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MODEL TO DESCRIBE A SMALL OUT-BREAK OF DAMAGED GRAINS DUE TO INSECTS

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Abstract

This paper is concerned with a small outbreak of a percentage of damaged grains in a large susceptible grain. The linear differential equation is formed with the help of same assumptions. The analysis of the result reveals that percentage of damage of grains increases with increasing number of insect population.
Keywords : Small out break ,percentage of damage grains. Insect population etc.

Introduction

The present model describes a small out-break of a percentage of damaged grains. I assume that a pair or many insects arrive in vacant area and start the out-break (Mathew *et al.*, 2012). To prevent the situation in which the out break gets out of control and eventually involves all susceptible in the population. For this we lay down certain assumptions as follows:

1. The conditions are sufficiently unfavourable that the outbreak never becomes large.

2. For conciseness, we consider that a single insect damages the grains at first rapidly.

This Process (mode) best describes the out-break after the introduction conditions (factors).

We suppose that when the model begins there are k insects in the ecosystem. Each of these insects produces zero or one or two or additional insects (Ashamo *et al.*, 2018) .If we perceive the original infectives as forming this zeroth generation of the insects, then the amount of grains damaged by the first generation of the insects, then the amount of grains damaged by the first generation and so forth for subsequent generations (Singh *et al.*, 2017). The outbreak ends once all of curves of insects perish or total grains are damaged. The typical small out-break has been presented by the fig.

The vertices of the graph represent insects and the edge represent the paths of insects from the source to the recipient (Prakash *et al.*, 2011).

Materials and Methods

Insect attack probability- The first problem to be considered is the attack rate of the insect. The simplest reasonable assumption is that each insect for the attack (till damage) length of time t, where t is a continuous random variable (Jian *et al.*, 2012).

Let x(t) be an integer valued random variable which serve as counter thus each time an 'event' occur x(t) as augmented by one .let us suppose that at t = 0 the counter is set to zero so

$$X(0) = 0$$

Let us suppose that insect occur independently at random i.e. we suppose that time is subdivided into small intervals of length Δt. The probability that one insect occurs in a particular intervals of Δt is $m\Delta t$, where m is any parameter. Because we make Δt as small as we wish. Is Thus the probability that no insect occurs in an interval of length Δt is $(1-m\Delta t)$. In general, all non overlapping time interval are independent of one another.

We will now calculate the probability density for the random variable x(t) .

Let Prob $(x(t) = n) = P_n(t)$, n = 0, 1, 2, 3 ...(1)

We wish to calculate Pn $(t + \Delta t)$, n = 1, 2, 3..... . There are two mutually exclusive situations at time t, which may be mentioned as follows:

1. At time t, x(t) = n – 1 with probability $P_{n-1}(t)$ and during the next time interval of length Δt an event occurs with probability $m\Delta t$.
2. At time t, x(t) = n with probability $P_n(t)$ and during the next time interval of length Δt no event occurs with probability $1-m\Delta t$.

Since above two cases are mutually exclusive they may be arranged in the form

$$Pn(t+\Delta t) = P_n(t)\, m\Delta t + P_n(t)(1-m\Delta t)$$

Which simplifies to yield,

$(P{\downarrow}n\,(t+\Delta t) - P{\downarrow}n\,(t))/\ \Delta t = m[P{\downarrow}\,(n-1)\,(t) - P{\downarrow}n\,(t)]$, under limiting conditions $\Delta t \to 0$

$$([d(P){\downarrow}n(t)))\ /\ dt = m\,[P{\downarrow}\,(n-1)\,(t) - P{\downarrow}n\,(t)]\quad n = 1,2,3 \ldots(2)$$

If we take n = 0, then above equation reduces to

$$\frac{[d(P)n(t)]}{dt} = -mP_0(t) \qquad \ldots(3)$$

Since x(0) = 0 , it follows that $P_0(0) = 1$ and $P_n(0) = 1$, n = 1, 2, 3.......

Solving the equation (3) for $P_0(t)$ with its initial condition we arrive at

$$P_n(t) = e^{-mt} \qquad \ldots(4)$$

Again if we let n = 1 in equation (2) and substitute P_n (t) from (3) it is fairly easy to get

$$\frac{[d(P)_1(t)]}{dt} + mP_1(t) = me^{-mt} \quad ...(5)$$

This is first order linear differential equation with constant coefficient, so integrating factor i.e IF = e^{mt}

Hence this can be written as $[d(P)_1 (t) e^{-mt}] = mdt$

On integrating this equation with initial condition P_1 (0) = 0 we get P_1 (t) = mt e^{-mt}

By adopting the parallel procedure for n =1 ,it inductively leads to the general result

P↓(n) (t) = ([(mt)↑ne↑ (–mt)) / (n!), n = 0, 1, 2, 3 ... (6)

This is well known time dependent Poisson density function .which describes the probability that by time t ,exactly n insects occurred randomly.

Let us consider that the length of time t spends by insect for damaging the grains. Thus we have proba (grain damage for time t) = μe^{-mt} ...(7)

During the time that the damage of grains remains continuous, the insect are being attacked on susceptible grains .we assume that environment is favourable for attack of insect to susceptible grains take place independently at random such that the average number of grains are damaged by one insect per unit time is m.

Again number of damaging j grains, given that the damaging period lasts for t units of time P(j/t) is given by

$$P = \left(\frac{j}{t}\right)\left[\frac{(mt)^j}{j!}\right]e^{-mt} \quad ...(8)$$

To eliminate the conditioning in P(j/t) make use of assumption that the length of infection period is exponentially distributed with parameter j. Thus the probability p, that one insect damage j grains during it is damage period is

$$P_1 = \int_0^\infty \frac{(mt)^j}{j!} e^{-mt}\mu e^{-\mu t}dt = \left[\frac{\mu}{m+\mu}\right]\left[\frac{m}{m+\mu}\right]^j \quad ...(9)$$

We will assume throughout the development of the model that that the number of the grains damaged by one particular victim of the insect is independent of the number damaged by any other victim. We consider the ith damaged grain, and let Q_i be an integer valued random variable which counts the number of cases of the grains which are damaged by the ith insect. Since Q_i is distributed according to P_i the expected number of new cases, E (Q) is given by

$$E(Q) = \theta\sum_0^\infty jP_i$$

$$E(Q) = \frac{m}{\mu},\ j=0 \quad ...(10)$$

It was stated in the introduction to this chapter that we imagine conditions to be unfavourable for a major epidemic; thus the insect outbreak dies out quickly. Let us determine what this means in terms of our variables.

Let us consider that one particular infective in the zeroth generation (grain).Let d_n be the probability that the portion outbreak developing from the chosen infective has died out by the nth generation .We assume that chosen infectives in the zeroth (grains)generation called A damage the jth grains (called B) (Tripathi *et al.*, 2016). We could view each B as the head of a curve of the damaged grains. If the A's portion of the outbreak is to have ended by the $(n+1)^{th}$ grains, then the portion from each of the j B's must independently have ended after n additional grains of the insect have occurred. This occurred with probability equal to $[dn]^j$. But since, we do not know j, we must do an average over all choices of j, weighted of P_j, the probability that A had B_j. Hence we have

$$dn+1 = \sum_{j=0}^{\infty} P_j[d_n]^j = f(d_n) \quad ...(11)$$

Now, we identify $f(d_n)$ as the probability generating function for this discrete density P_j

The expression found is a recurrence relation for the sequence $\{d_0, d_1, ... d_n, d_{n+1}\}$. Then we can make several observations.

1. Since d_n is the probability that a line of the damaging grains ended by the nth grain i.e.

   $0 \le d_0 \le d_1 \le d_2 \le ... . \le d_n \le d_{n+1} \le ... ... \le 1$

2. Since the A of line certainly has the disease, $d_0 = P_0$
3. The sequence must approach a limit since it can never exceed unity in numerical values, so

   $$\lim_{n\to\infty} d_n \to d \le 1 \quad ...(12)$$

Results and Discussion

The third observation allows us to rewrite the recurrence relation as a non-recursive equation ford ,the probability of ultimate extinction of one line of the damaged grain d = f(d).

This result, which is true for any insect transmission probability. Now equating d to the probability generating function for the geometric density determined earlier yields

$$d = \frac{1}{\left\{1+(1-d)\frac{m}{\mu}\right\}} \quad ...(13)$$

Solving for d provides $d = \begin{cases} \frac{\mu}{m}, & \text{if } m \ge \mu \\ 1, & \text{if } m < \mu \end{cases}$

The two choice arise as the roots of a quadratic equation. The proper choice is always the smaller root which turns out to be one satisfying $0 \le d \le 1$.

Finally, the probability that all of the branches shining damaged grains started by the K individuals is the zeroth grains will independently die out given by

$$\text{Prob [outbreak ends]} = d^k = \begin{cases} \left(\frac{\mu}{m}\right)^k, & \text{if } m \ge \mu \\ 1, & \text{if } m < \mu \end{cases} \quad ...(14)$$

Thus, the condition for the out break to end with certainty is that $\lambda < \mu$. This is equal to expected number of B's per A's θ, satisfying

$$\theta = \frac{m}{\mu} < 1 \qquad ...(15)$$

Next recall that the insects damage the grain independently and that the number of grain damaged by the ith insect Q_i is distributed with the same geometric pattern as before so we have

$$\text{Prob } (Q_{i=j}) = P_j \text{ and } E(Q_i) = \theta \qquad ...(16)$$

Now we define $W_\lambda = \sum_{I=1}^{W_{\lambda-1}} Q_i$ ...(17)

The expected value of W_λ follows easily from the conditional expectation given $W_{\lambda-1}$. Hence

$$E(W_l\lambda) = E[E(W_l\lambda / W_l(\lambda-1))] = \varepsilon\left[E\left(E_\downarrow(l=1)^\uparrow(W_\downarrow(\lambda-1)) \approx Q_\downarrow i / W_\downarrow(\lambda-1)\right)\right] \qquad ...(18)$$

As the expected values of a sum equals the sum of the expected values. We have

$$E(W_\downarrow\lambda) = E\left|\sum{}_\downarrow(l=1)^\uparrow(W_\downarrow(\lambda-1)) \approx ([E(Q)]_\downarrow i) / W_\downarrow(\lambda-1)\right| \qquad ...(19)$$

$$E(W_\lambda) = E[\theta W_{K-1}] \qquad ...(20)$$

Since θ is a constant above equation can be written as $E(W_j) = \theta E(W_{j=1})$

Solving above equation with the condition $E(W_\theta) = 1$, because the model counts the number of insect who damaged from a single insect in the zeroth damaged generation. Thus

$$E(W_\lambda) = \theta^\lambda, \quad \lambda = 0,1,2,3\dots\dots\dots$$

If we add up the expected number of insects in all successive generation then total number of insects in the zeroth generation, N is given by

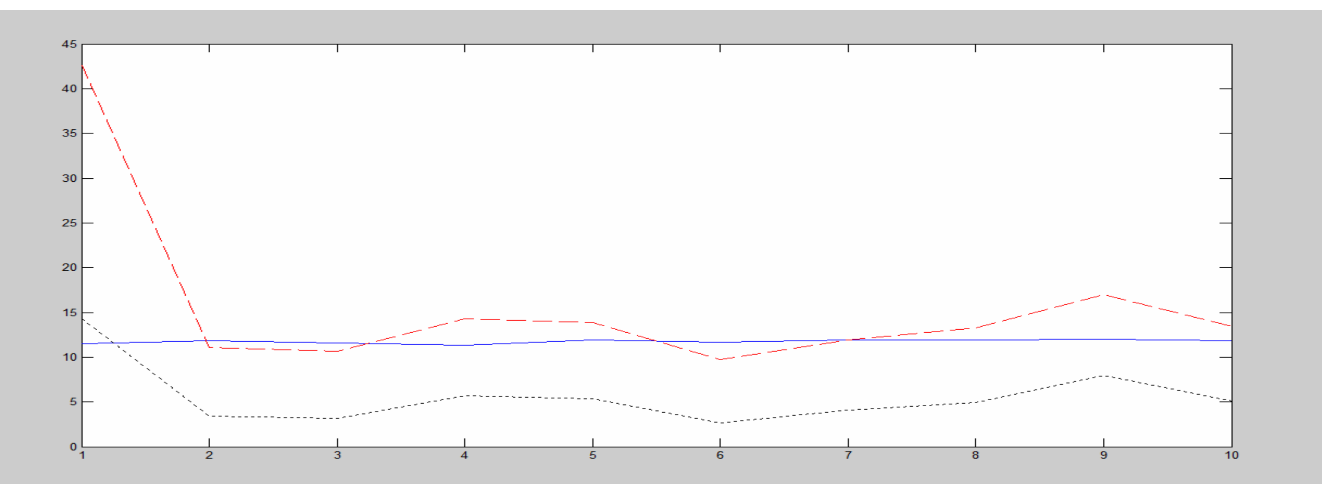
$$N = k\sum_{\lambda=0}^{\infty}\theta^\lambda = \frac{k}{1-\theta}$$

Using equation (15) in the above, we arrive at

$$N = \left(\frac{k}{1 = \frac{m}{\mu}}\right) = \frac{k\mu}{\mu - m} \qquad ...(21)$$

We has performed an experiment on different verities of paddy under storage condition, the environmental factors i.e R.H temperature and moisture content was maintained was maintained 75 % with KOH for two weeks and moisture content varied from 11.3 to 12.0 percent after two weeks. In this experiment 400 healthy grains were taken in the glass specimen tubes conserved with muslin cloth and ten pairs of adult moths (*S. cerealella Oliver*) of same age were introduced in each specimen tube .The experiment was carried out at a constant temperature of 27± 1ºC for three months (Pandey *et al.*, 2015). At the end of experiments, Percentage of damaged grains, total population of insects and loss of weight was recorded. Data regarding average insect population and percentage of damaged grains are presented in the table below:

Sr No	Moisture content of seed %	Average insect population	% damaged grains
1	11.50	42.64	14.25
2	11.82	11.07	3.41
3	11.55	10.64	3.17
4	11.30	14.26	5.67
5	11.95	13.84	5.33
6	11.63	9.75	2.67
7	11.90	11.95	4.08
8	11.90	13.27	4.92
9	12.00	16.94	8.00
10	11.88	13.43	5.08



Graph of Table -1

Conclusion

We conclude from this model with experimental data and plotted graph that the percentage damage of grains increases with increasing number of insect population. Here we take initially k = 10 pairs, then equation (21) becomes

$$N = \frac{10\mu}{\mu - m}$$

The quantity N is the one we ordinarily wish to know, its instructive to work the probability that exactly n_k insects are involved in the disease out-break. The model analyses that the greater the no of insects in the store are damaging the large amount of grains. This model lays emphasis on the role of insect infestation during storage, in reducing the out break of damaged grains due to insects in various conditions, which proves its efficiency in itself.

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