JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS
VOLUME 5, ISSUE 02
MOPNTHLY JOURNALS
ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

GROWTH AND DEVELOPMENT OF CEREAL CROPS

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Annotation. This article presents a comprehensive overview of the growth and developmental stages of cereal crops, with particular emphasis on germination, tillering, stem elongation, heading, flowering, and maturation, including the milk, wax, and full ripening stages.

Key words. Grain, plant, growth, enzyme, weight, disease, pest, morphology, crops.

Introduction. At present, cereal crops are cultivated in all countries of the world and are consumed as staple food products. The proper implementation of agrotechnical practices and irrigation measures during the growth and development stages of cereal crops ensures the attainment of high and high-quality yields. Therefore, the study of the growth and developmental stages of cereal crops remains highly relevant today.

During the period of individual development, that is, from seed germination to the formation of new seeds, plants pass through specific developmental stages. Morphological changes occur within the plant during these stages, and new organs are formed. Cereal crops, particularly spike-bearing grains, generally undergo the following developmental phases: germination, tillering, stem elongation, heading (in spike-type cereals) or panicle emergence (in panicle-type cereals), flowering, and maturation, which includes the milk, wax, and full maturity stages.

Germination and seedling emergence stage. Healthy seeds sown in the soil swell, germinate, and emerge above the soil surface under favorable conditions. Seed germination requires water, heat, and oxygen. Water promotes seed swelling and creates favorable conditions for enzymatic activity. The embryo absorbs water more rapidly than the endosperm; therefore, the seed does not swell uniformly. As a result, the seed coat ruptures during germination, and the primary root and initial shoot emerge. Enzymes (such as diastase, protease, lipase, and others) convert water-insoluble reserve nutrients into soluble simple compounds. For example, starch is converted into sugars, proteins into amino acids, and fats into glycerol and fatty acids. All these compounds are transported to the embryo through the scutellum.

Cereal grains require different amounts of water for swelling and germination. For example, wheat and rye require approximately 56% of water relative to the dry grain weight; barley about 48%; oats about 60%; maize about 44%; and millet and sorghum about 25%. The rate of seed swelling depends on environmental temperature, grain size, consistency, the presence or absence of a seed coat, soil conditions, and other factors.

Cereal crops germinate at different temperature ranges. The minimum temperature required for germination of wheat, rye, barley, and oats is 1–3°C, while at least 4–5°C is necessary for seedling emergence. Millet-type cereals require higher temperatures for germination. For maize and millet, the temperature should be 8–10°C during germination and 10–12°C during mass emergence. For sorghum, the corresponding temperatures are 10–12°C and 12–13°C, and for rice, 11–13°C and 14–16°C, respectively. When wheat, barley, oats, and rye are sown at the recommended dates, the optimal temperature for seedling emergence ranges from 6 to 12°C; for millet, maize, and sorghum from 15 to 18°C; and for rice from 18 to 22°C. However, the physiological optimum temperature is somewhat higher, reaching about 20°C for true cereals and

25–27°C for millet-type crops. Temperatures above these levels delay seedling emergence; at 30–32°C, seeds of one group of cereals fail to germinate, and at 40–44°C, seeds of the second group completely lose their ability to germinate.

Oxygen is also essential for embryo respiration; its deficiency delays germination. Therefore, excessively deep sowing and soil crust formation are considered harmful. The initially formed shoot attempts to break through the seed coat and emerge to the soil surface. It is enclosed by the first glossy leaf sheath known as the coleoptile. The coleoptile protects the shoot and the first green leaf from mechanical damage as they grow through the soil. Once the shoot reaches the soil surface, its elongation ceases, and the coleoptile splits to allow the next leaf to emerge, which turns green upon exposure to light. The appearance of these green leaves indicates seedling emergence.

Seedlings of true cereals usually emerge within 6–10 days. About one week after emergence, the second leaf develops, followed by the third and fourth leaves at similar intervals. Wheat seedlings are typically green; rye seedlings are purplish or brownish; oat seedlings are light green; barley seedlings are bluish-green; and millet-type cereals are green in color.

Tillering stage. After the plant produces 2–3 leaves, the growth of the main stem slows down. In the underground portion of the stem, several closely spaced nodes are formed; these are referred to as the tillering node. Lateral shoots and, simultaneously, secondary roots emerge from the tillering node, forming a fibrous root system. The future organs of the plant are located within the tillering node, where reserve nutrients are also accumulated. The subsequent development and productivity of the plant largely depend on the preservation of this tillering node without damage. If the tillering node is injured due to low temperatures, soil desiccation, pests, diseases, or other adverse factors, the plant may die, or its lateral shoots and root system may develop poorly, resulting in reduced yield.

The tillering node is usually located at a depth of 2–3 cm below the soil surface. When positioned deeper, the plant is less prone to lodging and winter crops exhibit greater resistance to low winter and early spring temperatures.

The depth of the tillering node depends on the crop species and variety, sowing depth, soil type, and temperature conditions. For example, under insufficient light, on compact soils, or in densely sown fields, the tillering node is situated closer to the soil surface. In winter wheat, the tillering node is generally deeper than in spring wheat; similarly, in durum wheat it is deeper than in soft wheat. The total number of stems produced by a single plant is referred to as total tillering. Tillering intensity also depends on the biological characteristics of the crop. Winter cereals generally tiller more vigorously than spring cereals. Cereals of the first group begin tillering at temperatures around 5°C, while at 10–15°C active tillering occurs.

Moisture, nutrients, temperature, and light strongly influence tillering. The greater the soil moisture and fertility, the more intensive the tillering. Conversely, dense sowing and insufficient light or nutrients reduce tillering intensity. The more favorable the growth conditions, the better cereal crops tiller.

In addition to total tillering, productive tillering is distinguished, which refers to the number of stems that produce grain-bearing spikes. The number of productive stems varies under field conditions. For example, winter cereals typically form 3–6 productive stems; spring barley and oats produce 2–3; and spring wheat usually forms 1–2. In cereals with delayed tillering, non-productive stems (tillers without spikes) may also develop alongside spike-bearing stems. Such stems grow and mature later.

Productive tillering is of particular agronomic importance, as it is associated with rapid and uniform stem emergence. Different crops initiate lateral stems at various developmental stages. For instance, in rye and oats lateral shoots form at the 3–4 leaf stage; in barley, winter wheat, and spring wheat at the 3-leaf stage; in millet at the 5–6 leaf stage; in maize at the 6–7 leaf stage; and in sorghum at the 7–8 leaf stage.

Stem elongation stage. During the tillering stage of cereal crops, the stem and the rudimentary inflorescence remain in an initial developmental state and are enclosed within the leaf sheath; therefore, they are not externally visible. After the plant completes the vernalization stage and transitions to the light-dependent (photoperiod) stage, organ formation begins and proceeds rapidly. This process is further accelerated under adequate light conditions and sufficient water supply.

Stem elongation begins from the lower internodes. The internodes located in the upper part of the stem are longer than those in the lower part. Each internode elongates from its basal portion. Typically, stem growth ceases toward the end of the flowering stage or at the beginning of the grain-filling period. In first-group cereals, the number of internodes generally ranges from 4 to 7, whereas in maize, sorghum, and rice, the number of internodes is considerably higher.

Heading stage. The emergence of the inflorescence from the upper leaf sheath indicates the onset of the heading stage in the plant. At this stage, approximately half of the spike or panicle has emerged from the leaf sheath.

From stem elongation to heading, the stem and leaves grow intensively, and the inflorescence is actively formed. Therefore, during this period the plant has a particularly high demand for water and nutrients. This stage is considered one of the most critical phases in the vegetative development of cereal crops.

Flowering stage. After the plant enters the heading stage, flowering begins. Barley usually flowers before full heading, while rye flowers 8–10 days after heading. Cereal crops are classified based on their mode of pollination into self-pollinating (wheat, barley, oats, millet, rice) and cross-pollinating species (rye, maize, sorghum). In self-pollinating cereals, the anthers typically mature and release pollen before the flower fully opens, allowing pollination to occur within the same flower. Occasionally, under hot and dry conditions, wheat and barley flowers may open slightly during anthesis, exposing the pollen externally; in such cases, the plant can undergo cross-pollination. In cross-pollinating cereals, the anthers mature and release pollen only after the flower has opened. The light pollen is then dispersed by wind to the stigmas of other flowers, enabling fertilization. If pollen lands on the stigma of the same flower, fertilization may be inefficient or may fail entirely. Rainy weather or strong winds can disrupt flowering, preventing proper pollination and resulting in sparsely filled spikes.

In spike-type cereals (wheat, barley, rye, maize tassel), flowering begins in the central spikelets of the spike. In panicle-type cereals (oats, millet, sorghum, rice, maize ear), flowering starts from the tips of the panicle. Experimental observations have shown that the first grains to form in the inflorescence are usually larger and exhibit superior seed qualities.

Ripening stage. After pollination, the ovule begins to develop, forming the seed and embryo. Nutrients accumulated in the leaves are mobilized to support grain formation. During this process, nutrients are transformed from soluble forms (such as sugars and amino acids) into insoluble storage compounds (such as starch, cellulose, and lipids). Grain maturation occurs in three distinct stages: milk stage, dough or wax stage, and full maturity stage.

Milk ripening stage. The milk stage begins 8–18 days after flowering. During this period, the plant remains green, although the lower leaves start to yellow. The grain is fully formed and green in color; when pressed, it releases a milky fluid. The grain's moisture content is approximately 50%, and organic compounds continue to accumulate. When such grain is dried, its volume can decrease by up to one-third. At the milk stage, the germination energy of the grain is high, but this property is quickly lost during storage. In southern regions, the milk stage lasts about 10–12 days. At this stage, harvesting for grain is absolutely not recommended.

Wax ripening stage. In cereal crops with spikes, by the wax (dough) stage, the grains and spikes turn completely yellow, although the upper part of the stem may remain green. In maize, sorghum, millet, and rice, the stalks often remain green while the grains ripen. At this stage, the grains turn yellow and soften, allowing them to be pressed or pinched by hand. Grain moisture at this stage is around 25%. The nutrients accumulated in the grain at the wax stage differ little from those in fully mature grain.

The duration of the wax stage varies significantly depending on weather conditions. In southern regions, it typically lasts 6–8 days, but may be prolonged under humid conditions. This period is considered the most suitable for harvesting cereals that are cut and collected in advance.

Full maturity stage. During the full maturity stage, the entire plant turns yellow, the grains harden, their volume slightly decreases, and moisture content drops to 14–16%. At this stage, the grains of most cereal crops, including maize and sorghum, may begin to shatter. Grain ripening in cereals depends on soil conditions, climate, weather, and other environmental factors. Grain matures faster in soils that are low in fertility, light in texture, and rich in nitrogen, compared to heavy soils. Additionally, in spring-sown crops, grains in lower areas and irrigated fields ripen earlier. Fully mature cereal crops are harvested directly using a combine harvester.

Conclusion: Seed germination requires water, heat, and oxygen. Water promotes seed swelling and provides favorable conditions for enzymatic activity. The embryo absorbs water more rapidly than the endosperm, so the seed does not swell uniformly. As a result, the seed coat ruptures during germination, and the primary root along with the initial shoots emerge. If soil moisture is excessively high or insufficient, sown seeds may germinate poorly or fail to germinate altogether. During the growth and development of cereal crops, their requirements for soil moisture and nutrients vary at different stages. Therefore, high and quality yields can only be achieved through proper implementation of optimal agrotechnical practices. This is because cereal crops pass through several distinct developmental stages from germination to harvest.

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