to lodging. Most of the plant K is absorbed by the grain fill stage of plant development. Adequate K in plants has been associated with higher tolerance to drought, higher resistance to frost and salt damage, and higher resistance to fungal attacks.

Potassium deficiency in plants may not result in visible symptoms before reductions in growth appears. Symptoms of K deficiency appear first on older leaves an spread to the young leaves. Irregular necrotic patterns intermingled with red pigmentation characterize visual K deficiency symptoms. Sometimes streaked patterns occur on the interveinal tissue, but the symptoms are fairly uniform over the leaf. Symptoms begin at the tips and margins and move toward the base and midrib of the leaves. The unaffected portions of leaves remain fairly green. It is often difficult to distinguish a K deficiency from "red-speckling" caused by excess P. Potassium deficient plants do not normally show the spindly growth observed for N and P deficiencies. Shoot/root ratios remain fairly constant with K deficiency and grain yields are frequently reduced.

Excess K disorders seldom occur unless plants are grown under abnormal conditions like saline soils. Excess K causes leaves to become uniformly pale, become water soaked, die and turn brown. The symptoms progress from the tips toward the base of leaves and are usually more severe in the older in the younger leaves.

## Calcium

The amount of Ca needed by sorghum is fairly high during vegetative growth, but not during reporductive growth. Leaf concentrations of Ca vary widely and concentrations of 50 to 70 mg/g dry matter are not uncommon. Thus, a readily available source of Ca in soils is needed for plants. Many soils normally contain adequate or high Ca (alkaline and calcareous), but acid soils are often low in soluble Ca. Because of this, Ca deficiencies seldom occur in plants grown on alkaline or nuetral pH soils, but occur frequently when grown on acid soils. Soluble Al and Mn in acid soils also interact with Ca to enhance Ca deficiencies in plants. Acid soil problems are usually corrected by lime amendments, which is a source of Ca to overcome Ca interactions with Al and Mn.

Calcium is taken into plants as a cation ($Ca^{2+}$) and remains in this form for its functions. Calcium can be complexed fairly readily, usually with organic acids. Calcium functions in plants are associated with membranes (conformation, integrity, leakiness, secretion, ion pumps), cells walls, a few enzyme reactions, phytohormone regulatory reactions, osmoregulation, pollen tube growth, cell division and mitosis, and gravi-, photo- and thigmo-tropic processes. Leaves normally accumulate relatively high Ca. This is not remobilized when Ca deficiencies appear in other tissues. Very little Ca accumulates in kernels. Most plant Ca is absorbed by early grain fill.

Calcium deficient plants become stunted because of death of newly emerging and developing tissues. Ca deficiency occurs first in the meristematic tissues. Young leaf tips often stick together (ladder-like effect), form sword-like projections, have serrated (torn and warped) leaf edges, and often show lightly bleached leaf margins. Severe Ca deficient leaves are brittle and form brown, sticky vesicles at or near the margins. The leaves frequently coalesce and turn brown. As Ca is mobile primarily in the xylem (upward translocation stream), older leaves usually





contain adequate or high concentrations of Ca and young leaves and even sections of leaves may be low in Ca. When plants overcome Ca deficiencies after Ca additions, leaves often show aborted, twisted symptoms with leaf tips sticking together as new plant leaves begin to regrow. If Ca deficiency persists, heads will not form because primordial and meristematic tissues are destroyed. Shoot/root ratios usually decrease with Ca deficiency, because shoot growth is affected extensively.

Calcium deficiencies often occur in sorghum plants grown in greenhouses and growth chambers. These Ca deficiencies appear to be associated with reduced transpiration and restricted root growth in pots. High light intensity, certain types of lights and high temperatures tend to enhance Ca deficiencies. Calcium deficiencies also appear to be accentuated by certain sources of N.

Detrimental effects from excess Ca seldom occur, but if they do these effects are likely to occur because of the accompanying anion or from Ca interactions with other elements like the induction of K and Mg deficiencies.

## Magnesium

Compared to K, Mg accumulates in sorghum plants at relatively low concentrations (2 to 3 mg/g). Deficiencies of Mg seldom occur in plants grown on neutral to alkaline pH soils, but are common for plants grown on acid soils. Magnesium deficiencies may also be accentuated by available Al. Exchangeable sources of Mg appear to be made available to plants fairly easy, but even these sources of Mg may not be sufficient to meet plant needs at a particular stage of plant development. Soil solution Mg can vary widely with different soils (sands or clays) and with different soil parent materials. Levels of Mg in soil solutions between 2 to 5 mM are oftern reported. Magnesium deficiencies in soils are commonly alleviated when dolomitic limestone is added. Both Ca and Mg are added with dolomite.

Like that of Ca, Mg is absorbed as a cation ($Mg^{2+}$), and this is the active form in metabolism. Magnesium is not readily complexed by organic compounds. The best known function of Mg is its occurence in the chlorophyll molecule. The greatest proportion of Mg in plants (often over 70%) is diffusible and associated with the cytoplasm or vacuoles of cells. Magnesium is required in essentially all enzymes activiting phosphorylation processes. As such, Mg is involved with phosphate and nucleotide transfer reactions. Magnesium is also associated with the stabilization and integrity of ribosomes and nucleic acids, and in the control of light-enhanced carbon dioxide ($CO_2$) fixation. Magnesium is fairly well distributed throughout the vegetative plant parts and about half of the plant. Mg accumulated in kernels because of its high remobilization.

Plant growth usually decreases when Mg deficiencies occur, and the reproductive stage of plant development is usually delayed. Deficiency symptoms appear first on older leaves. Relatively large irregular necrotic spots or lesions appear uniformly on tips and margins and spread toward the base and midrib of the leaf. A characteristic plant symptom that often appears with Mg deficiency on many sorghum genotypes is a deep red color on leaves. Under severe Mg deficiency, large areas of necrosis develop, leaves become brittle, die and turn browm. Shoot/root ratios increase extensively with Mg deficiency, because Mg affects root growth much more than shoot growth.

Disorders from excess Mg seldom appear unless plants are grown on serpentine (high Mg) or distributed soils. High Mg can cause Ca, K and Mn deficiencies.

## Sulfur

Relatively low amounts of S are required by sorghum and usually sufficient S is found in soils or added with other fertilizers (especially phosphates). Crops such as legumes have higher requirements for S, and if sorghum is in rotation or intercropped with some of these plants, residual soil S may be adequate to provide sorghum needs. Although both organic and inorganic forms of S occur in soils, organically bound S is the major reservoir. Since sulfate ($SO_4^{2-}$) is the form of S absorbed by plant roots, organic sources of S need to be converted to inorganic S before it is available for plant uptake and use. Under aerobic conditions, organic S is readily converted to inorganic S from microbial activity. Soils in arid conditions usually accumulate $SO_4^{2-}$, but $SO_4^{2-}$ is easily leached in humid regions (acid soils).

Sorghum plant concentrations of S are about 1 to 2 mg/g. One of the important functiones of S in plants is the formation of S-amino acids (cysteine, cystine and methionine) which are very important building blocks of proteins. These S-amino acids in proteins form disulfate bonds between polypetide chains which maintain protein configuration through cross-bonding. Other S containing compounds vital to plant growth and development include Fe-S proteins, ferrodoxin, lipoic acid, glutathione, biotin, thiamin and coenzyme A. Sulfur is relatively immobile and vegetative plant parts have comparable S concentrations. Kernels accumulate extensive amounts of S which is about half of the total plant S. The amount of S taken up with plant age follows closely that of dry matter accumulation.

Sulfur deficiencies can decrease plant growth and yield. Deficiency symptoms of S appear in the upper leaves and are more pronounced in the portion emerging from the whorl. Emerging leaves turn uniformly pale yellow. Sulfur deficiency is often indistinguishable from N dificiency, except that S deficiency ocurrs first in the upper leaves and N deficiency occurs first in lower leaves.

Disorders from excess S may occur because sulfur dioxide ($SO_2$) is a pollutant from many smelters and industrial plants burning fossil fuels. These S toxicities can occur at low levels of $SO_2$. Disorders from excess S fed to roots are seldom reported since plants are relatively insensitive to $SO_4^{2-}$ uptake. Because $SO_4^{2-}$ is not readily absorbed by plant roots, disorders attributed to excess S may likely be due to its accompanying cation.

## Manganese

Sorghum requires relatively low Mn concentrations for growth, and most soils usually contain more than adequate levels of Mn. The availability of Mn in soils may depend on factors like pH, moisture, microbial activity and organic matter which affect oxidation-reduction reactions. Total Mn levels of 200 to 3,000 μg/g soil are common. As the availability of Mn becomes greater with increased $H^+$ (lower pH), acid soil may contain relatively high available Mn which may be toxic to plants.

Manganese is absorbed as $Mn_2^+$ and this is the active form in plants. Manganese concentrations in plants vary, but are usually between 30 to 100 μg/g. The functions of Mn resemble those of Mg. Manganese may sustitutes for Mg in some





enzyme reactions, but in others Mn is more specific than Mg. Examples of these are decarboxylases and dehydrogenases of the tricarboxylic acid cycle. The oxidation of indolacetic acid has also been linked to specific Mn reactions. A major reaction specific for Mn is Photosystem II (photolysis of water) where Mn is essential in electron transfer. Manganese accumulates in metabolically active vegetative tissues (mostly in leaves), is fairly mobile in plants and about one-fourth of total plant Mn accumulates in kernels. Most Mn is taken up in plants by the early grainfilling stage.

Manganese deficiency is seldom a problem in sorghum, but when it is, plant growth and development are depressed. Manganese deficiency symptoms appear first in younger leaves. Leaves show a slight pale color in a streaked pattern in the interveinal tissue. In more severe Mn deficiency condition, long narrow lesions appear on leaves and each lesion is separated by veins. Portions of leaves, particularly the middle, may exhibit Mn deficiency symptoms and other portions will appear normal; leaves may bend or break at this point on the leaf. Shoot/root ratios tend to increase with Mn deficiency.

Disorders of excess Mn may occur on plants grown on acid and tropical soils or under flooded conditions. Fairly uniform small dark purple dots or flecks appear on leaves that otherwise remain dark green. In several cases, fairly long white (bleached) streaks or large sections of leaves may become white. Excess Mn can also cause Ca, K and Mg deficiency in leaves.

## Iron

Soils generally contain very high amounts of Fe compared to the amount required for plant growth. Soluble Fe in alkaline and calcareous soils is normally so low that insufficient amounts are available for plant uptake and use. The equilibrium of Fe changes by 1000-fold; soluble Fe increases with lower pH ($H^+$ increase). Like that of Mn, Fe may also become toxic to plants grown on acid soils.

Of the 2 major ionic forms of Fe, ferrous ($Fe^{2+}$) is the form absorbed by plants, but most Fe in soils exists in the unavailable or insoluble ferric ($Fe^{3+}$) form. Since the major function of Fe in plants is associated with electron transport, both forms of Fe occur in proteins that contains Fe. Iron is also involved in chlorophyll synthesis and as a catalyst of a few enzymes (e.g., aconitase).

Iron-containing enzymes include cytochromes, catalase, peroxidase, superoxide dismutase and nitritite reductase. Important Fe compounds include Fe-S proteins, ferrodoxin, and phytoferretin. Iron accumulates extensively in leaves, but roots contain even higher concentrations than leaves, often 5- to 10-fold higher. Iron is relatively immobile in plants, and only small amounts of Fe accumulate in kernels.

Sorgum is very susceptible to Fe deficiency chlorosis (often called "lime-induced chlorosis") when grown on many alkaline, calcareous soils. Whole fields or large areas within fields are commonly seen with Fe deficiency chlorosis. Since Fe in neutral or higher pH soils is usually insoluble, soil amendments or foliar sprays are added regularly to sorghum grown on these soils. Sorghum may require as many as 4 to 6 spray applications per crop during the vegetative growth cycle while soil amendments are usually good for only 1 or 2 crops. Even without foliar or soil amendments of Fe, sorghum plants usually regreen in the field as the season advances and a harvestable crop is normally produced. Shoot/root ratios of plants remain fairly constant with Fe deficiency. Plant growth is reduced as long as relatively severe chlorosis persists. Plant maturity is delayed when plants persist in the chlorotic state.

Even though the first 2 or 3 leaves seldom show symptoms, Fe deficiency chlorosis appears first in newly emerging or younger leaves. Interveinal tissue of leaves turn pale yellow (chlorosis) with green veins. The chlorotic pattern is distributed fairly uniform over the length and breadth of the leaf. Under severe Fe deficiencies, leaves will turn completely yellow or even white and eventually die and turn brown unless corrective measures are taken.

Disorders from excess Fe can cause deficiencies of Mn, Cu, and Zn.

## Boron

Sorghum plants containing deficient B concentrations have seldom been reported. Soils usually contain the low amounts of B required by sorghum, but under special conditions B deficiencies can occur in other kinds of plants (legumes and the brassicas). Some soils are formed from parent materials containing high B. Boron may be added to soils through irrigation with waters containing high B.

Boron is absorbed by plants as borate ($BO_3^{3-}$). Since B forms polyhydroxy compounds, the biochemistry of B is complex and elusive. Boron has been shown to be essential for many plant organisms, but has not been proven to be essential for all plants. A common feature of B deficient plants is the disturbance to and the poor development of meristematic tissues. Although the mechanisms for these disorders are not known. Boron has been shown to be required for the synthesis of nucleic acid compounds like uracil, which are essential components of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA). Without these nucleic acids, the essential functions of cells in processes like protein synthesis, sugar metabolism and cell division are inhibited. Boron has also been associated with pollen tube growth and hormone (cytokinin) synthesis. If B deficiencies occur, newly developing meristematic tissues would be affected. In plants where B deficiencies occur, apical growing points stop developing, leaves may become thick, are often brittle, and sometimes contain irregular chlorosis.

Boron toxicity may occur at relatively low concentrations. Of all elements required for plant growth, B has the narrowest concentration range between deficiency and toxicity. Boron toxicity can greatly reduce growth and occurs in tissues that transpire large amounts of water. Boron toxicity symptoms appear at the margins and tips of leaves, and a sharp demarcation between the light brown (strawcolored) affected tissue and the dark green unaffected tissue can be observed.

## Copper

Copper deficiencies have occured in plants grown on certain acid soils and have been reported for plants grown on many Australian soils. Soil solution concentrations of Cu range from 0.01 to 0.6 µM. Copper is associated extensively with organic matter and deficiencies occur most often in soils that contain high humus.

Copper is absorbed by plants as $Cu^{2+}$ and accumulates in concentrations of 5 to 15 µg/g. Major functions of Cu in plants are with enzymes connected with





electron transport (cytochrome oxidase, laccase, ascorbic acid oxidase and polyphenol oxidase). Disruptions of desaturation and hydroxylation of fatty acids, and protein and carbohydrate metabolism have been associated with Cu deficiencies. Copper is also a constituent of superoxide dismutase, an enzyme that detoxifies superoxide radicals (produced from oxygen) which are very detrimental to cells. Copper is remobilized to some extent, accumulates evenly in vegetative tissues, and accumulates to some extent in kernels. Most Cu is taken up into sorghum plants by the early grain fill stage.

Copper deficiencies do not appear frequently in sorghum, but when they do, the younger leaf tips turn brown, roll up and break over. In many respects, Cu deficiency resembles Ca deficiency and symptoms may be Ca deficiency since Ca in leaf tips is reduced with Cu deficiency.

Excess Cu can induce symptoms similar to Fe deficiency which are more accentuated near the base of leaves than in the apical portion of leaves.

## Zinc

Zinc deficiencies may appear in plants grown on both acid and alkaline soils. Zinc deficiencies are often noted on sandy soils and on scraped or distributed soils. Zinc solubility and mobility is very low in high pH soils, especially when carbonate is present. Zinc levels are low in soils (10 to 300 µg/g) and soil solutions vary between 0.03 to 3 µM. Zinc absorbed by plants is in the cationic ($Zn^{2+}$) form. Zinc concentrations in vegetative plants are fairly consistent and range from about 20 to 40 µg/g.

Zinc is a component of the enzymes carbonic anhydrase, glutamic acid dehydrogenase, lactic acid dehydrogenase, superoxide dismutase, and some peptidases and proteinases. Zinc has also been found to be a precursor to auxin synthesis, in RNA stability and synthesis, and in starch formation. Zinc is not readily mobile in plants, but kernels accumulate relatively high amounts of Zn. Most Zn in sorghum is taken up by the early grain fill stage. Shoot/root ratios usually decrease slightly with Zn deficiency.

Zinc deficiencies occur first in the younger leaves. Emerging leaves become uniformly pale green to yellow with chlorosis starting at the base and progressing toward the tip. Leaf margins may show a distinct red line. Under severe conditions, Zn deficiency may be expressed as bleached white patches on the leaves.

Zinc excesses seldom occur, but when they do, leaves have a fairly uniform pale green color with slight streaking. Fairly long dark brown lesions form intermittantly in the interveinal tissue.

## Molybdenum

Molybdenum deficiencies often occur in plants grown on acid soils. Molybdenum is fixed by soil particles similarly to P and is next to P in strength of binding by soil minerals. Solubility of Mo increases with increasing pH. Mo deficiency can often be controlled by liming or raising the soil pH. Soil concentrations of Mo are usualy well below 1 µg/g for many soils.

Molybdenum is taken up as $MoO_4^{2-}$ and accumulates in sorghum plants at concentrations below 1 µg/g. Molybdenum is a constituent of nitrate reductase, nitrogenase, sulfite oxidase, xanthine oxidase and reductase, and aldehyde oxidase.

Of these enzymes, only nitrate reductase has been found to be a true constituent of plants, while the other enzymes have been found in microorganisms associated with plants, particularly those associated with atmospheric N fixation. Molybdenum accumulation in kernels is usually low, but often sufficient to support the plant throughout its entire growth cycle after germination.

Molybdenum deficiency has not been reported in sorghum, but many reports of Mo deficiency in maize have been noted. Deficiency symptoms of Mo in maize appear in newly developing leaves similar to Ca and Cu deficiency. Leaf tips usually become slightly chlorotic than flaccid, become water-soaked, turn brown, curl, and often break over.

Plants can tolerate high levels of Mo without detrimental effects. When Mo excess occurs, symptoms are indistinguishable from P deficiency (uniform dark reddening over the leaf) symptoms.

# OTHER ELEMENTS

## Aluminum

Although aluminum (Al) has not been found to be essential for plant growth, beneficial effects of low Al has been reported. Beneficial effects of Al have been attributed to the solubilization of other elements, prevention of some other element toxicities, promotion of P uptake, prevention of P excess, delaying root deterioration by slowing growth and serving as a fungicide.

Aluminum toxicity is a common problem for sorghum grown on acid soils. Plants grow fairly well in soils with pH 5.0 to 5.5, and Al toxicities are minimal. Aluminum toxicities are usually alleviated by reducting available or exchageable Al with the addition of lime or P. Lime is a very effective means for alleviating Al toxicities in soils. When Al is taken up it is likely absorbed as a cation ($Al^{3+}$), but hydroxyl forms of Al are often reported in soils. Aluminum can accumulate in and on sorghum roots at relatively high concentrations (> 1,000 µg/g), but Al is not easily translocated to leaves. Therefore, Al does not accumulate in kernels.

Toxic effects of Al are observed extensively on roots. Roots turn dark black or purple, are short, thick, often corraloid, low branching and brittle. Adventitious roots are often initiated to compensate for affected seminal roots, but Al affects auxiliary roots similarly. Iron, P, Ca, and Mg deficiencies may be induced by Al, and these deficiencies have been noted on sorghum leaves when grown with Al. The type of symptomology on leaves from high Al is often genotype-specific, but Fe, Mg, P and Ca deficiencies have been noted. Reduced growth and poor rooting patterns are common symptoms of Al toxicity on field-grown plants. Shoot/root ratios increase dramatically with Al toxicity.

## Sodium

Sodium (Na) may accumulate to fairly high levels in saline soils. Even though Na is not required for sorghum growth, it is beneficial to some plant species. Sodium is a monovalent cation ($Na^+$) and may replace $K^+$ to some extent in plant metabolic and osmoregulatory reactions. Sodium usually accumulates in vegetative tissue and little goes to the kernels. Excess Na causes toxicity disorders. Symptoms appear first on younger leaves. The margins and tips of leaves turn flaccid and die. The remainder of the leaf turns pale, and distinct boundaries appear between



the flaccid margin and other portions of the leaf.

## Chlorine

Like that of Na, chlorine (Cl) accumulates in saline soils. Chlorine is absorbed as $Cl^-$, is required in photosystem II of photosynthesis and acts in neutralization and osmoregulatory processes. Chlorine may accumulate extensively in vegetative tissues, but little goes to the kernels. Chlorine excess is similar to and difficult to distinguish from Na excess; the leaf tips and margins wilt, turn brown, and die. Heavily transpiring leaves may be detrimentally affected by excess Cl.

## Silicon

Silicon (Si) is the second most abundant element (next to oxygen) in the lithosphere and in soils. The accessibility of Si to plants is dependant on the weathering processes in soils. Acid soils usually contain higher concentrations of soluble Si than higher pH soils, but highly acid soils (pH < 4.5) may contain relatively little Si.

Although Si has not been found to be essential to plant growth, some beneficial effects of Si have been noted. Silicon has been reported to enhance stalk strength and mechanical stability of cells, to better protect plants from parasitic fungi and bacteria attacks and to promote reproductive organs (especially in rice). Silicic acid appears to form hydroxyl groups similar to those of P and B and can condense with sugars, alcohols and organic acids. Silicon may be able to replace, interact or interfere with P and B nutritional processes.

Silicon in sorghum leaves has been found to accumulate at fairly high concentrations (usually 20 to 30 mg/g), but over 50 mg/g has been noted. High Si accumulated in sorghum plants grown on limed acid soils and in plants grown on alkaline soils. Concentrations of Si in leaves of sorghum plants grown on acid soils (pH 4.2) were near 5 mg/g. Even though information on the function of Si in plants is limited, Si has been reported to cause a better distribution of Mn in plants and help alleviate Mn toxicity.

Excess Si causes sorghum leaves to become pale and younger leavers are affected more than older leaves.

## Barium, Cadmium, Chromium, Cobalt, Lead, Mercury, Nickel, and Selenium

The essentiality of these elements in plants has not been established, and beneficial effects from some have been reported. For example, cobalt (Co) has been found in the cobamide coenzyme of microorganisms associated with atmospheric N fixation in plants; nickel (Ni) has been reported as a component of urease in some plants; chromium (Cr) has been found to participate in glucose metabolism, especially mammals; selenium (Se) may replace S in some plant reactions; cadmium (Cd) seems to mimic Zn in some processes; and strontium (Sr) and Ca chemistry appear to be similar. Most of these elements are toxic to plants at relatively low concentrations. Toxicity symptoms for each of these elements in sorghum have been noted:

### Barium

Dark red lesions with lighter color near the margins progressing toward the midrib; symptoms were more severe from the whorl toward the tip. Roots had no secondary root lengthening and were dark in color.

**Cadmium**

Leaves turned a fiery red from margin to midrib; severly affected, they became bright red over the entire leaf. Roots were dark red, small, and had no growth on secondary roots.

**Chromium**

Leaves turned light reddish-brown from tip toward base and from margin to midrib. Some leaves had somewhat dark reddening on tips and margins. Roots were darker and stubbier and growth was inhibited extensively.

**Cobalt**

Leaves had symptoms similar to Fe deficiency, except that the symptoms appeared only in the leaf just emerging from the whorl or on the sheath next to the whorl and not in the leaf tip sections. The symptoms were more diffuse than those typical of Fe deficiency. Roots showed some stubbiness.

**Lead**

Leaves turned reddish-brown and had necrotic dead spots with red around them. Leaf tips were affected more than the leaf base and symptom severity progressed from margin to midrib. Roots were stubbier and had fewer auxiliary roots, but were normal than roots grown with Cd.

**Mercury**

Leaves turned blackish-brown with dark and necrotic lesions. Leaves were wilted and became water-soaker, were leathery, and curled extensively. Leaves did not turn lighter in color. Roots were somewhat inhibited in growth, but otherwise were relatively normal.

**Nickel**

Leaf symptoms were similar to Fe deficiency. These symptoms did not extend as far out toward the leaf tip as noted for typical Fe deficiency. Roots were stubbier and showed symptoms resembling those of excess Al, but not as severe.

**Selenium**

Leaves showed symptoms that were indistinguishable from Mo exces which were similar to P deficiency. Roots showed no abnormal symptoms with excess Se.

**Strontium**

Leaves became necrotic in a spotchy pattern at the margins with a lighter color appearing in the margin progressing toward the midrib. Roots were dark red, coarse, stubby and somewhat slimy.



# 9

# IMPROVEMENT OF CROPS: THE ROLE OF MORPHOPHYSIOLOGICAL TRAITS

## INTRODUCTION

The productivity of a crop depends on the efficiency with which morphophysiological traits manifest themselves in diverse environments. To date, breeding criteria for sorghum have largely been on the basis of morphological characteristics, and very little attention has been paid to physiological traits. Because of the synthesis of crop growth and development in sorghum, the author urges plant breeders to modify their approach to increase productivity in diverse environments and breed cultivars adaptable to them. Identification of traits related to several abiotic and biotic stress factors affecting stages of crop development is desirable, and these need to be taken into account of any crop improvement program.

To formulate an efficient breeding program, breeders need to study the genetic variability of different traits in existing germplasm and breed materials of the crop to be investigated. Through different selection procedures they will identify a particular plant type or trait pertaining to yield and other desirable qualities, and use them in different crossing programs after establishing their purity. A wide range of genetic variability and genotypes showing the stability of yield under adverse climatic conditions are utilized by adopting suitable breeding techniques for a particular crop.

To formulate an efficient breeding program, it is desirable to identify morphophysiological traits related to resistance and yield, and search for variability of these traits existing in sorghum germplasms and incorporate them into elite breeding lines. Morphophysiological traits existing in sorghum germplasm and offering great scope of selection have been been discussed in earlier chapters, and some techniques for their evaluation and probable role in sorghum crop improvement have already been described.

Grain yields in sorghum have substantially increased with the use of high-yielding, management-responsive F1 hybrids and varieties, but these cultivars have miserably failed under adverse conditions prevailing in the SAT. Therefore, we should be aware of the problems that farmers face and test improved farming techniques before suggesting their adoption. Better agronomic practices and use of improved cultivars have significantly contributed to the enhancement of sorghum yields. Though the degree of improvement accomplished so far has been high, there is ample scope for increasing production by improving genetic stock and breeding material. In order to accelerate progress towards better yields, there