Genetics of important traits and their inheritance pattern in breeding of fruit crops

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In general, inheritance patterns for single gene disorders are classified based on whether they are autosomal or X-linked and whether they have a dominant or recessive pattern of inheritance. These disorders are called Mendelian disorders, after the geneticist Gregor Mendel.

Two types of inheritance pattern: They are

A. Mendelian inheritance patterns
B. Non- Mendelian inheritance patterns

Mendelian inheritance patterns

- ✓ Within a population, there may be a number of alleles for a given gene.
- ✓ Individuals that have two copies of the same allele are referred to as homozygous for that allele.
- ✓ Individuals that have copies of different alleles are known as heterozygous for that allele.
- ✓ The inheritance patterns observed will depend on whether the allele is found on an autosomal chromosome or a sex chromosome, and on whether the allele is dominant or recessive.

i. Autosomal dominant

If the phenotype associated with a given version of a gene is observed when an individual has only one copy, the allele is said to be autosomal dominant. The phenotype will be observed whether the individual has one copy of the allele (is heterozygous) or has two copies of the allele (is homozygous).

ii. Autosomal recessive

If the phenotype associated with a given version of a gene is observed only when an individual has two copies, the allele is said to be autosomal recessive. The phenotype will be observed only when the individual is homozygous for the allele concerned.

An individual with only one copy of the allele will not show the phenotype, but will be able to pass the allele on to subsequent generations. As a result, an individual heterozygous for an autosomal recessive allele is known as a carrier.

iii. Sex-linked or X-linked inheritance

- ✓ In many organisms, the determination of sex involves a pair of chromosomes that differ in length and genetic content - for example, the XY system used in human beings and other mammals.
- ✓ The X chromosome carries hundreds of genes, and many of these are not connected with the determination of sex.
- ✓ The smaller Y chromosome contains a number of genes responsible for the initiation and maintenance of maleness, but it lacks copies of most of the genes that are found on the X chromosome.

- ✓ As a result, the genes located on the X chromosome display a characteristic pattern of inheritance referred to as sex-linkage or X-linkage.
- ✓ Females (XX) have two copies of each gene on the X chromosome, so they can be heterozygous or homozygous for a given allele.
- ✓ However, males (XY) will express all the alleles present on the single X chromosome that they receive from their mother, and concepts such as 'dominant' or 'recessive' are irrelevant.

Non-Mendelian inheritance patterns

i. Complex and multifactorial inheritance

- ✓ Some traits or characteristics display continuous variation, a range of phenotypes that cannot be easily divided into clear categories.
- ✓ In many of these cases, the final phenotype is the result of an interaction between genetic factors and environmental influences.
- ✓ An example is human height and weight.
- ✓ A number of genetic factors within the individual may predispose them to fall within a certain height or weight range, but the observed height or weight will depend on interactions between genes, and between genes and environmental factors (for example, nutrition).
- ✓ Traits in which a range of phenotypes can be produced by gene interactions and gene-environment interactions are known as complex or multifactorial.

ii. Mitochondrial inheritance

- ✓ Animal and plant cells contain mitochondria that have their evolutionary origins in protobacteria that entered into a symbiotic relationship with the cells billions of years ago.
- ✓ The chloroplasts in plant cells are also the descendants of symbiotic protobacteria. As a result, mitochondria and chloroplasts contain their own DNA.
- ✓ Mitochondria are scattered throughout the cytoplasm of animal and plant cells, and their DNA is replicated as part of the process of mitochondrial division.
- ✓ A newly formed embryo receives all its mitochondria from the mother through the egg cell, so mitochondrial inheritance is through the maternal line.

Following a 'pattern of inheritance' requires:

- ✓ Two parent plants that are 'pure breeding',
- ✓ Performing a genetic cross using these plants to produce the f1 hybrids,
- ✓ Recording the form(s) of the trait seen in the f1 generation of plants,
- ✓ Using some of these f1 plants as parents in a second series of genetic crosses to produce the f2 hybrids,
- ✓ Counting the number of times a version of a trait occurs in the f2 hybrids,

- ✓ Calculating the ratios of plants showing one form to those plants showing the alternate form of a trait.

Inheritance pattern of quality traits in fruit crops

Mango

The mango is not a convenient plant for genetical analysis due to its long life cycle, cross pollination and high degree of heterozygosity, lack of detail information on its inheritance pattern, intricate arrangement of sexes in the panicle and excessive fruit drop. However the inheritance of some characteristics has been worked out which are readily analyzed.

- ✓ Some of the more desired characters like upright tree habit is dominant over spreading and spreading is dominant over dwarfness.
- ✓ There exists a strong linkage between bearing and fruit quality. Biennial bearing is dominant over regular bearing.
- ✓ Precocity and regularity of bearing are governed by recessive genes.
- ✓ Fruit bearing in bunches gas been observed to be dominant over single fruit bearing.
- ✓ The genetics of fruit color has not been studied in detail but available combinations resulting in different colors.
- ✓ The inheritance of duration of the juvenile period is yet to be examined critically.
- ✓ Totapari Red Small has been found to have a very short juvenile phase and thus it can be used as a male parent in hybridization programme to reduce the length of the juvenile phase.
- ✓ This is because no effect of the female parent has been found on the distribution of the juvenile period or fertility.
- ✓ Resistance to floral malformation is controlled by recessive genes. Spongy tissue, a physiological disorder of fruits has also been found to be governed by recessive genes.
- ✓ Susceptibly to bacteria canker is transmitted through cytoplasmic inheritance.

  Inheritance pattern
- ✓ Dwarfism, regular bearing and precocity are governed by recessive gene.
- ✓ Polyembryony, bunch bearing, presence of beak, biennial bearing & upright habit of the tree are governed by dominant gene.
- ✓ Fruit color is governed by multiple loci.
- ✓ Fruit size follows transgressive segregation.
- ✓ While malformation and spongy tissue are governed by recessive gene, bacterial canker followed cytoplasmic inheritance.

Banana

Continuous variation is considered a particular characteristic of quantitative polygenes. Several characteristics showing continuous variation in Plantain and banana are controlled by major genes. Dodds and Simmonds (1948) studied sterility and partenocarpy in diploid hybrids of *Musa* and verified that parthenocarpy is the result of the action of the dominant P gene, which expression is subject to the action of modifying genes. In addition, they concluded that parthenocarpy is independent from the hybrid structure and the polyploidy, and that the parthenocarpic plants are not completely sterile.

Subsequently, Simmonds (1953) verified that its inheritance is a more complex process, and that a minimum of three dominant genes (P1, P2 and P3) are involved in crossings among wild bananas. However, Ortiz and Vuylsteke (1992a) observed that the variation in fruit size and in parhtenocarpy of Plantain hybrids is due to the segregation of a single dominant gene. The dominance of male bracts and neutral flowers in the male rachis of the bunch is controlled by complementary and independent genes, which can be affected by the environment. Fouré et al. (1993) verified that male sterility in Plantain diploid hybrids can be due to the interaction of the sensitive cytoplasm in the Plantain with at least three recessive nuclear genes in the banana.

Phenotypic traits and types of gene action in *Musa*.

Traits	Types of gene action	Reference
Albinism Waxy in pseudostem	Two complementary recessive genes Ortiz and Vulsteke (1994b) Waxy in pseudostem One recessive gene, plus additive genes changing the expression	Ortiz and Vulsteke (1994b) Ortiz et al. (1995c)
Dry matter contents in the fingers	Additive genes	Ferris and Ortiz 1
Apical dominance	One major recessive gene in plantains	Ortiz and Vulsteke (1994c)
Male and female fertility	Recessives genes interacting with cytoplasm sensitive	Ortiz, (1995); Fouré et al. (1995)
Margins form of the petiole Blak pseudostem blotches Blotches in the pseudostem Dwarfism in Cavendish Dwarfism in type French	Duplicate genes with dominant effect Modifier gene due to recessive suppressor Two independents genes with	Ortiz (1995) Ortiz, (1995) Ortiz (1995) Rowe and Richardson (1975) Ortiz and Vulsteke (1995)

plantains	dominant epistasis in plantains and one complementary additional recessive gene in banana One dominant gene with modifier gene interaction One major recessive gene for short false internodes with modifiers affecting plant height	
Bunch orientation	Three loci with threshold effect of dominant genes	Ortiz (1995)
Fruit parthenocarpy	Three independent complementary dominant genes One segregating locus in plantain hybrids and Calcutta 4	Simmonds (1952) Ortiz and Vulsteke (1992)
Fruit ripening period	Transgressive segregation due two complementary genes or partially dominant gene(s) toward long shelf life	Ferris and Ortiz1
Persistence of male bracts	Two loci with complementary dominant genes, which are independent of the genes for persistence of hermaphrodite flowers in plantains	Ortiz (1995)
Persistence of hermaphrodite flowers and male bracts	Two independent loci with complementary and dominant genes in bananas and plantain-banana hybrids	Simmonds (1952); Ortiz (1995)
Bunch weight	Epistatic interactions increase yield in poliploid hybrids	Ortiz and Vulsteke (1993)
Red pigmentation in leaves	Modifier gene interaction due to	Ortiz (1995)

Pollen presence with 2n chromosomes Dominant gene Banana weevil resistance	recessive suppresor Gene(s) with incomplete/partial dominance toward resistant parent in the diploid plantain-banana hybrids	Ortiz (1997) Ortiz et al. (1995)
Bacterial wilt (moko disease) resitance	Several recessive genes	Vakilii (1965b); Rowe and Richardson (1975)
Fusarium wilt reistance	One major dominant gene for race 1. Polygenic system for race 4	Larter (1947);Vakili (1965a). Rowe (1991)
Burrowing nematode resistance	One or more dominant genes	Rowe (1991)
Yellow Sigatoka resistance Black Sigatoka resistance	Recessive genes in *M. acuminata* ssp. burmanica Dominant genes in *M. acuminata* ssp. m*alaccensis* Multiple genes with dosage effects in *M. acuminata* ssp. One major recessive gene and two additive minor genes with dosage effect in plantain – banana hybrids*icrocarpa* e ssp. e*rrans*	Shepherd (1990) Rowe (1984) Vakihi (1968) Ortiz and Vulsteke (1994 a)
Fruit size and weight	Larger fruits in polyploids due to epistasis. Several dominant genes in *M. acuminata ssp. malaccensis*	Ortiz and Vulsteke (1993) Rowe (1984)

Citrus (*Citrus spp* .)

- ✓ Sexual progenies from hybridization are commonly highly variable.
- ✓ Single gene inheritance is rarely found and F_1 offspring often display a wide quantitative range of character expression (Furr, 1969).
- ✓ Several undesirable characters such as Small fruit size, seediness, paleness of colour and presence of oil gland in juice sacs and rinds appear to be dominant (Soost,1987).

- ✓ Trifoliate leaf characters of Poncirus show essentially complete dominance over monofoliate condition of citrus.
- ✓ Purple colour in young leaves in lemon is governed by a dominant gene. Crossing between polyembryonic cultivars and monoembryonic cultivar resulted both type of offspring in 1:1 ratio.
- ✓ Small size of fruits, sadiness and paleness of colour to be dominant.
- ✓ Characters like presence of thorns, pubescence and oil gland are dominant characters whereas reduction of nectarines and scaleness of flower are recessive.

Papaya (*Carica papaya*)

- ✓ The studies with regard to inheritance of quantitative characters are limited in papaya.
- ✓ Wasee *et al*. (1983) found that additive gene effects controlled fruit weight, fruit shape, flesh thickness and total soluble solids.
- ✓ Dinesh (1989) also found that additive gene effects controlled the characters fruit length, fruit breadth, cavity index, total sugar and total carotenoids.
- ✓ Singh (1990) reported that yellow color of flesh is dominant over orange or red flesh color. Fruit flavor and odor is governed by multiple genes (Yadav and Prasad, 1990).

Guava (*Psidium guajava*)

- ✓ Heritability in the broad sense encompasses all types of gene action including dominance, additive, and epistasis.
- ✓ Considerable research effort has gone into estimating the heritability pattern in guava.
- ✓ It has been observed that commercially important traits, such as yield, fruit size and quality characteristics (Vitamin C, acidity, pectin etc.) are often in low – heritability category.
- ✓ None of these characters are determined solely by major genes, although basic genes, subject to the modifying effects of polygenes, have been identified for some quality characters like skin color and acidity.
- ✓ However, the red pulp color is dominant over white and this character is governed monogenically (Subramanyam and Iyer, 1982).
- ✓ Many cultivated red fleshed varieties were found to be heterozygous for this character.
- ✓ Similarly, bold seed in guava were found to be dominant over soft seeds and this character was also found to be governed monogenically.
- ✓ A linkage was also found between red pulp color and bold seed size (Subramanyam and Iyer, 1982).
- ✓ Obovoid shape of the fruit is dominant over round and pyriform.

Grape (*Vitis vinifera*)

- ✓ Inheritance pattern has been studied extensively for different characters, viz. yield and quality attributs (Avramov *et al*., 1996), Seedlessness (Spiegel- Rao *et al*., 1980), time of ripening and aroma (Hirakawa *et al*., 1998).

- ✓ In grape, 3 major colours viz. white, red and black are found.
- ✓ Segregation for character supports a 2-gene hypothesis where B, a gene for black fruit is dominant and epistatic to that for red and white fruit (Barrit and Einset, 1969). Red fruit (bb Rr) is dominant to white which is recessive for both genes (bbrr).
- ✓ Sandhu and Uppal (1988) infer that berry colours are not sharply differentiated but observations show that black is dominant over both red and white, and red colour is dominant over white, although most of the red and black varieties appear to be heterozygous.
- ✓ Avramov *et al*. (1996) have also observed almost similar colour inheritance pattern. According to Wagner (1967), muscat flavour is controlled by five 5 complimentary dominant genes. Hirakawa *et al*. (1998) observed that inheritance of *muscat* and *labrusca* flavour obeyed the rule of independent assortment.
- ✓ Their results suggested that six complimentary dominant genes were involved in the inheritance of *muscat* flavour and five in *labrusca* flavour. Singh *et al*. (1985) could observe that larger berry size is dominant over small.
- ✓ The wide variation in the progenies with regard to berry shape showed that it is a polygenecally inherited character.
- ✓ Seedlessness in grape controlled by recessive factor.
- ✓ The presence or absence of anthocyanins in grape skin was inheritance of a quality character controlled by oligogenes, and anthocyanins content was a quantitative character controlled by polygenes.
- ✓ Glabrous young shoot, thicker cane, longer cane and internodes, short stiff hair on leaf surface, smaller size of leaf, main vein length and petiole length, vigorous and drooping habit of the vine, pentagonal leaf shape, shorter maturity period, low bunch weight, round berry and oval shape of seed show dominance character.

Pomegranate

- ✓ Scanty information is available on the inheritance of pattern of the pomegranate.
- ✓ Manohar et al (1981) reported that economic characters like rind weight, acidity percentage, fruit weight, aril per fruit, yield per tree and number of fruits per tree exhibit high heritability and high genetic advance.
- ✓ However according to Purohit (1987) use of soft seeded cultivars as male parent slightly decreased seed hardiness in hard seeded cultivars. Smaller fruit possess bright aril colour.
- ✓ A positive and significant relationship between brighter fruit colour and TSS and dark aril colour

and TSS was observed. Further, mellowness was associated with less sweetness.

Apple (*Malus x domestica*)

- ✓ Anthocyanin pigmentation in *Malus pumila* is controlled by a single dominant gene (Lewis and Crane, 1987).
- ✓ Brown and Harvey (1971) reported that fruit size, shape and acidity is governed by polygenes and high acidity was found to be dominant over low acidity.

Pineapple (*Ananas comosus*)

- ✓ Quantitative fruit characters like size and quality (acid and sugar content) have been reported to be governed by polygenic inheritance (Loison, 1990).

Litchi (*Litchi chinenesis*)

- ✓ Abortion of seeds at later stage of fruit development appears to be a recessive character (Dwivedi and Mitra, 1996).

Pomegranate (*Punica granatum*)

- ✓ Inheritance studies carried out indicated that high acidity was always dominant to low acidity, pink aril colour and hard seed nature was dominant to soft (Jalikop *et al*., 2005).
- ✓ Hard seeded pomegranate had higher fruit weight and volume that soft seeded ones (Jalikop and Kumar, 2005).

Almond (*Prunus communis*)

- ✓ Bitterness is inherited as a simple, single recessive genes (ss) in cultivated almond.
- ✓ Sweetness is dominant transmitted from homozygous (SS) parents as 100% sweet and segregates from heterozygous parents as sweet to bitter ratio of 3:1.

References (if any)

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2. **A textbook on Pomology (subtropical Fruits) Vol. III- T.K. Chattopadhyay**
3.