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Rice Plant Growth and Development

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Abstract

Rice (Oryzae sativa L.) belongs to the grass family Oryzeae and is one of the leading food crops in the world. It is one of the leading food crop feeding approximately one half of world population; it is reported to feed approximately one half of the world's population. it is a staple of over half of the world's population, mostly in Asia. It is the second most cultivated cereal after wheat. It provides 20% of the per capita energy, and 13% of the protein consumed worldwide. It is known as a semi-aquatic, annual grass plant and is found growing in a wide range of soil types and water regimes: irrigated, rainfed lowland, upland, and flood-prone areas depending on where it is produced. Although there are multiple types of rice production the principles of land preparation, planting, management, harvesting, and finally processing are similar throughout the world, apart from the obvious difference between wetland and dry land cultivation. There are various types of rice based on grain length, width, and chemical characteristics, those being a long grain, medium grain, and short grain. Rice grows in approximately 115 countries on every continent except Antarctica. Production practices range from very primitive to highly mechanized. This chapter will focus on the various aspects of rice growth and development under normal and stressed conditions.

Keywords: Cultivation; Rice; Growth; Annual Grass

Introduction

Higher plants have many specialized organs, tissues, and cells. All these components are derived from a single cell (fertilized egg, zygote) through several developmental events. In animals, developmental and differentiation processes are restricted mainly to a short period of embryogenesis [1].

In contrast, development continues in plants until the end of the life cycle. Apical meristems repeatedly differentiate lateral organs. Meristematic tissues are generated in a variety of organs with proper timing to achieve continuous development. Therefore, developmental studies of the entire plant life cycle are essential to elucidate the establishment of plant formation [2].

Rice belongs to grass family and one of leading food crop. It is rich source of energy and provide 13% of protein globally [3]. It is semi aquatic plant and grows on variety of soil having various moisture regimes. In other word it is found on wide range of areas from deeply flooded to dry flat fields or hilly terreced or non terreced slopes [4].

Growth and development of the rice plant involve continuous change. This means essential growth events occur in the rice plant at all times. Therefore, the overall daily health of the rice plant is essential. If the plant is unhealthy during any stage of growth, the overall growth, development, and grain yield of the plant are limited. It is essential to understand the growth and development of the plant [5]. The ability to identify growth stages is essential for proper management of the rice crop. Because management practices are tied to the growth and development of the rice plant, an understanding of the growth of rice is essential for the management of a healthy crop [6]. Timing of agronomic practices associated with water management, fertility, pest control, and plant growth regulation is the most critical aspect of rice management. Understanding the growth and development of the rice plant enables the grower to correctly time recommended practices. Keeping in view the importance of rice growth this attempt will focus on the diferent aspect of rice growth and development under normal and stressed conditions.

Growth and Development of Rice

Growth and development of rice grown as an annual from seed begin with the germination of the seed and ends with the formation of grain. During that period, growth and development of the rice plant can be divided into three phases: vegetative, reproductive, and maturation. These three phases deal with growth and development of different plant parts. It is essential to remember the growth and development of rice are a continuous process rather than a series of distinct events. Growth of the rice plant starts from seed germination and ends up at the formation of grain. This process can be divided into three phases of development:

1. Vegetative Phase

a) Emergence

b) Seedling development

c) Tillering

d) Internode elongation.

2. Reproductive Phase

a) Pre-booting

b) Booting

c) Heading

3. Maturation (grain filling and ripening)

Vegetative Phase

A. Emergence

Seed Germination occurs when the seed coat has imbibed adequate water to become soft and elastic. The coleorhiza (the sheath covering the radicle or embryonic primary root) elongates slightly, emerging through the seed coat, allowing the radicle to break through the coleorhiza and become anchored in the soil. The coleoptile or primary leaf then elongates. Thus, under dry seeded or aerobic conditions, the radicle emerges before the coleoptile. Under water-seeded or reduced oxygen (anaerobic) conditions, the coleop tile may emerge before the root (radicle or coleorhiza). This typically occurs within two days when temperatures are between 70° to 97°F. Below or above this temperature, germination requires more time. Germination occurs within the temperature range of 50° to 107°F with an optimum temperature of about 87°F [7]. The series of events the takes place during the process of emergence are described in the (**Figure 1**).

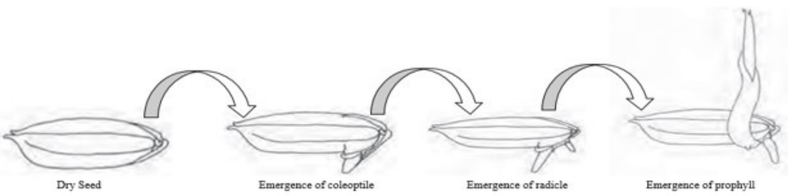

Figure 1: Events the takes place during the process of emergence

B. Seedling development

When the seed has imbibed water and germination begins, the seed radical emerges to anchor it in the soil, which subsequently leads to plumule emergence in the dry land, direct seeding. Seedling emergence is when the coleoptile emerges above the soil surface in dry-seeded rice or when it emerges from the water surface in the case of water-seeded rice. This occurs between 10˚C and 42˚C, optimum temperature 31˚C. This may take between 5 and 28 days based on the growing environment help the plant emerge faster. Planting depth is essential, particularly in the case of the semi-dwarf varieties, which should not be planted more than 3 cm deep, or they will not emerge [8]. A first leaf is not the individual leaf blade and generally of one inch or shorter in length, elongates from the coleoptiles. Developing leaf is based on the first leaf that acts as a protective layer. With the growth of seedlings elongation of next leaves occur. By the time this primary leaf grows further and develops into three different components, such as a sheath, collar, and blade, as mentioned in the (**Figure 2**).

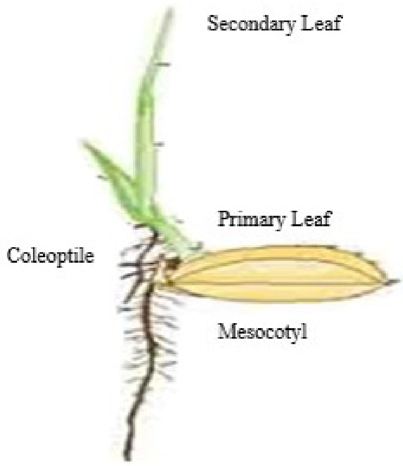

Figure 2: Germination and seedling development

C. Tillering

Tillering occurs when a sprout or stalk is produced from the crown, which forms just below the soil surface or from the axis of the lower leaves. Tillering usually begins three weeks after emergence, i.e., as the fourth-leaf fully emerges, and ends at the fifth leaf stage appears (approximately three weeks). A rice plant may develop from two to five tillers depending on the seeding method. Direct seeding may result in two to five panicle-bearing productive tillers while transplanted rice may have 5 to 30 productive tillers. It is from the surviving tillers that the potential panicles per unit area are determined, which has an impact on yield. The late tillers may die due to competition with the earlier established tillers. During tillering, the crown roots of each plant continue to develop growing downward, and it is only at the flooding that roots begin to develop laterally and vertically in response to the oxygen available on the water surface. For the duration of this period, second roots produce downwards till the flooding. After flooding, roots grow horizontally and vertically. The growth in horizontal direction depends upon the oxygen availability of water and soil interface [9].

Tillering amplifies in curve shape until the highest tiller number is attained. At this stage, there might be a difficulty to differentiate between culm and tiller. To increase the tiller population, nitrogenous fertilizers are the practical and standard tool, which enhances the amount of cytokinin inside the nodes of the tiller and also increases the germination process of tiller primordium [10].

The vegetative lag phase occurs as tillering ends, and the reproductive phase of plant development begins to be expressed in the plant. During this time, the number of tillers decreases while the plant height and stem diameter increase slowly. In short-season varieties (110-day maturity) this is not as evident as in longer-season varieties (150-day maturity). Since the plant is not actively growing during this period, it may appear yellow. In most cases, this is not due to a lack of nitrogen [11].

D. Internode elongation

Internode or stem elongation is directly linked with the growth period. In the early maturing varieties and medium maturing selections, it typically initiates approximately when panicle primordia start. However, in late maturing rice varieties it begins before the initiation of panicle primordia. In the photoperiod sensitive rice plant varieties, extensive photoperiod boosts up the total length and the number of internodes. On the other hand, in photoperiod insensitive plants varieties, it bears a zero influence on the elongation of the stem [9]. Unexpected environments, like deep water and deep seeding, stimulate the elongation of internode even at the very early growth phases. When the seed is placed 2 cm deep in the soil, it does not initiate the stem elongation, but when the same seed is placed deeper somewhere, 3-4 cm can stimulate elongation of internodes. In floating and rooted water rice plants, elongation of internode starts in response to the higher water depth. 2-10cm internode elongation per day is common, while the maximum rate is 23-25 cm per day [12]. **Figure 3** explains the plant structure at various leaf stages.

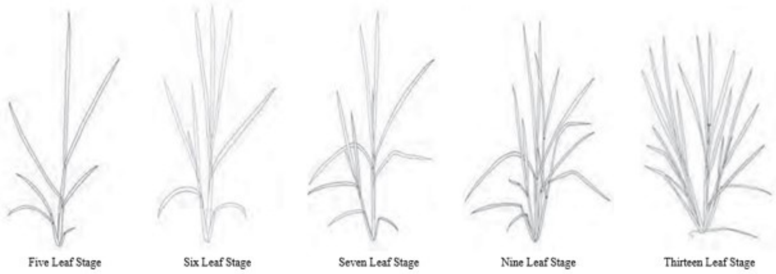

Figure 3: Rice plant at various leaf stages

Reproductive phase

The reproductive phase occurs from panicle initiation to anthesis and is characterized by a decrease in tillering activity, panicle initiation, then by internode elongation and jointing. The boot stage and flag leaf emergence are followed by heading and flowering. The reproductive phases of plant growth take 30 days depending on variety and environmental conditions. Panicle initiation starts when the panicle primordial begins to differentiate. The first sign of this is the “green-ring” stage when a bright green band is observed just above the top node. Once this stage concludes, the internode elongation begins. Panicle differentiation is a critical stage in yield build-up as the number of grains per panicle is set at this time.

A. Pre-booting

Prebooting refers to the interval after the onset of internode elongation and before flag leaf formation is complete. During prebooting, the remaining leaves of the plant develop, internode elongation and stem formation continue, and panicle formation begins uppermost branches first and progress downward. Because there are several panicle branches, development of florets within the panicle as a whole overlap. Florets at the tip of a lower branch might be more advanced in their development than florets near the base of an upper panicle branch. From a management stand point, panicle length defines plant development during this phase. A fungicide label, for example, might prescribe its application “from a 2- to 4-inch panicle”. By the time the panicle is about 4 inches long, individual florets can be easily recognized on the most mature panicle branches [13].

B. Booting

Booting is the period during which growth and development of a panicle and its constituent parts are completed inside the sheath of the flag leaf. The sheath of the flag leaf is the boot. Booting stages are classified according to visible development of the panicle without dissection. For convenience, it is divided into three stages: early, middle, and late boot. It is based on the amount of flag leaf sheath exposed above the collar of the leaf from which it emerges, the penultimate (second to last) leaf [14]. The early boot is recognized when the collar of the flag leaf first appears above the collar of the penultimate leaf on the main stem and lasts until the collar of the flag leaf is about 2 inches above the collar of the penultimate leaf. Middle boot occurs when the collar of the flag leaf is 2 to 5 inches above the collar of the penultimate leaf and late boot when the collar of the flag leaf is 5 or more inches above the collar of the penultimate leaf. By late boot, the increasing panicle development causes the boot to swell, giving rise to the term “swollen boot”. The boot becomes spindle-shaped; it is wider in the middle tapering to a smaller diameter at each end [15].

C. Heading

Heading occurs after the panicle begins to swell in the boot and as the panicle emerges from the boot. Panicle emergence may take 10 to 14 days depending on how many tillers there are on the plant. Heading date is when 50 percent of the panicles have emerged from the boot. There are several types of panicle emergence based on how much of the panicle exert from the boot, from well exerted to enclosed. Once exertion begins, anthesis/flowering are initiated. Anthesis is depicted when the floret opens, allowing the stamens to extrude, and the pistil becomes visible between the floret lemma and palea.

In most cases, pollen is shed from the anthers first while the floret is closed and then sheds more after it opens [16]. The majority of pollen shed occurs between 9 am and 3 pm. Flowering proceeds from the tip of the panicle downward to the base of the panicle as it emerges from the boot. This takes six to 14 days. At this time, the second factor of yield, seeds per panicle, is set. Factors that may negatively impact the seed set at this point in the reproductive phase include temperature, wind, rain, and pesticide applications. If ambient temperatures are less than 10˚C or greater than 35˚C, some of the seed may be empty [17].

Maturation (grain filling and ripening)

During grain filling, florets on the main stem become immature grains of rice. Initially, the starch is white and milky in consistency. When this milky accumulation is first noticeable inside florets on the main stem, the stage is milk stage. Before pollination, the panicle in most varieties is green, relatively compact and erect. During the milk stage, the accumulation of carbohydrate increases floret weight. Since the florets that accumulate carbohydrate first are located near the tip of the panicle, the panicle begins to learn and eventually will turn down. The milky consistency of the starch in the endosperm changes as it loses moisture. When the texture of the carbohydrate of the first florets pollinated on the main stem is like bread dough or firmer, this stage of growth is referred to as the dough stage. As the carbohydrate in these florets continues to solidify during the dough stage, the endosperm becomes firm and has a chalky texture [18]. Grains capable of being dented without breaking are in the soft dough stage. As more moisture is lost, grains become chalky and brittle. During the grain filling stages, the florets develop and mature unevenly because pollination and subsequently grain filling occur unevenly. In the dough stage, only the florets on the main stem, which pollinated first, have an endosperm with the texture of bread dough. At the same time, the florets, which pollinated later, including those on the tillers, may be in the milk stage. These are the last florets to accumulate carbohydrate. As more and more florets fill with carbohydrate, the translocation of carbohydrate to the panicle starts to decline, and the final phases of grain filling occur. The panicle changes in color and form as the florets develop and mature. For most varieties of rice, the panicle changes from uniform light green at the milk stage to a mixture of shades of brown and green during the dough stage. As the color changes so do the grain shape as a consequence of carbohydrate accumulation in the florets. The weight of the carbohydrate causes the panicle to bend over and the panicle branches to be less compact around the panicle axis [19].

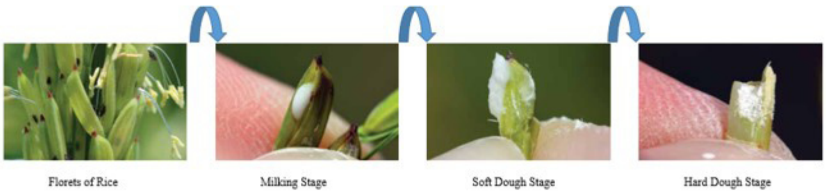

Figure 4: Reproductive Stages of the Rice Plant

At the end of the grain filling stages, the panicle on the main culm has a bent and slightly open shape and is various shades of brown and green. The bent and slightly open configuration of the panicle remains unchanged from dough to maturity. The ripening phase starts at the fertilization stage and prolongs up to 30-40 days through the filling of grain and ripening stages [3]. The grain filing takes place when the water and nutrients are carried from one area of the plant to other. This process may be affected by the number of nutrients, temperature, and water. The stage of grain filling, maturation, or ripening follows fertilization of ovary and is differentiating by the growth of grain. Within this period, weight and size of grain increases when the sugars and starch are transported from culms and sheath of the leaf, leaves of rice start to senesce, and the grain alters itscolor or color of straw at maturity [20].

Second (Ratoon) crop

Second crop stems originate from small axillary buds at the crown and stem nodes of the stubble remaining after harvest of the first crop. Generally, the second crop begins to initiate when the first crop approaches harvest moisture (18 to 21 percent). It is not uncommon to see second crop growth initiated before harvest of the first crop. Shoots develop in the second crop as they do in the first crop. New leaves emerge through sheaths of leaves on the first crop stubble; eventually, internode formation occurs, followed by panicle initiation and panicle differentiation, booting, heading, grain filling and maturity [21]. Development of buds on the crown is essentially the same process of tillering without the presence of a distinct primary shoot. Second crop growth is small and much more variable in all aspects compared with the first crop. There are fewer leaves and internodes per stem, a shorter maturation period (time from bud initiation to heading) and shorter mature plant height. There are fewer panicles per acre and per plant and fewer grains per panicle. Second crop yields are generally less than 40 percent of first crop yields. Second crop growth and development are limited by declining day length and falling temperatures at the end of summer and during the fall, which is opposite from the first crop that experiences mostly increasing day length and temperatures from planting to heading during the spring and early summer. The reduction in total sunlight translates to lower photosynthesis, which accounts in part for the lower yields. Reduced input costs often make ratoon cropping profitable despite lower yields [22].

Rice Growth under Stressed Conditions

Rice can be grown in different environments depending upon water availability and temperature conditions. Cold stress is a common problem in rice cultivation and affects global production as a crucial factor. Rice is a cold-sensitive plant that originated from tropical or subtropical zones [23]. When low temperature occurs during the reproductive stages, it can cause severe yield and yield components losses. The optimum temperature for rice cultivation is between 25°C and 35°C, and in temperate regions, rice growth is impressed by the limited period that favors its growth [24]. Exposure to cold temperature affects all phonological stages of rice and lower grain production and yield [25]. The low temperature in a vegetative stage can cause slow growth and reduce seedling vigor low number of seedlings, reduce tillering increase plant mortality increase the growth period and in the reproductive stage, it can cause to produce panicle sterility and lower grain production and yield [26].

Drought is abiotic stress, which affects plants at various levels and stages of their life period. This abiotic stress not only affects plant water relations through the reduction of water content, turgor, and total water, but it also affects stomatal closure, limits gas exchange, reduces transpiration, and disturbs photosynthesis [27]. Drought stress is characterized by reduction of water content, diminished leaf water potential, turgor pressure, stomatal activity, and decrease in cell enlargement and growth. Severe water stress may result in the arrest of photosynthesis, disturbance in metabolism, and finally, the death of plant [28]. It reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism, and growth promoters [29]. The reactions of rice plants to water stress differ significantly at various organizational levels depending upon the intensity, duration of stress, plant species, and its growth stages [28].

Rice is affected by salinity during transplanting, after transplanting and flowering. However, it logarithmically endures salinity stress until ripening [30]. In the reproductive stage, salinity decreases the number of filled panicles, fertile panicle, the weight of 100 grains, and the percentage of rich grains and increases fertile tillers-influences of this pressure increase in warm weather and high evaporation. Without any regard to the seasons of the year, salinity decreases yield, the number of panicles, the weight of 100 grains and increases sterility in all rice cultivars and any growth stages but the most sensitive stage is panicle initiation [31]. Increasing salinity tolerance in rice could develop its production in regions where influenced by salinity, and they are not usable at present [32].

Contamination of agricultural soil by heavy metals has become a critical environmental concern due to their potential adverse ecological effects. Different heavy metals have a significant effect on the growth and yield of the rice crop [33]. Rice plants exposed to high levels of metals stress causes reduction in photosynthesis, water uptake, of plant growth, chlorosis in young leaves, nutrient imbalance, wilting of tops, and root injury and nutrient uptake [34-37].

Conclusion

Rice is a very important crop, and it is usually grown in approximately 115 countries on every continent except

Antarctica. From germination to final maturity, each stage has its role in the final yield of the crop. Anthesis and ripening are the most sensitive stages in rice for different stresses. Further experimental studies of the effects of transgressing threshold biotic and abiotic stresses on the rice responses can be included in crop impact and adaptation models.

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