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# THE MORPHOLOGY AND VARIETAL CHARACTERISTICS OF THE RICE PLANT

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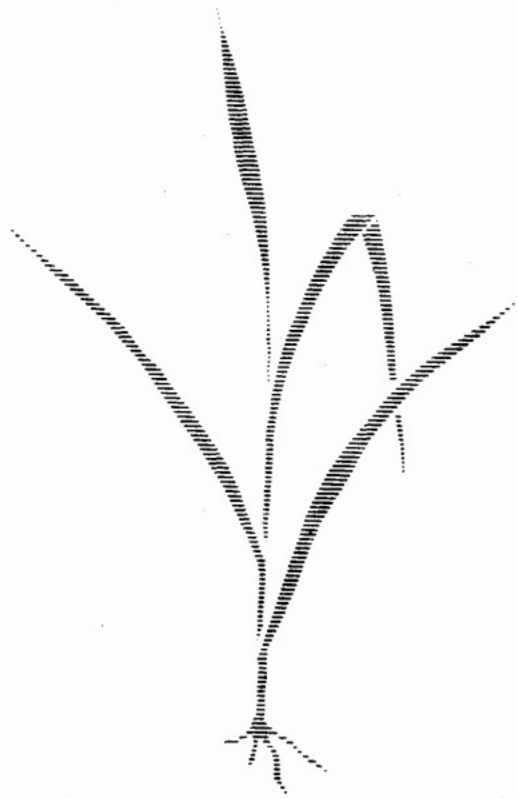
# Introduction



The wide geographical distribution of the rice plant ( *Oryza sativa* L.) and its long history of cultivation in Asian countries have led to the development of a great diversity of varietal types. Similarly, workers in various rice-growing countries use different terms to designate identical morphological and physiological characters, agronomic traits, gene symbols, and cultural practices. Whereas varietal diversity in germ plasm is desired in rice breeding, variations in nomenclature hinder scientific communication among the workers.

Workers long have recognized the need for uniformity in genetic nomenclature of rice. This led the International Rice Commission in 1959 to adopt a set of genetic symbols. Comprehensive reviews of genetic studies and linkage analysis have been published. The International Rice Research Institute has now assumed the task of monitoring gene symbols.

This publication (1) proposes a set of reasonably definitive terms that adequately describe the various parts of the rice plant and its processed products, (2) defines varietal characteristics that are useful in identification and classification, and (3) describes a number of commonly observed mutant traits in both morphological and genetical terms.

In selecting morphological names; terms based on botanical considerations take priority over agronomic terms of extensive usage. Synonyms are also included to provide a basis for concurrent use of terms.

In describing methods for measuring and recording varietal characteristics, simple and quick operations are preferred to elegant techniques that require precision apparatus. Considerable importance is given to the economic usefulness of the trait under description. Emphasis is also given to growth Characteristics of tropical varieties which constitute the bulk of the rice acreage of the world. It is recognized that many of the proposed techniques and methods are inadequate to describe fully. the enormous variation found in cultivated varieties or to cover the intricate growth behavior of the rice plant in different environments. Additional studies are needed to improve existing methods.

Rice workers are urged to adopt the proposed terms and methods of description, although some of them may appear inadequate, and to suggest ways and means of improvement.

# MORPHOLOGY OF THE RICE PLANT

The cultivated rice plant ( *Oryza sativa* L.) belongs to the tribe Oryzeae under the sub-family Pooideae in the grass family Gramineae (Poaceae) . Biosystematists recently divided the genus *Oryza* into several sections and placed *O. sativa* under series Sativa in section Sativae. *O. sativa* is indigenous to Asia.

*O. sativa* is a diploid species with 24 chromosomes. Its genomic formula is AA.

The rice plant may be characterized as an annual grass, with round, hollow, jointed culms, rather flat, sessile leaf blades, and a terminal panicle, Under favorable conditions, the plant may grow more than one year. As other taxa in the tribe Oryzeae, rice is adapted to an aquatic habitat.

While the ensuing description is based on the ubiquitous *O. sativa* L., the morphologic terms can also apply to the cultivated species of Africa, *O. glaberrima* Steud. (2n =24). *O. glaberrima* differs from *O. sativa* mainly in a lack of secondary branching on the primary branches of the panicle and in minor differences related to pubescence on the lemmas and length of the ligule. *O. glaberrima* is strictly an annual.

## Seedling Morphology

The grains of rice varieties that lack dormancy germinate immediately upon ripening. In dormant varieties, a rest period precedes germination and special procedures such as heat treatment (50°C. for 4-5. days) or mechanical dehulling are needed to break dormancy in freshly harvested samples.

The coleorhiza enveloping the radicle protrudes first if germination occurs in an aerated environment such as a well-drained soil. If the grain is submerged in water, the coleoptile emerges ahead of the coleorhiza.

The primary seminal root (radicle) [1] breaks through the coleorhiza shortly after the latter appears and is followed by two or more secondary seminal roots, all of which develop lateral roots. Seminal roots are later replaced by the secondary system of adventitious roots.

The coleoptile, which encloses the young leaves, emerges as a tapered cylinder. Its color varies from colorless, pale green to green, 'or pale purple to purple. The length of the axis between the coleoptile and the point of union of the root and culm is called the mesocotyl. The elongation of the mesocotyl elevates the coleoptile above the ground. The coleoptile later ruptures at the apex and the first seedling (primary) leaf emerges. The primary leaf is green and cylindrical and has no blade. The second leaf that follows is differentiated into sheath, blade, ligule, and auricles (Figs. 1 and 2).

[1]Term in parenthesis indicates a synonym.

## Vegetative Organs

The rice plant varies in size from dwarf mutants only .3 to .4 m. tall to floating varieties more than 7 m. tall. The great majority of commercial varieties range from 1 to 2 m. in height. The vegetative organs consist of roots, culms, and leaves. A branch of the plant bearing the culm, leaves, roots and often a panicle is a tiller.

### 1. Roots

The roots are fibrous, possessing rootlets and root hairs. The seminal roots are sparsely branched and persist only for a short time after germination. The secondary adventitious roots are produced from the underground nodes of the young culms and are freely branched. As the plant grows, coarse adventitious prop roots often form in whorls from the nodes above ground level. Some of the adventitious roots are positively geotropic, while others may be diageotropic. In floating varieties, fine branched roots form from the higher nodes on the long culm below the water surface.

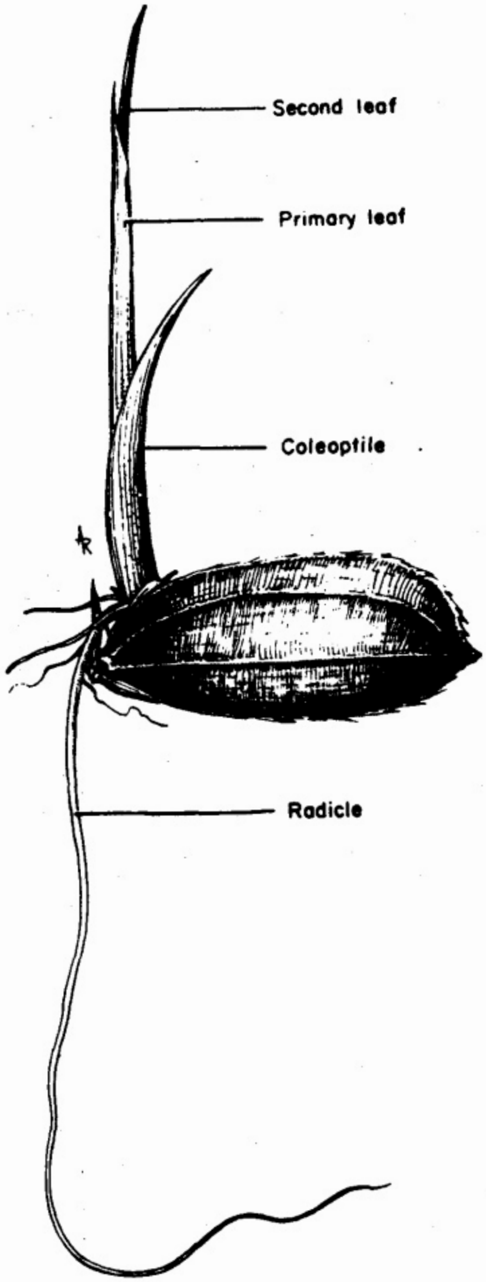



Fig. 1. Parts of a young seedling germinated under light.

Adventitious roots arise in both nodes and internodes and are usually found in the earlier formed ones.

**2. Culm**

The jointed stem of rice, called a culm, is made up of a series of nodes and internodes. The node (nodal region) bears a leaf and a bud. The bud is inserted in the axil between the nodal septum and the base of the sheath pulvinus. The bud may give rise to a tiller. Adventitious roots appear in the axis at the base of the internode. The septum inside the node separates two adjoining internodes. The mature internode is hollow, finely grooved, and glabrous on the outer surface. The nodal septum and internode may be differentially pigmented.

The internodes of a culm vary in length, generally increasing from the lower internodes to the

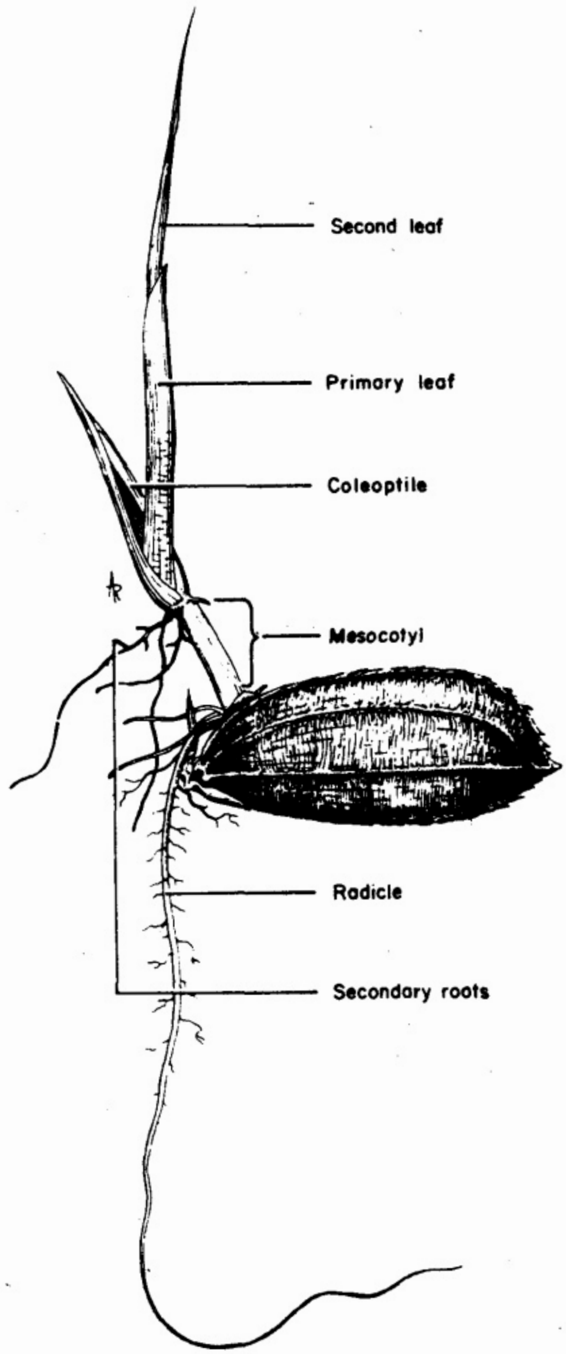



**Fig. 2. Parts of a young seedling germinated in darkness' showing the mesocotyl.**

upper ones. The lower internodes at the base of the culm are short and thickened into a solid section. A visually detectable internode (more than 5 mm. long) is considered as elongated. The internodes also vary in cross-sectional dimension, the lower ones being larger in diameter and thickness than the upper ones.

Tillers arise from the main culm in an alternate pattern. The primary tillers originate from the lowermost nodes and give rise to secondary tillers (Fig. 3). The latter give rise to tertiary tillers.

### 3. *Leaves*

The leaves are borne on the culm in two ranks, one at each node (Fig. 3). The leaf consists of the sheath and blade. The leaf sheath is continuous with the blade. It envelops the culm above the node in varying length, form, and tightness. A swelling at the base of the leaf sheath just above the point of its insertion on the culm is the sheath pulvinus. The sheath pulvinus is usually above the nodal septum and is frequently mistermed the node.

The blades are generally flat and sessile. Varieties differ in blade length, width, area, shape, color, angle, and pubescence. The uppermost leaf below the panicle is the flag leaf. The flag leaf generally differs from the others in shape, size, and angle. Varieties also differ in leaf number.

The upper surface of the blade has many ridges formed by the parallel veins. The most prominent ridge on the lower surface is the midrib.

Auricles are small, paired, ear-like appendages borne on either side of the base of the blade. At the junction of the blade and sheath on the inside is a membranous, glabrous or ciliate ligule. The ligule varies in length, color, and shape from variety to variety. The junction of the sheath and blade is the collar or junctura. The collar often appears as a raised region on the back of the leaf. The sheath pulvinus, auricles, ligule and collar on the same plant may be differentially pigmented. When pigmented, the dorsal, ventral and lateral parts of the collar may slightly differ in color. The auricles may not persist on older leaves.

The main culm bears the largest number of leaves. The leaf number on a tiller decreases progressively with the rise in tillering order. The first rudimentary leaf at the base of the main culm is a bladeless, 2-keeled bract, the prophyllum. The margins of the prophyllum clasp the young tiller with its back against the parent culm (Fig. 3). The prophyllum is also present between each secondary tiller and its tertiary tiller.

## Floral Organs

The floral organs are modified shoots. The terminal shoot of a rice plant is a determinate inflorescence, the panicle (Fig. 4). A spikelet is the unit of the inflorescence. The spikelets are pediceled on the branched panicle. The spikelet consists of the two sterile lemmas, the rachilla and the floret. A floret includes the lemma, palea and the enclosed flower. The flower consists of six stamens and a pistil, with the perianth represented by the lodicules.

### 1. *Panicle*

The panicle is borne on the uppermost internode of the culm which is often mistermed a peduncle. The extent to which the panicle and a portion of the uppermost internode extend beyond the flag leaf sheath determines the exsertion of the panicle. Varieties differ ·in degree of exsertion.

The nearly solid node between the uppermost internode of the culm and the axis of the panicle is the panicle base. This node generally does not bear a leaf or a dormant bud but may give rise to the first 1-4 panicle branches. The panicle base often appears as a ciliate ring and is used as a dividing point in measuring culm length and panicle length, The region about the panicle base is often called the neck.

The panicle axis (rachis) is the main axis of the inflorescence, extending from the panicle base to the apex, It is continuous and hollow except at the nodes where the panicle branches are borne. The swellings in the axils of the panicle where the branches are borne are the panicle pulvini.

The panicle has a racemose mode of branching in which each node on the main axis gives rise to the primary branches and each of which in turn bears the secondary branches. The secondary branches bear the pediceled spikelets. The primary branches may be arranged in a single or paired fashion.

Varieties differ greatly in the length, shape, and angle of the primary branches, and in the weight and density (number of spikelets per unit of length) of the panicle.

### 2. *Spikelets*

The spikelet is borne on the pedicel which is morphologically a peduncle. The apex of the pedicel below the sterile lemmas is expanded into a lobed facet of varying size, shape, and margin. Stapf and other systematists (cf. Chevalier 1937) considered the spikelet of *Oryza* as comprising three fiowers, two of which were reduced in development. Thus, the enlarged, cup-like apex is

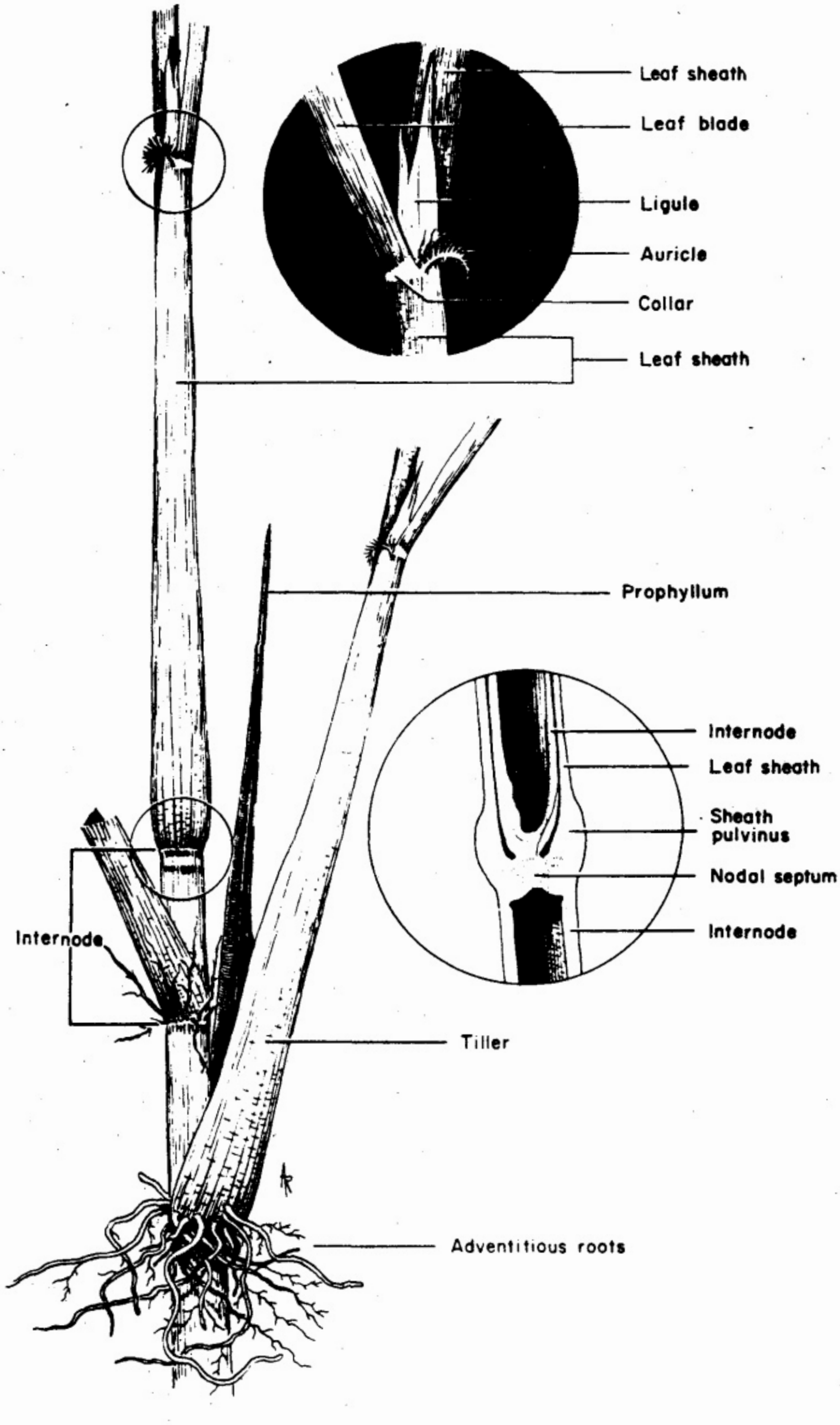



**Fig. 3. Parts of a primary tiller and its secondary tiller.**

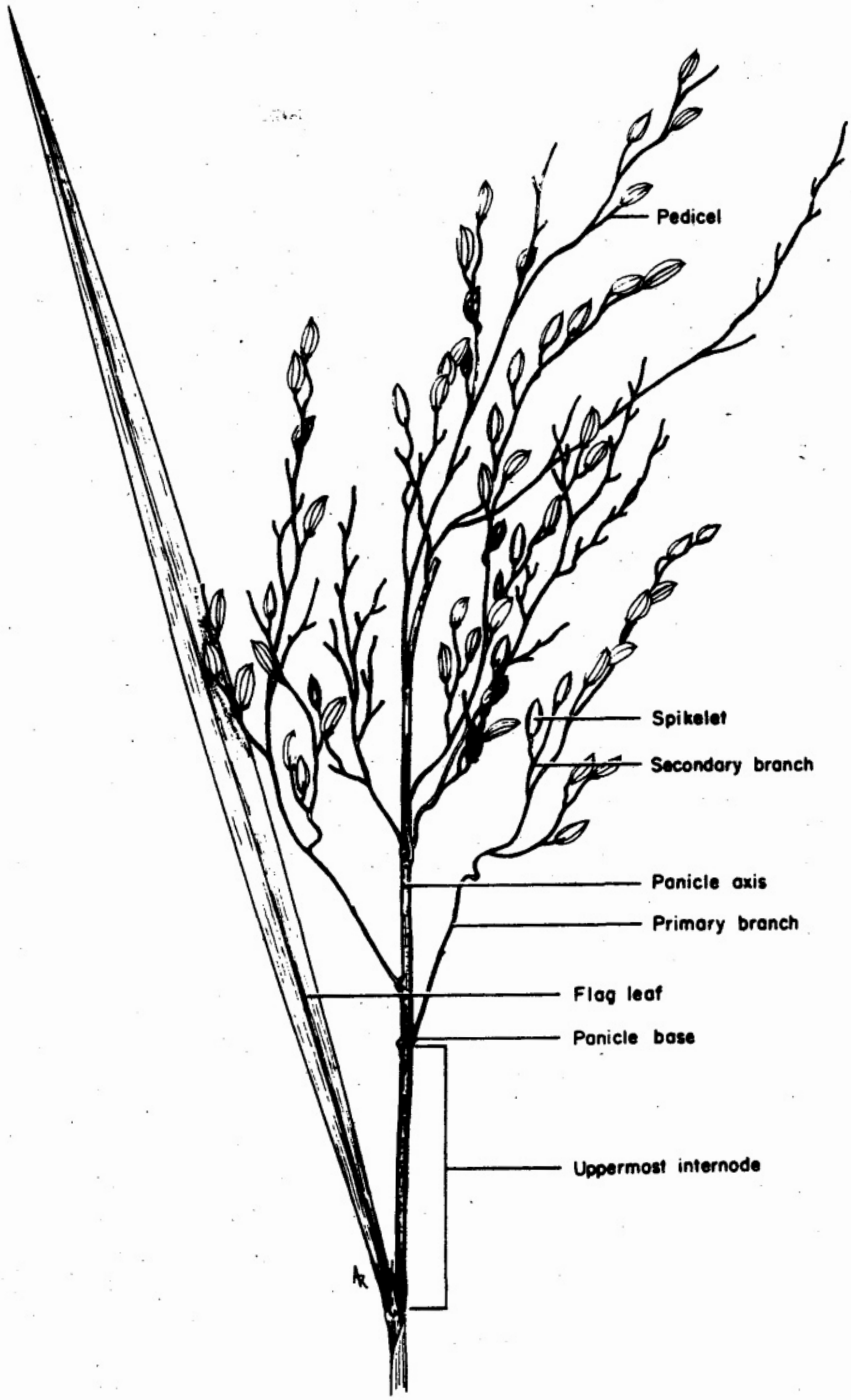



**Fig. 4. Component parte of a panicle (partly shown in this illustration).**

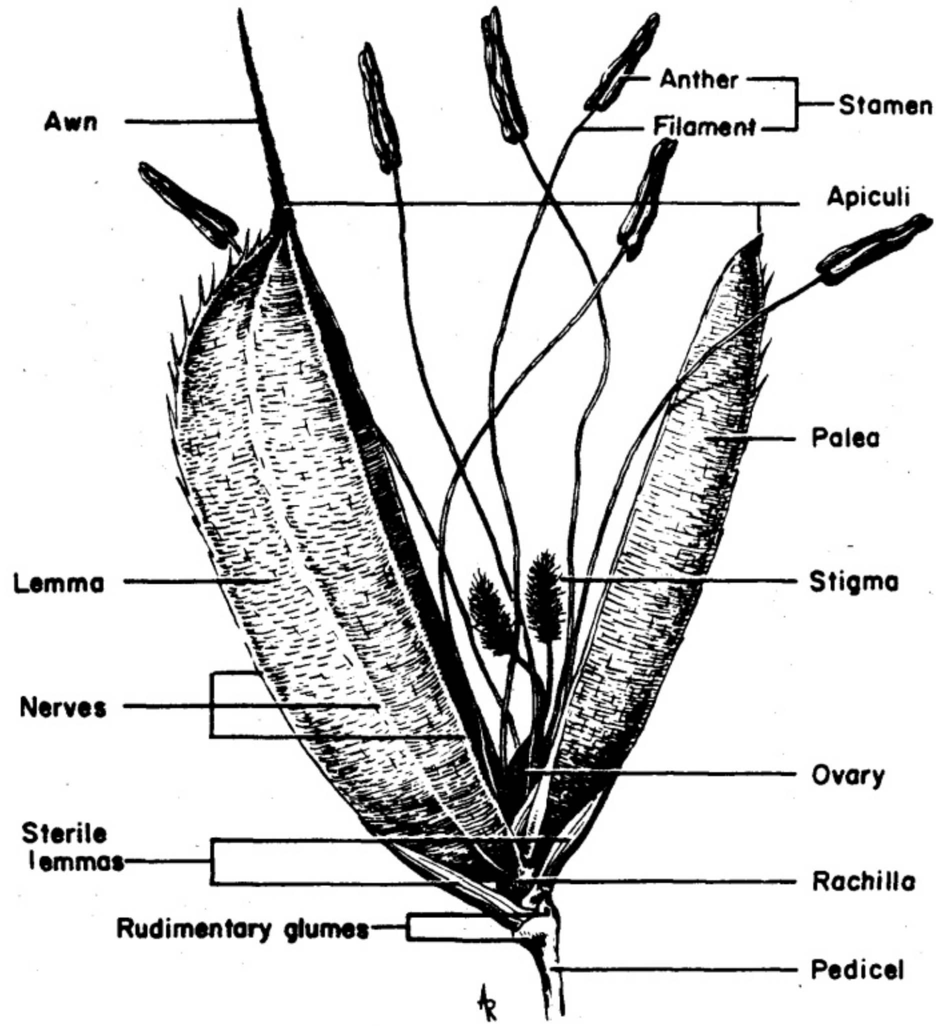



**Fig. 5. Parts of a spikelet.**

homologous with a pair of true glumes and may be termed the rudimentary glumes.

A spikelet consists of a minute axis (rachilla) on which a single floret is borne in the axils of 2-ranked bracts (Fig. 5). The bracts of the lower pair on the rachilla, being always sterile, are the sterile lemmas ("glumes," "empty glumes," "outer glumes")[2]. The upper bracts or the flowering glumes consists of the lemma (fertile lemma) and palea. The lemma, palea, and the included flower form the floret.

The sterile lemmas are generally shorter than the lemma and palea, seldom exceeding one-third the length of the latter. The sterile lemmas may be equal or unequal in size, the upper one generally being larger.

The lemma is the larger, indurate (hardened), 5-nerved bract which partly envelops the smaller, 3-nerved palea. The middle nerve or keel may be ciliate or smooth. The extended tips of the lemma and the palea are the apiculi. The apiculi may be separated into lemmal apiculus and paleal apiculus. The awn is a filiform extension of the keel of the lemma. The surface of the lemma and the palea may be pubescent or glabrous. In some varieties, a pair of lateral nerves on each side of the central nerve of the lemma may fuse to form a knob-like mucro on either side of the lemmal apiculus.

During natural shattering or the threshing process, the spikelet is separated from the pedicel at the junction of the lower sterile lemma and the

[2]As Stapf's interpretation is followed, the pair of bracts above the rudimentary glumes should be designated as the sterile lemmas. Therefore, such terms as glumes, empty glumes, outer glumes, and non-flowering glumes should be placed within inverted commas, e.g., "empty glumes."

facet (rudimentary glumes) . The base of the lower sterile lemma as is disarticulates from the pedicel is horizontal or oblique in appearance. The relative degree of development of the abscission layer between the sterile lemmas and tile facet is reported to be associated with the ease of shedding. Some varieties are threshed by the fracture of the pedicel rather than by disarticulation.

### 3. *Flower*

The flower proper consists of the stamens and pistil. The six stamens are composed of 2-celled anthers borne on slender filaments. The pistil contains one ovule. The short style bears the bifurcate, plumose stigma.

The lodicules are two wale-like, transparent, fleshy structures located at the base of the flower adnate to the palea. They represent the reduced perianth (calyx and corolla), At anthesis, the lodicules become turgid and thrust the lemma and palea apart, allowing the elongating stamens to emerge above or outside the open floret. Anther dehiscence may coincide with the opening of the lemmas, or immediately precede or follow it. The lemma and palea close after the pollen grains are shed from the anther sacs.

The rice fruit is a caryopsis in which the single seed is fused with the wall of the ripened ovary (pericarp), forming a seed-like grain. The grain is the ripened ovary, with the lemma, palea, rachilla, sterile lemmas, and the awn, if present, firmly adhered to it (Fig. 6). The lemma and palea and their associated structures such as the sterile lemmas, rachilla, and the awn whenever present constitute the hull or husk.

The dehulled rice grain (caryopsis) is called brown rice because of the brownish pericarp. Red rice owes its trade name to the red pericarp and/ or the red tegmen. The tip of the caryopsis is somewhat oblique, corresponding to the larger size of the lemma than that of the palea. The surface of the caryopsis has ridges which correspond to those of the lemma and palea.

The caryopsis is enveloped by the pericarp. The pericarp is fibrous and varies in thickness. Next to the pericarp are two layers of cells representing the remains of the inner integuments, the tegmen or seed coat (often mistermed the testa).

The embryo lies on the ventral side of the spikelet next to the lemma. The remaining part of the caryopsis is the endosperm which provides nourishment to the germinating embryo. The hilum is a dot adjacent to the embryo marking the point of attachment of the caryopsis to the palea. Another scar at the tip of the caryopsis marks the base of the style.

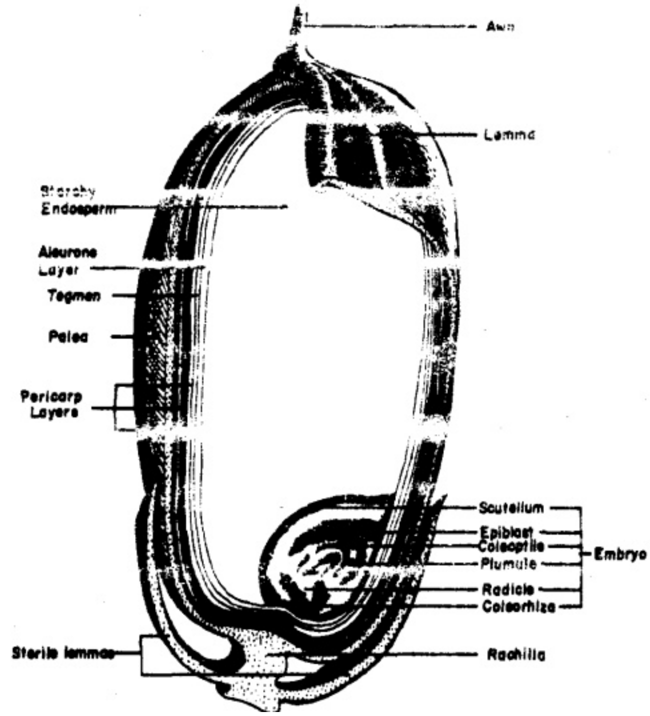



**Fig. 6. Structure of a grain (adapted from Grist, 1959).**

The embryo contains the embryonic leaves (plumule) and the embryonic primary root (radicle). The plumule is enclosed by the coleoptile and the radicle ensheathed by the coleorhiza; these form the embryonic axis, The embryonic axis is bounded on the inner side by the scutellum (cotyledon) which lies next to the endosperm. The coleoptile is surrounded by the scutellum and the epiblast, the vascular trace which is fused with the lateral parts of the scutellum.

The endosperm is enclosed by the aleurone layer which lies beneath the tegmen. The white starchy endosperm consists of starch granules embedded in a proteinaceous matrix. In the waxy (glutinous) varieties, the starch fraction is composed almost entirely of amylopectin and stains reddish-brown with weak potassium iodide-iodine solution. In the common, non-waxy (non-glutinous) types, the starch fraction contains amylose in addition to amylopectin and stains dark blue with potassium iodide-iodine solution. The starchy endosperm also contains sugars, fats, crude fiber. and inorganic matter.

Chalky white spots often appear in the starchy endosperm. Soft textured, white spots occurring in the middle part on the ventral side (side on which the embryo lies) are called white bellies. A white chalky region extending to the edge of the ventral side and. toward the center of the endosperm is called a white core. A long white streak on the dorsal side is called the white back

## Trade Terms

During the process of milling and polishing, the hull is first removed from the grain (trade name: rough rice or paddy) in a sheller. The pericarp, tegmen, embryo; aleurone layer, and a small portion of the starchy endosperm are then removed as the bran. In the U.S. rice trade, the coarse outer bran layers, the embryo (germ) and small bits of endosperm constitute the rice bran. The rice polish (white bran) refers to the inner layers of the bran removed during polishing. The bulk of the starch endosperm remains as the total milled rice (polished rice).

In U.S. trade terms, total milled rice is separated into head rice (whole kernels), second heads (broken kernels at least half as long as a whole one), screenings (broken pieces about 1/4 to 1/2 the length of a whole kernel), and brewers' rice (broken pieces which can pass through a 5½/64-inch sieve). The corresponding trade terms proposed by the Food and Agriculture Organization of the United Nations (FAO) are: whole rice or head rice (whole or nearly whole kernels), big brokens or second heads (broken kernels equal to or greater than half the length of a whole kernel), medium brokens (broken pieces between 1/2 and 1/4 the length of a whole kernel), small brokens (broken pieces which are smaller than 1/4 of a kernel but do not pass a sieve with perforations of 1.4 mm. or 0.055 inch), chips (small chips or particles of a kernel which can pass through a sieve having perforations of less than 1.47 mm.) and split kernels (pieces caused by a longitudinal splitting of the kernel).

Rough rice in the United States yields about 20 percent hulls, 8 percent bran, 2 percent polish, and 70 percent milled rice. Actually, the relative proportions of the above components vary greatly among rice varieties of any particular geographic region.

Parboiled rice is rough rice which has been subjected to a steam or hot water treatment prior to milling. Parboiling increases the percentage of head rice and the vitamin content of milled rice. Enriched rice is a blend containing ordinary milled rice and a small percentage of milled rice heavily fortified with thiamin, niacin, and iron phosphate to raise the vitamin and iron content slightly above the level present in brown rice. When the yellow-colored riboflavin is added to the enriching agents, white pigments such as calcium oxide, talc, and titanium dioxide are also included in the enriching mixture to make the finished product appear white.

## Growth Stages of the Rice Plant[3]

The vegetative phase of the rice plant begins with grain germination which is signified by the emergence of the radicle or coleoptile from the germinating embryo. This is followed by the pre-tillering stage during which seminal and lateral roots and the first few leaves develop while the contents of the endosperm are absorbed by the growing seedling. The tillering stage starts with the appearance of the first tiller from the axillary bud in one of the lowermost nodes. The increase in tiller number continues as a sigmoid curve until the maximum tiller number is reached, after which some tillers die and the tiller number declines and then levels off. The visible elongation of lower internodes may begin considerably earlier than the reproductive phase or at about the same time.

The reproductive phase may begin before the maximum tiller number is reached, or about the period of the highest tillering activity, or thereafter. This phase is marked by the initiation of the panicle primordium of microscopic dimensions in the main culm. Panicle development continues and the young panicle primordium becomes visible to the naked eye in a few days as a hyaline structure 1-2 mm. long with a fuzzed tip. The developing spikelets then become distinguishable. The increase in the size of the young panicle and its upward extension inside the upper leaf sheaths are detectable as a bulge in the rapidly elongating culm, often called the booting stage. When the auricles of the flag leaf are directly opposite the auricles of the next lower leaf, meiosis is usually occurring in the microsporocytes (pollen mother cells) and macrosporocytes of the panicle. This is followed by panicle emergence from the flag leaf sheath, commonly called heading. Anthesis or blooming begins with the protrusion of the first dehiscing anthers in the terminal spikelets on the panicle branches. Pollination and fertilization follow. The development of the fertilized egg and endosperm becomes visible a few days following fertilization. Grain development is a continuous process, but agronomic terms such as the milk stage, soft dough stage, hard dough stage, and fully ripe stage are often used to describe the different stages.

As the grains ripen, the leaves become senescent and turn yellowish in an ascending order. The non-

[3]The terms used were largely adapted from a tentative, unpublished nomenclature of growth stages of the rice plant proposed by a committee appointed during the Symposium on the Mineral Nutrition of the Rice Plant held at The International Rice Research Institute, February 23-28, 1964. The members of the committee are R. Best, T. F. Chiu, N. S. Evatt, S. Matsushima, C. P. Owen, A. Tanaka, and N. Yamada.

functioning leaves and culm tissues are termed dead straw. in some varieties, the culms and upper leaves may remain green when the grains are fully ripe.

Under favorable growth conditions, new tillers may grow from the stubble of the harvested plants. The second and subsequent harvests from the crop are called the first and second ratoon crops, respectively.

## Glossary of Morphologic Terms

1. ABSCISSION LAYER (syn. point of disarticulation, point of spikelet separation). Layer of cells related to the separation of a plant part, such as a leaf or fruit, from the plant. Structural changes (dissolution) in the abscission layer precede separation. In rice, the thickness of the abscission layer between the spikelet and the pedicel is reported to be associated with the ease of shedding in certain varieties.
2. ALEURONE LAYER. The peripheral layer of the endosperm, containing oil and protein but no starch.
3. APICULUS. The extending tip of .the lemma or palea. The two apiculi may be distinguished as lemmal apiculus and paleal apiculus.
4. AURICLES (syn. sickles). A pair of small, ear-like appendages borne at the base of the blade and usually arising at the sides where the ligule and the base of the collar are joined. This structure may not persist on the older leaves.
5. AWN (syn. arista, beard). A filiform extension of varying lengths from the keel (middle nerve) of the lemma.
6. BLADE (syn. lamina). The linear-lanceolate, flat, sessile and free portion of the leaf. It is continuous with the leaf sheath. Blades on the same plant differ in length, width, and angle of insertion.
7. BROWN RICE (syn. husked rice, cargo rice). The caryopsis or dehulled grain.
8. CARYOPSIS (syn. brown rice). The mature fruit of grasses in which the seed coat firmly adheres to the pericarp.
9. COLEOPTILE (syn. sheathing leaf, "first leaf"). The cylinder-like, protective covering that encloses the young plumule. It persists only for a short time after germination.
10. COLEORHIZA. The sheath covering the radicle.
11. COLLAR (syn. junctura, neck, leaf cushion). The joint between the leaf sheath and balde. The collar usually differs in color from the leaf sheath and blade.
12. CULM (syn. stem, haulm). The round, smooth-surfaced ascending axis of the shoot, consisting of hollow internodes jointed by solid nodes. It bears the leaves, panicle, adventitious roots and axillary buds, it may be primary, secondary, or tertiary, depending on tillering order.
13. EMBRYO (syn. germ, eye). The miniature plant developed from the fertilized (diploid) egg, the zygote, which upon germination gives rise to a young seedling. The basic parts of a mature embryo are the embryonic axis and the scutellum. The embryo is appressed to the endosperm by the scutellum. The embryo lies on the ventral side of the caryopsis next to the lemma., It is easily detached and removed in the milling process as pert of the bran.
14. EMBRYONIC AXIS. The plumule enclosed by the coleoptile and the radicle ensheathed by the coleorhiza form the embryonic axis in the embryo.
15. ENDOSPERM. Nutritive tissues of the ripened ovary, consisting of the aleurone layer and the starchy endosperm. The endosperm is triploid, derived from the fertilization of two polar nuclei in the embryo sac by one sperm nucleus from the pollen tube.
16. EPIBLAST. A small structure opposite the scutellum in the embryo. Sometimes. considered to be a rudimentary cotyledon. It has no vascular tissue.
17. FLORET. A unit of the spikelet, including the lemma, palea, and the enclosed flower.
18. FLOWER. The two lodicules, six stamens, and the pistil.
19. GRAIN (syn. rough rice, paddy, caryopsis, seed). The ripened ovary and its associated structures such as the lemma. palea, rachilla, sterile lemmas, and the awn if present. Sterile or under-developed ovaries enveloped by a well-developed lemma and palea should be termed empty or under-developed spikelets.
20. HILUM. A scar on the caryopsis indicating the point of attachment to the palea.
21. HULL (syn. husk. chaff). Includes the lemma ana palea. Structures such as the rachilla, sterile lemmas, the awn if present, and broken segment of the pedice1 are usually associated with the hull, if they survive the threshing process.

22. INTERNODE. The smooth, solid (when young) or hollow (when mature) part of the culm, short basally and long apically, between two successives nodes.

23. LEAF SHEATH (syn. sheath, vagina). The lower part of the leaf, originating from a node and enclosing the internode above it and sometimes the leaf sheaths and blades of the succeeding internodes.

24. LEMMA (syn. fertile lemma, flowering glume, "glume," "outer glume," lower palea, palea inferior, valve). The indurate (hardened), 5-nerved bract of the floret partly enclosing the palea,

25. LIGULE. A thin, upright, membranous structure seated on the inside of the collar at ita base where the blade joins the leaf sheath. It is often bilobed, ciliate or glabrous.

26. LODICULES. The two scalelike structures which are adnate to the base of the palea. They represent the rudiments of the perianth (calyx and corolla).

27. MESOCOTYL. The internode between the scutellar node and the coleoptile in the embryo. In the young seedling, mesocotyl is the internode between the coleoptile node and the point of union of the culm and root. Its length can be measured only when the seedlings are grown in the dark or from the underground portion of the seedling,

28. MUCRO (syn. glandular process). A small bulge on either side of the lemmal apiculus formed by the fusion of the two lateral nerves.

29, NODAL SEPTUM. The solid partition in the node separating two adjoining internodes.

30. NODE. The solid portion of the culm, panicle axis, and panicle branches. From the axils of nodes on the culm may arise a leaf, a tiller, or adventitious roots; from nodes on the panicle, the branches or spikelets.

31. NON-WAXY ENDOSPERM (syn. common, non-glutinous rice). Starchy endosperm in which the starch fraction contains both amylose and amylopectin. It stains dark blue with weak potassium iodide-iodine solution. The non-waxy type cooks drier than the gluey waxy type.

32. OVARY. The bulbous, basal portion of the pistil containing one ovule.

33. PALEA (syn. palet, pale, upper palea, palea superior, "inner glume," "glume," flowering glume, valvule). The indurate, 3-nerved bract of the floret which fits closely to the lemma. It is similar to the lemma but narrower, keeled, with a median bundle but with no strong midnerve on the back. The two other nerves are close to the margins.

34. PANICLE (syn. inflorescence, head, ear). The determinate inflorescence of rice with a racemose mode of branching, bearing pediceled spikelets and flowering from the apex downward.

35. PANICLE AXIS (syn. rachis, rhachis). The distinctly grooved, main axis of the panicle, extending from the base to the apex. The axis is hollow except at the regions (nodes) where the primary panicle branches are borne.

36. PANICLE BASE. The nearly solid node between the uppermost internode of the culm and the main axis of the panicle. This node gives rise to the first primary branches of the panicle (1-4) and usually bears no leaf or dormant bud.

37. PANICLE PULVINUS. A swelling in the axils of the primary panicle branches, more noticeable during panicle emergence.

38. PEDICEL (syn. foot stalk, peduncle). The stalk supporting a spikelet on the panicle branch. The distal end appears as a lobed cup, representing two rudimentary glumes (facet).

39. PERICARP. The wall of the ripened ovary, consisting of layers of cells which form a protective covering around the seed. The pericarp layers may be differentiated into epicarp, mesocarp and endocarp. The pericarp is derived from diploid maternal tissue. It is light brown, speckled reddish-brown, red or purple.

40. PLUMULE. The embryonic leaves of the young plant in the embryo. It is enclosed by the coleoptile.

41. POLLEN GRAINS. The minute, spheroidal structures (spores) in the anthers of a floret. They are microgametophytes, consisting of a haploid tube nucleus and a haploid generative nucleus. Upon germination, the pollen tube containing a tube nucleus and two sperm nuclei (gametes) grows down through the style, penetrates into the embryo sac, and the sperm nuclei achieve the double fertilization process.

42. PRIMARY LEAF (syn. prophyll, "second leaf"). The first seediing leaf without a blade that emerges next to the coleoptile.

43. PROPHYLLUM (syn. coleoptyloid) . A small, 2-keeled bract enclosed by the leaf sheath with the back against the parent culm and its margins clasping the young tiller.

44. RACHILLA (syn. rhachilla, callus). A diminutive axis between the rudimentary glumes,

the sterile lemmas, and the fertile floret. It rarely branches.

45. RADICLE. The embryonic primary root ensheathed by the coleorhiza and the root cap? persisting only for a short time after germination.

46. ROOTS. The organs of absorption and anchorage, growing opposite the shoot, comprising the short-lived seminal roots and adventitious secondary roots which arise from the lower nodes of the culm.

47. RUDIMENTARY GLUMES (syn. glumes, vestigial glumes, first and second glumes, facet). The true glumes of .a typical grass spikelet which are reduced to minute lobes in rice, opposite one another at the tip of the pedicel.

48. SCUTELLUM (syn. cotyledon). The portion of the embryo partly surrounding the embryonic axis, containing oil and protein for the germinating plant. It serves as an absorbing organ to transfer nutrients from the endosperm to the young seedling.

49. SEED. The mature, fertilized egg including the seed coat, embryo and endosperm. In rice, the seed coat is firmly adhered to the maternal pericarp. Therefore, the seed is an inseparable part of the fruit (caryopsis). The term seed, as used in seeding or sowing, actually refers to the grain.

50. SHEATH PULVINUS (syn. sheath joint). A small swelling at the base of the leaf sheath just above its point of insertion on the culm. Often mistermed the node.

51. SPIKELET. A unit of the rice inflorescence consisting of the two sterile lemmas, the rachills and the floret. The two rudimentary glumes are considered to be a part of the spikelet.

52. STARCHY ENDOSPERM. The bulk of the endosperm within the aleurone layer, consistting largely of starch granules embedded in a proteinaceous matrix. The starchy endosperm also contains sugars, fats, and fibers. The bulk of the starchy endosperm survives the milling and polishing process as the milled white rice.

53. STERILE LEMMAS (syn. “glumes,” “empty glumes,” “outer glumes,” lower and upper glumes, "non-flowering glumes,” first and second glumes, sterile glumes, lower and upper empty lemmas). The two flowerless bracts at the base of the spikelet. The two sterile lemmas may differ in length and shape.

54. TEGMEN (syn. seed coat). The two layers of cells lying next to the pericarp, representing the inner cell layers of the inner integuments of the ovule. The tegmen is often mistermed as testa which is derived from the outer integuments of the ovule and which is destroyed before the caryopsis ripens.

55. TILLER (syn. stool, branch, innovation). The intravaginal vegetative branch of the rice plant, typically including roots, culm and leaves, but which may or may not develop a panicle. The primary tillers originate from the lower nodes of the main culm. The primary tillers give rise to secondary tillers and the latter to tertiary tillers. All tillers arise in an alternate pattern.

56. WAXY ENDOSPERM (syn. glutinous rice). Starchy endosperm in which the starch fraction is composed almost entirely of amylopectin. It stains reddish brown with weak potas-. sium iodide-iodine solution. Waxy endosperm has an opaque appearance. It is “glutinous” in character, i.e., it becomes pasty and sticky when cooked. However, the waxy type of endosperm does not contain gluten. Rice pastries and high-quality rice wine are made from milled waxy rice.

# BOTANICAL AND AGRONOMIC TRAITS USEFUL IN VARIETAL CLASSIFICATION AND IDENTIFICATION

The thousands of cultivated varieties (cultivars) of *O. sativa* L. vary greatly in growth habit, form, size and structure. A strict botanical classification based on morphological differences does not provide sufficient criteria to embrace the enormous diversity in rice. Economic traits of a physiological, pathological, or quantitative nature may be used to aid in varietal identification. In such cases, it is desirable to indicate the environmental conditions under which the particular trait or traits were observed, e.g., latitude, growing period, cultural methods, essential meteorological data, and soil fertility level.

The commonly used plant characteristics and the methods of recording them are enumerated below. Some of these are being used to catalog The International Rice Research Institute's collection of 10,000 cultivated varieties. As some of the criteria are empirical measures, they may be modified to suit local needs. Standards may be based on local varieties if such standards are indicated in the published results. Information on sampling methods or sample sizes for quantitative traits may be obtained from Institute publications (IRRI 1964, 1965; Oñate 1964; Oñate and Moomaw 1965).

For quantitative traits which continuously vary within a variety when grown under different environments, such as height, maturity and size, physical measurements are more meaningful than generalized descriptive classification of tall and short, early and late, and others. Experiments showed that certain characters which were believed to exhibit discontinuous variation such as awn length, grain shedding, grain weight, grain dormancy, and intensity of pigmentation have shown marked variability when the plants are grown under different sets of environments.

Some of the exotic or extreme types are described under "Mutant Traits" which follows.

## Seedling Characteristics

**1. Seedling height:** For seedlings grown in the seedbed or directly sown in the field, the distance (in cm.) is measured from the base of the plant to the tip of the longest leaf of seedlings pulled at random at a given date (14-21 days) following seeding. Although varieties differ greatly in seedling vigor and rate of growth, there is no precise definition or means of measuring seedling vigor. Prompt emergence and rapid growth are generally desired in commercial varieties, particularly those designed for direct seeding.

**2. Juvenile growth habit:** Juvenile growth habit may be measured from the angle of the tillers observed from the entire plot prior to the maximum tillering stage.

a. *Erect* - an angle of 30° or less from the perpendicular.
b. *Spreading* - tillers have a pronounced spreading habit, leaning more than 60" from the perpendicular.
c. *Intermediate* - the angle is intermediate between erect and spreading.

Plants with prostrate habit in early growth may assume a less spreading form later in their lives. Juvenile plants of the intermediate type are less prostrate than those with the spreading habit.

**3. Leaf color:**

a. *Blades:* Foliage color is readily distinguished in the seedling stage. Standard color charts for plant tissues are available from the Munsell Color Charts for Plant Tissues (1963).
b. *Leaf sheath* : The sheath color of the lower leaves is readily classified. Color classes are shades of green, red, and purple. Description and color plates are given by Hutchinson et al. (1938) and Ghose et al. (1960).

4. Resistance to blast and other diseases: Seedling leaf reaction to the blast fungus *(Piricularia oryzae)* can be readily determined in a blast disease nursery. Operational details may be obtained from the procedure for establishing a Uniform Blast Nursery (Ou 1965) ., Varieties also differ markedly in seedling reaction to the bacterial streak disease, *Xanthomonas translucens* f. sp. *oryzae* ( *X. oryzicola* ) , the bacterial leaf blight disease ( *X. oryzae* ), and virus diseases (IRRI 1965, 1966).

5. Length of mesocotyl, coleoptile and primary leaf : Mesocotyl length is measured from 7-day old seedlings germinated at about 30°C. in total darkness. Mesocotyl and coleoptile development may serve as indices of seedling vigor during emergence. Length ratios of primary leaf/coleoptile and mesocotyl/coleoptile may also be used to differentiate varieties (cf. Nagai 1958).

6. Root color: Colorless (white) or red (under sunlight). As roots grow older, colorless roots may turn reddish brown because of the deposit of ferric hydroxide on the root surface.

7. Seedling reactions to specific chemicals: Varieties differ in their seedling reactions to specific chemicals. For instance, most of the tropical indica varieties are susceptible to the phytotoxicity of organo-mercuric fungicides, whereas the japonica varieties are largely resistant. The differential effect of herbicides on rice varieties may also be used to differentiate varieties.

Additional tests for physiological characters of rice seedlings have been described by Oka (1958).

## Adult Plant Characteristics

The characteristics of the adult plant are recorded during or shortly after anthesis. Some floral organs may also lose their color or fade as the plant matures. Therefore, when recording pigmentation it is desirable to indicate whether the plant is at the blooming or mature stage.

**1. Blade:** The uppermost leaf below the flag leaf on the main culm is taken as a representative blade.

a. *Pubescence* : Pubescent or glabrous (including smooth surface and ciliate margins).
b. *Length:* The distance (in cm.) from the junction of the blade and leaf sheath to the tip of the blade.
c. *Width:* Measured at the widest portion of the blade.
d. *Area:* Leaf area can be estimated by the product of length and width.
e. *Color:* Green is divided into pale green, green, and dark green. Standard color charts may be referred to for finer differentiations. Other colors are full purple, purple stripes, purple margins, and purple wash of a spreading type (Ramiah and Rao 1953).
f. *Angle* : Two measurements can be taken on the same blade. One is the angle of attachment of the blade measured near the collar. The other is the angle of blade openness measured up to the apex of the blade. In descriptive terms, blade angle may be classified as erect (angle of attachment and angle of blade openness nearly equal, straight blade), recurvate at the tip (angle of blade openness slightly larger than the angle of attachment., blade largely straight and erect but curved near its tip), curving (angle of openness larger than that of attachment, blade gently curving throughout its length) and drooping (angle of openness much larger than that of attachment, blade generally long and its tip dips lower than the collar).

2. Angle of flag leaf: Angle of 0-30' at full blooming is rated erect; 31-60°, intermediate: 61-90°, horizontal ; and 91° or more, descending.

3. Leaf sheath: Sheath color is taken on the first leaf below the flag leaf. Colors of the sheath on the outside are green, several shades of purple, full purple, purple stripes, and purple lines. Sheath color variations have been illustrated by Hutchinson et al. (1938), Ramiah and Rao (1953). and Ghose et a1. (1960).

The color of the inside sheath base (sometimes called the leaf axil) just above the pulvinus is another taxonomic criterion. It varies from colorless (white) to green and shades of purple.

**4. Ligule:** Characteristics of the ligule are also recorded on the first leaf below the flag.

a. *Pubescence of fringes:* glabrous or ciliate.
b. *Length:* short (5-19 mm.), medium (20-34 mm.), and long (35-50 mm.).
c. *Color:* colorless (white), and shades of purple.

**5. Auricles:** Auricles are examined for presence or absence, coloration (colorless, or shades of purple), length and density of pubescence.

**6. Collar:** The collar may be colorless (white), green or purple.

**7. Culm:** Characteristics such as outer diameter, length, and color are recorded on the main culm at full blooming.

a. *Outer diameter* (in mm.) : the lowest elongated internode which is longer than 5 cm.
b. *Color of internode surface:* green, gold, shades of purple and purple lines. Color plates have been given by Hutchinson et al. (1938), Ramiah and Rao (1953), and Ghose

et al. (1960).

c. *Length:* The distance in centimeters from the ground level to the panicle base.

d. *Number:* Culm or tiller count includes both panicle-bearing and non-bearing tillers. Data are taken at the Institute during the main (wet) growing season, June-November. The ratio of bearing tillers to the total number of tillers is also a varietal charac-. teristic.

e. *Strength* : Culm strength varies among varieties and also within a variety with changing environments. This trait is first rated following panicle emergence by gently pushing the tillers back and forth at a distance of about 30 cm. from the ground. This bending test gives some indication of stiffness and resilience. Additional observation at maturity is made to record the standing position of the plants. Upright plants are considered sturdy. If culms break readily, they are termed brittle. Plants with bending or buckled culms are called weak or lodged.

Detailed information on straw strength may be obtained by (i) mechanical culm breaking or pulling devices, (ii) a brass chain hanging from the panicle base to give cLr (lodging resistance factor) estimates, or (iii) P/E estimates (ratio of critical straw strength to the modulus of elasticity) derived from culm measurements (cf. IRRI 1964, Chang 1964b).

**8. Nodal septum:** The color of the septum is best seen by slitting longitudinally the lower portion of the culm and examining the cut surface. Colors are light yellow, pink, and shades of purple.

**9. Sheath pulvinus:** The pulvinus can be colorless (white), green, shades of purple (including red), or purple dots.

**10. Stigma color:** This is examined during anthesis using a hand lens. Colors are colorless, yellow, light purple, or purple.

**11. Sterile lemmas** (recorded as the terminal spikelets start maturing) :

a. *Color:* colorless (white), straw, gold, brown, red or purple.

b. *Length:* short (less than one-third of lemma), long (more than one-third), or extra long (longer than lemma) ; nearly equal or unequal (one-sided) in length.

**12. Lemma and palea:**

a. *Color at anthesis:* green, pale yellowish green, gold, blackish brown furrows, shades of purple (purple tips, purple spread, or full purple), piebald and mottled patterns.

b. *Color at maturity:* White, straw, tawny (light to dark brown), gold, brown furrows, brown spots (piebald), russet, reddish brown, shades of purple, or sooty black. Color illustrations have been given by Hutchinson et al. (1938), Ramiah and Rao (1953), Takahashi (1957), and Ghose et al. (1960).

c. *Pubescence* : glabrous or pubescent ; short or long trichomes (indicate the length and density of trichomes and specific areas of measurement).

d. *Phenol staining:* Grains are soaked in 1.5 percent aqueous phenol solution for 24 hours, drained and air-dried. Hull color is then recorded : unstained, entirely stained (dark brown), or partly stained.

**13. Apiculus** (examined first during anthesis and then at maturity) :

a. *Color at anthesis* : straw white, seashell pink, rose red, tyrian rose, pomegranate purple, amaranth purple, pansy purple, and blackish red purple. Color plates have been given by Takahashi (1957).

b. *Color at ripening:* white, straw white, warm buff, ochraceous-buff, tawny (light to dark brown), russet, faded pink, faded red purple, and faded purple. Color plates have been given by Takahashi (1957).

c. *Pubescence* : glabrous or pubescent (indicate length and density).

**14. Awn** (recorded as the terminal spikelets start maturing)

a. *Presence* ;

 (i) Fully awned: all spikelets on the panicles are awned: but awns often vary in length.

 (ii) Partly owned : awned and awnless spikelets are present on the same panicle.

 (iii) Terminally awned: short awns are present on spikelets near the tip of the panicle branches.

 (iv) Awnless: awns are absent and do not develop under any condition.

b. *Length:* long, medium, short, or tip awn.

c. *Color:* colorless (white), straw, gold, brown, pink, red, purple, or black.

**15. Rachilla:** May be cup-like, elbow-like, or comma-like.

**16. Panicle:**

a. *Type:* open, compact, or intermediate.

b. *Length:* measured from the panicle base to the tip.

c. *Angle of primary branches:* erect, drooping, or intermediate.

d. *Form:* equilateral (paired branching) or unilateral (one-sided branching).

e. *Density* (number of spikelets per unit length of panicle) : dense, lax, and intermediate.

f. *Clustering:* in most varieties, the spikelets are evenly distributed along the primary or secondary branches. Occasionally, some varieties have two or more spikelets clustered on the' panicle branches at irregular intervals. The degree of clustering varies from 2 to as many as 48 on a secondary branch.

g. *Exsertion* :

(i) Exserted (panicle base is clearly above the flag leaf sheath).
(ii) Partly exserted (panicle base appears at the same level as the top of the flag leaf sheath).
(iii) Partly enclosed (panicle is partly enclosed by the flag leaf sheath).
(iv) Enclosed (panicle is entirely enclosed by the flag leaf sheath).

h. *Shattering:* Tight, intermediate, or shattering. Shattering can be measured in the field by gently grasping by hand the mature panicle and applying a slight rolling pressure. Ratings are:

(i) Tight.: few or no grains removed.
(ii) Intermediate: 25-50 percent of grains removed.
(iii) Shattering: more than 50 percent of grains removed.

Shattering can also be determined in the laboratory by rolling a weighted cylinder (about 1 kg.) several times over panicle samples placed on a flat or inclined board and counting the percentage of dropped grains.

i. *Weight* (of panicles on the main culm dried to 13 percent moisture content of grains).

**17. Maturity:** Maturity is computed in days from seeding to ripening of more than 80 percent of the grains on the panicle. Another commonly used measure is the date of panicle emergence (heading). Days from sowing to 5 percent emergence of all panicles in a plot may be called days to first heading; 60 percent emergence of all panicles, middle heading: and more than 90 percent emergence of all panicles, full heading.

For tropical varieties, the following maturity ranges are applicable: 100 or less, 101-115, 116-130, 131-145, 146-160, 161-176, 176-190, 191-205, and 206 or more.

The total growth duration of a rice variety generally may be resolved into 4 components: (a) basic vegetative phase, (b) photoperiod-sensitive phase, (c) thermosensitive phase, and (d) reproductive phase from panicle initiation to maturity. Among photoperiod-sensitive genotypes of diverse geographic origin, varieties often differ in the optimum photoperiod at which the panicle-initiation process is critically affected. Therefore, the growth duration of a photoperiod-sensitive variety at a given location or latitude is determined by the optimum photoperiod of the variety and the dates on which the critical photoperiod prevails at that latitude. Consequently, different planting dates usually affect the total growth duration.

Presently, no standard methods are available to evaluate readily the photoperiod response or thermosensitivity of many varieties. However, if duplicate plantings are made during different seasons, information on photoperiod sensitivity and/or thermosensitivity may be obtained, When photoperiod chambers are available, two controlled photoperiods (10 hr. and 16 hr. of light) would differentiate most varieties. A photoperiod-insensitive variety would initiate panicles under the 16-hour photoperiod (or comparable, natural long-day conditions) with a duration comparable to or not more than 10 days longer than that grown under the 10-hour treatment (or comparable, natural short-day conditions). Varieties showing a difference of 10-20 days in heading date may be classified as weakly photoperiod-sensitive: those with a difference longer than 20 days are definitely photoperiod-sensitive. The effect of thermosensitivity on growth duration is generally less than that of photoperiod sensitivity, especially in the tropics.

Formulas for estimating photoperiod sensitivity have been given by Chandraratna (1966, 1966), Oka (1954), and Katayama (1964).

Varieties also differ in the duration from anthesis to full maturity. The duration of grain development generally varies from 25 to 40 days.

**18. Plant height:** Measured on the main culm (or the tallest tiller) at or following anthesis from ground level to the tip of the panicle. Planting most of the photoperiod-sensitive varieties under short-day length would result in fewer tillers, shorter plants, and earlier maturity. At the Institute, plant height and other quantitative traits are measured in the main (wet) season, June-November.

**19. Internode elongation pattern:** Plant height is largely the summation of elongated internodes (including the panicle axis) on the culm. Rice varieties generally have 12 to 22 internodes, of which 4 to 9 are elongated 5 cm. or longer. The number and individual length of elongated internodes are characteristic of a certain variety under a given environment and are often associated with growth duration (cf. Guevarra and Chang 1965). Internode elongation patterns represented by ideograms or internode length/culm length ratios for specific internodes facilitate comparison of varieties under identical or different treatments (IRRI

1964, 1966 ; Guevarra and Chang. 1966).

**20. Photosynthetic leaves at maturity:** This characteristic is not commonly reported but may prove. useful to rice agronomists and breeders. It may be expressed as a ratio of photosynthetic leaves to the total number of leaves on the culm.

a. *Photosynthesis:* leaves retain their green color when panicles ripen.
b . *Dead* : leaves become non-functional even before the grains are fully mature.

**21. Spikilet or pollen fertility:** The mean percentage of fertility is obtained from the percentage of welldeveloped spikelets (or pollen grains) in the panicle and sampled from a number of panicles in the plot.

| Percentage of fertility | Classification |
|---|---|
| more than 90 | highly fertile |
| 75-90 | fertile |
| 50-74 | partly sterile |
| 10-49 | sterile |
| less than 10 | highly sterile |

**22. Grain dimensions, shape and weight:**

a) *Length. (mm.)* : longitudinal dimension measured from 10 well-developed grains as the distance from the base of the lowermost sterile lemma to the tip (apiculus) of the lemma or pales, whichever is longer. In the case of awned varieties, length is measured to a point comparable to the tip of the apiculm (Fig. 7). A photo-enlarger with a calibrated easel is used at the Institute for the above classification.
b) *Width (mm.)* : dorsiventral diameter messured from 10 grains as the distance across the lemma and–the palea at the widest point (Fig. 7).
c) *Thickness (mm.)* : lateral diameter measured from 10 grains as the largest distance between' the two lateral sides in the middle part of the caryopsis. A screw micrometer or a dial-type vernier caliper is used.
d) *Shape:* generally expressed as a ratio, between length and width.
e) *Weight:* measured from 100 grains dried to 13 percent moisture. Seven grain weight classes are given by FAO . Volumetric weight such as test weight or liter weight is another useful varietal characteristic.

**23. Hull percentage:** Hulls are readily removed in a sheller or dehuller. The proportion of hull to grain (rough rice) on a weight basis is another useful varietal characteristic. Hull percentage may vary from 16 to 35 percent among varieties. The complement of hull percentage is the percentage of brown rice.

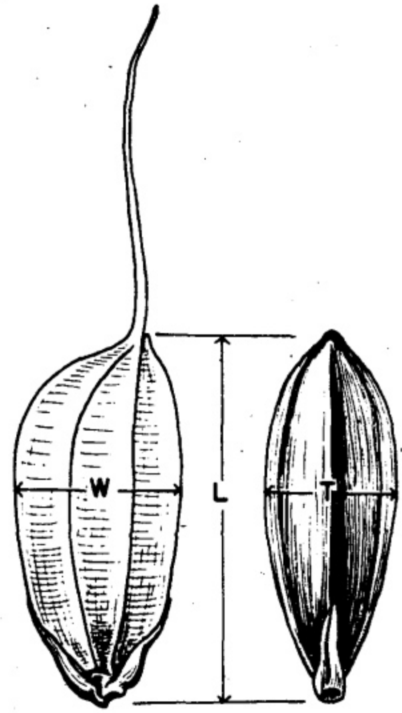



**Fig. 7. Length and width measures of the grain.**

**24. Dimensions, shape, and weight of brown or milled rice:** The size, shape, and 100-kernel weight of brown or milled rice are additional criteria for identifying varieties.

Two ,classification schemes that have been suggested are as follows:

| Size (length) | USDA scale for milled rice[4] | FAO scale for milled rice |
|---|---|---|
| Extra long | more than 7.60 mm. | more than 7 mm. |
| Long | 6.61-7.50 mm. | 6.0-7.0 mm. |
| Medium or middling | 5.51-6.60 mm. | 5.0-6.9 mm. |
| Short | less than 5.51 mm. | less than 6 mm. |

| Shape (length/ width ratio) | USDA scale for milled rice | FAO scale for brown ria |
|---|---|---|
| Slender | more than 3.0 | more than 3 |
| Medium | 2.1-3.0 | 2.4-3.0 |
| Bold | less than 2.1 | 2.0-2.39 |
| Round | - | less than 2 |

[4] Unofficial scale used by USDA rice researchers and is not the basis for official USDA marketing classes.

25. Pericarp and tegmen color: The color of brown rice is determined by pigments in the pericarp and tegmen. The starchy endosperm of all rice varieties is white. Pericarp and tegmen colors include white, light red, red, reddish brown, brown, grayish brown, golden, reddish purple, and full purple (almost black).

26. Amylopectin/amylose ratio in starchy endosperm : The amylopectin, amylose ratio expresses the relative proportion of each type of starch in the endosperm.

a. *Waxy or glutinous:* brownish staining reaction with weak potassium iodide-iodine solution, indicating that only amylopectin is present in the starch granules. Potassium iodide-iodine solution is prepared by dissolving 1 g. of potassium iodide and 0.3 g. of iodine in 100 ml. water.
b. *Non-waxy or non-glutinous, common* : dark blue staining reaction with potassium iodide-iodine solution, indicating the presence of amylose in the starch granules.

27. **Embryo size:** Small, medium, large.

28. **Physical features of milled rice:**

a. *Shape:* No standard measures are available for tropical varieties. Commonly used designations are slender (fine). medium, bold (coarse), round, and flat.
b. *Translucency* : translucent, opaque, and intermediate.
c. *Size:* Whole kernels and broken pieces may be separated by a sizing device and expressed as a ratio or percentage.
d. *Chalky spots:* white belly, white core, and white back.
e. *Hardness:* determined by a grain hardness tester as g./mm.[2]
f. *Weight:* 3 weight classes are given by FAO for 1,000-kernel weight of milled rice - very large (more than 28 g.) , large (22 to 28 g.), and small (less than 22 g.) .

29. Chemical properties of starchy endosperm related to cooking characteristics: Among rice varieties, grain size and shape are generally associated with certain cooking and processing characteristics. Most long-grain Varieties tend to become dry and fluffy when cooked and the cooked kernels do not split or stick together. Short-grain varieties are usually more cohesive and firm than long-grain varieties. Medium-grain varieties have generally intermediate features. There are many exceptions to this classification.

The differences in cooking and processing behavior are largely due to inherent differences in the chemical make-up of the starchy endosperm rather than to grain size and shape. Some of the inherent varietal quality differences are given below. Environmental factors such as temperature, light, nitrogen supply, and storage conditions also affect the cooking behavior.

a) *Amylose content:* High amylose content is associated with the dry, fluffy cooking features. Amylose content may be determined analytically (Williams *et al.* 1958) or estimated by the starch-iodine-blue test (Halick and Keneaster 1956).
b) *Gelatinization temperature* : Gelatinization temperature indicates the temperature at which starch granules swell irreversibly in water with a simultaneous loss of birefringence. It may be estimated by soaking milled rice for 23 hours in a weak alkali solution at 30°C. The extent of endosperm disintegration gives an estimate of relative gelatinization temperature. Alkali-resistant samples indicate high gelatinization temperature. Three classes are generally recognized: low (62°-69°), intermediate (70°-74°), and high (75°–80°). Gelatinization temperature also may be estimated by the amylograph test, the granule-swelling method, and the loss of birefringence of starch under a polarizing microscope. Amylose content and gelatinization temperature appear to be genetically independent (Beachell and Stansel 1963, Juliano *et al.* 1964).
c) *Pasting viscosity:* The difference ("setback") between peak viscosity of hot-paste (95°C.) and cooled paste (50°C.) measured with an amylograph suggests certain parboiling and canning characteristics of rice samples (Halick and Kelly 1959). Pasting viscosity is affected by amylose content and protein content.
d) *Protein content:* The exact role of protein content in determining cooking quality is not well understood but it is known to be affected by environmental and nutritional conditions under which the crop is grown. Protein content is determined by analytical methods.
e) *Aroma:* scented or non-scented. Whether a variety is scented or not may be detected during anthesis, milling and/or cooking. The identity of the volatile chemical (s) in scented rice has not been determined.

30. Resistance to diseases and insects: Rice varieties differ in their reaction to a specific pathogen or insect pest. Known examples include rice blast, bacterial leaf blight, bacterial streak, *Helminthosporium* leaf spot, *Cercospora* leaf spat, culm rot, sheath blight, rice stunt and other virus diseases, Rhizoctonia seedling blight, Fusarium seedling blight, white-tip disease (nematodes), leaf-hoppers, stem maggots, and the stem borers.

Varieties can be further differentiated in their reaction to specific pathogenic or physiologic races of one pathogen. Well known samples are specific varietal reactions to different races of the blast fungus. In other staple cereals, pure isolates of the rust fungi are sometimes used as a tool in purifying a breeder's seed of commercial varieties.

**31 . Reaction to physiological diseases.** Rice varieties also differ in their reaction to certain physiological disturbances. Known examples are differences in varietal resistance to straight head which is largely caused by prolonged flooding of some soils. Other examples are physiological diseases such as "Akiochi" and "Akagare" caused by a deficiency in certain nutrient elements and/or an excess of harmful products of extreme soil reduction.

**32. Cultural adaptation:** Rice culture is generally divided into lowland and upland culture. Lowland culture refers to continuous flooding of the fields except for occasional drainage, i.e., controlled irrigation. But upland culture embraces a continuous range from the strictly non-irrigated, upland type of cropping in Japan and certain parts of west Africa to the rain-fed "upland' 'fields of the tropics where the rice plant grows in flooded soil for a substantial portion of its life cycle. In the tropics an "upland" field means that either the field is elevated ground which gravity-fed irrigation system cannot reach and where water-retaining devices are not available, or is low-lying without adequate irrigation facilities. Yields from upland fields are generally lower than those from lowland fields.

Experiments have shown that most of the so-called upland tropical varieties gave higher yields when grown under irrigated conditions than under a natural, haphazard type of intermittent flooding. Some of the "upland" varieties yielded as high as or even higher than certain lowland varieties when grown under flooded conditions. Designating a variety as upland is not necessarily related to the resistance to drought of the variety either in the seedling or the adult stage.

A number of the so-called upland varieties grown in the tropics have the following characteristics in common: (1) rapid emergence from the soil following direct seeding, (2) vigorous seedling growth to compete with weed growth, (3) low to medium tillering ability, (4) non-sensitive or weakly sensitive to photoperiod, and (6) maturity ranges of 100 to 150 days.

No clearcut morphological or physiological criteria are yet available to differentiate rice varieties into lowland and upland types, although such terms are widely used as cultural designations.

In many river deltas of tropical Asia, rapidly rising water levels during the peak of the monsoon season permit only the growing of the floating varieties. Floating varieties are generally described as long duration (160-240 days), photoperiod-sensitive varieties with many internodes which can elongate rapidly to cope with rapid increases in water level. They are known to withstand 5 to 8 meters of standing water. There is also a group of varieties intermediate between the common, non-floating varieties and the fioating varieties. Called "deep-water'' varieties, they can stand 2 to 3 meters of water without obvious adverse effects.

The term saline-resistant or saline-tolerant varieties has been used to denote varieties than can tolerate salinity levels between 0.5 percent and 1.0 percent and still produce a fair yield of grain. Again, simple and reliable .tests for resistance to salinity need to be formulated.

Varieties also differ markedly in tolerance to low air temperatures and strong air movement shortly after seedling emergence from the soil. These differences are crucial in sub-tropical and temperate regions where rice is sown early in the year. As a general rule, the temperate zone japonica varieties are more tolerant than the tropical indicas.

At high latitudes, low air temperatures during the period between panicle development and pollen fertilization cause high sterility. Heritable differences among Japanese varieties have been obtained to facilitate selection for more tolerant strains.

Irrigation water of low temperature readings early in the planting season has caused severe mortality to rice seedlings in California and Hokkaido. There is sufficient varietal diversity to enable rice breeders to select cold-water resistant strains.

**33. Seasonal adaptation** : Rice varieties of India and Pakistan are divided into autumn, winter, spring, and summer varieties on the basis of the harvest season. Other classification schemes based on growing period are : main and off seasons ; early, medium, and late seasons; first and second seasons ; and wet and dry seasons.

Experiments have shown that the above divisions were based largely on photoperiod sensitivity and thermosensitivity. As mentioned before, varietal differentiation based on specific physiological characters is preferred to cultural designation.

**34. Ratooning ability:** Rice varieties differ in ratooning ability following initial harvest. But attention must be given to uniformity in cultural factors such as water and nutrient supply when comparing varietal differences in ratooning ability.

**35. Yield and yield components:** The three basic physical components of grain yield per unit area are (a) the number of panicles per unit area, (b) the number of welldeveloped grains per panicle, and (c) grain weight. Under comparable growth conditions, each variety shows a fairly consistent composition of grain yield in terms of the three components. Rice varieties have been divided into three groups on the above basis : (a) "panicle-weight" or "heavy-eared" type (large and heavy panicles, few panicles per plant), (b) "panicle-number" or "many-eared" type (small and light panicles, many panicles per plant), and (c) an intermediate type.

Grain yielding ability is also used as a varietal characteristic. When used as such, plot yield is more meaningful than single-plant yield. Grain yield data supplemented by data on the three components provide more information for comparative or diagnostic studies.

The grain/straw weight ratio is another criterion which has shown relatively high consistency in certain varieties and may therefore be used as an additional basis for varietal differentiation.

**36. Geographic designation** : Since two hundred B.C., rice varieties of China were recorded under three groups: 'hsien', 'kêng', and glutinous. In 1928-1930, Japanese workers (Kato et al. 1928) divided cultivated rice into two subspecies, *"indica"* and *"japonica,"* on the basis of geographical distribution, plant and grain morphology, hybrid sterility, and serological reaction. The indica group (= 'hsien') included varieties from Ceylon, southern and central China, India, Java, Pakistan, Philippines, Taiwan, and other, tropical areas, whereas the japonica group (= 'kêng') consisted of varieties from northern and eastern China, Japan and Korea. Japanese workers (Matsuo 1952, Oka 1958, Morinaga 1954, Morinaga and Kuriyama 1958) later added a third group, "javanica," to designate the bulu and gundil varieties of Indonesia.

The above three groups and their general morphological and physiological features are summarized as follows :

| INDICA | JAPONICA | JAVANICA |
|---|---|---|
| Broad, light-green leaves | Narrow, dark green leaves | Broad, stiff, light green leaves |
| Slender, somewhat flat grains | Short, roundish grains | Broad, thick grains |
| Profuse tillering | Medium tillering | Low tillering |
| Tall plant stature | Short plant stature | Tall plant stature |
| Mostly awnless | Awnless to long awned | Awnless or long awned |
| Thin and short hairs on lemma and palea | Dense and long hairs on lemma and palea | Long hairs on lemma and palea |
| Easy shattering | Low shattering | Low shattering |
| Soft plant tissues | Hard plant tissues | Hard plant tissues |
| Varying sensitivity to photoperiod | Varying sensitivity to photoperiod | Low sensitivity to photoperiod |

Other criteria used by Japaneee workers to classify varieties are endosperm characteristics, physiological characters of germinating seedlings and adult plants, phenol staining of hulls, resistance of seedlings to $KClO_3$ toxicity, and seedling reaction to organo-mercuric compounds.

Later studies with larger collections of varieties showed that the morphological and physiological variations among the three geographic groups were largely continuous, and the phenomenon of intervarietal hybrid sterility was much more complicated than a simple classification of three groups.

Therefore, the above scheme of dividing rice varieties into geographic races is rapidly losing its significance. Varieties which fall into the japonica group have been isolated in semi-wild conditions from Nepal, Ceylon, the Jeypore Tract of Orissa State in India, and northern Thailand. Hybridization on a wide genetic basis has further confused the classification scheme. This is particularly true with U.S. and Taiwan varieties developed in recent years.

Despite these shortcomings, the terms indica, japonica, and javanica are often used by rice scientists in Asia as convenient designations to indicate different plant and grain types.

**37. Other tests of potential value:** In addition to the above methods and criteria, several others which show promise in differentiating varieties are cited below :

a. *Spodogram analysis:* The shape, density, and distribution of silica cells in the epidermal tissues of blades and leaf sheath are highly characteristic of certain varieties.
b. *Grain (seed) dormancy:* Germination tests of freshly harvested panicles, air-dried to about 14 percent moisture, will give an indication of dormancy. Varieties differ in the duration and intensity of dormancy (Jennings and de Jesus 1964).
c. *Leaf characters:* Varieties differ in leaf dimensions, density and arrangement. The leaf area index (LAI) of the blades is highly characteristic of a variety when grown under a given set of environmental condition8 and is useful in comparing the efficiency of leaves in utilizing sunlight. Other criteria related to leaf area index and useful in differentiating varieties are the light transmission rate ($I/I_0$) and the extinction coefficient (K). Among the three, the light transmission rate is the most readily measurable criterion (cf. Hayashi and Ito 1962, IRRI 1964, Tanaka et al. 1964).
d. *Numerical symbolization of pigmentation in plant parts* : In view of the complexity of the anthocyanin distribution among plant parte and the various properties of color expres-

sion (hue, value, and chroma), Ito and Akihama (1962) suggested the use of a numerical scale to combine recordings of the hue, value and chroma in 5 selected plant parts, using the Munsell color charts. An extension of this scheme may facilitate the card cataloging of varieties.

e. *Protein fractions of plant tissues:* Studies at the Institute have shown that certain indica and japonica varieties differ in the protein fractions of leaf tissues (IRRI 1964). They also indicated that the greenness of leaves is correlated with nitrogen responsiveness and chlorophyll content (Tanaka et al. 1964). Other aspects of chemical plant taxonomy have been discussed in a symposium on the subject (Swain 1963).

f. *Statistical approach to varietal classification:* When a number of taxonomic units of either a quantitative or codable nature are recorded, a variety of multivariate-analysis techniques are now available to assist in evaluating similarities between taxonomic units and the ordering of these units into groups on that basis. Principles and techniques have been given by Sokal and Sneath (1963).

## Classification of Cultivated Varieties of *O. Sativa*

The great majority of the classification schemes found in the literature emphasize varietal differences of a regional scope (cf. Grist 1959, Chandraratna 1964) and therefore have limited application. This is illustrated by Beale's (1927) classification of rice varieties from lower Burma in which five major groups were recognized on the basis of grain length and the length/width ratio, supplemented by similar measurements of the dehulled grain. Beale further subdivided each group into seven classes on the basis of pigments in the stigma, apiculus, leaf axil, leaf sheath, and the blade. The 35 combinations supposedly embraced the total varietal diversity in Burmese rice. In addition to anthocyanin pigmentation and grain dimensions, the presence or absence of awns, the nature of the starchy endosperm, the arrangement of spikelets on the panicle branches, the size and shape of the sterile lemmas, the pubescence of the lemma and palea, and the form of spikelet separation from the pedicel were the criteria used in other classification schemes.

Since 1950, the Food and Agriculture Organization of the United Nations has published a World Catalogue of Genetic Stocks (Rice), totaling 1.1 issues, in which available informatior, was given on as many as 78 items for each variety. This has helped rice workers select and exchange experimental materials. However, the information on individual varieties is based on data furnished by breeders in the variety's home country. Consequently, some of the quantitative data have limited applicability when the variety concerned is grown under a markedly different set of environmental conditions. This is particularly true with varieties of the temperate zone when grown in tropical areas under cultural practices adapted to the profuse tillering tropical varieties.

While none of the presently available classification schemes is entirely satisfactory for the thousands of rice varieties under cultivation and probably none will ever serve the needs of all interested workers, a centralized agency is needed to work toward planting, recording and cataloging existing commercial varieties for morphological and agronomic characteristics under a uniform set of conditions and to preserve the valuable germ plasm when the existing stock of varietal diversity rapidly dwindles. The world collection of the Institute is being investigated and maintained in the above manner to meet this need. But the task of continuously developing identification and classification schemes for commercially important varieties of a country or region should be largely the responsibility of national governments concerned, since it is impossible for one agency to develop a catalog that would contain all of the information desired by various workers and which would also apply to all of the varieties when grown at different locations. Therefore, international and interagency cooperation is needed to pool all available information on cultivated varieties in a form that would be readily accessible to all interested workers.

# MUTANT TRAITS

A mutant trait is defined as a variant that is relatively discrete from the normal or parental type and is inherited in a simple Mendelian manner. The normal type refers to that of the great majority of cultivated varieties. Thus, the mutant traits are variants of a more extreme nature than those commonly observed in a small group of commercial varieties.

A wide array of mutant traits has been reported in rice. The more commonly observed ones are reviewed under eight convenient groupings. Definitions of specific mutant traits and assignment of the IRC-recommended gene symbols are given in the attached glossary. Genetic information on other mutants of a more exotic nature have been given by Jones (1933), Nagao (1951), Ramiah and Rao (1953), Jodon (1957), Nagai (1958), Ghose, Ghatge and Subrahmanyan (1960), and Chandraratna (1964). Recent tabulations on gene symbols, genetic ratios and authors are given in two IRC reports (Anon. 1963, Chang and Jodon 1963).

## Variations in Anthocyanin Pigmentation

The plant parts which may be pigmented with anthocyanin are the apiculus, auricles, awn, blade, coleoptile, collar (junctura), hull (lemma and palea), internode, leaf axil (inner sheath base), leaf sheath, sheath pulvinus, leaf tip and margin, ligule, midrib, nodal septum, pericarp, tegmen, sterile lemmas, and stigma. The color variations are colorless (white), green, pink, red, and several shades of purple.

The genes controlling anthocyanin pigmentation are basically three complementary genes: C[5], A, and P[6]. C is the basic gene for producing chromogen. A controls the conversion of chromagen into anthocyanin, and P controls the distribution or localization of anthocyanin in specific plant organ or organs. C and A are genes with multiple allelic series. Some of the *P* genes also have several alleles, ex., *Pl*, $Pl^w$ and $Pl^t$. Inhibitor genes *(I-)* are known to suppress the effect of the distribution genes, e.g., *I-P*, *I-Pl*, and *I-Pla*. Through the interaction of the above genes, a great variety of color expressions and intensities are observed in nature.

The *P* and *Pl* alleles also have a pleiotropic effect upon the pigmentation of the other plant organs.

Red pericarp and tegmen (red rice) is controlled by two complementary genes, *Rc* and *Rd*. When *Rc* alone is present, the color of the caryopsis is speckled reddish-brown.

Colors for the above have been designated by Hutchinson et al. (1938), Ramiah and Rao (1953), Takahashi (1957). and Ghose et al. (1960).

## Variations in Non-Anthocyanin Pigmentation

The coloration of plant parts such as gold, brown, and sooty black does not involve anthocyanin. Non-anthocyanin pigmentation generally involves a single pair or a series of alleles, such as *Bf* alleles for brown furrows on hull at maturity, *Bh* genes for black hull, *gh* for gold hull, *H* alleles for dark brown furrows on hull at blooming, and *Wh* for white hull. Inhibitor genes such as *I-Bf* and *I-H* have been reported.

## Modifications in Size and Shape

A common modification in size is dwarf stature which is about one-third to one-half the height of normal plants. Dwarf plants form discrete classes in segregating generations and are characterized

[5] Letters in italics are IRC-recommended gene symbols (cf. Anon. 1959, Anon. 1963, Chang and Jodon 1963).

[6] P, when used as the first letter of a gene symbol, denotes anthocyanin color in a certain plant organ or organs; exceptions: *Ph, Pi.* Examples are *P* for apiculus, *Pau* for auricles, *Pin* for internode, *Pl* for leaf blade, *Prp* for pericarp, *Psh* for leaf sheath, *Ps* for stigma, and *Px* for leaf axil.

by under-sized grains and proportionally thickened plant parts. A number of independent, recessive genes ($d_1$, $d_2$. . . ) of a pleiotropic nature control the dwarfed growth. These single-recessive dwarfs have no economic value in a breeding program.

Plants of intermediate (sub-normal) height with normal panicles and grains may be called short or semi-dwarf plants. The short (circa 100 em.), nitrogen-responsive and high yielding indica varieties from Taiwan, viz., Taichung (Native) 1, I-geo-tze and Dee-geo-woo-gen, belong to this class. Differences in plant stature between the tall tropical varieties and these short varieties are controlled by a partially dominant allele and a few modifying genes (Chang et d. 1965). In others cases, an inhibitor for tall plant height *(I-T)* may be involved.

Other simply inherited differences in size and shape involve grain length( *lk* alleles. for long), grain shape (*Rk* for roundness), sterile lemma length (*g,* or *Gm* for long), blade width (*nal* for narrow blade), and panicle length. Some of the above variations in size and shape are probably more of a quantitative nature.

## Presence or Absence of Structures

The presence or absence of awns, auricles, collar, ligule, neckleaf, and pubescence generally involves differences in one allele. The. presence of a certain structure is generally controlled by the dominant allele, such as An for awned, *Lg* for liguled, anti *Gl* for pubescence. The presence or absence of the ligule, auricles, and collar is generally inherited as a unit (*Lg* vs. *lg*) in a pleiotropic manner.

## Modifications in Structure

Marked variations in the structural features of plant organs include rolled leaf *(rl),* twisted leaf *(tl)* , glossy leaves, bend node *(bn)* , lazy (la), non-exserted panicle *(ex),* sinuous neck *(sn),* undulate rachis on the lower panicle branches *(Ur),* verticillate rachis *(ri),* spreading panicle branches *(spr)* , lax panicle *(dn),* clustering of spikelets on the panicle branches *(Cl)* , cleistogamous spikelets *(cls)* , claw-shaped spikelets *(clw)* , triangular hull (tl-i) , extra lemma *(lmx)* , double awn *(da),* depressed palea *(Dp),* beaked hull *(Bd),* open hull *(o),* shattering *(Sh* or *th),* multiple pistil *(mp),* poly-embryonic grain *(me),* and notched or twisted kernel *(nk* or *tk).* Although some of the above traits, such as panicle density and shattering, were described as simple Mendelian characters they are probably polygenic in inheritance.

## Modifications in Chemical Composition

Some of the simple modifications in chemical constitution of plant parts are extremely brittle culm and leaves *(bc),* fragrant flower *(fgr),* scented endosperm ($Sk_1$. $Sk_2$. . . ), waxy endosperm *(wx),* translucency and chalkiness of the starchy endosperm *(wb, wc)* , and phenol staining of hulls *(Ph).* Pigmentation, chlorophyll deficiencies, growth habit, and other physiological characters mentioned in preceding sections also involve modifications in the chemical composition of the plant organ or tissues.

## Modifications in Growth Habit

Some of the well-known modifications in growth habit are erect *(er)* vs. spreading, erect vs. lazy or ageotropic growth *(la),* floating vs. non-floating growth ($Dw_1$, $Dw_2$), and differences in ratooning ability. These differences in growth habit also are known to be controlled by specific chemicals (hormones or growth substances).

## Modifications in Other Physiological Characters

Other well-known modifications in physiological characters involve a complex of chlorophyll deficiencies, leaf discolorations, variations in maturity or photoperiod sensitivity, gametic and zygotic sterility, variations in grain dormancy, and resistance to specific diseases and insects.

Chlorophyll deficiencies occur in a variety of expressions. Albino *(al)* , xantha *(I-y)* , lutescent *(lu)* , and tip-burn yellow *(tb)* are lethal types and are detectable immediately following seedling emergence Chlorina *(chl)* . pale yellow *(y),* zebra stripe *(z),* green and white stripes *(fs* or *gw),* and virescent *(v)* are non-lethal and the seedlings usually regain the green color later in growth. White streaks or stripes *(ws)* may also be found on the blade, leaf sheath, culm, and spikelets persisting throughout the growing period. The above chlorophyll deficiencies are largely controlled in each case by a single recessive allele. In other cases, maternal inheritance of chloroplasts has been indicated. Color plates for the above types have been given by Ramiah and Rao (1953).

Gustafsson (1942, 1947) has described a number of chlorophyll mutations in barley, e.g., albina, striata, viridis and xantha, which also may apply to rice.

Physiological diseases showing dark brown or blackish mottled discoloration of leaf blade are inherited as single recessive characters *(bl).* Other types are blotches of white spots on the blade and discolored spots on the hull *(hsp).*

Differences in growth duration have been reported to be controlled by a single gene, *Ef* alleles for earliness, or *Lf* alleles for lateness. In other cases, photoperiod sensitivity ( *Se* alleles) was interpreted as the basic factor in late maturity. As discussed in the preceding section, a study of maturity by the component-analysis approach may clarify this complex trait.

Sterility occurs in the reproductive organs at different .stages of development either as morphological aberrants or physiological disturbances of the reproductive process. Morphological steriles include empty anther sacs, replacement of stigma by supernumerary stamens, replacement of pistils and stamens by glumes, and other malformations. Among physiological disturbances, asynapsis (as) and desynapsis *(ds)* which occur during meiosis are cytologically detectable. Non-dehiscent anther is a common type of male sterility. Chromosome aberrations such as deletions, inversions, translocations, haploidy, triploidy, tetraploidy, and aneuploidy also cause sterility. Intervarietal hybrid sterility of a genic and/or chromosomal nature is often observed in progenies of distant crosses.

Grain dormancy has been reported as a dominant trait controlled by two complementary genes *($Sd_1$, $Sd_2$)* or several genes. The inheritance of dormancy is probably more complicated than generally held as the hull, pericarp, and embryo are involved, and each may play a specific role in conditioning dormancy.

Resistance to fungus diseases such as blast and *Cercospora* leaf spot was studied genetically either with pure isolates or composite cultures of the pathogen. Interpretations were offered either in terms of a single dominant gene for resistance *(Pi, Ce)* or a dominant gene for susceptibiity (or inhibitor gene), or duplicate genes for resistance *($Pi_1$, $Pi_2$. . . )* which showed cumulative action in conditioning resistance to different pathogenic races. Similarly, varietal reactions to insect pests were reported in terms of single allelic differences. Details are given in recent reviews by Chandraratna (1964) and Chang (1964).

Resistance to drought and low air temperature have been reported to be under polygenic control.

Exceptions to the above generalized patterns of inheritance are included in reviews by Ramiah and Rao (1953), Nagai (1958), Anon. (1963), and Chang and Jodon (1963).

Previous studies on the genetics of the rice plant are marked by a predominance of major genes and duplicate loci. As the genetical studies of economic, quantitative traits receive more attention by rice breeders and geneticists, polygenic inheritance would gain the attention it deserves.

Rice workers are urged to look for additional mutant traits of economic value, including yellow endosperm, solid or semi-solid culms, opaque endosperm with high lysine content, and male sterility. The above mutant traits found in some of the other staple cereals have been utilized in breeding programs.

## Glossary of Mutant Traits and Gene Symbols

1. **albino** *(al)* - Young seedlings are white due to the absence or degeneration of chloroplasts. The seedlings die shortly after emergence.

2. **awned** *(An)* - The awned condition is classified according to length as long or full awn *($An_1$ $An_2$ $An_3$ or $An_1$ $An_2$ $an_3$),* medium awn *($An_1$ $an_2$ $An_3$ or $An_1$ $an_2$ $an_3$),* short awn *($an_1$ $An_2$ $An_3$ or $an_1$ $An_2$ $an_3$),* or tip awn *($an_1$ $an_2$ $An_3$).* Awnless condition has the formula $an_1$ $an_2$ $an_3$.

3. **rudimentary auricles** *(au)* - Auricles are reduced to protuberances with 1 to 2 cilia or without cilia.

4. **brittle culm** *(bc)* - The culm, leaves, and panicles are extremely brittle, particularly at maturity, due to low content of a-cellulose in cell walls.

5. **beaked hull** *(Bd)* - The tip of the lemma is recurved over the palea.

6. **brown furrow** *(Bf)* - The furrows on the lemma and palea· are dark brown.

7. **blackhull** *(Bh)* - Sooty black color of the hull is controlled by two or more complementary genes which are not related to genes for anthocyanin production *(C, A, P).*

8. **physiologic leaf spots** *(bl)* - Physiologic leaf spots are non-pathogenic physiologic diseases showing dark brown or blackish mottled discoloration of leaf sheaths and blades.

9. **blotched white** - Leaf blade has white spots which give a pie-bald appearance.

10. **bent node** *(bn)* - The culm forms an angle at the node, similar to a twisted stem.

11. **aerial branching at nodes** *(Br)* - New shoots and roots develop at nodes high on the culm following the cutting of panicles.

12. **chlorina** *(chl)* - Seedlings are yellowish green as a result of chlorophyll deficiency. Plants are often smaller in stature than normal.

13. **clustered spikelets** *(Cl)* - Spikelets show a clumped arrangement on the primary or se-

condary panicle branches with two or more spikelets per branch. Bunched arrangement of spikelets in groups of 10 to 48 is termed superclustering.

14. cleistogamous spikelets *(cls)* — The lemma and palea unite at the lower end. The spikelets therefore cannot open at anthesis. Plants also are short, with compact panicles and small spikelets.

15. claw-shaped spikelets *(clw)* - The spikelets have undersized paleas which are overlapped by recurving lemmas; synonymous to "parrot beak."

16. dwarfs *(d)* - Dwarf plants are about one-third to one-half the height of normal plants, owing to shortened internodes and/or fewer elongated internodes. Dwarfs form discrete classes in segregating populations. The plants are often characterized by undersized grains and proportionally thickened plant parts.

17. double awn *(da)* - Spikelets have awns developing on both lemma and palea. The awns may have unequal length.

18. dense or compact panicle *(Dn)* — Avery dense arrangement of spikelets on the panicle branches, resulting in a large number of spikelets per unit length of panicle.

19. depressed palea *(Dp)* - The palea is underdeveloped and shows a depressed appearance.

20. erect growth habit *(er)* - The culms are erect and closely grouped. Erect growth is recessive to the spreading or procumbent habit which has culms growing obliquely outward. In crosses with ageotropic lazy *(la)* type, erect growth is dominant to lazy.

21. exserted panicle *(Ex)* - The panicle emerges fully from the flag leaf sheath at panicle emergence. The exserted type is dominant over the enclosed condition which is due to a shortened internode below the panicle base.

22. fuzzy hull *(Fg* or *Lh)* - Long, smooth, dense hairs on the hull result in a fuzzy appearance; probably synonymous with shaggy hull.

23. fine stripe *(fs)* - Seedlings show fine greenish white longitudinal stripes at tip and margin of leaf blade. Stripes often disappear in the tillering stage.

24. long glume *(g)* - The sterile lemmas ("outer glumes") exceed one-third the length of the lemma and palea. Another dominant gene, *Gm,* controls the sterile lemmas which are longer than the lemma and palea. The two sterile lemmas may have unequal length.

25. goldhull *(gh)* - The hulls show a golden yellow color at maturity. Goldhull is recessive to straw colored hull.

26. glossy - Leaf blades have a glossy surface to which water easily adheres in large droplets, .

27. glabrous *(gl)* - Hairs arc scarce or absent on the hull and/or the leaf blade. In a glatbrous strain, few hairs may be found on the margins of the blade.

28. green-and-white striped *(gw)* - Green and white stripes on the leaf blade and occasionally on the lemma and palea.

29. hull colors *($H^m$, $H^i$, $H^o$, $H^f$)* - A number of hull colors are non-anthocyanin colors which appear on the lemma and palea only when the straw hull gene, Gh, is present.

30. hullspot *(hsp)* - Small tissue areas on the lemma and palea which are thin and transparent and appear discolored.

31. lazy *(la)* - Plants grow prostrate rather than upright because of an ageotropic growth habit. In rice literature, some extreme spreading forms have been mistermed lazy.

32. liguleless *(lg)*–Leaves lack collar, ligule. and auricles; synonymous with juncturaless. The blade stands upright at base.

33. very hairy *(Lh)* - Long and dense hairs on the leaf blade, dominant to ordinary pubescence.

34. extra lemma *(lmx)* - Spikelets have an extra glume between the fertile lemma and the sterile lemma; synonymous with polyhusk.

35. lutescent *(lu)* - Seedlings are normal green at first, but the chlorophyll gradually disappears and the plant ultimately dies.

36. lax panicle *(Lx)* - Panicles with few lateral branches and sparsely distributed spikelets on the branches are called lax. Lax panicle has also been used to denote open and spreading forms.

37. polyembryonic *(me)* - Multiple embryos are present in one caryopsis.

38. polycaryoptic *(mp)* - Several pistils with multiple ovaries are present in the spikelet.

39. notched kernel *(nk)* - A small wedge-shaped depression occurs at the middle portion of the abdominal side of the brown rice.

40. neckleaf *(nl)* - The panicle is enclosed by a spathe-like leaf or leaf sheath arising at the panicle base. Occasionally, additional bracts may arise at the base of the panicle branches.

**41. open hull** *(o)* - The lemma and palea cannot close after they have opened at blooming time.

**42. opaque endosperm** - The starchy endosperm is soft and crumbly with a dull, opaque appearance. The starch is non-waxy.

**43. pigmentation of vegetative parts** - Anthocyanin colors in vegetative organs are controlled by the complementary *C-A-P* system. The basic genes involved are activator (A alleles), chromogene ( *C* alleles), localizers or distributors *(P-),* inhibitors *(I-),* and modifiers. For color illustrations, refer to Hutchinson et al. (1938), Ramiah and Rao (1963), Takahashi (1957), and Chose, Ghatge and Subrahmanyan (1960).

**44. pericarp and tegmen colors** - Brown, gray, golden, purple, red, and white pericarp and tegmen colors were reported. Purple pericarp is controlled by *Prp* or *PI* alleles; red pericarp and tegmen, *Rc* and *Rd;* speckled reddish-brown tegmen and pericarp, Rc. For details, refer to Nagao (1961) and Ramiah and Rao (1953).

**46. verticillate rachis** *(ri)* - Panicle branches are arranged as a whorl around the basal node of the panicle axis.

**46. rolled leaf** *(rl)* - Leaf blade margins are incurved, forming a half cylinder; sometimes as a result of underdeveloped midrib or absence of midrib in the blade.

**47. shattering** *(Sh* or *th)* - Shattering or easy threshing are partly correlated with the degree of development of the abscission layer between the spikelet and the facet of the pedicel.

**48. scented kernel** *(Sk)* - Grains contain aromatic substances in the endosperm which give a strong aroma when the polished rice is cooked.

**49. sinuous neck** *(sn)* - The portion of the uppermost internode of the culm below the panicle base is curved and wavy; opposed to straight neck.

**50 spreading panicle branches** *(spr)* - The primary panicle branches extend obliquely outward so that they appear spreading and lax.

**51. short non-dwarf plant** *(I-T)* - Plant height is shorter than normal. However, the panicle and grain sizes are about normal.

**52. tipburn yellow** *(tb)* - Yellowish seedlings die after the second foliage leaf is formed. The leaf apexes wither and die.

**53. long twisted kernel** *(tk)* - The long caryopsis shows a slight twist in the middle portion.

**54. triangular hull** *(tri)* - The spikelet appears triangular because the lemma is so shaped.

**55. undulate rachis** *(Ur)* - The primary panicle branches, especially the lower ones, have undulating secondary axes. This condition is caused by mechanical compression exerted on the branches owing to the premature extension of the axes while they are inside the flag leaf sheath.

**56. virescent** ( u ) - Young seedling is nearly white or slightly yellow as a result of the delayed development of chloroplasts. Later the plant gradually turns green.

**57. white belly** *(wb)* - A chalky white spot occurs in the middle part of the caryopsis on the ventral side (on which the embryo lies). The starch in the white belly is soft.

**58. white core** *($wb_2$)* - The chalky white, soft portion extends to the edge of the ventral side and toward the center of the caryopsis.

**69. white hull** *(Wh)* - Chalky white hull is dominant over straw-colored hull and epistatic to goldhull *(gh)* .

**60. white stripe** *(ws)* - Longitudinal white streaks appear in the leaf shath, blade, culm, and spikelet throughout the growing period.

**61. waxy endosperm** *(wx)* - Waxy or glutinous type of starchy endosperm, in which the starch fraction is composed of nearly 100 percent amylopectin, stains reddish brown with weak potassium iodide-iodine solution instead of the blue black color of the common or non-waxy type of starch.

**62. yellow leaf** *(y)* - Seedings have pale yellow leaves, but this condition is non-lethal.

**63. xantha** *(l-y)* - Seedlings have pale yellow leaves and perish shortly after germination.

**64. zebra stripe** *(z)* - Seedling leaves have transverse, alternating chlorotic bands which later disappear.

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