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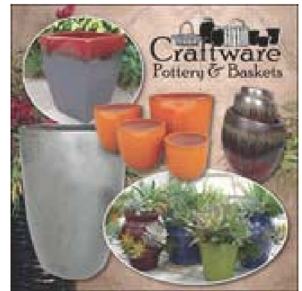

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"Sucking It Up:" Understanding How Systemic Insecticides Kill Insect

Systemic insecticides are compounds in which the active ingredient is taken up, primarily by plant roots, and translocated (=transported) to areas throughout the plant such as growing points where it negatively affect certain plant-feeding insects. Systemic insecticides may move within the vascular tissues either through the water-conducting tissue (xylem) by means of the transpiration stream or the food-conducting tissue (phloem) or both depending on specific characteristics of the active ingredient. Additionally, once inside the plant, the active ingredient may move back-and-forth from the water-conducting tissues to the food-conducting tissues or vice versa through the process of passive diffusion. However, this is contingent on the physical and molecular properties associated with the active ingredient of the systemic insecticide. Some of the "older" systemic insecticides that are no longer available for use against insect (and mite) pests of ornamental plants include aldicarb (Temik), oxamyl (Vydate), and oxydemeton-methyl (Metasystox-R). Currently, systemic insecticides commercially-available to professionals associated with nursery, landscape, greenhouse, and/or turfgrass include acephate (Orthene/Precise), dimethoate (Cygon), disulfoton (Di-Syston), acetamiprid (TriStar), imidacloprid (Merit and many generics), thiamethoxam (Flagship/Meridian), dinotefuran (Safari), clothianidin (Arena), flonicamid (Aria), and pymetrozine (Endeavor). Other products that contain a systemic insecticide in the formulation (as one of the active ingredients) are Allectus (imidacloprid + bifenthrin), Discus (imidacloprid + cyfluthrin), and Aloft (clothianidin + bifenthrin).

The benefits of using systemic insecticides include: 1) plants, in general, are continuously protected throughout most of the growing season without the need for repeat applications, 2) systemic insecticides are less susceptible to ultra-violet (UV) light degradation or "wash off" from rainfall following an application, 3) minimal, if any, unsightly residues on leaves or flowers when systemic insecticides are applied to the growing medium or soil, and 4) plants treated with systemic insecticides may be less harmful to workers and customers compared to plants receiving spray applications of insecticides.

Most systemic insecticides move-up the plant via the transpiration stream, and are primarily effective on insect pests with piercing-sucking mouthparts such as aphids, whiteflies, mealybugs, and soft scales because these insect pests feed extensively within the food-conducting tissues or phloem. As an insect feeds, it withdraws a lethal concentration of the insecticide active ingredient and is killed. For example, the piercing-sucking mouthpart (proboscis) of an aphid is inserted into plant tissues, reaching the conductive cells or phloem sieve tubes through which food is transported. The aphid takes up the active ingredient of the insecticide during the process of withdrawing plant fluids. Systemic insecticides may also be active on certain leaf-feeding beetles. Spider mites including the twospotted spider mite (Tetranychus urticae) and eriophyid mites (many species) do not feed within the xylem or phloem. Twospotted spider mite feeds within leaf cells damaging the spongy mesophyll, palisade parenchyma, and chloroplasts with their stylet-like mouthparts, reducing the chlorophyll content and the plants' ability to photosynthesize. Since spider mites do not feed in the vascular tissues, they are typically not susceptible to systemic insecticides.

Systemic insecticides may be applied directly to the growing medium or soil, or sprayed onto plant leaves or stems. Systemic insecticides, when applied to the growing medium or soil, are taken-up by plant roots providing up to 12 weeks of residual activity; even longer depending on the systemic insecticide. However, they may take longer to be distributed throughout the plant. In contrast, systemic insecticides applied to plant leaves may provide up to 4 weeks of residual activity. Nonetheless, foliar applied systemic insecticides provide quicker kill of target insect pests. In either case, systemic insecticides may provide the plant with long-term protection from insect injury.

Systemic insecticides, in general, are water soluble, which allows them to be absorbed by plant roots. The water solubility, which may be expressed as grams per liter (g/L) or parts per million (ppm), determines how rapidly the active ingredient in systemic insecticides is distributed throughout plant parts including plant leaves and roots. However, the affinity of the plant for the active ingredient may also contribute to the movement of systemic insecticides within plant tissues, and plants do not readily metabolize systemic insecticides. A highly water-soluble systemic insecticide may kill insects quickly but may not provide long-term control or regulation compared to a "less" water-soluble systemic insecticide. Due to their water solubility, systemic insecticides are susceptible to leaching; however, this will be influenced by watering techniques and ability of growing media or soils to bind to the active ingredient, which may reduce leaching but prohibit plant up-take. For example, growing media containing >30% bark and/or peat moss tend to bind to the active ingredient of certain systemic insecticides thus reducing the amount of active ingredient taken-up by the plant. This may result in a delay in controlling or regulating target insect pest populations.

Applications of systemic insecticides to the root zone must be performed when plants are actively growing and have an extensive, well-established root system in order to enhance the up-take of the active ingredient through the vascular plant tissues. Systemic insecticides applied during warm, sunny days will result in increased movement of the active ingredient through the transpiration stream. In contrast, up-take is inhibited when plants don't have well-established root systems. Any delayed movement of the active ingredient may result in the systemic insecticide taking longer to kill insect pests. Systemic insecticides are also more effective when plants are herbaceous rather than woody, particularly on stem-feeding insects such as aphids, mealybugs, and certain scales.

Systemic insecticides, when applied to the growing medium or soil, need to be used preventatively in order to control or regulate phloem-feeding insects such as aphids, whiteflies, mealybugs, and soft scale, and certain leaf-feeding beetles. If systemic insecticides are applied after insect pest populations are already established on plants or plants have developed woody tissue, this may delay control or regulation, resulting in insect pests causing damage before ingesting a lethal concentration of the active ingredient, while in the meantime, the insect pests are still producing offspring (=young) for additional generations.

Systemic insecticides, in general, are more active on soft scales than hard scales. The reason for this is that soft scales feed on plant fluids that translocate through the vascular system, primarily the phloem or food-conducting tissues. The food canal in their mouthparts transports large quantities of plant fluids (containing carbohydrates, amino acids, and proteins) from phloem sieve tubes. These plant fluids, after passing through the digestive tract of the scale, are emitted as honeydew. Soft scales can produce copious amounts of honeydew, which is a clear sticky liquid exudate that serves as a growing medium for sooty mold fungi resulting in a black coating on leaves. As such, they ingest lethal concentrations of the active ingredient. In contrast, hard scales do not produce honeydew because they feed differently than soft scales. Hard scales insert their mouthparts into plant tissues and rupture and destroy plant cells; oftentimes bypassing the plant vascular bundles that are responsible for transporting water and nutrients through the plant. Furthermore, their food canal contains various kinds of cells that don't ingest or transport large quantities of plant fluids. This means that hard scales tend not to ingest lethal concentrations of the active ingredient. Research has reported that applications of imidacloprid may lead to an increase in twospotted spider mite populations. In fact, enhanced plant growth has been observed in ornamental plants (trees) treated with imidacloprid. It has been suggested that imidacloprid applications may alter plant physiology that favors plant-feeding mites by increasing the nutritional quality of plant leaves, resulting in enhanced twospotted spider mite development and reproduction. "High" concentrations of imidacloprid may stimulate the expression of photosynthesis marker-genes that prolong the production of energy, which is correlated with induced improvement in plant nutritional quality or nitrogen content. As such, twospotted spider mite populations tend to respond favorably to increased nitrogen levels in plants. This response may be due to an alteration of plant nutrition or an induced physiological change in plants. In conclusion, systemic insecticides may provide long-term control of certain insect pests without having to rely on regular spray applications. However, it is important to use proper insecticide stewardship in order to minimize the risk of insect populations' potentially developing resistance to systemic insecticides.

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