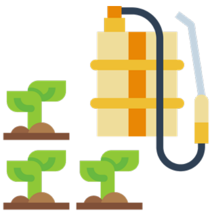
Montogue

Quiz BI107-2



PESTICIDES and PEST MANAGEMENT

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PROBLEMS

Problem 1

Which of the following alternatives ranks the three main types of pesticides – herbicides, insecticides, and fungicides – in order of decreasing market share in the United States?

A) Insecticides > Herbicides > Fungicides
B) Herbicides > Insecticides > Fungicides
C) Herbicides > Fungicides > Insecticides
D) Fungicides > Herbicides > Insecticides

Problem 2

The WHO's *Recommended Classification of Pesticides by Hazard* classifies active pesticide ingredients in five classes according to hazard level, as summarized below.

Class	Definition
Ia	Extremely hazardous
Ib	Highly hazardous
II	Moderately hazardous
III	Slightly hazardous
U	Unlikely to present acute hazard

In the following table, the left column contains four of the ten most commonly used pesticides in the US for the year 2012, while the right column contains the corresponding hazard level per the WHO's classification. What designations should replace letters P to S?

Pesticide	Hazard Level
Glyphosate	**P**
Atrazine	**Q**
Metolachlor-*S*	**R**
2,4-D	**S**

A) P.II; Q.III; R.Ib; S. Ia
B) P.III; Q.II; R.II; S. III
C) P.II; Q.III; R.III; S. II
D) P.III; Q.III; R.III; S.II

Problem 3

The economic injury level (EIL) is defined as the pest density at which the loss caused by the pest equals in value the cost of available control measures. In simpler terms, the EIL can be viewed as the lowest population density that will cause economic damage. Let *C* denote the cost of control measures per production unit, *V* the market value per unit of product, *D* the yield loss per unit number of insects, and *K* the proportionate reduction of insect population caused by control measures. These four variables are related to the EIL by the simple relationship:

(A)	(B)	(C)	(D)
$EIL = \dfrac{CD}{VK}$	$EIL = \dfrac{CDV}{K}$	$EIL = \dfrac{C}{VDK}$	$EIL = \dfrac{VDK}{C}$

▶ Problem 4

Manual application of pesticide with knapsack sprayers is cheap and simple to execute, but must be calibrated with precision if a specific volume application rate is to be achieved. One simple method to estimate the volume application rate is to divide the nozzle output flow rate by the product of swath and walking speed. Accordingly, if an individual is walking at 1 meter per second while spraying a nozzle at a flow rate of 0.3 liters per minute with a swath of 75 cm, the corresponding volume application rate will be, most nearly:

A) 46.5 L/ha
B) 52.5 L/ha
C) 66.7 L/ha
D) 75.7 L/ha

▶ Problem 5

Regarding various aspects of pest management and pesticide science, true or false?

Use of insecticidal chemicals is as ancient as any other pest control technique. It has been reported that the Sumerians apparently applied sulfur for pest control as early as 4500 years ago. Around 3000 years ago, the Chinese were already treating seeds with toxins extracted from plants.
1.( ) Biological control is more recent and was first employed by the Romans in the third century AD. ■ **(A black square indicates the end of a multi-paragraph statement.)**

One of the objectives of insect pest management research since the 1950s has been to improve the decisions made in relation to insecticide application, mainly through the use of action or economic thresholds. Since such thresholds are often inaccurate or difficult to obtain, alternative approaches have been implemented. One of the simplest solutions is to deploy calendar-based applications, applications in which the chemical is applied to the crop at regular intervals without information on the level of pest infestation.
2.( ) Calendar-based applications not only enable the farmer to do away with the need for costly forecasting work, it also proves advantageous in the long term, shielding crops from potential insect pests while offering no risks regarding, say, heightened insecticide resistance or pest resurgence. ■

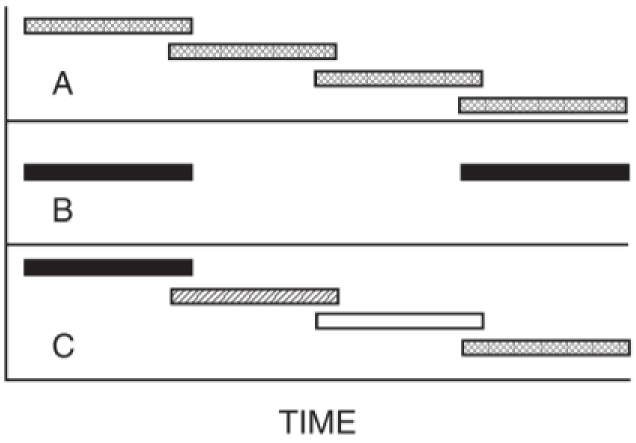
3.( ) Early suppression of weeds is important so that crops can get established without competition. Indeed, the consensus in the literature is that herbicides, if at all necessary, must be applied as early as possible. Use of herbicides close to harvest is unconscionable.

4.( ) One issue of growing importance regarding herbicide use is the development of *cross-resistance*, the development of a single mechanism that provides defense against herbicides of different chemical families. The term *multiple-resistance* has the same meaning.

Selection criteria for biological control agents has long been an area of an active research. After all, Dent's *Insect Pest Management* states that only one out of each seven biological control attempts will prove successful. One hypothesis in biocontrol is the notion that potentially more successful agents for control are to be found among natural enemies that are not normally associated with the target pest. The co-evolution of the parasitoid/predator and its host, the hypothesis goes, has led to an increased resistance in the host with a concomitant decrease in the effect of the natural enemy. Hence, the longer the history of association between a pest insect and its natural enemy, the less effective the enemy will be.
5.( ) While plausible, the hypothesis in question has lost some credence since the 1980s, as analyses of ever growing biocontrol databases have reported results that do not validate the supposed advantages of "new" associations relatively to "old" ones or even run contrary to them. ■

In annual agroecosystems, the availability of a crop varies substantially in time and space. Such a variability is schematically illustrated below, where we represent three hypothetical sequences of crops in a temporal axis; bars with different patterns represent different crops or crop cultivars. At one end of the gradient, as shown in *A*, an agroecosystem may consist of a sequence of a single crop cultivated throughout most or all of the growing season. At the other end of the gradient, as shown in *C*, an agroecosystem may be characterized by a sequence of plantings and harvests of different crops. A third point in this gradient is represented by agroecosystems in which a given crop may occur discontinuously at two different times during a season, as shown in *B*.

6.( ) Implementation of biological control tactics will vary among crop sequences. Of the three temporal sequences, we can surmise that sequence *A* offers the best resource diversity for natural enemies and the least temporal stability for pests to complete their life cycles. ■



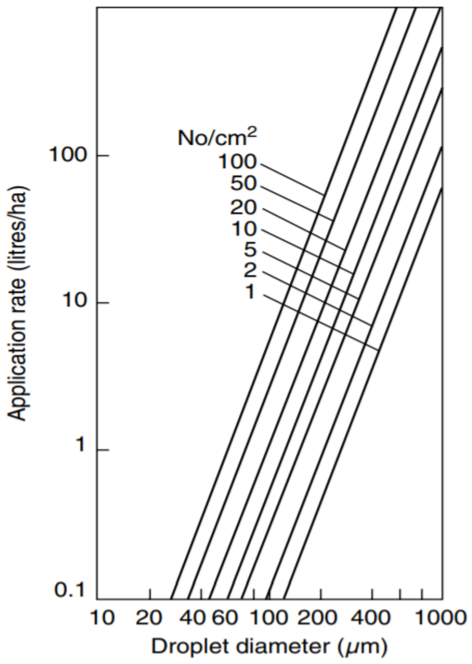
7.( ) The influence of agricultural techniques in pest management goes beyond the effect of succession patterns mentioned in statement 6. Tillage practices also influence insect survival either indirectly by creating inhospitable conditions and by exposing the insects to their natural enemies, or directly by physical damage inflicted during the actual tillage process. Of course, different tillage practices lead to different effects and consideration of these practices should be related with soil parameters such as temperature, humidity, and aeration for a more integrated understanding of the influence of tillage practices on pest management.

8.( ) The first step prior to release of natural enemies in a biocontrol operation is to ensure that the target pest is present in sufficient numbers at an appropriate life stage at different release sites. Use of pesticides is generally independent from biological control and can be implemented concomitantly with the latter without the need for pre-introduction studies on pesticide selectivity.

In situations where natural enemies are absent or population levels are too low to be effective, numbers may be augmented by the release of laboratory-reared insects. Augmentation of natural enemies has been regarded as particularly useful in glasshouses, as these environments usually involve one or a no more than a few pest species, the glasshouse environment can be actively controlled, and the crops grown are of high value and intensively produced.

9.( ) Two prominent examples of successful biocontrol by augmentation of natural enemies in glasshouses are those of *Encarsia formosa* against the whitefly *Trialeurodes vaporariorum* and the use of the phytoseiid mite *Phytoseiulus persimilis* to control the two spotted spider mite *Tetranycus urticae*. ■

With the growing concern about the release of pesticides to the environment, it is increasingly important to optimize the delivery systems used in application of agrochemicals. Instead of wetting the whole target, the optimum droplet size range is selected to increase the proportion of spray which adheres to the target. Generalized indicators of optimum droplet size in terms of collection efficiency on insects and foliage are provided in the following table. Equipped with a suitable droplet size from this table and an estimate of the coverage (droplets/unit area), the volume of spray can be read from the accompanying chart.



Target	Droplet diameter (μm)
Flying insects	10 – 50
Insects of foliage	30 – 50
Foliage	40 – 100
Soil (and avoidance of drift)	> 200

10.( ) For example, in assigning a volume of spray for insects of foliage with the maximum droplet diameter recommended in the table above and a coverage of 100 droplets/cm^2, an application rate greater than 2 liters/ha is read from the chart. ■

11.( ) A key issue in pesticide application sites is the potential "spray-drift" of agrochemicals from the crop in which they were intended to act to neighboring fields and surface waters. To counter this problem, regulators have specified a *no-spray* or *buffer* zone downwind of field boundaries; no agrochemicals are to be applied in such regions. The width of the untreated buffer zone (UBZ), as it is called in the UK, depends on a number of factors, including spray droplet spectra and wind conditions; for simplicity, however, the Local Environmental Risk Assessment for Pesticides (LERAP) has fixed the UBZ at 1 meter for spray methods and equipment that meet LERAP approval. This provision has remained unchanged despite concern over drift of novel agrochemicals and application practices.

12.( ) The so-called trap-crop effect is the notion that the presence of a second crop in the vicinity of a principal crop attracts a pest that would otherwise attack the main crop, thereby providing some degree of protection to the latter. One example of trap-cropping in action occurs when corn, planted in strips in cotton fields, may lure the cotton bollworm away from cotton cultivars.

Starting in the 1940s, DDT and other pesticides were widely introduced in crops all over the US. Dissenting voices were raised with steadily increasing impact – the publication of Rachel Carson's *Silent Spring* in 1962 being the most widely quoted example – but pesticide use enjoyed a relatively regulation-free environment for many years.
13.( ) Two reasons for this posture were, first, the widespread notion among stakeholders, farmers and pesticide manufacturers alike, that pesticides could solve the pest problem indefinitely, and second, the inexistence of ecological issues such as pesticide resistance, the first cases of which were only reported in the 1970s. ■

14.( ) The Huffaker Project and the Consortium for Integrated Pest Management (CIPM) were pioneering efforts in US agricultural practice, established with the goal of introducing a modern, more rational approach to farming including, for instance, lower reliance on pesticide use. Similar initiatives have been put in place by successive governments since the 1970s; in the 1990s, for example, the National IPM Initiative of the Clinton Administration was introduced, projecting, among other goals, the implementation of IPM on 75% of the US crop area by the year 2000. The goal was largely achieved in that, at the dawn of the new century, IPM had been adopted in more than three quarters of cultivated area of the US' most valuable agricultural products, including cotton, soybeans, corn, barley and wheat. Moreover, the Clinton IPM Initiative managed to reduce pesticide use substantially between 1993 and 2000.

Since the 1850s, the Colorado potato beetle (*Leptinotarsa decemlineata*, illustrated to the side) has been associated with several pest outbreaks in potato crops in North America. The CPB migrated to the European mainland at some point in the first quarter of the 20th century and has since become one of the main potato pests in that continent.
15.( ) Since the 1990s, European crop protection authorities have developed various decision support systems to forecast and mitigate CPB outbreaks. One example is SIMLEP, developed by French authorities to counteract potential CPB infestations in the southern part of the country. ■

Legislation has been introduced by the European Parliament aimed at decreasing the use of conventional pesticides in European agriculture. As part of a suite of legislation collectively known as the Thematic Strategy on the Sustainable Use of Pesticides (TSSP), the European Commission has introduced a statutory requirement for crop protection to be conducted under a system of integrated pest management on all farms in the European Union Member States. EU Member States are expected to deliver action plans to encourage IPM and facilitate a decrease in pesticide use.

16.( ) France, the second largest consumer of pesticides in Europe, set forth with the most ambitious goal of all Member States, introducing in 2008 a plan, known as Ecophyto 2018, aimed to decrease pesticide use by 50% over the ten-year period to 2018. In an outcome that surprised few, France has failed miserably in its endeavor, as pesticide use not only failed to reduce by half, it actually *increased* in the ten-year period spanned by the initiative. ■

17.( ) Integrated pest management has also been implemented in India for about as long as anywhere else. However, IPM programs failed to defend India's cotton crops from the ravages caused by *Helicoverpa armigera*, shown below, in the 1990s. Since then, the Indian government has been proactively upgrading its agricultural practices. IPM programs for cotton began to include an insecticide resistance management (IRM) component. Starting in the early 2000s, the Central Institute for Cotton Research (CICR) implemented a comprehensive IRM-based IPM program in ten of the country's main cotton-producing states. The initiative was quite successful, as evidenced by the substantial yield increases relatively to the previous decade and, most importantly, by the substantial reduction in pesticide use on a national scale.

18.( ) Some bacteria have been implemented in pesticide solutions marketed as safer, more environmentally friendly alternatives to traditional agrochemicals. The most successful such solutions employ *Bacillus thuringiensis*, often denoted simply as *Bt*. Various products containing this bacterium have been introduced since the 1940s to control lepidopteran pests of agriculture. Importantly, thousands of *Bt* isolates - grouped into serotypes or subspecies that are characterized by flagellar antigens - have been identified, including *Bt kurstaki* and *Bt israelensis*. These variants of *Bt* have been used in their own insecticide products, and all of them have been shown to affect lepidopteran larvae only; that is, to date none of the *Bt* variants employed in commercial pesticides have biocidal effects on insects of orders other than Lepidoptera.

19.( ) Plant-derived pesticides have been successfully explored as alternatives to synthetic agents in eradicating plant disease pathogens, viruses, nematodes, and snails. However, most plant-derived products have slow action or limited effectiveness when used individually. To circumvent these limitations, it has become common practice to mix several plant products together or even include chemical insecticides in the formulation. Indeed, several commercial solutions of synthetic insecticides or fungicides combined with plant-derived products are already available on the market.

20.( ) Semiochemicals are signaling chemicals that cause changes in the behavior of the organisms involved. Pheromones are semiochemicals that act within the same species. Pheromones were once attempted as alternatives to pesticides in controlling insect pests, but toxicological research conducted in the past 25 years has revealed that some of the candidate sex pheromones for pest control are just as deleterious as the most toxic insecticides when it comes to effects on public health, non-target organisms, and the environment.

21.( ) Entomopathogenic fungi are being actively researched as pest-control agents and can be divided into two categories. Some are facultative saprophytes, which are parasitic microbes that attack living organisms but can also survive on non-living environments. Others are obligate parasites, which require a suitable live host to be viable. It can be said that only obligate parasites such as *Beauveria* sp. and *Metarhizium* sp. are potentially useful for pest-management applications.

22.( ) Adequate disposal of pesticides is an active area of research and policymaking. For containers emptied by manual pouring, experience in various countries has led to the adoption of a triple rinsing technique for comparing different types of container, formulation and alternative rinsing methods. To quote one European example, the Dutch have proposed a rule requiring containers to be rinsed such that less than 0.01% of the original contents remained after rinsing. Unfortunately, investigations have shown that no available triple rinsing technique can meet the 0.01% requirement in question, which calls for either the adoption of a new standard rinsing technique or an increase of the minimum residue level considered adequate after application of one of the rinsing techniques already available.

23.( ) Organophosphates and carbamates include some of the most toxic insecticides in use, and probably still account for the largest number of acute life-threatening exposure episodes worldwide. Importantly, they are the only insecticide group for which there are highly specific antidotes: atropine and the oximes.

Agricultural adjuvants are chemicals added to pesticides and pesticide mixtures in order to aid the operation and improve the effectiveness of the active ingredients. "Good adjuvants make ordinary chemicals do extraordinary things," goes the 1992 textbook *Adjuvants for Agrochemicals*. In toxicity evaluation, it is common practice to examine each of the chemicals in an adjuvant formulation individually for their acute and chronic animal toxicity. However, in usage, adjuvants are complex chemical mixtures. Given the meager data available regarding the toxicity of these complex mixtures, the relative toxicity of adjuvants and other ingredients in pesticide formulations has been and remains understudied.
24.( ) Nevertheless, investigations available at the present time present worrisome results. A 2000 study showed that commercial-grade X-77 and Activate Plus, two alkylphenol ethoxylate adjuvants commonly used in Minnesota, may stimulate MCF-7 breast cancer cell line proliferation. This study in particular examined adjuvant toxicity as an individual compound, but there are studies indicating that use of adjuvants may enhance the toxicity of synthetic formulations. ■

▶ Problem 6

The excerpt below describes the Mills procedure, one of the earliest multiresidue methods for analysis of pesticides in food samples.

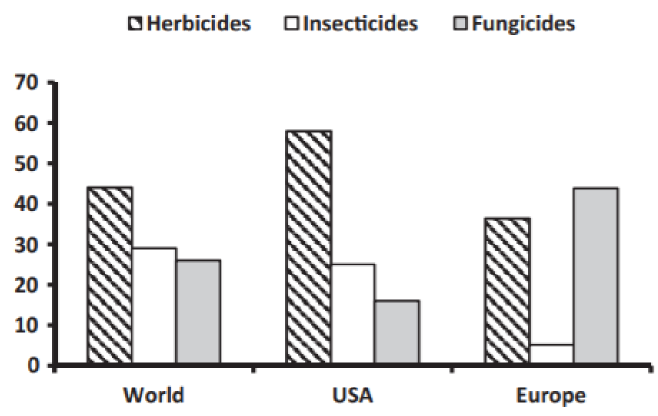
Mills and his colleagues from the US Food and Drug Administration developed one of the earliest multiresidue procedures that involved "stripping" or extracting pesticides from plant foods using ________, partitioning the ________ extract with sodium chloride and petroleum ether, cleanup with Florisil column chromatography, and analysis by gas chromatography-microcoulometric detection. The Mills procedure has been successfully studied, collaborated, and used for the analysis of organochlorine and some nonpolar organophosphorus pesticides in a variety of foods.

Which of the following terms correctly fills the blank spaces above?
A) Acetonitrile
B) Acetone
C) Ethanol
D) Ethyl acetate

SOLUTIONS

P.1 ➡ *Solution*

The following graph illustrates the market shares of the three main types of pesticides in the US and Europe for the year 2016. As can be seen, herbicides dominate the market in the US, whereas fungicides hold a slim lead over herbicides in Europe. Also, insecticide sales are much more expressive in the US than in the old continent.



♦ The correct answer is **B**.

P.2 ➡ *Solution*

Glyphosate is classified under category III (slightly hazardous); atrazine is classified under category III; metolachlor-*S* is classified under category III; 2,4-D is classified under category II (moderately hazardous).

♦ The correct answer is **D**.

P.3 ➡ *Solution*

The correct relationship is given by option (C). Increasing the cost of control measures (variable *C*) increases the injury level at which deployment of pest control becomes warranted. On the other hand, increasing any of product market value (variable *V*), yield loss attributable to a number of insects (variable *D*), or effectiveness of control (variable *K*) will reduce the *EIL*. Some approaches include in the denominator a factor for the injury per insect per production unit. It is noteworthy that, due the presence of a number of intricate variables, economic thresholds such as the *EIL* are very hard to quantify with precision. Some situations are just too complex or, irrespective of the suitability of the data or how good the understanding of damage functions, some pest-crop complexes are just inherently uncertain.

♦ The correct answer is **C**.

P.4 ➡ *Solution*

Applying the formula we were given,

$$\text{Volume Application Rate} = \frac{\text{Output}}{\text{Swath} \times \text{Speed}} = \frac{0.3\,\text{L/min}}{0.75\,\text{m} \times 60\,\text{m/min}} = 0.00667\,\text{L/m}^2$$

or, noting that 1 ha = 10,000 m^2,

$$\text{Volume Application Rate} = \boxed{66.7\,\text{L/ha}}$$

♦ The correct answer is **C**.

P.5 ➡ *Solution*

1. False. Walter (see reference below) states that biological control was first used in China by the third century AD, where people bought colonies of tailor ants (*Oecophylla smaragdina*) to place in their citrus trees, so the ants would prey on herbivorous insects and reduce damage. Walter goes on to say that the Chinese also pioneered early pest-control policy, as laws for control of locusts were promulgated by the twelfth century.

Reference: Walter (2003).

2. False. Scheduled applications may be beneficial in the short term, but Dent (see reference below) notes that they may be disastrous when deployed for a long time, contributing to development of insecticide resistance, bouts of secondary pest resurgence, and destruction of natural-enemy populations. Chronic health effects on farmers due to overexposure to insecticides may also be a greater issue when the products are applied in frequent and rapidly successive fashion.

Reference: Dent (2000).

3. False. Matthews *et al.* (see reference below) argue that late-season herbicide application may be beneficial even if no increase in yield is obtained, because harvesting is easier in the absence of weeds and the harvested produce is cleaner. Those authors also argue that in some areas of erratic rainfall farmers may prefer to wait as long as possible before investing in chemical weed control, as insufficient rain will depress crop yields.

Reference: Matthews *et al.* (2014).

4. False. Cross-resistance indeed refers to a weed's development of resistance, using the same mechanism, to herbicides of different chemical nature. The term *multiple-resistance*, in turn, refers to the occurrence in a single weed population of more than one defense mechanism against a given compound, or the resistance to several compounds due to expressing multiple resistance mechanisms. These are general scientific terms that may not apply to weeds only; Gullan and Cranston (see reference below), for example, use the same phrases to discuss insecticide resistance.

Reference: Gullan and Cranston (2014).

5. True. Dent (see reference below) indeed reports that analyses of different databases since the 1980s have produced conflicting results regarding this hypothesis. One analysis of BIOCAT, a database of the International Institute of Biological Control, found no significant difference between new and old associations for the number of introductions that provided complete, partial, or no successes. In another analysis of the same database, one worker actually found that for all realistic methods of analysis old associations were actually associated with a significantly *higher* probability of establishment and success – the very contrary of the hypothesis in question. As a final note, Dent warns that database analyses should be handled with care because the datasets from which they derive are often unreliable and, even when accurate, should not be unduly extrapolated to produce universal biocontrol selection criteria.

Reference: Dent (2000).

6. False. Obviously, an agroecosystem that maintains the same crop uninterruptedly for the entire growing season, as in the case of *A*, will offer little resource diversity for natural enemies and endow pests with the stability they need to complete their lifecycles. It follows that the best sequence for biological pest control is *C*, not *A*.

Reference: Altieri and Nicholls (2004).

7. True. Comparisons of the results obtained from different tillage practices may shed some light on the way in which infestation is reduced. Dent (see reference below) reports a study in which emergence of the sunflower seed weevil (*Smicronyx fulvus*) was reduced by 29 – 56% with the use of a mould-board plough which turns over the soil, effectively burying the late larval and pupal stages. However, this covering effect was thought to be only partially responsible for the increased mortality, as a chisel plough resulted in a reduced emergence of between 36 and 39% without moving the larvae substantially deeper in the soil profile. Thus, it was concluded that variables such as aeration, soil temperature and drying and physical damage resulting from tillage were also important contributory factors.

References: Dent (2000).

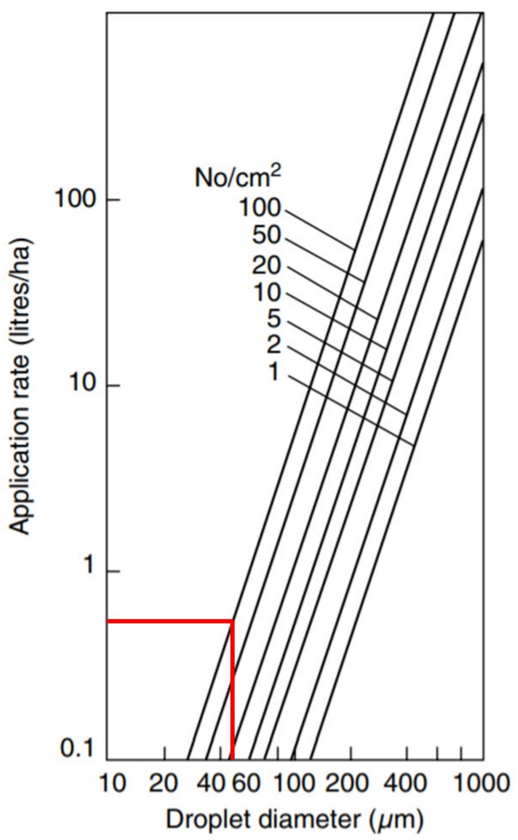
8. False. Much to the contrary, Dent (see reference below) advocates that if insecticides have to be used in the vicinity of a crop area subjected to biocontrol, pre-introduction studies should be executed including work on pesticide selectivity. Use of agrochemicals should be postponed in the immediate area after natural enemy release.

Reference: Dent (2000).

9. True. Dent (see reference below) indeed quotes these two examples of successful augmentation of natural enemies. The mite *P. persimilis*, in particular, has been introduced in control of *T. urticae* attacking tomato, cucumber, egg plants, sweet peppers, and gerbera crops.

Reference: Dent (2000).

10. False. The maximum droplet diameter recommended for insects of foliage is 50 μm. Entering such a diameter and a droplet coverage of 100 cm^{-2} into the chart, the recommended application rate is read to be somewhat below 1 liter/ha (say, 0.8 L/ha), as indicated below.



11. False. While it is true that LERAP has opted for a simplified, 1-meter UBZ requirement, Matthews *et al.* (see reference below) say that concern about drift of certain pesticides has led to adoption of wider buffer zones; a simple rundown of the UK's buffer zone system can be found in Bayer's UK website (see reference below).

Reference: Matthews *et al.* (2014); Bayer.co.uk (https://cropscience.bayer.co.uk/blog/articles/2018/03/the-ultimate-guide-to-buffer-zones/).

12. True. Luring cotton bollworm away from cotton by planting corn is but one example of trap crop. Altieri and Nicholls (see reference below) mention that sorghum acts as an effective trap for the stem borer *Chilo partellus* in India. Trap crops have also been used to control jassids in cotton. In Central America, use of a trap crop of beans reduced damage to tomato plants from the armyworm *Spodoptera sunia* to nearly zero.

Reference: Altieri and Nicholls (2004).

13. True. The two points that supposedly underpin the widespread acceptance of pesticides are debatable. For one, the notion that pesticide use is a temporary solution at best had been already posed by H.S. Smith, a pioneer of American pest control, as early as the 1940s. Further, encounters with pesticide resistance actually predate the seventies; one early example is the development of resistance to chlorinated hydrocarbons in boll weevils, a major pest in the southern USA, as documented in the early 1960s. While farmers and agrochemical manufacturers were aware of such early pockets of pest resistance and resurgence, the natural reaction in the "pesticide-centric" mentality of the time was to simply switch to a different pesticide. The answer to the boll weevil crisis, for example, was to change to calcium arsenate in some cases, or to organophosphates, carbamates, and various mixtures in others.

Reference: Walter (2003).

14. False. The statement errs by mentioning that pesticide use decreased from 1993 to 2000; despite the IPM initiative in question and the introduction of the first GM crops, pesticide use estimated for all agricultural crops actually *increased* from 401 million kg in 1992 to 430 million kg in 2000. Also false is the fact that by 2000 IPM had reached 75% of the American cultivars mentioned in the statement. The table below, taken from the USDA, lists the estimated percent area in which IPM practices were adopted by the year 2000; as can be seen, the 75% goal established by the Clinton administration was not attained for products such as barley, wheat, and alfafa.

Crop	% Area estimated by USDA
Cotton	86
Fruits and nuts	62
Vegetables	86
Soybeans	78

Corn	76
Barley	71
Wheat	65
Alfafa-hay	40
All other crops and pastures	63

15. False. SIMLEP is a DSS actually conceived by the Central Institution for Decision Support Systems in Crop Protection in Germany (German acronym ZEPP). Founded in 1997, ZEPP was instituted to collect and examine existing predictive and simulation models for important agricultural and horticultural pests and diseases and to develop these models for practical use. One of the most successful undertakings of ZEPP has been the development of the SIMLEP decision support system. SIMLEP consists of two models, SIMLEP1-Start for the prediction of the first occurrence of a beetle in a region, and SIMLEP3 for the simulation of further development in potato fields. Racca *et al.* (see reference below) describe the model in greater detail.

Reference: Racca *et al.* (*in* Abrol, 2014).

16. True. *Science* (see reference below) notes that Ecophyto 18 indeed failed, by far, to achieve its goal, as national pesticide use has in fact increased 12% in the decade spanning the beginning of the initiative to 2018. Nonetheless, some hail effects of Ecophyto 18 as indicators of positive outcomes; after all, the project has inspired technological and social changes as farmers have begun mixing crops, planting new varieties, and employing data analysis systems that help identify the best times to spray pesticides. Furthermore, the French government has not given up and recently proposed a new initiative, called Ecophyto 2+.

Reference: *Science* (https://www.sciencemag.org/news/2018/10/france-s-decade-old-effort-slash-pesticide-use-failed-will-new-attempt-succeed).

17. True. Peshin and Zhang (see reference below) report that the savings achieved by India's IRM-IPM cotton program in the early 2000s are estimated at US$ 39.5 million, of which $23.0 million stemmed from yield increases and another $16.5 million from savings in pesticides. Moreover, total pesticide use in Indian agriculture has declined from 75,418 tons in 1988 – 1989 to 39,773 tons in 2005 -2006. It is worth noting that the period between these two datapoints also spans the 2002 introduction of *Bt* cotton, which may have contributed to upticks in yield and reduction in pesticide use to a considerable extent.

Reference: Peshin and Zhang, *in* Pimentel and Peshin (2017).

18. False. Well known subspecies such as *Bt kurstaki* and *Bt azaiwai* indeed mainly affect lepidopterans, but other variants do show action against different orders: *Bt isralensis* is effective against dipteran larvae, while *Bt tenebrionis* is effective against coleopteran larvae.

19. False. Gahukar (see reference below) notes that, indeed, it is common practice to mix several plant products together, along with chemical insecticides or fungicides (deltamethrin, endosulfan, cypermethrin, carbendazim), biopesticides (*Bt*, *Beauveria bassiana*), nuclear polyhedrosis virus (NPV), or adjuvants (teepol, soap water). Several pesticide companies have also formulated commercial products containing 2 – 3 plant products.

Reference: Gahukar (*in* Abrol, 2014)

20. False. This overstuffed statement is entirely made-up. In a review, Witzgall *et al.* (see reference below) noted that regulators in several countries consider pheromones to be safe. Many pheromones have been registered for pest control, and there is no evidence of adverse effects on public health, non-target organisms, or the environment. Pheromones are applied in slow release formulations, which results in low exposure; residues of lepidopteran pheromones in pheromone-treated food crops have not been detected.

Reference: Witzgall (2010).

21. False. The statement errs twice. Firstly, facultative saprophytes are in fact promising candidates for pest management in that, as Skinner *et al.* (see reference below) point out, these microbes can be easily mass-produced on artificial media or a solid substrate for commercialization. Secondly, *Beauveria* sp. and *Metarhizium* sp. are genera of mostly facultative saprophytes, not parasitic fungi.

Reference: Skinner *et al.* (*in* Abrol, 2014).

22. False. In contrast to what is said in the statement, studies have shown that triple rinsing techniques can in fact give residue levels that comfortably meet the 0.01% requirement. Miller (see reference below) quotes a reference that examined the measured residues in a 5.0-liter container filled with a commercial formulation that were rinsed in different ways; manual triple rinsing gave the lowest residue levels at 8×10^{-4}% of the original contents of the container.

Reference: Miller (*in* Wilson, 2003).

23. True. Indeed, Richter (see reference below) notes that organophosphates and carbamates likely account for most acute life-threatening episodes involving pesticides. (Many readers would point to organochlorines, especially DDT, as equally dangerous, but these often manifest poisonous effects more slowly, with symptoms such as seizures occurring as late as 48 h after exposure.) They are also the only insecticide groups for which there exist specific antidotes: atropine sulfate, which in emergency treatment is administered intravenously or intramuscularly in conjunction with oxygenation; and oximes (Pralidoxime – Protopam, 2-PAM), which reactivate cholinesterase, the enzyme inhibited by the insecticides in question.

Reference: Richter (*in* Pimentel, 2002).

24. Probably. The one study I could get my hands on was Coalova *et al.* (see reference below). Those authors worked with glyphosate, which is minimally toxic to humans but happens to be one of the most used insecticides in Argentina (and the world, for that matter). All agrochemicals assayed were found to induce dose- and time-dependent cytotoxicity. Importantly, adjuvant addition to one of the formulations tested by those workers showed higher cytotoxicity than the formulation alone, which agrees with what is said in our statement.

Reference: Coalova, de Molina, and Chaufan (2014).

P.6 ➡ *Solution*

The Mills procedure, one of the earlist multiresidue methods (MRMs), relied on acetonitrile as the organic solvent of choice. More recent tests employ different extraction solvents; the original Luke method, for example, uses acetone.

♦ The correct answer is **A**.

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