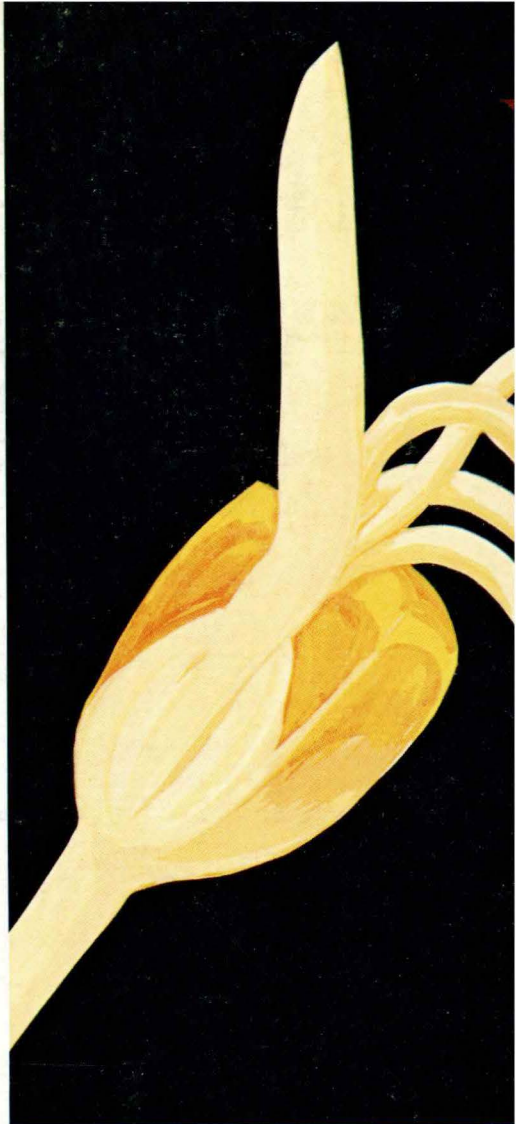
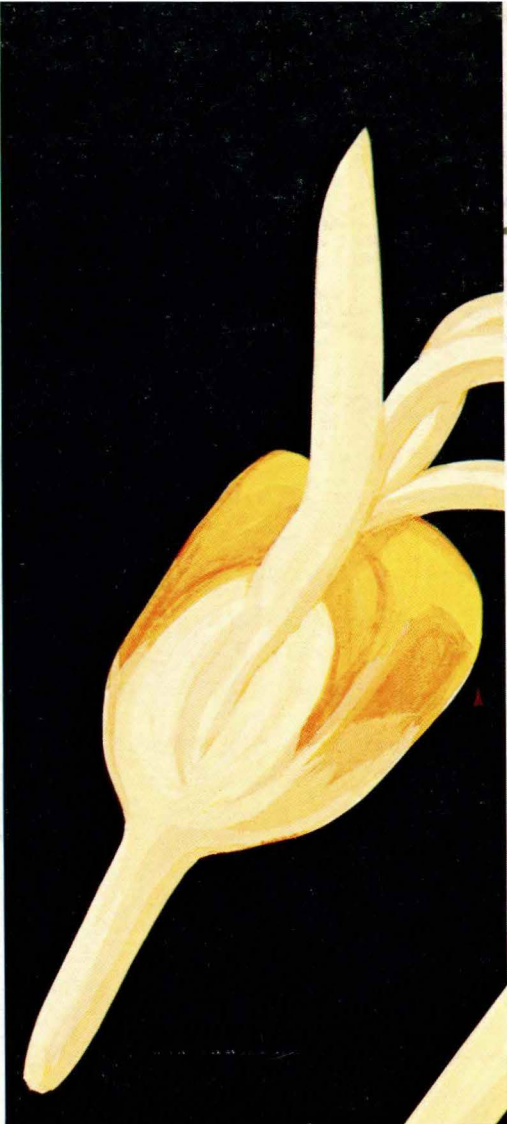


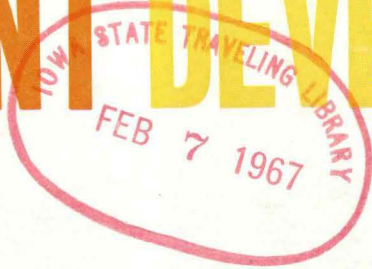
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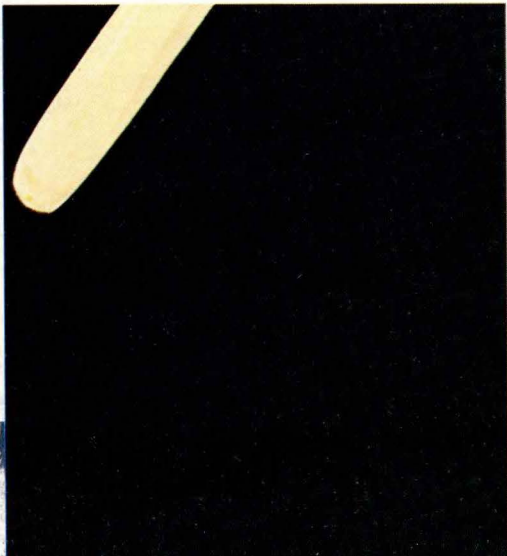
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HOW A CORN PLANT DEVELOPS

by John J. Hanway



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IOWA STATE UNIVERSITY
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HOW A CORN PLANT DEVELOPS

There's more than meets the eye in a field of growing corn.

One way to look behind the scene is to consider the cornfield as a complex and constantly changing community.

It is a manufacturing community, with many thousands of "factories" per acre. Every corn plant is a factory that produces dry matter. The corn plant is one of the most efficient factories in the world!

There's competition in this community: competition for the raw materials from the soil and atmosphere; competition coming from other dry matter producers (weeds); and competition coming from insects and diseases that interfere with the factory operation.

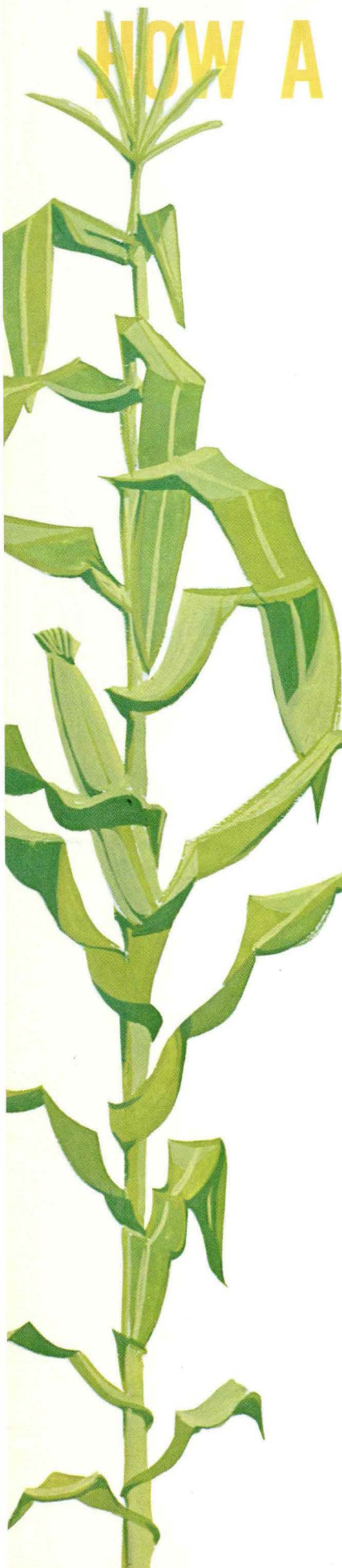
Forces of nature provide the basic plan for this community. But each of those forces can be influenced by the man who manages it. Every production practice affects the performance of the manufacturing system.

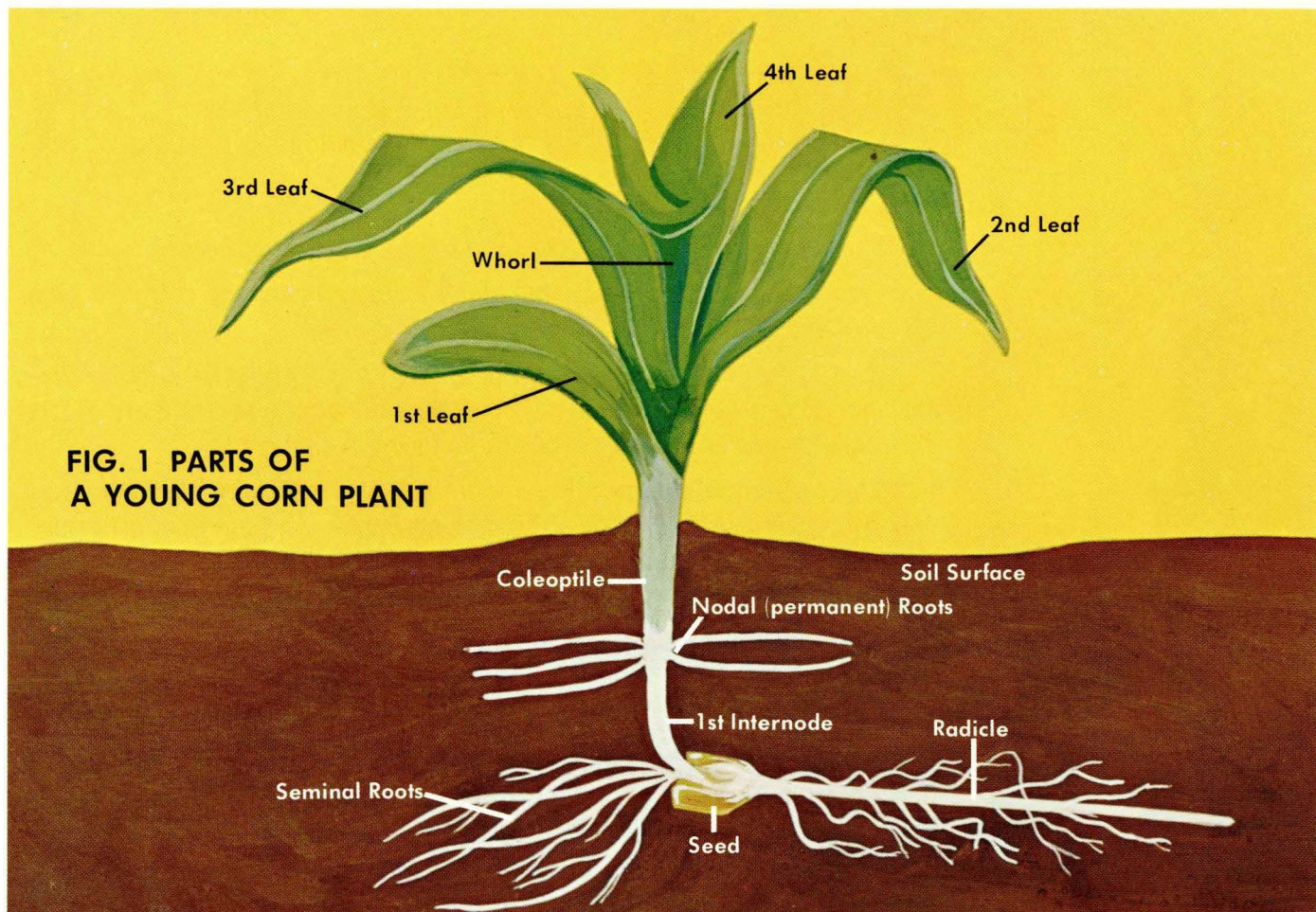
Science and experimentation have given corn producers many practices that improve total output from a field of corn. They are effective practices. Great jumps in productivity have come from them. Still, they are gross practices. They are adaptable over a wide range of situations. They will work under different levels of management. The manager who follows the general recommendation can be confident of getting a profitable return. He can do that without understanding why there is improvement, without really knowing what effect he causes.

As knowledge has been gathered, a much greater precision in practices has become possible. Output goes up with the precision.

In the factory analogy, general practice recommendations can be compared to one kind of business approach: Set up a good plant, arrange for a supply of raw materials, hire good workmen and tell them to do their best. By contrast, consider the factory that maintains continuous lines of information flowing on raw materials inventories, efficiency studies of the various processes, trouble-shooting crews and constant surveillance to achieve maximum performance.

This publication is designed for the person who is interested in corn production precision. It centers on one part of the management: **HOW A CORN PLANT DEVELOPS.**





**FIG. 1 PARTS OF
A YOUNG CORN PLANT**

The logic is straightforward: The manager who knows how the corn plant develops and functions can do a more precise job of controlling the forces that affect the output. An understanding of the plant—to the extent that is now possible—relates to his practice decisions on:

- Selection of most suitable varieties
- Timing of fertilizer applications
- Timing of such cultural practices as weed, insect and disease control
- Timing of harvest operations
- Production planning for total corn production operations

THE ILLUSTRATIONS

The pictures and discussion in this publication represent an adapted, midseason hybrid in central Iowa. Each such plant will develop 20 leaves and will silk 66 days after plant emergence.

All normal corn plants will follow this same general pattern of development, but the specific times between stages and numbers of leaves developed may vary between different hybrids,

different seasons, different dates of planting and different locations. For example:

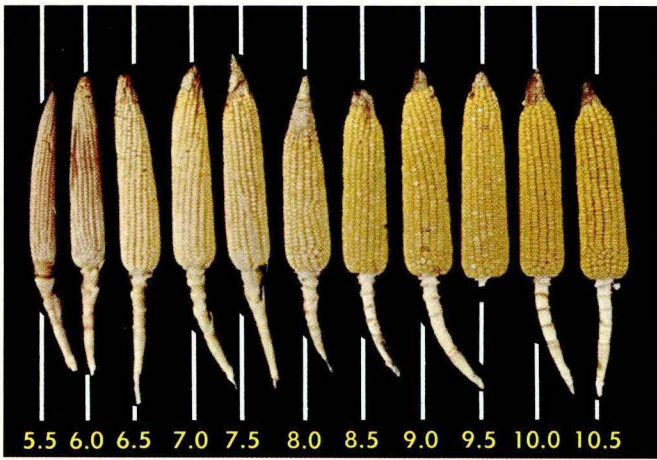
1. An early maturing hybrid may develop fewer leaves or progress through the different stages at a faster rate than indicated here. A late-maturing hybrid may develop more leaves or progress more slowly than indicated here.

2. The rate of plant development for any hybrid is directly related to temperature, so the length of time between the different stages will vary as the temperature varies, both between and within growing seasons.

3. Increased day length early in the development of the plant results in more leaves per plant and lengthens the time between plant emergence and flowering or silking. Day length increases from south to north in the United States at corn planting time.

4. Deficiencies of nutrients or moisture may result in lengthening the time between different stages before silking.

5. The number of kernels which develop, the final size of the kernels, and the rate of increase in weight of the kernels influence the length of the period from silking to maturity. These vary between different hybrids and different environmental conditions.



UNDRIED

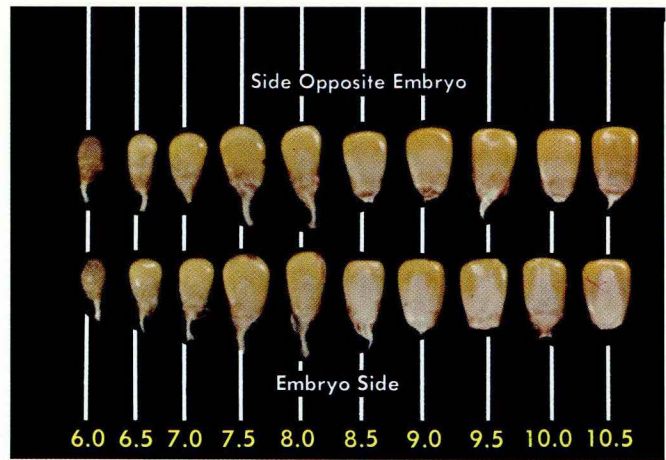
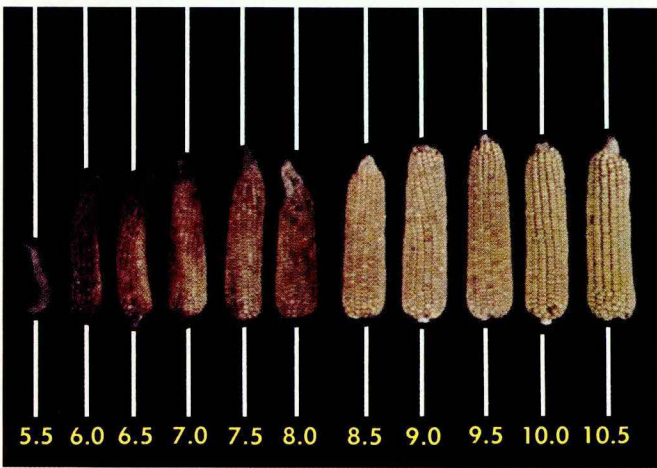
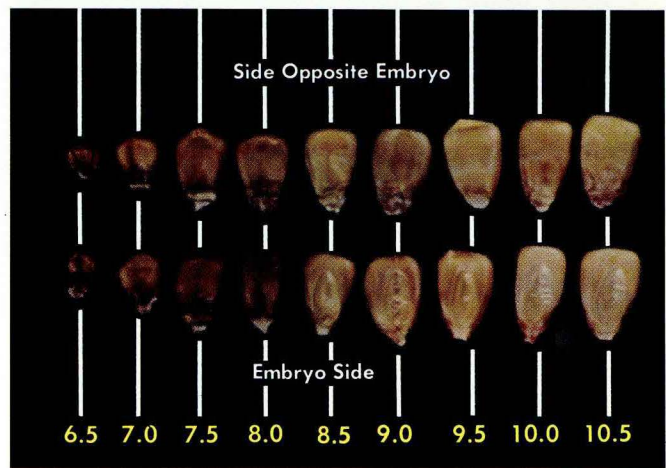


FIG. 2 STAGES OF EAR AND GRAIN DEVELOPMENT



OVEN-DRIED



The pictures show plants and plant parts at identifiable stages of morphological (form and structure) development. The plants were grown in the field but were photographed in the laboratory. Scientific names of parts in a young plant are shown in fig. 1.

A numbering system is used to identify the different stages of plant development. The stage at which the plant tip emerges from the soil is stage 0 and the stage when the plant is mature is stage 10. Intermediate stages are assigned numbers between 0 and 10. For example, stage 5 refers to the silking stage—silks just emerging from the husk. A decimal is used to refer to a stage of development (intermediate) between those identified by whole digits. For example, the stage halfway between stage 2 and stage 3 is identified as stage 2.5.

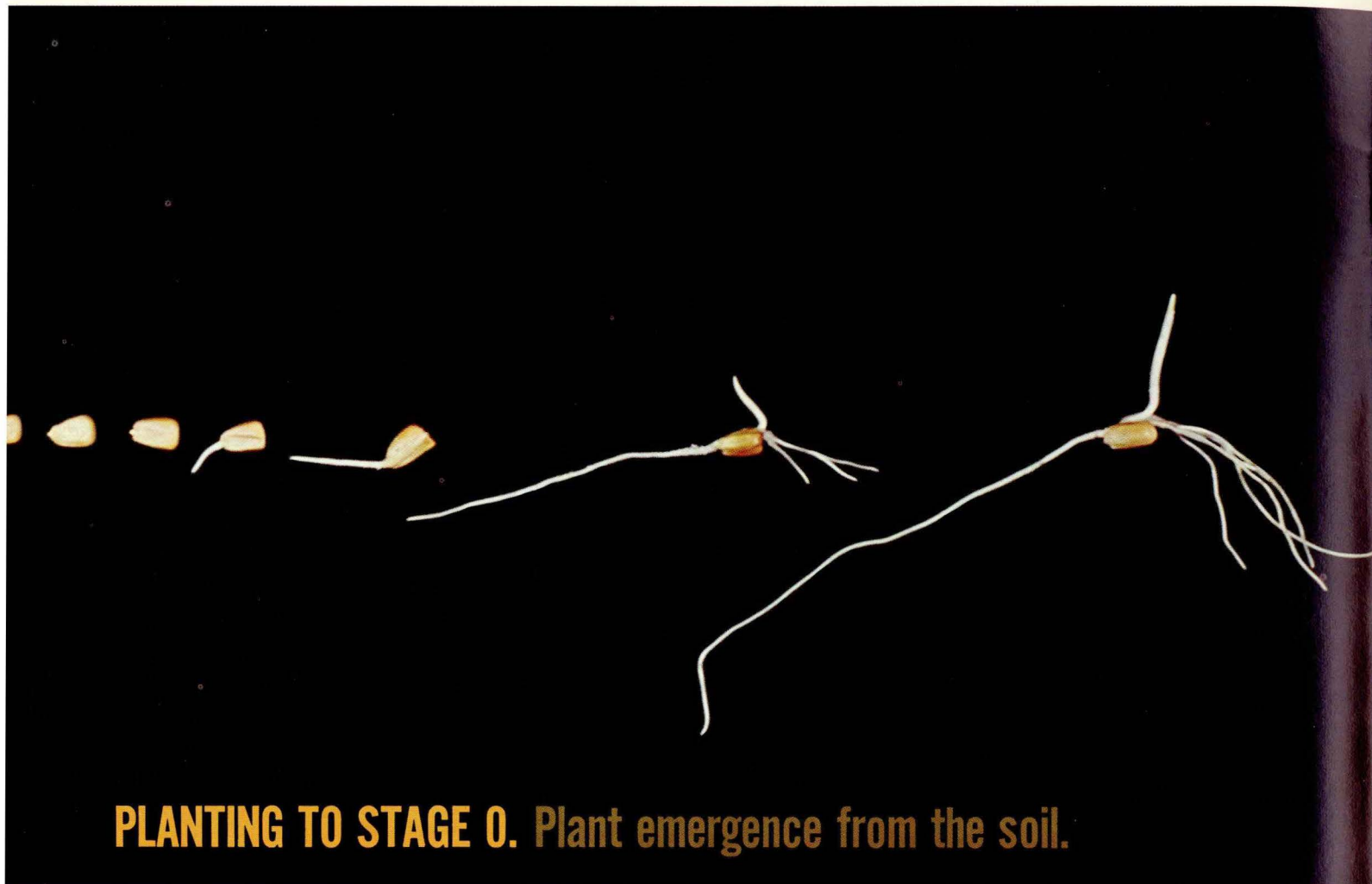
IDENTIFYING STAGES OF GROWTH

Stages of growth *before silking* can be identified in the field by counting the number of leaves that are fully emerged (with the collar visible) from the whorl. This is not difficult during the

first 3 weeks of growth—the first leaf normally has a rounded tip, all later leaves are pointed, and each succeeding leaf of the first seven or eight leaves is almost twice as large as the leaf below it.

However, when the stalk begins to elongate, the first (lowest) five or six leaves may be torn loose by stem enlargement and by development of the nodal roots. After this occurs, the lowest leaf remaining on the plant may be identified by the length of the internode below the attachment of the leaf sheath. The internodes below the first four leaves never elongate. The internode below the attachment of the fifth leaf elongates to about 1/2 inch in length; the internode below the sixth leaf elongates to about 1 inch; below the seventh leaf to about 2 inches; and below the eighth leaf to about 3 1/2 inches.

Stages of growth *after silking* can be identified by the development of the kernels on the ear (fig. 2). At stage 6, the cob is full size and the kernels are in the blister stage. At stage 7, the kernels are in a soft dough (just past roasting-ear) stage. At stage 8, a few kernels are beginning to show dents. At stage 9, all kernels are dented, but are not dry.



PLANTING TO STAGE 0. Plant emergence from the soil.

The embryo in the seed has five leaves and the primary roots have been initiated. After planting, the seed absorbs water and the young plant begins to grow. The radicle elongates most rapidly, followed by the plumule (young plant or shoot) and the seminal roots. The radicle emerges from the end of the seed opposite the shoot. Two to five seminal roots emerge from the end of the seed near the shoot. All roots, except the radicle, tend to grow at an angle of 25 to 30 degrees from the horizontal. The radicle can be aimed any direction (except up) by orienting the seed.

The first internode elongates to raise the plant to the soil surface. When the tip of the plant emerges from the soil surface into the light, elongation of the first internode stops and leaves begin to emerge from the coleoptile. Under warm, moist conditions, the tip of the plant will emerge within 4 or 5 days after planting; but, under cool or dry conditions, 2 weeks or longer may be required.

At emergence, the growing tip of the plant and all the nodes of the stem are 1 to 1 1/2 inches below the soil surface.

MANAGEMENT GUIDES

Depth of planting influences the length of time from planting to emergence. Seedlings from deep-planted seeds have a greater depth of soil to penetrate. In addition, temperatures are cooler at greater depths and growth is slower. Depth of planting determines the depth at which the primary roots (radicle and seminal roots) develop but does not influence the depth at which the nodal (permanent) roots develop.

Nutrients and food reserves in the seed generally supply the young plant adequately prior to emergence. Fertilizer placed in a band to the side and slightly below the seed may be contacted by the primary roots before the plant emerges from the soil. Placement of too much fertilizer too near the seed can result in salt injury to the young plant.



STAGE 0.5. Two leaves fully emerged, 1 week after plant emergence.

Roots of the first whorl at the coleoptile node have elongated, but have not branched or formed root hairs. The primary roots, especially the radicle, have many branches and root hairs. Photosynthesis by the leaves is now feeding the plant.

MANAGEMENT GUIDES

Since the root system is relatively small and the soil is cool, higher concentrations of fertilizer nutrients stimulate early plant growth. However, the amounts of nutrients required are relatively small. Fertilizer placed in a band where the primary roots (especially the radicle) will contact it will be effectively taken up at this stage. Roots are not attracted to this fertilizer band, so the fertilizer must be placed where the roots will be.



STAGE 1. Four leaves fully emerged, 2 weeks after plant emergence.

Roots of the second whorl have elongated. Roots of the first whorl have root hairs and are branched. The primary roots grow very little after this stage. At about this time the tassel is initiated in the tip of the stem, but it is still below the soil surface. (Day length influences the time of tassel initiation.) All the leaves and ear shoots have been initiated.

MANAGEMENT GUIDES

Cultivation too near the plant after this time will destroy some of the permanent root system.

A frost (light freeze) or hail may destroy the exposed leaves but not damage the growing point below the soil surface and therefore usually results in very little reduction in the final yield.



STAGE 1.5. Six leaves fully emerged, 3 weeks after plant emergence.

The nodal roots now form the major part of the root system. The third whorl of nodal roots is elongating. The internodes below the fifth, sixth and seventh leaves have begun to elongate, so the stem tip (growing point) is at or slightly above the soil surface. Suckers have begun to develop from each below-ground node. The amount of sucker development will vary with different hybrids, plant spacings, fertility and environment.

MANAGEMENT GUIDES

The nodal root system is now well distributed in the soil, so precise placement of fertilizer is less critical. However, the plant now begins to absorb greater amounts of nutrients, so fertilizer applications in amounts adequate to supply those nutrients which are deficient in the soil will be beneficial.

Rootworms may destroy the developing nodal roots and thereby restrict plant growth. Later root development at successively higher nodes may result in plant recovery.



TASSEL



STAGE 2. Eighth leaf fully emerged, 4 weeks after plant emergence.

This is the period of rapid leaf formation. The ninth, tenth and eleventh leaves are full size but not fully emerged. Enlargement of the stalk and development of nodal roots have torn the first (lowest) two leaves from the plant. The stem has begun rapid elongation and the growing tip is 2 to 3 inches above the soil surface. The internodes below the seventh, eighth and ninth leaves are elongating. The internodes below the fifth and sixth leaves are fully elongated to about 1/2 inch and 1 inch in length, respectively. The tassel is beginning to develop rapidly. The fourth whorl of nodal roots is elongating.

MANAGEMENT GUIDES

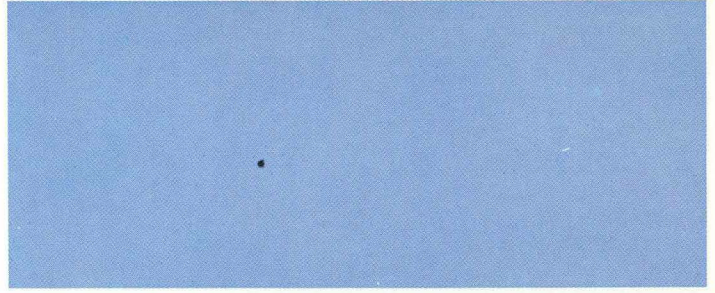
Nutrient deficiencies at this stage seriously restrict leaf growth. Nitrogen fertilizer may be effectively sidedressed up to this stage if the fertilizer is placed in moist soil and if serious injury to the root system, through root pruning, is avoided.

Removal of all of the unfurled leaves at this stage (by frost or hail) may result in 10 to 20 percent reduction in final grain yield.

Spraying with 2,4-D may cause the developing stalk to be brittle, and the stalks can be easily broken at the soil surface.

Corn borer eggs begin to hatch at this stage. Watch for leaf feeding and treat if necessary.

Flooding at this or any previous stage when the growing point is below the soil surface can kill corn plants in a few days, especially if temperatures are high. Flooding at later stages, when the growing point stays above the water, is not as detrimental.



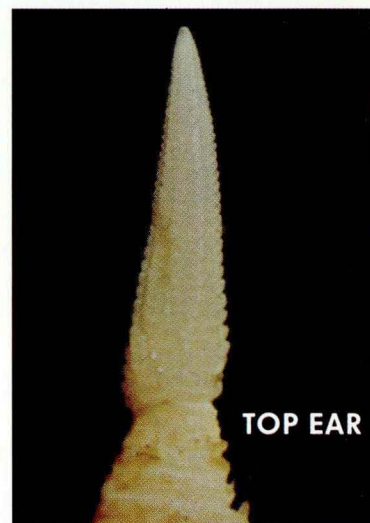
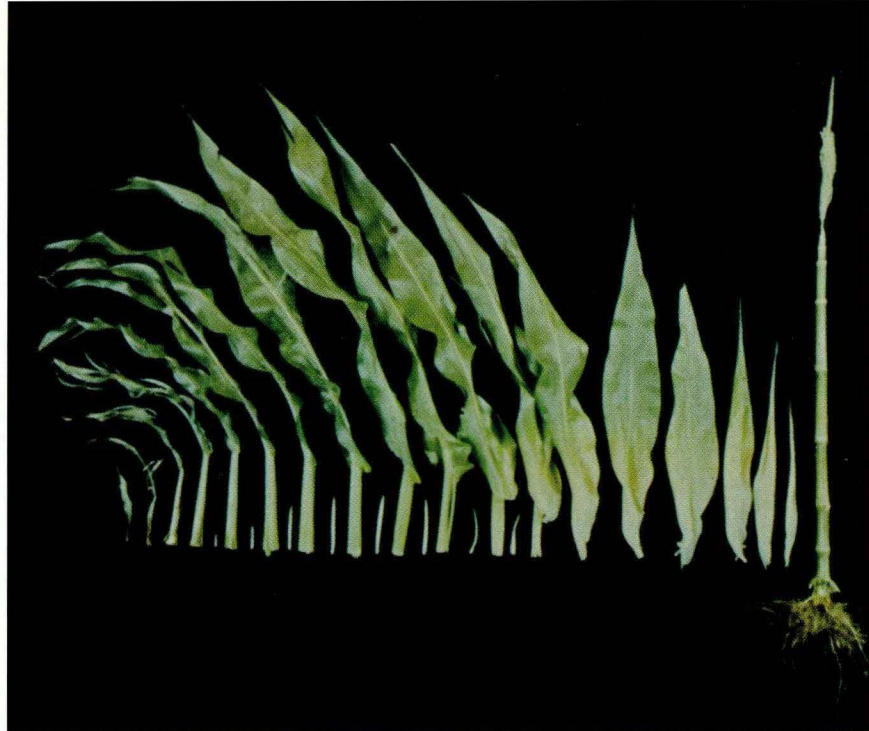
STAGE 2.5. Tenth leaf fully emerged, 5 weeks after plant emergence.

The fourteenth leaf is full size but only partially emerged from the whorl. The internodes below the tenth, eleventh and twelfth leaves are elongating. The internode below the ninth leaf is fully elongated. Rapid growth of the tassel is initiated at this stage. Ear shoots are developing in six to eight aboveground nodes. The uppermost ear shoot is still smaller than ones below it. Uptake of nitrogen, phosphorus and potassium is rapid.

MANAGEMENT GUIDES

Moisture and nutrient deficiencies from this stage on will markedly influence the growth and development of the ears. Since the root system is extensive and the soil is warm, banded, high concentrations of nutrients are not essential. But the nutrients must be in moist soil to be absorbed. Thus, plowed-under fertilizer is preferred since surface-applied nutrients (especially phosphorus and potassium, which do not move any appreciable distance in most soils) may be in dry soil and unavailable to the plants.

The stalk is now growing well above the soil surface. Plants broken over below the growing point will not recover. Yield losses from hail or leaf damage are greater than at any previous stage.



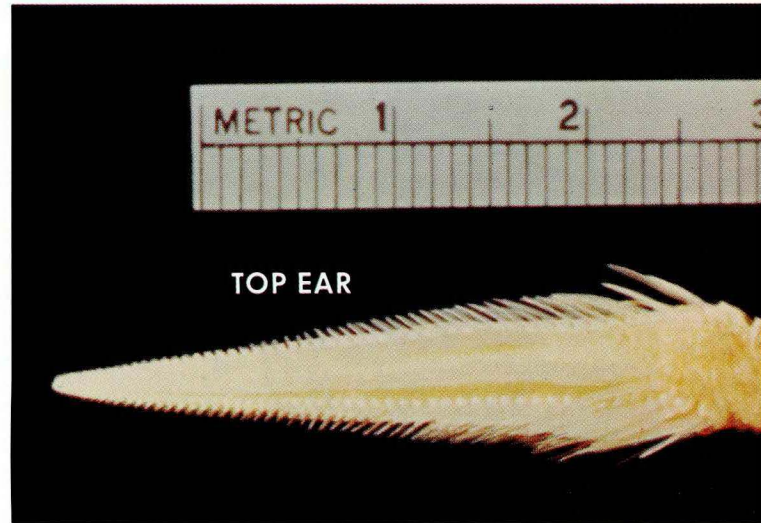
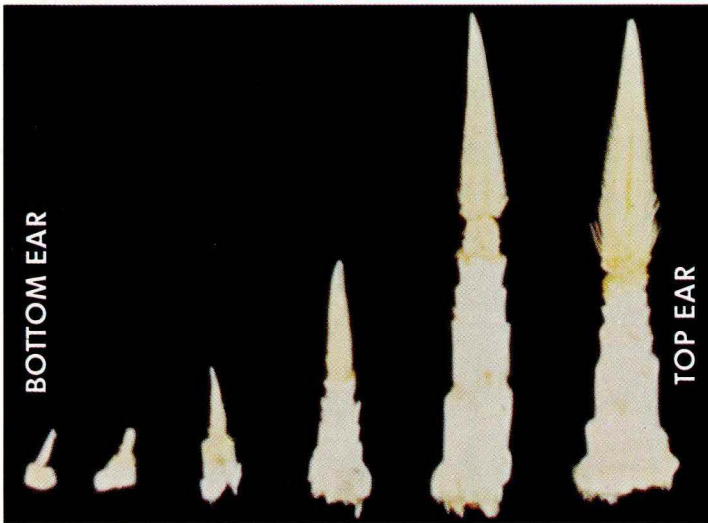
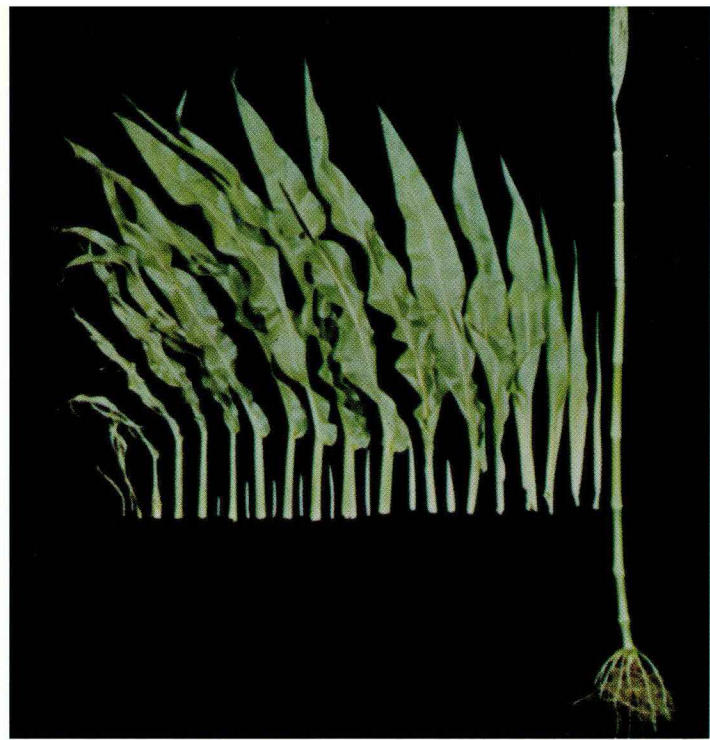
STAGE 3. Twelfth leaf fully emerged, 6 weeks after plant emergence.

Leaf enlargement is complete. The four lowest leaves have been lost. Stalk and tassel are growing rapidly. Brace roots are developing at the first aboveground node. The uppermost ears are initiating rapid development. The potential number of ovules on the top (major) ear is determined at about this time.

The rapid and nearly constant daily rate of increase in the dry weight of the aboveground plant begins about this time and continues until near maturity.

MANAGEMENT GUIDES

This is a critical period in determining the size of the uppermost ear (or ears). Moisture or nutrient deficiencies at this time may seriously reduce the potential size of the ear that will be harvested. The potential size of the harvested ears is also related to the length of time between stage 3 and silking (stage 5). Earlier maturing hybrids, which progress through these stages in a shorter time than later maturing hybrids, usually have small ears and must, therefore, have more plants per unit area to produce the same grain yield.

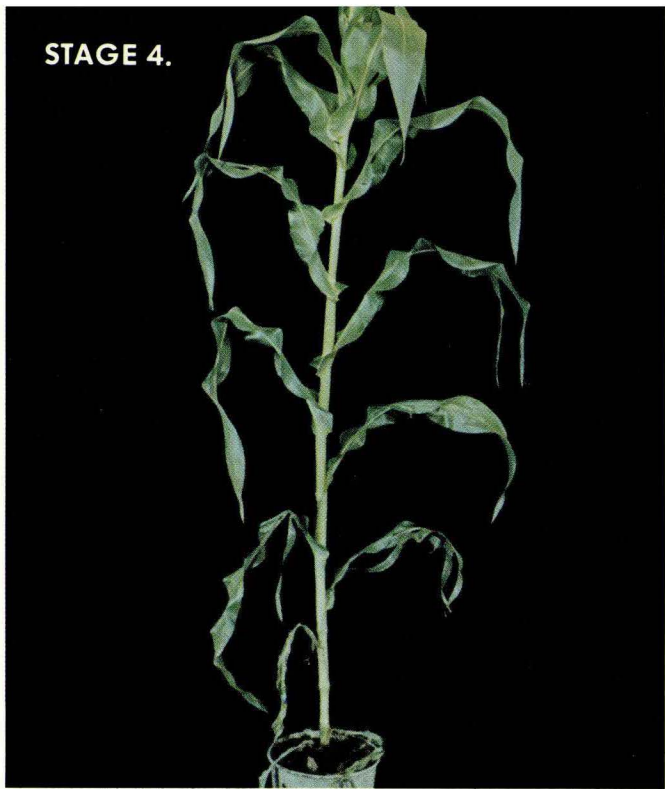


STAGE 3.5. Fourteenth leaf fully emerged, 7 weeks after emergence.

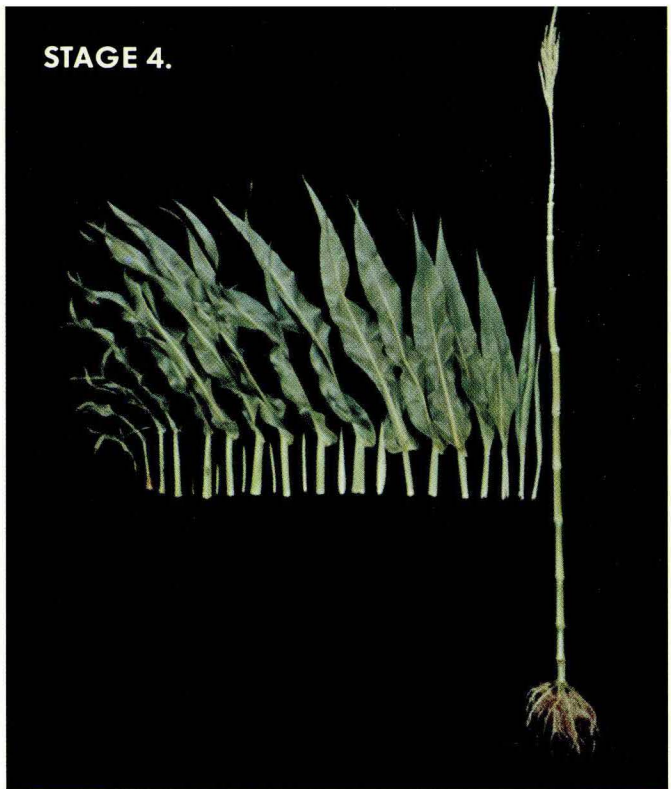
The stalk is elongating rapidly. The tassel is near full size. The top one or two ears are developing rapidly. Silks are developing, especially from near the base of the top ear. Brace roots from the seventh leaf node are developing.

MANAGEMENT GUIDES

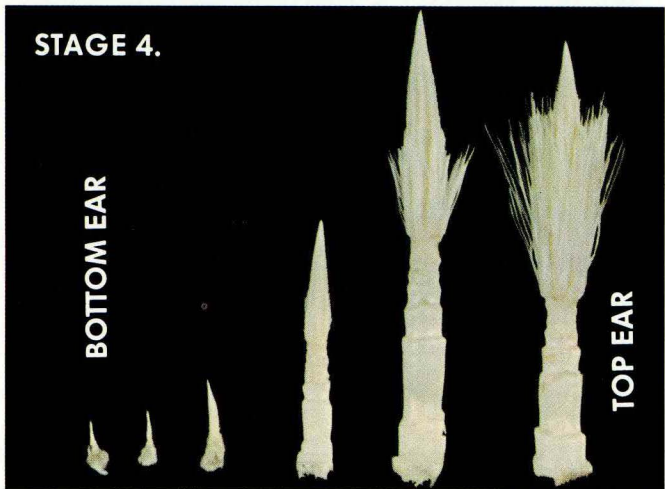
The number of ovules which develop silks, and thus the number of kernels, is being determined. Any nutrient or moisture deficiency or injury (hail, insects) may seriously reduce the number of kernels that develop.



STAGE 4.



STAGE 4.



STAGE 4.

BOTTOM EAR

TOP EAR



TOP EAR STAGE 4.5

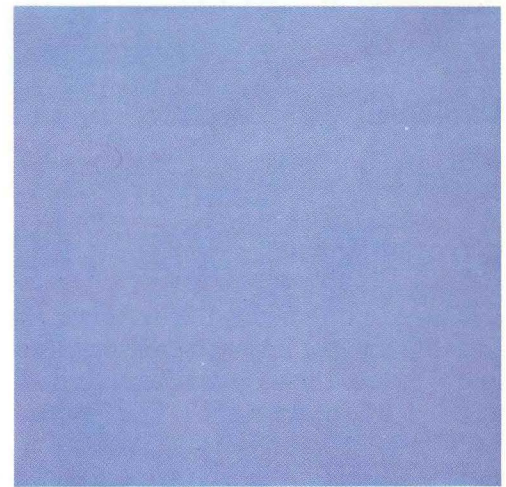
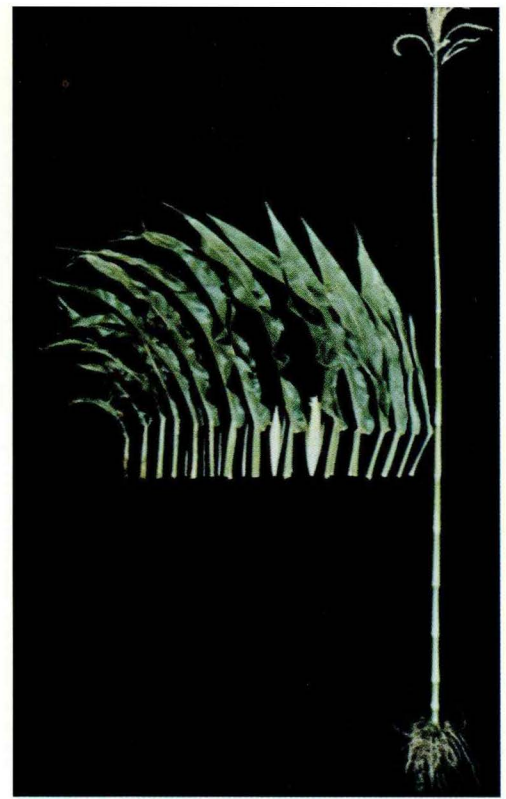
STAGE 4. Sixteenth leaf fully emerged, 8 weeks after plant emergence.

The tip of the tassel has emerged from the whorl. The upper internodes of the stalk are elongating rapidly. The top one or two ears are undergoing rapid enlargement and elongation. Silks from the base of the ears are elongating rapidly. The first (lowest) five or six leaves at the base of the plant may be missing.

MANAGEMENT GUIDES

Moisture stress or nutrient deficiencies usually increase in intensity from the top to the bottom of the plant and will delay silking more than tassel emergence and pollen shedding.

Complete leaf removal (by hail) at this stage will result in essentially complete loss of grain yield. Removal of half of the leaves would result in 25 to 30 percent yield loss.



STAGE 5. Silks emerging, pollen shedding; 66 days after emergence.

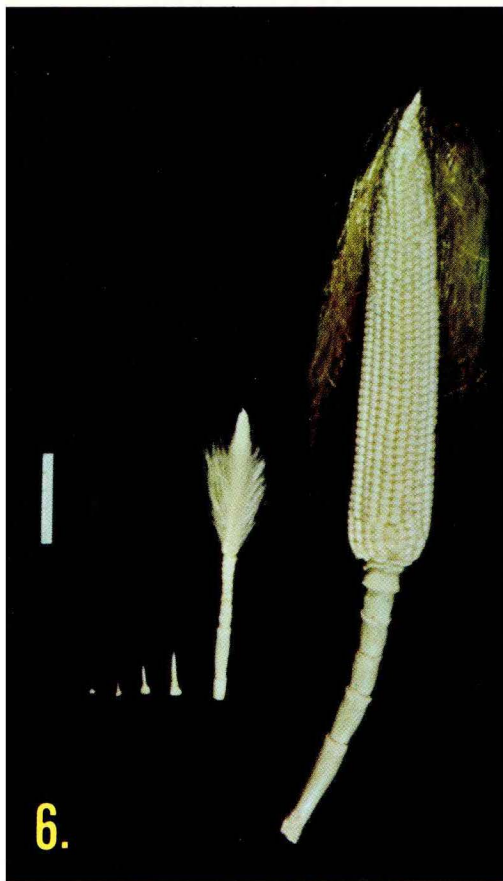
The leaves and tassel have been fully emerged for 2 to 3 days. Elongation of the stem internodes has ceased. The ear shank and husks have nearly completed growth. The cob and silks are growing rapidly. Ovules are enlarging. The silks from the ovules near the tip of the ear have not yet emerged. All silks will continue to elongate until they are fertilized.

MANAGEMENT GUIDES

The number of ovules that will be fertilized is being determined at this stage. Moisture stress (hot, dry days) or nutrient deficiency may result in poor pollination and seed set. Earlier planting and other management practices should be followed so this stage will occur when climatic conditions are most likely to be favorable.

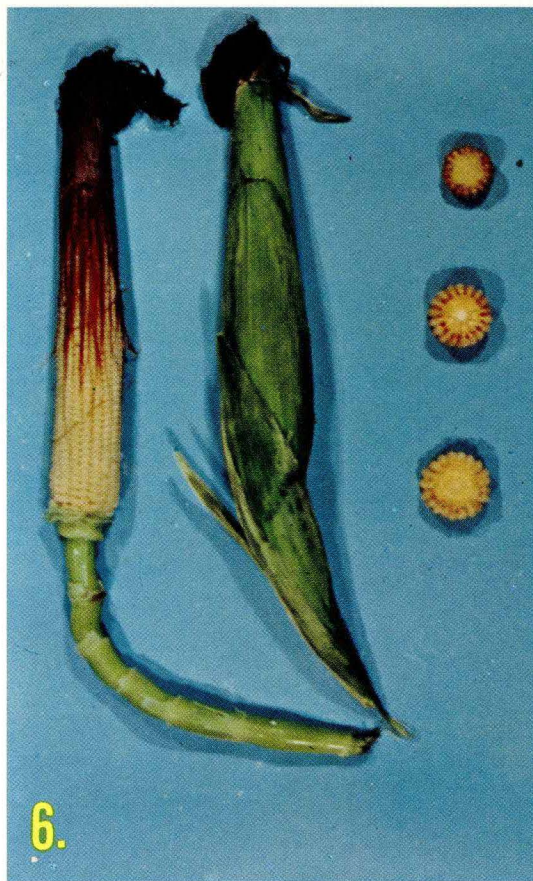
Watch for corn rootworm beetles feeding on silks. Treat if necessary.

Potassium uptake is essentially complete, and nitrogen and phosphorus uptake are rapid. Leaf analysis for nutrients in the plant at this stage is highly correlated with final grain yield and yield response to fertilizer applications.



STAGE 6. Blister stage, 12 days after silking.

The cob, husks and shank are fully developed. Starch has just begun to accumulate in the endosperm, and the kernels have begun to increase rapidly in dry weight. This rapid rate of dry weight accumulation will continue until approximately stage 9. The plants continue rapid uptake of nitrogen and phosphorus, but loss of nitrogen and phosphorus from other plant parts to the developing grain has begun. The coleoptile, first leaf and radicle have been initiated in the embryo of the kernel.



STAGE 7. Dough stage, 24 days after silking.

The kernels are growing rapidly. A new plant is developing in each kernel. The main axis in the embryo of the new plant is fully differentiated, and the fourth leaf initial is usually present. Starch is accumulating in the endosperm. Cell division in the epidermal layer of the endosperm has ceased.

MANAGEMENT GUIDES

This is the beginning of rapid increase in grain weight. Where possible, irrigate to assure adequate moisture for grain production. Loss of leaves from hail or other unfavorable conditions at this time will result in unfilled kernels, usually at the tip of the ear.

MANAGEMENT GUIDES

This is the period of rapid increase in grain weight and development of the young plant in the embryo of each seed. Unfavorable conditions or deficiencies of nutrients such as potassium will result in unfilled kernels and "chaffy" ears.



**STAGE 8. Beginning dent stage.
A few kernels are showing dents,
36 days after silking.**

Growth of the embryo is rapid. In the embryo, the radicle and embryonic leaves are fully differentiated and the seminal roots are initiated. Enlargement of the endosperm after this stage is chiefly due to an increase in cell size.



**STAGE 9. All kernels fully dented,
48 days after silking.**

The embryo is morphologically mature with five leaves initiated. Dry matter accumulation in the kernels will soon cease.

**STAGE 10. Physiologic maturity,
60 days after silking.**

Dry matter accumulation has ceased; but the grain will continue to lose moisture after this time. The husks and some of the leaves are usually no longer green.



MANAGEMENT GUIDES

The rapid increase in grain weight and development of the young plant in the embryo of each seed continues. Unfavorable conditions or deficiencies of nutrients such as potassium will result in unfilled kernels and "chaffy" ears.

MANAGEMENT GUIDES

There is relatively little increase in grain weight after stage 9 and no increase after stage 10. Harvest for silage at stage 10. Grain harvested at stage 10 would need to be mechanically dried to be stored safely. The rate of drying in the field will depend upon climatic conditions and properties of the husks, and other characteristics which are not well understood. Rates of drying may vary among hybrids.

CONCLUSIONS

HOW A CORN PLANT GROWS

Corn plants increase in weight slowly early in the growing season. But as more leaves are exposed to sunlight, the rate of dry matter accumulation gradually increases.

The leaves of the plant are produced first, followed by the leaf sheaths, stalk, husks, ear shank, silks, cob and finally the grain. By stage 3, enough leaves are exposed to sunlight so the rate of dry matter accumulation is rapid.

Under favorable conditions this rapid rate of dry matter accumulation in the aboveground plant parts will continue at a nearly constant daily rate until near maturity (see fig. 3).

Cell division and enlargement in the leaves occurs at the growing tip of the stem. Leaves become green and increase in dry weight when they emerge from the whorl and are exposed to light, but no cell division or enlargement occurs in the leaves after they are exposed. All the leaves are full size by the 12-leaf stage, but only about half the leaves are exposed to sunlight.

If a corn plant is grown without competition from other plants, ears will develop from several of the ear shoots that are initiated on the plant. Increasing the number of plants in a given area reduces the number of ears per plant and the number of kernels per ear. This reduction is greater for some hybrids than for others. Grain production per acre will increase with an increase in number of plants per acre until the advantage of more plants per acre is offset by the reduction in number of kernels per plant.

The optimum plant population is different for different hybrids and in different environments.

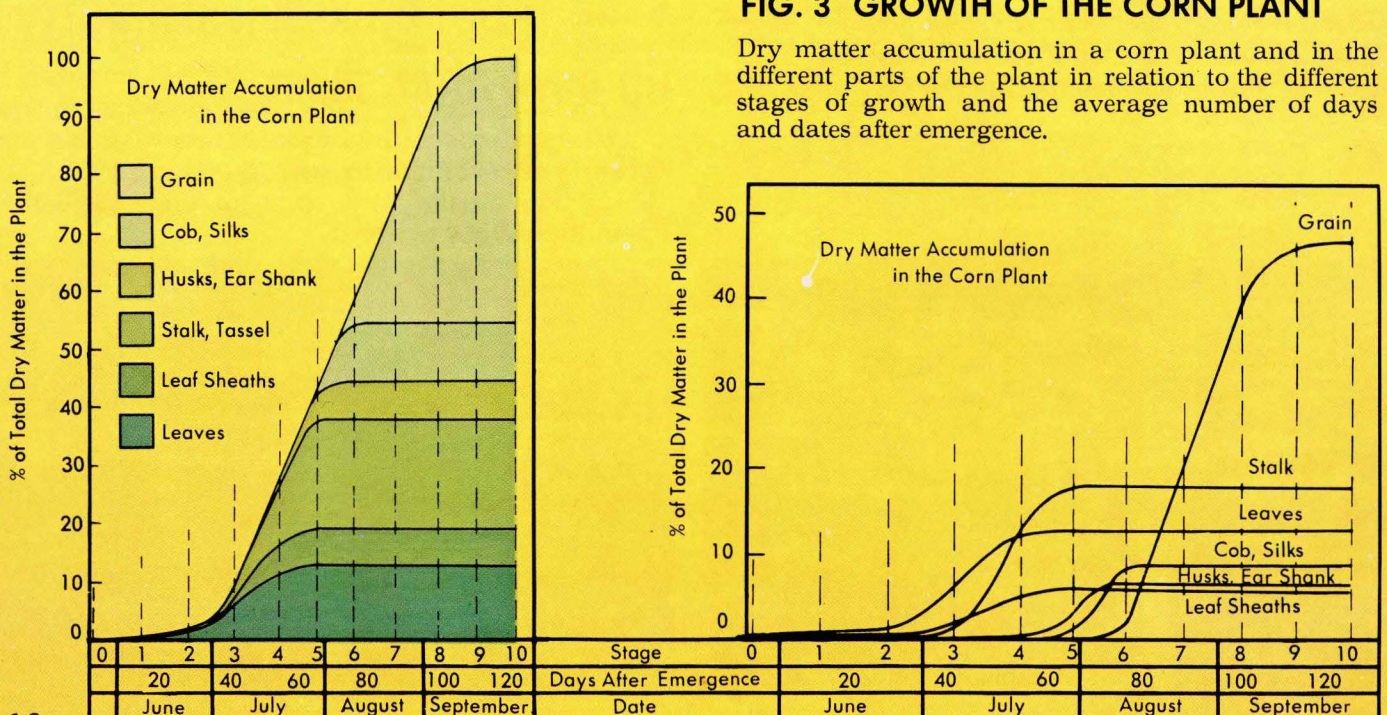
Highest yields will be obtained only where environmental conditions are favorable at all stages of growth. Unfavorable conditions in early growth stages may limit the size of the leaves (the photosynthetic factory). In later stages, unfavorable conditions may reduce the number of silks produced, result in poor pollination of the ovules and restrict the number of kernels that develop, or growth may stop prematurely and restrict the size of the kernels produced.

NUTRIENT UPTAKE

The rate of nutrient uptake by the corn plant is relatively slow early in the season, but the rate increases as the plant grows and develops (see fig. 4). *However, an adequate supply of nutrients at each stage is essential for optimum growth at all stages.*

Uptake of potassium is completed soon after silking, but nitrogen and phosphorus uptake continues to near maturity. Much of the nitrogen and phosphorus and some of the potassium are translocated from other plant parts to the grain as it develops. Unless adequate nutrients are available to the plant during this latter part of the growing season, translocation of nitrogen and phosphorus to the developing grain may cause serious deficiencies in the leaves and premature death of the leaves.

A large portion of the nitrogen and phosphorus taken up by the plant is removed in the grain that is harvested. But most of the potassium taken up is returned to the soil in the leaves, stalks and plant residue, unless these plant parts are removed for silage or other forms of feed.



FERTILIZER APPLICATIONS

Although only relatively small total amounts of fertilizer nutrients are required in the very early stages of plant growth, high concentrations of nutrients in the root zone at that time are beneficial in promoting early plant growth. This is the period when all the different plant parts are being initiated and begin to grow. Even though the amount of the nutrients taken up is relatively small, the final size of the leaves, ear and other plant parts depends to a large degree upon having an adequate supply of nutrients available to the plant during this early part of the growing season.

During early growth the root system is limited and the soil is often cold. The primary roots (radicle and seminal roots), which are elongating when the plant emerges from the soil, serve as the main root system during the first weeks after plant emergence. *Fertilizer placement in a band at about 2 inches to the side and slightly below the seed is important so the primary roots may intercept the band of fertilizer.* Roots will branch and proliferate in and near the band of fertilizer after they contact it; but they are not attracted toward the fertilizer band, so the fertilizer must be placed where the roots are going to be. Placing the fertilizer too near the seed can result in salt injury to the young plant.

At later stages of growth, the plants require much larger amounts of nutrients. These nutrients must be in moist soil for effective root uptake. *Therefore, plowing under adequate amounts of fertilizer to supply deficient nutrients is the most efficient method of providing nutrients to the plants at the later growth stages.* Fall or pre-plant application of nitrogen becomes

increasingly necessary for narrow rows and early planting.

The nodal, or permanent, roots begin to develop above the coleoptile node when the plant emerges from the soil. Successively higher whorls of nodal roots develop at about weekly intervals. Within 2 or 3 weeks after plant emergence, the nodal roots become the main root system of the plant. They develop at each of the six or seven below-ground nodes and nodal brace roots develop from two or more aboveground nodes. This permanent root system becomes well distributed in the soil, so precise fertilizer placement is less critical after these roots have developed.

Care should be taken to be certain that roots are not destroyed by cultivation or by side-dressing of fertilizer after the root systems of the plants become established.

SUMMARY

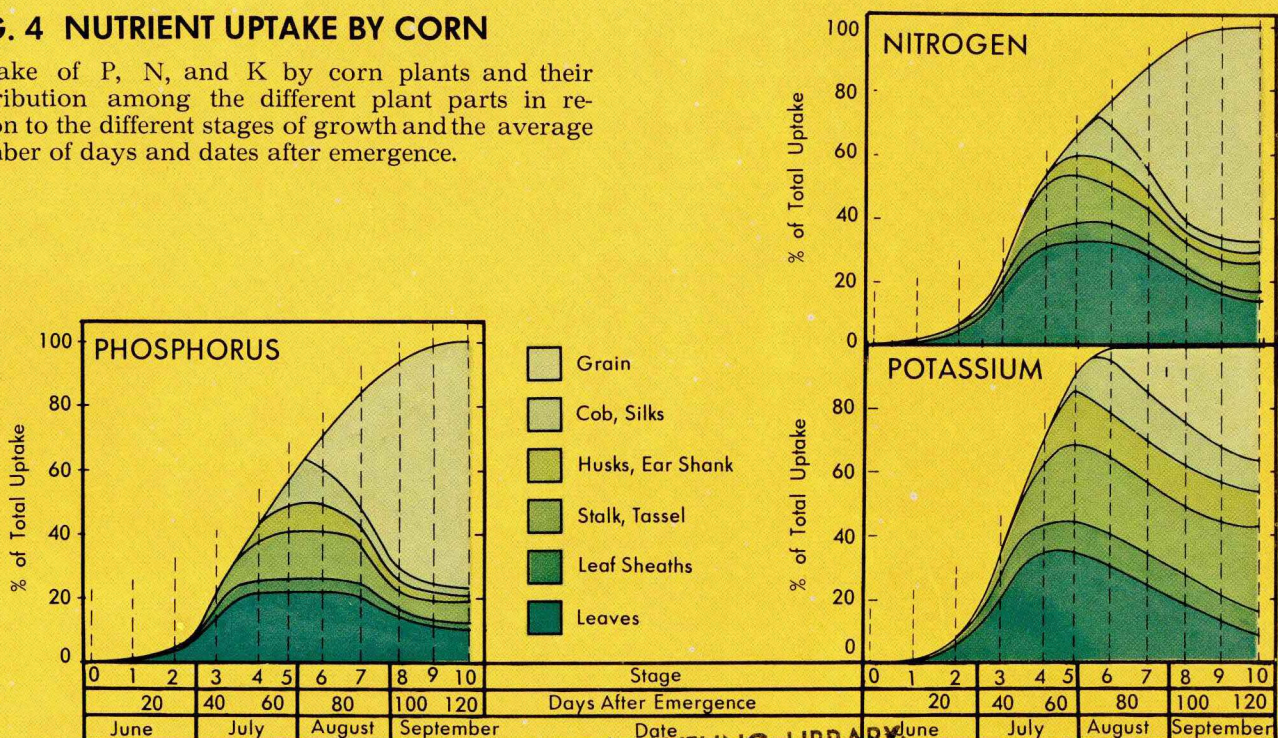
The illustrations tell us that the amount of grain produced by the corn factory will depend upon the rate and length of time of dry matter accumulation.

Take advantage of these implications by using these pointers to produce high yields:

- Fertilize according to soil tests for the production level you're after.
- Select the hybrid best suited to your farm operation.
- Plant early at the correct population and spacing.
- Eliminate competition from weeds, diseases and insects.
- Carry out all other cultural practices to maximize the rate and length of time of dry matter accumulation in the grain.

FIG. 4 NUTRIENT UPTAKE BY CORN

Uptake of P, N, and K by corn plants and their distribution among the different plant parts in relation to the different stages of growth and the average number of days and dates after emergence.



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