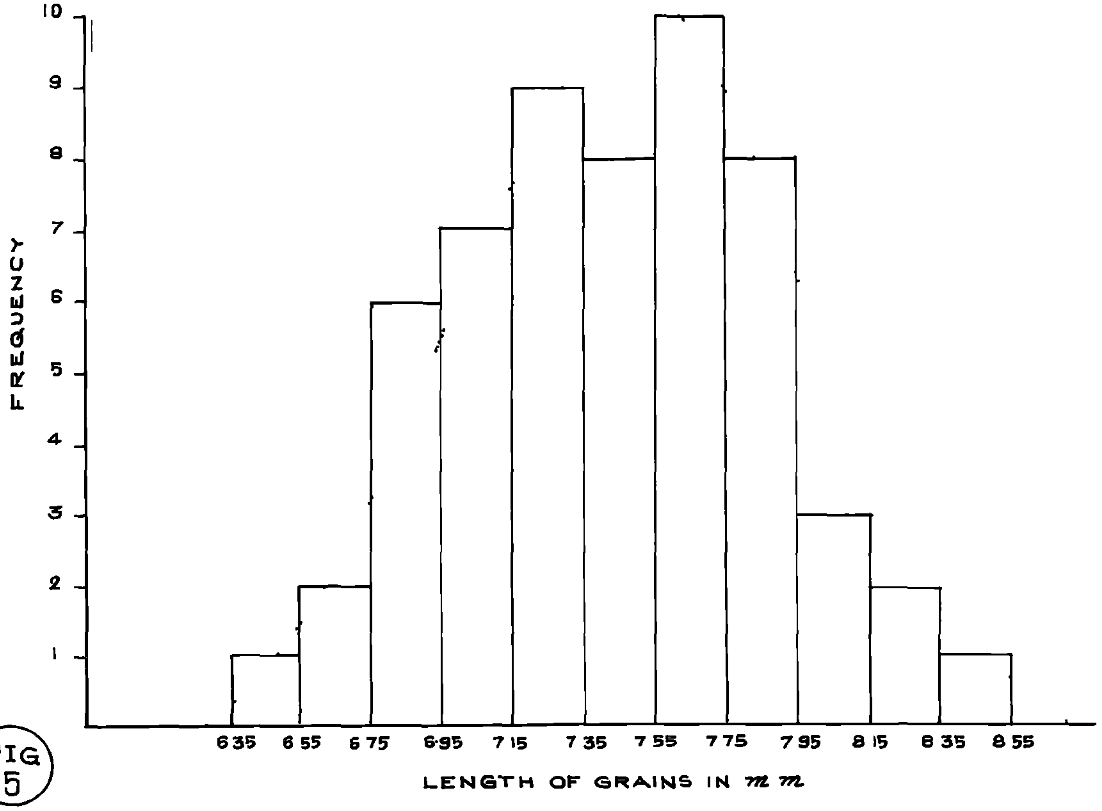


FIG
5

HISTOGRAM REPRESENTING THE FREQUENCY DISTRIBUTIO
F_2 INDIVIDUALS FOR LENGTH OF GRAINS

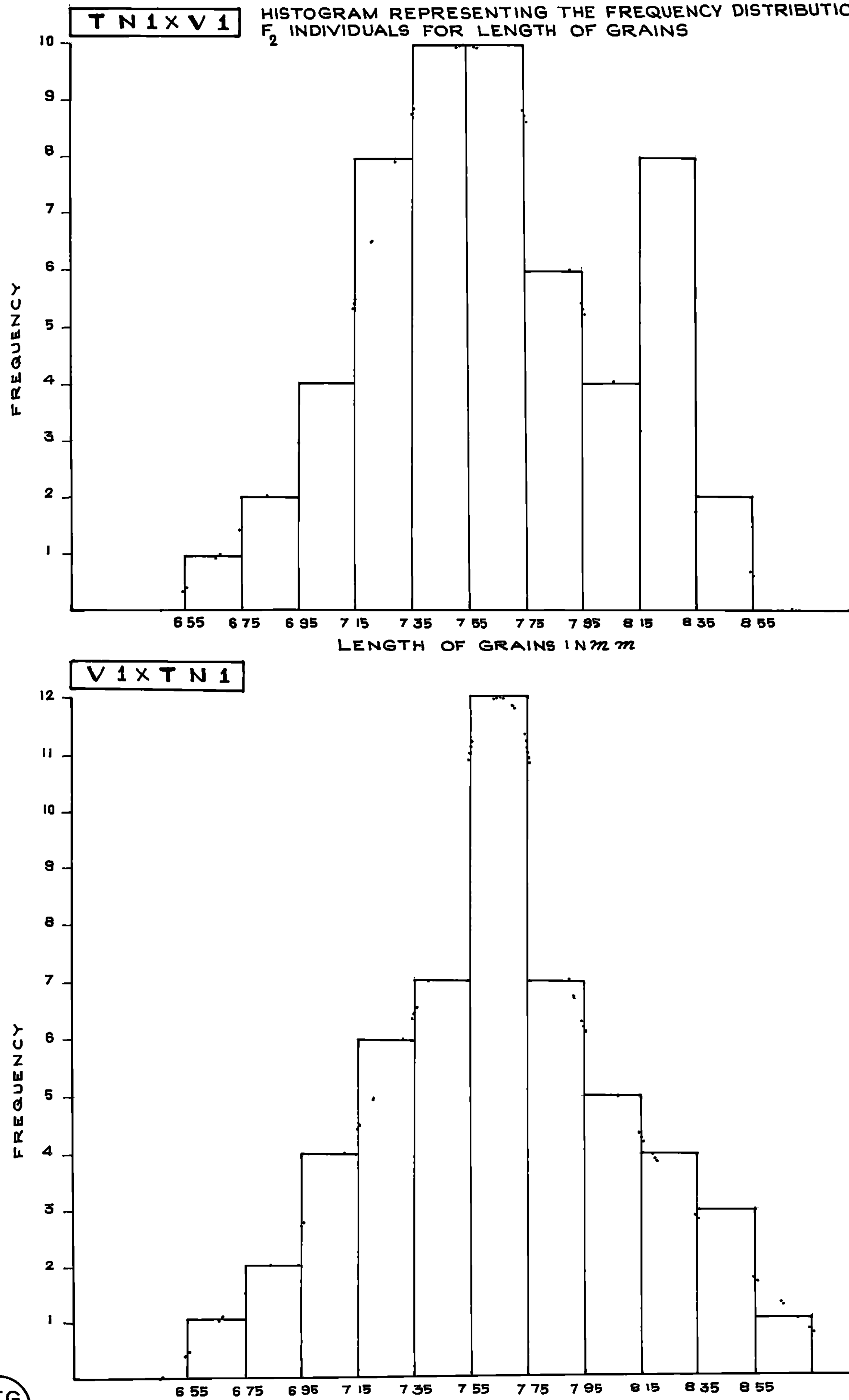


FIG
6

TABLE X

Frequency distribution of individuals (parents and F_2) for breadth of grain (in mm)

Classes – particulars *	2.2 2.3	2.4 2.5	2.6 2.7	2.8 2.9	3.0 3.1	3.2 3.3	3.4 3.5	3.6 3.7	Total	$\bar{X}$	S.E.	C.V.
1	..	..	..	8	2	..	..	..	10	2.8	0.01	0.7
2	..	..	..	..	..	3	6	1	10	3.4	0.04	3.2
3	..	..	..	3	7	..	..	..	10	3.0	0.01	0.8
4	..	2	9	16	11	12	7	..	57	3.0	0.04	9.0
5	..	..	1	5	16	11	8	..	41	3.1	0.03	5.5
6	1	2	9	15	15	8	1	..	51	2.9	0.03	8.5
7	..	..	4	24	18	8	1	..	55	3.0	0.02	5.7

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 - 14)
5 Tainan-3 x Vellayani-1 (,, 5 - 7)
6 Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7 Taichung Native-1 x Vellayani-1 (,, 6 -14)

$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation

Higher coefficient of variation is observed in all the four cases as compared to the respective parents. Transgressive variation on both the sides is seen only in two of the four cases studied.

XI <u>Thickness of grains</u>

Data pertaining to the above are presented in Table XI.

(TABLE XI)

The F_2 progeny of the cross between Vellayani-1 and Tainan-3 shows a range from 1.5 to 2.4 mm with mean 2.0 mm. This is in accordance with the mean of the two parents. The reciprocal cross shows a lesser range of variation i.e., 1.9 to 2.4 mm with mean 2.1 mm which is in agreement with the mean of the direct cross and also that of the two parental means.

The cross between Vellayani-1 and Taichung Native-1 shows a variation of 1.7 to 2.2 mm with mean 2.0 mm. This is in agreement with the mean of the two parents. The reciprocal cross also shows a similar results.

The coefficient of variation is observed to be more in all the four crosses as compared to the respective parents, thereby indicating the wider range of variability in hybrids.

TABLE XI

Frequency distribution of individuals (parents and F_2) for thickness of grain (in mm)

Classes particulars *	1.5 1.6	1.7 1.8	1.9 2.0	2.1 2.2	2.3 2.4	Total	$\bar{X}$	S.E.	C.V.
1	..	1	8	1	..	10	2.0	0.03	4.7
2	..	..	..	3	7	10	2.3	0.03	4.1
3	..	..	8	2	..	10	2.0	0.03	4.2
4	1	3	31	21	1	57	2.0	0.02	5.7
5	..	..	19	19	3	41	2.1	0.02	6.8
6	..	2	28	21	..	51	2.0	0.02	6.0
7	..	1	32	22	..	55	2.0	0.02	5.4

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 - 14)
5 Tainan-3 x Vellayani-1 (,, 5 - 7)
6 Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7 Taichung Native-1 x Vellayani-1 (,, 6 -14)

$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation

XII Phenol reaction

Results of the phenol reaction test conducted for the hybrids Vellayani-1 x Tainan-3 and its reciprocal are presented in Table XII

TABLE XII

Phenol reaction test

Class	Observed frequency (0)	Expectdd frequency in 3:1 ratio (E)	0 - E	$\chi^2 = \frac{(0-E)^2}{E}$
	a) Cross Vellayani-1 x Tainan-3			
Stained	45	42	3	0.21
Unstained	11	14	-3	0.64
Total	56	56	-	0.85
	b) Cross Tainan-3 x Vellayani-1			
Stained	42	39.75	2.25	0.13
Unstained	11	13.25	-2.25	0.382
Total	53	53.00	-	0.512

Critical value

χ^2 (0.05) = 3.841

χ^2 (0.01) = 6.635

The obtained values are 0.85 and 0.512 respectively.

Since the calculated value is less than the critical value, the χ^2 is significant at both the levels.

The results show that there is a clear cut segregation of F_2 individuals in both direct and reciprocal crosses, into phenol positive and phenol negatives in a 3:1 phenotypic ratio, thereby suggesting the complete dominance of the phenol positive to phenol negative.

Hybrid sterility

Data on pollen and spikelet sterility are tabulated and presented in Tables XIII and XIV.

a) Pollen sterility

(TABLE XIII)

The results show that the mean range of pollen sterility observe in the hybrids of the four cross combinations is from 22.1 to 45.2 per c whereas in the parental varieties the range is as low as 9.5 to 14.0 per

In the cross between Vellayani-1 x Tainan-3 and its reciprocal, percentage of pollen sterility is found to be more as compared to the ot set of crosses.

The hybrids of Vellayani-1 x Tainan-3 and its reciprocal shows a mean sterility of 45.2 and 38.0 per cent. The sterility percentage in t parental varieties Vellayani-1 and Tainan-3 is 11 and 14 per cent. The hybrids of Vellayani-1 x Taichung Native-1 and its reciprocal show 31.1

TABLE XIII

Frequency distribution of individuals (parents and F_2) for pollen sterility (in %)

lasses articu- ars *	0 4	5 9	10 14	15 19	20 24	25 29	30 34	35 39	40 44	45 49	50 54	55 59	60 64	65 69	70 74	75 79	80 84	85 89	90 94	95 99	Total	$\bar{X}$	S.E.	C.V.
1	2	2	3	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	11.0	2.0	56.8
2	1	2	3	2	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	14.0	2.5	55.8
3	3	3	1	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	9.5	2.6	85.7
4	..	..	..	1	4	3	4	3	4	1	..	3	..	2	1	1	1	1	1	..	30	45.2	4.6	55.3
5	..	4	3	1	3	5	1	2	1	2	2	..	..	..	1	1	1	..	2	1	30	38.0	5.7	81.5
6	..	3	2	5	7	4	5	..	..	..	1	1	..	1	..	..	1	1	..	1	32	31.1	4.0	73.3
7	..	3	5	4	6	4	3	3	2	..	..	..	..	..	..	..	..	..	..	..	30	22.1	2.7	67.6

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 - 14)
5 Tainan-3 x Vellayani-1 (,, 5 - 7)
6 Vellayani-1 x Taichung Native-1 (Family 2 - 6)
7 Taichung Native-1 x Vellayani-1 (,, 6 -14)

$\bar{X}$ = Mean
S.E. = Standard error of mean
C.V. = Coefficient of variation

TABLE XIV

Frequency distribution of individuals (parents and F_2) for spikelet sterility (in %)

Classes	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	Total	$\bar{X}$	S.E.	C.V.
particulars *	4	9	14	19	24	29	34	39	44	49	54	59	64	69	74	79	84	89	94	99				
1	9	4	3	6	5	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	28	11.0	1.9	91.6
2	..	11	4	3	2	2	2	1	..	..	..	..	..	..	..	..	..	..	..	..	25	15.0	1.9	62.5
3	2	8	12	5	5	2	4	5	..	..	..	..	..	..	..	..	..	..	..	..	43	17.8	1.6	59.1
4	4	11	27	15	26	14	22	16	14	16	13	11	4	5	9	4	..	1	..	2	214	31.8	1.7	76.2
5	1	12	20	28	27	26	13	15	16	12	16	11	10	5	3	4	1	..	1	2	223	33.3	1.4	63.2
6	4	23	23	38	24	23	15	15	14	11	8	5	9	2	1	3	3	3	..	..	224	29.4	1.3	65.3
7	3	11	29	35	26	22	17	21	10	3	4	4	5	3	1	1	3	2	1	2	203	29.0	1.3	65.9

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 - 12)
5 Tainan-3 x Vellayani-1 (,, 5 - 9)
6 Vellayani-1 x Taichung Native-1 (Family 2 - 2)
7 Taichung Native-1 x Vellayani-1 (,, 6 -12)

$\bar{X}$ = Mean
S.E.= Standard error of mean
C.V.= Coefficient of variation

and 22.1 per cent sterility, whereas the parents record 11 and 9.5 per cent respectively.

b) Spikelet sterility

(TABLE XIV)

The mean spikelet sterility in the hybrids of the four cross combination ranged from 29.0 to 33.3 per cent, whereas the range in the parental varieties is seen to be from 11.0 to 17.8 per cent.

The two crosses Vellayani-1 x Tainan-3 and its reciprocal show 31.8 and 33.3 per cent spikelet sterility as against 11.0 and 15 per cent recorded by the parents Vellayani-1 and Tainan-3 respectively.

The cross between Vellayani-1 and Taichung Native-1 records 29.4 per cent sterility as compared to 29.0 per cent sterility, recorded by its reciprocal cross. The parents Vellayani-1 and Taichung Native-1 have recorded a mean percentage of 11.0 and 17.8 per cent sterility respective

Meiotic studies

Chromosome behaviour in meiosis I

All the plants examined showed a somatic chromosome number of 24. They normally formed 12 closely synapsed bivalents during meiosis I with regular disjunction of 12 chromosomes to each poles during anaphase.

In Pachytene, a few instances of formation of chromosome loops characteristics of inversion were seen in both the cross Vellayani-1 x

Tainan-3 and its reciprocal. No such instance is observed in the other set of crosses and also in the parents. Metaphase and anaphase were observed to be regular in all the crosses studied.

DISCUSSION

DISCUSSION

In the present investigation the behaviour of F_2 hybrids belonging to four combinations of crosses between *indica* and *japonica* varieties of rice has been assessed. Results relating to the mode of inheritance of 15 characters in both inter-racial and intra-racial hybri have been obtained and analysed fully. An attempt to discuss the result briefly has been made here in order to draw valid conclusions regarding the essential nature of inheritance of the characters.

Ramiah (1933) has suggested that multiple genes controll culm height. Results obtained in the present study show that plant height m be assumed to be governed by many genes. This is due to the facts that all the four crosses studied, the mean value of the F_2 population lies very close to the parental means; transgressive segregation is observed in all the cases; variability in the F_2, as measured by standard deviation and expressed by coefficient of variation is very large. The wider range of variability in F_2 is indicative of segregation of large number of factors. Approximately equal number of individuals is seen o both sides of the modal class which gives a typical normal curve, when plotted to suitable scales. In both *indica* x *indica* and *indica* x *japon* hybrids, the mode of inheritance follows almost a similar pattern.

Tillering has been reported to be a polygenic character (Bhide 1926). The present results are in support of the above statement

Similar pattern of inheritance is observed for both productive and non-productive tillers. Mean of the F_2 progeny is found to agree with t parental means. Individuals having parental values are found to occur i all the F_2s. Transgressive segregation is also observed. Nagai (1926) and Jones (1928) have also observed in crosses between heavy and light tillering varieties a transgressive variation in F_2 with the mean values falling somewhere between the parental means. A segregation pattern alm typical of normal distribution is seen in all the cases in the present study. From this, it can be assumed that many genes govern tillering in rice.

As per the data obtained, the *indica* x *japonica* hybrids show transgressive segregation for flowering duration with its mean nearing t the mean of the two parents. The *indica* x *indica* hybrids show a variati within the limits of the variation shown by the parents with the mode close to that of the parents. Chandrasekharan and Parthsarathy (1960) have stated that this type of inheritance cannot be considered as due to blending of characters, but due to the characters being governed by a ve large number of factors. Thus all the four cross combinations studied, show a mode of inheritance typical of quantitative characters. This is agreement with that of Nandi *et al.* (1940). Nagai (1959) also expressed that duration in terms of number of days to heading in rice is governed a large number of multiple genes, but the qualifying values of these genes are not the same.

Results of studies relating to exsertion of panicle show an accumulation of frequency in the initial zero class and this accumulatio is found to be considerably more in the *indica* x *indica* hybrids than tha in the *indica* x *japonica* hybrids. This fact seems to eliminate the possibility of considering this trait to be inherited as a quantitative one at the first sight though evidences from other angles such as agreement of F_2 means with that of the parents, extent of variability in F_2 etc., support a polygenic nature of inheritance of this character. The present situation can be explained if it is assumed that panicle exsertion can have negative values, the possibility of which has been strongly indicated by the high magnitude of coefficient of variation shown by the F_2. In the present investigation two classes - 'exserted' and 'not exserted' have been recognized and in the 'exserted' class different segregants have been measured and grouped into frequences base on the results. With respect to the 'not exserted' group no test has been applied to score off the different segregants and hence they will all behave in the same way. This can account for the accumulation of frequencies in the initial zero class as is observed in the present case Thus, assuming that the 'not exserted' class is split up into different groups based on their negative values of exsertion and their frequencies calculated and drawn to suitable scales, we get a smooth curve, characteristic of normal distribution. This hypothesis seems to be reasonable since in the curve so obtained, mean, median and mode coincide as in a normal distribution. All these evidences tend to suggest that panicle exsertion is a quantitative character governed by polygenes or major and minor genes. This is in agreement with the results of Ramiah (1922).

Studies made by Bhide (1926) and Ramiah (1930) show that length of panicle is governed by the polygenes. The results obtained in this study agree with this report. The indica x japonica and indica x indica hybrids show similar pattern of segregation, with means coinciding with that of the parents and coefficient of variation being higher than that of the respective parents. Typical transgressive segreation is observed in all the four cases studied, thereby indicating that many genes determine expression of the character.

In indica x japonica crosses mean grain yield is found to be low as compared to that in indica x indica hybrids. In other words in inter-racial hybrids-both direct and reciprocal crosses-the modal class is in 1-2 g as against 7-8 g in the intra-racial hybrids. This reduced yield may probably due to high spikelet sterility in inter-racial hybrids. As a results of this, the inheritance of grain yield in inter-racial hybrid is found to follow no definite pattern. In intra-racial hybrids a normal curve is obtained with transgression towards higher yields, indicating that yield is governed by multiple factors or major gene-minor gene systems. With respect to straw yield both *indica* x *japonica* and *indica* x *indica* crosses give similar results. There is a clear evidence of transgressive variation on both sides. Mean of the F_2 progeny is found to lie near the mean of the respective parents. It can be assumed that many factors control straw yield.

Grain size is determined by length, breadth and thickness of individual grains. In the present study, the results obtained show that in both *indica* x *japonica* and *indica* x *indica* hybrids, the mean length of grain of the F_2 is found to agree with the mean of the respective parents. A higher range of variation as evidenced by the magnitude of coefficient of variation, is observed in the F_2s as compared to the respective parents. Mean, mode and median coincide in all the four case and typical normal curve is obtained with transgressive segregation in two of the four cases studied (vide Fig. 5 and 6). The same is the mod of inheritance observed in case of breadth and thickness of grains also. These facts suggest that length, breadth and thickness of grains are inherited as quantitative character governed by many genes. Similar results has been obtained by Bhide (1926), Ramiah and Parthasarathy (1933, 1937), Mitra and Ganguli (1938) and Majid (1939).

Among the parental varieties, the *japonica* type (Tainan-3) is seen to be phenol negative and the *indica* types (Vellayani-1 and Taichung Native-1) phenol positive. This agrees with the view expressed by Oka that 'continental' forms (*indica* types) are phenol positive and 'insular forms' (*japonica* types) phenol negative. It is found that F_2 hybrids segregate into phenol positive and phenol negative in a clear 3:1 phenotypic ratio. This suggests the complete dominance of phenol positive to phenol negative. This observation is in confirmity with the report of Nageo (1951) and Jennigs (1966) that phenol staining is a simple inherited dominant trait to non staining.

Oka (1953 a, 1953 b) has reported that percentage of pollen sterility in *indica* x *japonica* hybrids varies widely among different crosses, ranging from zero to 100. In Henderson's (1964) study, F_2 pollen fertility has ranged from one to 98% with an average of 53% and consisted of an indefinitely large number of genetically distinct classes. Results obtained in the present study of *indica* x *japonica* hybrids show a similar range of variation recorded by the above workers with a mean of 45.2% for the *indica* x *japonica* cross and 38% for the reciprocal. This lower percentage of pollen fertility when japanese variety is used as the female parent is in agreement with the result obtained by Sampath and Mohanty (1954).

In *indica* x *indica* hybrids also instance of sterility has been reported by Oka (1956). Richaria *et al*. (1962) have recorded a range from zero to 100% sterility in 11 crosses studied by them. Results obtained in the study of *indica* x *indica* hybrids show lesser percentage of pollen sterility as compared to *indica* x *japonica* hybrids. In this case also lesser percentage of pollen sterility is observed when the variety Vellayani-1 is used as the male parent. This may probable be due to the comparatively lesser percentage of pollen sterility in the *indica* parent itself or due to the effect of certain cytoplasmic factors. This has to be strengthened by further experiment. As reported by Miller (1959), no detectable ratio for pollen stainability, could be noticed in the F_2.

Hsu (1945) has reported that spikelet sterility often exceeds pollen sterility. The results obtained in the present study do not seem to agree with that of Hsu. In three out of four crosses studied, the mean spikelet sterility is found to be lesser than the corresponding mean pollen sterility. As reported by Sampath (1959) a wide segregation for spikelet is observed in *indica* x *japonica* hybrids. There is no definite relation with respect to pollen and spikelet sterility in *indica* x *indica* hybrids unlike in *indica* x *japonica* hybrids. This does not agree with the findings of Joseph (1962) who has reported lesser spikelet sterility than pollen sterility in *indica* x *indica* crosses. This disagreement may be attributed to the difference in the material studied and also due to the variation in the climatic factors. Moreover Hoshika (1941) and Webster (1950) have indicated that climatic factors can play a decisive role in the expression of sterility.

Both genic and chromosomal causes have been proposed to account for the sterility in inter-racial hybrids of *Oryza sativa*. Regular pairing of chromosomes at metaphase I of meiosis in partly sterile intervarietal rice hybrids to form 12 bivalents as found in the present study, is in agreement with the report of other workers, such as Kaung (1951), Oka (1953) and Sampath and Mohanty (1954).

Appearance of chromosome loops at pachytene indicates structural differences of chromosomes of *indica* and *japonica* types. Since no detailed study on chromosome behaviour during meiosis in hybrids has been undertaken valid conclusion cannot be drawn in this line.

SUMMARY

SUMMARY

A study on the F_2 generation of inter-racial, (Vellayani-1 x Tainan-3) and intra-racial (Vellayani-1 x Taichung Native-1) rice hybrids of both direct and reciprocal combinations of crosses, with reference to the mode of inheritance of 15 plant characters, has been conducted during October to January, 1968. Based on the results the following conclusions have been drawn.

In both inter-racial and intra-racial hybrids, plant height, number of productive as well as non-productive tillers, flowering duration, exsertion and length of panicle, grain and straw yields, length, breadth and thickness of grains are inherited as quantitative characters controlle either by multiple genes or by one or two major genes and a few minor genes. No reciprocal difference in either of the two racial groups, is observed. Transgressive segregation is seen in all cases.

Pollen sterility and spikelet sterility are more and yield of grain and straw-less in inter-racial hybrids unlike those in the intra-racial hybrids where the order is reversed. In both the racial groups, hybrids exhibit the minimum percentage of pollen sterility when Vellayani-1 is used as the male parent.

The *indica* parents, Vellayani-1 and Taichung Native-1 are phenol positive and *japonica* parent, Tainan-3, phenol negative. The F_2 hybrids in both the racial groups, segregate into phenol positive and phenol negative in a 3:1 phenotypic ratio without reciprocal difference, thereby showing that phenol positive is monogenic dominant over phenol negative.

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APPENDIX I

Frequency distribution of individuals (parents and F_2) height of plants (in cm)

Classes particu-lars*	40 44	45 49	50 54	55 59	60 64	65 69	70 74	75 79	80 84	85 89	90 94	95 99	100 104	105 109	110 114	115 119	120 124	125 129	130 134	135 139	Total	$\bar{X}$	S.E.	C.V.
1	..	1	..	..	1	1	2	3	7	4	15	13	11	3	2	..	..	..	..	..	63	91.8	1.5	12.8
2	..	..	1	..	2	..	3	5	8	18	14	9	2	..	..	..	..	..	..	..	62	86.5	1.2	10.9
3	..	..	..	2	4	6	18	11	11	2	1	..	..	..	..	..	..	..	..	..	55	74.1	1.0	9.9
4	..	2	3	2	..	3	11	9	5	6	11	3	..	2	..	..	..	..	..	..	57	78.4	2.2	21.2
5	..	..	..	1	1	..	3	2	7	2	9	2	6	2	4	2	1	2	..	..	44	94.2	2.4	16.9
6	..	..	..	1	..	..	1	4	3	3	2	3	1	1	1	..	..	..	..	..	20	87.1	2.7	13.9
7	1	..	4	5	10	8	23	14	19	17	11	7	2	..	4	..	1	..	..	..	126	77.5	1.7	25.1
8	..	..	3	6	6	9	11	10	12	13	16	14	9	6	3	3	..	..	..	..	121	85.2	1.1	13.6
9	..	..	..	2	3	2	4	7	6	7	6	6	4	2	3	2	1	1	..	..	56	88.2	2.2	18.9
10	..	..	2	1	4	4	6	4	3	2	1	4	1	..	..	..	..	..	..	..	32	75.6	2.4	14.9
11	..	1	1	4	4	3	5	1	3	6	2	2	1	1	1	..	..	..	..	..	35	74.9	3.8	30.0
12	..	1	..	..	2	1	3	3	..	1	4	3	2	3	2	1	..	..	..	..	26	88.3	3.5	20.5
13	..	1	1	4	6	12	14	9	9	7	13	7	6	5	3	..	..	1	..	..	98	82.0	1.6	19.3
14	..	1	2	2	2	7	11	9	8	4	5	3	4	..	2	..	..	..	..	..	60	78.8	1.9	18.2
15.	..	..	..	4	5	9	8	4	2	3	8	6	4	2	..	..	..	..	..	..	55	79.1	2.5	23.1

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family1- 14)
5 Vellayani-1 x Tainan-3 (,, 1- 7)
6 Vellayani-1 x Tainan-3 (,, 1-17)
7 Tainan-3 x Vellayani-1 (,, 5-1)
8 Tainan-3 x Vellayani-1 (Family - 5 - 5)
9 Tainan-3 x Vellayani-1 (,, 5 - 7)
10 Vellayani-1 x Taichung Native-1 (Family 2-6)
11 Vellayani-1 x Taichung Native-1 (Family 2-21)
12 Vellayani-1 x Taichung Native-1 (Family 2-3)
13 Taichung Native-1 x Vellayani-1 (Family 6-16)
14 Taichung Native-1 x Vellayani-1 (Family 6 -7)
15 Taichung Native-1 x Vellayani-1 (Family 6-14)

$\bar{X}$ = Mean S.E. = Standard error of mean C.V. = Coefficient of variation

APPENDIX II

Frequency distribution of individuals (parents and F_2) for the number of productive tillers

Classes particulars *	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total	$\overline{X}$	S.E.	C.V.
1	..	10	16	13	16	3	1	1	..	..	..	..	..	..	..	..	..	..	60	3.9	0.2	34.8
2	3	12	13	11	8	4	3	3	4	1	..	..	..	..	..	..	..	..	62	4.3	0.3	53.2
3	..	..	1	1	6	8	5	12	4	7	2	4	2	..	..	1	..	..	53	7.9	0.5	43.1
4	2	7	10	13	8	5	4	4	1	1	1	..	..	..	..	..	..	..	56	4.6	0.3	47.1
5	..	1	6	4	6	6	3	5	3	3	3	..	2	1	..	..	..	..	43	6.8	0.5	44.7
6	..	..	1	1	1	1	2	2	3	1	..	..	2	..	..	2	1	2	19	10.3	1.1	45.8
7	3	26	33	23	20	9	2	4	2	3	..	..	..	..	..	..	..	..	125	4.0	0.2	47.0
8	1	12	21	16	19	12	16	4	7	4	4	2	1	..	1	1	..	..	121	5.5	0.3	55.6
9	3	9	8	6	12	3	6	3	3	..	2	..	..	..	1	..	..	..	56	4.9	0.4	56.8
10	..	..	..	1	4	2	5	5	2	3	1	2	1	2	..	2	..	2	32	9.5	0.7	40.9
11	..	..	6	4	9	7	4	4	..	..	1	1	..	..	..	..	..	..	36	5.7	0.3	30.5
12	..	1	..	..	2	1	2	2	..	3	5	3	2	2	..	1	1	1	26	10.5	0.8	36.5
13	1	4	3	1	7	15	10	13	11	7	12	2	3	3	2	1	1	1	97	8.3	0.3	41.2
14	4	6	12	6	8	4	3	9	3	3	..	1	..	..	..	..	..	..	59	5.1	0.4	53.6
15	..	2	1	13	12	12	3	3	5	3	..	..	..	1	..	..	..	..	55	5.9	0.3	38.3

* 1	Vellayani-1
2	Tainan-3
3	Taichung Native-1
4	Vellayani-1 x Tainan-3 (Family 1 -14)
5	Vellayani-1 x Tainan-3 (,, 1 - 7)
6	Vellayani-1 x Tainan-3 (,, 1 -17)
7	Tainan-3 x Vellayani-1 (,, 5 - 1)
8	Tainan-3 x Vellayani-1 (Family 5 - 5)
9	Tainan-3 x Vellayani-1 (Family 5 - 7)
10	Vellayani-1 x Taichung Native-1 (Family 2 - 6)
11	Vellayani-1 x Taichung Native-1 (,, 2 -21)
12	Vellayani-1 x Taichung Native-1 (,, 2 - 3)
13	Taichung Native-1 x Vellayani-1 (,, 6 -16)
14	Taichung Native-1 x Vellayani-1 (,, 6 - 7)
15	Taichung Native-1 x Vellayani-1 (,, 6 -14)

$\overline{X}$ = Mean   S.E. = Standard error of mean   C.V.= Coefficient of variation

APPENDIX III

Frequency distribution of individuals (parents and F_2) for the number of non-productive tillers

Classes particulars*	1	2	3	4	5	6	7	8	9	10	11	12	Total	$\bar{X}$	S.E.	C.V
1	15	22	9	2	2	..	..	..	..	..	..	..	50	2.1	0.1	47.8
2	13	32	5	3	2	..	..	..	..	..	..	..	55	2.1	0.1	47.8
3	..	1	7	9	10	10	1	9	3	4	..	1	55	6.0	0.3	38.7
4	8	32	6	2	2	2	..	..	..	..	..	1	53	2.3	0.3	85.0
5	6	14	11	5	..	..	1	..	..	..	..	..	37	2.5	0.2	46.0
6	15	2	4	..	..	..	..	..	..	..	..	..	21	1.7	0.1	13.8
7	2	23	32	30	21	10	4	2	..	1	..	..	125	3.9	0.1	40.6
8	16	47	12	10	10	2	2	2	..	1	..	..	102	2.8	0.1	51.4
9	5	28	4	9	4	1	..	..	..	..	..	..	51	2.6	0.2	46.5
10	2	18	1	8	2	..	..	..	..	..	..	..	31	2.7	0.2	42.3
11	1	5	10	8	4	7	..	1	1	..	..	1	38	4.0	0.4	66.7
12	..	19	2	3	1	..	..	..	..	..	..	..	25	2.4	0.2	35.0
13	9	38	5	20	17	2	2	..	..	2	..	..	95	3.3	0.2	54.4
14	6	26	11	5	1	3	1	1	..	1	..	..	55	2.9	0.2	61.5
15	2	12	15	11	8	5	1	1	..	..	..	..	55	3.6	0.2	42.1

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 -14)
5 Vellayani-1 x Tainan-3 (Family 1 - 7)
6 Vellayani-1 x Tainan-3 (Family 1 -17)
7 Tainan-3 x Vellayani-1 (Family 5 - 1)
8 Tainan-3 x Vellayani-1 (Family 5 - 5)
9 Tainan-3 x Vellayani-1 (Family 5 - 7)
10 Vellayani-1 x Taichung Native-1 (Family 2 - 6)
11 Vellayani-1 x Taichung Native-1 (Family 2 -21)
12 Vellayani-1 x Taichung Native-1 (Family 2 -3)
13 Taichung Native-1 x Vellayani-1 (Family 6 -16)
14 Taichung Native-1 x Vellayani-1 (Family 6 -7)
15 Taichung Native-1 x Vellayani-1 (Family 6-14)

$\bar{X}$ = Mean S.E. Standard errof of mean C.V. Coefficient of variation

APPENDIX IV

Frequency distribution of individuals (parents and F_2) for flowering duration in days

sses ticu- s*	50 52	53 55	56 58	59 61	62 64	65 67	68 70	71 73	74 76	77 79	80 82	83 85	86 88	89 91	92 94	95 97	98 100	101 103	104 106	107 109	Total	X̄	S.E.	C.V.
	..	..	..	..	..	1	3	15	1	16	17	6	1	3	..	..	..	..	..	..	63	78.0	0.7	6.9
	..	..	..	..	..	..	1	1	1	5	26	7	9	7	1	1	3	..	..	..	62	83.9	0.7	7.0
	..	..	..	..	..	..	..	1	1	3	38	3	3	4	2	..	..	..	..	..	55	82.2	0.5	4.6
	..	..	..	..	..	3	7	11	2	13	10	2	2	3	3	1	..	..	..	..	57	77.8	1.0	9.4
	..	1	..	2	3	9	3	11	2	13	10	2	2	3	3	..	..	..	..	..	64	75.3	1.1	11.8
	..	..	..	..	1	3	1	4	4	5	1	1	..	..	..	..	..	..	..	..	20	73.7	1.0	6.3
	..	..	..	..	..	4	18	23	24	14	26	1	2	3	6	2	1	1	..	..	125	77.1	0.7	9.8
	1	1	2	4	4	16	6	27	3	7	39	3	1	2	1	1	1	1	1	..	121	75.0	0.8	11.7
	..	..	..	..	..	1	4	11	4	15	10	3	2	2	2	1	1	..	..	..	56	78.6	0.9	8.7
	..	..	..	..	..	2	2	10	1	9	4	3	1	1	..	..	..	..	..	..	33	76.4	0.9	6.9
	..	..	..	..	..	4	3	14	3	10	2	..	..	..	..	..	..	..	..	..	36	73.5	0.7	5.7
	..	..	..	..	..	1	..	2	11	10	2	..	..	..	..	..	..	...	..	..	26	76.0	0.8	5.1
	..	..	..	..	..	2	..	25	3	48	9	6	3	1	1	..	..	..	..	..	98	77.3	0.5	6.5
	..	..	..	..	..	..	5	2	23	7	11	7	2	1	1	1	..	..	..	..	60	78.2	0.7	7.2
	..	..	..	..	..	6	9	19	7	6	8	..	..	..	..	..	..	..	..	..	55	73.2	0.6	6.2

1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1-14)
5 Vellayani-1 x Tainan-3 (,, 1- 7)
6 Vellayani-1 x Tainan-3 (,, 1-17)
7 Tainan-3 x Vellayani-1 (,, 5-1)
8 Tainan-3 x Vellayani-1 (Family 5-5)
9 Tainan-3 x Vellayani-1 (,, 5-7)
10 Vellayani-1 x Taichung Native-1 (Family 2-6)
11 Vellayani-1 x Taichung Native-1 (Family 2-21)
12 Vellayani-1 x Taichung Native-1 (Family 2-3)
13 Taichung Native-1 x Vellayani-1 (Family 6-16)
14 Taichung Native-1 x Vellayani-1 (Family 6-7)
15. Taichung Native-1 x Vellayani-1 (Family 6-14)

X̄ = Mean S.E. = Standard error of mean C.V. = Coefficient of variation

APPENDIX V

Frequency distribution of individuals (parents and F_2) for grain yield (in g)

Classes particulars *	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	21 22	23 24	25 26	27 28	29 30	31 32	33 34	35 36	37 38	Total	$\bar{X}$	S.E.	C.V.
1	1	7	8	9	2	..	1	1	1	..	..	..	..	..	..	..	..	..	..	30	6.8	0.6	51.9
2	2	2	10	4	4	4	2	..	1	1	..	..	..	..	..	..	..	..	..	30	8.1	0.8	51.9
3	1	1	3	6	3	4	4	2	3	..	..	2	..	1	..	..	..	..	..	30	11.8	1.1	50.9
4	..	..	3	5	5	5	6	5	1	1	1	..	..	..	..	..	..	..	..	32	11.8	0.7	35.2
5	..	1	2	6	4	4	2	3	3	2	4	..	3	..	..	..	..	..	1	35	14.3	1.3	54.3
6	..	1	1	1	2	5	..	3	2	..	..	..	..	1	..	..	..	..	..	16	12.6	1.4	43.8
7	5	16	11	17	15	11	5	7	5	3	1	1	2	2	..	..	..	..	..	101	9.8	0.6	60.4
8	..	..	5	7	9	5	3	2	1	2	2	1	2	2	..	..	..	..	..	41	12.1	1.2	62.9
9	..	5	5	1	5	1	1	2	4	..	2	1	1	1	1	..	..	..	..	30	12.5	1.4	62.0
10	10	5	6	4	2	1	2	1	..	..	..	..	..	..	..	..	..	..	..	31	5.4	0.7	73.2
11	..	3	1	3	3	3	2	5	1	..	1	..	3	..	..	..	..	..	..	25	12.9	1.3	49.7
12	2	7	13	13	12	7	4	5	5	3	..	2	2	..	..	..	1	..	..	76	10.5	0.7	59.4
13	..	10	11	10	8	3	..	6	..	..	..	1	1	..	..	..	..	1	..	51	9.0	0.9	68.1
14	..	9	6	14	11	1	1	6	..	..	1	..	..	..	..	..	..	..	..	49	8.4	0.6	48.1

* 1 Vellayani-1
2 Tainan-3
3 Taichung Native-1
4 Vellayani-1 x Tainan-3 (Family 1 - 14)
5 Vellayani-1 x Tainan-3 (,, 1 - 7)
6 Vellayani-1 x Tainan-3 (,, 1 -17)
7 Tainan-3 x Vellayani-1 (,, 5 - 1)
8 Tainan-3 x Vellayani-1 (Family - 5 - 5)
9 Vellayani-1 x Taichung Native-1 (Family 2 - 6)
10 Vellayani-1 x Taichung Native-1 (,, 2 -21)
11 Vellayani-1 x Taichung Native-1 (,, 2 - 3)
12 Taichung Native-1 x Vellayani-1 (,, 6 - 16)
13 Taichung Native-1 x Vellayani-1 (,, 6 - 7)
14 Taichung Native-1 x Vellayani-1 (,, 6 - 14)

$\bar{X}$ = Mean

S.E. = Standard error of mean

C.V. = Coefficient of variation.

APPENDIX VI

Frequency distribution of individuals (parents and F_2) for straw yield (in g)

Classes particulars *	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	21 22	23 24	25 26	27 28	29 30	31 32	33 34	35 36	37 38	Total	$\overline{X}$	S.E.	C.V
1	..	3	3	10	7	1	2	2	2	..	..	..	..	..	..	..	..	..	..	30	9.1	0.7	41.5
2	..	1	3	4	5	7	5	1	2	2	..	..	..	..	..	..	..	..	..	30	11.2	0.7	36.0
3	..	..	3	6	3	9	2	3	2	2	..	..	..	..	..	..	..	..	..	30	11.4	0.7	34.8
4	..	..	3	5	5	5	6	5	1	1	1	..	..	..	..	..	..	..	..	32	11.2	0.9	32.9
5	..	1	2	6	4	4	2	3	3	2	4	..	3	..	..	..	..	..	1	35	14.5	1.2	50.4
6	..	1	1	1	2	5	..	3	2	..	..	..	..	1	..	..	..	..	..	16	12.6	1.4	43.3
7	5	16	11	17	15	11	5	7	5	3	1	1	2	2	..	..	..	..	..	101	9.8	0.6	61.0
8	..	..	5	7	9	5	3	2	1	2	2	1	2	2	..	..	..	..	..	41	12.8	1.0	50.1
9	..	1	3	1	4	6	..	5	..	2	2	2	1	2	..	1	..	..	..	30	15.1	1.3	48.6
10	6	4	7	5	1	4	1	3	..	..	..	..	..	..	..	..	..	..	..	31	6.9	0.8	63.5
11	..	..	1	..	5	2	1	4	3	4	2	..	3	..	..	..	..	..	..	25	16.0	1.1	34.2
12	..	..	..	..	8	20	12	3	7	5	9	3	3	4	..	..	1	1	..	76	16.5	0.7	36.8
13	..	1	9	10	14	4	..	5	2	1	2	..	2	..	1	..	..	..	..	51	11.0	0.8	52.9
14	..	3	10	11	13	2	1	4	1	4	..	..	..	..	..	..	..	..	..	49	9.5	0.7	53.1

*	
1	Vellayani-1
2	Tainan-3
3	Taichung Native-1
4	Vellayani-1 x Tainan-3 (Family 1 -14)
5	Vellayani-1 x Tainan-3 (,, 1 - 7)
6	Vellayani-1 x Tainan-3 (,, 1 -17)
7	Tainan-3 x Vellayani-1 (,, 5 - 1)
8	Tainan-3 x Vellayani-1 (Family 5 - 5)
9	Vellayani-1 x Taichung Native-1 (Family 2 - 6)
10	Vellayani-1 x Taichung Native-1 (,, 2 -21)
11	Vellayani-1 x Taichung Native-1 (,, 2 - 3)
12	Taichung Native-1 x Vellayani-1 (,, 6 -16)
13	Taichung Native-1 x Vellayani-1 (,, 6 - 7)
14	Taichung Native-1 x Vellayani-1 (,, 6 -14)

$\overline{X}$ = Mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

PLATE I

Photograph showing the segregation of F_2 hybrids for plant height.
(Cross: Vellayani-1 x Tainan-3).

PLATE II

Photograph showing the segregation of F_2 hybrids for plant height.
(Cross: Tainan-3 x Vellayani-1).

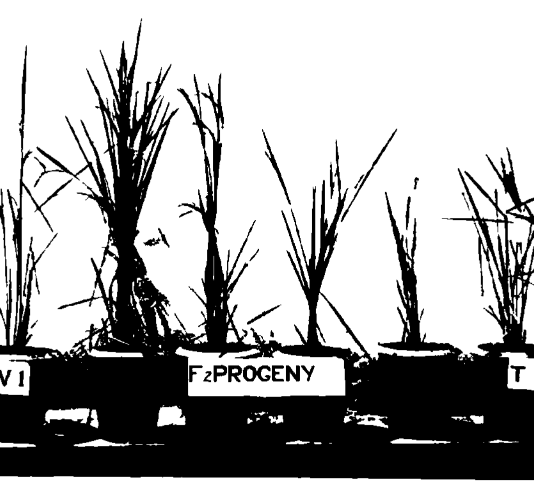

PLATE I

PLATE II

PLATE III

Photograph showing the segregation of F_2 hybrids for plant height.
(Cross: Vellayani-1 x Taichung Native-1).

PLATE IV

Photograph showing the segregation of F_2 hybrids for plant height.
(Cross: Taichung Native-1 x Vellayani-1).

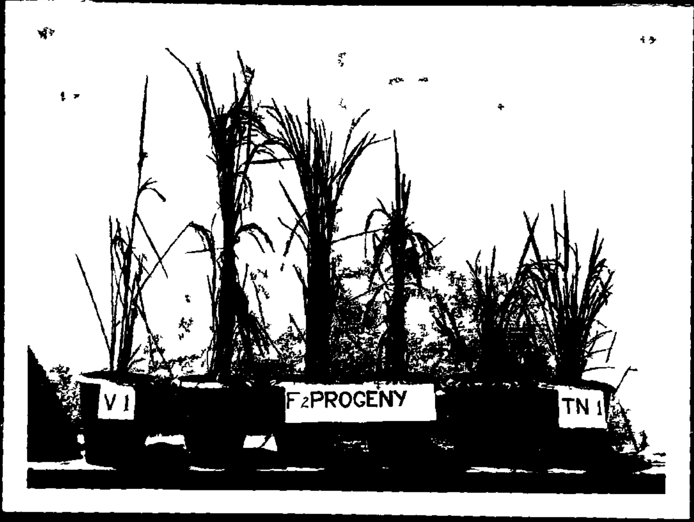

PLATE III

PLATE IV

PLATE V

Photograph showing the segregation of F_2 hybrids for the number of tillers.

(Cross: Vellayani-1 x Tainan-3).

PLATE VI

Photograph showing the segregation of F_2 hybrids for the number of tillers.
(Cross: Tainan-3 x Vellayani-1).

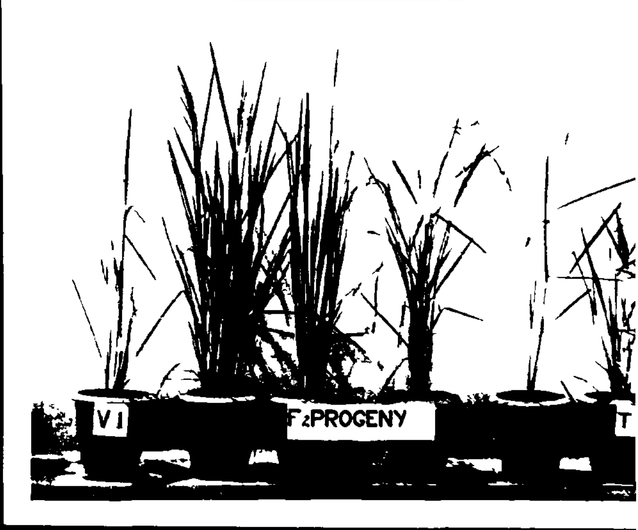

PLATE V

PLATE VI

PLATE VII

Photograph showing the segregation of F_2 hybrids for the number of tillers. (Cross: Vellayani-1 x Taichung Native-1).

PLATE VIII

Photograph showing the segregation of F_2 hybrids for the number of tillers. (Cross: Taichung Native-1 x Vellayani-1).

PLATE VII

PLATE VIII

PLATE IX

Photograph showing the segregation of F_2 hybrids for the exsertion of panicle.

(Cross: Vellayani-1 x Tainan-3).

PLATE X

Photograph showing the segregation of F_2 hybrids for the exsertion of panicle.

(Cross: Tainan-3 x Vellayani-1).

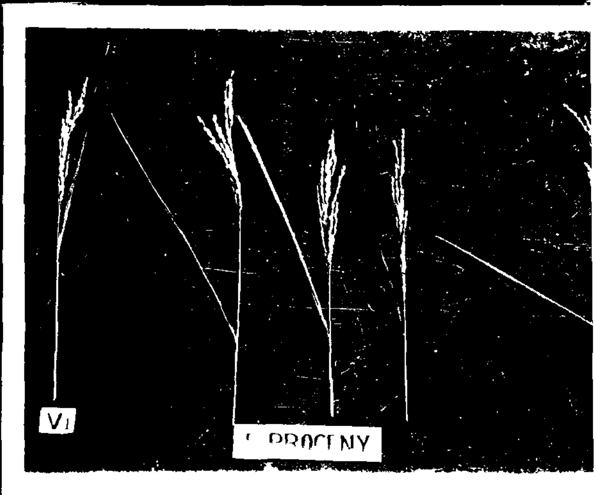

PLATE IX

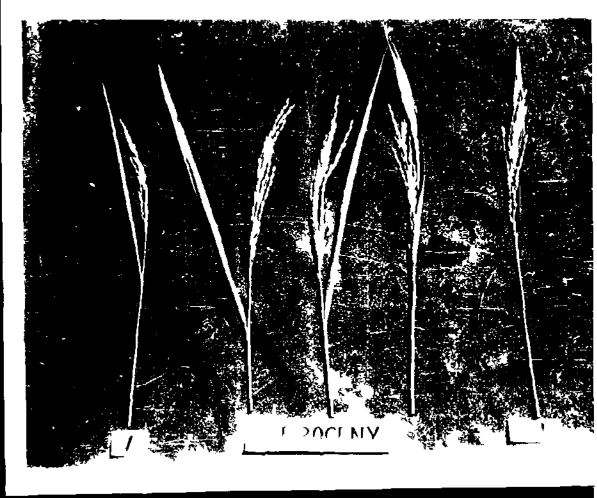

PLATE X

PLATE XI

Photograph showing the segregation of F_2 hybrids for the length of panicle.

(Cross: Vellayani-1 x Tainan-3).

PLATE XII

Photograph showing the segregation of F_2 hybrids for the length of panicle.
(Cross: Tainan-3 x Vellayani-1).

PLATE XI

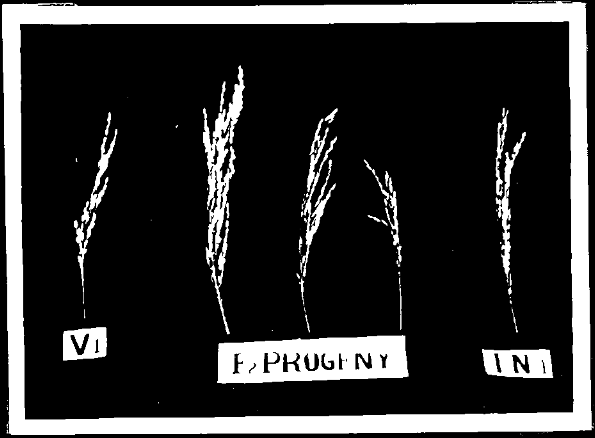

PLATE XII