INHERITANCE STUDIES ON THE F_2 GENERATION OF INTERVARIETAL CROSSES IN RICE

By

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THESIS

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CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Shri P.V. Abdurahiman, 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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CONTENTS

INTRODUCTION

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Rice is the foremost cereal of the world. It occupies the second place in total cropped area and first place in total production of food grains in the world. About 60 percent of rice production is concentrated in Asiatic countries, of which 23 percent is produced in India. And it is paradoxical that India which accounts for nearly one third of the world's rice area happens to produce a very low per hectare yield. Attempts are therefore made to maximise the production of this staple food.

One of the means by which substantial increase in yield will be possible is through varietal improvement. It has been realised that the most important factor which limits top performance at high fertility level is the tall growing, lodging susceptible nature of <u>indica</u> varieties. Evidently, the cultivated varieties have to be improved for better performance. The richness of varietal diversity in cultivated rice and the easy crossability between them are well recognised, and these have helped in the development of a large number of improved strains through intervarietal hybridisation.

The principal target of rice breeding would be high yield and better quality of grain. Rice yield can be increased substantially by using early maturing, short statured, moderate tillering, photo insensitive, pest and disease resistant varieties that are otherwise adopted to the various regions. Through breeding it should be possible to develop varieties of this type.

The last decade has witnessed dramatic developments in the improvement of rice, chiefly through the efforts of IRRI which has spread the gospel of plant type in relation to yielding ability. The direct introduction of some of the high yielding varieties like IR.8 released by IRRI, has been successful in increasing rice production in a short span. Besides, the tremendous yield potential created by these dwarf indicas has led to a crash hybridisation programme in the Rice Breeding Stations all over the country, in order to improve the local varieties. Falling in line with this, the Central Rice Research Station, Pattambi has recently released a high yielding variety called Annapurna, evolved by crossing Ptb.10 with Taichung Native.1.

IR.8, a high yielding medium duration variety, satisfies the desiderata of the plant type of the present concept. But it has chalky grains which has a poor consumer perference. Annapurna is a short duration variety with red rice of good cooking quality which is preferred in Kerala.

In the present investigation the two high yielding semi dwarf varieties viz., IR.8 and Annapurna are crossed with two local strains, Ptb.9 and Kochuvithu. Ptb.9 is of medium duration and Kochuvithu is a short duration variety. Further, these two local varieties, though typical tropical *indicas*, are popular for their rice qualities. Bringing together these local strains in hybrid combinations with the high yielding varieties may be expected to produce recombinants which are early flowering, medium statured, high yielding types of good rice quality.

Hence the objective in the present investigation is directed to study the pattern of inheritance of characters and the relationship of some of the important characters with yield, in the segregating population of the intervarietal crosses. A study in this line, will throw light on the scope of improving the local varieties towards more promising plant types.

REVIEW OF LITERATURE

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Quantitative inheritance in rice in relation to its economic importance has not received enough attention (Chang 1964). Matsura (1933) listed length of grain, height of plant, width of leaf, diameter of stem and grain yield as quantitative characters controlled by multiple genes. In addition to these, length and thickness of grain, semi-sterility of spikelets, tillering and seed dormancy were considered by Indian workers as quantitative traits controlled by polygenes (Ghose *et al* 1960).

Plant height

The inheritance of plant height in *indica* varieties has been investigated by Ramiah (1933). From a cross between T-24 and T-280, he has suggested that additive action of several polygenes determines culm height. In a cross of T-24 and T-310 he observed 3:1 ratio of tall to short plants. In this case a major dominant gene controlled plant height. When T-102 was crossed to T-29 a 1:3 proportion of tall to short forms was obtained in F_2 indicating that a single recessive gene determined the tall character.

Syakudo et al (1952) found that in the cross between a semidwarf form and normal form with 70 and 90 cm in height respectively, the height was controlled by the multiple genes H_2 and H_3 with the combined action of the gene complex C_1 and the gene for semi-dwarf D_1. The gene D_1 was perfectly dominant over d_1 which determined dwarf stature. According to him genes controlling panicle length (P_4P_4, P_5P_5) also affected culm length. The same authors observed in another set of crosses involving japonica types that three genes E_3, E_4 and E_5 which cumulatively determined heading date had pleiotropic effects on culm length.

Sakai and Niles (1957) have reported that plant height is determined by 3 factors.

Mitra (1962) has suggested that the inheritance of plant height is polygenic and the cumulative effect of the genetic complex for height is different in different varieties.

Sastri and Misro (1963) based on their study of japonica x indica crosses considered that the effective factors for height may represent the operation of at least 2 major genes, each one being associated with several polygenes, thus leading to continuous variation in F_2 progeny.

Mohammed and Hanna (1964) have reported that two factor pairs with identical interaction values appear to be involved, 'Aa' pair having approximately 7 times the effect of 'Bb' pair.

From a cross of Peta x I-geo-tze it has been reported from IRRI that tallness is partly dominant to short height and modifying genes epistatic to shortness genes are involved (IRRI. 1964).

Chalam and Venkiteswarlu (1965) have reported that inheritance of height in many cases is governed by atleast 3 genes designated as T_1, T_2 and T_3 each having differential effect in controlling height.

Seetharaman and Sreevastava (1969) in their study of inheritance of plant height have concluded that a few suppressor genes interact in the expression of dwarf habit.

From the diallel analysis of crosses between *indica* varieties at IRRI (1969) it is suggested that the minimum effective factors controlling plant height vary from 2 to 4 pairs. The genes show equal additive effect but differ in the strength of dominance effects. Thus inheritance is reported to be polygenic additive.

Thus no generalisation seems to be possible in the nature of inheritance of plant height in rice. Results are found to vary depending upon the parental types involved in each case.

Internode number

Culm length is primarily determined by the interaction of two main factors, the number and the length of internodes (Kato 1958).

From a study of internode elongation in rice varieties of reduced plant stature, Gueverra and Chang (1965) have reported that culm length is positively correlated with mean length of elongated internodes and to a lesser extent although still significantly, with the mean number of internodes. Further, internode number and elongation are associated with duration.

From the analysis of genetic variations in plant type in a segregating population of the cross between Peta (tall) and I-geo-tze (dwarf) Morishima et al (1968) have proposed the variation in plant height due to polygenic effects concerned with internode number and internode elongation. The internode length type has a smaller number of elongated internodes and more errect leaves than the internode number type. It is also reported that high yielding and early lines appear as internode length type.

Tillering

Tillering has been reported to be a polygenic character. (Nagai 1926, Ramiah 1953, Bhide 1962). Bhide loc. cit. observed transgressive variation in F_2 with the mean value falling somewhere between the parental means. According to Ghose et al (1960) genes numbering 3 to 4 in some cases and more than four in others control tillering.

Tillers in rice can either be ear bearing or nonear bearing of which the former is of greater economic value.

Wu (1968) from the diable analysis of 5 crosses has reported matrocliny for ear number per plant. Regression analysis indicated complementary gene action for number of panicles and tillering. Partial dominance has been observed for panicle number and tiller number.

From a cross between 4 varieties of profuse and low tillering types it has been reported (IRRI 1969) that a range of 21 ear bearing tillers between the two extreme parents is the effect of 4 independant genes having additive effect. Dominant alleles control their number. The heritability estimates are relatively low, as the trait is markedly affected by nutritional levels and environmental differences.

<u>Leaf size</u>

Leaf size is determined by the length and breadth of leaf. Matsura (1933) has considered leaf width as a quantitative character controlled by multiple genes.

Mitra (1962) from a cross between charnock (short broad leaves) and Patnai (long narrow leaves) has reported that mean leaf width in F_2 is same as charnock in early sowings but is closer to the mean of the two parents in mid season and late sowing. Mean leaf length is similar to that of Patnai irrespective of time of sowing. No clear segregation ratio has been obtained for either character. F_2 frequency distribution is unimodal with transgressive segregation. He concluded that leaf size is controlled by multiple genes.

Chang <u>et al</u> (1965) from the study of the cross Peta x Ai-chiao-tzu have reported that leaf number and width are simply inherited characters controlled by two or more genes. The inheritance of leaf length has been reported to be complex.

Duration for flowering

Hoshino (1915) found in a cross between early and late maturing rices that though the time of flowering in F_1 was intermediate, it was nearer to the early parent. He suggested that three multiple genes would explain the results. Ikeno (1918) reported that in cross of early and late rices the F_1 was intermediate and segregation in F_2 was complex 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 date 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 occured. The ratio of early to late was 1:3.

Nomura (1925) found that F_1 hybrids were a few days later in shooting than the late parent and in the F_2 the segregation was in the ratio of about 3 late : 1 early with transgressive segregation on both sides.

Bhide (1926) observed in certain crosses a monogenic segregation, lateness being dominant over earliness, though this was not uniformly applicable to all the crosses studied.

Ramiah (1933) suggested that two genes designated as E_2 and E_3 with a cumulative effect controlled earliness in a cross. In another case he explained the results on a trigenic basis assuming a differential effect for the 3 genes.

Sethi et al (1938) have found F_2 distribution to be continuous with transgressive variation and concluded that the inheritance of duration is governed by multiple genes.

In the cross studied by Grant and Alam (1939) the segregation has been observed to be transgressive with the progenies giving normal curve, suggesting polygenic type of inheritance.

Nandi and Ganguli (1941 a) 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 F_1 was intermediate and in the F_2 the transgression was again one sided, ie. towards lateness only.

Ramiah (1953 a) has concluded from the available evidences that the inheritance of duration may be simple in some cases and more complicated in others.

Syakudo *et al* (1955) from their studies reported that heading period was determined by the three loci E_3, E_4 and E_5. E_3 and E_4 appeared to be dominant. The effect of the three factors was cumulative though the genes appeared to interact.

Yu and Yao (1957) studied that inheritance of duration by crossing two Taiwan varieties, Shinriki and Taichung 65. The plants were grown in summer and winter seasons. The ratio of early to late heading individuals was 3:1 in F_2 progeny grown in the first part of the year and 15:1 for the late crop. F_3 progeny from the F_2 has a segregation ratio of 3:1 late to early heading types. The results were explained by assuming that 2 gene pairs influenced flowering. Gene 'F1-f1' determined early and late flowering respectively and 'Se-se' were responsible for sensitivity and insensitivity to photoperiod.

According to Nagai (1959) earliness or lateness in terms of number of days to heading in rice is governed by a large number of multiple genes, but the qualifying values of those genes are not all the same. Besides these basic genes, many more genes may determine minor differences.

Yao & Yu (1963) from crosses of early *japonicas* with late *indicas*, obtained a value between 11 and 20 for the number of effective pairs of genes.

From the study of a cross between varieties Peta and I-geo-tze, it was reported (IRRI. 1964) that earliness is either heterotypic or is controlled by more than one gene with partial dominance.

Chalam and Venkateswarlu (1965) have observed that shorter duration is simple dominant to long duration, and in some cases, however, lateness is found to be dominant, and still in some others the segregation is polygenic.

Sen and Banerjee (1967) have suggested that transgressive segregation and other variabilities in the heading dates among the parental and hybrid population indicate the modifying influences of other factors either situated in the same sensitivity locus or in other loci.

From a trial conducted at IRRI (1967) with four varieties and three IRRI selections, it has been observed that in the presence of the photoperiod sensitive gene the expression of early flowering which is controlled by dominant gene for a short vegetative phase is suppressed under long day conditions.

In the absence of the sensitivity gene or genes the dominant nature of earliness is fully expressed in hybrids with the normal range of day length.

Thilppanavar et al (1968) have reported that earliness is simply inherited and dominant. From frequency distribution of F_1 and F_2 individuals it has been reported that the major gene is influenced by several modifiers.

From the experiments conducted at IRRI (1969) it is reported that earliness is dominant to lateness and that the action of the polygenes is cumulative but unequal.

Hsu, Chang and Beachell (1969) have reported from a cross between Sigadis and TN-1 that number of days from sowing to heading is controlled by five allelic pairs of polygenes with additive effects.

Panicle length

Bhide (1920), Ramiah (1930) and Grant (1935) have concluded that this character is governed by multiple genes. Many of the hybrids between short and long ear types demonstrated in the F_2, a continuous variation, extending over the range of the parents.

Syakudo (1950) and Syakudo et al (1951, 1952) conducted a series of gene analysis and have reported that a number of multiple genes govern the ear length, density and kernal size.

From a cross between a variety with long loose panicle having large grains and another with short compact panicles and small grains, it has been reported that the panicle length, in the presence of a fundamental gene complex G, depends upon genes P_1, P_2, P_3 and Ka which exert a pleiotropic and inhibitary effect. Further genes influencing panicle length may possibly exist.

Mohammed and Henna (1965) indicated the existence of partial dominance for longer length of panicle over shorter one. It was found that the two parents were differentiated by two effective factor pairs.

From a diallel analysis at IRRI (1969), it is reported that the genetic variance of this trait can be largely attributed to additive effects, while dominance playing a small part. A difference of 12 cm between the extreme parents is controlled by 5 genes with long panicle parent carrying as many as three pairs of alleles. Again the five pairs of alleles show difference in the strength of each pair.

Panicle exsertion

Ramiah (1932) based on studies of three different crosses has concluded that the inheritance of this character is conditioned by numerous polygenes.

Sethi *et al* (1937 a) have reported the distinct dominance for exsertion which involved the interaction of 3 factors.

Chalam and Venkateswarlu (1965) have reported that exsertion is governed by at least three genes.

Spikelet sterility in F_2 generation

Hsu (1945) has stated that F_1 and F_2 of the two partially sterile hybrids derived from *indica* x *japonica* crosses exhibit a wide range among F_2 plants, from complete fertility to plants as sterile as the F_1. and has concluded that sterility is due to lethality of germ cells governed by complementary genes.

Oka (1953 and 1956) has arrived at the conclusion from the study of segregating populations of several crosses that the sterility can be accounted for most logically by set of duplicate genes in which homozygous recessive combination leads to the abortion of spores or gametes.

Oka (1957) has postulated a mechanism of dominant lethals to explain the weakness of F_1 plants and another complementary recessive lethals to account for vegetative breakdown in F_2 plants.

Miller (1959), from his observation on the percentage of pollen and seed setting in F_1 to F_3 of a cross between 2 varieties has suggested that sterility is more due to structural differences of chromosomes than to genes conditioning 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 <u>indica</u> x <u>japonica</u> hybrids and that plants having more sterility than the F_1s were present in most F_2 populations.

Oka (1964) made extensive review of this problem in the light of results, obtained by him and his collaborators over the period from 1953 to 1962. He has suggested that true breeding partly sterile plants can be obtained in the later generation of the intervarietal hybrids and this sterility is diplontic or sporophytic and is not correlated with F_1 sterility. This phenomenon which might be considered as a partial break-down of hybrids can be explained by duplicate genes of diplontic effect.

Grain characters

Of the many characters in rice, grain size and shape are the ones least liable to environmental fluctuation (Ramiah 1933). U tin, from his study of the developmental variation in rice, has reported that significant difference in grain length occurs between panicles on the same plant and between plants of the same pure line. He has further reported that the length and weight of grains decline from apex to the base of the panicle and the grain measurements are highly influenced by spacing, manuring, season and stage of harvest.

However grain diamensions have formed the basis of system of classification of rice. (Sethi and Saxena 1930).

Length of grain

Parnell *et al* (1917) have reported that the normal length of grain is simple dominant over short length. Chao (1928) obtained a monogenic segregation of 3 short to 1 long kernel types.

Ramiah et al (1931) have reported a monogenic segregation of 3 short round to 1 long grain types in F_2.

Ramiah and Parthasarathy (1933) observed a case in which the grain length is governed by interaction of three factors K_1, K_2 and K_3 but they have not determined the degree to which each gene modifies the length.

Alam (1939) has reported in one cross a monogenic segregation of 3 short to 1 medium and in another cross a diagenic ratio of 9 long 7 short grained types.

Dave (1939) studied a number of crosses between parents which classed as very short, short, medium and long. The results obtained in F_2 indicated that the longer length behaves like simple dominant over the next lower length and this behaviour is contrary to the results reported by other workers. But in a cross between short and long, he obtained a polygenic inheritance.

Similar results have been reported by other workers like Bhide (1926), Magid (1939), and Chakravarty (1939). Hara (1942) found that kernel length is controlled by two pairs of genes in the cross between oval shaped japonica variety and a long red kerneled indica variety.

Mitra (1962) has reported that the character is controlled by multiples genes.

Murthy *et al* have reported transgressive and continuous variation for grain length and inferred the polygenic nature of the character.

Ikeda (1953) reported that the characters, length of grain and panicle length are determined by a gene pair denoted by Gr-gr whose effect is multiplicative to that of a fundamental gene complex.

Syakudo, Kawase and Nagao (1953) studied the behaviour of a cross between Nabeshima (Gr_3 G_3 D_1 D_1) and an improved strain Daikoku (Gr_3 gr_3 d_1 d_1) and concluded that Gr_3 is incompletely dominant and increases grain length and diameter while D_1 is completely dominant and increases grain length but causes a reduction in diameter.

Breadth of grain

Jones *et al* (1935) have recognised one to many genes for grain width. Ramiah and Parthasarathy (1938) have suggested that the inheritance of breadth as in the case of length is of the polygenic type. Grant (1937) observed similar behaviour in crosses between Burmese varieties.

Majid (1939) has reported a digenic F_2 segregation. Dave (1939) obtained a monogenic F_2 segregation of 3 medium to one coarse in one cross and 3 medium to 1 fine in another. Thus according to him grain with a medium width is dominant over coarse as well as fine grain.

Ramiah (1953) has come to the conclusion that the genes controlling length and those controlling breadth though different are not altogether independant.

Syakudo (1951) and Syakudo et al (1953) argued that alleles at several loci excercise simultaneous control over earlength, ear density and caryopsis size.

Bollich (1957) reported that two or more genes control spikelet length; 3 to 5 genes govern spikelet width with narrow floret.

Kadam and D' Cruz (1960) have reported as many as 4 complementary genes for the inheritance of round or short spikelet.

Thickness of grain

Thickness of grain does not vary much among varieties.

Majid (1939) has reported that thickness of grain is governed by polygenes. He observed a shift towards the narrow parent in the F_2 generation.

Vinodini (1968) and Rajendran (1968) have reported the polygenic nature of grain thickness.

Correlation studies

Extensive investigations have been made by different plant breeders to associate various plant characters with yield and with each other, with a view to obtain some suitable indices for evaluating the yield potentialities of the strains or of plants in the segregating populations. Various workers have reported different degrees of correlation between yield and other characters.

Vibar (1920) has reported that height and length of panicle are correlated with yield, although greater straw weight has not always been associated with yield. Bhide (1924) and Bhide and Bhalerao (1927) found high correlation of tillering with yield and low correlation of length of the main panicle with yield. Height has been found to be definitely associated with the final yield (Ramiah 1933). Mahalanobis (1934) studying various characters of 147 varieties in Bengal has found that mean yield is moderately correlated with the number of tillers per plant but appears to be independent of characters like weight and size or shape of grain, plant height and ear length.

Narasinga Rao (1937) has reported that high correlation has been found between yield and number of tillers followed by the number of grains per ear and panicle length.

Ganguli and Sen (1941) have stated that height of tillers, length of panicle and the number of grains per panicle are correlated with yield.

Ramiah (1953) summarising the results obtained at various research stations has reported that a moderate correlation exists between mean yield and number of tillers per plant. Height, ear length and mean number of grain per ear are feebly correlated with yield.

Abraham et al (1956) have found the correlation between progeny yield and number of ear bearing tillers per plant varying from 0.5 to 0.8 and they have also found that plant height at flowering time is highly correlated with yield.

Ghose et al (1957) after a study of correlation taking into account the number of panicles, length of panicle and height of plant at harvest have stated that contribution of height towards yield is negligible in all cases while other factor showed positive correlation in different degrees.

Syed Ibrahim and Krishnamurthy (1958) have found that ear length and number of tillers are contributing mainly to yield. Number of ear bearing tillers is the most potent yield component in rice.

Chandramohan (1961) studying the varieties representing different geographical races has found that number of ear bearing tillers and yield of straw have strong positive correlation with grain yield while plant height and length of prim ear have only feeble correlations.

Abraham _et al_ (1962) have reported that significant correlation exists between yield and number of ears, and yield and mean ear head length, of which the latter is found to be greater than the former.

Sane (1962) has recorded positive correlation between yield and number of grains per ear, number of ears per plant and length of ears.

Rajagopal (1963) after a study of the associations between different plant characters under drought and normal water supply has reported that ear number, ear length and grain number, height of plant, yield of straw etc. have positive and significant total correlation with grain yield under both the conditions.

Narahari and Pawar (1965) in their study of the interracial hybrids has observed strong correlation between yield and number of grains, yield and panicle length, yield and effective tillers and no correlation between yield and height.

Chang et al (1965) have found that plant height is positively correlated with panicle length in the F_2 and F_3 of a cross Peta x I-geo-tze.

Ghose et al (1966) have found positive and significant correlations of height and ear bearing tillers with yield in 4 interracial crosses and correlation between panicle length and yield in only 3 crosses. The study has shown positive but feeble correlation of number of grains per panicle and 1000 grain weight with yield in general.

Sastry et al (1967) have found number of ear bearing tiller in an undisputed position in influencing the yield directly as well as being a vehicle through which other characters get expressed indirectly. It has also been found that 100 grain weight has a largely independent role in influencing yield.

Wang (1967) in a study of F_2 plants of an indica x japonica cross has reported that plant height, length of panicle and number of panicles are positively and highly correlated with grain yield.

Grain colour

Inheritance of grain colour has been investigated by various workers and interesting results are reported. A monogenic difference between red and white has been reported by several workers (Hector 1913, Parnell 1917, Mitra 1932, Jobithraj 1936).

A digenic ratio of 12 purple : 3 red : 1 white was recorded by Parnell (1917) in a cross between purple and red riced varieties. In F_2 of a cross between varieties of purple and white rice, Parnell et al (loc. cit.) obtained a large variation in colour, some with traces of purple, but the dark type corresponding to parent was never obtained. The variation was practically continuous. From the results obtained in F_1, F_2 and F_3, the authors suggested that there must be minor modifiers besides the main gene.

According to Parnell (1922) an inhibitory gene 'ih' in the presence of the red gene Pr converts red rice to white, its absence resulting in golden rice. A ratio of 9 reddish brown : 3 yellow : 4 white in F_2 has been reported in one of the crosses studied by him.

Ramiah and Mudaliar (1935) obtained a 15 red to 1 white in a cross between red and white riced varieties.

When two white riced varieties were crossed a 9:7 segregation is reported by Mitra *et al* (1928). Similar segregation has been reported by Chang (1962) and Nagai (1962).

Alam (1940) reported a ratio of 1 light red : 2 very light red : 1 white in a cross between a light red riced variety and a white riced variety.

Nagai (1951) recorded an F_2 segregation of 9:3:4 in crosses between *japonica* varieties. Kato and Ishikawa recognised reddish brown and white to be either monogenically or digenically different from each other. An interesting case has been reported by the same authors in which two varieties of white rice when crossed gave brown in F_1, and three phenotypes in the ratio of 9 reddish brown : 3 yellow : 4 white in F_2. The result was explained on a trigenic basis.

According to Ramiah (1953 a) two genes Prp and Pr are involved, purple is either PrpPr or Prppr, red is prpPr and white is prp pr.

Vinodini (1968) observed from the cross of two white riced varieties a red riced F_1, and an F_2 ratio of 3 red to 1 white, which is interpreted on monogenic basis.

MATERIALS AND METHODS

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A. Materials

Selfed seeds collected from three F_1 plants of the intervarietal crosses, Ptb.9 x IR.8, IR.8 x Kochuvithu and Annapurna x Ptb.9, available in the Botany Division of Agricultural College & Research Institute, Vellayani were utilised for the present study.

B. Methods

The study was undertaken from October 1969 to February 1970. All the available seeds borne on the F_1 plants and seeds of the parental varieties were sown separately in pots. Twentyfive days after sowing the seedlings were transplanted in singles with a spacing of 30 cm either way in randomised plots replicated four times with the three F_2 families and 4 parental varieties as treatments. The manuring schedule recommended for the high yielding varieties was adopted.

Observations on the following characters were recorded as detailed below:-

Plant height

Height was measured in cm from the base of the plant to the tip of the tallest panicle at maturation. The observation was taken on 259 parental plants and 575 F_2 plants.

Number of internodes

The plants were uprooted at maturity and the number of internodes on main culm was counted. Data were taken on 200 parental plants and 569 F_2 plants.

Number of productive tillers

Total number of productive tillers per plant was counted on 279 parental plants and 538 F_2 plants.

Duration for flowering

The number of days from seedling to flowering was taken as the flowering duration. Data of 795 parental plants and 600 F_2 plants were recorded.

Leaf width

Width of the leaf just below the boot leaf was measured in cm from 211 parental plants and 452 F_2 plants.

Length of panicle

The length of main panicle was measured from the neck to the tip in cm. Observations were confined to 200 parental plants and 469 F_2 plants.

Exsertion of panicle

Exsertion of the main panicle was measured in cm from the base of the flag leaf to the neck of the panicle. Data on 231 parental plants and 558 F_2 plants were recorded.

Spikelet sterility

The study was confined to the main panicles of a total number of 215 parental and 547 F_2 plants. Fully matured main panicle was scissored off. Well filled grains and chaffs were counted for each panicle and the percentage of sterility was estimated in each case as shown below.

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

Length, breadth and thickness of grains

Length, breadth and thickness of 10 grain from each of the main panicle were measured and average measurements worked out. The observation was confined to 50 plants of each F_2 family and 10 plants of each parental variety selected at random.

Grain yield

Individual plants were harvested, threshed, grains cleaned and dried properly. Grain yields in g of 240 parental plants and 535 F_2 plants were recorded.

The data collected in the above observations were grouped into frequency tables and arithmatic mean, standard error and coefficient of variation were calculated for individual F_2 families and parental varieties.

Correlation studies

Observations on height, panicle length, panicle number and yield were recorded for 48 individuals plants, selected at random in each cross. Simple correlation of the above yield attributes with grain yield in the segregating population was worked out for each F_2 and the combined total correlation also worked out using 'Z' transformation method.

Colour of grain

A total number of 548 F_2 plants in the three crosses were scored for grain colour and the F_2 plants were grouped as red riced and white riced by visual observation. The observed frequencies were tested to expected ratios by X^2 test of goodness of fit and the results were interpreted.

RESULTS

RESULTS

Results of observations on plant height, internode number, productive tillers, leaf width, flowering duration, length of panicle and its exsertion, spikelet sterility, length, breadth and thickness of grains, yield of grain, correlation studies, nature of inheritance of grain colour etc. are presented in tables I to XIV.

Plant height

The data pertaining to the frequency distribution of individuals of parents and F_2s based on plant height are presented in table I.

The observed mean heights of the two local varieties Ptb.9 and Kochuvithu are 94.2 cm and 85.1 cm respectively. The mean heights of dwarf varieties are 68.7 cm for Annapurna and 80.1 cm for IR.8.

Among the crosses, the mean height of F_2 of Ptb.9 x IR.8 is 93.3 cm which is nearer to the height of the tall parent. The range observed is from 54 cm to 114 cm. The distribution of the frequency is not continuous and transgression is one sided ie. towards dwarfness.

Table I

Frequency distribution of individuals (parents and F_2s) for plant height in cm

Class value particulers	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5	102.5	107.5	112.5	117.5	122.5	Total	$\bar{X}$	S.E.	C.V.
1	..	..	..	..	..	..	..	6	9	15	17	9	3	1	..	..	60	94.2	1.07	8.75
2	..	..	..	..	3	9	12	20	17	8	1	..	..	..	..	..	70	85.1	0.76	7.46
3	..	..	..	13	28	20	4	..	..	..	..	..	..	..	..	..	65	68.7	0.53	6.26
4	..	..	..	..	2	4	18	26	12	2	..	..	..	..	..	..	64	80.1	0.68	6.74
5	..	3	3	3	..	..	2	13	24	46	49	30	19	2	..	..	194	93.3	0.77	11.47
6	1	8	6	12	10	15	11	32	20	21	20	7	3	2	2	1	171	82.4	1.15	18.21
7	1	..	3	18	29	14	12	15	27	33	16	21	7	3	1	..	210	84.1	1.00	17.30

1 Ptb.9
2 Kochuvithu
3 Annapurna
4 IR.8
5 Ptb.9 x IR.8
6 IR.8 x Kochuvithu
7 Annapurna x Ptb.9

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

FREQUENCY DISTRIBUTION OF F_2 FOR PLANT HEIGHT

Ptb.9 x IR.8.

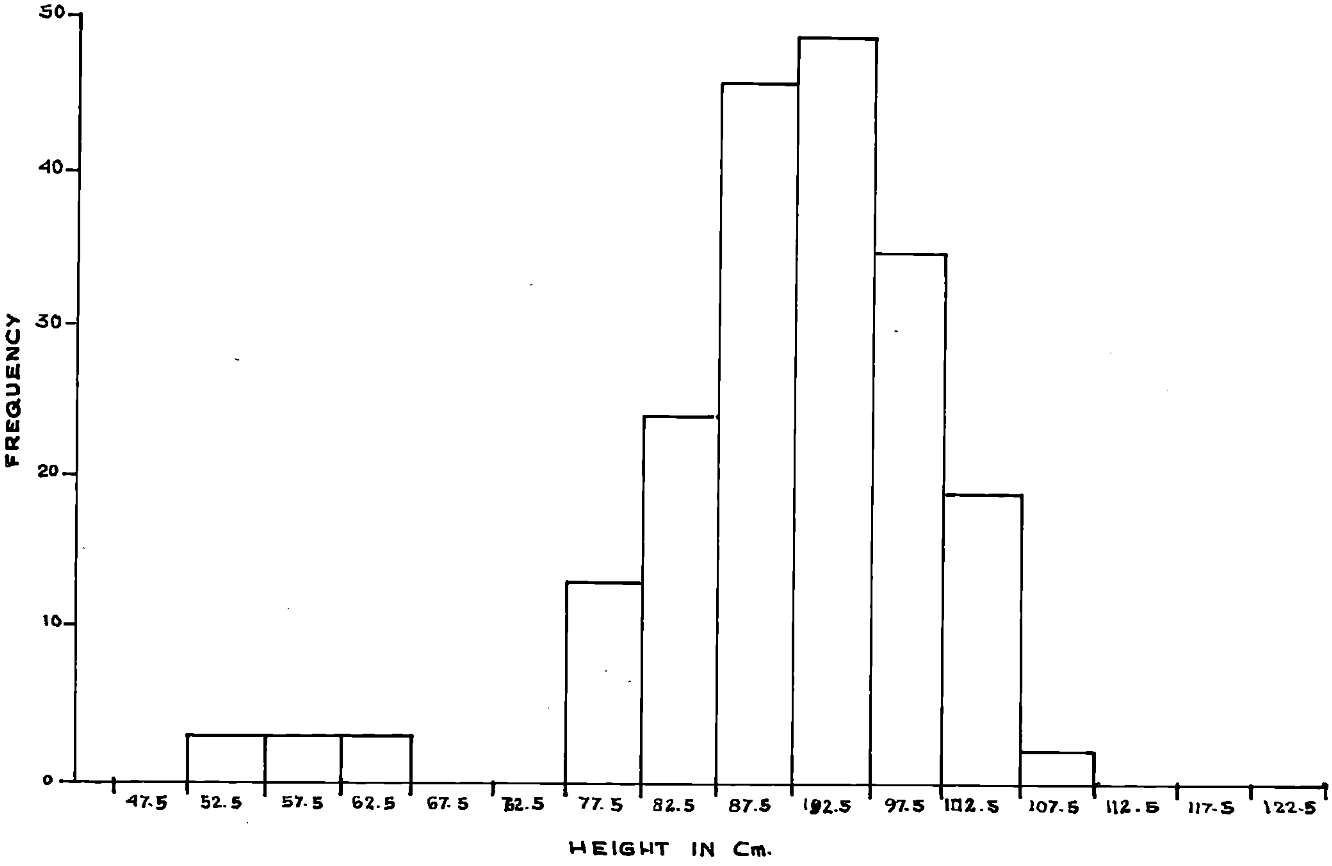


FIG: I A

FREQUENCY DISTRIBUTION OF F_2 FOR PLANT HEIGHT

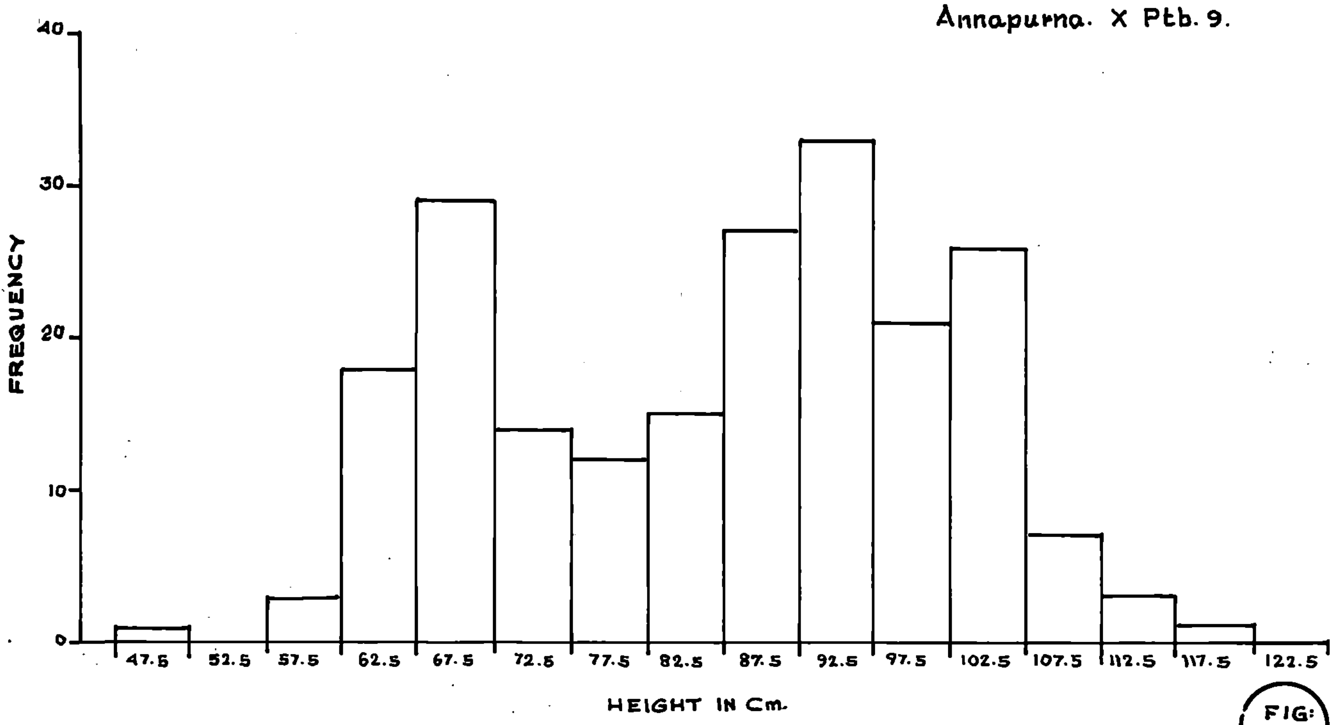


FIG: I B

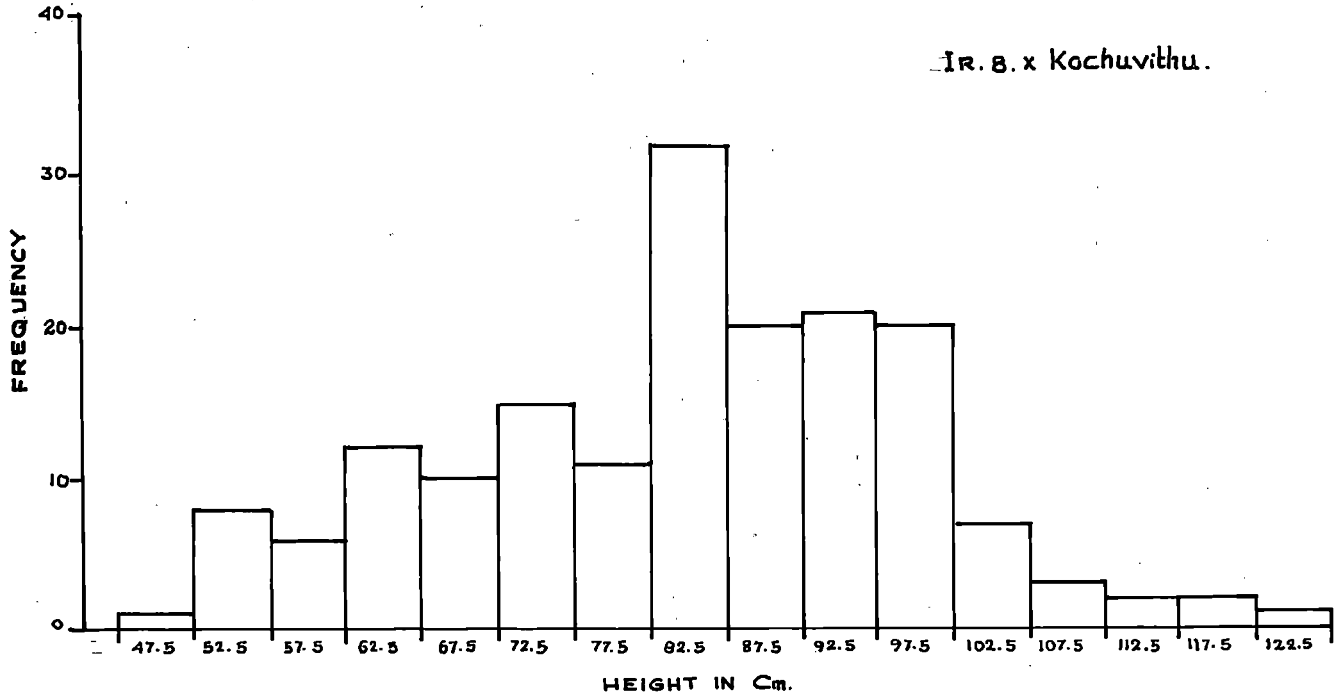


FIG: I C

In the cross IR.8 x Kochuvithu, the mean height of F_2 is 82.3 cm which is close to the mean of the two parents. Variation is observed to be maximum in this cross with a range from 45 cm to 125 cm. The distribution of frequency is continuous and transgression is observed on both sides.

The mean height of F_2 of Annapurna x Ptb.9 is 84 cm, which also approximates to the mean of the parents. Wide range is observed ie. from 45 cm to 119 cm. The distribution of frequency is continuous and transgression is observed only towards dwarf stature.

In all the three crosses, the variability in F_2, as evidenced by the coefficients of variation, is more than that in the respective parents.

Number of internodes

Data pertaining to the frequency distribution of individuals of parents and F_2s are presented in table II.

From the table it is evident that the mean internode number is more in IR.8 than the other varieties, though IR.8 is a dwarf type.

Among the F_2s the mean internode number is nearer to that parent having lower value, except in the cross

Table II

Frequency distribution of individuals (parents and F_2s) for internode number

Class value particulars	3	4	5	6	7	8	Total	$\bar{X}$	S.E.	C.V.
1	.	48	10	.	.	.	58	4.2	0.05	9.83
2	4	38	18	.	.	.	60	4.2	0.07	13.81
3	.	20	22	.	.	.	42	4.3	0.16	24.30
4	.	.	4	22	32	2	60	6.5	0.86	10.21
5	.	158	30	.	.	.	188	4.2	0.03	10.09
6	3	55	106	9	.	.	173	4.7	0.04	12.55
7	.	21	156	31	.	.	208	5.1	0.03	9.90

1 Ptb.9
2 Kochuvithu
3 Annapurna
4 IR.8
5 Ptb.9 x IR.8
6 IR.8 x Kochuvithu
7 Annapurna x Ptb.9

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

Annapurna x Ptb.9 where the mean is above the parental values. Among the crosses variation is maximum in the progeny of IR.8 x Kochuvithu. Distribution of frequency is continuous in all crosses thereby suggesting the action of polygenes in determining the expression of this character.

Productive tillers

Frequency of individuals grouped on the basis of number of ear-bearing tillers is presented in table III.

The mean number of productive tillers for Ptb.9, Kothuvithu, Annapurna and IR.8 are 8.9, 11.7, 13.5 and 11.9 respectively.

In the F_2 progeny of the cross Ptb.9 x IR.8, the mean number of productive tillers is 9.1 which is nearer to the mean value of Ptb.9.

In the cross IR.8 x Kochuvithu the mean number of productive tillers surpasses the mean of the higher tiller producing parent. There is a wider range, from 3 to 26 numbers of productive tillers and transgression is observed exceeding the limits of the higher tiller producing parent. Same features are observed in the progeny of Annapurna x Ptb.9.

Table III

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

Class value particulars	3.5	5.5	7.5	9.5	11.5	13.5	15.5	17.5	19.5	21.5	23.5	25.5	Total	$\bar{X}$	S.E.	C.V.
1	3	6	22	12	11	5	1	.	.	.	.	.	60	8.9	0.34	29.98
2	1	3	13	10	10	10	11	5	2	.	.	.	65	11.7	0.47	32.59
3	.	.	2	6	21	12	10	10	3	.	.	.	64	13.5	0.37	21.93
4	.	4	11	19	18	17	12	6	3	.	.	.	90	11.9	0.36	34.79
5	12	29	45	47	32	15	8	1	1	1	.	.	191	9.1	0.25	35.59
6	3	7	25	7	28	32	12	13	9	5	.	.	148	13.2	0.41	38.09
7	2	7	20	29	34	29	33	24	12	5	3	1	199	13.2	0.31	32.93

1	Ptb.9
2	Kochuvithu
3	Annapurna
4	IR.8
5	Ptb.9 x IR.8
6	IR.8 x Kochuvithu
7	Annapurna x Ptb.9

$\bar{X}$ = Arithmatic mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

The distribution of the frequenty is continuous in all the crosses, thereby indicating that this is a polygenic character. Variability is more in the segregating population than that in their respective parents as evidenced by the coefficients of variation.

Leaf width

Data pertaining to the frequency distribution of individuals of parents and F_2s grouped on the basis of leaf width are presented in table IV.

The results reveal that the mean width in all the F_2 families is almost near to the mean of the respective parents. The variability of F_2 is more than that of corresponding parents. The distribution of frequency is continuous, with more number of individuals in intermediate classes , thereby indicating the quantitative nature of this triat.

Duration for flowering

Data pertaining to the frequency distribution of individuals of parents and F_2s grouped on the basis of number of days taken to flowering are presented in table V.

Table IV

Frequency distribution of individuals (parents and F_2s) for leaf width in cm

Class value particulars	.5	.6	.7	.8	.9	1	1.1	1.2	1.3	Total	$\bar{X}$	S.E.	C.V.
1	.	.	.	7	33	23	8	2	.	73	0.83	0.009	9.24
2	2	4	10	14	10	6	.	.	.	46	0.80	0.016	13.82
3	.	.	1	21	22	7	1	.	.	52	0.81	0.011	9.57
4	.	.	.	.	2	28	10	.	.	40	1.02	0.008	5.00
5	.	.	1	17	49	40	35	12	2	156	0.99	0.009	11.45
6	1	16	51	16	23	15	3	.	.	125	0.88	0.012	15.78
7	4	12	54	42	22	27	9	1	.	171	0.91	0.011	16.06

1 Ptb.9
2 Kochuvithu
3 Annapurna
4 IR.8
5 Ptb.9 x IR.8
6 IR.8 x Kochuvithu
7 Annapurna x Ptb.9

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

Kochuvithu and Annapurna which are short duration varieties, have recorded a mean duration of 63.3 and 70.5 days respectively for flowering. Ptb.9 has taken only 64.5 days which is a few days less than its duration in the main cropping season. The difference may be due to its photosensitiveness. In IR.8 the mean duration taken is 88.9 days.

The progeny of the cross Ptb.9 x IR.8 has recorded a mean of 62.5 days. This is very close to the duration of the earlier parent, Ptb.9. Variability is very low when comparing with other crosses.

The mean duration of F_2 in the cross IR.8 x Kochuvithu is 65.8 days. Here also it is very close to the mean of earlier parent. Variation is maximum in this cross with a range from 54 days to 83 days, but is only within the parental limits.

The mean duration observed in the progeny of Annapurna x Ptb.9 is 70.5 days which is the mean flowering duration of Annapurna. The difference in duration between parents is only six days and the variability in F_2 is very low.

The frequency is having a continuous distribution in all families and there is no transgressive segregation.

Table IV

Frequency distribution of individuals (parents and F_2s) for flowering duration in days

Class value particulars	54.5	56.5	58.5	60.5	62.5	64.5	66.5	68.5	70.5	72.5	74.5	76.5	78.5	80.5	82.5	84.5	86.5	88.5	90.5	92.5
1	..	..	21	31	42	30	22	19	14	8	8	..	..	..	..	..	..	..	..	..
2	2	7	21	29	36	59	24	20	2	..	..	..	..	..	..	..	..	..	..	..
3	..	..	..	..	..	3	10	81	37	32	32	5	..	..	..	..	..	..	..	..
4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	29	90	59	12
5	..	...	2	8	35	85	36	20	9	3	2	..	..	..	..	..	..	..	..	..
6	2	7	29	10	25	33	14	20	19	17	7	5	4	4	2	2	2	2	..	..
7	..	..	1	1	1	2	30	39	48	44	25	9	..	..	..	..	..	..	..	..

	Total	$\bar{X}$	S.E.	C.V.
1	195	64.6	0.31	6.68
2	200	63.2	0.23	5.22
3	200	70.5	0.19	3.74
4	200	88.8	0.13	2.08
5	200	65.2	0.19	4.09
6	204	66.6	0.49	10.54
7	200	70.5	0.22	4.38

1 Ptb.9
2 Kochuvithu
3 Annapurna
4 IR.8
5 Ptb.9 x IR.8
6 IR.8 x Kochuvithu
7 Annapurna x Ptb.9

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

FREQUENCY POLYGON OF F_2 FOR FLOWERING DURATION

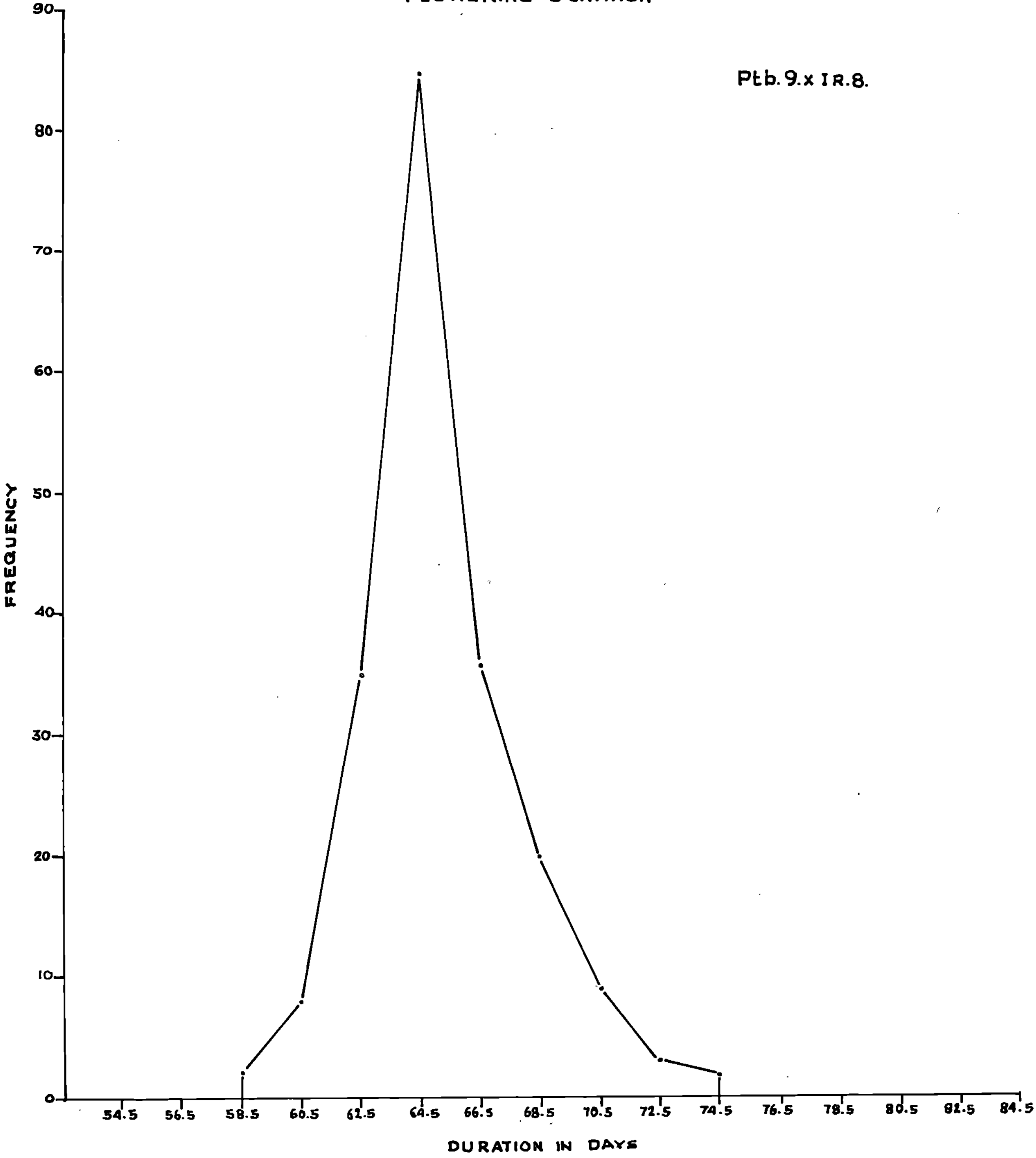


FIG: II A

FREQUENCY POLYGON OF F_2 FOR FLOWERING DURATION

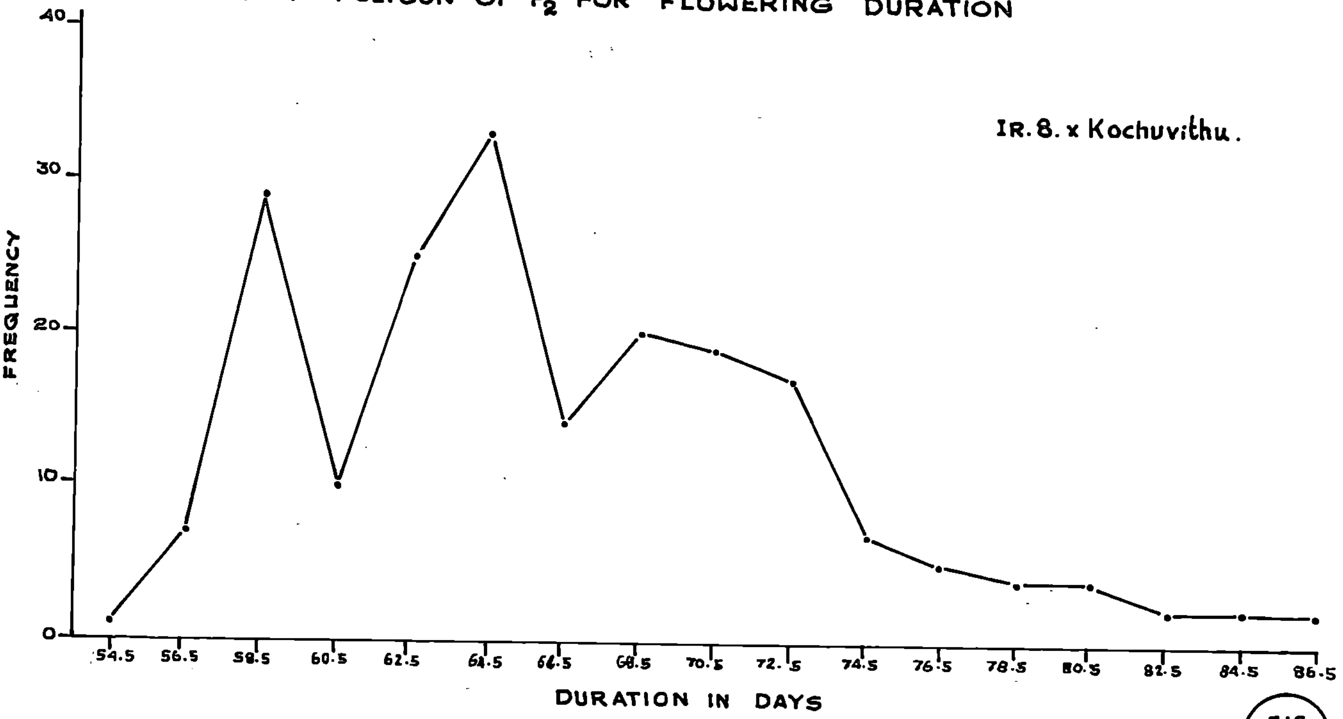


FIG: II B

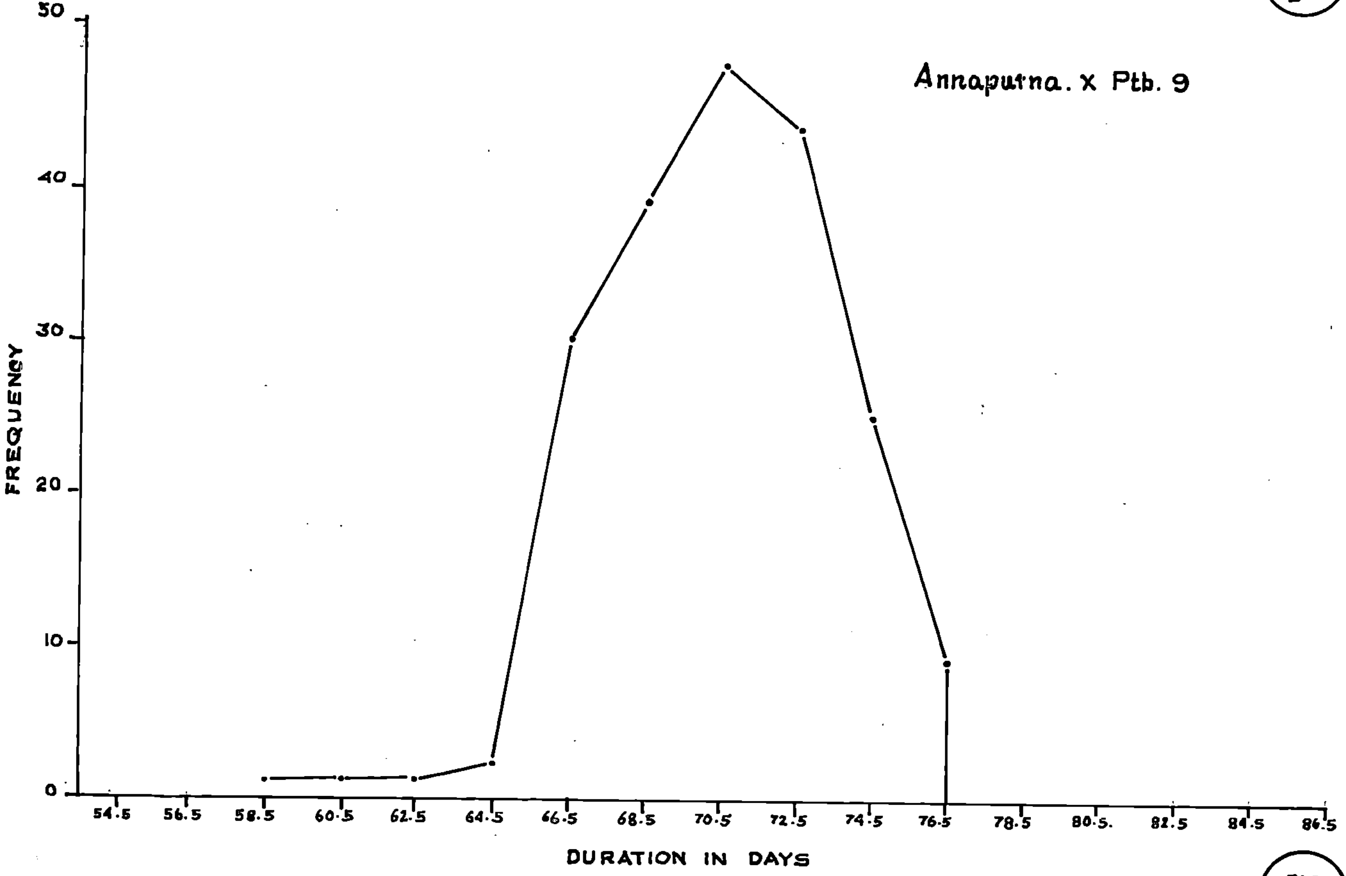


FIG: II C

Panicle length

Data pertaining to the distribution of individuals of parents and F_2s grouped on the basis of panicle length are presented in table VI.

The mean panicle length of the four parental varieties are 19.5 cm, 17.4 cm, 22.16 cm and 24.26 cm for Ptb.9, Kochuvithu, Annapurna and IR.8 respectively. Evidently the high yielding varieties have longer panicles than the local varieties.

Among the F_2 families, Ptb.9 x IR.8 has a mean panicle length of 19.7 cm which is almost close to the mean of Ptb.9. There is wide variation ranging from 13 cm to 25cm. Transgression is observed towards the parent having the lower value.

The mean length in the F_2 of the cross IR.8 x Kochuvithu is 19.9 cm which is near to the mean of the parents. Here also there is wide variation ranging from 13 cm to 26 cm and transgression is towards shorter panicle.

In the cross Annapurna x Ptb.9 the F_2 mean is 21.3 cm which is near to the mean of the parental values. Transgressive segregation is observed in both sides and the range is from 13 cm to 28 cm.

Table VI

Frequency distribution of individuals (parents and F_2s) for panicle length in cm

Class value parti-culars	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Total	$\bar{X}$	S.E.E	C.V.
1	•	•	•	•	5	6	8	22	7	2	•	•	•	•	•	•	50	19.5	0.18	6.45
2	•	•	4	10	16	8	7	4	1	•	•	•	•	•	•	•	50	17.4	0.22	8.97
3	•	•	•	•	•	•	2	4	8	16	12	6	2	•	•	•	50	22.2	0.19	6.18
4	•	•	•	•	•	•	•	•	2	3	10	12	13	8	2	•	50	24.3	0.20	5.81
5	1	1	1	3	11	24	40	36	35	16	3	2	2	•	•	•	175	19.7	0.14	9.25
6	1	1	5	11	10	12	24	23	14	11	16	6	6	1	•	•	141	19.9	0.22	13.43
7	•	1	2	2	8	5	12	19	23	36	23	10	5	3	2	1	152	21.31	0.19	11.36

1	Ptb.9
2	Kochuvithu
3	Annapurna
4	IR.8
5	Ptb.9 x IR.8
6	IR.8 x Kochuvithu
7	Annapurna x Ptb.9

$\bar{X}$ = Arithmatic mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

FREQUENCY DISTRIBUTION OF F_2 FOR PANICLE LENGTH

Ptb. 9. x IR. 8.

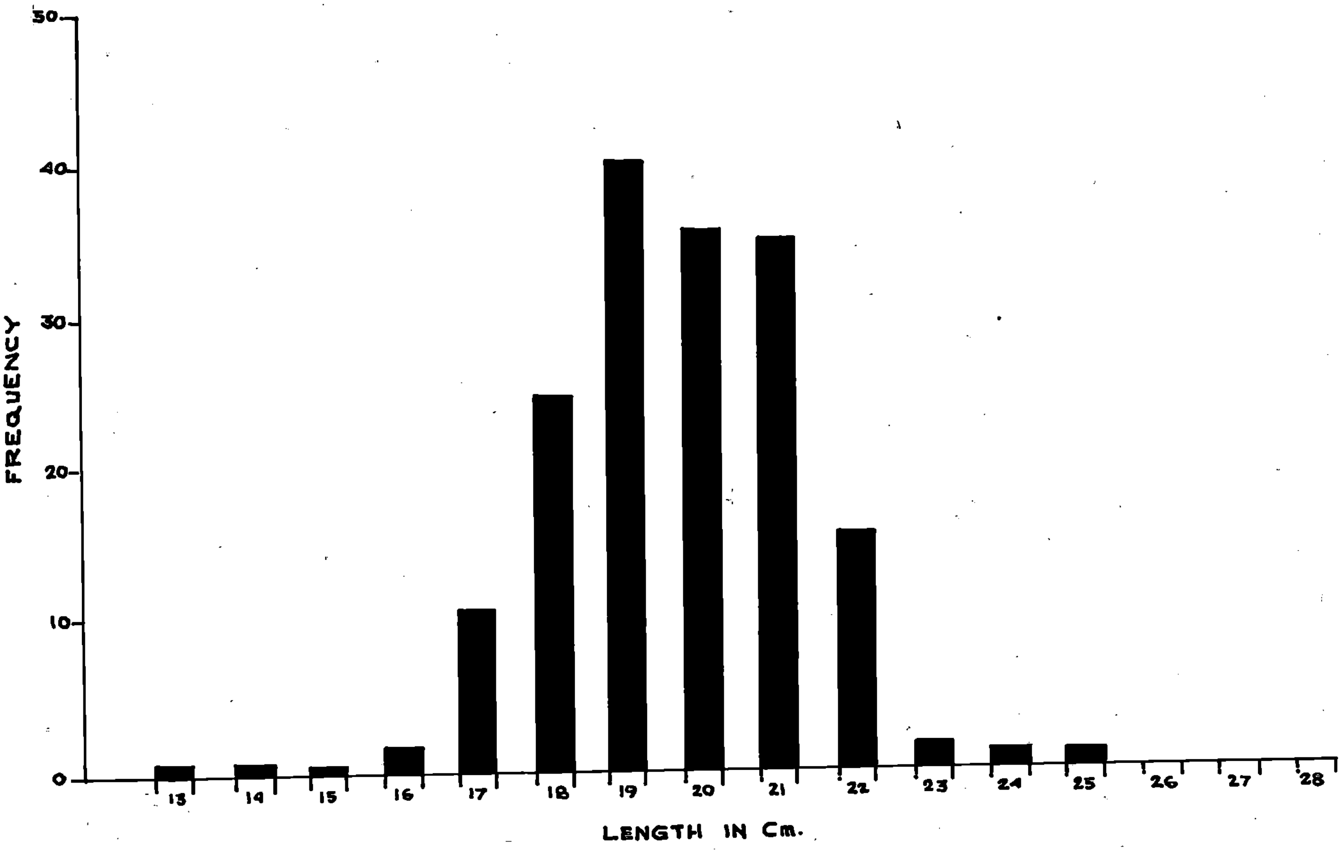
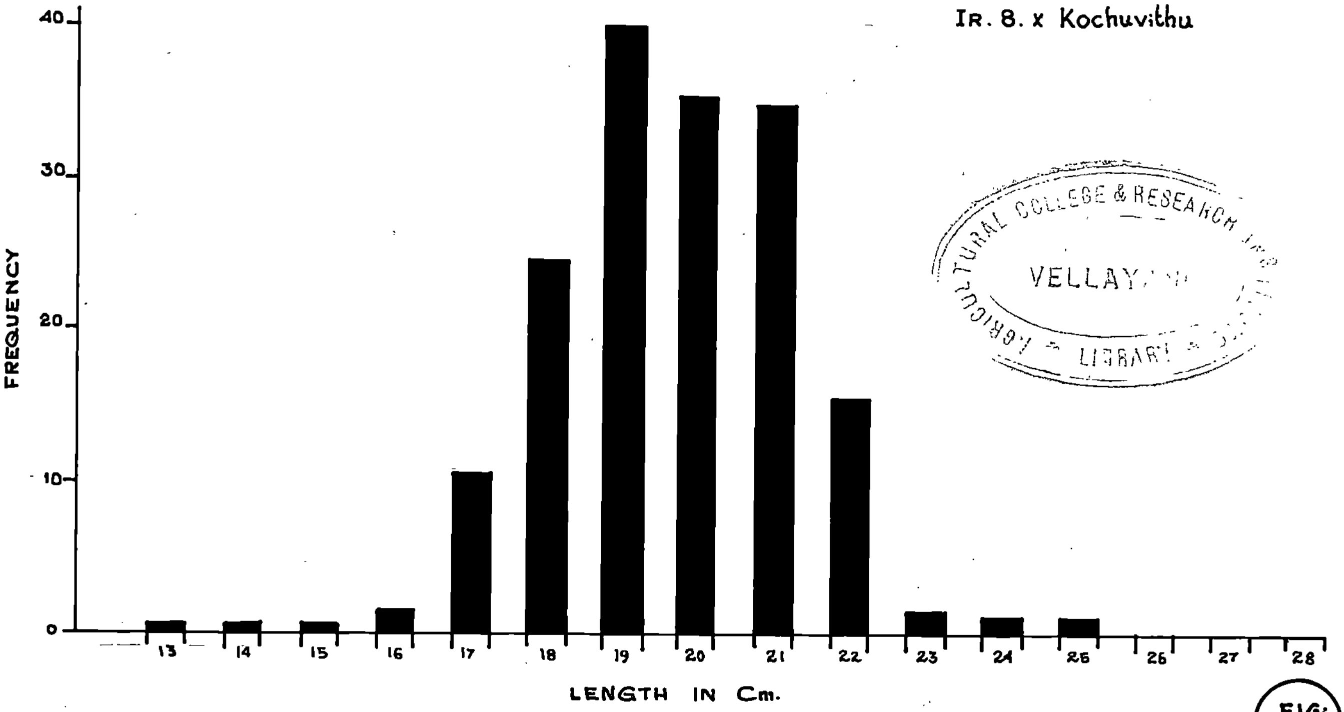


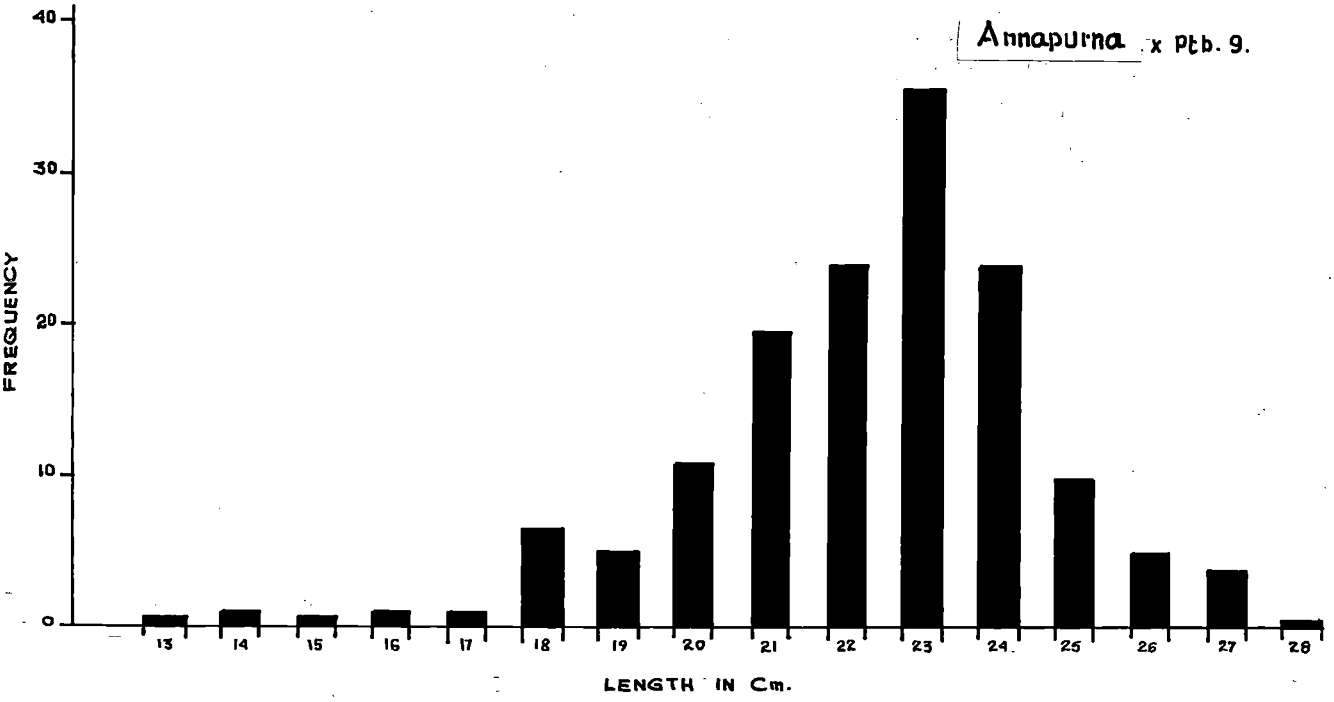
FIG: III A

FREQUENCY DISTRIBUTION OF F_2 FOR PANICLE LENGTH



IR. 8. x Kochuvithu

FIG: III B



Annapurna x Ptb. 9.

FIG: III C

In all the crosses variation in F_2 is more than that in the respective parents. The distribution of frequency tends to be normal. These features indicate the polygenic nature of this character.

Exsertion of panicle

The results are presented in table VII.

From the table it is evident that Ptb.9 has a well exserted panicle as compared to Annapurna and Kochuvithu which are medium exserted types.

In the cross Ptb.9 x IR.8 the mean exsertion is near to the mean of Ptb.9. There is wider variability in the progeny ranging from 4 cm to 13 cm and one sided transgression is observed resulting in partly enclosed panicles. The distribution does not seem to be continuous.

In the cross IR.8 x Kochuvithu, the mean exsertion value is in between the parental values. Here also transgression is one sided ie. towards lower values and distribution of frequency appears to be continuous.

The F_2 mean of the cross Annapurna x Ptb.9 is close to the mean value of Annapurna, the medium exserted parent.

Table VII

Frequency distribution of individuals (parents and F_2s) for excertion of panicle in cm

Class value parti- culars	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	$\bar{X}$	S.E.	C.V.
1	.	.	.	.	.	.	.	.	.	.	.	1	6	6	5	8	12	9	2	3	3	55	8.5	0.30	26.33
2	.	.	.	.	3	7	8	14	18	12	2	1	1	.	.	.	.	.	.	.	.	66	0.4	0.21	428.20
3	.	.	.	.	4	17	22	14	3	.	.	.	.	.	.	.	.	.	.	.	.	60	-1.1	0.13	91.66
4	.	.	.	.	.	.	.	4	22	12	10	2	.	.	.	.	.	.	.	.	.	50	1.7	0.14	60.12
5	.	.	.	1	2	1	0	2	.	1	2	1	12	12	26	23	29	31	21	15	5	184	8.3	0.21	35.10
6	1	1	3	4	8	17	18	29	23	29	15	14	5	1	1	.	.	.	.	.	.	169	0.6	0.18	396.61
7	.	.	2	12	16	23	29	48	38	.	.	.	.	.	.	.	.	.	.	.	.	205	0.2	0.14	820.83

1	Ptb.9
2	Kochuvithu
3	Annapurna
4	IR.8
5	Ptb.9 x IR.8
6	IR.8 x Kochuvithu
7	Annapurna x Ptb.9

$\bar{X}$ = Arithmatic mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

Here also transgression is observed towards lower values of exsertion. Distribution of frequency is continuous. Thus there is indication that exsertion of panicle is a polygenic character.

Spikelet sterility

The results are presented in the table VIII.

Among the four parental varieties Annapurna has the maximum spikelet sterility and Ptb.9 the minimum.

In all F_2 progenies, the mean percentage of sterility is higher than that in the respective parents. The mean percentage is maximum in the F_2 of Annapurna x Ptb.9. It is minimum in the progeny of IR.8 x Ptb.9.

The distribution of frequency is continuous in all crosses studied and there is wider variability as evidenced by the range of distribution and coefficient of variation. Segregants exceeding the maximum limit of the parents in percentage of sterility are observed in all the crosses.

Grain characters

The data pertaining to the frequency distribution of individuals of parents and F_2s grouped on the basis of grain

Table VIII

Frequency distribution of individuals (parents and F_2s) for spikelet sterility in per cent

Class value particulars	2	7	12	17	22	27	32	37	42	47	52	57	62	67	72	77	82	87	Total	$\bar{X}$	S.E.	C.V.
1	14	12	15	7	2	•	•	•	•	•	•	•	•	•	•	•	•	•	50	9.1	0.81	63.19
2	2	20	9	6	4	4	4	1	•	•	•	•	•	•	•	•	•	•	50	14.3	1.09	54.20
3	2	5	24	18	5	3	1	1	1	•	•	•	•	•	•	•	•	•	60	15.6	0.93	45.96
4	4	19	18	10	3	1	•	•	•	•	•	•	•	•	•	•	•	•	55	11.5	0.80	51.88
5	2	16	51	45	35	24	14	2	0	1	2	•	•	•	•	•	•	•	192	18.7	0.60	44.64
6	3	18	18	28	19	21	12	10	9	6	4	5	1	2	1	2	•	•	159	28.0	1.22	55.05
7	2	12	16	29	30	22	28	27	12	3	4	3	2	1	1	2	1	1	196	28.0	1.06	52.39

1 Ptb.9
2 Kochuvithu
3 Annapurna
4 IR.8
5 Ptb.9 x IR.8
6 IR.8 x Kochuvithu
7 Annapurna x Ptb.9

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

length, breadth and thickness are given below.

Length of grain

Results are presented in table IX.

In general the variability in F_2 is more as compared to the respective parents. The F_2 mean is found to approximate the mean of the parents in all the crosses. The distribution of frequency is continuous, typical of quantitative characters. Transgressive segregation is observed in two of the three crosses. In the cross IR.8 x Kochuvittu transgression is towards the parent having lower grain length, whereas in the cross Annapurna x Ptb.9, it is observed on both sides. The results indicate that this is inherited as a polygenic character.

Breadth of grain

The results are presented in table X.

In all the F_2 families there is wide range of variation as evident from the table. The F_2 mean is close to the parent with larger breadth in all the crosses. Distribution of frequency is continuous and transgressive segregation in both sides is observed in all the crosses. The above facts suggest the polygenic control of this trait.

Table IX

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

Class value particulars	6.7	7	7.3	7.6	7.9	8.2	8.5	8.8	9.1	9.4	Total	$\bar{X}$	S.E.	C.V.
1	•	1	2	6	1	•	•	•	•	•	10	7.5	0.07	3.07
2	•	•	1	1	6	2	•	•	•	•	10	7.87	0.08	3.18
3	•	•	•	•	3	6	1	•	•	•	10	8.14	0.06	2.21
4	•	•	•	•	•	•	•	1	7	2	10	9.13	0.05	1.75
5	•	2	5	10	14	12	5	2	•	•	50	7.91	0.02	1.77
6	1	3	5	5	8	11	7	5	3	2	50	8.11	0.09	7.77
7	1	1	3	8	19	9	6	2	1	•	50	7.96	0.06	5.65

1	Ptb.9
2	Kochuvithu
3	Annapurna
4	IR.8
5	Ptb.9 x IR.8
6	IR.8 x Kochuvithu
7	Annapurna x Ptb.9

$\bar{X}$ = Arithmatic mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

Table X

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

Class value particulars	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	Total	$\bar{X}$	S.E.	C.V.
1	•	•	3	4	3	•	•	•	•	•	10	2.90	0.02	2.76
2	•	•	•	•	•	4	5	1	•	•	10	3.17	0.02	1.89
3	•	•	•	4	4	2	•	•	•	•	10	2.99	0.02	2.68
4	•	•	2	7	1	•	•	•	•	•	10	2.89	0.02	1.73
5	1	2	9	15	14	8	1	•	•	•	50	2.93	0.02	4.09
6	•	1	1	4	5	12	15	8	3	1	50	3.15	0.02	5.08
7	1	2	10	20	7	6	2	1	1	•	50	2.93	0.02	5.12

1	Ptb.9
2	Kochuvithu
3	Annapurna
4	IR.8
5	Ptb.9 x IR.8
6	IR.8 x Kochuvithu
7	Annapurna x Ptb.9

$\bar{X}$ = Arithmatic mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

Thickness of grain

Results are presented in table XI.

There is wide range of variation in the F_2s for the character. The frequency distribution is continuous and tends to be normal. The mean value of the F_2 is almost close the parental means. Transgressive segregation is observed only in the F_2 progeny of Annapurna x Ptb.9 where plants with grain thickness exceeding the upper limit of the parent is observed. Thus thickness of grain also seems to be controlled by polygenes.

Grain yield

The frequency distribution of parents and F_2s grouped on the basis of individual plant yields is presented in the table XII.

The yield data reveal that among the short duration varieties Annapurna gives higher grain yield per plant than Kochuvithu and among the medium duration varieties IR.8 gives higher yield than Ptb.9.

Among the F_2 families, the mean yield of Ptb.9 x IR.8 is lower than that in the low yielding parent. The F_2 of IR.8 x Kochuvithu has recorded a mean yield in between the parental

Table XI

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

Class value particulars	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	Total	$\bar{X}$	S.E.	C.V.
1	.	.	.	.	1	8	1	.	10	2.30	0.014	1.96
2	.	.	.	.	.	2	7	1	10	2.39	0.017	2.26
3	1	8	1	.	.	.	.	.	10	1.90	0.014	2.37
4	.	2	8	.	.	.	.	.	10	1.98	0.013	2.02
5	.	5	9	17	12	5	2	.	50	2.12	0.017	5.66
6	.	3	7	11	14	10	3	2	50	2.18	0.020	6.61
7	1	2	4	14	15	7	5	2	50	2.18	0.023	7.34

1	Ptb.9
2	Kochuvithu
3	Annapurna
4	IR.8
5	Ptb.9 x IR.8
6	IR.8 x Kochuvithu
7	Annapurna x Ptb.9

$\bar{X}$ = Arithmatic mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

Table XII

Frequency distribution of individuals (parents and F_2s) for grain yield in gm

Class value particulars	3.5	5.5	7.5	9.5	11.5	13.5	15.5	17.5	19.5	21.5	23.5	25.5	27.5	29.5	31.5	33.5	35.5	37.5	Total	X	S.E.	C.V.
1	•	•	2	5	16	8	10	9	6	1	1	1	1	•	•	•	•	•	60	14.7	0.54	28.30
2	•	2	10	26	16	8	7	1	•	•	•	•	•	•	•	•	•	•	60	10.9	0.36	25.43
3	•	•	•	2	13	18	12	9	3	3	•	•	•	•	•	•	•	•	60	14.6	0.37	19.69
4	•	•	•	•	•	2	5	6	4	6	8	8	10	4	4	1	1	1	60	23.9	0.68	22.19
5	•	•	12	23	21	18	35	26	12	9	9	5	8	1	1	•	•	•	180	13.0	0.39	37.75
6	5	10	19	25	32	17	13	6	12	5	5	5	5	1	1	1	•	•	162	13.4	0.49	46.87
7	2	14	18	17	24	26	14	19	15	14	11	4	5	5	1	2	1	1	193	16.4	0.46	47.14

1	Ptb.9
2	Kochuvithu
3	Annapurna
4	IR.8
5	Ptb.9 x IR.8
6	IR.8 x Kochuvithu
7	Annapurna x Ptb.9

$\bar{X}$ = Arithmatic mean

S.E. = Standard error of mean

C.V. = Coefficient of variation

values and in the cross Annapurna x Ptb.9 the mean yield recorded is higher than that of the high yielding parent.

The variability is higher in all the F_2s as compared to that in their respective parents as is evident from the higher magnitudes of coefficient of variation. The frequency of individuals tends to follow approximately a normal distribution, thereby indicating the polygenic nature of this character.

Correlation studies

The simple and total correlation coefficients of the characters viz., height, panicle number and panicle length with grain yield in respect of the 3 segregating population are presented in table XIII.

There is significant positive correlation for all the characters with grain yield. In the case of plant height correlation with yield is very high, which is significant at 1% level. For panicle number high correlation is observed in two crosses whereas in the cross IR.8 x Kochuvithu it has shown only a feeble correlation. In the case of panicle length, correlation with yield is significant at 1% level in all crosses.

Table XIII

Simple correlation coefficient of characters with grain yield in the F_2 progenies

Cross Characters	Ptb.9 x IR.8	IR.8 x Kochuvithu	Annapurna x Ptb.9	Total correlation coefficient
Height	0.462 **	0.510 **	0.481 **	0.485 **
Panicle number	0.732 **	0.311 *	0.599 **	0.572 **
Panicle length	0.509 **	0.511 **	0.483 **	0.516 **

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

Grain colour

The results of observations relating to inheritance of grain colour in the three crosses studied, are presented in table XIV.

Among the parents, Annapurna and Kochuvithu are red riced and Ptb.9 and IR.8-white riced. Irrespective of the grain colour in the parents, all the F_1s are observed to have red rice in all the three crosses, thereby indicating the complete dominance of red over white. The behaviour of F_2 in all the three crosses is also in support of the above. Clear cut segregants, red and white in different proportions are distinguished in F_2. This indicates the qualitative nature of inheritance of grain colour.

In the cross IR.8 x Kochuvithu (white x red), the F_2 frequencies are found to fit in well in a 3:1 ratio of red to white, thereby suggesting a single gene difference between the parents. In the cross Annapurna x Ptb.9 (Red x white) where two families have been studied, the F_2 segregation agrees well to a 63:1 red to white proportion in both the families. This suggests a trigenic basis for grain colour in this cross. In the cross Ptb.9 x IR.8 where both the parents are white riced,

Table XIV

Behaviour of F_1 and mode of segregation in F_2 for grain colour

No.	Combination of		Colour of F_1	Observed F_2 frequency		Expected ratio	'P' value
	Cross	Grain colour		Red	White		
1	IR.8 x Kochuvithu	White x Red	Red	106	40	3:1	0.70 - 0.50
2	Annapurna x Ptb.9	Red x White					
	Family I		Red	200	6	63:1	0.20 - 0.10
	Family II		Red	156	5	63:1	0.20 - 0.10
3	Ptb.9 x IR.8	White x White	Red	192	4	251:5	0.95 - 0.90

the results indicate the operation of four factors since the segregants are observed in a 251:5 ratio of red to white. In the predominant red class of F_2 individuals in all the three crosses, variation in the intensity of redness is also noticed and this variation is found to be high in the cross Ptb.9 x IR.8 and low in IR.8 x Kochuvithu.

DISCUSSION

DISCUSSION

In the F_2 generation of three sets of crosses involving two semi dwarf high yielding varieties and two local varieties, the pattern of segregation exhibits some common features with reference to certain characters and striking differences with reference to some others.

An examination of the data for plant height reveals that this is inherited as a polygenic character. Continuous variation in the F_2, transgressive segregation, a general agreement of F_2 mean with mean of the parents, a wider range of variability in the F_2 etc., observed in all crosses studied in the present investigation support the above view. This is in agreement with the findings of Ramiah (1933), Syakudo (1952), Mitra (1962), Sastry (1963 and that from IRRI (1969).

A detailed examination of the results does not fully agree with the generalisations drawn above. Though in one of the three crosses an almost normal curve in F_2 is obtained, in another a bimodal curve and in the third two discrete classes of individuals with the F_2 mean nearing to the mean of the taller parent are observed.

In the cross Ptb.9 x IR.8, where two discrete groups have been observed in F_2 (Fig. I A), the proportion of tall to dwarf individuals has been observed to be 189:9 which makes a good fit to a 15:1 ratio thereby suggesting a two gene difference between the parents concerned. A similar case has been reported by Yamaguchi (1927) in the case of daikoku dwarf. In the cross Annapurna x Ptb.9, where a bimodal curve is seen (Fig. I B), a monogenic segregation with complete dominance can be infered if a separation is made between the two peaks of the bimodal curve. In the cross IR.8 x Kochuvithu, where an almost normal distribution is observed in F_2 (Fig. I C) the frequencies can be made to fit in well in a 3:1 ratio if individualshaving a height of 70 cm and above are considered as tall and those below 70 cm as dwarf, as has been reported earlier. (Seetharaman 1969).

A suitable genic basis capable of explaining the results observed in the three above crosses has to be given. Height is primarily controlled by a set of minimum of three genes having additive effect, which is designated as T_1, T_2, T_3 ....each having differential effect in controlling height (Chalam and Venkateswarlu 1965). Besides this, dwarfness in rice is controlled by a gene pair 'D-d' which in the recessive condition with modifier complex, results in semi dwarf stature (Chang T.T. 1965), Hsu et al (1969). Such dwarfing genes are present in IR.8 and in Annapurna.

Taking the above facts into account, the segregation can be most satisfactorily explained if it is assumed that above two categories of genes - 'T' - series and 'D' - interact. Thus in the cross IR.8 x Ptb.9 where the results indicate a two gene difference between the parents, one can be in the 'T' locus and another in the 'D' locus.

In the other two crosses, Annapurna x Ptb.9 and IR.8 x Kochuvithu where the results are indicative of a single gene difference between the parents involved, this can be in the 'D' locus. But these two crosses differ in the fact that in one when a bimodal curve in F_2 is observed, in the other there is a unimodal curve. This may perhaps be due to the differences in the modifier complex present in the two sets of parents which has to be confirmed by further detailed analysis.

Thus plant height is inherited as a polygenic character governed by many genes, the cumulative action of which varies from variety to variety depending upon the number of 'T' loci governing height. Besides, the inheritance of plant height in the three crosses involving the semi dwarf varieties is also influenced by the dwarfing gene with modifier complex. Transgressive segregation, either one sided or two sided, observed in all crosses again confirms the fact that large number of genes interact in the determination of this trait. The recovery of extremely dwarf plants in the F_2 may perhaps be due to the effect of negative modifiers on the dwarfing gene. As the presence of such modifying genes in the negative direction has been reported in Taichung Native.1 and Dee-jeo-wu-gen, it is quite reasonable to assume that such modifier complex is also present in Annapurna and IR.8, in as much as Taichung Native.1 and Dee-jeo-wu-gen form one of the two parents of the above strains.

Plant height, however, cannot be considered as an entity by itself. It is primarily determined by two variables - number of nodes and length of individual internode, each of which may have independent or interdependant contribution to plant height. In agreement with the polygenic nature of inheritance of plant height, results of inheritance of internode number in the present study also suggest a quantitative nature of this trait. This is in accordance with the findings of Morishima (1968).

Thus variation in plant height can be due to a change in the internode number as well as in the internode length. Among two groups of plants having similar height the 'internode length type', will have high yield potentiality as compared to 'internode number type' and such 'internode length type' will take lesser time to maturity (Morishima 1968). A comparison of the mean for internode number, duration for flowering and per day yield of the three F_2s in the present investigation agrees well with the above view.

The results of inheritance of flowering duration suggest a polygenic nature of this trait. The F_2 frequencies in all the three crosses are seen to be distributed within the two parents as indicated by their mean values. This is in support of earlier findings reported by Ramiah (1933), Sethi (1938), Alam (1939) and Nagai (1959). In the crosses IR.8 x Kochuvithu and Ptb.9 x IR.8 where the differences in flowering duration between the two parents involved are 26 and 24 days respectively, an accumulation of frequency towards earliness is seen in F_2, resulting in a skewed distribution, which is highly pronounced in the former (Fig. II A & B). This may perhaps be due to the fact that the qualifying values of the genes involved may not be the same as reported by Narai (1959). In the cross Annapurna x Ptb.9 where the difference in the mean flowering duration among the parents is only six days, there is an accumulation of individuals towards the late flowering parent, thereby resulting in a skewed distribution (Figure II C). The skewness towards lateness may be the result of the differential value of the genes governing this trait, which has to be supported by further studies.

The results in general indicate the scope for selection of early flowering, internode length types which are characters of a high yielding strain according to the present concept (Beachell and Jennings 1966, Morishima, 1968).

Tillering is a character of great economic importance in rice. Two types of tillers, productive amnon-productive can be recognised, of which productive tillers are of higher economic value. In the present study it is observed that there is large variation in F_2, where the distribution of frequencies is almost normal. A one sided transgression is also observed in all the three cases. The above facts suggest that the trait under consideration is inherited as a quantitative one controlled by many genes.

A comparison of the four parents in their ability to produce ear bearing tillers indicates that they possess varying potentiality. These parents can be ranked as Annapurna, IR.8, Kochuvithu and Ptb.9 in their decreasing order of mean productive tillers per plant. This fact leads us to assume that the parents have varying number of contributing genes for the production of ear bearing tillers in the order mentioned above.

A comparison of the F_2 means of the two crosses Ptb.9 x IR.8 and IR.8 x Kochuvithu, where IR.8 is common in both, indicates that the mean value is more in the latter. This may perhaps be due to the more number of contributory genes donated by Kochuvithu as compared to Ptb.9. This conclusion is further supported by the fact that Kochuvithu has more contributory genes than Ptb.9 as is evidenced by a higher mean for Kochuvithu. The same explanation holds good in the comparison of F_2 means of the two other crosses Ptb.9 x IR.8 and Annapurna x Ptb.9, where Ptb.9 is common to both. In all the three crosses though the F_2 means, within the limits of error, are within the respective parental means, they appear to be nearer to the ovule parent. This suggests the matroclinous nature of inheritance of this character as reported by Wu (1968) which has to be confirmed by further detailed investigation.

The results in general indicate that a good proportion of F_2 population in all the three crosses surpasses the mean of higher tiller producing parent which opens the chances of realising suitable 'panicle number type' segregants which are generally high yielding ones.

It is a fact that area of leaf exposed to solar radiation is a criterion for higher productivity. Leaf area is primarily determined by length and width. In the present investigation width of leaf appears to be inherited as a quantitative character in as much as the variation is continuous in the F_2 of all the three crosses, and F_2 means fall within the respective parental means. Similar results have been recorded by Mitra (1962). The present results indicate the possibility of recovering long narrow leaved segregants in the F_2, which forms one of the pre-requisites of the high yielding plant type.

Excertion of panicle is a character which cannot be attributed to have much significance economically. However, a well exserted type is desired since in types with no exsertion or those having negative exsertion, where a few of the bottom most spikelets in the panicle will be enclosed by the leaf sheath, there is greater chance for sterility. In the present case exsertion appears to be inherited as a polygenic character controlled many genes with a one sided transgression. The results of spikelet sterility in the present study reveal wide variation among the F_2 segregants. Segregants ranging from almost complete fertility to almost complete sterility have been recorded in the F_2 as reported by Sampath (1959), which may perhaps be due to partial breakdown of the F_1 as suggested by Oka (1964).

One of the major criteria in any breeding programme is yield. Rice which is no exception to the above, is mainly cultivated for its grain. But grain yield in rice cannot be considered as a unit by itself. It is a complex character conditioned by a number of components including, panicle number, panicle length, grain size etc. As discussed earlier panicle number is inherited as a quantitative trait controlled by many genes. The same is the case with regard to the pattern of interitance of panicle length as evidenced by a continuous variation and normal distribution in the F_2 in all the crosses studied (Figure III A, B & C). In two of the three crosses transgression is only one sided ie., towards shorter panicle length. In the cross Annapurna x Ptb.9 it is observed on both sides which can be exploited economically.

Grain size is determined by length, breadth and thickness. The study of their inheritance reveals that they have almost similar pattern of inheritance in all the three crosses studied. All are inherited as quantitative characters controlled by polygenes. Similar results have been obtained by Bhide (1926), Ramiah (1935), Mitra (1938), Majid (1939), Syakudo (1951), Kandam et al (1960), Vinodini (1968) and Rajendran (1968).

These grain characters have great significance in the commercial classification of rice grain. The length/breadth ratio is one basis for classification. Based on this ratio the grain types of the four parents - IR.8, Annapurna, Kochuvithu and Ptb.9 used in the present study can be defined as medium, medium bold, bold and oval respectively. As indicated in the present investigation the F_2 means for grain length tends to agree with the mean of the parents whereas that for breadth is found to be nearer to that parent having the higher value. This indicates the trend of occurrence of higher frequency of types having low l/b ratio. Evidently in practical breeding programmes for the evolution of fine grained types, large population of F_2 will have to be raised and scored for this character in order to spot out the high yielding, fine grained types which are of very low occurance.

Just as the quantitative nature of inheritance observed in the case of various contributory factors, the yield is also inherited as a quantitative trait controlled by polygenes. It is of significance that in the cross Annapurna X Ptb.9 about 4 per cent of F_2 segregants surpass the higher parental limit in their mean yield. This suggest the potentiality of Annapurna as a good source for further improvement in grain yield.

Correlation studies

Yield, the genetic improvement of which is the primary concern of the rice breeder, is a complex character. As discussed earlier it is the product of a number of components each of which is under polygenic control. While all changes in yield must be accompanied by changes in one or more of the components, all changes in the components need not be expressed in changes in yield (Grafius (1964)). This is due to varying degrees of positive or negative correlations between yield and any of its components on the one hand, and between the components on the other.

In the present investigation correlation with yield for plant height, panicle number and panicle length, which are easily assessable morphological features under field conditions has been worked out and interesting results have been obtained. The high correlation of plant height with yield, observed in all the three crosses, is in perfect agreement with the observations of Vibar (1930), Ramiah (1933), Ganguli (1941), Abraham (1956), Rajagopal (1963), Ghose (1966), Wang (1967) but contrary to Mahalanobis (1934), Ghose (1956), Chandramohan (1961) and Narahari (1965).

It is a fact that extremely tall plants as compared to semi dwarf and dwarf ones are more liable to lodging which may affect the yield adversely. Therefore utilisation of coefficient of height as a selection index for yield may not have much significance in extremely tall group of plants, but in semi-tall and dwarf groups as in the present case it assumes great significance. The results give indication to the fact that it is disadvantageous to select plants of extremely dwarf stature since they will be poor yielders. Therefore, it will be always desirable to select plants of medium height from segregating population. Such plants are less liable to lodge and will be good yielders.

It is also evident from the results that panicle number is correlated with yield. This is in agreement with the findings of Bhide (1924), Mahalanobis (1934), Narasinga Rao (1937), Ganguli (1941), Abraham (1956), Syed Ibrahim (1958), Chandramohan (1958), Rajagopal (1963), Ghose (1966) and Sastri (1967). Further, the high correlation obtained for panicle length with yield in all the three crosses is in accordance with the observations of Vibar (1920), Narasinga Rao (1937), Syed Ibrahim (1958), Chandramohan (1961), Sane (1962), Abraham (1962), Rajagopal (1963) and Narahari (1965).

Thus all the three characters studied are seen to be significantly correlated with yield. Among the characters panicle number is seen to have the highest correlation with yield followed by panicle length and plant height. Thus it has to be concluded that the panicle number is the most potent one among the yield components studied.

Grain colour

Presence or absence of colouring pigments in pericarp, which is the wall of the ripened ovary, determines the coloured or colourless nature of grain. Pericarp is derived from the diploid maternal tissue and hence it is the plant generation that is followed in the study of inheritance of grain colour.

In the present investigation results relating to the inheritance of grain colour in the three crosses are interesting. Irrespective of grain colour in the parental varieties, all F_1s are red and in the F_2 a clear cut segregation of red and white is observed. This indicates that grain colour is inherited as a qualitative character with the red colour having complete dominance over white.

In the cross between IR.8 and Kochuvithu which is a white x red combination, the results indicate a single gene difference between the parents. Contrary to the above, a trigenic segregation is indicated in the results of the red x white combination of the cross between Annapurna and Ptb.9. In the third cross between Ptb.9 and IR.8 where both the parents are white riced, the F_1, surprisingly, is red and in F_2, a segregation explainable on a four factor basis is obtained. It has also been observed that in the predominant red group of the F_2, the intensity of redness is found to vary and this variation is least in the cross IR.8 x Kochuvithu. This fact leads us to conclude that genes involved are duplicate ones.

Considering all these aspects together it is proposed that three basic duplicate loci 'Pr_1', Pr_2', and 'Pr_3' are involved for colour development in the varieties studied. The appearance of red riced F_2 in the cross Ptb.9 x IR.8 where both the parents are white riced, necessitates the action of another non-allelic inhibitory gene 'ih' the presence of which has already been reported by Parnell (1922). This inhibitory gene in the homozygour recessive condition completely masks the effect of the duplicate gene. The interaction is slightly complicated that the masking effect of 'ih ih' is nullified by the recessive allele of the three duplicate genes either individually or jointly. Thus this can be supposed to be a case of duplicate recessive epistasis. Based on this assumption the genotypes of the parents and progenies of the three crosses can be represented as follows:-

I. IR.8 x Kochuvithu

(White) (Red)

$Pr_1Pr_1Pr_2Pr_2Pr_3Pr_3$ Ihih $Pr_1Pr_1Pr_2Pr_2Pr_3Pr_3$ IhIh

F_1 $Pr_1Pr_1Pr_2Pr_2Pr_3Pr_3$ Ihih

F_2 3 Red : 1 White

Here F_1 is heterozygous for 'Ih' locus which in F_2 will segregate into 1 IhIh, 2 Ihih and 1 ihih in combination with six basic genes to all. Out of the four genetypes those with 'ihih' will be white and others red. Thus a 3:1 phenotypic rationobserved in F_2 is explained.

II. Annapurna x Ptb.9

(Red) (White)

$Pr_1Pr_1Pr_2Pr_2Pr_3Pr_3$ IhIh $pr_1pr_1pr_2pr_2pr_3pr_3$ IhIh

F_1 $Pr_1pr_1Pr_2pr_2Pr_3pr_3$IhIh (red)

F_2 63 red : 1 white

In this case the F_1 is heterozygous for three basic gene loci which in F_2 on random mating will produce 64 combinations, of which one will have no basic contributory gene, and hence will be white. All the other combinations will have one to six contributory genes and hence will be red in appearance with varying intensities of redness. Thus 63:1 phenotype proportion observed in the F_2 of the above cross is obtained.

III. Ptb.9 x Ir.8

(White) (White)

$pr_1pr_1pr_2pr_2pr_3pr_3$ IhIh $Pr_1Pr_1Pr_2Pr_2Pr_3Pr_3$ ihih

F_1 $Pr_1pr_1Pr_2pr_2Pr_3pr_3$ Ihih (red)

F_2 251 red : 5 white

Here the F_1 is heterozygous for four loci which on random mating will result in 256 combinations out of which four have no contributory basic gene and consequently are white riced. One with the genotype $Pr_1Pr_1Pr_2Pr_2Pr_3Pr_3$ ihih is also white because of the epistatic action of 'ih ih' over the basic contributory genes. Thus five out of 256 will be white in appearance and the rest 251 combinations will be red with varying intensities. Thus observed phenotypic proportion of 251:5 in the above cross is well explained.

The above assumptions appear to be most satisfactory because the observed frequencies fit well to the expected ratios as has been proved by the χ^2 test of goodness of fit. And the fact that minimum variation in the intensity of red colour in the red group observed in the F_2 of cross IR.8 x Kochuvithu as compared to others, is due to lack of segregation in the Pr loci, further testifies the validity of the above assumption.

SUMMARY AND CONCLUSIONS

SUMMARY

The present investigation was carried out in the Division of Botany, Agricultural College and Research Institute, Vellayani during the period from October, 1969 to February, 1970. The pattern of segregation of 13 characters and correlation of three of them with yield in the F_2 generation of three intervarietal crosses involving two local varieties, Ptb.9 and Kochuvithu and two high yielding semi-dwarf varieties, IR.8 and Annapurna was studied and the following conclusions have been drawn.

Plant height has a complex nature of inheritance and is controlled by many genes of different qualifying values. Internode number, which is contributory to plant height, has also the same mode of inheritance.

Flowering duration is under the control of polygenes. The distribution of individuals in F_2 is influenced by the difference in flowering duration among the parents.

The number of productive tillers, leaf width, length of panicle, exsertion of panicle, length, breadth and thickness of grains, yield of grain etc., are inherited as quantitative

characters controlled by either polygenes or by a few major genes whose action is suitably modified by minor genes.

Panicle number, panicle length and Plant height are positively correlated with yield.

Rice colour is inherited as a qualitative character controlled by one to three pairs of genes, red colour having complete dominance over white.

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PLATE I

Photograph showing the height of parents and F_2 plants of the cross Ptb.9 x IR.8.

PLATE II

Photograph showing the height of parents and F_2 plants of the cross IR.8 x Kochuvithu.

PLATE III

Photograph showing the height of parents and F_2 plants of the cross Annapurna x Ptb.9.


IR8
Ptb9xIR
Ptb9xIR
Ptb9


IR8
IR8xK
IR8XK
K


A
AxPtb9
AxPtb9
Ptb9

PLATE IV

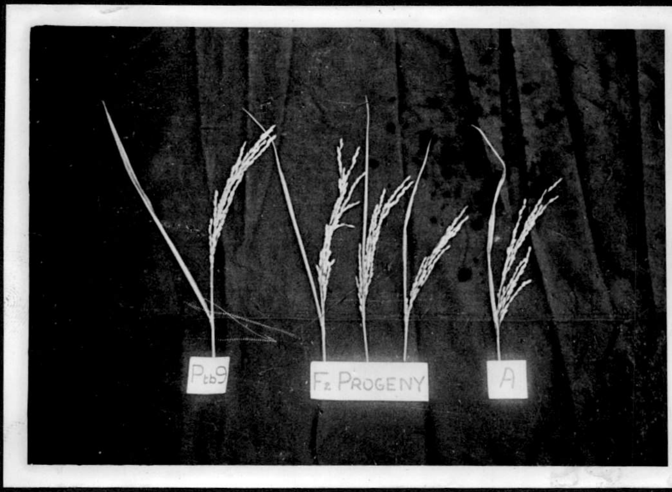
Photograph showing exsertion of panicle of parents and F_2 plants of the cross Annapurna x Ptb.9.

PLATE V

Photograph showing exsertion of panicle of parents and F_2 plants of the cross IR.8 x Ptb.9.

PLATE VI

Photograph showing exsertion of panicle of parents and F_2 plants of the cross IR.8 x Kochuvithu.


Ptb9
F_2 PROGENY
A

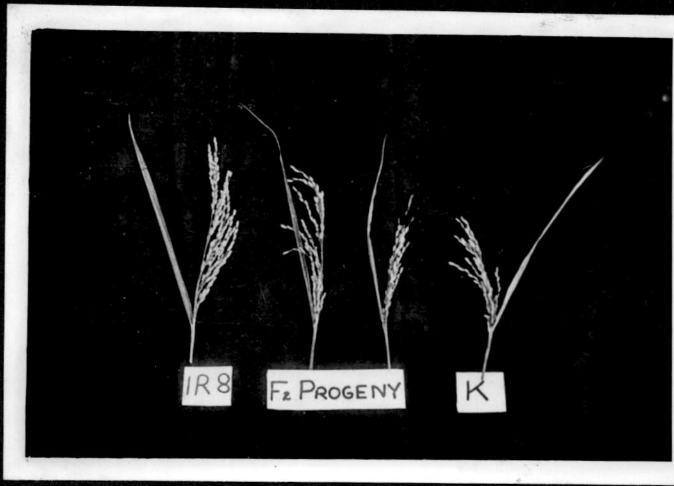
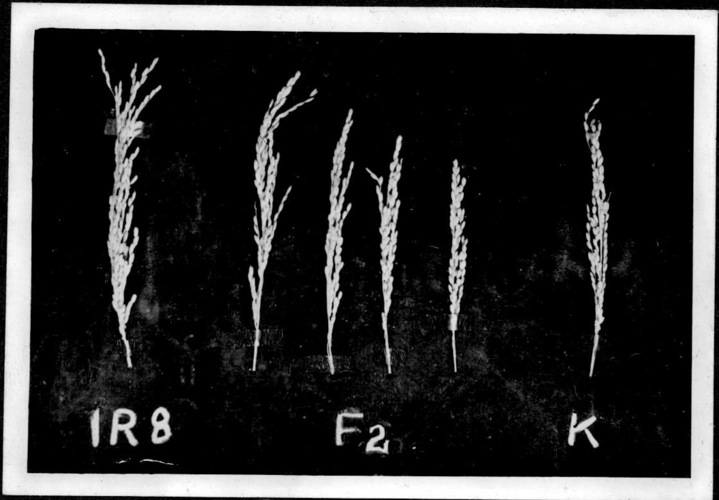

IR8
F_2 PROGENY
K

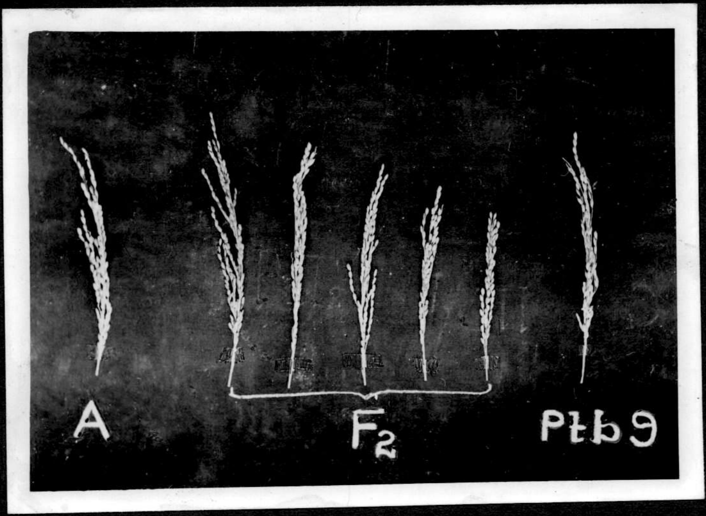
PLATE VII

Photograph showing panicle length of parents and F_2 plants of the cross IR.8 x Kochuvithu.

PLATE VIII

Photograph showing panicle length of parents and F_2 plants of the cross Annapurna x Ptb.9.


IR8
F2
K


A
F2
Ptb9