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Quantitative determination of loss in yield of black pepper (*Piper nigrum* L.) in Kannur District (Kerala, India)

P V PRABHAKARAN

Kerala Agricultural University
Thrissur - 680 654, Kerala, India.

Abstract

A method for estimation of yield loss (including stand loss) in black pepper (*Piper nigrum*) due to various factors was developed. The method was applied for estimating the loss in yield of black pepper due to incidence of pests, diseases and drought in Kannur District (Kerala, India) during 1989-1992. The average annual yield loss in black pepper due to these factors was around 33 per cent. The major contributors towards stand loss, was foot rot caused by *Phythopthora capsici* contributing to 9 per cent loss followed by drought. Among the causal factors contributing to yield loss the most disastrous was incidence of pollu beetle (*Longitarsus nigripennis*) which accounted for about 13 per cent loss followed by fungal pollu caused by *Colletotrichum gleosporioides.* The percentage avoidable loss in yield by adopting plant protection measures was estimated to be around 43 per cent.

Key words : black pepper, *Piper nigrum*, statistical model, yield loss.

Introduction

Though India is the second largest producer of black pepper (*Piper nigrum* L.) in the world next to Indonesia, the productivity of the crop in the country is very low due to infestation by numerous pests and diseases. Quantitative determination of crop loss is useful in setting priorities for plant protection measures and for commercial horticulture. The available information on this aspect are generally specific to particular pests, diseases or localities and do not provide a comprehensive account of the total loss. Samraj & Jose (1966), Nambiar & Sarma (1976) and Balakrishnan *et al.* (1986) attempted to quantify the loss in black pepper yield due to the incidence of foot rot disease caused by *Phytophthora capsici.* Abraham (1959) and Premkumar (1980) reported the extent of yield loss in black pepper caused by pollu beetle (*Longitarsus nigripennis*). However no attempt has been made so far to obtain a comprehensive account of yield loss in black pepper using multivariate methods taking into account all major diseases and pests and drought generated from periodic surveys. The present study was therefore undertaken to develop a statistical model for assessing the loss in yield of black pepper caused by the incidence of pests, diseases and drought.

Materials and methods

A random sample of 384 plots belonging to 96 holdings in 16 villages of Kannur District (Kerala, India) constituted the material for the study. The sample was selected as in a three stage random sampling design with villages, fields and plots of four standards of black pepper vines each were the units of the first, second and third stages of the sampling process. For the estimation of avoidable loss, a group of nine farmers who were not users of plant protection chemicals and another group of nine farmers from the same village who were users of plant protection chemicals were also selected.

The major diseases of the crop in the survey tract were foot rot caused by *P. capsici*, slow wilt and fungal pollu caused by *Colletotrichum gloeosporioides*. The major pests affecting the crop were pollu beetle (*L. nigripennis*) and leaf gall thrips (*Liothrips karnyi*). In addition to these there were several minor diseases and pests. The total number of vines that died due to foot rot, slow wilt and drought in each field was recorded at fortnightly intervals for three years from April 1989 to April 1992. Other biometric observations were also recorded at fortnightly intervals during the period. A sample quadrat of 0.5 m x 0.5 m size was randomly located at breast height in each selected standard for taking periodic observations on leaf, spike and berry characters. A record of spikes shed due to various causal factors at fortnightly intervals was also taken from an identified plant in each plot. The severity of the incidence of diseases and pests was measured by using severity indices based on observations generated through plant, leaf or spike sampling at different stages of plant growth. A suitable score chart was prepared for this purpose in collaboration with Pepper Research Station, Panniyur. The intensity of attack of slow wilt was quantified through the Slow Wilt Index (SWI). Severity of leaf incidence of foot rot was measured through Spotted Black Index (SBI). Other indices like Spotted Red Index (SRI), Spotted *Collectotrichum* Index (SCI) and Margin Folding Index (MFI) were also developed to quantify the incidence of algal leaf spot disease, fungal pollu disease and leaf gall thrips.

The Slow Wilt Index (SWI) was calculated as:

SWI $= \frac{\Sigma x_i f_i}{n}$, $n = \Sigma f_i$ where SWI is the Slow Wilt Index, x_i is the score of the plant based on the categorical classification and 'n' is the sample size. The different categories and the scores assigned to each category to build up SWI are as follows:

Category	Description	Score
A	No disease	0
B	Yellowing of leaf	1
C	Yellowing and drooping of leaf	2
D	Defoliation	3
E	Shedding of branches	4
F	Death of vine	5

Other indices used for the study were generated from sampling of leaves at breast height of the canopy of each sampled plant. The distribution of scores is as follows:

Category	Affected number of leaves	Score
No infestation	0	0
Mild	4	1
Semi - medium	4 to 8	2
Medium	8 to 12	3
Severe	12 to 16	4
Very severe	above 16	5

By adding the plant-wise scores of the disease/pest attack and dividing by number of plants (n=4) an index of severity of infestation was obtained.

The procedure suggested by Khosla (1977) was suitably modified and used for the estimation of crop loss. A multiple linear regression equation of yield (Y) on the incidence of pests and diseases (X_i) was worked out between plots within fields as, $Y = Y_0 + \Sigma b_i X_i$ where $Y_0 = \overline{Y} - \Sigma b_i \overline{X}_i$, Y is the general mean yield, b_i's are partial regression coefficients of yield on X_i's incidence and $\overline{X}_i$ the mean of X_i incidences. For obtaining partial yield loss the above regression equation was converted to percentage yield as :

$$Y' = 100 + \Sigma b_i' X_i \text{ where } b_i' = \frac{b_i x100}{Y_0}, Y' = \frac{Yx100}{Y_0}$$

Variance of $b_i'$is given by :

$$V(b_i') = b_i'^2\{\sigma^2 c_{ii}/b_i^2 + \hat{V}(y_o)/y_o^2 - 2\ \hat{cov}\ (b_i', y_0/biy_0\}$$

where c_{ii} refers to the i^{th} diagonal element of the inverse of SS-SP matrix of X_i incidences and σ^2 is the estimated error mean square.

The expected percentage yield loss due to the individual mean incidence $\overline{X}_i$ given by Loss $(l_i) = \overline{X}_i \times b_i'$ and its approximate variance is :

$$V(l_i) = \overline{X}_i^2\ \hat{V}(b_i') + b_i'^2\ \hat{V}(X_i) - \hat{V}(b_i')\ \hat{V}(\overline{X}_i)$$

The percentage overall (partial) loss $= L = \sum_{i=1}^{k} l_i = \sum_{i=1}^{k} \overline{X}_i b_i$ where 'k' is the number of causal factors considered for the estimation of loss. $V(L) = \sum_{i=1}^{k} V(l_i)$ where V(L) is the estimated variance of the total estimated loss.

In black pepper, the overall yield loss of a population of plants arises from two components, (l) Direct loss due to death of plants, and (2) Indirect or partial loss due to yield reduction.

Let f_i (i = 1, 2, ...k) denote the frequency of stand loss due to i^{th} causal factor. Then total stand loss is given by $T = \sum_{i=1}^{k} f_i$. The proportion of plants lost by death due to the i^{th} causal factor is $P_i = f_i/N$. The total proportionate loss due to various causal factors is P = T/N where N is the total population of the plants in the sampled holdings. If L denotes the total percentage yield loss due to incidence of pests and diseases, the expected yield from the surviving plants is $N_i(1+L/100)\ Y_0$ where N_i is the estimated number of surviving plants in the field and Y_0 the intercept in the regression equation. Now N_1=N(1-P), let q = (1+L/100). Then the expected yield from an initial population of N plants after one year will be $(N-N_1) \times 0 + N_1 q Y_0$. If none of the plants were affected by diseases or pests (If there is no partial yield loss) the probable yield from the N plants is NY_0. Overall percentage yield

$$\text{loss} = \frac{(NY_0 - N_1 q Y_0)100}{NY_0} = 100\ [1-(1-P)\ q]$$

where P = percentage of plants died due to 1^{th} causal factor and q = yield loss due to wilt.

The average annual percentage yield loss for the period was worked out by taking the geometric mean of the annual estimates. Percentage Avoidable Loss (PAL) was estimated as:

$$PAL = \frac{\overline{Y}_p - \overline{Y}_{up}}{Y_p} \times 100$$

where $\frac{Y_p}{Y_p}$ = Mean yield of green pepper determined from protected plots and $\overline{Y}_{up}$ = Mean yield of green pepper determined from unprotected plots.

Results and discussion

Regression equations were developed at fortnightly intervals to identify significant causal factors at each period and these were further used at a later stage to build up comprehensive prediction models. A subset of predictors which would really contribute to yield loss was identified through step-wise regression analysis. The estimates of partial yield loss based on the results of the step-wise regression analysis during the three year period are given in Table 1.

Table 1. Estimates of expected partial yield loss in black pepper due to various causal factors and their standard errors (1989-90 to 1991-92)

1989-90		1990-91		1991-92	
Variable	Per cent yield loss	Variable	Per cent yield loss	Variable	Per cent yield loss
SWI (DF)	-1.51(0.74)	SWI(D)	0.41(1.16)	PSPB(NF)	-13.72(2.53)
PSPB(DS)	-5.51(1.15)	PSPB(DF)	-11.07(5.08)	TSS	-5.84 (3.12)
PBPB(DF)	-6.65(1.54)	PUPB(DS)	-5.48(3.74)	SWI(D)	-0.72(0.72)
		SBI(A)	-2.01(1.21)	SCI(A)	-0.07(0.19)
		SCI(S)	-4.81(1.98)	PSPB(NS)	-11.56(2.81)
				SBI(A)	-0.07(0.12)
Total loss	-13.67(2.22)		-22.96(7.14)		-31.98(4.96)
R^2(%)	19.3**		8.5**		25.3**

SWI = Slow wilt index

PBPB = Percentage of berries affected by pollu beetle

SBI = Spotted black leaf index

TSS = Total number of spikes shed due to fungal pollu disease (cumulative for entire year)

PSPB = Percentage of spikes affected by pollu beetle

PUPB = Percentage of undeveloped berries

SCI = Index indicating intensity of leaf infection by *Collectotrichum*

R^2 = Coefficient of determination of the regression function

** = Significant at 1% level

Figures in parantheses indicate standard errors of estimates. Letters in parantheses indicate the month and serial number of fortnight (first or second) of taking observations. In cases where only the month is indicated, a single observation during the first fortnight was undertaken.

Estimates of overall yield loss taking into account both stand loss and yield reduction per stand during each year and a pooled estimate over the entire period are given in Table 2.

The total average annual yield loss in black pepper was 33 per cent with the geometric mean estimator while it was 34 per cent with the arithmetic mean estimator. The share of stand loss in total loss was about 13 per cent and the remaining 20 per cent was the loss due to the decline in productivity of plants infested by pests and diseases. Among the various factors contributing to direct loss, foot rot was the major contributor accounting for about 9 per cent loss through the death of affected vines. The percentage annual average stand loss due to drought was estimated to be about 4 per cent. The annual loss caused by slow wilt was relatively small. Among the indirect causes which would adversely affect the yield of affected vines, infestation by pollu beetle was the most destructive. The annual yield caused by this insect ranged from 8.59 to 21.59 per cent during different years, the geometric average being 12.63 per cent. The insect, at times, multiplies in epidemic proportions on unsprayed plots causing heavy damage. Leaf rating index for the damage caused by *C. gloeosporioides* is an indirect indicator of the intensity of incidence of pollu disease on the affected vine. Hence the share of this variable in yield reduction has to be considered along with the yield loss due to spike shedding and the presence of undeveloped berries. The total contribution by pollu disease from these three components was about 5 per cent. Leaf and branch infection by *Phytophthora*, although not lethal, often resulted in yield decline; it was estimated that the indirect yield loss due to infestation by *Phytophthora* on leaves was about 1 per cent.

Application of plant protection chemicals as per the package of practice

Table 2. Pooled estimate of yearly average yield loss in black pepper due to various causal factors (1989-1990 to 1991-1992)

Component	Causal factor	Percentage loss 1989-90	1990-91	1991-92	Average annual loss $\bar{X}$	GM
Stand loss	Foot rot	5.80	12.50	9.13	9.14	8.72
	Slow wilt	0.30	0.48	0.48	0.42	0.41
	Drought	4.50	2.00	5.31	3.94	3.63
	Total	10.60	14.98	14.92	13.50	13.33
Partial yield loss	Pollu beetle	10.91	8.59	21.51	13.67	12.63
	Fungal pollu	0.00	10.87	5.03	5.30	-
	Slow wilt	1.34	0.18	0.61	0.71	0.53
	Phytophthora	0.00	2.39	0.06	0.82	-
	Total	12.25	21.96*	27.21	20.47	19.42
Overall loss		22.85	36.94	42.13	33.97	32.88

$\bar{X}$ = Arithmetic mean; GM = Geometric mean
* Includes loss/gain due to the infestation by minor insect pests also

recommendations of Kerala Agricultural University resulted in a significant increase in yield. The average yield of green pepper of protected plants exceeded twice that of unprotected plants, the overall avoidable loss during the three year period being 43.13 per cent per annum.

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