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EXPORT INDUSTRY TECHNOLOGY SUPPORT PROJECT (AGRICULTURAL COMPONENT)

ONION PRODUCTION IN THE TROPICS

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EFFECT OF ENVIRONMENT ON ONION GROWTH AND DEVELOPMENT AND SWEET ONION PRODUCTION IN THE TROPICS

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Onion Growth and Development:

Vegetative growth: After the seedling is established, the young onion plant enters the juvenile phase where new foliage leaves and new shoot-borne roots continue to be produced. New leaves are produced at the center of the plant and the later-formed leaves are larger. This results in the earlier-formed leaves being split open and discarded as the juvenile plant grows.

During the adult vegetative phase, the stem thickens and increases in height such that each successive node is wider than the previous ones. Each new leaf blade is thicker than the previous leaf blade resulting in a change in the shape of the stem as the plant gets older.

New roots are continuously produced throughout vegetative growth. Each successive group of roots is produced close to the shoot apex, sometimes called the root plate. This results in younger roots being produced above the level of older ones. As the stem diameter gets larger, roots are produced in rings in the stem and each successively produced ring has more roots.

Under short days and cool temperatures, onion plants continue to produce new leaves at a uniform rate. As new roots are produced, older roots near the center of the root plate die. Plants harvested at this stage are sold as green onions. There is no evidence of bulb formation and the leaves are green.

Bulb initiation and development: When the day length becomes longer and the temperatures increase, onion plants bulb. During this process, morphological changes occur which result in preparing the onion plant for a resting state. These changes result from the mobilization of reserves to the leaf bases to form the bulb.

Morphological changes that occur during bulb development include: 1) Initial enlargement of the bulb results from thickening of the bases of the foliage leaves. 2) As bulbing continues, the leaves developing near the center of the plant abort their blades, the bases of these leaves enlarge, and foliage growth ceases. 3) When the bulbs are mature, the outer (oldest) three to four leaf bases dry up and disappear or remain as papery coverings.

Effect of Environment and Plant on Bulb Initiation and Development:

Environmental factors: The environmental factors influencing bulb initiation and development include: 1) the photoperiod, 2) the duration of exposure to the photoperiod, 3) light intensity and quality, 4) temperature, 5) nitrogen supply, 6) water supply.

Photoperiod: Onion bulbing is promoted by long photoperiods. The rate of bulb development and bulb maturity increases as the daylength increases. Bulbs are smaller when onions are grown under photoperiods that are substantially longer than the minimum required for bulbing.

Continued long photoperiods are required for the completion of bulb development. Transfer of plants from inductive photoperiods to noninductive photoperiods can reverse bulb development. The number of days of short photoperiods necessary to reverse the bulbing reaction increases as bulbing advances, but it is possible to cause the reversion to leaf blade production near bulb maturity. A delay in bulbing in the field can be induced by imposing artificial short photoperiods and this usually results in larger plants at bulbing and a larger final bulb size.

Duration of exposure to the photoperiod: Under photoperiods that cause slow bulbing, the bulbing stimulus may slowly accumulate to a sufficient level to cause bulbing. Also, as the plants grow larger the sensitivity to the bulbing stimulus increases and the critical daylength needed to induce bulbing may become shorter. With very short photoperiods, plants show no signs of bulbing after growth periods of 190 days.

Light intensity and quality: Onion bulbing is controlled by the high irradiance response of the phytochrome system which needs continuous irradiation and has a dependency on light intensity. Bulbing increases more rapidly as the light intensity of inductive photoperiods increases. A delay in bulb initiation occurs when plants were shaded.

The minimum photoperiod needed to induce bulbing at a specific light intensity depends on the red:far-red ratio (daylight has a ratio of about 1). Far-red light and to a lesser extent blue light promote bulbing. Far-red and blue light have a synergistic effect in promoting bulbing. Conversely, red light prevents bulbing and can reverse the bulb promotive effect of a preceding period of far-red or blue light; therefore, irradiation with far-red light is necessary throughout the photoperiod.

Temperature: The daylength needed to initiate bulbing and the time required to develop a bulb is less as temperature increases; however, no bulbing can occur even at warm temperatures if daylengths are sufficiently short. High day temperatures are more promotive of bulbing than high night temperatures.

Nitrogen supply: Excessive levels of nitrogen stimulates leaf growth more than the growth of bulbs. In onions grown under controlled photoperiods, low nitrogen resulted in a greater increase of initial bulbing than high nitrogen, but bulb scale development was delayed by low nitrogen. Normal bulb maturity was delayed by nitrogen deficiency in all photoperiods.

Water supply: Irrigation prolongs leaf blade growth and delays bulb maturity. Delays in bulb maturity of 5 to 19 days by irrigation have been reported.

Plant factors: The plant factors affecting onion bulb initiation and development include: 1) cultivar, 2) plant size and age, 3) interplant competition, 4) plant production and handling methods. The magnitude of the bulbing response to the environmental stimuli varies with these plant factors since the leaf blade is the receptor of the photoperiodic stimulus for bulbing. The cessation of root production is a normal feature of bulb development; therefore, reduced root growth is the result rather than the cause of the bulbing.

Cultivars: Cultivars differ in the photoperiod needed to induce bulb development. The rate of bulb development of different cultivars remains ranked in the same order when grown under a range of photoperiods. Therefore, the earliness of bulbing of a cultivar under field conditions can be judged from its performance relative to other cultivars at any bulb inducing photoperiod.

The terms long-day, intermediate-day, and short-day can cause confusion when applied to onion cultivars. Short-day cultivars can form bulbs under the short photoperiods found at low latitudes, whereas long-day types cannot. Long-day types will only bulb in the long photoperiods of high latitudes in the summer. In short-day cultivars, bulbing is faster with longer photoperiods.

The photoperiodic requirement for bulbing is the prime determinant of the suitability of a cultivar for a particular region. Cultivars adapted to lower latitudes require shorter photoperiods to induce bulbing than those adapted to higher latitudes. Cultivars adapted to high latitudes fail to bulb when grown at low latitudes. Conversely, cultivars adapted to low latitudes start to bulb when the plants are very small and produce low yields of small bulbs when sown during the spring at high latitudes.

Plant size and age: The rate of bulb initiation is not affected by the age or size of the plant when plants are exposed to very long photoperiods, but the rapidity of bulbing in shorter photoperiods increases with larger plants. Older plants bulbed more rapidly than younger plants when both had similar leaf areas. However, given a strong photoperiodic stimulus, seedlings with only one leaf can form a bulb.

Interplant competition: The environment of an individual plant

is influenced by neighboring plants in a field situation. As the crop grows, the intensity of interplant competition increases. Interplant competition for light can modify the process of bulb development. Under good fertilizer and irrigated conditions, bulb maturity is advanced by higher plant density, and earlier sowing. Both of these factors result in a higher leaf area index and a higher light interception by the crop leaf canopy during bulb development. The earlier maturity date is the result of an earlier transition from leaf blade to bulb scale initiation under high crop light interception. Small plants in mixed stands initiated bulb scales about 2 weeks earlier than when small plants were grown either mixed with older large plants or in pure stands. Therefore, the timing of scale initiation depends on the size of neighboring plants and the leaf area index of the crop and is not simply determined by the size or age of individual plants.

Plant production and handling methods: The photoperiod required for bulb development is normally shorter when onions are grown from sets than from seed. When onions are grown from sets, bulb development is delayed and a longer photoperiod is required for bulbing when sets are stored at 30°C than at lower temperatures for several months before planting. Bulbs stored at 30°C may ripen a month later than bulbs stored at lower temperature. The delay in maturity is longer with cooler climatic conditions after planting.

Effect of Environment on Onion Production in the Tropics:

Photoperiod: Due to the temperature, plant size, plant age, plant density, nitrogen fertilization, and irrigation interactions, bulbing and yields of short-day onions in the tropics may vary considerably within a small range of photoperiods. Cultivars are best adapted to regions where the minimum photoperiod and temperature required for bulbing occur. Under conditions of increasing daylength, cultivars having shorter daylength requirements bulb and mature earlier relative to other cultivars. Therefore, the time of year the onions and the latitude at which the onions are to be grown should be considered when selecting the short day onion cultivar.

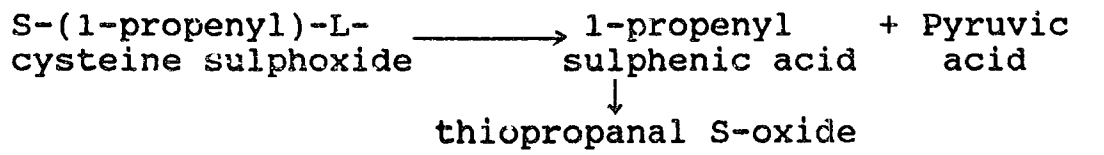
Temperature: Since high temperatures reduce the minimum photoperiod requirement and increases the rate of bulb development, temperature rather than daylength may be the primary factor determining the suitability and performance of cultivars and growing areas in regions where seasonal changes in photoperiod are small. In the tropics, temperature changes occur primarily with changes in altitude. At the same latitude, onions form bulbs earlier at low elevations than at high elevations. Therefore, premature bulbing and low yields may occur when onions having very short day requirements for bulbing are seeded at low elevations during summer months in areas of greater latitude. Premature

bulbing is less likely to occur when these onion cultivars are planted at higher elevations due to lower growing temperatures. Although onions have been planted and harvested at all times of the year in some areas of Africa, Hawaii, Central America, and South America where photoperiods change very little during the year, premature bulb development occurred when onion cultivars having very short daylength requirements for bulbing were seeded during August in the Sebaco Valley of Nicaragua.

The apparent decrease of critical photoperiod with age of the onion crop may be due to: 1) the minimum photoperiod/temperature combination required for bulbing decreases with plant age or plant size, 2) the stimulus for bulbing slowly accumulates resulting in bulbing after sufficient, and 3) the change of the environment of individual plants during crop growth promotes bulb initiation and development. Presently the available information does not allow accurate projection of the most effective cultivar-latitude-elevation combinations needed for year-round production of short day onions in all areas of the tropics. For example, it is likely that transplants for onions to be harvested in November or December at latitudes and elevations similar to that of the Sebaco Valley of Nicaragua will have to be grown either at lower latitudes or at higher elevations.

Chemistry of Onion Pungency:

Volatile flavor compounds of onions are not present as such in the intact bulbs. The normal flavor and odor characteristics are formed by enzymatic hydrolysis of nonpungent flavor precursors. The principal flavor precursor of onion is S-(1-propenyl)-L-cysteine sulphoxide. When onion tissue is injured, the alliinase enzyme very rapidly hydrolyses this precursor to form the very unstable sulphenic acid, pyruvic acid and ammonia as follows.



The sulphenic acid rapidly changes to thiopropanal S-oxide, the lachrymator or tear causing and pungent compound of onion. Pungency rather than sweetness is the factor that determines whether an onion is a sweet onion. Pungency of onion has been highly correlated with enzymically produced pyruvic acid. The determination of pyruvic acid development (PAD) provides a simple and rapid method of objectively estimating onion pungency since pyruvic acid and pungent compounds are formed in equimolar concentrations. Using this system, onions have been classified by PAD values as:

Pungency classification	PAD range
Very Pungent	More than 6.6
Pungent	5.4 to 6.5
Slightly Pungent	4.2 to 5.3
Mild	3.0 to 4.1
Very Mild	2.0 to 3.0
Extremely Mild	Less than 2.0

We have been able to detect distinct pungency differences among onions with PAD values of less than 3.0; therefore, the extremely mild classification is added to describe these onions.

Growing Sweet Onions in the Tropics:

Growing sweet or mild onions requires that some identification and selection of conditions be done before the onions are planted. Both genetic and environment influence the pungency level of onions. The maximum level of pungency is controlled by genetics, but pungency levels below the maximum are a response to cultural conditions.

Genetics: In general, long day onion varieties are more pungent than short day onion varieties, but PAD values within short day onion varieties and hybrids have ranged from less than 1.0 to more than 7.5. Several onion varieties that have been grown as sweet onions in the United States are shown in the following table.

Sweet Onion Variety or Hybrid (H)	Source of Seeds*
Yellow Granex Hybrids	
Dessex (H)	SunSeeds Genetics
Early Yellow Premium (H)	Hygrotech
Equanex (H)	Hygrotech
Granex 33 (H)	Asgrow
Granex 429 (H)	Asgrow
Granex 2000 (H)	Hazera
Rio Bravo (H)	Rio Colorado
Special 38 (H)	SunSeeds Genetics
Sweet Georgia (H)	Rio Colorado
Sweetex (H)	Ferry-Morse
Yellow Granex Hazera (H)	Hazera
Yellow Granex Improved (H)	SunSeeds Genetics
Yellow Granex PRR (H)	Ferry-Morse
Yellow Granex 99 PRR (H)	Neuman
White Granex Hybrids	
White Granex (H)	SunSeeds Genetics
White Granex PRR (H)	Neuman
Red Granex Hybrids	
Red Granex (H)	SunSeeds Genetics
Yellow Grano	
Texas Early Grano 502	Ferry-morse
Texas Early Grano 502 PRR	Ferry-Morse
Texas Grano 502	Asgrow
Texas Grano 502 PRR	Asgrow
Texas Grano 1015Y	Asgrow
Texas Grano 438	Asgrow
Texas yellow Grano 502 Select	Petoseed
White Grano	
New Mexico White Grano	Neuman
White Grano PRR	Neuman
Red Grano	
Red Grano	Sunseeds Genetics

* The seed source listed is not the only source of these varieties.

Although all of the onions listed have been marketed as sweet onions, the pungency of these cultivars vary widely when grown in the same field. The PAD values of onions from an experimental plot in Georgia ranged from 1.2 for Hybrid Yellow Granex to 3.5 for Texas Grano 1015Y. There is evidence that the pungency changes less with cultural system for some cultivars than for others, but these have not been clearly defined.

Field selection: The volatile components responsible for pungency in onions are sulphur-containing compounds: therefore, the sulphur content of the soils and the sulphur nutrition has a dramatic effect on onion pungency and flavor. Onions grown under extreme sulphur deficiency in solution culture or sand culture in a greenhouse did not have the characteristic flavor and pungency of onions. Pungency and flavor increased with increased concentration of sulphate sulfur in the nutrient medium supplied to the growing plants. Similar conditions have been produced in the very sandy (80-95% sand) soils on which the sweet "Vidalia" onions are grown in Georgia when the SO_4-S level of this soil was about 1 ppm. The soils in the Vidalia onion production area normally contain 3-10 ppm SO_4-S.

Although close attention to the sulfur level may not be required when sweet onions are grown on very sandy soils, the sulfur level of the soil should be of major concern when attempting to grow sweet onions on soils having a high organic matter content in the tropics. The total sulfur levels of tropical soils having a high organic matter and allophane (a hydrous aluminum silicate) contents may have total sulfur contents in excess of 1,000 ppm and SO_4-S levels greater than 100 ppm. Sulfur mineralization from organic matter associated with allophane is relatively slow, but flushes of sulfur mineralization have been observed after wetting of dry soils. Whether this sulfur mineralization will have a significant effect upon onion pungency has not been established, but onions grown on soils having a high (20-55 ppm) SO_4-S level have been pungent. In general, onions produced on soils having lower SO_4-S before planting will be less pungent. Soils having an initial sulphate sulphur of more than 10-15 ppm should be avoided if possible.

Fertilization: Applications of sulfur in the fertilizer has increased the pungency level of onions grown on sandy soils in Georgia. Although Yellow Granex Hybrids generally produce onions with PAD values ranging from 1.5 to 2.5, application of sulfur in the fertilizers late in the growing season has increased in onion pungency to a PAD value of 4.0 to 5.5. These sandy soils contain very little organic sulfur and the low levels of sulphate sulfur leaches very rapidly. Production of sweet onions on relatively high organic matter tropical soils will require that sulfur applications be kept to the minimum needed to prevent sulfur deficiency. Usually no sulfur should be applied during growth of the onion crop after a field having a low (10-15 ppm) sulphate sulfur prior to planting has been selected.

In general, the pungency of onions decreases as nitrogen fertilization increases. The pungency response to nitrogen fertilization is very small and does not occur when the nitrogen level is adequate for good bulb growth. These results suggest that the effect of nitrogen fertilization on onion pungency is due a dilution of the pungency precursor associated with an increased bulb growth response. Pungency responses to other fertilizers have been small and variable.

Water regime: Onions grown with an abundant supply of water tend to be large and succulent, but relatively low in pungency, whereas onions grown under water stress are smaller and more pungent. This response appears to be a simple effect on onion bulb growth when onions are grown on sandy soils. However, infrequent water applications to tropical soils could maintain an elevated SO_4-S level and produce pungent onions due to the occurrences of flushes of mineralization of organic sulfur from tropical soils having a high organic matter content.

In summary, growing sweet onions as compared to other short day onions in the tropics is predominantly a matter of selection. This selection process includes:

1) Select cultivars that have a history of producing mild onion bulbs.
2) Select fields that have a low sulfate sulfur content before planting onions.
3) Select a fertilization program that produces large succulent bulbs that have a low pungency level. This fertilization program will usually have no sulfur added to the onions grown on tropical soils.
4) Select a water regime for soils having high levels of organic matter and allophane content that does not allow extensive drying before these soils are wetted.

Use of these four selection criteria in addition to other good cultural and handling practices for onions should produce good yields of sweet onions.