MACADAMIA NUT IPM PROTOCOL
SUPPORTING DOCUMENTATION

Overview. The Macadamia Nut Integrated Pest Management (IPM) Protocol was modeled after the National IPM Protocol for Potatoes. The Macadamia Nut IPM Protocol is supported by guidelines which were defined by a multi-disciplinary team of faculty from the University of Hawaii at Manoa, College of Tropical Agriculture and Human Resources (UH-CTAHR) and the Hawaii Macadamia Nut Association (HMNA). This program was specifically designed to establish the best management approach for the production of macadamia nuts in the State of Hawaii. Guidelines and point values are used to determine the level of IPM being utilized and are subject to change with new IPM developments.

Point System

Pest management practices are grouped according to five categories: 1) cultural, 2) physical, 3) mechanical, 4) biological, and 5) chemical. Each category is assigned a point value. This point system provides higher value to pest management practices that require active management decisions or reduction of environmental risks.

The system enables the UH-CTAHR IPM Program to determine the level of IPM being utilized while providing growers with a flexible, cost effective and environmentally responsible approach to crop management. To receive 'IPM Verification' the grower must enroll in the program, provide documentation that the Basic IPM level was achieved. This means that the grower has accrued a total of 70% of the total possible points set forth in the Macadamia Nut IPM Protocol. Pest management practices and the relative credited IPM points for macadamia were developed by UH-CTAHR IPM in collaboration with the HMNA.

Five Categories of Integrated Pest Management:
Five terms were used to identify IPM practices. They are:

- **Cultural.** Those practices used in general decisions making on the farm and in pest control.

  Scouting and monitoring of fields for pest problems. (5 points)

  Establishment of an economic action threshold. (7 points)

  Non chemical management. (5 points)

- **Physical.** Those cropping practices used that physically change the farming landscape to control or alter pests. (3 points)

- **Mechanical.** Those farming practices that require mechanical use, cleaning, or adjustment to control or alter a pest. (2-3 points)

Calibration of sprayers. (3 points)

- **Biological.** Those practices used in pest control that are based on biological manipulation, biocontrol measures, etc. Biological decisions receive higher point values due to the promotion and adoption of agricultural practices that minimize risks associated with pesticide use. (3-7 points)

  Resistance management decisions involves the rotation of chemicals to effectively control pest populations to prevent jeopardizing new chemicals to pest resistance. (4-5 points)

- **Chemical.** Those practices used in pest control that are chemically based. Examples: herbicides, fungicides, and insecticides. Chemical applications are awarded points due to their ability to provide remedial action to reduce pest populations and severe outbreaks. However, chemical treatments will be credited with points according to their specificity and potential impacts on the environment. (1-4 points)

  Choose One:
  Broad-spectrum compounds (chemicals that are less specific): (1 point)
  (i.e. Roundup, Aatrex, Gramoxone, Simazine, Goal, Sulfur, Rodeo, Rascal, etc.)
  Narrow spectrum compound: (3 point)
  Reduce-risk or biological compounds: (4 points)
  **At present, narrow and reduced risk compounds are not available to growers.*

  Spot and/or border sprays for weed or host plant pest control. (3 points)

BONUS points are awarded to advanced IPM practices as well as practices which are currently experimental and require additional time before conclusions are drawn.

Calculating Grower IPM Adoption Level

The Macadamia Nut IPM Protocol does not penalize growers for not having or not-managing pests. To ensure fairness, growers who do not have certain pest problems are not responsible for points under those specific areas of the protocol. These points are deducted from the total possible points available. The grower's score will be divided by the new total possible points and plotted on the IPM adoption continuum. To receive 'verification' the grower must acquire a minimum of 70% (Basic IPM Level) of the total possible points set forth in the Macadamia Nut IPM Protocol. Total possible points available will vary from farm to farm. An accounting of the production practices of each plantation will be reviewed and verified annually by UH-CTAHR IPM.

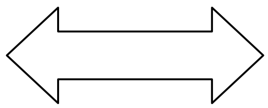
Macadamia Nut IPM Adoption Continuum

Macadamia Nut IPM Points Available: 132 Points
Advanced IPM Points Available: 30 Points

LEVELS OF IPM

No IPM	Emerging	Basic	Established	Advanced	Optimal
< 50% < 66 Points	**> 50%** > 66 Points	**70%** 92.4 Points	**80%** 105.6 Points	**100%** 132 Points	**>110%** > 145.2 Points

Chemically dependent
Low decision-making



Biologically dependent
High decision making

** Total possible points will vary depending on the pest situation at different geographic locations.

PEST MONITORING AND MANAGEMENT

✓ **DO YOU HAVE A PEST PROBLEM?**

What is a pest? The Macadamia Nut IPM Protocol has defined a pest to be an organism that causes economic damages or losses which in turn affects the profitability and/ or sustainability of agricultural production systems. The primary goal of the Macadamia Nut IPM Protocol is to retain or enhance production system yields without providing a negative impact to the environment. The strategy of IPM encompasses the utilization of principles including proper pest identification, continual pest monitoring, establishing an economic action threshold, and the implementation of pest control measures. Therefore, it is important to first identify if an organism is a pest or not. Growers who do not have certain pest problems are not responsible for points under those specific areas of the protocol.

✓ **PEST MONITORING:**

IPM is an ecologically based system that focuses on minimizing crop losses through the use of multi–disciplinary collaboration of crop production practices and principles. The importance of crop monitoring is to assess the pest situation to determine if the existing population numbers justify control actions. Monitoring of pest and diseases on a routine basis prior to implementation of control measures ensures that pesticide applications are precise and reflect time.

✓ **ESTABLISHMENT OF AN ECONOMIC ACTION THRESHOLD:**

Establishment and enforcement of an economic action threshold is a fundamental component of integrated pest management systems. A pest specific action threshold is the established level a pest population must reach before treatment to control the pest can be initiated without jeopardizing economic loss. Development of pest thresholds are area and season specific and require extensive research and knowledge on the targeted pest's lifecycle and history. Economic action thresholds promote effective pest management, while minimizing risk to human health and our existing natural resources. It will be at the discretion of growers to decide whether to take or to withhold action triggers once economic action thresholds are surpassed.

Tropical Nut Borer (TNB) Management

- **Utilize recommended harvest schedule interval to minimize TNB (*Hypothenemus obscurus*) damage.**

  The increasing spread of *H. obscurus* in areas of macadamia nut production on Hawaii can be curbed with the application of currently available technology. For maximum quality, nuts should be harvested at ≤ 1-month intervals and husked within 24 h of harvest (Cavaletto 1983) to avoid higher spoilage rates and increased insect damage from *H. obscurus* and other pest (Jones et al. 1992;K.M.D. & V.P.J. unpublished data; K.M.D. et al., 1994).

- **Administer Ethrel to induce a concentrated nut harvest that minimizes nut exposure to the TNB.**

  Ethrel is a growth regulator which can be applied when nuts are near maturity. It causes the abscission layer to mature and nuts fall within a short time. If Ethrel can help speed harvesting, it should be able to dramatically reduce TNB damage by dropping the entire crop within three weeks. We are excited about the possibilities of the Ethrel because its use dramatically improves the ability to schedule and harvest nuts quick enough that TNB damage is prevented (Jones et al., 1996).

- **Modify harvest schedule to reduce TNB losses.**

  Early harvest and processing is the best way to deal with TNB. If harvests are delayed too long, particularly with the more susceptible cultivars, damage can dramatically reduce profits. It is important for TNB management that cultivars which are prone to sticktights (such as Kakea [508]) be removed, because TNB builds up in those sticktights. TNB damage is also worst on the thin-shelled cultivars. (Jones 1995).

- **Use tree shakers to minimize sticktight density in large-scale production.**

  Sticktight nuts are nuts whose abscission layer dies before it has time to mature. They typically hang in the tree for 1-2 years until the husk rots and they fall to the ground. The number of sticktights varies by cultivar and location (wetter areas have fewer sticktights). Sticktights in the tree are typically the best place to search for TNB and we have recorded up to 190 beetles in a single sticktight nut. When an infested sticktight drops during the normal season, it essentially places TNB right next to this season's crop (Jones 1995).

- **Remove susceptible TNB cultivars.**

  There are clear differences in the attack rate and level of damage experienced by different cultivars. Jones & Capio (1990) found that cultivar differences in damage also exist for the koa seed worm and southern green stink bug. In areas where these insects are found, it is important that cultivar selection in new orchards consider not only horticultural factors but should also be heavily influenced by susceptibility to insect damage (Jones et al., 1992).

<u>Southern Green Stink Bug (SGSB) Management</u>

- **Manage weed host of SGSB within and adjacent to the orchard to prevent seedpod formation and buildup of SGSB populations. Concentrate weed control efforts to eliminate spiny amaranth, Spanish needle, balsam apple, and fuzzy rattlepod.**

  Macadamia nuts are attacked by *N. niridula* after preferred host plants senesce or are destroyed by weed management practices. Macadamia nut is not a suitable host by itself and the removal of alternate host plants associated with macadamia orchards should reduce *N. niridula* numbers and minimize *N. niridula* damage to the crop (Shearer & Jones 1996).

  SGSB has a very broad host list, including many common weeds in macadamia orchards. The most common hosts are *Desmodium spp.* (Beggar weed), *Crotolaria* (rattlepod), *Amaranthus spp*. (Spiny amaranth), and several other different types of legume (beans and relatives). The insects develop on these weeds and supplement their diet by casually feeding on macadamia when their host plants are destroyed, such as when mowing occurs in the orchard. Studies performed in other laboratories show that SGSB reproduction increases dramatically when host plant sets seeds or pods. Weeds within and at the edge of the orchard should be prevented from setting seeds if at all possible. This can be accomplished by frequent mowing or use of herbicides. (Jones 1995).

<u>Koa Seed Worm/ Litchi Moth Management</u>

- **Use pheromone traps in historically high damage areas.**

  The adults of KSW and LFM are attracted to the commercially available oriental fruit moth pheromone. A pheromone is a chemical released by females to attract males. The pheromones are a long-range attractant and probably function up to 100 yards or more. The pheromone is fairly specific and generally only affects a few closely related species. This trapping system is nice because it is cheap, specific to KSW and LFM, and easy to use and maintain (Jones 1995).

Red Banded Thrips and Broad Mite Management

- **Monitor for red banded thrips (RBT) and broad mite to young foliage and treat when environmental conditions permit.**

There is no threshold for RBT. RBT are most likely found on the nut or leaves. The recently hardened off foliage is what is affected, so its really only a problem on young trees or just after a growth flush in the field. If you find high levels on the nuts, then you should check the leaves, but if there is no sign of damage on the nuts, it is unlikely to find RBT on the leaves. Jones

Rodent Management

Roof rats (*Rattus rattus*) damage an estimated 5-10% of the developing nut crop in Hawaiian macadamia orchards (*Macadamia integrifolia*). Macadamia orchards provide abundant food and cover for these rats, which commonly burrow beneath the orchard floor in the cavities of the lava rock substrate. Roof rats typically feed in the trees during the night, and return to their burrows in the morning. They spend little time on the orchard floor, but readily move from tree to tree via the interlocking branches of mature macadamia trees. Macadamia nut is the dominant food item in the diet of rats in these orchard throughout the year. Rats feed on macadamia nuts by gnawing an opening in the shell, then extracting the meat by scraping the inside of the nut with their incisors. In contrast, pigs (*Sus scrofa*) crush the nuts during feeding, leaving behind angular pieces of shell rather than the hollowed out shell typical of rat damage. The prolonged and asynchronous flowering pattern of macadamia nut trees in Hawaii results in an almost continuous availability of nuts, which allows roof rats to reproduce throughout the year in these orchards. Thus, rats are a potential threat throughout the crop cycle.
Campbell

- **Monitor rodent population and damage. Maintain accurate scouting records.**

Rat populations and their impact can vary among years and throughout the crop cycle. Monitoring rat populations/damage provides information about the magnitude and distribution of rat damage, which can help growers decide when and where to control rats. Low levels of rat damage occurring early in the crop cycle may have little economic impact because macadamia trees are able to compensate for some damage as the crop develops. Trees are less able to reallocate resources to compensate for damage occurring later in the crop cycle. Therefore, increases in rat numbers or severity of damage later in the crop cycle may warrant control. Roof rats have relatively restricted home ranges. Therefore, if damage is very localized, concentrating control efforts in such “hot spots” could be effective.

Maintaining accurate records (e.g. location and magnitude of rat infestations/damage, cost and result of control efforts) aids growers in making timely and cost-effective management decisions. With such records growers can identify problem areas (and better target controls), identify and respond to unusual pattens of rat activity/damage, and assess the cost-effectiveness of control efforts (and modify subsequent efforts if appropriate) Campbell

- **Set approved rodenticide bait stations out in rodent infested areas. Use economic thresholds and follow label specifications.**

Currently, zinc phosphide is the only toxicant registered for use in Hawaiian macadamia orchards. It may be applied in tree in bait stations, in burrows, or broadcast on the orchard floor. Based on the activity and foraging patterns of roof rats, baiting in tree is likely to be the most effective. A registration for use of an anticoagulant rodenticide in macadamia orchards is being pursued, and this product may become available in the coming months. As with all pesticides, rodenticides must only be used in accordance with label specifications.
Campbell

- **Snap trapping rats in trees for small orchards.**

Though labor intensive, snap-trapping rats in trees can be effective. This technique is best suited for use in small orchards or to alleviate localized problems. Trap boxes can be used to reduce non-target (e.g. bird) captures.
Campbell

- **Weeds and debris that host rodents and encourage rodent breeding are eliminated.**

Another tool for controlling rat problems involve modifying orchard management practices to make orchards less attractive to rats. This includes eliminating harborage/cover in and around the orchard by controlling weeds, removing waste and debris, and not piling rocks around tree trunks for bracing. Maintaining a clean buffer area between the field perimeter and the non-crop (e.g. removing encroaching vegetation) could also help. Campbell

Use practices requiring minimal herbicide use or non-chemical practices to eliminate specific weeds that have been identified to host rodents and encourage rodent breeding. Refer to WEED MANAGEMENT IN MACADAMIA.
DeFrank & Nishimoto

Macadamia Nut Quick Decline Management

Macadamia Quick Decline (MQD) refers to a syndrome where macadamia trees die rapidly. Affected trees initially bleed from the trunks and have a mild leaf chlorosis. Leaves rapidly become copper-brown to red in color and the tree usually rapidly defoliates and dies in about 15 days.

Two species of ambrosia beetles, *Xyleborus affinis* and *X. perforans;* and at least seven different fungi (*Nectria rugulosa, Xylaria arbuscula, X. enteroleuca, Shizopora paradoxa, Phytophthora capsici, Acremonium* sp., and an unidentified basidiomycete) have been associated with MQD and implicated as it's cause. Several of the fungi have been demonstrated as capable of killing small branches after artificial wounding and inoculation but, except for *P. capsici*, are probably opportunistic fungi affecting trees that become predisposed by other factors.

Although the cause of MQD has not yet been unequivocally determined, there is substantial evidence that excessive soil moisture, through irrigation or rainfall, as being critical factors in MQD development. Compacted soils, mechanical injuries, etc. are suspected of having a major role in predisposing trees to MQD.
Nishijima

- **Monitor all fields for MQD and other diseases.**

Orchards should be continuously monitored and observed for general health and vigor. Moss growth on the tree should be removed so the bark on the trunks can be carefully watched for signs of ambrosia beetle frass (tendrils of fine saw dust oozing out of tiny holes in the bark), abnormal bleeding from the trunk or lower branches, fruiting bodies of *Nectria* sp. (red) or *Xylaria* spp. (small black pegs) on the trunks. Nishijima

- **Map out location of diseased areas.**

Maintain accurate records of dates of occurrence, location, and cultivar and look for patterns or trends in the field. Nishijima

- **Remove diseased trees and destroy residue.**

Macadamia nut trees infected with MQD should be removed immediately from the orchard. Destruction of residue should follow to prevent the movement of infectious material.

<u>Blossom and Raceme Blight Management</u>

Phytophthora capsici--"Phytophthora blight". This fungus has a wide host range and was first observed on macadamia in 1967. It usually is present in fields at low levels causing negligible effect but may develop to epidemic levels after a prolonged (about two weeks) period of heavy rains. The fungus will infect racemes in all developmental stages as well as the young developing nut itself. Dead racemes remain attached to branches for many months and serve as a source of inoculum. In addition to heavy rains the disease appears to be favored by the denseness or degree to which the canopy has closed; therefore, mature orchards tend to have higher levels of infection. A second *Phytophthora* (*P. palmivora*), which is common to papaya, occasionally causes *Phytophthora* blight and is indistinguishable from that caused by *P. capsici* except by microscopic examination or by culturing onto agar media.

Botrytis cinerea--"Raceme blight" caused by this fungus can be commonly found sporulating on dead racemes, nut husks, twigs, and leaves during humid weather, but it appears to infect only racemes. Racemes are susceptible when the florets are in the nearly fully expanded stage to immediately after the sepals fall. The young nutlet is not susceptible. Low levels of this disease can be found during most flowering periods but epidemic levels are not reached unless about two weeks of continuous heavy rains occur.

Fungicides are generally not necessary because the extended flowering period usually makes up for early or midseason losses. However, if nut set from the early season peak was low, the crop is heavily dependent on the current set of flowers, and disease pressure is high, fungicides such as benomyl (effective on raceme blight only), copper hydroxide and products derived from neem are registered.

Nishijima

- **Trees are pruned once a year to increase spray circulation and penetration. Prunings are removed or destroyed.**

Preventive measures such as spacing, pruning to prevent an extremely dense canopy to allow air circulation are also recommended during the flowering season. Avoid planting in areas that are prone to cool, wet, rainy periods to minimize this disease.

Nishijima

Weed Management

Weeds cause a variety of problems in macadamia orchards, if left uncontrolled. They can compete with macadamia trees for water, nutrients, and sunlight. Younger orchards are generally more susceptible to weed competition than older orchards, as tree canopy increases and severely restricts weed growth. Weeds interfere with harvesting, and increase harvesting costs. Weeds can harbor insect pests, and their predators, and weed management can enhance or reduce insect damage to macadamia nuts. In addition, weeds can harbor rodents, and make rodent management more difficult. Thus, weed management must consider the roles that weeds play in a macadamia orchard.

All weeds in Hawaiian macadamia orchards can be grouped by life cycle. Annuals arise from seed; they germinate, grow, flower, and produce seeds within a few months, but may continue to grow for more than one year. Perennials can arise from seed or vegetative parts (rhizomes, stolons, tubers, and roots), and live for more than two years; many perennials do not require seed to propagate themselves. They are generally more difficult to control because of its extensive vegetative reproductive system.

Weeds can be controlled by non-chemical means such as mowing, cover crops, mulching, cultivation, and sheep grazing, or chemically with preemergence and postemergence herbicides. A key element of integrated pest management is to reduce the amount of herbicides used. This may include the effective use of a non-chemical control measure, but in some cases, the proper choice and timing of herbicides can greatly reduce the total amount of herbicide used. The following are weed management practices that are useful in integrated pest management:
DeFrank & Nishimoto

- **Strip weed management (strip application of herbicides).**

  Apply herbicides in a band below trees to minimize herbicide use in the orchard. Weed in the between row space can be mowed or grazed to manage growth. Mowing should be timely to prevent seed formation which can infest the clean strip maintained below the trees. Special attention should be paid to weeds that spread with aggressive runners or stolens. These weeds can maintain a vegetative reservoir that can compromise the weed free strip. Aggressive weeds such as California grass (*Brachiaria mutica*) and torpedo grass (*Panicum repens*) should be eradicated from the between row space to reduce herbicide needed to check their growth. DeFrank & Nishimoto

- **Spot weed management treatment.**

  Many larger orchards make use of side mounted boom sprayers which operate most efficiently when spraying long continuous lengths of row. It is often impractical to spot treat with these large boom rigs. Overall, herbicide applications can be reduced if smaller more flexible system can be developed which allow for a rapid response capability used for highly accurate spot applications. Inexpensive electric sprayers can be operated from a pickup truck using the 12-volt power source generated by the motor. Spot treatment units can clean up weeds missed by larger boom rigs and provide for backup spraying during equipment breakdown and boom spraying delayed by unfavorable weather conditions. Flexibility in spray applications is key to a comprehensive herbicide management program in all tropical orchard and nut crops.

  Weeds have different sensitivities to preemergence applications and those species tolerant to a specific herbicide practice will emerge first. Strip or spot applications of postemergence and/or preemergence herbicides to extend the effectiveness of broadcast applications, thereby reducing the amount of herbicide necessary can treat minor outbreaks. To the extent possible, the herbicide practice used needs to match the weed problem. For example, annuals may best be treated with a combination of preemergence/postemergence herbicide mixture, as it signifies that the broadcast preemergence application has dissipated. Species present would dictate the choice of herbicide. For example, Spanish needle is somewhat tolerant to oryzalin and oxyfluorfen; atrazine or simazine as a preemergence herbicide should be considered. Ageratum is tolerated by oryzalin, and either atrazine, simazine, or oxyfluorfen should be considered. Buttonweed is somewhat tolerant to atrazine or simazine and either oryzalin or oxyfluorfen would be better choices with buttonweed present. If only small annual weeds are present, the postemergence herbicide dose to control small annual weeds should be used, which would substantially reduce the amount of herbicide used. Larger weeds and perennials require higher doses. Once weeds get too large, drift problems become more severe, as spray containment is difficult, and injury to macadamia nuts become a more serious consideration.

If the predominant weeds are perennials arising from stolons, tubers, and other vegetative structures, preemergence herbicides may be left out of the mixture and the choice of herbicide would depend upon species sensitivity. Shrubs such as guava and lantana quickly regrow following paraquat applications, while lantana can be effectively controlled by glyphosate. While guava is somewhat tolerant to glyphosate, better control can be achieved by a higher dose of glyphosate than with paraquat. Other perennial species like wandering jew (honohono) tolerate glyphosate, but are susceptible to paraquat and oxyfluorfen postemergence. Simazine and atrazine also provides partial control of emerged wandering jew.

Another consideration for the choice of herbicide should be considered. Of the herbicides commonly used for weed management in macadamia, atrazine and simazine has the greatest chance to move into the ground water. Thus, the use of these herbicides should be minimized. DeFrank & Nishimoto

- **Use non-chemical weed management techniques (mowing, cover crops, mulching, cultivation, sheep, etc.).**

Cover crops represent and effective way to reduce herbicide use in macadamia nut orchards. The cover crop must be adapted to specific environments and maintained in a weed free condition to obtain desired benefits. An ideal ground cover for macadamia orchards should be easily established, shade tolerant, low growing, easily managed with currently available herbicides and able to suppress undesirable vegetation. Easy establishment most often means planting from seed. In high rainfall areas, carpet grass can be used. In low rainfall areas, common bermuda is well adapted. A vegetatively propagated grasses like Tropic Lalo is well adapted to deep soils and higher rainfall areas where mowing is the main operation for managing between row vegetation. Tropic Lalo is well adapted to low mowing and thus aids in the suppression of many more upright and aggressive weeds.

Mulching is well documented for weed suppressing ability but is seldom practiced on a large scale. Hauling mulch to the orchard and spreading it evenly beneath the trees is time consuming and difficult. In-field production of mulch would lower costs and help to improve fertilizer efficient. A technique called “Mow and

Blow" refers to the process of actively growing a mulch crop in the between row space then mowing and distributing the cuttings beneath the trees. The ideal in-field mulch crop should be sterile, fast growing, unable to root at the nodes and perennial. A suggested species for Mow and Blow would be sorghum x sudan grass hybrid commonly referred to as Sudex. Fertilization is an important component of the mow and blow system. Growers who attempt to blow weedy ground covers below trees without fertilization quick deplete nutrients in this area and favor rank weed growth and seed production.

Pasturing animals in macadamia orchards sounds like a good idea but managing both animals and orchard crops quickly becomes a burdensome task for larger operations. Fencing livestock is expensive and can be easily compromised by dogs, thieves and wayward stock. An alternative to free ranging stock could involve more controlled foraging using harnessed stock moving through the orchard as a chewing phalanx. A moving harness could be controlled by a small-motorized unit or pulled on a cable system. To maintain the health and vigor of the stock, orchards should be planted and maintained with a high quality tropical forage such as Rhodes grass, Pangola grass or a mixture with a perennial peanut. Forcing stock to eat unpalatable or poisonous weeds invites a multitude of gastro-intestinal problems. DeFrank & Nishimoto

- **Rotation of crop protection chemicals to avoid herbicide resistance.**

Herbicides are the primary crop protection chemicals used in macadamia nut production. Rotation of herbicides will effectively control pest populations and minimize jeopardizing new chemicals to pest resistance.

Maintain spray records and calibrate sprayers twice a year.

All spray equipment should be inspected for leaks and overall good operation at the beginning of each spray day (cleaning equipment at the end of each spray day is desirable as it could prevent equipment deterioration and cross-contamination). If applicable (e.g. broadcast applications), the sprayer should be calibrated before each spray day. Worn nozzles should be replaced and any other component of the equipment immediately repaired or replaced before spraying. Maintain spray records (e.g. amount of pesticides applied, method of application, area treated, etc.) Note: Although spot spraying generally does not involve calibration, equipment still should be inspected, and application records maintained.

Kawate

Orchard Nutrient Management

- **Leaf tissue analysis conducted twice a year (preferably spring and summer). Maintain records and fertilize according to test results.**

Regular use of soil and plant tissue analysis is critical to maintaining adequate, but not excessive levels of soil fertility. In macadamia nuts, tissue analysis is a more useful tool since the actual plant uptake is indicated and deficiencies or excesses of elements can be corrected in subsequent nutrient or amendment applications. Occasional soil analyses can also be helpful to better interpret the tissue analysis data. Evensen

- **Annual soil analysis to determine soil amendments for pH regulation and pre-plant fertilizer requirements.**

Tissue and soil analyses are proven effective crop management tools in determining nutrient status of macadamia trees. Currently, there are many documented nutritional problems such as deficiencies of nitrogen, phosphorus, potassium, magnesium, sulfur, zinc, and boron. Also nutrient imbalances such as phosphate induced iron chlorosis and toxicity of manganese and aluminum. Because of the perennial nature of orchard crops, it is prudent for growers to monitor the nutritional status of their trees by regular soil and leaf analysis.
Hirae

Some amendments such as lime and phosphorus are best applied at tree planting since they should be mixed with the soil. In mature orchards, surface applied lime and P may not leach to deeper soil layers. Requirements for the application of nutrients can best be determined through graphing of long-term trends in plant tissue levels and through comparison with established critical and adequate nutrient levels. Evensen

- **Maintain a nutrient management log recording the fertilizers, application rates and dates of application.**

Nitrates and phosphates are currently under scrutiny as pollutants, and uses need to be monitored for optimum efficiency. The inevitable consequence of federal regulation resulting from the Federal Water Pollution Control Act, Water Quality Act, and the Coastal Zone Act Reauthorization Amendments is the quantitative monitoring of many agricultural production inputs. Soil and tissue analysis will become regular established procedures mandated by regulations which influence human safety and the conservation, environmental protection, and pollution control of our natural resources. Hirae

- **Calibrate and service fertilizer spreaders annually.**

Regular servicing and calibration of spreaders is necessary to insure accurate and uniform application of nutrients to avoid excessive or insufficient applications to various areas on the farm. Evensen

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