Introduction

Light air-cured tobacco is common in many locations all over the world. Production practices vary depending on local weather patterns, socio-economic status of the growers and the degree of industrialization of the region. Even in developed countries, light air-cured tobacco production is a labor-intensive enterprise when compared with other crops. The common factor is that curing is primarily without artificial sources of heat and humidity. Because air-cured tobacco is not cured under a prescribed set of temperatures and humidities, the end product may differ considerably from one location to another and from year to year. The two most common types of light air-cured tobacco are burley and Maryland.

Maryland tobacco refers to the relatively light bodied, mild, air-cured tobacco grown on the sandy coastal plains of southern Maryland, USA. Maryland tobacco has a relatively small, but loyal niche market in European cigarette manufacturing. Some blended cigarettes contain small amounts of Maryland tobacco.

Burley tobacco comprises most of the light air-cured tobacco. Burley tobacco, as we know it today, originated in Southern Ohio and Northern Kentucky, USA in 1864. Because of this, the light air-cured tobacco produced in Kentucky and the surrounding states set the standard of quality for burley tobacco. Burley tobacco growers in other parts of the world strive to produce a similar style of leaf, but often find it difficult to duplicate the growing and curing conditions necessary to produce a full flavor burley. This milder burley type leaf, often called filler tobacco and valued for its filling power and open structure, accepts flavoring compounds well. Most burley type tobacco becomes a component in the manufacturing of blended cigarettes.

Soil Factors

Light air-cured tobacco production utilizes a wide range of soil types around the world that influence the character of the cured leaf. Soil factors with an impact on tobacco production include soil texture, structure, fertility and landscape position. Management practices such as tillage and fertilization modify the crop response to these factors and influence the style of tobacco produced.

Soil texture is an inherent soil property that is not subject to easy manipulation. The conventional wisdom is that sandy soils produce very light-bodied open tobacco, and clay soils are more likely to result in heavy-bodied tight leaf. Most air-cured tobacco grows on intermediate loamy textured soils.

The relatively coarse textured soils of Southern Maryland tend to produce light-bodied tobacco with an open leaf structure and the mild flavor typical of Maryland tobacco. In one study Maryland tobacco, grown on soils ranging from fine sand to loam textures, produced higher yields, total alkaloids and total N with lower filling capacity on loam soils when compared to that grown on coarser textured soils (Mulchi, 1985). Visual quality was lowest for tobacco grown on fine sand. In general, loams and sandy loams are the best soils for the production of Maryland tobacco (McKee & Conrad, 1994).

Burley tobacco production is common on both coarse and fine textured soils in various parts of the world. Much of the burley tobacco produced in Latin America and Africa grows on sandy loams and loams and tends to be ‘filler’ type burley. Cured tobacco in these areas has a light-body, open leaf structure and a neutral character with little impact on the smoke (Glass, 1983). Conversely, in areas of heavier silt loams and silty clay loams the tendency is to produce a medium-bodied tobacco that imparts a strong burley character to the smoke. The tobacco grown in the US burley belt is an exception to the rule that heavy soils produce tight, lifeless leaf. Although most burley grows on silt loam soils with clay subsoils, the cured leaf is relatively open in structure and accepts flavorings well.

A soil with good internal drainage produces the best burley (Sims, 1993) and Maryland tobacco (McKee & Conrad, 1994). Sandy soils generally have good
drainage because of their coarse texture; however, heavier soils must have a strong stable soil structure, particularly in the subsoil, to maintain good drainage. A fine textured soil with poor structure and drainage will percolate water very slowly and have a greater tendency to become saturated in the root zone. This will result in reduced root growth and increase the potential to produce thin-bodied leaf. Maintenance of soil structure is essential to continued production of a high yield of good quality light air-cured tobacco.

With its high biomass production, tobacco removes relatively large quantities of nutrients from the soil. Soil fertility refers to the capability of the soil to supply these nutrient elements to crops. Very few soils are fertile enough to supply the needs of a high yielding tobacco crop without supplemental fertilization. Typically, sandy soils are more difficult to manage due to the relatively low capacity to store nutrients in the root zone. Finer textured, deep soils are generally more fertile because of their capacity to retain nutrients in forms that are not subject to leaching loss, yet are readily available to plants.

Selection of flat to gently rolling landscapes for air-cured tobacco production prevents excessive loss of soil due to erosion. Most burley tobacco production in the USA is on flat land without ridges or beds. This, coupled with intensive tillage practices, makes tobacco ground very susceptible to soil erosion. Soil erosion can, in just a few years, destroy the productivity of the soil. Steep-sided slopes hasten the loss of productivity. Other landscape positions can cause production problems. Depressional areas often produce poor tobacco due to water logging. Bottom lands near streams and rivers can have drainage problems but, where well drained, bottom lands produce excellent tobacco crops. Well drained upland sites, ridge tops or gently rolling side slopes, with deep soil that has sufficient water capacity consistently produce the best tobacco crops. The coastal plain region is flat to gently rolling and well suited for the culture of Maryland tobacco.

SITE SELECTION AND TILLAGE PRACTICES

Site selection for tobacco production 1 to 2 years prior to growing the crop provides ample time to test for chemical properties and make amendments. Besides soil drainage, good air drainage is also advantageous. Sites with limited air drainage may be more prone to certain diseases like blue mold or target spot. However, factors other than soil conditions, such as proximity to irrigation or curing facilities, often dictate site selection.

Crop rotation is necessary to maintain soil tilth and reduce disease incidence. An ideal rotation for burley tobacco is tobacco at the same site for 2 years and then grass sod for 4 years. However, due to land limitations, the same site may have continual tobacco production or limited rotation. Continuous tobacco production can result in severe soil degradation due to intensive tillage and the high nutrient demand of tobacco. Proper fertilization replaces depleted nutrients, but structural degradation continues. Structurally degraded soils tend to be cloddy and puddle easily. Such soils may require more intensive tillage to produce a ‘suitable’ seed bed, thus perpetuating a destructive cycle. In many parts of the world the lack of sufficient land area for adequate rotation is a serious impediment to air-cured tobacco production. Proper rotation intervals reduce the severity of some soil-borne diseases like black shank and black root rot, although some rotational crops, like legumes, can maintain damaging levels of soil pathogens.

Site preparation generally begins with a primary tillage operation. In developed countries, cultivation of the site usually involves turning of the soil with a moldboard plow in late winter or early spring. This operation kills any winter vegetation and buries surface residues so they will decompose. Sealing plowed soil with a heavy drag levels the soil and aids in organic matter decomposition. Plowing a large quantity of residue under near setting time contributes to a disorder commonly known as organic matter toxicity. Organic matter toxicity causes yellowing and stunted growth and is the result of a toxic accumulation of nitrate from the rapidly decomposing organic matter (Hamilton & Lowe, 1981). Plowing soils and heavy cover crops at least 6 weeks before setting reduces the chances of organic matter toxicity.

Working the field site several times with a disk harrow or similar implement before setting produces a good bed for transplanting. Field preparation provides a means of incorporating any fertilizer, herbicides, fungicides and insecticides needed. The use of power driven tillers leads to more rapid destruction of soil structure.

Intensive cultivation after transplanting contributes to structural degradation and soil erosion. Cultivating for weed control may be essential. However, deep cultivation damages roots and brings viable weed seeds to the surface.

Minimal or no-tillage methods of production reduce soil loss but comprise a small amount of the total
production. No-till production methods generally result in greater reliance on chemical methods of weed control. Modified transplaters can successfully establish seedlings in chemically killed sods and cover crops (Phillips & Zeleznik, 1989). Adequate control of weeds in no-till tobacco production allows the tobacco the chance to yield comparably to that of conventionally grown tobacco (Pearce & Zeleznik, 1996). Inconsistent weed control limited adaptation of no-till in the past. New herbicide chemistry recently approved for use on tobacco makes no-till tobacco more feasible.

Developing nations utilize hand or animal power for tillage. Nevertheless, tillage of tobacco ground is intensive in these countries compared to other crops. Clearing ground for tobacco production is common in some regions. After several years of tobacco production, it is transferred to newly cleared land and the abandoned area regenerates. Land for this type of slash and burn culture is becoming scarce. In some places it is prohibited by regulations. Production of light air-cured tobacco on top of low ridges or beds, formed following any secondary cultivation and just before transplanting, is common in some countries.

FERTILIZATION PRACTICES

Fertilization practices for light air-cured tobacco vary depending on the type of product desired. Producers of Maryland and filler burley tobacco use low rates of nitrogen in the 70 to 90 kg/ha range (McKee & Conrad, 1994). Burley tobacco growers in the USA typically apply 200 to 300 kg N/ha, while in Kentucky, N rates approaching 300 to 400 kg N/ha are common. Ammonium nitrate and urea are the primary sources of N with sodium nitrate more commonly reserved for side dressing. As a result of heavy nitrogen applications, burley growers must apply large quantities of lime to offset the acidity produced by nitrogen fertilizers. Maryland lime recommendations call for liming to a pH of 5.5 to 5.6 (McKee & Conrad, 1994). The recommendation for burley tobacco in Kentucky is to lime to pH 6.4 to 6.6 (Anon, 1996). The reason for liming is to insure that after fertilization the pH does not drop below 5.4 where manganese (Mn) toxicity can become a problem.

Manganese toxicity, considered to be the most significant nutritional disorder of burley tobacco in Kentucky, generally appears 2 to 4 weeks after setting. Tobacco develops poorly with interveinal chlorosis between veins that remain dark green. A rescue treatment of 1100 kg/ha fine lime improves soil pH and helps the tobacco recover. However, prevention is the key to reducing losses from Mn toxicity. Agricultural grade limestone applied at least 6 to 12 months before planting tobacco produces the best results.

Recommendations for phosphorus range from 0 to 200 kg P/ha based on soil test levels. Limited root growth in the spring under cool, wet conditions compounds phosphorus deficiencies. The symptoms of deficiency include stunted growth and occasionally the appearance of small, shiny, metallic looking spots on the lower leaves of young plants. This condition is usually temporary and normal growth resumes eventually with little or no impact on cured leaf yields. The most commonly used source of phosphorous is triple super phosphate with ordinary super phosphate also used in some regions.

Potassium is well known for its effects on improving the burning qualities of cured leaf. Light air-cured tobacco, because of its large biomass production and high potassium content, has a high requirement for potassium. The symptoms of deficiency are first chlorosis and eventually necrosis of the leaf margins of older leaves. Affected leaves will be thin and trashy at harvest. Potassium deficiency can reduce cured leaf yields by as much as 800 to 1000 kg/ha. Soil tests for available potassium provide assessment of needs that range from 0 to 400 kg K/ha. The preferred source is potassium sulfate. The cost of fertilization tempts tobacco growers to use the cheaper muriate of potash source. Muriate of potash costs half as much per unit of K as potassium sulfate, however the use of muriate can lead to the accumulation of unacceptable levels of chloride and impair the quality of the cured leaf.

Trends in recent years in the USA are toward the use of customized blends, based on soil tests, that provide only the nutrients needed for the current crop year. A practice that was common in the past, and still in use today, is to apply a prescribed quantity of blended fertilizer, regardless of the crop need. The most common 'recipe' in recent years called for 2240 kg/ha of 5-10-15 fertilizer plus a supplemental application of nitrogen. Such practices are inefficient and may result in the over- or under-application of some nutrients.

In the USA, the majority of the fertilizer applications are made prior to transplanting with incorporation into the top 7.6 to 10.2 cm of soil. Some growers side-dress nitrogen at the first or second cultivation to improve fertilizer efficiency and to replace nitrogen lost by leaching. In developing regions where fertilizer is scarce and expensive, growers are more likely to apply lower rates of fertilizer in bands or to individual plants to improve efficiency. Banding or other forms of fer-
ilizer placement can improve fertilizer efficiency by as much as 50% compared to broadcast applications (Sims, et al., 1994).

Micronutrient deficiencies in tobacco are relatively rare and usually occur in isolated pockets. Most micronutrient deficiencies occur as a result of pH imbalances. The only micronutrient recommended for use on burley tobacco in Kentucky is molybdenum (Mo) when the pH is less than 6.4. Transplant water solutions of Mo are easy and simple to apply. Sims (1980) reported that Mo fertilization in Kentucky resulted in a significant yield increase on about 50% of the sites tested. Yield increases ranged from 225 to 900 kg cured leaf/ha. Precise micronutrient fertilization is necessary due to a narrow window between sufficiency and toxicity.

TRANSPANT PRODUCTION

The majority of burley tobacco transplants production in the USA is in containerized plant production systems. The most commonly employed system is the float system, in which transplants grow in polystyrene flats (trays) floating on beds of nutrient solutions. The float system has been in use since the early 1990s yet comprises over 70% of all burley transplants production. The cost is somewhat higher than for conventional transplant beds, but for many growers the advantages of the system outweigh the costs. The main advantage cited by most growers is the ability to easily handle and transport groups of plants instead of having to pull individual plants from a conventional bed.

Excessive fertilization can lead to salt damage in young seedlings and to increased disease susceptibility in older plants. The nitrogen concentration in the float water should not exceed 125 ppm and the preferred range for burley is 75 to 100 ppm N. Commonly used fertilizers are 20-10-20, 20-9-20, and 15-4-15. These ratios provide the proper balance of nutrients for good transplant growth. The use of urea-based fertilizers in the float system produces nitrates that are toxic to plants.

Seeds, pelleted with diatomaceous earth to increase size and uniformity, allow for singulation and automated handling of seeds. Seeding begins 6 to 8 weeks prior to transplanting, depending on light and temperature. A peat-based soil-less mix placed in the trays wicks moisture and nutrients from the float bed. Producers utilize greenhouses covered with polyethylene film or unheated outside float beds. Outside beds are subject to damage from rains and cold temperatures.

The float system dramatically increases the long distance transport of tobacco transplants in the USA. Suitable precautions are necessary to prevent the spread of diseases by infected transplants.

A condition known as spiral root is common for seeds germinated in the float system. Spiral root is a result of media over-saturation. The extreme moisture in the float system makes for an environment that is more conducive to disease development. Plants produced in float systems appear to be more susceptible to chill injury than conventionally produced plants. Though the transplants usually recover from this chill injury, problems with lateral suckers from the base of the stem increase as a result of bud damage.

Conventional tobacco beds are still common in many areas of the world. Fertile, well drained soils are preferable. The site should be free from shade and located near a source of clean water. A fine seed bed is important to insure the best start for seedlings. A broad spectrum biocide used to fumigate the site kills weed seed and pathogenic organisms. A gas-impermeable covering prevents rapid dissipation of the fumigant and protects from recontamination. A mix of raw tobacco seed and sand or fertilizer allows a uniform distribution of seeds. Straw or other mulch helps hold moisture and provide insulation where needed. A cotton, polypropylene or polyethylene cover permits light to pass but retains heat. The provision of adequate moisture promotes good plant growth.

One of the issues facing growers of conventional plant beds is the potential loss of the fumigant, methyl bromide, due to environmental concerns. Few alternatives exist for use on tobacco plant beds.

The ideal burley tobacco transplant is 10 to 15 cm in height with a stem diameter of 8 to 10 mm. A healthy burley transplant has a pale green color. Dark green colors indicate a plant that is tender and may have more difficulty surviving in the field.

PLANT POPULATION

Plant population can have a significant impact on economic return per unit area, plant size parameters, yield and quality. Economic and quality considerations should determine the plant population. However, producers often base plant population decisions on tradition. Manual transplanting often has an inadvertent influence on plant population. Limiting factors, such as land availability and labor, are the best indicators for determining plant population. If labor is limiting, a decrease in plant population produces more
cured leaf weight per unit handled. If land is the limiting factor, an increase in plant population produces more cured leaf weight per unit area. If quality is significantly affected by a high or low population, plant population should be shifted to improve quality.

In the USA before 1971 a government control program limited burley production based on land area. Limits (quotas) are now based on cured leaf weight. Production gradually shifted to wider plant spacing as labor availability decreased. Current recommendations call for plant populations to range from 15,000 to 18,000 plants per hectare. However, spacing ranges from 40 to 60 cm within a row and 90 to 120 cm between rows. Maryland tobacco benefits from slightly wider spacing with recommended populations ranging from 12,000 to 15,000 plants per hectare. Row spacing ranges from 90 to 107 cm with spacings of 45 to 90 cm within a row. Producers in many areas of light air-cured tobacco production would benefit from careful consideration of optimum plant population (Isaacs, 1993; McKee & Conrad, 1994).

WEED CONTROL

Weeds compete with light air-cured tobacco for water, nutrients and space just as they do with all types of tobacco. Climbing weeds may physically damage the tobacco before or during harvest. Mechanical and chemical controls significantly reduce the loss of yield and quality associated with weed growth. Whether by hand cultivation or motor driven cultivators, a shallow cultivation is sufficient to disturb weed root systems or shear the weed stem just below the soil level. A deep cultivation is not necessary and may damage tobacco root systems or pull untreated soil to the surface, allowing regrowth of weeds. Cultivation during dry conditions exposes soil moisture and promotes evaporation. Cultivation with machinery when soils have high soil moisture contributes to soil compaction.

The number of cultivations required depends on weed species and population, weather conditions, efficiency of cultivators, herbicide use and how well the tobacco competes with the weeds. The light air-cured tobacco produces a moderate amount of shading quickly. By 6 weeks tobacco is capable of shading most weeds that regrow later in the season. Exceptions include perennial weeds that may have established root systems or other structures that have the potential to grow rapidly. Yellow nutsedge (Cyperus esculentus L.), which reproduces primarily from underground tubers, can re-establish quickly and crowd out newly transplanted tobacco plants. Although cultivation may disturb or kill a nutsedge plant, the death or severance of the mother plant from the tubers stimulates sprouting and increases the weed problem. Annual climbing weeds such as morning glory (Ipomea sp.) and honeyvine milkweed (Ampelopis albidus (Nutt. Britt.) may grow sufficiently to intertwine tobacco leaves, causing leaf breakage and loss.

Chemical weed control is common in light air-cured tobacco production. An ideal herbicide selectively controls weeds without damaging the tobacco. It persists long enough to prevent loss of yield or quality from weed pressure without causing damage to any subsequent crop. Although ideal herbicides don't exist, several chemicals successfully control weeds in light air-cured tobacco with tolerable effects on the crop.

Pendimethalin (Prowl®) is a dinitroaniline herbicide applied preemergent or preplant incorporated for control of most annual and certain broadleaf weeds (Thomson, 1993). Pendimethalin controls weeds by inhibiting cell division of roots or shoots emerging from a germinating seed. Incorporation to a depth of no more than 5 cm prevents loss from photodecomposition and volatility, places the chemical in the weed seed zone and allows room for adequate root development below the treated zone. Photodecomposition and volatilization account for minor losses in activity compared to some herbicides. Rapid incorporation is, therefore, not necessary. A high application rate, deep incorporation, or soils with a high clay content increase the potential for root damage. Since little or no uptake of the chemical occurs, damage is primarily in the treated root zone. Pendimethalin injury induces root swelling and prevents secondary and tertiary root development. Low rainfall during the growing season reduces the breakdown of pendimethalin, increasing the persistence and the potential damage to cover crops or other rotational crops. Benefin (Balan®) and isopropalin (Paarlan®) are similar herbicides used to a lesser extent in tobacco production. They vary in their persistence, photodecomposition rate and crop safety (Thomson, 1993).

Clomazone (Command®) is an isoxazolidinone herbicide applied preemergent or preplant incorporated for control of most annual grasses and certain broadleaf weeds (Thomson, 1993). Clomazone is a chlorophyll-inhibiting compound. Weeds germinate, take up lethal doses of the chemical and turn white before dying. Some Amaranthus species tolerate clomazone, therefore other means of control are necessary where infestations of amaranths occur. Although new formulations of
clomazone volatilize less readily, damage to susceptible plants near areas of application is possible. Incorporation reduces drift. Light air-cured tobacco tolerates clomazone, but a few white leaves are common. They recover quickly with no lasting damage to yield or quality. Clomazone persists for a long period of time in soils, presenting a threat to susceptible rotational or cover crops.

Pebulate (Tillam®) is a thiocarbamate herbicide applied preplant incorporated for control of nutsedge, annual grasses and certain broadleaf weeds (Thomson, 1993). Volatilization occurs quickly, requiring immediate incorporation to reduce loss of activity. Pebulate leaches easily in sandy soils and with heavy rainfall. Microbial breakdown reduces persistence, potentially allowing regrowth of weeds before harvest. Good activity on nutsedge makes it an ideal chemical in areas with high nutsedge infestation. A tank mix with other herbicides provides a broader spectrum of weed control. Pebulate has excellent crop safety. Tobacco tolerates pebulate by rapid breakdown of the chemical. However, under conditions of rapid transpiration newly transplanted tobacco plants with extensive root systems absorb excessive pebulate. Plants develop strap-like leaves and/or bud damage. Pebulate damage is rare.

Napropamide (Devrinol®) is a propionamide herbicide applied preplant incorporated or preemergent for annual grasses and certain broadleaf weeds (Thomson, 1993). Napropamide is highly persistent, lasting up to 12 months in most soils, and can damage rotational or cover crops. Banding of napropamide over a tobacco row before weed emergence can aid weed control. However, delaying application increases the length of persistence. A tank mix with other herbicides provides a broader spectrum of weed control.

Sulfentrazone (Spartan®) is a new soil-applied herbicide for selective control of broadleaf and certain grass weeds (Anon, 1993). It is especially effective on morning glories and nutsedge. Sulfentrazone controls weeds through root and shoot uptake and subsequent membrane disruption. Weeds turn necrotic and die after emerging from the soil. A tank mix with other herbicides improves grass control. Excessive application rates or incorporation of sulfentrazone may cause leaf stunting and tissue breakdown on lower leaves of tobacco.

Annual and perennial grasses in tropical and subtropical regions present an extra challenge for tobacco producers. In countries where selective grass herbicides are registered, they could be used to improve weed control.

TOPPING

Before the development of effective sucker control chemicals, burley and Maryland tobacco were topped late or just prior to harvest primarily to prevent sucker growth (Anon, 1954). Other methods included topping when two-thirds to three-fourths of the plants were in bloom and suckering once or twice before cutting. Leaving the top two suckers until just before harvest prevented other sucker growth. Early topping in general produces a darker, heavier-bodied tobacco, while late topping produces the opposite. Leaves of any plant serve as a store for seed production. As blooms develop, energy stored in the leaves moves to the area of highest demand, the seed head. Removing the seed head in a timely manner prevents excessive loss from the marketable leaves.

Since the topping stage affects yield, quality and nicotine content, the method should fit the style of tobacco desired. In burley regions where stalk-cut tobacco cores under good to ideal conditions, topping at 10 to 25% bloom produces the best quality and yield. Both bud topping and late topping reduce yield but affect the quality differently. Ideal topping for stalk cut Maryland is at 60% bloom. Stalk-cut burley curing rapidly under less than ideal conditions may produce undesirable quality if topped too early. The same applies to primed burley and Maryland tobacco. Topping height depends not only on the desired result but also on the sucker control method. Low topping reduces labor but removes true tip leaves. Since a tobacco plant supports a specific number of leaves, topping high does not insure increased yield. Ideal leaf number varies but should range between 18 and 26 leaves. Length of the top leaf after topping varies but ranges from 20 to 35 cm (Palmer & Calvert, 1993; McKee & Conrad, 1994).

SUCKER CONTROL

With the loss of apical dominance (normally by topping), laterals shoots, or suckers, begin to grow. Suckers, like inflorescences, rob leaves of valuable nutrients. Sucker control is essential for high yield and quality. Hand suckering is one option, but chemical growth regulators are more commonly used. However, in situations where topping occurs after significant blooming begins, manual sucker removal is essential before application of sucker control chemicals.

Sucker control chemicals fall into three categories:
(1) systemics – chemicals absorbed by the plant and translocated inside the plant,
(2) contacts – chemicals that must come in contact with the sucker to achieve control, and
(3) local or contact systemics – chemicals that need to contact the sucker bud where absorption occurs.

These chemicals differ in application methods, activity and residue (Bruns & McKee, 1985; Palmer, et al., 1986).

Maleic hydrazide (MH) is a systemic chemical used for sucker control in burley and Maryland tobacco in certain regions of the world, most notably in the USA (Thomson, 1995). The most common type is the potassium salt formulation used since the late 1970s. Removing existing suckers reduces sucker control problems. This is especially a concern in varieties of burley that initiate suckers quickly and in Maryland tobacco where topping time may occur after sucker initiation. Failure to remove existing suckers prior to application encourages repeat applications that increase residue in cured leaf. Application of MH within 24 hours after topping produces the best results. Avoiding the hottest part of the day improves uptake and control. Small leaves left after topping may develop slowly. MH retards the spread of leaves smaller than 20 cm. A sufficient volume of water (375 to 475 L/ha) should provide adequate coverage of the top one-third to one-half of each plant. A reduced volume will compensate for small tobacco and low plant populations. Current research suggests that a coarse spray applied with low pressure (1.4 to 1.7 × 10³ Pa) performs better than a fine spray mist, especially under hot, dry conditions. MH-treated tobacco often yellows after treatment, making assessment of maturity difficult. Other indicators must be used to judge maturity when MH is used. Control lasts approximately 3 to 4 weeks depending on weather conditions and nutrient levels in the plant. Rainfall within 6 hours after spraying requires a full reaplication. However, after 6 hours and before 12 hours elapse, a half rate is sufficient (Palmer & Calvert, 1993; McKee & Conrad, 1994).

The contacts contain fatty alcohols as their active ingredient. Fatty alcohols must contact the sucker bud to achieve control (Thomson, 1995). Contacts kill small suckers rapidly, therefore fatty alcohols are not susceptible to rainfall after 1 hour passes. Removal of suckers greater than 2 cm in length improves control. Fatty alcohols work best before sucker initiation. Applications at bud stage and before topping or within 2 days after topping are effective. Arrangements of three nozzles directed over each row are common on power sprayers. A direct spray from a manual sprayer also provides good coverage and control. Low pressure sprayers are sufficient for application of fatty alcohols. A coarse spray or stream applied to the top of the plants provides good coverage of leaf axillary buds. Leaves of tobacco plants form a natural funnel that directs the spray down the stalk. Control diminishes where plants are not upright. Straightening plants prior to application could improve control. High rates of fatty alcohol and hot, humid conditions promote leaf drop. Fatty alcohol efficacy lasts for 7 to 10 days and requires reaplication for season-long control. The desired time between topping and harvest will determine the number of reaplications required.

Fatty alcohols alone or in combination with other sucker control chemicals are beneficial for improving uniformity in tobacco with an irregular bloom stage. By topping and treating only those plants that are in the desirable stage, uniformity improves. Repeating the process in 7 days continues to improve uniformity if needed. However, retreatment of initially treated plants is necessary when fatty alcohols are used. MH as a final treatment or fatty alcohols applied as sequential treatments controls suckers for the rest of the season. Applications of MH too close to harvest increases undesirable residue.

Local or contact systemics are dinitroaniline chemicals that fall in the same class as some herbicides (Thomson, 1995). Two examples are flumetrilin (Prime®) and butralin (Butralin®, Tamex®). These formulations control suckers in the same manner as they control weeds, by interrupting cell division at the growing point. Since uptake is minimal the chemical must come in contact with all axillary buds. A spray mix may miss the growing point of suckers longer than 3 cm, reducing control. The most common application method consists of pouring a 2% solution to the top of the stalk. Volume will depend on the size of the tobacco plants, but will be approximately 20 ml per plant. Precise application is necessary to insure complete axil contact and to prevent excess soil exposure. Residual chemicals on the soil can damage cover crops and rotational crops. Poor sucker control is common on plants that are not completely vertical. Misses often occur in the top of the plant due to imprecise application. Any suckers missed by the local systemic chemicals grow unimpeded. This could include ground suckers stimulated by topping but that are large enough for the sucker control mix to miss as it travels down the stalk. Good coverage insures good control for a 6 to 8 week
period of time. The length of control is more than sufficient to provide the length (time) of control needed in either burley or Maryland tobacco.

Combinations of reduced rates of MH and either of the dinitroaniline type chemicals may offer advantages over MH alone, while reducing the negative impact of each chemical. By reducing MH rates by a half or three-fourths of the normal rate and by limiting local systemics to 1% of the final solution, a combination results with the best activity of both chemicals.

Mechanical applications with high clearance sprayers equipped with solid cone, coarse nozzles provide sufficient coverage and economical application for large tobacco fields. Backpack sprayers similarly equipped are equally acceptable. Besides excellent sucker control and yield, a combination offers the true systemic activity of the MH and the rain safety (wash off) and extended control of the dinitroanilines. Good sucker control should reduce the tendency to over-apply or reapply, which increases MH residue. Reducing the rate lowers MH residue and decreases the cover crop damage associated with the local systemics. Variation of the rates may be necessary depending on production practices that may influence sucker pressure.

HARVESTING

Maturity and ripeness are terms used frequently to describe the appropriate time to cut tobacco. However, both terms are somewhat ambiguous and often mean different things to different people. Since light air-cured tobacco must depend on natural curing conditions, selection of the right time to harvest tobacco can influence the cure. Although time after topping is the most common criterion used to judge harvest, many factors influence true maturity or ripeness of a crop. Time after transplanting is not a good criterion due to seasonal variation. Weather has a primary influence affecting nutrient uptake and active growth of tobacco. Other factors such as soil type, pH and fertility influence maturity.

Plant characteristics such as color, stalk hardness and leaf firmness do signal maturity but are not clearly defined (Massie & Smiley, 1974; McKee & Conrad, 1994). A plant's normal green color degrades to a lighter color as physiological maturity occurs. This may be subtle or different depending on varietal influence. For example, varieties like the burley variety, TN 86, or MD 609 grow with a light green color initially.

Stems and stalks of burley tobacco do turn a noticeable light cream to white color at maturity, making assessment of maturity easier in burley than Maryland tobacco. Stalk hardening begins as floral initiation occurs and may not be a good indicator of the best time to harvest. Delaying topping till full bloom allows the stalk to harden before topping. This would eliminate stalk hardiness as a useful tool for determining maturity under these circumstances. A tobacco leaf that breaks easily when bent signifies maturity and is a relatively easy and nondestructive test. Leaf firmness is easy to evaluate but may also vary due to moisture stress or time of day.

Harvesting light air-cured tobacco is labor intensive regardless of the method used. Depending on the location, light air-cured tobacco harvesting is by whole stalk cutting, leaf removal or priming and a combination of the first two methods. The method used may depend on several factors including labor availability, production practices, curing facilities, curing conditions and the style of tobacco desired.

In the USA, whole stalk harvesting is almost the exclusive method and it is becoming increasingly popular in countries where other methods predominate. Cut tobacco left standing in the field to wilt is susceptible to sunburn, which reduces quality. Significant water loss during the field wilting period helps reduce labor demands and leaf breakage. Maryland tobacco is more susceptible to sun damage than burley, and field wilt should be minimal to reduce damage. However, Maryland tobacco is more brittle at harvest and may suffer less damage if allowed to field wilt for a short time. Sun intensity and temperature in some locations prevent the use of field wilting as an option. If tobacco sunburns, an extra 2 to 3 days in the field will bleach the damaged areas, improving quality. However, quality still suffers. Extending the time in the field exposes the tobacco to potential rainfall in some locations. Rainfall can splash soil onto leaves, further reducing quality or physically damaging more mature leaves.

Priming of bottom leaves before stalk cutting to prevent deterioration is common in some areas. Priming of leaves as they ripen or just the bottom leaves of the plant before stalk cutting is also common in many areas. Removal of leaves as they reach maturity is critical for producing high quality tobacco. The leaf maturity characteristics described above are useful in assessing maturity. Style desired may differ, but in general leaves that are over-mature will produce a thin-bodied leaf, and immature leaves may produce green tobacco when cured.
CURING

Moisture loss and curing begin at harvest. Primarily harvesting is by hand with few exceptions, including mechanical leaf and stalk harvesters in Japan and other locations (Ohori, 1996). Curing, however, is more than drying of the leaves. It involves complex physical and chemical changes that occur as tobacco leaves slowly lose moisture.

There are three stages in the curing process (Jeffrey, 1940; Massie & Smiley, 1974; McKee & Conrad, 1994). The first stage, the green stage, is short in duration, lasting for 2 to 5 days. During this stage the chlorophyll degrades, giving way to the second, the yellow stage. Burley tobacco left in the field to wilt may continue through the green stage while still in the field. Green color may result if leaf damage occurs during this stage or if rapid drying conditions prevail with no attempt to regulate the moisture loss.

The second stage is longer in duration and lasts for 5 to 10 weeks, depending on curing conditions. The yellow pigments of the second curing stage degrade more slowly than the chlorophyll. However, color change is only part of the curing process during the second stage. During the second stage many chemical reactions occur before the leaves become dehydrated. Any factor that increases the drying rate can leave yellow pigment in the cured leaf as well as undesirable chemical characteristics. High ambient moisture that would delay curing may provide fungi and bacteria with favorable conditions for growth. Houseburn, the destruction of tobacco by these organisms, causes loss of dry matter and reduction in quality.

The third stage of curing, the brown stage, follows as the yellow pigment degrades and the leaf dies. Once the tobacco reaches the third stage most of the chemical changes cease. This does not mean that the tobacco cannot change once it reaches the brown stage. Moisture is still influential, and tobacco may darken substantially as it takes up and gives off moisture as the ambient humidity changes. As tobacco takes up and gives off moisture it varies from a fragile to wet state. If tobacco cures too quickly this process of taking up and releasing moisture will change the color of the tobacco. However, excessive dry conditions that halt chemical changes during curing leave unfavorable residual products that degrade quality. Curing stopped in the green stage leaves the green pigments in the cured leaf. These pigments will degrade slowly with time and favorable moisture levels to a more desirable product.

Primed leaves cure more quickly than stalk-cured leaves. Primed burley has a tendency to be light in color and to have more green or yellow color than stalk-cured burley.

Temperature, humidity, air flow and sunlight control curing rate. As temperature, air flow and sunlight increase, drying increases but decreases as humidity increases (Jeffrey, 1940; Jeffrey, 1946). Temperature has the greatest influence over chemical reactions during the curing process. The desirable range is 18 to 32°C. However, Jeffrey determined that humidity plays the more significant role due to a narrow desirable range of 65 to 70% relative humidity (Jeffrey, 1940). In areas with little rainfall during curing, it is common to leave tobacco exposed to sunlight on curing frames. Sunlight may compound the negative effects of low humidity on the curing process in these situations. Low humidity and high temperatures common during dry curing seasons in Central America and Mexico speed curing during the yellow stage. Variegated or ‘pie-bal’d’ tobacco results. Quick cured tobacco is less desirable than more slowly cured tobacco in current markets. Green or mottled tobacco is also undesirable and is highly influenced by temperature and humidity during the early stages of curing. Low temperature, regardless of humidity, produces green tobacco. The degree of damage is dependent on the extent that humidity varies from the norm (Walton & Henson, 1971). Low humidity with temperatures in the desirable range produces greenish or mottled tobacco. As temperature increases toward the upper limit, high humidity provides favorable conditions for microbial activity. The resulting rot or houseburn darkens the tobacco and reduces dry weight.

Curing Facilities

Air-cured tobacco curing facilities must take advantage of the ambient conditions to achieve the best cure. Curing facilities vary from basic open-air scaffolding to conventional burley barns typical of the Bluegrass regions of Kentucky. Attributes of a good curing facility should minimize detrimental curing conditions and protect cured tobacco from rainfall and wind damage. Conservation of moisture and a slower cure are desirable, especially in dry areas. Regardless of the curing conditions, curing facilities allow little regulation of environmental factors except for air flow. Regulation of air flow affects temperature and humidity and controls curing. Density of tobacco leaves or stalks in the curing structure, orientation of the structure to
prevailing winds, ventilators and other openings in the structure and the size of the structure all affect air flow. O’Bannon (1943) expressed the relationship as:

\[ Q = \frac{Vd (A + C)}{BSP} \]

where  
- \( Q \) = quantity of air entering and leaving barn  
- \( V \) = velocity of wind  
- \( d \) = direction of wind, greatest when perpendicular to the structure  
- \( A \) = area of ventilator opening  
- \( C \) = area of cracks  
- \( B \) = width of structure  
- \( S \) = spacing of tobacco  
- \( P \) = size of plants

As air moves through curing tobacco, moisture evaporates, so cooling the tobacco. At the same time the ventilation increases curing. Curing structures filled tightly will prevent proper air movement. Tightly packed tobacco is more susceptible to houseburn. Leaving air channels through the tobacco allows air to pass around the tobacco and not through the tobacco, reducing the benefits of ventilation. Spacing tobacco uniformly in both the horizontal and vertical planes assures even curing. Tobacco curing conditions in a specific area dictate the appropriate spacing for that area. Since air traveling across short distances is more efficient, orientation of curing structures broadside to the prevailing wind improves ventilation. Exceeding 12 m in width reduces the effectiveness of ventilation, while length is not critical with proper orientation. Structures with ventilators comprising one-third of the side surface area maximize ventilation potential. Where air flow is minimal fans can improve ventilation. Fans designed to pull air through the curing tobacco are more efficient than other methods. Curing improves with appropriate regulation of the ventilators as dictated by ambient conditions (O’Bannon, 1947; Massie & Smiley, 1974; McKee & Conrad, 1994).

Traditional curing barns are slowly being replaced by various temporary or semi-permanent scaffolds. These structures offer low investment, reduced labor cost and, in some cases, improved curing and quality. Common black plastic material serves as the roof and siding. Although plastic provides less protection from wind and rain, raising and lowering the plastic side curtains regulate air flow and provide maximum conservation of moisture under dry climates. These structures generally have less air space below the tobacco, reducing ventilation. Keeping width to a minimum reduces the chance of rot or houseburn. These structures do not substitute for proper curing management. Management of ventilation is as critical as with more conventional structures.

The conditions of cured leaves exposed to the air inside a curing facility are good indicators of relative humidity (Table 5.11). Samples in dry to low case or order indicate a relative humidity in the target range of 65 to 70%. The condition of the cured leaves helps to determine the need for more or less ventilation. If cured leaves are placed in a protected area but exposed to ambient humidity this further enhances the ability to assess ventilation needs properly. Cured leaves in moderate to high case inside the curing structure indicate the need for more ventilation. Brittle leaves signal rapid curing conditions. Closing ventilators conserves moisture, slowing the cure. If rapid curing conditions prevail, ventilators opened at night allow cooler, more moist air to enter the structure. With proper regulation of the rate of moisture loss, a good cure is possible.

<table>
<thead>
<tr>
<th>Feel of cured leaf</th>
<th>Relative humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High case</td>
<td>90 to 100</td>
</tr>
<tr>
<td>Medium to high case</td>
<td>85 to 90</td>
</tr>
<tr>
<td>Medium case</td>
<td>80 to 85</td>
</tr>
<tr>
<td>Low to medium case</td>
<td>75 to 80</td>
</tr>
<tr>
<td>Low case</td>
<td>70 to 75</td>
</tr>
<tr>
<td>Dry to low case</td>
<td>65 to 70</td>
</tr>
<tr>
<td>Dry</td>
<td>60 to 65</td>
</tr>
<tr>
<td>Dry to brittle</td>
<td>55 to 60</td>
</tr>
<tr>
<td>Brittle</td>
<td>50 to 55</td>
</tr>
<tr>
<td>Fragile</td>
<td>0 to 50</td>
</tr>
</tbody>
</table>

*From Kentucky Agricultural Experiment Station Bulletin 501, Principles of Burley Tobacco Barn Operation.

The use of heat to control humidity is possible, but risky and expensive. Proper spacing and control of the heat is necessary to prevent hot spots that set green or yellow pigments in the cured leaf. Moderate heat produces better results, and multiple heat sources insure distribution of heat. As heated air picks up moisture from the tobacco, ventilation is necessary to allow moisture to escape. Natural gas, liquid propane (LP) gas or coke are suitable fuels for curing under high humidity. Fuels with possible impurities that could influence quality are not suitable.
MARKET PREPARATION

Once tobacco completely cures, sorting or grading of tobacco can begin. ‘Fat’ stems or stems that have not completely cured are an indication that the tobacco is not ready for stripping. Fat stems can cause rot if bulked with other cured leaves. Leaves on stalk-cult tobacco should break clean from the stalk when fully cured. Handle cured tobacco only when in proper case or order (moisture level).

Good lighting is important for sorting or stripping tobacco. Either natural or fluorescent light is suitable for this process. Direct sunlight should be avoided for best color distinction.

Grading of tobacco varies depending on the market demand. The priming process is a form of pregrading, but further classification is often necessary to sort out off-color variation and damaged leaves after curing. Stalk cut tobacco must be graded as it is stripped. Leaves are sorted by stalk position, color, leaf texture and the degree of damage during the stripping process in stalk cut tobacco. Mixing across stalk positions is undesirable regardless of the market. Leaf chemical and physical handling characteristics vary considerably with change in stalk position.

REFERENCES