A Primer on Integrated Pest Management for *Cannabis sativa* Cultivation

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Cannabis sativa growers and consumers are highly concerned with flower quality – good taste, strength, cannabinoid mix, and smoothness. However, production concerns and targets often conflict with and trump quality objectives, especially when a valuable crop suffers a pest infestation and the grower must respond quickly and drastically to save it. Arthropods contain several classes of organisms detrimental to *C. sativa* production, including insects (thrips, aphids, and scales, for example), arachnids (specifically mites) and symphylans. Because *C. sativa* growers produce large supplies of food for these pests, the infestation cycle is inevitably common. In many cases, the grower will spray foliage with pesticides of varying toxicity, and in the worst cases, the grower will spray buds in a desperate attempt to stave off economic disaster. These tactics are part of a larger eradication strategy that is conventional in agriculture, but that fails in the long-run because it decreases product quality and natural defenses and promotes resistant pest populations.

In contrast, Integrated Pest Management (IPM) is a decision-making framework that combines strategies to limit pest damage to a level determined by the grower's goals and objectives, while minimizing risk to people, pets, and wildlife. With IPM, the grower uses the minimal intervention necessary to meet production objectives, while favoring smart farm design, prevention and natural control mechanisms. This approach optimizes labor and material costs in the workspace and minimizes chemical impact on the plant. The grower monitors the growing space for pests and responds on a scale and intensity appropriate to the levels of damage and infestation. Low-cost, minimal-risk, and least-damaging solutions take preference.

This approach recognizes that pests will inevitably be present and combines a variety of complementary strategies and tactics to keep pest populations below a harmful threshold. Mimicking natural ecological systems, the grower must integrate these techniques and tactics into a larger, adaptive strategy that begins before catastrophic situations arise, thereby preventing most potential problems.

While IPM is the best approach to responding to infestation crises and crisis-management, its greatest advantage is in avoiding crises through planning, preparation, and prevention. Whether the grower creates a complete, documented IPM plan or briefly outlines an IPM plan, a well-conceived and executed plan can preclude expensive losses to arthropod and pathogen infestation.

Further, a good IPM program will identify, make explicit and quantify the many assumptions underlying threat assessment and response – supplementing the manager's intutition with an explicit account of the problem-solution framework. As an equally important corollary, a good IPM will allow the farmer to budget expected costs and benefits in detail, drastically improving short- and long-term planning. This report briefly explains IPM and outlines the planning and management process.

Overview of Integrated Pest Management

IPM is a pest management framework that emphasizes maximizing the spread between expected benefits (income) and expected costs. When considering pesticide use – or any other cultural practice – the farmer compares the expected costs from pest-induced damage to the expected management costs for labor, equipment and materials. The farmer must also assess the risk of decreased product value, bad press, consumer dissatisfaction and possible action, regulatory action, and health hazards (to workers and community) due to pesticide contamination. Having assessed costs and benefits, the producer can avoid cultural practices that don't show a return.

Overall, several general principles guide IPM:

1. "Ya can't just do one thing." This old adage emphasizes the uncertainty involved when carrying out management treatments in an ecological setting. Unintended consequences are the norm and some of them can create long-term costs much greater than their short-term benefits.

2. A corollary to the above principle is *Primum non nocere*, or First, do no harm. A refinement of this principle is the Precautionary Principle, which states that before undertaking any action that will affect public health or the environment, in the absence of scientific knowledge on the effects, the manager should adopt full precautionary measures. Plan for the worst.

3. Management treatments should make economic sense, short-term and long-term. Managers should focus treatments on the most severe problems (in terms of short-term and long-term economic outcome) on which they can have the most impact.

4. "Managers should use treatments that have the least disruption on natural controls, the least hazardous to human health, the least toxic to non-target organisms, and the least damaging to the garden and general environment." (Quoted from Olkowski, et.al., p. 40.)

5. Strategies and treatments should focus on long-term and permanent pest reductions.

6. Strategies should be easy and economic to implement in the field.

7. Designing pests and problems out of the agricultural system should take priority.

IPM includes a large set of cultural practices that fall into four groups. *Ecological & Sanitation practices* create a low-risk growing environment that's healthy for plants and isn't vulnerable to pest outbreaks. *Monitoring* is key to catching problems early, before serious infection or infestation. *Indirect controls* (also called *environmental controls*) involve adjusting growing environments (lighting, atmosphere and soil) to thwart pests. *Direct controls* follow or accompany indirect controls. Direct controls include mechanical, biological and chemical controls.

The manager/farmer employs controls in response to a perceived threat, which is based on analyzing monitoring data in light of economic *damage-thresholds*, which the manager will have already established (as described below). When a pest infestation reaches a threshold and triggers a response, the grower should begin by consulting the *response strategy* he or she has already completed. (Again, see below.) If the infestation arises from a pest on the *target pest list*, the grower can devise a specific treatment based on the prescribed general response. If the infestation is not on a target pest list, the grower must research the specific pest and devise a response that reflects and supports management objectives.

Ecological and Sanitation Controls. *Ecological controls* encourage biodiversity in the growing ecology. Above ground, ecological controls involve creating biodiverse ecosystems that attract and support beneficial arthropods while blocking and confusing pests. In outdoor operations these ecosystems involve blocks, strips and corridors planted with carefully selected plants to provide the pest management functions while building healthy soil to decrease management needs of the special areas. In indoor operations (including closed greenhouses as is common in Colorado), ecological controls involve carefully designed polycultures designed and optimized for indoor use without interfering with state-mandated space constraints (as in Washington state).

Sanitation controls combine cultural principles with physical, permanent growing facility features. Facility features can include exclusion tactics, for instance, building tight, slightly-depressurized changing rooms, separate quarantine rooms, and HVAC filtering. Cultural principles can include such rules as restrictions against pets and street ware, a strict policy against importing clones and a well-established container-media procurement policy.

Monitoring. Monitoring combines observation with data-keeping. Monitoring is an on-going process that starts at a base level (no infestation) and increases in intensity when an infestation exceeds critical-thresholds and triggers a response. A response typically involves intensifying monitoring, implementing direct controls (and treatment), or both.

Monitoring effort and cost will depend upon the size of the crop and the grower's desired sample intensity. Monitoring practices can range from casual, visual observations to systematic counts based on traps and/or filters, depending upon the grower's goals and priorities. Growers can also monitor plant damage as an index of infestation. We recommend combining systematic visual inspection with sticky-pad sampling.

Scouting involves physically inspecting plants and can vary in rigor from the casual glance to systematic observations. Sample intensity can range from a representative sample to full-intensity (monitoring every plant), as often as necessary. Growers follow a specified protocol beginning with visual inspection of plant parts in whatever order the grower prefers, perhaps live-sampling branches or entire plants when necessary. Inspections can occur during light-periods or dark-periods, depending upon the target pest's life cycles.

Traps and Lures can be specific to one or a few pests, but the idea is simple. Sample intensity can range depending upon the management situation (trigger response). Trap placement depends upon the sample intensity, the type of trap used, and the known life-cycles of the targeted pests.

Data-keeping formats can range from GIS-based data-bases or spreadsheets to written note-taking or "taking note" mentally.

Indirect Controls or Environmental Controls. Response strategies proceed along a path beginning with indirect control, which involve altering the growing environment to impede pest population development. Indirect controls can including disrupting habitat by cleaning, re-arranging, or redesigning the growing area or changing environmental parameters like room temperature, relative-humidity, air-movement (wind) and dust. (Some authors use the term “environmental controls” for indirect controls.)

Direct Controls. Depending upon need, plant-stage and farm objectives, farmers can proceed to using direct-control strategies. When assessing direct control alternatives, the IPM farmer heeds the precautionary principle assuring that he or she will “first do not harm.” Safely within this important constraint – and all things being the same – the farmer will prefer to err towards minimizing pest risk – a “false-positive” error (or Type I error). Within the constraint of doing no harm to society or environment, the farmer would generally “rather be safe than sorry.”

Direct-control strategies begin with *mechanical controls* like hand-picking insects or spray-hosing plants.

If mechanical methods are not adequate, the manager proceeds to employing *biological controls*, like introducing store-bought predators and parasitoids, as individual species or in combination – for example the spider-mite predator combination of *Stethorus punctillum* (a type of “lady beetle”) or *Phytoseiulus persimillis* (a predatory mite). Other biological solutions include using fungi and bacterial that thwart or kill pests, for example moulds in the Hyphomycetes fungal order or bacteria in the *Pseudomonas* genus.

If necessary, direct controls can involve minimum damage chemical controls and application techniques. Most states with legal *C. sativa* cultivation have published lists of allowable pesticides and products. However, under federal law, using pesticides on *C. sativa* is illegal. The U.S. Environmental Policy Administration has registered no pesticides for *C. sativa*, which means that no label includes the species as a crop category. Since a pesticide label is considered a legal contract, using a pesticide outside those label restrictions is breaking that contract. The states of Colorado and Washington have maneuvered around this conflict by adhering to a provisional understanding that unofficially references the EPA allowable pesticide list for “Herbs and Spices.”

When choosing an allowable pesticide, the manager should choose from this list as well as a list consistent with company goals, values and policy – recognizing the potential long-term problems and costs that can follow from chemical treatment. In IPM parlance, these include *residue* (persistent effects), *resurgence* (which means a pest population rebounds after a treatment because the treatment has killed that pest's predator population), and *resistance*, which describes a pest strain's proclivity to evolve resistance to commonly-used pesticides. *Secondary pest* infestations occur when an additional pest moves after a treatment has eliminated its competition and predation.

Thus, a manager should use the least disruptive, hazardous, generally toxic and damaging alternative that meets the objective – and only in the most severe cases when the economic benefits are clear. If feasible, spot applications are better than broad-scale applications, and they minimize impact while saving on materials costs. Managers should time treatments to match up with appropriate pest morphology stages and with an appropriate range of weather and environmental conditions – as well as social conditions.

Generally, pesticides can be broken into essential oils and their extracted volatiles, botanicals and vegetable extractions (like *Allium sativum*, garlic), non-organic compounds (for example, sulfur products), microbe-synthesized pesticides, insect growth regulating hormones, vegetable oils, horticultural soaps of various strength and disruptiveness, horticultural oils, and a multitude of synthetic pesticides.

If infestations persist after an initial or successive response, a triggered response may require a more expensive or intensive strategy or strategic combination, as prescribed in the response strategy. The grower should document all strategic actions for cost-tracking and for building a knowledge base.

Putting together the IPM program

The IPM process begins with some basic planning steps. These steps make clear and explicit the grower's priorities and guide the choice of strategies throughout a growing cycle and in the case of a pest infestation.

Farm Goals. Goals are statements of purpose that declare "what" the grower wants to accomplish. For example, a goal might be written like this one: "Our goal is to grow high-quality product with minimum-possible chemical application." Farm goals reflect the grower's priorities and should be explicit, no matter what they are. A farm will generally have many goals – which together make up its mission – and making these goals explicit is an important step towards agronomic success.

Assessment. An assessment is a structured analysis and description of the growing environment based on systematic observations. An assessment includes information on growing space basics (zones, area sizes, spacing, etc.), physical limiting factors (light, water, CO_2, temperature), ventilation and airflow, soils and containers, surrounding vegetation and wildlife, chemical and biological limiting factors (nutrients and soil biological nutrient-cycling), or other pertinent items.

Objectives and Constraints. Objectives state how the grower intends to meet his or her farm goals. For example, "our objective is to grow healthy plants by using soil mixes and practices that yield maximum biological nutrient-cycling." That objective is one of two or more how-to statements that will together meet the goal. Another example is an objective that could help with the minimal application goal, "...to monitor for pest infestation from beginning to end of each cycle."

Constraints are specific restrictions on objectives, based on values, economic limits, or environmental limits. A constraint might read, "We will use no organophosphate pesticides," or "We will use no chemical application during the budding cycle."

Objectives Implementation. Implementing objectives involves creating a well-defined and explicit program that includes several components.

A *List of Tasks* could include such items as creating a mix recipe, filling and placing containers with a 12-inch buffer between adult crowns, and placing pest traps at designated locations. For long-term cost-tracking and budgeting, this list is a valuable resource.

Schedules are key for planning as then help with identifying critical pathways and avoiding bottlenecks, labor-scheduling, budgeting and cost-tracking.

Management Principles are rules that support implementation of objectives. These principles include *cultural controls*, which shape the general growing environment. Management principles can include items like keeping personal pets out of the grow area, entering the grow space with clean-clothes, leaving no standing water in the grow space, or maintaining the grow room within specified temperature or relative humidity ranges. These principles focus on preventing problems, but they also include measures that will affect monitoring and response practices.

Map-based Designs are highly-useful guides for implementing objectives, and we encourage the grower to make one or have one made. A map on a geographical information system is very handy because one can try several designs while analyzing growing-space area – per plant or per zone – or other parameters such as the volume of individual growing spaces.

A *Monitoring Plan* is vital to IPM. A monitoring plan specifies the types, locations, and scheduling of monitoring tactics (for example observing sticky traps) on the basis of a sample-design. A monitoring plan should target as many types of pests as possible, with special attention to known target species and types. Monitoring intensity will increase with the known presence of pests and with the intensity of the infestation. The plan should also include an estimation of the labor demands for each response – for cost-tracking and future budgeting.

A *Critical Threshold and Triggers Statement* defines the level of damage that the grower is willing to suffer before responding with an abatement strategy or intensified monitoring. (A critical threshold is also known as an *Economic Threshold*.) Creating critical thresholds involves making decisions on economic risks before a crisis occurs. After establishing the critical thresholds, the grower defines observation-based action-triggers that indicate an infestation is reaching that threshold. When the trigger conditions are met, the grower responds with an appropriate strategy or combination of strategies and prescribed tactics within that strategy. Response strategies and tactics will vary with different strains, pest species (or complexes), timing, and other factors. Intensified monitoring follows a treatment and the persistence of an infestation may trigger a further response.

A *Strategic Response Statement* is a list of the sequential strategies and associated tactics that follow triggers. Tactics can include treatments, cleaning actions, etc. Each trigger corresponds to one or more strategies and tactics, which may include any combination of intensified monitoring, treatment of a targeted pest or complex, and identification of an un-targeted pest and formulation of a treatment strategy. More intensive monitoring is important following any treatment.

If a treatment fails to suppress the pest satisfactorily (below the critical threshold), the grower may need to redefine thresholds and/or escalate to more intensive strategies. The Response Statement includes each successive strategy and associated tactics that the grower intends to use in a triggered response.

With larger operations, where labor costs are significant, the response strategy should include an estimation of the labor demands for each response – for cost-tracking, budgeting, and assigning additional labor during an outbreak.

A *Materials Inventory and Sourcing Guide* is key for quick response on all treatments not requiring fresh beneficial organisms, especially for target pests. In addition, being aware of all commercial sources of biologicals for quick procurement is key, since these organisms must be fresh (so storage is not feasible). This guide is useful for ordering-efficiency and cost tracking.

Conclusion

Integrated Pest Management plans enable the grower to prevent unnecessary crises and frame a coherent, systematic and economic response to an infestation. With IPM, the grower can minimize the economic impact of infestations while maintaining the integrity and quality of the product. For growers on any scale seeking to sustain profits into the future, the IPM plan is highly useful.

IPM obviously requires financial and time investment at the beginning of the process. Those up-front costs reflect the initial work involved in creating a resilient, management, pest-unfriendly environment (with design that optimizes work flows). But, those investments last through decades of production.

Further, once the grower has created an IPM strategy, he or she can adjust it and improve it according to new information, scale it up applying the same framework to a larger area, or extend it to other scenarios with site-specific modifications. (As a note, a scale-up is greatly facilitated with a geographical information system – which is a relational database that will integrate any conceivable type of data and creates maps with precise geo-coordination. Cool stuff.)

Coupled with a comprehensive ecological pest management design, an IPM strategy can create a protective environment for high-value crops like *C. sativa*, maintaining pests at sub-threshold populations and for all the critters that subdue pests populations. (See http://growecology.com/growecology_greenpapers/growecology_greenpaper_8.pdf.)

Finally, with a well-implemented, successful IPM strategy the farmer and the consumer benefit. Neighbors benefit and animals benefit. The soil and the complex soil food web benefit. IPM presents a win-win scenario.

McPartland, Et.al. state the case succinctly. “With IPM, careful obervation replaces the brute force of conventional chemical warfare. Farmers using IPM must closely monitor crop conditions, biocontrol organisms, the weather, and all pests in the area, not just single target species. IPM is pest management for the information age” (p. 3).

Additional Reading

Whitney Cranshaw, “Challenges and Opportunities for Pest Management of Cannabis in Colorado,” Iowa State Department Seminar, March 7, 2014, http://webdoc.agsci.colostate.edu/bspm/Cannabis%20IPM%20Iowa%20March%207.pdf

J. M. McPartland, R.C. Clarke & D.P. Watson, *Hemp Diseases and Pests: Management and Biological Control*. 2014. Boston: CABI.

William Olkowski, et.al., *The Gardener's Guide to Common-Sense Pest Control*. 2013. Newtown, CT: Taunton Press.