INHERITANCE OF PLANT PIGMENTATION, GRAIN COLOUR, CHARACTER ASSOCIATION, PATH ANALYSIS AND HERITABILITY OF YIELD AND ITS COMPONENTS IN FINGER MILLET (*Eleusine coracana* Gaertn).

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BANGALORE

1988

INHERITANCE OF PLANT PIGMENTATION, GRAIN COLOUR, CHARACTER ASSOCIATION, PATH ANALYSIS AND HERITABILITY OF YIELD AND ITS COMPONENTS IN FINGER MILLET (*Eleusine coracana* Gaertn).

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Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the degree of

Master of Science (Agriculture)

IN

AGRICULTURAL BOTANY
(Plant Breeding and Genetics)

BANGALORE OCTOBER 1988

Dedicated to my Beloved Parents
and Brothers

DEPARTMENT OF AGRICULTURAL BOTANY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

CERTIFICATE

This is to certify that the thesis entitled

"INHERITANCE OF PLANT PIGMENTATION, GRAIN COLOUR, CHARACTER ASSOCIATION, PATH ANALYSIS AND HERITABILITY OF YIELD AND ITS COMPONENTS IN FINGER MILLET (*Eleusine coracana* Gaertn.)"

submitted by

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in partial fulfilment of the requirements

for the degree of

MASTER OF SCIENCE (AGRICULTURE) IN AGRICULTURAL BOTANY (PLANT BREEDING AND GENETICS)

to the University of Agricultural Sciences, Bangalore, is a record of research work carried out by him during the period of his study in this university under my guidance and supervision, and that no part of this thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.

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ACKNOWLEDGEMENT

I heartily express my deep sense of gratitude to Mr. B.T. Shankare Gowda, Geneticist, Small Millets Germplasm Unit, G.K.V.K, University of Agricultural Sciences, Bangalore, and Chairman of my Advisory committee for his inspiring guidance, encouragement, critical comments, suggestions and sustained interest from the initial step of selection of the problem for research till the preparation of the thesis.

I also record my deep sense of gratitude to the members of my advisory committee Dr. A. Seetharam, Project Co-ordinator, Small Millet Germplasm unit (ICAR) and Mr. S. Vishwanath, Virologist, Small Millets Germplasm unit, University of Agricultural Sciences, G.K.V.K., Bangalore, for their valuable suggestions during the course of this study.

I wish my sincere thanks to Mr.K.Seenappa, Junior Statistician, All India Co-ordinated Research Project (Sun flower) and member of my advisory committee who helped me in the statistical aspects of my research work.

I am thankful to Mr. M. Byregowda, Mr. B.M. Ramakrishna and Mr. Y. Vishwanath shetty for their help and co-operation during the course of my study.

I am equally thankful to my friends Sriyuts M.S. Maiya, R.L. Ravi kumar, Basavalingappa and N. Shivaprakash for their valuable co-operation in conducting the experiment.

I extend my sense of gratitude to Mr. D.L. Rajagopal, Mr. K.C. Chikkegowda, Mr. H.P. Jayakrishnappa, Mr. K.M.V. Reddy and field workers of Small Millet Germplasm Unit, without their help and co-operation timely completion of this work would have been difficult.

I take this chance to express my respectful gratitude to my beloved parents and brothers for their unfailing support, constant encouragement and ambitious inspiration throughout the course of my studies. I also gratefully acknowledge the help rendered by my cousin Mr. L.J. Onkareswara, B.Sc. LL.B., during the course of my studies.

My sincere thanks to Mr. R.Ravichandra, Campus Electronic Impression, I.I.Sc., for his exacting care rendered by him in the typing of this thesis.

(G.SHANTHAKUMAR)

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INTRODUCTION

I INTRODUCTION

Ragi (finger millet) is one of the important food crops of India. It is the staple food of rural and working people in many states of Indian union in general and southeast and Central Karnataka in particular. In India among millet ragi stands third only to sorghum and pearl millet and is cultivated on an area of about 2.6 million hectares with a production of 2.7 million tonnes. Karnataka alone accounts for 40 per cent of total area and 46 per cent of total production in the country. Apart from Karnataka ragi is chiefly grown in states of Tamil Nadu, Andhra Pradesh, Orissa, Maharashtra, Uttar Pradesh, Bihar and Gujarath.

Ragi has high sustaining nutritive value. It provides a fair amount of protein, carbohydrates, fats and minerals especially calcium with an amount of 0.34 per cent on the whole seed basis (Kurian et al., 1959). Ragi also possesses good malting properties.

Improvement of seed yield is one of the primary objectives in most ragi breeding programmes. Seed yield is a complex character and is considered as the ultimate product of its components. As such, the study of each component separately and their association with yield will help in improvement of yield through selection of components which have high heritability. The relationship between yield and its components is measured using correlation, regression and path co-efficient analysis. Path co-efficient analysis not only differs from correlation but also offers additional advantages.

Correlation co-efficient provides a measure of association among characters and can serve to identify the factors which can be used as indicators of high yielding ability in early generation. Though correlation coefficients give the extent of association between any pair of characters, path coefficient analysis delineates correlation coefficient in to direct, indirect and extraneous effects. It is in general a standardized partial regression coefficient (Tukey, 1954). Path co-efficient analysis facilitates partitioning of the correlation coefficients into direct contribution of each of the component to yield and its indirect effect through other components. Path analysis also helps to elucidate the intrinsic nature of the observed associations and imparts confidence in the selection scheme adapted for a given situation.

Understanding of heritability of quantitative characters is useful for improving the efficiency of selection of segregating populations. If individual components of yield are demonstrated as indicators of yield in a segregating population and if they are highly heritable than yield, then yield could be selected effectively in early generations by selecting yield components.

Plant pigmentation is often a reliable, easily discernable and serves as marker gene in the identification of true hybrids.

Among brown and white grain types, white grained types are preferred because of high protein, low fibre and low tannins. However, the yield potentiality of all white grained types available is significantly lower than browns. Obviously, one of the important breeding objectives has been to combine high protein and yield in white grain types. In this context genetics of plant pigmentation, grain colour and other agronomic attributes will go a long way in combining grain colour and high yield potential.

Keeping these information in back ground, the present study was initiated with the following specific objectives.

1. To study the relationship between different quantitative traits and yield.

2. To workout the path-coefficient, so as to find out the relative contribution of different metric traits to the final grain yield.

3. To estimate the heritability of seed yield and its components, and

4. To study the inheritance of qualitative characters-plant pigmentation and grain colour.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

2.1 CORRELATION CO-EFFICIENT

Estimations of correlations that exists between yield and its components have been of immense value in evolving and planning future breeding strategies. The nature of relationship between yield conponents and yield in a plant, as revealed through correlation estimates is being used very frequently in planning selection for increased yield. The correlation of characters may be due to the following reasons.

(i) Pleiotropy:

It is due to gene governing more than one character. Correlations of this nature are of immense value to the breeder when they are desirable only. Because, physiological associations between characters are not possible to break by breeding.

(ii) Genetic linkage:

Correlation exists due to association of characters during inheritance which is due to the location of genes governing these characters on the same chromosome. This linkage is of immense value to the breeder when they are desirable. Such correlations can only be broken if linkages are not very tight. Correlation studies in segregating generation will indicate whether tight linkage is implicated in the association.

(iii) Temporary correlations many also be the result of association of loci located on different chromosomes and any kind of non random segregation (Luner, 1958).

The correlation studies made in finger millet and other small millets along with other related crops are presented:

2.1.1 Ragi (Eleusine coracana Gaertn)

Mahadevappa and Ponnaiya (1963) revealed positive correlation between grain yield per plant and number of ear bearing tillers, number of fingers per plant and straw weight per plant. Similar correlations were recorded by Narasimha Rao and Pardasarathi (1968b). Patnaik (1968) showed moderate positive correlation of yield with number of fingers and finger length. Further, he found negative association of tiller number and number of fingers, finger length and seed size. Plant height was negatively correlated with grain density.

Mahadeswaran and Murageshan (1973)observed significant and positive correlation between grain yield and number of productive tillers.

Michael Raj et al. (1973) studied the correlation in white and brown seeded ragi types and observed high positive correlation between ear bearing tillers and grain yield in brown types, but in white grained types the correlation was low.

Dhagat et al. (1973) revealed that grain yield per plant was positively correlated with plant height and grain weight of main ear. The grain weight of main ear was positively correlated with length of main ear and days to maturity.

Significant negative correlation was reported by Goud and Laxmi (1977) among plant height, number of tillers and ear weight.

Subramanian et al. (1977) revealed a trend of highly significant positive correlation between yield and number of fingers per plant and number of productive tillers; 1000 grain weight had a small positive effect on yield.

Mochizuki et al. (1979) found positive significant relationship of yield with leaf length, leaf width, stem length and stem diameter.

Shanthappa (1980) observed in segregating generation that yield was positively correlated with number of productive tillers, harvest index and 500 grain weight.

Chaugale et al. (1982) found positive correlation of harvest index and biological yield (total dry matter) with grain yield.

Krishnasastry et al. (1982) noticed a significant positive correlation between shoot dry weight and yield. Average ear weight per unit area was significantly correlated with yield.

2.1.2 Foxtail millet (Setaria italica Beauv)

The study conducted by Kang (1936) revealed positive significant correlation betwen yield and straw weight, number of branches and 1000 grains weight. There was no significant correlation between yield and plant height, number of tillers and circumference of spike. But the results of investigation by Li et al. (1936) revealed significant correlation of plant height, length of panicle and kernel weight with yield.

Ratnaswamy and Ponnaiya (1963) recorded that number of productive tillers have closer relationship with grain yield as compared to plant height.

Sandhu et al. (1974) while working out the inter relationship between yield and yield components reported that yield was positively correlated with primary tillers per plant and plant height.

Chinnaswamaiah (1975) observed negative correlation between yield and length of panicle; correlation between grain yield and plant height, panicle emergence and number of internodes was not significant. Studies conducted by Dhagat et al. (1977) on character association and selection indices revealed that grain yield was positively correlated with 100 seed weight, grain weight of main ear and flag leaf area.

Positive significant association of yield with days to maturity, plant height, number of tillers, panicle length, panicle girth, grain density, panicle weight, straw yield, 1000-grain weight and harvest index was observed by Vishwanath (1978). Godawath (1980) observed correlation betwen number of ears per plant, 1000 grain weight and ear length with grain yield.

Wang and Han (1981) while studying correlation for various agronomic characters in the F_2 and F_3 of three hybrid combinations derived from six varieties, reported a highly significant correlation between yield per plant with panicle weight per plant and straw weight. The study conducted by Liu (1984) on 74 varieties revealed positive correlation between grain yield and growth period characteristics like plant height, maturity date, days from heading to maturity and number of nodes.

2.1.3 Pearl millet (Pennisetum typhoids S & H)

Narasimha Rao and Damodaran (1964) reported significant positive correlation between yield and height, weight of ear, thickness of panicle and thickness of 4th internode from the top.

Pokhriyal et al. (1976) showed direct positive effect of 1000 grain weight, leaf area and seed set with yield; he also observed negative correlation between seed size and days to flowering.

Singh and Prasad (1976) reported that number of days to flowering, leaf length, plant height, tiller number and stem girth were positively correlated with green fodder.

Raveendran and Appadurai (1984) showed that grains/unit - length of panicle, panicle length and productive tillers/plant were positively correlated with grain yield.

Kanjir and Patil (1986) in their studies with 6 F_1 of crosses between 4 inbred lines and 10 tester showed that tiller number had strongest correlation with yield.

2.1.4 Little millet (*Panicum miliare* Lamk.)

Abinash yadav and Srivastava (1976) observed positive correlation of grain yield with number of days to maturity, number of tillers per plant, number of panicle per plant, length of panicle and straw yield.

2.1.5 Common millet (*Panicum miliaceum* L.)

Saxena *et al*. (1979) observed correlation between yield and height, panicle length and test weight.

2.2 PATH CO-EFFICIENT ANALYSIS

It is seen that, very often, correlation values between yield and its components are misleading due to interrelationship existing between the components of yield. As a result, the direct contribution of each component to the yield and indirect effect of it through other components cannot be discerned from mear correlation studies. The path coefficient analysis suggested by Wright (1921) offers a solution to this problem. Frakes *et al*. (1961) have demonstrated the utility of path analysis in plant selection in case of alfa-alfa.This type of analysis helps in measuring the direct and indirect effect of one variable on others. The work on path analysis studies in small millets with special reference to finger millet is presented.

2.2.1 Ragi (Eleusine coracana Gaertn.)

Path co-efficient analysis in forty seven varieties by Chaudhari and Acharya (1969) indicated that number of productive tillers and grain weight of the main ear were the major components of seed yield. Mahudeswaran and Murugeshan (1973) opined from path-analysis in twenty lines that tiller number and plant height have direct effect on grain yield.

Appadurai et al. (1979) indicated that plant height influenced the grain yield indirectly through tillers; number of ear bearing tillers was the most important yield contributing factor.

Subramanian et al.(1977) reported that number of fingers per plant had the greatest influence on yield; plant height had a negative influence on yield.

Agalodia et al. (1979) showed that grain weight from the main inflorescence was the only character with a high positive direct effect on yield, other characters contributed indirectly through grain weight.

Path-coefficient analysis in F_2 and F_3 segregating generations by Shanthappa (1980) revealed that ear weight per plant and harvest index had high positive direct effect on yield.

Prabhakar and Prasad (1983) did path analysis in F_3 and F_4 populations from three intervarietal crosses and found that productive tillers and 1000 grain weight had the strongest direct effect on yield.

2.2.2 Foxtail millet (Setaria italica Beauv)

Dhagat et al. (1977) indicated that grain weight of main ear, 1000 grain weight, length of main ear and days to maturity had a negative direct effect.

Randhawa et al. (1978) found that heading date, tiller number, ear length, ear width and grain weight had direct effect on yield and direct selection for wider ears would give improvement in yield.

Vishwanatha (1978) showed that panicle weight had direct effect on yield followed by number of tillers and straw yield; while, plant height and panicle length exhibited negative direct effect.

Godawat (1980) revealed that 1000 grain weight and number of ears per plant were the major characters contributing towards yield.

2.2.3 Pearl millet (Pennisetum typhoids S & H)

Singh and Prasad (1976) showed days to flowering, leaf length and plant height have direct effect, while, tiller number and stem girth have indirect effect on yield.

Path-coefficient analysis of yield components in the 72 diverse lines showed that days to flower, total tiller number and number of leaves had a positive direct contribution to grain yield. While, plant height showed an indirect positive contribution through days to flower, total tiller number and number of leaves [Singh and Singh, 1976].

Ravindran and Appadurai (1984) showed that grains/unit length of panicle, panicle length and productive tillers/ plant contributed positive direct effect on grain yield.

2.2.4 Little millet (Panicum miliare Lamk)

Yadav and Srivastava (1976) showed that number of panicles per plant had the direct effect on grain yield, followed by 1000 grain weight, length of panicle and days to maturity.

A study of path analysis in 225 accessions of little millet germ plasm by Reddy et al. (1984) revealed straw weight as an important direct contributor of yield. Futher, plant height had a positive indirect effect through straw weight and tiller number per plant and a negative effect on yield through straw weight.

2.3 INHERITANCE OF QUALITATIVE CHARACTERS

Plant Pigmentation and grain colour

A knowledge of plant pigmentation is often reliable and easily pursued index to varietal classification and identification of true F_1S. An attempt is made here to review various aspects of pigmentation.

2.3.1 Anthocyanin Pigmentation

The pigmentation on parts of the plant are due to three groups of colouring substances, viz (i) anthocyanins, (ii) reddish brown and brown pigments and (iii) chlorophyll with their accompanying yellow pigments. The colour characters expressed by anthocyanin are most spectacular when the plants are in full grown stage but they generally loose colour as maturity advances: Whereeas, those of reddish brown, brown and grey pigments commence to develop from the later stage in growth and reach a full expression at maturity (Nagai, 1959).

A brief introduction about the chemical composition of anthocyanin pigments, their histological position and the pattern of their distribution over different plant parts in rice and sorghum have been reviewed, as similar information is lacking in finger millet.

2.3.1.1 Chemical Composition

Flavone and Flavonol compounds are the chief components of chromogenic substances which on reduction form anthocyanins and on oxidation form brown pigment (Nagai, 1959). Four kinds of anthocyanins viz. Cyanin (Cyanidin, 3,5, glucoside), Chrysanthemin (Cyanidin,3-glucosides), Kerocyanin (Cyanidine, 3 - rhamnoglucoside) and uliginosin (Nalvidin 3 - galactoside) occur in various species of rice (Nagai et al., 1960, 1962 and Mizushima et al., 1963).

2.3.1.2 Histological position

The anthocyanin pigment which occurs in the cell sap has generally been referred to as purple but its actual appearance to the naked eye, on different plant parts varies from various grades of purple, through scarlet, red, rosy red, bluish red, blue, dark blue to black. This appearence depends on (i) The position at which the pigment is localized in the anatomy of the plant part, (ii) the intensity of the pigment, and (iii) the depth of chlorophyll colour of the tissue in which it is present.

2.3.1.3 Pattern of distribution

The occurrence as well as distribution of anthocyanin pigmentation in the organs of the rice plant is variable and is a very striking feature of the crop. The plants range from fully green to fully pigmented in only one or more parts (Ghose et al., 1960).

2.3.2 Related Studies

Except for the studies of Shanthappa (1980) who reported that purple pigmentation was dominant over green in ragi, literature on the studies of inheritance of pigmentation is scanty, and hence studies on related crops is reviewed.

Dhulappanavar and Mensinkai (1970) suspected the pleiotropy between leaf sheath, ligule, leaf-blade and apiculous anthocyanin pigment in rice.

Dhulappanavar (1973) studied the inheritance of pigmentation in the leaf-axil of rice and observed three loci controlling the pigmentation. Dhulappanavar and Hiremath (1974) studied the inheritance of a few pigmented characters in rice and the study revealed that three duplicate complimentary factors involved in the inheritance of pigmentation in the coleoptile, sheath, internode, septum, axil and stigma. Dhulappanavar *et al*. (1975) reported that the occurrence of a pleiotropic complimentary gene for pigment in coleoptile, leaf-sheath, ligule, auricle and node in rice. It may be one of the basic genes for anthocyanin pigment and is designated as "A". The second inhibitory pleiotropic gene was identified for pigmentation on coleoptile, leaf-sheath, auricle, leaf tip and node.

Casady (1975) in his work on the inheritance of purple testa in sorghum cited that brown or purple colour to be controlled by a single pair of alleles, with brown as dominant.

Madhava rao and Kullaiswamy (1975) reported that yellow grain of *Pennisetum typhoids* was controlled by a single dominant gene.

Pavithran and Mohandas (1976) opined that ligule pigmentation in rice (Purple Vs Green) was controlled by three complimentary genes. Kadam (1976) observed six genes for the control of pigmentation and not three as originally proposed.

Thimmappaiah (1976) suggested that two duplicate genes controlled colour in ligule, auricle, node, septum, glumes, pericarp and leaf margin. Three complimentary duplicate genes controlled colour in the internode and junctura. Four duplicate genes controlled colour in leaf sheath and leaf tip.

Setty (1976) obtained a pleiotropic gene in rice, designated "pl" for colour at 16 parts of the plant. Yadav (1976) studies the inheritance of pigmentation in coleoptile of pearl millet and reported the presence of single dominant gene controlling the purple pigmentation.

Ilin et al. (1978) observed that four partially dominant genes control grain colour in Panicum miliaceum. Further, he explained that white grain colour was due to an inhibitor, the order of dominance was white > brown > grey > cream > red and gene was represented by the symbol IIbbCCgg (white grains, iiBBccgg (brown grains), iibbCCGG (grey grains), iibbCCgg (cream grains) and iibbccgg (red grains).

Khan and Srivastva (1978) worked out the inheritance of the stem pigmentation in panicum miliare found that presence of pigmentation was controlled by five complimentary genes.

Dhulappanavar (1979) revealed in rice the action of duplicate, complimentary, inhibitor and anti-inhibitor genes in controlling pigmentation of the ligule, auricle, junctura, node, nodal ring, internode, glume and lemma.

Kolhe and Bhat (1979) noted that anthocyanin colouration of leaf sheath, both external (Psa) and internal (Psa int), Stigma (Ps) apiculus (Ap) and internode (pin) were linked in that order in rice.

Jayaramaiah (1980) suggested two duplicate inhibitory genes and one anti-inhibitory gene controlling plant colour in sorghum.

Indi and Goud (1981) from their studies in six crosses of sorghum recorded a segregation of 3:1 in F_2 for red purple: tan indicating single gene inheritance.

Bhat et al. (1982) in their work on the inheritance of plant pigmentation in sorghum postulated that purple pigmentation was dominant over tan and was controlled by two sets of complimentary genes [pla plb and plc pld].

Goud and Kullaiswamy (1984) in sorghum detected one common gene for pigmentation in leaf sheath, ligule, auricle, junctura, node, internode, septum, glumes and pericarp and the gene was represented by the symbol PSh_1; the other duplicate gene designated PSh_2 found to have pleiotropic effect for purple colouratian on leaf-sheath, junctura and internode.

Ghorpade and Kadam (1985) studied six grain characters in songhum. Their study indicated three genes involved in the inheritance of hilum spot.

Swarnalata et al. (1987) reported that a gene controlled plant and glume pigmentation in sorgnum; purple plant was dominant to tan and red glume dominant to straw coloured glume.

2.4 HERITABILITY

Knowledge of heritability to a plant breeder is of immense use as it indicates the extent to which the improvement is possible through selection (Liang and Walter, 1968). The heritability is used to know the relative degree to which a character is transmitted from parent to off-spring. Highly heritable characters, associated with yield and influenced to a lesser degree by environment, serve as indicators of yield in a selection programme. Johanssen (1909) attributed the somatic variation in a segregating population to both heritable and non heritable agencies. The broad-sense heritability refers to the functioning of the whole genotype as a unit and is used in contrast with environmental effects. The narrow sense heritability largely includes only the average of genes transmitted additively from parent to progeny (Weber and Moorthy, 1952). The heritable variation was further divided into additive and non additive componenets and the latter portion includes additive, dominance and epistatic effects.

The response of a character to selection is determined by its heritability which in practice is computed as a ratio of genetic variation to the phenotypic variation. The additive component of the genetic variation is most important in obtaining true heritability values.

2.4.1 Ragi (*Eleusine coracana* G)

Kempanna and Thirumalachar (1968) reported high heritability for grain yield per plant.

Narasimha Rao and Pardasarathi (1968a) reported high heritability for plant height, panicle weight, panicle length, finger number per ear, and low for grain yield, stalk diameter, tiller number and panicle length. Patnaik (1968) reported high heritability for seed size, heading date, plant height; moderate values for finger length and yield; low for number of tillers, number of fingers and density of grain. Chaudhari and Acharya (1969) found higher heritability values for straw yield, plant height, number of fingers per ear, seed yield and length of main ear. Dhagat *et al*. (1973) reported high heritability for days to 50 per cent flowering, length of main ear, number of tillers and plant height ; medium values for grain weight and number of fingers; low for grain yield per plant and 1000 grain weight.

Setty *et al.* (1974) reported high estimates of heritability for grain yield. Other yield componenets,namely, days to heading, plant height, tiller number, number of leaves, number of fingers,finger length, number of spikelets, peduncle length had only moderate heritability.

Goud and Laxmi (1977) reported high heritability for the characters plant height and number of fingers. Tiller number had moderate heritability.

In an experiment conducted by Mahudeswaran and Murugeshan (1973), high heritability was observed for plant height, straw yield and 1000 grain weight.

Shanthappa (1980) reported from his studies involving two finger millet crosses, high heritability for plant height, straw weight and grain weight; medium for ear weight and number of tillers and low for other characters.

Goswami and Asthana (1984) reported high broad sense heritability for days to flowering and maturity.

Prabhakar and Prasad (1984) in an experiment conducted in the F_4 of 3 inter varietal crosses observed high heritability for grain yield.

2.4.2 Foxtail millet (*Setaria italica* Beauv)

Gian Singh (1966) recorded high heritability values for number of days to flowering, plant height and ear length.

While, ear girth showed relatively low heritability. Sandhu et al. (1974) reported high heritability estimates for grain yield, secondary tillers per plant and medium for primary tillers per plant, ear length, days to maturity and 1000 grain weight. Chinnaswamaiah (1975) reported moderate heritability for grain yield, tiller number and plant height.

Gill and Randhawa (1975) observed high heritability for days to heading, days to maturity, grain weight, plant height and tiller number; low for girth and grain yield. Vishwanath (1978) observed high heritability for days to 50 per cent flowering and days to maturity, moderate to low heritability for number of productive tillers, density of seeds and panicle length. Nagarajan and Prasad (1980) showed high heritability for straw yield, grains per branch, productive tillers and number of branches.

Wang and Han (1981) in the F_2 and F_3 of three hybrid combinations from six varieties estimated high heritability for days to heading, medium to low for panicle weight, stem weight, straw weight, panicle length and seed weight per plant. Rao et al. (1984) showed high heritability for plant height, branches/panicle, panicle length, straw yield and grain yield.

MATERIAL AND METHODS

III MATERIAL AND METHODS

3.1 MATERIAL

The experimental material for the present study consisted of three cultivars viz., WR 9, U 6 and Indaf 9. The varieties were obtained from the Project Co-ordinating Unit. Small Milletes Improvement Project, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore and the study was conducted at the G.K.V.K farm which is located at the latitude of $12^{o}15$ N, longitude of $77^{o}35$ E and altitude of 930 metres above MSL. The characteristics features of the cultivars used in the study are given in Table 1. The F_1, F_2 and F_3 generations of the following two crosses were studied.

1. WR 9 x U 6
2. WR 9 x Indaf 9

3.2 METHODS

3.2.1 Development of Experimental Material

Finger millet is a self-pollinated crop and the flowers are small. Hence, obtaining sufficient number of crossed seeds through hand emasculation and hand pollination is difficult. Therefore, contact method of hybridization was followed in the present study to get the required number of crossed seeds.

TABLE 1

SALIENT FEATURES OF THREE FINGER MILLET CULTIVARS UTILIZED IN CROSSING PROGRAMME

Cultivar	Pigmentation	days to 50% flowering	Plant height (cm)	No. of productive tillers	No. of fingers per ear	Length of finger (Cm)	Length of ear (Cm)	No. of grains/ Cm Length of finger	Grain yield/ per plant	Grain colour
WR 9	Green	62.0	89.2	4.6	7.6	3.7	4.94	71	12.20	White
U 6	Purple	65.0	102.6	3.4	6.0	5.4	6.64	60	12.08	Brown
Indaf 9	Purple	67.0	93.0	4.2	5.8	6.8	7.84	67.2	17.78	Brown

3.2.2 Contact Method of Hybridization

The ears of the pigmented male parent and the green female parent were brought together and finger to finger contacts were established by tying them together with a thread before anthesis. This method enhances the chances of out crossing by providing an opportunity for the pollen of male parent to come in close contact with the stigmatic surface of female parent. This has been one of the widely practiced methods in grass species including finger millet where floret size is too small for easy emasculation.

3.2.3 Production of Hybrids

All the three parents were grown in pots as well as in field during <u>Kharif</u> 1986. The male parent was sown at staggered intervals to achieve synchrony in flowering. WR 9 was used as female to cross with males U 6 and Indaf 9. F_1 Seeds were harvested on WR 9 plant, after maturity. These F_1 seeds were sown in nursery bed and the true F_1 plants showing purple pimentation were identified as purple is dominant over green. The true hybrids were transplanted in the main field. The F_1 plants were selfed. The seeds from F_1 plants were collected at maturity, dried and stored for raising F_2 generation. The F_2 seeds of each cross were raised in four plot of size 2M x 3M to get at least 1,000 population in each cross, along with their parents and F_1. A spacing of 25cm between rows and 5cm between plants were adopted.

Observations were recorded at different growth stages on one hundred random plants from each F_2 population. At maturity all the random 100 plants were harvested and threshed separately. For raising F_3 families. The F_3 families were sown on plant to row basis and all the observations recorded on F_2 generation were again recorded.

3.2.4 Crop Management

Out of the total recommended 40N:20 P_2O_5: $20K_2O$/acre dose of fertilizers, 50 per cent of N and the entire dose of P_2O_5 and K_2O were applied at the time of sowing. After 10 days of seedling excess seedlings were removed retaining one seedling at 5 cm interval within rows. Remaining 50 per cent of N was applied as top-dress 30 days after sowing. All the recommended agronomical practices were adopted as per the package of practices, U.A.S., Bangalore. The F_2 population was raised in summer 1987 under irrigated conditions. During *Kharif* 1987 F_3 population was raised under rainfed condition. The F_3 generation during *Kharif* 1987 received one protective irrigation at the later stage of crop growth owing to the failure of rains.

3.2.5 Recording of Data

One hundred plants from each F_2 segregating populations were randomly selected. In F_3, five plants in each progeny were selected randomly and observations were recorded in F_2 and F_3 on twelve traits. The characters chosen were plant pigmentation, days to 50 per cent flowering, plant height, number of productive tillers per plant, number of fingers per ear, length of finger, length of ear, grain colour, number of seeds per spikelet, number of seeds per cm length of finger, ear weight per plant and grain yield per plant. The methods adopted for recording the observation for each of the trait is given below:

3.2.5.1 Qualitative Characters

Plant Pigmentation and Grain Colour : In the present study plants were classified based on plant pigmentation as purple and green. Grain colour was recorded at maturity. The inheritance of plant pigmentation and grain colour was studied in the F_1's, 100 F_2 plants and their F_3 families of the two crosses.

3.2.5.2 Quantitative Characters

1. Days of 50% Flowering

   The number of days taken from sowing to 50% anthesis in the primary ear.

2. Plant height

   The plant height was measured in centimetre from the base of the plant to tip of ear.

3. Number of Productive Tillers Per Plant

   The number of ear bearing tillers were counted at the time of harvest.

4. Number of Finger Per Ear

Number of fingers on the main ear were counted at harvest

5. Finger length

Measured from the base of the finger to the tip of finger at maturity and expressed in centimetre.

6. Length of Ear

Length of the main ear was measured in centimetre.

7. Number of Seeds Per Spikelet

Mean number of seeds were counted by selecting twenty five spikelets from random ears from each plant.

8. Number of Seeds Per cm length of Finger

Number of grains present in one centimetre length of finger in the middle position in ear were counted.

9. Ear Weight Per Plant

All the ears in a plant were harvested and the total weight was recorded in grams after sun drying.

10. Grain Yield Per Plant

After threshing and cleaning, grain weight of each plant was taken and recorded in grams.

3.2.6 Statistical Analysis of Quantitative Characters

3.2.6.1 Estimation of Correlation Co-efficient

The phenotypic correlation co-efficients were determined for all possible combinations of characters for each populations by taking appropriate variances and co-variances. The calculation were made as per the formula suggested by All-Jibouri, Miller and Robinson (1958).

$$r_{P_{12}} = \frac{P_{12}}{\sqrt{P_{11}^2 \times P_{22}^2}}$$

where $r_{P_{12}}$ = Phenotypic correlation coefficient between X_1 and X_2

P_{12} = Phenotypic covariance between the character X_1 and X_2

P_{11} and P_{22} = Phenotypic variance of X_1 and X_2, respectively.

The significance of phenotypic correlation co-efficient was tested and compared with "t" value at n-2 df at five per cent and one per cent using Fisher and Yates (1963) table.

3.2.6.2 Path Co-efficients

Path co-efficient analysis was carried out for the segregating populations (F_2 and F_3 population) using the phenotypic correlation co-efficients to know the direct and indirect effects of the yield components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

In this particular instance, the path coefficients were obtained by the solution of P normal equations through the use of the following matrix method suggested by Singh and Choudhary (1979).

Correlations among all the variables were utilized to set up simultaneous equations.

1. $r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}P_{3y} + \ldots.. + r_{19}P_{9y}$

2. $r_{2y} = r_{12}P_{1y} + P_{2y} + r_{23}P_{3y} + \ldots.. + r_{29}P_{9y}$

3. $r_{3y} = r_{13}P_{1y} + r_{23}P_{2y} + P_{3y} + \ldots.. + r_{39}P_{9y}$

.
.
.

9. $r_{9y} = r_{19}P_{1y} + r_{29}P_{2y} + r_{39}P_{3y} + \ldots.. + P_{9y}$

10. $P_{xy}^2 = 1-(P_{1y}^2 + P_{2y}^2 + P_{3y}^2 + \ldots. + P_{9y}^2 + 2\ P_{19}r_{12}P_{2y} + 2\ P_{1y}r_{13}P_{3y} + \ldots + 2\ P_{1y}r_{19}P_{9y} + 2\ P_{2y}r_{23}P_{3y} + \ldots .. + 2\ P_{2y}r_{29}P_{9y} + 2\ P_{3y}r_{34}P_{9y} + \ldots .. + 2\ P_{3y}r_{39}P_{9y} + \ldots. + 2\ P_{8y}r_{89}P_{9y})$

where,

r_{iy} = Correlation between the ith variable and the yield, the dependent variable.

r_{ij} = Correlation between ith and jth variable

p_{iy} = Direct contribution of ith variable which in

9.5

P^2_{xy} = Residual effect

matrix form becomes.

$$
\begin{bmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ \vdots \\ r_{9y} \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{19} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{29} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{39} \\ \vdots \\ r_{91} & r_{92} & r_{93} & \cdots & r_{99} \end{bmatrix} \begin{bmatrix} P_{1y} \\ P_{2y} \\ P_{3y} \\ \vdots \\ P_{9y} \end{bmatrix}
$$

The equation can be written as A = BC, where, C is the vector of path co-efficients which represents the direct effects and can be derived by writing the above equation as:

$$C = B^{-1} A$$

The indirect effect through other characters was obtained by the product of direct effect and correlation between them. Finally a matrix of direct and indirect effects was constructed.

The residual effect was found out using the formula

$$R = 1 - P_{iy}\, r_{iy}$$

3.2.6.3 Statistical Analysis of Qualitative Characters

In 1900, Carl Pearson proposed X^2 (Chi-square) test. It is defined as the sum of deviation from observed to expected frequencies divided by expected and is given by the formula

$$= \frac{(O-E)^2}{E} \text{ with n-1 df}$$

where O = Observed frequencies

E = Expected frequencies

n = number of classes

The X^2 is a valuable tool to test goodness of fit of genetic ratios.

3.2.6.3.1 Inheritance of pigmentation and gran colour

1) F_2 Generation Analysis

The expected values corresponding to the observed values for each character was calculated based on expected ratio. The deviations were subjected to Chi-square test of significance.

2) Confirmation Through F_3 Analysis

All the one hundred F_2 plants observed were used and F_3 progenies were grown. The pigmentaion and grain colour were recorded. On the basis of segregation the F_3 progenies were classified as true breeding or segregating. The deviations were again subjected to X^2 test. The appropriate ratio for each character was determined only after confirmation in F_3 generation.

3.2.6.3.2 Joint Segregation Studies

For workingout the joint segregating ratios, the observations belonging to two characters under study viz., Plant pigmentation and grain colour were grouped.

The Chi-squre test was also employed for testing the association of characters i.e., to test the independent assortment of genes and the linkage.

3.2.6.4 Heritability

Several techniques have been used to calculate heritabilities. Lush (1940) described a method for computing narrow-sense estimates based on the regression (b) of F_3 progeny means on F_2 individual. The narrow-sense heritabilities were calculated in standard unit heritabilities as suggested by Frey and Horner (1957). As per this method, regressions were calculated on data coded in terms of standard deviation units to reduce the effect of any season genotype interaction. Finally to avoid over estimating heritability, regardless of inbreeding or breeding system, Smith and Kinman (1965) suggested co-efficients for various parent off-spring relationship under continuous self pollination. This estimate provides an automatic adjustment for known degree of inbreeding (selfing) and the consequent genetic correlation between parent and off-spring.

$$h^2 (F_2,F_3) = 2/3\ b(F_3,F_2)$$

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

4.1 CORRELATION CO-EFFICIENTS

Phenotypic correlation coefficients for all pairs of traits were worked out separately for both the crosses in F_2 and F_3 segregating populations and the results are presented in table 2 to 5.

4.1.1 F_2 population (WR 9 x U 6)

1) Days to 50% flowering

This character showed significant positive association with number of productive tillers per plant alone and none of the other characters showed any association with this character (Table 2).

2) Plant height

The trait did not show any positive significant association with any of the components of yield studied. However, it was significantly associated negatively with number of grains per Cm length of finger.

3) Number of productive tillers per plant

Number of productive tillers/plant was found to have significant positive association with days to 50% flowering, number of fingers per ear, number of grains per cm length, ear weight per plant and and grain yield per plant.

TABLE 2

PHENOTYPIC CORRELATION CO-EFFICIENTS BETWEEN YIELD AND YIELD COMPONENTS IN F_2 OF THE CROSS WR 9 X U6

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1.0000	0.0152	0.357**	0.0833	0.1900	-0.0106	0.0899	0.0284	0.466	0.0309
X_2		1.0000	-0.0680	0.0442	0..1977	0.1864	-0.1028	-0.3535**	0.0120	0.0035
X_3			1.0000	0.2809**	0.1769	0.1058	0.0867	0.2545**	0.8761**	0.8663**
X_4				1.0000	0.1900	0.0437	-0.1975	0.0342	0.3020**	0.2895**
X_5					1.0000	0.6433**	0.1624	-0.0604	0.2269*	0.2199*
X_6						1.0000	0.1945	-0.1327	0.1464	0.1546
X_7							1.0000	0.2779**	0.1852	0.1883
X_8								1.0000	0.2911**	0.2885**
X_9									1.0000	0.9958**
X_{10}										1.0000

* Significant at 5% level

** Significant at 1% level

X_1 = days of 50% flowering

X_2 = plant height

X_3 = number of productive tillers/plant

X_4 = No. of fingers/ear

X_5 = length of finger

X_6 = length of ear

X_7 = No. of grains per spikelet

X_8 = No. of grains per Cm length of finger

X_9 = ear weight/plant

X_{10} = grain yield/plant

4) Number of fingers/ear

Number of fingers/ear showed significant positive association with productive tillers, ear weight per plant and grain yield per plant.

5) Length of finger

It exhibited a high positive significant association with length of ear and its relationship was also found to be significant with ear weight per plant and grain yield per plant.

6) Length of ear

Except with length of finger which was positively significant, this character did not show association with any of the yield components studied.

7) Number of grains per spikelet

This trait showed positive significant association with number grains per Cm length of finger. However, its relation with other characters was not signifincant.

8) Number of grains per Cm length of finger

This character expressed significant positive association with number of productive tiller/plant, number of grains per spikelet, ear weight per plant and grain yield per plant and it had negative significant association with plant height.

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9) Ear Weight per plant

It exhibited a very high significant positive assoication with number of productive tillers per plant, number of fingers, number of grains per cm length of finger and grain yield per plant. Its association with length of finger was positively significant.

10) Grain yield per plant

Grain yield per plant was found to have a highly significant positive association with number of productive tillers per plant (0.8663), number of fingers per ear (0.2895), number of grains per cm length of finger (0.2885) and ear weight per plant (0.9958). It had positive significant association with length of finger (0.2199).

4.1.2 F_2 Population (WR 9 x Indaf 9)

1) Days to 50% flowering

It had no significant relationship with any of the yield components studied (Table 3).

2) Plant height

It exhibited a positive significant association with length of finger, length of ear and a negative association with number of grains per cm length of finger.

3) Number of Productive tillers per plant

This character showed highly significant positive

TABLE 3

PHENOTYPIC CORRELATION CO-EFFICIENTS BETWEEN YIELD AND YIELD COMPONENTS IN F_2 OF THE CROSS WR 9 X INDAF 9

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1.0000	0.0703	-0.1329	0.1484	-0.0042	-0.0535	-0.0315	-0.1096	-0.0945	-0.0899
X_2		1.0000	-0.0473	0.1178	0.5081**	0.4812**	0.1115	-0.2453*	0.0814	0.0758
X_3			1.0000	0.1037	-0.586	-0.0207	0.1183	0.0863	0.7960**	0.7877**
X_4				1.0000	-0.0012	0.1657	-0.0879	-0.0690	0.2088*	0.2404*
X_5					1.0000	0.6128**	0.2830**	-0.3151**	0.0388	0.0135
X_6						1.0000	0.1269	-0.1334	0.1097	0.1304
X_7							1.0000	0.4302**	0.2441*	0.2112*
X_8								1.0000	0.2594**	0.2602**
X_9									1.0000	0.9805**
X_{10}										1.0000

* Significant at 5% level

** Significant at 1% level

X_1 = days of 50% flowering

X_2 = plant height

X_3 = number of productive tillers/plant

X_4 = No. of fingers/ear

X_5 = length of finger

X_6 = length of ear

X_7 = No. of grains per spikelet

X_8 = No. of grains per Cm length of finger

X_9 = ear weight/plant

X_{10} = grain yield/plant

correlations with ear weight per plant and grain yield per plant. Its relationship with other characters was not significant.

4) <u>Number of fingers per ear</u>

The association between number of fingers per ear and ear weight per plant, grain yield per plant was significant.

5) <u>Length of finger</u>

It expressed significant positive relationship with plant height, length of ear and number of grains per spikelet. But, it had a negative significant association with number of grains per Cm length of finger.

6) <u>Length of ear</u>

This character was found to have a high positive significant association with plant height and length of finger.

7) <u>Number of grains per spikelet</u>

It showed significant positive association with length of finger and number of grains per Cm length of finger. It had also expressed significant association with ear weight per plant and grain yield per plant.

8) Number of grains per Cm length of finger

Number of grains per spikelet, ear weight per plant and grain yield per plant were found to have a high positive significant association with number of grains per cm length of finger. However a negative correlation was recorded with plant height and length of finger.

9) Ear weight per plant

Ear weight per plant showed positive correlation with number of productive tillers per plant, number of fingers per ear, number of grains per spikelet, number of grains per Cm length of finger and grain yield per plant.

10) Grain yield per plant

The correlation co-efficient between grain yield per plant with ear weight per plant almost reached unity (0.9805). The grain yield per plant had positive significant association with number of productive tillers per plant (0.7877) and its relation was found to be significant with number of fingers per ear (0.2404), number of grains per spikelet (0.2112) and number of grains per Cm length of finger (0.2602).

4.1.3 F_3 Population (WR 9 x U 6)

1) Days to 50% flowering

This chracter showed significant positive association with ear weight per plant and grain yield per plant. Its relationship with other characters was not significant (Table 4).

2) Plant height

This chracter was found to be significantly associated with number of productive tillers per plant,length of finger, length of ear and ear weight per plant.

3) Number of Productive tillers per plant

Significant positive correlation was observed between this trait and ear weight per plant and grain yield per plant. This character was also found to be significantly associated with plant height.

4) Number of fingers per ear

It exhibited a high positive association with ear weight per plant and grain yield per plant. In contrast, it was found to have a significant negative relationship with length of finger.

5) Length of finger

This character expressed significant positive association with plant height and length of ear. Its correla-

TABLE 4

PHENOTYPIC CORRELATION COEFFICIENTS BETWEEN YIELD AND YIELD COMPONENTS IN F_3 POPULATION OF THE CROSS WR 9 X U 6

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1.0000	0.1666	0.1695	0.0597	-0.0012	-0.0294	0.1915	0.0633	0.3093**	0.2839**
X_2		1.0000	0.2827*	-0.0164	0.2126*	0.2195*	-0.1292	-0.0799	0.2386*	0.1728
X_3			1.0000	0.1680	-0.0260	-0.0068	0.0122	0.0886	0.5072**	0.4814**
X_4				1.0000	-0.2983**	-0.1622	-0.1842	-0.1015	0.3215**	0.3080**
X_5					1.0000	0.8591**	0.0859	-0.0289	0.1749	0.1647
X_6						1.0000	-0.0115	-0.1204	0.1689	0.1530
X_7							1.0000	0.7710**	0.3358**	0.3337**
X_8								1.0000	0.3483**	0.3236**
X_9									1.0000	0.9734**
X_{10}										1.0000

* Significant at 5% level

** Significant at 1% level

X_1 = days of 50% flowering

X_2 = plant height

X_3 = number of productive tillers/plant

X_4 = No. of fingers/ear

X_5 = length of finger

X_6 = length of ear

X_7 = No. of grains per spikelet

X_8 = No. of grains per Cm length of finger

X_9 = ear weight/plant

X_{10} = grain yield/plant

tion coefficant almost reached unity in case of length of ear (0.8591). But, it had negative association with number of finger per ear.

6) Length of ear

This was found to have a very high positive significant relationship with length of fingers (0.8591) and its relationship with plant height was also found to be significant.

7) Number of grains per spikelet

This character expressed a high positive significant relationship with number of grains per Cm length of finger, ear weight per plant and grain yield per plant.

8) Number of grains per Cm length of finger

A similar trend of relationship between this character and other yield components as in the case of number of grains per spikelet was observed. This character had a high significant positive relationship with number of grains per spikelet , ear weight per plant and grain yield per plant.

9) Ear weight per plant

This trait had significant association with days to 50% flowering, plant height, number of productive tillers/ plant, number of grains per spikelet, number of grains per Cm length of finger and grain yield per plant which was similar to the association between grain yield and other traits.

10) Grain yield per plant

Grain yield per plant was found to be significantly associated with days to 50% flowering (0.2889), productive tillers/plant (0.4814), number of fingers per ear (0.3080), number of grains per spikelet (0.3337) number of grains per Cm length of finger (0.3236) and ear weight per plant (0.9734).

4.1.4 F_3 Population (WR 9 x Indaf 9)

1) Days to 50% flowering

This character showed positive significant association with ear weight per plant and grain yield per plant. Its relationship with other characters was not significant (Table 5).

2) Plant height

It had a positive significant association with length of finger, length of ear, ear weight per plant and grain yield per plant.

3) Number of productive tillers per plant

This character expressed significant and positive association with plant height, ear weight per plant and grain yield per plant. But its relationship with number

TABLE 5

PHENOTYPIC CORRELATION COEFFICIENTS BETWEEN YIELD AND YIELD COMPONENTS IN F_3 POPULATION IN THE CROSS WR 9 X INDAF 9

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1.0000	0.0661	0.0661	0.1134	0.0862	0.1698	0.1213	0.1181	0.2448*	0.2196*
X_2		1.0000	0.2520*	-0.1859	0.2888**	0.3737**	0.0110	-0.0513	0.3009**	0.3172**
X_3			1.0000	-0.3142**	0.1752	0.1340	-0.0572	0.0339	0.5140**	0.4641**
X_4				1.0000	-0.0618	-0.3196**	0.1135	0.1075	0.2177*	0.2449*
X_5					1.0000	0.8251**	-0.0473	-0.1450	0.4146**	0.4470**
X_6						1.0000	-0.0327	-0.1904	0.3604**	0.3847**
X_7							1.0000	0.7268**	0.2593*	0.2744**
X_8								1.0000	0.3345**	0.3106**
X_9									1.0000	0.9378**
X_{10}										1.0000

* Significant at 5% level

** Significant at 1% level

X_1 = days of 50% flowering

X_2 = plant height

X_3 = number of productive tillers/plant

X_4 = No. of fingers/ear

X_5 = length of finger

X_6 = length of ear

X_7 = No. of grains per spikelet

X_8 = No. of grains per Cm length of finger

X_9 = ear weight/plant

X_{10} = grain yield/plant

of fingers/ear was negative and significant.

4) Number of fingers per ear

It showed a significant positive association with ear weight per plant and grain yield per plant, whereas it was found to possess a negative relationship with number of productive tillers per plant and length of ear.

5) Length of finger

Plant height, length of ear, ear weight per plant and grain yield per plant were found to be positively correlated with length of finger.

6) Length of ear

It expressed a positive association with plant height, length of finger, ear weight per plant and grain yield per plant. But, it had a negative association with number of fingers.

7) Number of grains per spikelet

This character showed significant positive association with number of grains per Cm length of finger, ear weight per plant and grain yield per plant.

8) Number of grains per Cm length of finger

It showed a significant positive association with number of grains per spikelet, ear weight per plant and grain yield per plant.

9) Ear weight per plant

This character expressed a high positive relationship with all the characters studied viz., days to 50% flowering, plant height, number of productive tillers/plant, number of fingers per ear, length of finger, length of ear, number of grains per spikelet, number of grains per Cm length of finger and grain yield per plant.

10) Grain yield per plant

The correlation co-efficient between grain yield per plant and ear weight per plant almost reached unity (0.9378). Grain yield/plant had positively associated with days to 50% flowering (0.2196), plant height (0.3172), number of productive tiller per plant (0.4641), number of fingers per ear (0.2449), length of finger (0.4470), length of ear (0.3847), number of grains per spikelet (0.2744) and number of grains per Cm length of finger (0.3106).In magnitude as well as in direction of its assocaition with other characters,this character resembles ear weight per plant.

4.2 PATH CO-EFFICIENT ANALYSIS

Path co-efficient analysis was worked out to partition the correlation Co-efficients into direct and indirect causes. In the present study direct and indrect effect of nine traits viz., days to 50% flowering, plant height, number of productive tillers per plant,number of fingers per ear, length of finger, length of ear, number of grains per spikelet, number of grains per Cm length of finger, ear weight per plant with grain yield per plant were worked out using F_2 and F_3 generation of both the crosses separately. For both generations in each cross path co-efficient results are presented in Table 6, 7, 8 and 9, and Figures from 1 to 4.

I. F_2 Population (WR 9 x U 6)

1) Days to 50% flowering Vs grain yield per plant

This character had no significant association with yield. This is mainly due to its low direct negative effect and very low positive and negative effects through other characters (Table 6 and Figure 1).

2) Plant height Vs grain yield per plant

This character neither showed any significant direct effect nor indirect effect on yield resulting in its low association with yield.

3) Number of productive tillers per plant Vs grain yield per plant

Though number of productive tillers per plant showed a highly significant positive correlation with yield, its direct effect was negative and low. The indrect effect

TABLE 6

PATH CO-EFFICIENT ANALYSIS OF GRAIN YIELD V/S NINE YIELD COMPONENETS IN F_2 POPULATION OF THE CROSS WR 9 X U 6

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Phenotypic correlation with yield
X_1	-0.01193	-0.00022	-0.00161	-0.00078	-0.00248	-0.00019	-0.00026	-0.00015	0.04853	0.03091
X_2	-0.00018	-0.01440	0.00307	-0.00041	-0.00258	0.00339	0.00029	0.00182	0.01249	0.00349
X_3	-0.00043	0.00097	-0.04517	-0.00263	-0.00231	0.00192	-0.00025	-0.00131	0.91551	0.86630
X_4	-0.00099	-0.00064	-0.01269	-0.00940	-0.00248	0.00079	0.00057	-0.00018	0.31450	0.28948
X_5	0.00227	-0.00284	-0.00799	-0.00178	-0.01305	0.01171	-0.00047	0.00031	0.23630	0.21992
X_6	0.00013	-0.00268	-0.00478	-0.00041	-0.00841	0.01817	-0.00056	0.00068	0.15246	0.15460
X_7	-0.00107	0.00148	-0.00391	0.00186	-0.00212	0.00353	-0.00289	-0.00143	0.19287	0.18832
X_8	-0.00034	0.00509	-0.01150	-0.00032	0.00079	-0.00241	-0.00080	-0.00520	0.30316	0.28847
X_9	-0.00056	-0.00017	-0.03971	-0.00284	-0.00296	0.00266	-0.00054	-0.00150	1.04142	0.99580

Residual = 0.007323

X_1 = days to 50% flowering

X_2 = plant height

X_3 = number of productive tillers/plant

X_4 = No. of fingers/ear

X_5 = length of finger

X_6 = length of ear

X_7 = No. of grains per spikelet

X_8 = No. of grains per Cm length of finger

X_9 = ear weight/plant

X_{10} = grain yield/plant

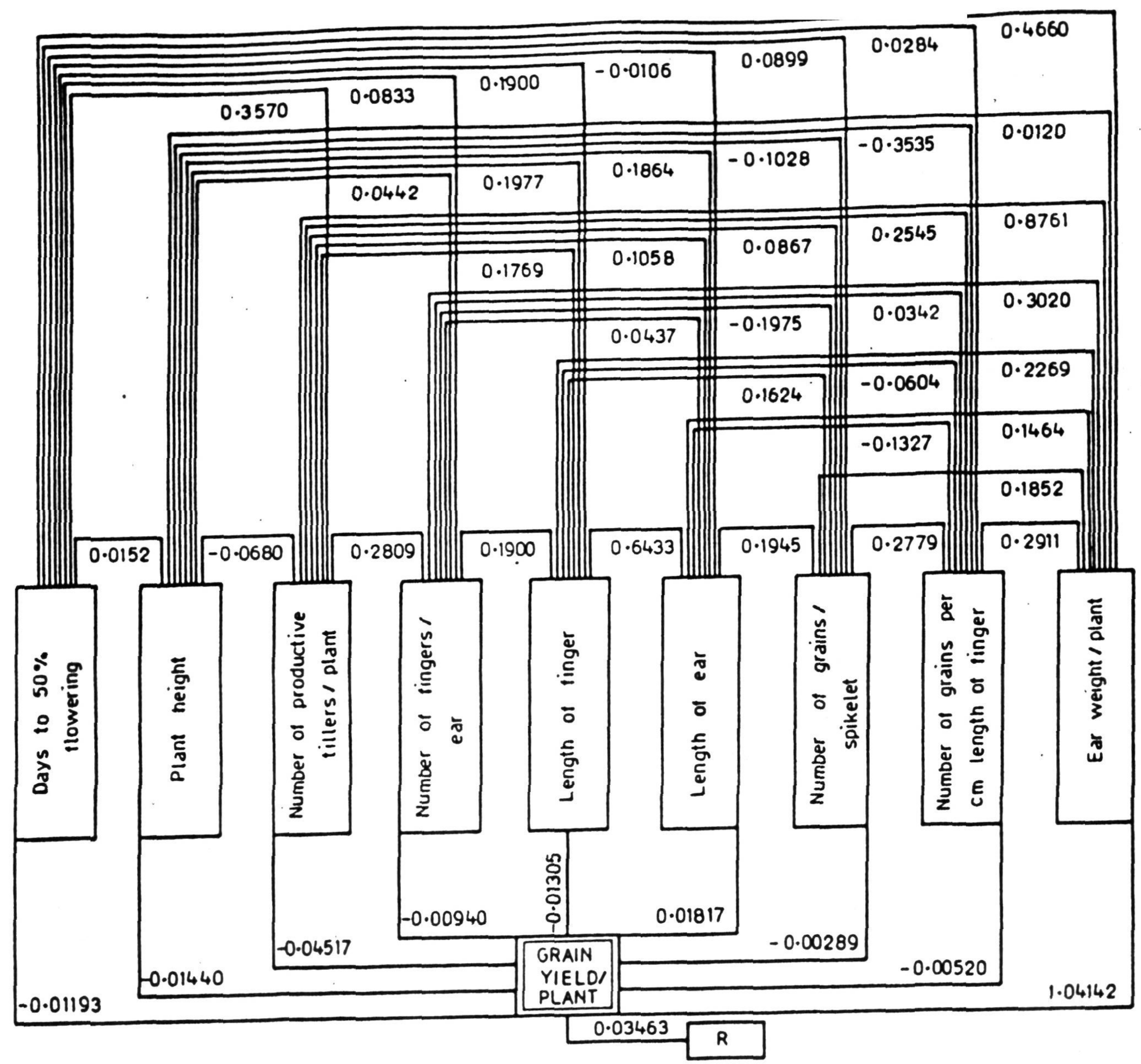

FIG.1 : PHENOTYPIC PATH DIAGRAM OF THE INFLUENCE OF NINE CHARACTERS ON GRAIN YIELD IN F_2 POPULATION OF CROSS WR 9 × U 6

through ear weight per plant is the main cause for its highly significant association with yield.

4) Number of finguers per ear Vs grain yield per plant.

The moderate positive association of this character is mainly due to its indirect effect through ear weight per plant as its direct effect was negative and very low.

5) Length of finger Vs grain yield per plant

The cause and effect of this character almost followed the same line as that of number of fingers per ear.

6) Length of ear Vs grain yield per plant

The low association of this character with grain yield per plant is due to its low direct effect and a similar low indirect effect through ear weight per plant.

7) Number of grains per spikelet Vs grain yield per plant

Number of grains per spikelet followed a similar trend in direct and indirect effect, as that of length of ear with only difference of a low negative direct effect of number of grains per spikelet as compared to a low positive direct effect of length of ear.

8) Number of grains per Cm length of finger Vs grain yield per plant

This followed a similar trend as in case of number of grains per spikelet. Its low association with yield was due to its very low direct negative effect and a low positive indirect cause through ear weight per plant.

9) Ear weight per plant Vs Grain yield per plant

A highly significant association of this character with grain yield per plant mainly comes from its direct association than its indirect effect through any of the components studied.

4.2.2 F_2 population WR 9 x Indaf 9

1) Days to 50% flowering Vs grain yield per plant

Days to 50% flowering had a very low insignificant negative association with yield. Neither it had any significant direct effect or indirect effect through any other characters on yield (Table 7 and Figure 2).

2) Plant height Vs grain yield per plant

Plant height had a similar, cause and effect as observed in case of days to 50% flowering and yield.

3) Number of productive tillers per plant Vs grain yield per plant

Number of productive tillers had a low direct effect (0.03495) on yield but its indirect effect through ear weight per plant (0.75087) was very high resulting in a very high correlation between number of productive tillers per plant and grain yield per plant.

TABLE 7

PATH COEFFICIENT ANALYSIS OF GRAIN YIELD V/S NINE YIELD COMPONENETS IN F_2 POPULATION OF THE CROSS WR 9 X INDAF 9

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Phenotypic correlation with yield
X_1	0.00380	-0.00028	-0.00464	0.00456	0.00012	-0.00261	0.00088	-0.00258	-0.08891	-0.08966
X_2	0.00027	-0.00405	0.00165	0.00362	-0.01461	0.02106	-0.00314	-0.00579	0.07678	0.07578
X_3	-0.00050	-0.00019	0.03495	0.00319	0.01685	-0.00101	-0.00333	0.00203	0.75087	0.78769
X_4	0.00056	-0.00048	0.00362	0.0307	0.00013	0.00809	0.00247	-0.00163	0.19696	0.24032
X_5	-0.00002	-0.00206	-0.00205	0.00004	-0.02875	0.02992	-0.00796	-0.00743	0.03188	0.01357
X_6	0.00020	-0.00175	-0.00072	0.00509	-0.01762	0.04883	-0.00357	-0.00314	0.10348	0.13040
X_7	-0.00012	-0.00045	0.00413	-0.00270	-0.00814	0.00620	-0.02812	0.01014	0.23026	0.21120
X_8	-0.00042	0.00099	0.00302	-0.00212	0.00906	-0.00651	-0.01210	0.02358	0.24469	0.26019
X_9	-0.00036	-0.00033	0.02782	0.00642	-0.00097	0.00536	-0.00687	0.00612	0.94331	0.9805

Residual = 0.03468

X_1 = days to 50% flowering

X_2 = plant height

X_3 = number of productive tillers/plant

X_4 = No. of fingers/ear

X_5 = length of finger

X_6 = length of ear

X_7 = No. of grains per spikelet

X_8 = No. of grains per Cm length of finger

X_9 = ear weight/plant

X_{10} = grain yield/plant

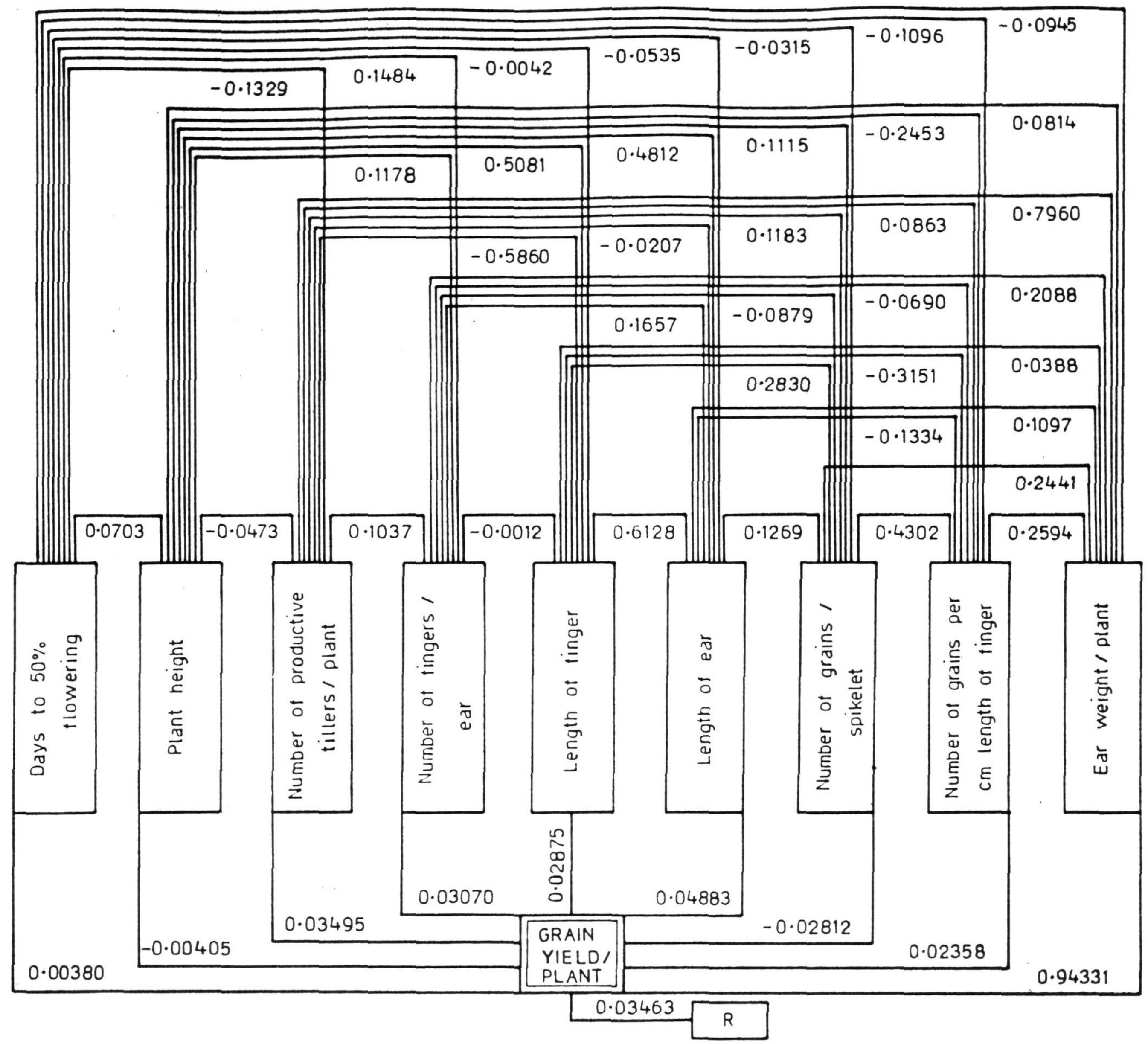

FIG. 2 : PHENOTYPIC PATH DIAGRAM OF THE INFLUENCE OF NINE CHARACTERS ON GRAIN YIELD IN F_2 POPULATION OF CROSS WR 9 × INDAF 9

4) Number of fingers per ear Vs grain yield per plant

The association between number of fingers per ear and grain yield per plant was moderate (0.24032). The cause for such an association was due to its indirect-effect through ear weight per plant and not due to its direct effect (0.0304) or its indirect effect through other characters.

5) Length of finger Vs grain yield per plant

Neither the correlation between length of fingers and grain yield per plant nor the direct or indirect contribution of length of finger through other characters was of any significance.

6) Length of ear Vs grain yield per plant

Length of ear followed a similar trend in its association and contribution to grain yield as seen between length of finger and grain yield.

7) Number of grains per spikelet Vs grain yield per plant

The low correlation (0.21120) observed between number of grains per spikelet and ear weight per plant was mainly due to the indirect contribution of number of grains per spikelet through ear weight per plant (0.23026) and not due to its direct or indirect effects through any other components.

8) Number of grains per Cm length of finger vs grain yield per plant

A similar trend of association and contribution was noticed for this character as seen between number of grain per spikelet with grain yield per plant.

9) Ear weight per plant Vs grain yield per plant

The correlation between these two traits was positive and very high (0.9805). This is the reflection of its high direct positive influence on grain yield (0.94331). Its indirect effect through other characters was negligible.

4.2.3 F_3 generation (WR 9 x U 6)

1) Days to 50% flowering Vs grain yield per plant

Days to 50% flowering had no direct effect on yield. However, it had an indirect effect only through ear weight per plant (0.31453). This indirect effect was the main cause for a moderate association of days to 50% flowering with grain yield per plant (Table 8 and Figure 3).

2) Plant height Vs Grain yield per plant

The plant height had a very low negative direct effect on yield. The indirect effect of other characters except ear weight per plant was also low resulting in a low correlation of plant height with grain yield per plant.

TABLE 8

PATH CO-EFFICIENT ANALYSIS OF GRAIN YIELD V/S NINE YIELD COMPONENTS IN F_3 OF THE CROSS WR 9 X U 6

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Phenotypic correlation with yield
X_1	-0.02119	-0.01051	-0.00074	-0.00113	-0.00002	0.00081	0.00618	-0.00403	0.31453	0.28391
X_2	-0.00353	-0.06313	-0.00123	0.00031	0.00287	-0.00604	-0.00417	0.00508	0.24263	0.17274
X_3	-0.00359	-0.01785	-0.00436	-0.00318	-0.00035	0.00019	0.00039	-0.00564	0.51578	0.48139
X_4	-0.00126	0.00103	-0.00073	-0.01893	-0.00403	0.00446	-0.00594	0.00645	0.32694	0.30799
X_5	0.00002	-0.01342	0.00011	0.00564	0.01350	-0.02364	0.00277	0.00184	0.17786	0.16468
X_6	0.00062	-0.01386	0.00003	0.00307	0.01160	-0.02751	-0.00037	0.00766	0.17175	0.15299
X_7	-0.00405	0.00815	-0.00005	0.00349	0.00116	0.00032	0.03227	0.04907	0.34148	0.33370
X_8	-0.00134	0.00504	-0.00039	0.00192	-0.00039	0.00331	0.02488	-0.06364	0.35419	0.32358
X_9	-0.00655	-0.01506	-0.00221	-0.00608	0.00236	-0.00465	0.01084	-0.02216	1.01692	0.97341

Residual = 0.046786

X_1 = days to 50% flowering

X_2 = plant height

X_3 = number of productive tillers/plant

X_4 = No. of fingers/ear

X_5 = length of finger

X_6 = length of ear

X_7 = No. of grains per spikelet

X_8 = No. of grains per Cm length of finger

X_9 = ear weight/plant

X_{10} = grain yield/plant

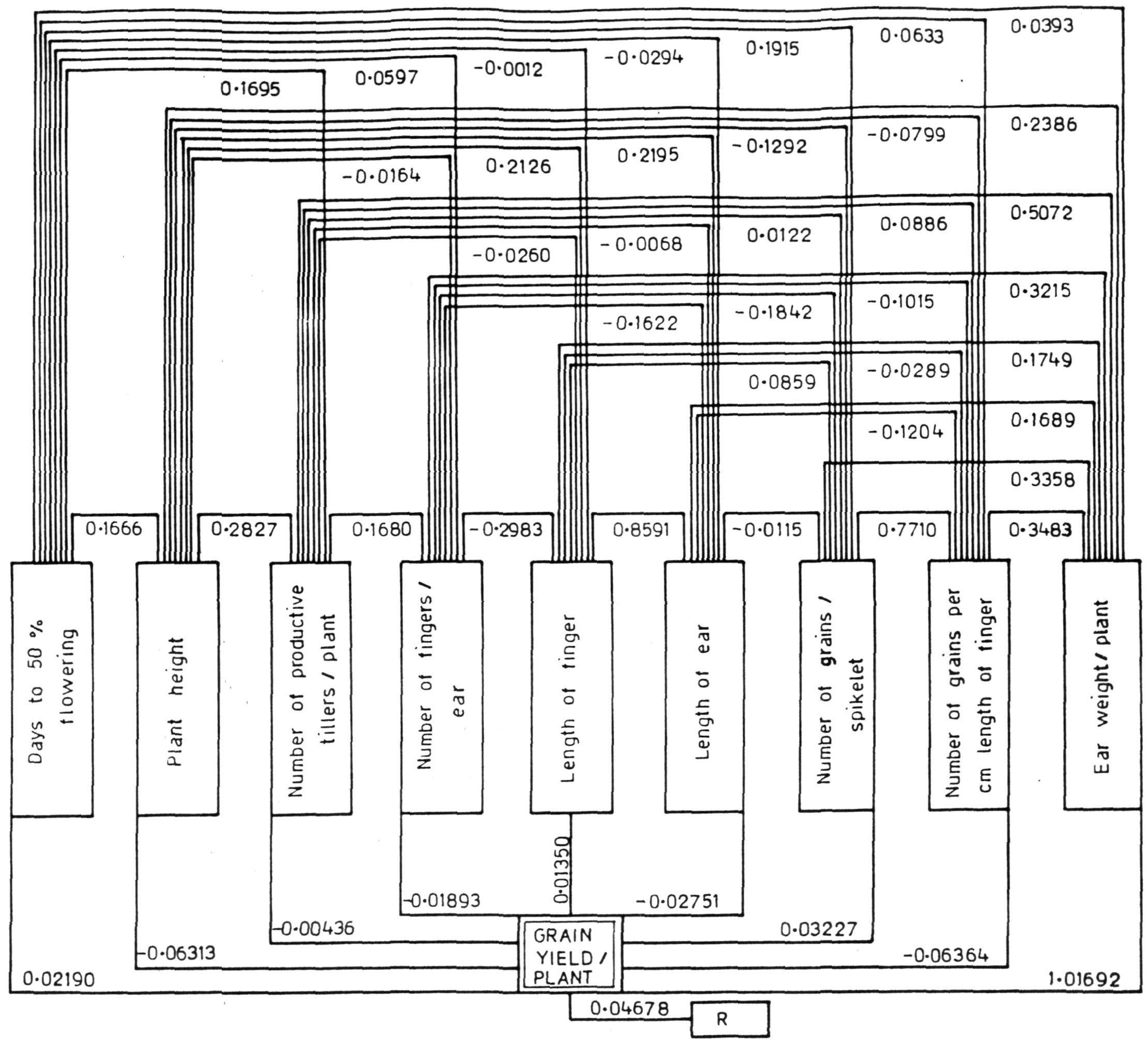

FIG.3 : PHENOTYPIC PATH DIAGRAM OF THE INFLUENCE OF NINE CHARACTERS ON GRAIN YIELD IN F_3 POPULATION OF CROSS WR 9 × U 6

3) Number of productive tillers per plant Vs grain yield per plant

A fairly high correlation (0.48189) between number of productive tillers per plant and grain yield per plant was mainly due to a fairly high (0.51578) indirect effect of productive tillers through ear weight per plant. The direct effect of productive tillers and the indirect effect through other characters was very low.

4) Number of fingers per ear Vs grain yield per plant

The character number of finger per ear had a very low negative direct effect (-0.01893) and a very low indirect effect through other characters except ear weight per plant. The moderate association (0.30799) between this character and yield was mainly due to its indirect effect through ear weight per plant.

5) Length of finger Vs Grain yield per plant

The length of finger had either a direct effect (0.01350) nor an indirect effect through other characters on grain yield per plant.

6) Length of ear Vs grain yield per plant

A similar cause and effect as existed between length of finger and grain yield per plant was also observed between length of ear and grain yield per plant.

7) Number of grains per spikelet Vs grain yield per plant

A fairly moderate association (0.33370) recorded between number of grain per spikelet with grain yield per plant was mainly due to an indirect effect of ear weight per plant (0.34148) and not due to either the direct effect of number of grains per spikelet or its indirect effect through other characters.

8) Number of grains per Cm length of finger Vs grain yield per plant

The number of grains per Cm length finger had a very low negative (-0.06364) effect on grain yield per plant. It had a very low indirect effect through other characters. Its moderate correlation (0.32358) with yield was mainly due to its moderate indirect effect through ear weight per plant.

9) Ear weight per plant Vs grain yield per plant

Ear weight per plant expressed a high positive direct effect (1.01692) which was responsible for its very high correlation with yield (0.97341). Its indirect effects were negative through most of the other characters studied.

4.2.4 F_3 Population (WR 9 x Indaf 9)

1) Days to 50% flowering Vs grain yield per plant

The direct effect of days to 50% flowering on grain yield per plant was low (0.00458). The indirect effect of days to 50% flowering through other characters was also low except ear weight per plant (0.20521). The main indirect contributing factor for correlation (0.21960) between days to 50% flowering and grain yield per plant was ear weight per plant (Table 9 and Figure 4).

2) Plant height Vs grain yield per plant

A fairly moderate correlation (0.31720) recorded between plant height and grain yield per plant was due to a low direct effect of plant height (0.04428) and its indirect effect through ear weight per plant.

3) Number of productive tillers per plant Vs grain yield per plant

The number of productive tiller per plant had a low direct effect (0.03613) and a fairly moderate indirect effect (0.43088) through ear weight per plant on yield. The other characters had no indirect effect.

4) Number of fingers per ear Vs grain yield per plant

The correlation of 0.24490 estimated between number of fingers per ear and grain yield was mainly due to a low direct effect (0.08240) of number of fingers per ear and its indirect effect through ear weight per plant

TABLE 9

PATH CO-EFFICIENT ANALYSIS OF GRAIN YIELD V/S NINE YIELD COMPONENTS IN F_3 POPULATION OF THE CROSS WR 9 X INDOF 9

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Phenotypic correlation with yield
X_1	0.00458	0.00292	0.00220	-0.00934	0.00720	0.00064	0.00709	-0.00092	0.20521	0.21960
X_2	0.00030	0.04428	0.00911	-0.01532	0.02413	0.00142	0.00064	0.00040	0.25224	0.31720
X_3	0.00028	0.01160	0.03613	-0.02590	0.01464	0.00051	-0.00334	-0.00026	0.43088	0.46410
X_4	-0.00052	-0.00823	-0.01135	0.08240	-0.00517	-0.00053	0.00663	-0.00084	0.18250	0.24490
X_5	0.00039	0.01278	0.00633	-0.00510	0.08354	0.00311	-0.00277	0.00113	0.34756	0.44690
X_6	0.00078	0.01654	0.00484	-0.01150	0.06855	0.00379	-0.00191	0.00149	0.30212	0.38470
X_7	0.00055	0.00049	-0.00207	0.00935	-0.00395	-0.00012	-0.05845	-0.00568	0.21737	0.27440
X_8	0.00054	0.00227	0.00122	0.00886	-0.01211	-0.00072	0.04249	-0.00781	0.28041	0.31060
X_9	0.00112	0.01332	0.01857	0.01794	0.03464	0.00136	0.01516	-0.00261	0.83830	0.93780

Residual = 0.109429

X_1 = days to 50% flowering
X_2 = plant height
X_3 = number of productive tillers/plant
X_4 = No. of fingers/ear
X_5 = length of finger
X_6 = length of ear
X_7 = No. of grains per spikelet
X_8 = No. of grains per Cm length of finger
X_9 = ear weight/plant
X_{10} = grain yield/plant

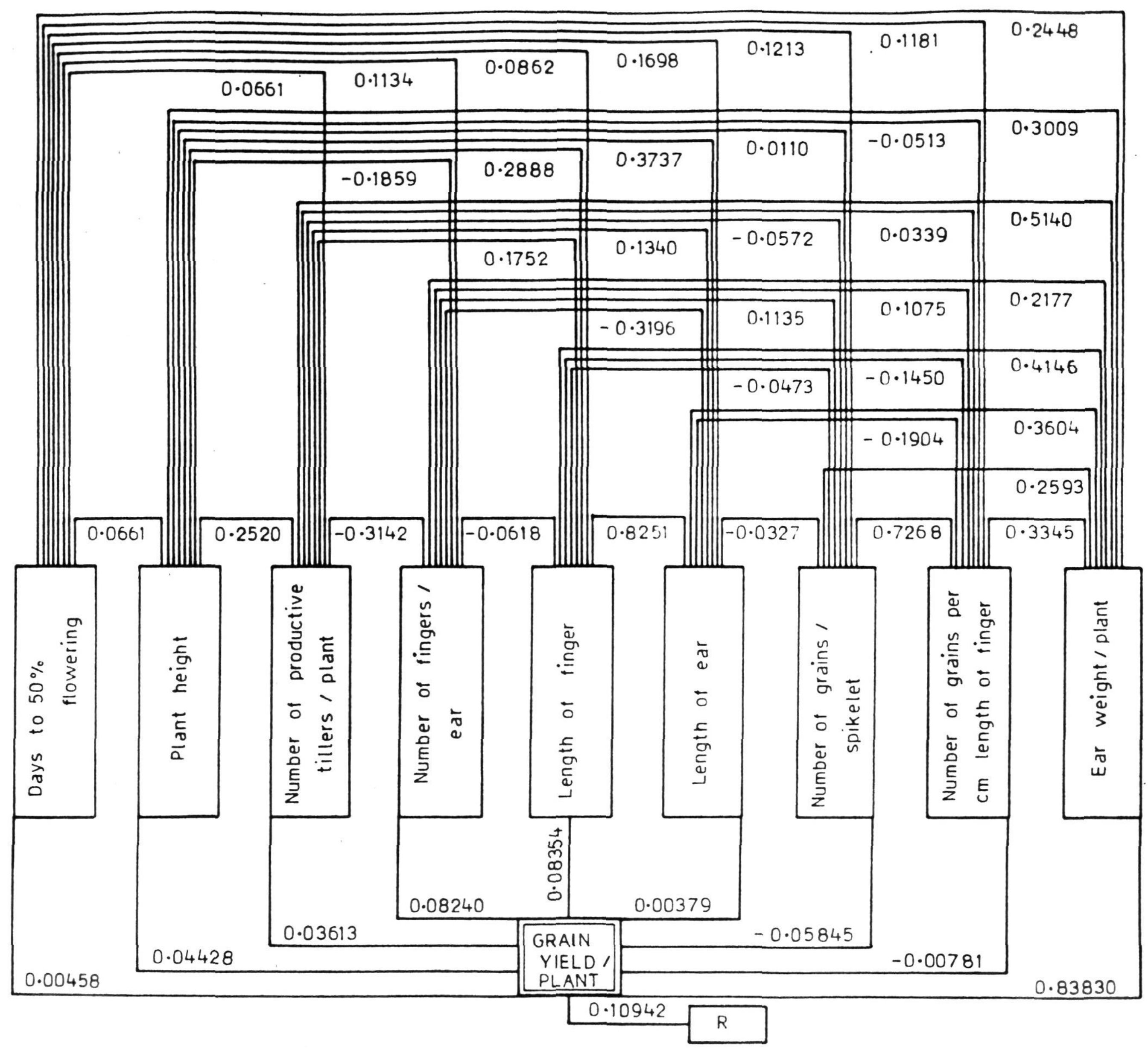

FIG. 4 : PHENOTYPIC PATH DIAGRAM OF THE INFLUENCE OF NINE CHARACTERS ON GRAIN YIELD IN F_3 POPULATION OF CROSS WR 9 × INDAF 9

(0.18250). The indirect contribution of other characters was negligible.

5) <u>Length of finger Vs grain yield per plant</u>

The character,length of finger had a low direct positive effect (0.08354) and a fairly moderate (0.34756) indirect effect through ear weight per plant on grain yield per plant. None of the other characters had any indirect contribution.

6) <u>Length of ear Vs grain yield per plant</u>

Except for a moderate indirect effect of ear weight per plant, the character length of ear had neither a direct effect nor an indirect effect through other characters for the moderate associaiton of (0.38470) length of ear with grain yield per plant.

7) <u>Number of grains per spikelet Vs grain yield per plant</u>

A moderate correlation (0.27440) between number of grains per spikelet and grain yield per plant was due to a low direct effect (0.05845) and a moderate indirect effect (0.21737) through ear weight per plant.

8) <u>Number of grains per Cm length of finger Vs grain yield per plant</u>

The direct effect (-0.00781) and the indirect effect of number of grains per Cm length of finger through other characters except ear weight per plant had not contributed to the moderate relationship (0.28041) between ear weight per plant and grain yield per plant. The indirect effect through ear weight per plant alone was responsible for the moderate correlation.

9) Ear weight per plant Vs grain yield per plant

Ear weight per plant showed a very high positive direct effect (0.8383) with grain yield per plant; its indirect effect through other characters was negligible. It showed a high positive correlation with grain yield per plant (0.9378).

4.3 INHERITANCE OF QUALITATIVE CHARACTERS

4.3.1 Cross WR 9 x U 6

4.3.1.1 Inheritance of plant pigmentation

All the plants of WR 9 which was used as female parent had no pigmentation. The male parent U 6 was purple pigmented. The F_1 plants were purple pigmented. This indicated the dominance of purple pigmentation over green. In F_2 generation out of 99 plants studied, 89 plants were purple and 10 plants had green pigmentation. This showed a good fit of 15:1 indicating operation of a pair of duplicate genes in the control of pigmentation. This was further confirmed in F_3. In F_3 generation, out of 99 families, 44 families bred true for dominant character (purple pigmentation), 27 families seqregated in the ratio of 15 purple : 1 green; 21 families segregated in the ratio of 3 purple : 1 green; 10 families bred true for recessive character (green). The pigmentation of parents, hybrid, F_2 segregation ratio and F_3 breeding behaviour are presented in table 10,11 and 12, respectively.

4.3.1.2 Inheritance of grain colour

All the plants of WR 9 had white grains and all the plants of U 6 possessed brown grains. Brown grain colour was observed in all the F_1 plants suggesting the dominance of brown grain colour over white. In F_2 generation, out of 99 plants 89 plants were brown grained and 10 plants were white grained showing a good fit to the digenic segregation ratio of 15:1 with X^2 value of 2.49. Out of 99 F_3 families studied, 44 families bred true for dominant character; 27 families segregated into 15 brown : 1 white; 21 families segregated into 3 brown:1 white; 10 families bred true for recessive character (Table 10,11 and 12).

4.3.2 Cross WR 9 x Indaf 9

4.3.2.1 Inheritance of plant pigmentation

The female parent WR 9 was devoid of pigmentation and purple pigmentation was observed in all the plants of Indaf 9. The dominance of purple pigmentation over green

TABLE 10

BEHAVIOUR OF PARENTS AND F_1 FOR PLANT PIGMENTATION AND GRAIN COLOUR IN THE CROSS WR 9 X U 6

Character	WR 9	U 6	F_1
Plant pigmentation	Green	Purple	Purple
Grain colour	White	Brown	Brown

TABLE 11

SEGREGATION IN F_2 GENERATION FOR PLANT PIGMENTATION AND GRAIN COLOUR IN THE CROSS WR 9 X U 6

Character	F_2 segregation		Ratio	X^2 value	p value
	Purple	Green			
Plant pigmentation	Obs : 89 Exp : 92.8125	10 6.1875	15:1	2.49	0.2-0.1
Grain colour	Brown	White			
	Obs : 89 Exp : 92.8125	10 6.1875	15:1	2.49	0.2-0.1

obs = observed

Exp = expected

TABLE 12

F_3 BEHAVIOUR FOR PLANT PIGMENTATION AND GRAIN COLOUR IN CROSS WR 9 X U 6

Character		No. of families Segregating for				X^2 value	P value
		BT+	15:1	3:1	BT-		
Plant pigmentation	Obs.	41	27	21	10	3.2452	0.3-0.2
	Exp.	43.3125	24.75	24.75	6.1875		
Grain colour	Obs.	41	27	21	10	3.2452	0.3-0.2
	Exp.	43.3125	24.75	24.75	6.1875		

Obs = observed
Exp = expected

BT+ = number of families bred true for dominant character

Bt- = number of faimilies bred true for recessive character pigmentation was indicated by the occurrance of purple pigmentation in F_1 generation, wherein all the F_1 plants were purple. In F_2 generation out of 100 progenies studied, 89 plants were purple and 11 plants were green which showed a good fit to the digenic segregation ratio of 15:1 with a X^2 value of 3.85. The F_2 ratio was confirmed in the F_3; in F_3 generation out of 100 familes, 39 families bred true for dominant character, 28 families segregated in the ratio of 15:1; 22 families segregated in the ratio of 3:1; 11 families bred true for recessive (green) character. The character of parents, hybrid, F_2 segregation ratios and F_3 breeding behaviour are presented in Table 13,14 and 15, respectively.

4.3.2.2 Inheritance of grain colour

The parent WR 9 had white grains in all the plants. The male parent Indaf 9 had brown grains. In F_1 all the plants were brown grained indicating the dominance of brown grain colour over white grain. In the F_2 generation, out of a total 100 plants studied, 89 plants were brown grained and 11 plants were white grained. The digenic ratio of 15:1 showed a good fit as indicated by X^2 value of 3.85. The F_2 segregation was confirmed through the study of behaviour of F_3 families. In F_3 generation, out of 100 families studied, 39 families bred true for Brown grain; 28 families segregated in the ratio of 15:1; 22 families segregated in the ratio of 3:1; 11 families bred true for white grain colour (Table 13, 14 and 15).

TABLE 13

BEHAVIOUR OF PARENTS AND F_1 FOR PLANT PIGMENTATION AND GRAIN COLOUR IN THE CROSS WR 9 x INDAF 9

Character	WR 9	Indaf 9	F_1
Plant pigmentation	Green	Purple	Purple
Grain colour	White	Brown	Brown

TABLE 14

SEGREGATION IN F_2 GENERATION FOR PLANT PIGMENTATION AND GRAIN COLOUR IN THE CROSS WR 9 X INDAF 9

Character	F_2 segregation		Ratio	X^2 value	p value
	Purple	Green			
Plant pigmentation	Obs : 89 Exp : 93.75	11 6.25	15:1	3.85	0.3-0.1
Grain colour	Brown	White			
	Obs : 89 Exp : 93.75	11 6.25	15:1	3.85	0.3-0.1

Obs : Observed Exp : Expected

TABLE 15

F_3 BEHAVIOUR FOR PLANT PIGMENTATION AND GRAIN COLOUR IN CROSS WR 9 X INDAF 9

Character		No. of families Segregating for				X^2 value	P value
		BT+	15:1	3:1	BT-		
Plant pigmentation	Obs.	39	28	22	11	0.484	0.2-0.1
	Exp.	43.75	25	25	6.25		
Grain colour	Obs.	39	28	22	11	0.484	0.2-0.1
	Exp.	43.75	25	25	6.25		

BT+ = Number of families bred true for dominant character.

BT- = Number of families bred true for recessive character.

4.3.3 Joint segregation

Joint segregation ratio was worked out by considering both the character (plant pigmentation and grain colour) together. The genes were tested for independent assortment, pleiotropy and linkage. The combined segregation revealed the existance of both pleiotpropy and linkage. The results are present below.

4.3.3.1 WR 9 x U 6

The qualitative characters plant pigmentation and grain colour were studied in the cross WR 9 x U 6. The parent WR 9 had no pigmentation and possessed white grains. The male parent U 6 was purple pigmented and had brown grains. All the F_1s were purple pigmented with brown grains. Out of 100 F_2 plants, 89 plants were purple pigmented and 10 plants were green showing a good fit to the digenic ratio of 15:1. Among these F_2 generation, 89 plants had brown grain colour and 10 plants were white grained. The digenic interaction of 15:1 showed a good fit to this F_2 segregation. Thus, the joint segregation observed in F_2 for purple pigmentation with brown grains; purple pigmentation with white grains; green pigmentation with brown grains; green pigmentation with white grains were 89:0:0:10 plants, respectively, out of 99 plants. The expected joint segregation ratio for these characters on the basis of independent assortment was 87.01: 5.8: 5.8: 0.38. Thus, the observed values were not close to the expected values and chi-square value was very high (Table 16 and 17).

4.3.3.2 WR 9 x Indaf 9

All the plants of WR 9 were non pigmented and white grained. The male parent Indaf 9 was purple pigmented and had brown grains. In F_1, all the plants had purple pigmentation and brown grains. In F_2 generation, out of 100 plants, 89 plants were purple pigmented with brown grains and remaining **11** plants were green with white grains. The digenic segregation ratio of 15:1 showed a good fit. Thus, the joint segregation observed in F_2 for purple pigmentation with brown grain colour; purple pigmentation with white grains; green pigmentation with brown grains; green pigmentation with white grains were 89:0:0:11, respectively, out of 100 plants. The expected joint segregation ratio for these characters on the basis of independent assortment was 87.89: 5.85: 5.85: 0.39. The observed values of joint segregation was not close to the expected ratios. Chi. square value was higher than the table value at 3 d.f at 5 per cent probability level (Table 18 and 19).

4.4 HERITABILITY

In the present study heritability values were estimated from parent off spring regresion method involving F_2 plant data and F_3 progenies mean. The results obtained from the study are presented (Table 20).

TABLE 16

JOINT SEGREGATION FOR PLANT PIGMENTATION AND GRAIN COLOUR IN PARENTS, F_1 AND F_2 GENERATION OF THE CROSS WR 9 x U 6

Generation	AB	Ab	aB	ab	Total
P_1 (WR 9)	0	0	0	20	20
P_2 (U 6)	20	0	0	0	20
F_1	5	0	0	0	5
F_2	89	0	0	10	99

Where

A = Purple pigmentation　　B = Brown grain colour

a = Green pigmentation　　b = White grain colour.

TABLE 17

X^2-TEST FOR JOINT SEGREGATION FOR PLANT PIGMENTATION AND GRAIN COLOUR IN THE F_2 GENERATION OF THE CROSS WR 9 x U 6

	AB	Ab	aB	ab	Total	X^2
Observed	89	0	0	10	99	255.18
Expected	87.01	5.8	5.8	0.38	99	

Where

A = Purple pigmentation

a = Green pigmentation

B = Brown grain colour

b = White grain colour

and F_2 segregation for individual character were

15 : 1 for purple : Green pigmentation

15 : 1 for brown : White grain colour

TABLE 18

JOINT SEGREGATION FOR PLANT PIGMENTATION AND GRAIN COLOUR IN PARENTS, F_1 AND F_2 GENERATION OF THE CROSS WR 9 x INDAF 9

Generation	AB	Ab	aB	ab	Total
P_1 (WR 9)	0	0	0	20	20
P_2 (Indaf 9)	20	0	0	0	20
F_1	7	0	0	0	7
F_2	89	0	0	11	100

Where

A = Purple pigmentation B = Brown grain colour

a = Green pigmentation b = White grain colour.

TABLE 19

X^2-TEST FOR JOINT SEGREGATION FOR PLANT PIGMENTATION AND GRAIN COLOUR IN THE F_2 GENERATION OF THE CROSS WR 9 x INDAF 9

	AB	Ab	aB	ab	Total	X^2
Observed	89	0	0	11	100	255.18
Expected	87.89	5.85	5.85	0.39	100	

Where

A = Purple pigmentation

a = Green pigmentation

B = Brown grain colour

b = White grain colour

and F_2 segregation for individual character were

15 : 1 for purple : Green pigmentation

15 : 1 for brown : White grain colour

4.4.1 WR 9 x U 6

Narrow sense heritability estimates using parent off spring regression method were high for days to 50% flowering (39.37) and plant height (42.27). A moderate heritability estimates were observed in case of number of fingers per ear (16.6), length of finger (11.44), length of ear (14.27) and very low estimates of heritability were observed for number of productive tillers per plant (8.93%), number of grains per spikelet (4.02), number of grains per Cm length of finger (3.26), ear weight per plant (1.94) and grain yield per plant (2.79).

4.4.2 WR 9 x Indaf 9

The heritabilities estimated in this cross were high for length of finger (32.34) and length of ear (29.87). A moderate estimates of heritability were recorded for days to 50% flowering (19.12), number of grains per spikelet (11.65) and number of grains per Cm length of finger (12.51). Low heritabilities were observed in case of plant height (7.78), number of productive tillers per plant(5.4), number of fingers per ear(3.51), ear weight per plant (5.74) and grain yield per plant (6.16).

TABLE 20

HERITABILITY VALUES FOR YIELD AND OTHER YIELD COMPONENTS IN TWO CROSSES

WR 9 x U 6 AND WR 9 x INDAF 9

Cross	Days to 50% flowering	plant height	No. of productive tillers per plant	No. of fingers per ear	length of finger	length of ear	No. of grains per spikelet	No. of grains per Cm length of finger	ear weight/ plant	grain yield/ plant
WR 9 x U 6	39.37	42.27	8.93	16.60	11.44	14.27	4.02	3.26	1.94	2.79
WR 9 x Indaf 9	19.12	7.78	5.40	3.51	32.34	29.87	11.67	12.51	5.74	6.16

DISCUSSION

V DISCUSSION

The ultimate objective of plant breeder is to enhance yield per unit area and time. Yield being a complex quantitative trait and is a function of several components, selection of superior genotypes based on yield as such is difficult due to integrated structure of a plant in which most of the characters are interrelated and often a change in one influence the other.

For improving yield through breeding it is necessary to know the extent and nature of relationship prevelent between contributory charactors and grain yield and also among components themselves. The association of characters will determine the direction of action of different characters and also indicate the number of traits to be considered in improving grain yield. The present study envisaged to investigate the contribution of different yield attributes to grain yield and their interrelationship by estimating correlation co-efficients.

The correlation values denote only the extent of association existing between characters. But, path co-efficient analysis provides an effective means of untangling direct and indirect causes of association and permits a critical examination of the specific forces acting to produce a given correlation and measures the relative importance of each causal factor; such a study finds more meaning in formulating selection indices.

The nature of inheritance of qualitative charaters especially plant pigmentation will help the breeders in identifying the true F_1s in self pollinated crops. Due to its potentiality as a marker gene, an attempt was also made to understand its inheritance.

Heritability estimates are widely used in breeding programme to estimate the transmission of genetically controlled characterstics. Heritability estimates represent the relative genetic strength of characters and indicate the efficiency of selection Heritability calculated in the narrow sense is of greater value as it reflects the additive genetic variance component, which is fixable through selection.

5.1 CORRELATION

1. Days to 50% Flowering

Days to 50% flowering showed a positive significant association with ear weight per plant and grain yield per plant only in F_3 generation of both the crosses. This could be explained based on the new recombinations obtained in the F_3 generation. The result obtained in the present study in F_3 generation is in agreement with the findings of Singh and Prasad (1976) in *P.pedicellatum* who obtained positive correlation between these traits. In contrast, Pokhriyal *et al.* (1986) observed negative correlation between these two traits. The character also showed association with number of productive tiller per plant only in F_2 of the cross WR 9 x U 6. The results suggest that the grain yield per plant and one of its important components ear weight per plant are associated strongly in the advanced generation and could be used as criterion for selection for yield enhancement.

2 Plant height

Plant height showed a significant association with length of finger, length of ear in F_3 of cross WR 9 x U 6 and both the generation of cross WR 9 x Indaf 9. It also recorded a significant correlation with number of grains per cm length of finger in F_2 of WR 9 x U 6; number of productive tillers per plant, ear weight per plant in F_3 of WR 9 x U 6; number of productive tillers per plant, ear weight per plant and grain yeild per plant per plant in F_3 of corss WR 9 x Indaf 9. Narasimha Rao and pardasarathi (1980b), Dhagat et al. (1973), Nagarajan and Prasad (1980), Li et al. (1936), Ratnaswamy and Ponnaiya (1963), Sandhu et al. (1974), Vishwanath (1978), Liu (1984) in foxtail millet; Saxena et al. (1976) in proso millet observed correlation between yeild and plant hight. The result also suggests that plant height in general was associated with length of finger and length of ear.

3. Number of productive tillers per plant

It is interesting to note that number of productive tillers per plant has been contributing towards increase in ear weight per plant and grain yield per plant in both the generations of both the crosses. This clearly brings out that indirect selection for yield through these two characters can be made. Earlier findings also showed a similar results [Mahadevappa and Ponnaiya, 1963; Mahudeswaran and Murageshan, 1975; Michel Raj et al., 1973; Subramanian et al., 1977; Shanthappa, 1980; Prabhakar and Prasad, 1983 in ragi; Ratnaswamy and Ponnaiya, 1963; Vishwanath, 1978; Chinnaswamaiah, 1975 in foxtail millet; Raveendran and Appadurai, 1984 in pearl millet].

4. Number of fingers per ear

Similar to number of productive tillers per plant, number of fingers/ear was correlated significantly with ear weight per plant and grain yield per plant in F_2 and F_3 generations of both the crosses. As such this character can be used effectively for improvement of ear weight per plant and grain yield per plant through selection.

The present finding is in agreement with the findings of Mahadevappa and Ponnaiya (1963), Patnaik (1968), Subramanian et al. (1977) and Agalodia et al. (1979) in ragi.

5. Length of finger:

Length of finger has shown a significant association with length of ear in both the crosses and in both the generations. However, it has shown correlation with yield in only F_2 of the cross WR 9 x U 6 and F_3 of the cross WR 9 x Indaf 9. Patnaik (1968) in ragi found positive association between yield and length of finger.

6. **Length of ear**

Length of ear was correlated with finger length in both the generations of both the crosses. It was also associated with plant height in both the generations of cross WR 9 x Indaf 9. It had showed relationship with ear weight per plant and grain yield per plant only in the F_3 generation of cross WR 9 x Indaf 9. Narasimha Rao and Pardasarathi (1968), Dhagat et al. (1973) in ragi; Vishwanath (1978), Godawart and Gupta (1981) in foxtail millet; Abinash yadav and Srivastava (1976), Saxena et al. (1979) in proso millet recorded positive association between length of ear and yield.

7. **Number of grains per spikelet**

Number of grains per spikelet which is mainly responsible for total number of grains in ear seem to be one of the important selection criterion for yield as it showed a positive association between ear weight per plant and grain yield per plant in both the generations of the two crosses. The other component showing a good association with this character was number of grains per cm length of finger. This is the first report wherein the relationship between number of grains per spikelet and yield was established.

8. **Number of grains per cm length of finger**

Number of grains per cm length of finger virtually indicates the grain density on the finger. This character has recorded a consistant positive association with number of grains per spikelet, ear weight per plant and grain yield per plant in the two generations of both the crosses studied. This clearly brings out the importance of the character in the improvement of yield. This is in confirmation of the findings of Viswanath (1978) in foxtail millet wherein he observed positive significant association of yield with grain density.

9. **Ear weigth per plant**

Ear weight has shown a very strong correlation with grain yield in both the generations of both the crosses as also observed by Vishwanath (1978) and Wang and Han (1981) in foxtail millet; Narasimha Rao and Damodaran (1964) in pearl millet. As this character has also shown strong association with number of productive tillers per plant, number of finger per ear, and length of finger, indirect selection for ear weight per plant could effectively be done through direct selection of number of productive tillers per plant, number of fingers per ear and length of finger as indicated earlier.

5.2 PATH ANALYSIS

1. Days to 50% flowering

Path analysis showed negligible direct effect of days to 50% flowering on grain yield per plant in all the populations of both the crosses. This is in contrast to the findings of Singh and Prasad (1976), Singh and Singh (1976) in pearl millet who reported a positive direct effect on yeild.

2. Plant height

Path coefficient analysis revealed that its correlation with grain yield per plant was not reflected by its direct effect which was low in all the populations. Its indirect effect via. ear weight per plant was more than its direct effect which was mainly responsible for positive correlation with grain yield per plant. In contrast to the present findings, Mahudeswaran and Murugesan (1973) reported positive direct effect on yield. But Subramanian et al. (1977) reported that this character had negative inluence on yield in ragi; similarly, Vishwanath (1978) in foxtail millet and Singh and Prasad (1976) in pearl milet reported negative direct effect of this character on yeild. Reddy et al. (1984) reported that plant height had a positive indirect effect through straw weight and tiller number per plant on yield in little millet.

3. Number of productive tillers per plant

In all the populations direct effect of number of productive tillers per plant on grain yield per plant was very low, which is in contrast with the earlier findings of Chaudhary and Acharya (1969), Mahudeswaran and Murugeshan (1973), Prabhakar and Prasad (1983) in ragi; Randhawa et al. (1978), Vishwanath (1978), Godawat (1980) in foxtail millet; Raveendran and Appadurai (1984) in Pearl millet, who have reported its direct effect on yield. The correlation between this character and grain yield per plant was high, which was due to its high indirect effect through ear weight per plant.

4. Number of fingers per ear

This character also exerted negligible direct effect on grain yield per plant. In the cross WR 9 x U 6 its, direct effect was negative as also observed by earlier workers Subramanian et al. (1977) in ragi. Nevertheless, its correlation with grain yield was positive in all the populations, because of its indirect effect via ear weight per plant.

5. Length of finger

This character had a negligible direct effect on grain yield per plant in all the populations. Its direct effect was negative in both the F_2 populations. Its indirect effect via other character was also very low. Therefore, very low correlation was observed between this character and grain yield per plant. This is the first time the character was studied to know its association with grain yield per plant.

6. Length of ear

Length of ear exerted a low positive direct influence on grain yield in F_2 population on both the crosses and F_3 population of WR 9 x U 6. This is in contrast to the findings of previous workers viz., Randhawa et al. (1978) in foxtail millet; Yadav and Srivastava (1976) in little millet: Raveendran and Appadurai (1984) in pearl millet who recorded a positive direct effect. While, in F_3 of cross WR 9 x Indaf 9 a negative influence on grain yield was recorded. Similar result was reported by Vishwanath (1978) who obtained direct negative effect in foxtail millet.

7. Number of grains per spikelet

Number of grains per spikelet did not have a favourable direct effect in any of the populations studied. It had negligible direct effect with grain yeild in all the populations. Its indirect effect via other characters was also negligible. The correlation of this character with grain yield per plant was also low. This character was studied for the first time.

8. Number of grains per cm length of finger

In all the four populations the direct contribution of number of grains per cm length of finger on grain yield per plant was negligible. But, Raveendran and Appadurai (1984) in pearl millet reported positive direct effect of this trait. Its correlation with grain yield per plant was positive due to its indirect effect through ear weight per plant.

9. Eer weight per plant

In all the populations studied, this character had high positive direct effect on grain yield per plant and had high correlation with grain yield per plant. The indirect effect via other characters was negligible. Similar findings were obtained by Shantappa (1980) in ragi and Vishwanath (1978) in foxtail millet.

The path co-efficient analysis has clearly demonstrated the need for giving due weightage for ear weight per plant for yield improvement in finger millet through selection.

5.3 INHERITANCE OF QUALITATIVE CHARACTER

Presence of anthocyanin pigment in many plant parts is a varietal character in ragi. Of the several characters which could be used as marker to identify true F_1's, the plant pigmentation is one that could be used advantageously. The results obtained in F_2 and F_3 generation of the crosses viz. WR 9 x U 6 and WR 9 x Indaf 9 are discussed.

Inheritance of plant pigmentation

Cross WR 9 x U 6

All the F_1 plants were purple confirming the dominence of purple pigmentation over green. F_2 segregation showed a good fit to the digenic ratio of 15 purple: 1 green indicating that the parents are differing with respect to two pairs of genes which was further confirmed by the corresponding F_3 ratio. It was found that two pairs of genes acts as duplicate dominant genes. The presence in either or both the genes results in purple pigmentation of plants. Homozygous recessive genes result in green plant colour.

Cross WR 9 x Indaf 9

Purple pigmentation observed in all the F_1's confirmed the dominance of purple pigmentation over green. A digenic ratio of 15:1 for purple pigmentation to green type was shown by F_2 analysis, which was confirmed by the corresponding F_3 breeding behaviour. Thus ,the parents differed with respect to two pairs of genes for pigmentation; purple parent (Indaf 9) having both the genes in homozygons dominant condition and green parent (WR 9) possessing both the genes in recessive homozygous condition.

Thus, the results from both the crosses involving parents with contrasting characters for pigmentation revealed that purple pigmentation is dominant over green plant colour which is in confirmation with the result of earlier workers like Shanthappa (1980) in ragi; Indi and Goud (1981), Goud and Kallaiswamy (1984), Swarnalata et al.(1987) in sorghum; Madhava Rao and Kallaiswamy (1975) in Pennisetum typhoids.

Further it is also very clear from the studies using both the crosses that pigmentation in finger millet is controlled by two duplicate dominant genes, the presence of either or both the genes results in purple colour. This is the first report of its kind in finger millet.

Inheritance of grain colour

Cross WR 9 x U 6

F_1's of this cross were all brown grained indicating dominance of brown grain colour over white grains. F_2's showed a digenic segregation ratio of 15:1 for brown to white which was confirmed by the corresponding F_3 ratio. Thus the two parents differed with respect to two pairs of genes.

Cross WR 9 x Indaf 9

The results in this cross were similar to those in the previous cross. Presence of brown grains in F_1's confirmed the dominance of brown colour over white colour. The two parents differed with respect to two pairs of genes responsible for production of brown colour as evident from the digenic segregating ratio of 15:1 for brown to white, which was confirmed through F_3 breeding behaviour.

A similar pattern of inheritance of grain colour in both the crosses clearly brings out that the brown grain colour in finger millet is controlled by two dominant duplicate genes. The presence of either or both the genes in dominant condition results in brown grain colour. If both the genes are homozygous-recessive the grain colour will be white. There are no reports so far on the inheritance of grain colour in finger millet.

Joint segregation

Joint segregation worked out using the crosses where both the parents had contrasting characters revealed that there was pleiotropy or very tight linkage between plant pigmentation and grain colour. Pleioptropy is defined as a set of two or more gene governing more than one character. Linkage is the association of characters during inheritance which is due to location of genes governing those characters on one and the same chromosome. complete or tight linkage is a case wherein no genetic crossing over of the linked gene takes place. It is also called "Absolute linkage".

All the plants of WR 9 which was used as female parent had no pigmentation and possessed white grains. The male parents WR 9 and U 6 were purple pigmented and brown grained. All the F_2 plants were purple pigmented with brown grains indicating dominance of purple pigmentation over green and brown grain colour over white. In F_2 generation out of 99 plants, 89 plants were purple pigmented and brown grain coloured and 10 plants had green pigmentation with white grains. This showed a good fit of 15:1, indicating operation of a pair of dominant duplicate genes in the control of both the characters. In F_2 there was no recombination between plant pigmentation and grain colour indicating pleiotropy or absolute linkage of genes for pigmentation and grain colour. This was further confirmed through F_3 breeding behaviour. In cross WR 9 x U 6 out of 99 families studied, 41 families bred true the purple pigmentation and brown grain colour; 10 families bred true for green pigmentation and white grain colour; 27 families segregated in to 15 purple pigmented and brown grained: 1 green pigmentated and white grained; 21 families segregated in ratio of 3 purple pigmentated and brown grained: 1 green pigmentated and white grained. In the cross WR 9 x Indaf 9 out of 100 families, 39 families bred true for purple pigmentation and brown grains; 11 families bread true for recessive character; 28 families segregated in the ratio of 15 purple pigmentated and brown grained: 1 green pigmentated and white grained; 22 families segregated in the ratio of 3 purple pigmented and brown grained: 1 green pigmented and white grained.

In both the crosses WR 9 x U 6 and WR 9 x Indaf 9 the genes controlling the inheritance of pigmentation on plant parts and grain colour have shown phenomenon of pleiotropy or tight linkage. The genes for pigmentation on plant parts appears to be responsible for the expression of grain colour.

Though the present study reveals the possibility of pleiotropy, a very close linkage between the genes for plant pigmentation and grain colour cannot be ruled out totally as

9.5

there are quite a few green coloured genotypes possessing brown grain although, there are no cultivars with purple plants bearing white grains.

5.4 HERITABILITY

In the present study heritabilities for different characters have been worked out using parent off-springs regression method. As such the estimates are under narrow sense indicating the extent to which the character are under additive gene control.

In general moderate heritability values were recorded for days to 50% flowering, plant height, length of finger, length of ear, while low heritabilities were observed for number of productive tillers per plant, number of fingers per ear, number of grains per spikelet, number of grains per cm length of finger, ear weight per plant and grain yeild per plant. Patnaik (1968), Chaudhary and Acharya (1969), Mahudeswaran and Murugesaan (1973), Setty et al. (1974), Goud and Lakshmi(1977) Vishwanath (1978), Nagarajan and Prasad (1980), Rao (1984) in foxtail millet recorded high broad sense heritability for plant height. Gian Singh (1966), Vishwanath (1978) in foxtail millet recorded high broad sense heritability for days to 50% flowering. Setty et al. (1974) recorded high broad sense heritability for length of finger in ragi. Gian singh (1976) and Rao et al. (1984) recorded high broad sense heritability for length of ear;

Wang & Han (1981) recorded low broad sense heritability for ear weight/plant and grain yield per plant. A comparitively high heritability for days to 50% flowering and plant height in the cross WR 9 x U 6 and length of finger and length of ear in the cross WR 9 x Indaf 9 suggested effectiveness of selection for these characters in the respective crosses based on phenotypic values. It is difficult to make any improvement through selection for number of fingers per ear, length of finger, length of ear, number of grains per spikelet and number of grains per cm length of finger in the cross WR 9 x U 6 and days to 50% flowering, plant height, number of fingers per ear, number of grains per spikelet and number of grains per cm length of finger in the cross WR 9 x Indaf 9. Similarly, a very low heritability for number of productive tillers per plant, ear weight per plant, grain yield per plant in both the crosses has suggested the difficulty in improving these characters through selection.

SUMMARY

VI. SUMMARY

Two crosses WR 9 x U 6 and WR 9 x Indaf 9 comprising of three cultivars viz., WR 9, U 6 and Indaf 9 were made; the F_1, F_2 and F_3 progenies were raised at GKVK Farm, University of Agricultural Sciences, GKVK, Bangalore, to study (1) Phenotypic correlation between grain yield and its components, (2) the direct and indirect contribution of different components to grain yield in F_2 and F_3 generations, (3) Inheritance of plant pigmentation and grain colour and (4) Heritability of yield and its components by parent off-spring regression.

Observations were recorded on ten metric traits viz., days to 50% flowering, plant height, number of productive tillers/plant, number of fingers/ear, Length of finger, length of ear, number of grains/spikelet, number of grains/cm length of finger, ear weight/plant and grain yield/plant on 100 random plants from each of the F_2 segregating generation and 5 plants from each F_3 families. Simple correlation coefficients were estimated based on the model proposed by Al-Jibouri <u>et al.</u> (1958). Further, the correlation co-efficients were split into direct and indirect effects by using path coefficient analysis suggested by Dewey and Lu (1959). For inheritance of qualitative characters, the expected values corresponding to the observed values for each character were calculated. The deviation were put to the chi-square test. Heritability was computed using the techniques suggested by Smith and Kinman (1965).

Correlation studies indicated that grain yield/plant was positively associated with number of productive tillers /plant, number of fingers/ear, number of grains /cm length of finger and ear weight/plant in F_2 and F_3 populations of both the crosses. It also showed a positive significant association with days to 50% flowering in F_3 populations of both the crosses. Its association was also positive and significant with plant height in F_3 populations of the cross WR 9 x Indaf 9. Length of finger was positively correlated with grain yield/plant in F_2 population in cross WR 9 x U 6 and in F_3 of cross WR 9 x Indaf 9. Length of ear showed significant correlation with ear weight/plant only in F_3 of the cross WR 9 x Indaf 9. Number of grains/ spikelet recorded consistant positive association with grain yield/plant in all the populations of except F_2 of WR 9 x U 6.

In the present study, path co-efficient analysis of grain yield/plant and other character revealed that only ear weight/plant has a maximum direct effect on yield. In F_2 populations of both the crosses ear weight/plant had the strongest direct positive effect on grain yield/plant. In the F_3 population of cross WR 9 x U 6, ear weight/plant exerted maximum influence on grain yield/plant followed by number of grains/spikelet. In F_3 of the cross WR 9 x Indaf 9, ear weight/plant was the most important yield contributing factor followed by length of finger, number of fingers/ear and number of grains/spike let and plant height.

Purple pigmentation was dominant over green. Plant pigmentation was controlled by two genes which act as duplicate dominant genes. Presence of either or both the genes in dominant condition results in purple pigmentation. A 15:1, purple to green colour segregation was observed in F_2 of both the crosses which was confirmed in F_3. Inheritance of grain colour followed similar pattern as that of plant pigmentation. Brown grain colour was dominant over white. Inheritance of brown grain colour was controlled by two dominant duplicate genes; presence of either or both the genes in dominant condition result in brown grain colour. F_2 segregation of 15:1 was observed in both crosses. Joint segregation study revealed either very close linkage between the genes for pigmentation and grain colour or pleiotropy.

Heritability values for all the characters estimated from a modified parent progeny regression method by the regression of F_3 on F_2 indicated a low heritability for number of productive tillers per plant(8.9%), number of grains/spikelet (4.02%), number of grains/cm length of finger (3.26%), ear weight/plant (1.94%) and grain yield/plant (2.79%), a moderate heritability for number of fingers/ear (16.59%), length of finger (11.44%), length of ear (14.27). Fairly high heritability for days to 50% flowering (39.33%), plant height (42.22%) in the cross WR 9 x U 6.

In the cross WR 9 x Indaf 9 a fairly high heritability was observed for length of finger (32.34%) and length of ear

(29.87%); moderate heritability was observed for days to 50% flowering (19.12%), number of grains/spikelet (11.67%) and number of grains/cm length of finger (12.51%); low heritability was observed for number of productive tillers/plant (5.4%), number of fingers/ear (3.51%), ear weight/plant (5.74%) and grain weight/plant (6.16%), Plant height (7.78%).

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VII. REFERENCES

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* Original not seen.