FIVE FACTORS OF PLANT GROWTH

H. F. Wilkins
Professor and Floricultural Specialist
Department of Horticultural Science & Landscape Architecture
University of Minnesota

The five factors of plant growth are light, water, mineral nutrition, gases (CO_2/O_2) and temperature. All are interactive and none are independent. One brief example is if a plant is under water stress, the stomates close and photosynthesis ceases because CO_2 can not enter into these stomatal cavities. You can have adequate light, nutrition, and root/medium aeration, but plant growth ceases. Further, water stress causes a plant hormone (ABA) to increase and even after hydration, ABA levels do not drop and slows photosynthesis for days after wilting. Consequently, plants should never be stressed.

WATER

If one were considering a new or old production site, besides availability, the quality of water is a major consideration. Qualities to be considered are pH, soluble salts, hardness, toxic ions and other pollutants.

i) pH. Water should have a pH level between 5.5 and 7.0. Water with higher pH levels can cause two types of problems. First, the alkalinity, which is caused by bicarbonate (HCO_3), can accumulate and become toxic to plants, as well as, increase the pH. Second, an alkaline water supply will slowly increase the pH level of root media or soil. At high pH levels phosphorus, iron, manganese, zinc, copper, and boron may be tied up in root media resulting in plant deficiencies. True, ammonium based sources of nitrogen lower the pH. But if soils are cold and too wet, the conversion of ammonium to nitrate is slow and ammonium may become toxic as well. Phosphoric, sulfuric or nitric acid may be injected into the water source via a fertilizer proportioner to lower the pH.

ii) Soluble Salts. The salt content of water is generally determined by measuring the electrical conductivity (EC) of the water. This is a measure of all disolved ions in the water. If excessive, in the water or soil, movement of water into the plant is restricted.

iii) Fluoride. Fluoride can cause injury to plants. Tips and margins of older leaves turn brown. This is particalarly true of monocots, plants with long narrow/parallel veined leaves. (Examples are: gladiolus and lilies). Fluoride reaches toxic levels at the ends of the veins in leaves. Many municipalities add 1 ppm of fluoride to drinking water to help prevent tooth decay. Concentrations of fluoride greater than 0.25 ppm in water can cause injury. Fluoride can also be an air pollutant and injuries can be seen many miles from the source.

iv) Boron. Boron levels in water are generally low except in the southwest United States. The symptoms of boron toxicity affect older foliage first and then spread up the plant to younger foliage. Margins turn a bright brown.

v) Irrigation Consideration. Hand watering is unrealistic and uneconomical. If hand watering is practical, a water breaker at the end of the hose should be used. Watering frequently accounts for loss of crop quality. Frequently plants are over watered. Watering would appear to be a simple operation. The decision to water is not a simple decision. Overwatering reduces O_2 in the medium/root zone and causes root rots; underwatering causes stress. Both situations reduce growth rates, reduce quality and even cause plant death. As stated earlier, when a plant wilts, photosynthesis is retarded. If watered too frequently, growth may be "soft" and plants may be taller and of poor quality. Damaged root systems cannot take up water or nutrients.

The importance of soil texture and structure is critical. Production sites must be well-drained and aerated. If not well-drained, it is difficult to irrigate property or to enter the field soon after irrigation or natural rain fall. It is important to water the soil thoroughly each time water is applied. Actually this brings in new air as the water column drains down into the lower level of the soil profile. As a general rule of thumb for soil-based media, 1/2 gallon of water should be applied to each square foot for each inch of root zone depth.

vi) Automatic Watering Systems:

Perimeter watering consists of a metal or now commonly a plastic pipe around the perimeter of a bed. Nozzles are secured in the pipe which sprays water over the root medium surface at or below the lower foliage level. Polyethylene or PVC pipe are commonly used. Water under sufficient pressure forced through these nozzles put out a spray arc of 180^o or 45^o. Nozzles are spaced 20 to 30-inches apart. Nozzles are staggered across the bed so that each spray pattern is projected between two other nozzles.

Ooze-Hose are polyethylene tubes which run the length of a bed and are placed 8-inches apart. The usual lengths are 60 feet. A normal 3/4-inch water supply (4 to 9 psi within the Ooze-Hose) can handle up to 1,200 square feet of bed space.

Spray Hose. Longer lengths of beds can be irrigated, up to 250 feet, by this method. The hose is made from polyethylene and is actually a hose inside a hose. Outlets are 8-inches apart.

Overhead Irrigation. While we feel the foliage should be kept dry for disease control and to prevent water residue problems. This method is frequently most practical and can be cheaply installed. Field grown fresh flowers and bedding plants are commonly watered from overhead.

Pipes are installed down the middle of a bed, riser pipes with nozzles are installed 2 feet above the crop. Nozzles vary from those which throw a continuous 360^o water pattern or a pulse/trigger rotating type. The spray diameter will vary as to the water pressure. In conclusion, water is perhaps the most critical aspect of the five factors affecting production. Remember, 80 or more percent of fresh plant weight is water. Only 5 percent of water that enters into a plant is utilized. Most of the water that enters into a plant is not incorporated, as 95 percent is transpired. If leaf transpiration exceeds root absorption, wilting occurs and growth is retarded.

Lastly, water content of plants varies between species, plant age and tissue or organ type and the time of day. Young leaves and stems, and roots have high cell water content. Maintaining water turgor pressure in cells is an essential condition for growth or cell enlargement, as new cells are essentially baloons and must be blown up by water.

Water must bring and distribute nutrient ions throughout the plant. Water quality, application timing and technique are critical.

TEMPERATURE

The day/night temperatures at which flower crops are grown have a decisive effect on their yield and quality. Under field conditions we have little control over this growth factor. Food material is manufactured through the process of photosynthesis. Food material is consumed (respired) to provide energy for metabolic or energy requiring processes. The balance is used or stored or converted into components of which the plant is constructed and growth occurs. Plants grow (increase in size and addition of new cells) only when the food supply is greater than respiration. The major method to reduce temperature is to shade plants. Saran is used in field production to increase quality and to reduce light, as well as, temperature stress.

i) Flower Initiation and Development. One of the most important events in the life cycle of a flower crop is the initiation and development of flowers. This is frequently controlled by temperature. Initiation is that stage in the life cycle when the plant changes from a vegetative to a reproductive condition. The various flower parts (sepals, petals, stamens, and pistil) can be distinguished in the individual flower primordium as development proceeds. The final stage of development is antheis or pollen shed.

Horticulturally, visible flower bud is often used to indicate the change from initiation to development. Recognition of these two stages is necessary because temperature and light may be needed to be changed and may have different effects on each stage. The optimum temperature for initiation may be different from the optimum temperature for flower development. Likewise, the critical daylength for the long day or short day photoperiodic initiation of flower buds may be different than the daylength required for development. For example, chrysanthemums initiate flowers under short days at a daylength of 14-1/2 hours. However, further development does not occur unless the daylength continues to decrease. Further, photoperiod is modified by too high or too low night temperatures and can delay or hasten flowering. It is correct to refer to a cold treatment vernalization as if flower initiation is the result. However, if flowers have already been initiated, a cold treatment should not be called vernalization as it is not inductive. With biennials and perennials, the effect of low temperature on flower initiation is a direct one; that is, flowers are initiated during the (vernalization) cold temperature treatment.

ii) Classification of flowering response as impacted by temperature are:

1. Biennials - plants which require two growing seasons, interrupted by a cold treatment. Frequently long days are also required for stem elongation. Subsequently after flowering, they frequently die.

2. Perennials are plants that live and flower for many years. These plants frequently initiate flowers during summer when temperatures are above a critical level; but for further differentiation and development a cold treatment is required.

3. Annuals are plants that initiate flowers at temperatures above a critical level. Some examples:

Clarkia (C. elegans Dougl.) is an annual whose flowers are initiated at temperatures above 55°F (12.8°C); succulent vegetative growth occurs below this temperature level. To produce plants with sufficient stem length and flower quality, seedlings are grown at 50°F (10°C) for 4 to 6 weeks before temperatures are raised for flower initiation and development.

Annual Larkspur (Delphinium ajacis L.). This plant rosettes at temperatures below 55°F (12.8°C). Stem elongation and flower initiation occur when temperatures are increased above 50°F (10°C). Long photoperiods will produce a response at 50°F (10°C) similar to the effect of high temperature.

Perennials and common bulbs require a series of warm to cold to warm temperature treatments. Most have flower buds present in the late summer and early autumn. Warm temperatures regulate flower initiation and early differentiation, cold temperatures are required for further development, and for stem elongation warmer temperatures are required.

LIGHT (Solar Radiant Energy)

Sunlight is the chief source of energy for plant growth and indeed flowering. When we think of light, we should always think of light duration or daylength, light intensity, and light quality.

i) Daylength. In the Temperate Zone, there is an obvious seasonal daylength change. These seasonal changes in daylength result from the inclination of the earth's axis. At the equator, 12-hour daylength is relatively constant throughout the year.

As stated earlier under temperature, plants given a cold treatment frequently require a long photoperiod for the flowering stem to elongate. Some plants depend on shortening day length and long dark periods beyond some critical photoperiod in order to flower. These plants are termed short day plants. The classic example is the chrysanthemum.

Inversely some plants require lengthening days and short dark periods beyond some critical photoperiod in order to flower. The classic example is tobacco; certainly, many plants flower under any photoperiod - an example is the rose.

ii) Light intensity, when all other factors are considered, light intensity is frequently the limiting factor in growth in greenhouses. In summer field production this is not true. Intensity may be too great, and it may be wise to reduce light in order to reduce water loss for example as light impacts both leaf and air temperature. Plants grown under saran in the field have superior quality.

iii) Light quality. Light quality is referred to as the color or spectral energy bands of light. In this conference, we will be little involved with light quality. A quick example of light quality is when we compare plant growth under a fluorescent and incandescent lamp sources. The fluorescent lamp produces light high in the red spectrum, low in the far-red. Incandescent light is low in the red and high in the far-red. Plants grow tall, branch little and have weak stems with thin pale green leaves under incandescent. The opposite is true with fluorescent. Light quality impacts seed germination. This will be discussed by another speaker covering propagation.

MEDIUM NUTRITION AND AERATION

Plants can be grown in almost any type of substrate from a heavy clay soil to sand to peat or indeed hydroponically. Naturally the substrate must be free of toxins and pests. Medium must hold or supply the water and nutrients. All that a medium or soil does is, in theory, support the plant via its root system.

With field production we must not only be concerned about nutrition but also about drainage (oxygen). Desirable characteristics of soil include a high volume of air space, moderate water holding capacity, stability against compaction, rapid decomposition of organic matter, low soluble salt level, freedom from pests and toxins, and uniformity within a field.

Air space is essential for water movement as well as to maintain oxygen for good root growth. Air space is also essential for root growth or penetration.

i) Nutrient ions. The essential nutrient ions are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), manganese (Mn), molybdenium (Mo), boron (B), copper (Cu) and zinc (Zn). The demand or use of N, P and K is the greatest and are called the major (macro) nutrient ions. Calcium is rarely in short supply and is more impactive on pH, and the availability of the various other ions. The micro or minor elements are rarely deficient in most field soils. However, slow release fritted trace elements are commercially available. Soil and tissue analyses for all the essential elements are available in commercial and university labs. Mineral nutrition application must be based on these tests.

ii) Raising pH. Ground limestone (calcium carbonate) is the material most commonly used for increasing the pH of a growing medium. Dolomitic lime (a limestone containing both calcium and magnesium carbonates) is preferred because it also supplies magnesium for plant growth. Dolomite lime is neutral.

iii) Lowering pH. Several materials can be used to lower the pH of a growing medium. Elemental sulfur is the most inexpensive and long lasting material used for this purpose. However, it requires six to eight weeks to take effect during the summer months.

iv) Supplying nitrogen. Nitrogen can be supplied in a variety of carriers. The most common is ammonium nitrate or sulfate.

v) Supplying phosphorus. Phosphorus can be cheaply supplied by super- or treble-superphosphate. In these forms, the supply of phosphorus is slowly made available over time. These carriers are long lasting and are frequently tilled into the field or soil. Diammonium phosphate supplies both nitrogen and phosphorus.

vi) Supplying potassium. Potassium is supplied by the common carrier potassium nitrate.

All field soils should be tested prior to planting and every 4 to 6 weeks thereafter. Fertilizers can be supplied as dry applications to the soil or in the irrigation water.

OXYGEN AND CARBON DIOXIDE

The absorption of water and mineral elements is the primary function of plant roots. Oxygen, along with atmospheric carbon dioxide, is one of the two gases grouped as one of the five factors of plant growth.

Carbon dioxide is an essential factor for plant growth; primarily thought of as a main component for photosynthesis to occur along with water. This gas enters the leaves and in the presence of sunlight, "food" is synthesized. In field production carbon dioxide would never be a limiting growth factor.

However, oxygen can be a limiting factor in soils. A well drained soil is a must. Poorly drained fields or beds will result in poor growth and production. A well drained medium will result in the rapid absorption of water - either from natural rain or when irrigation occurs. Concepts of the need of oxygen is covered in the sections on water as well as medium nutrition and aeration.