Effect of Tridemorph on Epidemic Development of Rust and Yield of Groundnut

By

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(Agriculture)
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Department of Plant Pathology
Marathwada Agricultural University,
Parbhani.

1984

CANDIDATE'S DECLARATION

I, hereby declare that the dissertation or part thereof has not been previously submitted by me for a degree of any University.

Parbhani

Dated : August , 1984

(K.G. Baheti)

Certificate I

Shri Khushalchand Govindlal Baheti has satisfactorily prosecuted his course of research for a period of not less than four Semesters and that the dissertation entitled Effect of tridemorph on epidemic development of rust and yield of groundnut, submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the dissertation or part thereof has not been previously submitted by him for a degree of any University.

Date: August 14,84

(C. D. Mayee)
Guide and Chairman, Advisory Committee,
Professor of Plant Pathology
College of Agriculture,
Parbhani.

Certificate II

This is to certify that the dissertation entitled Effect of tridemorph on epidemic development of rust and yield of groundnut subbmitted by Khushalchand Govindlal Baheti to the Marathwada Agricultural University in partial fulfilment of the requirements for the degree of Master of Science (Agriculture) in the subject of Plant Pathology has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.

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Parbhani (K.G. Baheti)

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INTRODUCTION

CHAPTER - 1

INTRODUCTION

Groundnut (Arachis hy pogaea L.) suffers heavily on account of fungal diseases, namely; rust (Puccinia arachidis Speg.), tikka leaf spots(Cercospora arachidicola Hori; Cercosporidium persinatum (Berk. & Curt.) Deighton), seed and seedling rots (induced by Sclerotium rolfsii Sacc., Aspergilla niger Van Tiegh, A. flavus Link ex. Fr., Rhizoctonia solani Kuehn Fusarium spp. etc), black root rot (Macrophomina phaseolina (Tassi) Goid. pod rots (induced by Fusarium solani (Mart.) Sacc; F. oxysporum, Schecht; Rhizoctonia solani Kuehn, M. phaseolina (Tassi) Goid. etc.) and root and stem rots caused by R. solani Kuehn and S. rolfsii Sacc., respectively.

Rust, a disease unknown, in India prior to 1970, became a serious problem when it was recorded in 1969 from Punjab and subsequently from many states (Chahal and Chohan, 1971; Mayee, et al., 1977; Subrahmanyam et al., 1979). It is now wide spread and cause economic losses in groundnut (Mayee, 1982; Mayee, 1983; Subrahmanyam et al., 1980). Mayee (1982) stated that the rust is a potential danger to rainy season crop in Maharashtra and this may be one of the factors in reduction of area, production and productivity of groundnut in the state.

Yield losses due to rust alone or in combination exceed 70% (Ghuge et al., 1981; Subrahmanyam et al., 1980; Smith and Littrell, 1980).

Fortunately, rust is amenable to fungicidal management (Mayee et al., 1977; Mayee, 1982; Smith and Littrell, 1980). During continuous experimentation (1977 to 1980) at Marathwada Agricultural University, Parbhani it was demonstrated that rust of groundnut can be effectively controlled by tridemorph (Ghuge et al., 1980; Mayee et al., 1978; Mayee et al., 1979). This was later confirmed at several locations under different agro-ecological zones in India through multilocational trials by the 'All India Coordinated Research Project on Oilseeds (Anonymous, 1983).

The information on spray schedule of the chemical, however, is very limited. The present work was undertaken with the objectives of determining the rate of rust disease development and the subsequent yield loss in tridemorph protected and un-protected groundnut. Further, the studies were also aimed at deriving critical stages of spray application that would be highly effective not only in reducing rust damage but also in increasing the pod yield so that profit function that decides the acceptability of such a costly input can be decided by the grower who is often subjected to cost constraints (Gibbon, 1980).

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REVIEW OF LITERATURE

CHAPTER - 2

REVIEW OF LITERATURE

Puccinia arachidis, the causal agent of groundnut rust, survive from season to season on groundnut itself in central and southern India because the host crop is available practically through out the year. (Mayee, 1983; Subrahmanyam and Mc Donald, 1982; 1983). The air borne uredospores freely disseminate and bring about new pustules. In rainfed groundnut the inoculum is provided by the late sown rust infected summer crop and the symptoms appear just within 20-30 days after sowing. The rust reach epidemic proportion on the rainfed crop when it infects the crop during early stage.

Diagnosis of P. arachidis is based on the observations of pustules on the abaxial leaf surface. Flecks are visible two or three days before the pustule appear. This is the general stage at which fungicidal applications have been recommended.

Fortunately rust is amenable to fungicidal management, foliar application of various fungicides have been reported to reduce the disease spread significantly. These fungicides include chlorothalonil, (Anneson, 1970; Harrison, 1973; O'brian and Devis, 1977; Subrahmanyam et al., 1980; Raemackers and Presten 1977), mancozeb, maneb (Durairaj and Mohan, 1978; Felix and Ricaud, 1977; Harrison 1977;

O'brien 1974; Padmanabhan et al., 1977; Patil et al., 1979; Schillar and Indhaphun 1978; Schillar and Sampoapol, 1981), sulphur (Patil and Kalekar, 1974; Kin and Cheng, 1980). nicklel chloride (Padmanabhan et al., 1977; Barve, 1980), tridemorph (Mayee et al., 1977b, 1978; 1979b, 1982a, Ghuge et al., 1980; 1981; Prasad and Vyas, 1981), carboxin and oxycarboxin (Patil and Kalekar, 1974; Mayee et al., 1977b; Siddaramaiah et al., 1977; Quebral et al., 1975-76) and thiophanate methyl) (Wankheda and Mayee, 1980). Foliar sprays of non systemic fungicides are usually infective. Tridemorph has been found to contain the disease development when sprayed 2-3 times but is ineffective against leaf spot and need to be combined with carbendazim for total foliar disease control.

Rust usually appear in combination with leaf spots and then the two together cause heavy defoliation and reduce yield. Evenin U.S.A. where rust has been known since long the chemical management strategies was often directed for the combined control of both the foliar diseases. Befone, 1971 dust formulations of copper, sulphar and copper plus sulphar were routinely used to supress groundnut foliar diseases in U.S.A. (Smith and Littrell, 1980). After the introduction of benomyl, chlorothalomil and fentin hydroxide, however, there was rapid change from dusting to spray. The differences between a field sprayed with multiple applications of a fungicide and un-sprayed fields were so striking that fungicide application became one of the routine practices for control of foliar diseases.

Chlorothalonil, one of most extensively used fungicide has been shown effective against early and late leaf spot and rust and is being used in many countries where rust was newly introduced. (O'brien, 1977; Raemackers and Prestan, 1977; Hammons, 1977). Before tolerant strains developed in the south-eastern U.S., benomyl was highly effective against early and late leaf spots, though ineffective against rust (Harrison, 1967; 1973). Tank mixes of benomil and mancozeb are being used in some groundnut growing areas of the U.S.A. because of effectiveness against all foliar diseases. (Smith and Littrell, 1980). Fentine hydroxide was also found effective against early and late leaf spot but because of it's phytotoxicity it never became popular. In India, several people reported the utility of sulphar, the mancozeb and this was normally recommended for management of foliar diseases. After the introduction of systemics, oxycarboxin, carboxin and tridemorph have been reported to be effective against rust.

Patil and Kalekar (1974) found that sulpher, oxycarboxin and carboxin were highly effective in controlling groundnut rust.

Padmanabhan *et al.* (1977) reported that rust of groundnut was best controlled by chlorothalohil and mancozeb.

Durairaj and Mohan (1978) recommended a spray schedule of three sprays of mancozeb followed by sulpher dust and kaocide (coppr hydroxide) for the control of rust.

Ponniah *et al.* (1982) suggested a schedule of two sprays (35 and 50 DAS) with Baycor at 750 ml/ha, Daconil at 1125 gm/ha and Dithane M-45 at 15 Kg/ha for control of both tikka and rust diseases.

Patil *et al.* (1979) found mancozeb as effective in controlling rust severity and increasing yield. At Marathwada Agricultural University Mayee and associates in series of experiments obtained best control of groundnut rust by application of three spray of tridemorph at the rate of 0.07% and therefore it was recommended for the extension workers in the state of Maharashtra (Mayee *et al.*, 1977; Mayee *et al.*, 1978; Mayee *et al.*, 1979; Mayee, 1982; Ghuge *et al.*, 1980; Mayee, 1983).

Increased pod yields attributable to effective management folia diseases have been demonstrated by various workers in several countries. For example; Ghuge et al. (1980) evaluated carbendazim and tridemorph on rainfed groundnut at Parbhani and found that the mean pod weights of SB XI from sprayed plots ranged from 500-700 Kg/ha higher than those from unsprayed plots.

There has not been specific recommendations for the time of applications of the fungicides. However, the first applicationhhas usually been recommended either before or at the first appearance of symptoms i.e. 30-40 DAS, with subsequent applications at intervals of 10 to 14 days until two or three weeks before the anticipated harvest. Thus, foliage was usually sprayed five to seven times during the growing season. The initial and final applications of the season and the total number of applications differed widely among production areas and among growing season in a particular local because of variable environmental conditions.

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MATERIALS AND METHODS

Fig. 1. Field layout for conduct of experiment on rust epidemic in relation to tridemorph .

Treatment	Number of sprays	Sprays application DAS
A	5	30-78
B	4	30-66
C	3	30-54
D	2	30-42
E	1	30
F	4	42-78
G	3	54-78
H	2	66-78
I	1	78
J	-	Control

Germination count as on 22/7/84

	RI	R II	R III
A	426	439	445
B	445	446	450
C	435	446	444
D	446	442	449
E	448	447	449
F	446	444	446
G	446	450	449
H	436	448	435
I	444	448	445
J	441	444	442

I	G	H	F	B
C	E	J	D	A
B	J	A	C	F
H	I	D	G	E
F	B	A	E	I
G	D	C	J	H

CHAPTER - 3

MATERIALS AND METHODS

3.1 Field layout :

Seeds of groundnut variety SB XI were procured from Central Farm, M.A.U. Parbhani. They were sown in 4.5 x 4.5 M field plots on July 10, 1982. The plants were 15 cm apart in rows spaced at 30 cm. The design of field experiment was randomisedblock design with three replications (Fig. 1). Fertilizers totalling 20-40-20 Kg/ha. N,P, and K as urea, single super-phosphate and muriate of potash, respectively were added uniformly to all plots. The cultural practices such as; weeding, hoeing, application of necessary protective irrigation etc. were followed similarly to all plots. One protective irrigation was provided on September 14, 1982.

Four sprayings of 0.1% carbendazims (Bavistin 50 WP) were given at 30, 42, 54, and 70 DAS as it selectivity inhibited leaf spots caused by Cercospora arachidicola and Cercosporium personatum (Ghuge et al., 1981). These sprays were deliberately given as it was known tht they will not interfere with the rust development as the present study envisaged to see the effect of tridemorph spray schedule application on the epidemic development of rust alone. Three sprays of Rogor (0.03%) were given to check the damage by pests to the growing groundnut.

3.2 <u>Rust inoculation</u> :

Uredospores of *P. arachidis* were multiplied on groundnut plants (SB x I) 30 days old grown in pots in the screen house. The uredospores from newly formed uredospori were harvested in sterilled distilled water containing 0.2 ml Trition X 100 per litre of water and adjusted to a concentration of ca. 4 x 10^6 sprays/ml. Actively growing 23 day old plants in each plot were inoculated on August 3, by spraying with the spore suspention using a "Ganesh" pneumatic hand sprayer (American spring ad pessing works Ltd., Malad, Bombay 400064, India).

All leaves were covered with the spora suspention. The inoculations were carried out in the evening after 1700 hrs and were continued again on the next day during evening hosse. Artificial humidity was created by subsequently spraying the plots with water every morning and evening for four to five days.

3.3 <u>Fungi6idal treatments</u>:

Early, light brown pustules of rust were noticed within seven days after inoculation. Initial rust incidence and further development were manipulated by sprayed with tridemorph., (Calixin 80 EC). Different spray schedule treatments were started after the initial rust pustules were evident. Sprays of 0.1% tridemorph (0.5 l/ha) were applied on August 10 (30 DAS) and 22 Augu. (42 DAS). Subsequent sprays (0.6 l/ha) were applied on 3 September (54 DAS), 15 September (66 DAS) and 27 September (78 DAS), depending on the spraying schedule. The number of sprays and the frequency of application along with the quantity applied are given in Table 6 in the Chapter on Results.

3.4 Evaluation of rust :

Two parameters were used to quantity the amount of rust infection. These were, per cent incidence (% INC) calculated from the number of infected compound leaves on a plat and the pustule count per compound leaf (EC) averaged over six leaves selected from the main stem of a plant. Fifty individual plants were labelled and used for scoring.

Similarly, at each observation the number of green compound leaves were counted on the randomaly selected plants.

Six observations on % INC, PC and number of compound leaves per plant were recorded from 17 August to 8 November, 1982. The observations on the disease thus were taken ca. 36, 52, 68, 84, 100 and 118 days after sowing.

3.5 Infection rate (r) :

Average apparent infection rates were calculated according to van der Plank's (1963) logistic equation.

$$r = 2.3\ (t_2 - t_1)^{-1} \log 10\ x_2\ (1-x_2)^{-1} - \log 10\ x_1\ (1-x_1)^{-1}.$$

in which 'r' denotes the infection rate in units per day, t_1 and t_2 denote the times (days) of first observations and subsequent observations and x_1 and x_2 represent the proportion of rust pustules on the first and subsequent observation dates. To convert pustules per compound leaf to proportions, the data showed that infection increased to a maximum of 400 pustules per compound leaf when epidemic was complete, i.e. when x = 1. Infection rates were calculted for the values of 'X' accordingly determined at each interval in all the treatments. The methods of rust evalution and calculations for apparent infection rate were those modified from Ghuge et al. (1980, 1981) and Gangwal (1980).

3.6 Groundnut yield :

Pod yields per plot were obtained after initial sundrying the field harvested pods. The harvesting was done on November 14, 1982. Yield loss was calculated as explained by James *et al.* (1972). Yields of the plots, where tridemorph was applied five times was considered as base and treated as 100%.

The nuts from the pods were shelled sufficiently to obtain more than 100 kernels from each plot. Randomly selected 100 nuts were weighed to obtained 100-kernel weight for each plot.

The data on yield contributing factors such as; per cent dry matter; dry matter per plant (g), number of mature and immature pods per plant and weights of mture and immature pods per plant (g) were obtained by randomly selecting a minimum of five plants per net plot and averaged out.

3.7 Activity analysis :

The dry pod yield was assumed to be the function of number of sprays applied during physiologically sensitive crop growth period i.e. $Y = f(x_i)$ by dividing the spray period in Niji periods where, Y = crop yield, x_i= ith spray at ith stage, i = 1,2,3 -- n sprays at J = 1,2,3 -- n growth stages. The form of yield function developed by least squse technique was;

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 \quad \text{------ (1)}$$

where;

Y = dry pod yield in kg/ha, x_1 to x_3 = one spray applied at each stage and b_1 = regression coefficients of sprays given at specific growth stage (xi).

The yield function was converted to profit function (p) by introducing cost and price elements in the equation (1) thus;

$$P = b_0 + b_1x_1S + b_3x_3S + b_3x_3S + b_4x_4S \; b_5x_5S \; -q- xir \text{ -----(2)}$$

Where;

P = profit in Rs/ha, S = selling price of produce Rs. 4.00 kg, r = Cost of spray application 75/- spray and q = cost of cultivation Rs. 1200/ha excluding the cost of spray.

The final conditional profit function was then reformulated as; $P = (X \; b_0S \; -r + X_1 \; (b_1S \; -r) + X_2(b_2S \; -r) + X_3(b_3S - r) + X_4(b_4S \; -r) + X_5(b_5S \; - r\;)$ (3)

with the constraints,

$$0 < Xi < 5, \; F < C \quad 0 \quad \text{and } P < 0$$

where; F is found available in Rs/ha; C = total spray cost. The optimum solutions for maximization of profits under different constraint levels were obtained by simplex method (Anand, 1981).

3.8 Statistical analysis :

Experimental results were statistically analysed on computer 'Micro 2200' using the programmes for randomised block design and correlations. The analysis of variance was obtained and the significance determined as per F on t tests as was the case.

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RESULTS

CHAPTER - 4

RESULTS

4.1 Effect on foliage retention :

Tridemorph enhanced the retention of number of compound leaves per plant when applied at 30 DAS. The defoliation rate in the sprayed treatment slowed down when the chemical was applied. Highest foliage retention was observed in plots receiving five sprays, which was significantly higher over control as well as over the plots receiving only one early spray or one to three late sprays (Table 1). The data further revealed that at all stages of observations spread over the entire growth period, the green foliage retention was of higher order in the treatments where a minimum of two early sprays (30-42 DAS) or four late sprays (42 DAS onward) were given.

When the sprays were delayed upto 66 DAS and onwards no marked differences in the foliage occurred. At no time, these treatments were superior to control. When the first spray was delayed upto 54 DAS, the defoliation during 100 and 118 DAS was reduced. Similarly one early spray (30 DAS) was also not effective in the beginning of crop growth.

Table 1 : Effect of tridemorph spray applications on retention of folige of SB XI

Number of sprays	Sprays DAS	Average no. compound leaves/plant (DAS)					
		17-8	2-9	18-9	4-10	20-10	8-11
Water spray	Control	26.7	30.2	36.3	30.8	19.7	1.5
5	30-78	32.8	40.3	63.3	51.3	41.3	33.3
4	30-66	29.2	37.7	49.0	48.7	35.8	23.1
3	30-54	26.2	32.3	49.0	42.8	32.3	20.8
2	30-42	30.2	35.0	48.3	46.7	35.3	19.3
1	30	30.2	32.3	34.3	36.1	31.6	7.6
4	42-78	22.3	36.1	48.7	39.1	33.1	22.4
3	54-78	30.3	36.9	40.3	41.2	33.1	18.3
2	66-78	24.9	34.9	43.9	38.7	20.1	13.1
1	78	27.5	35.5	43.0	33.5	24.0	8.1
SE ±		2.2	2.9	4.7	4.5	2.7	3.6
CD at 5%		6.4	8.6	14.1	13.5	7.9	10.7

Fig. 2. Effect of five early sprays of triosmorph on development of rust (% INC) in S6 XI

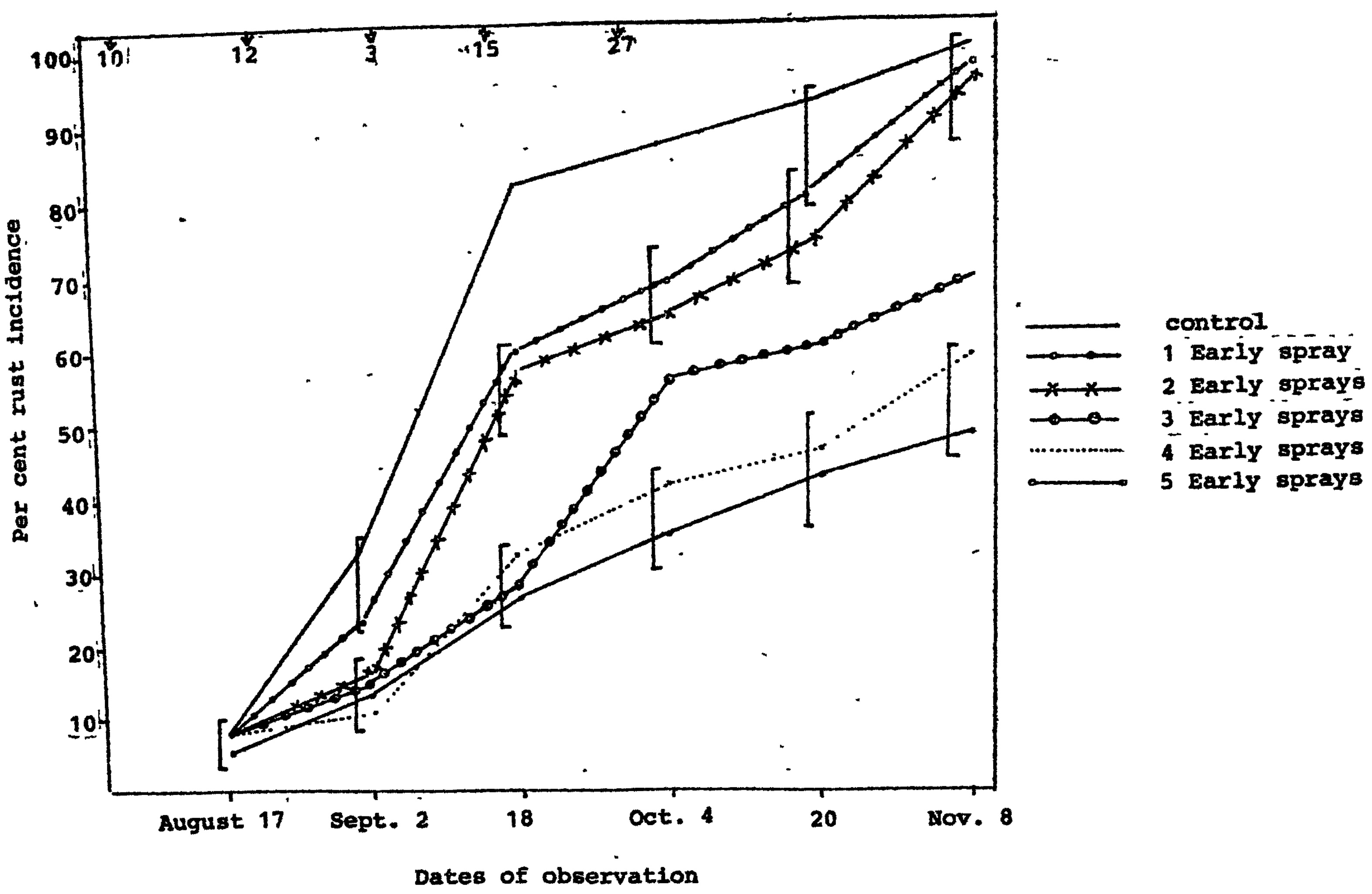
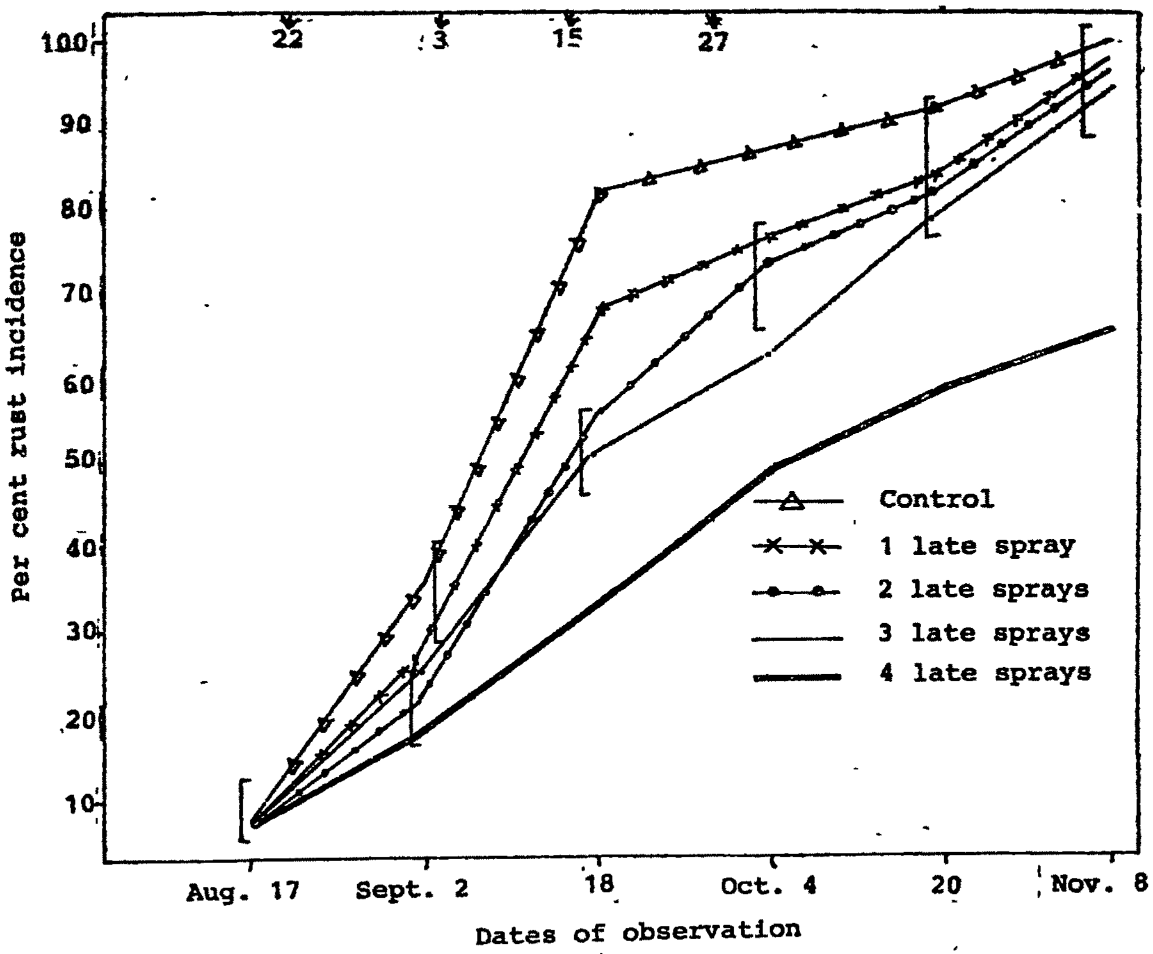

Per cent rust incidence
100
90
80
70
60
50
40
30
20
10
10
12
3
15
27
August 17
Sept. 2
18
Oct. 4
20
Nov. 8
Dates of observation
control
1 Early spray
2 Early sprays
3 Early sprays
4 Early sprays
5 Early sprays

Fig. 3. Effect of four late sprays of tridemorph on development of rust (% INC) in SB XI


22
3
15
27
100
90
80
70
60
50
40
30
20
10
Per cent rust incidence
Aug. 17
Sept. 2
18
Oct. 4
20
Nov. 8
Dates of observation
Control
1 late spray
2 late sprays
3 late sprays
4 late sprays

4.2 Effect on rust incidence :

The fungicide, tridemorph, reduced rust incidence on SB XI groundnut when applied at 30 DAS (Fig. 1) and this was sufficient to keep the disease levels significantly below those in unsprayed check plot upto 66 days. One additional application at 42 days resulted in little additional reduction, but it was not markedly below the levels achieved with one early spray. The effectiveness of one or two early sprays lasted for about 32 days after which the rust increased significantly above that in plots that received additional applications.

Third spraying at 54 days kept rust incidence significantly below that in check plots and also below those that received only one or two early sprays until last evaluation at 118 DAS. Plots with four and five early applications of tridemorph had significantly less rust incidence than did plots that received any other treatment (Fig. 2).

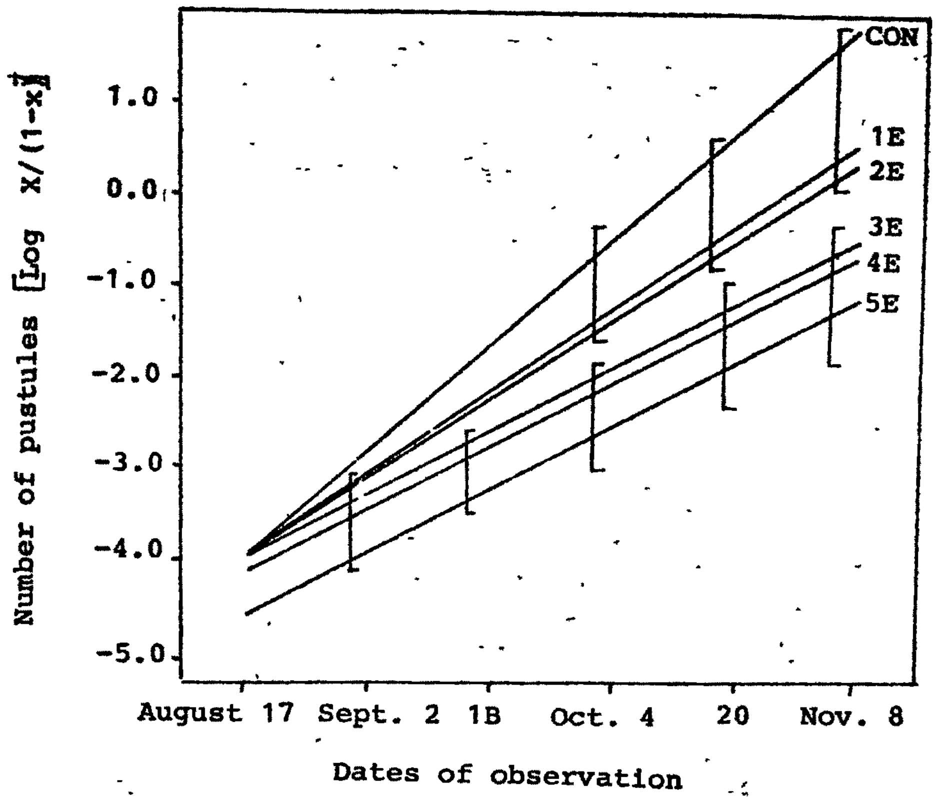
When tridemorph application was delayed until 66 DAS, one additional spray at 78 DAS was not adequate to keep disease levels significantly below that in unsprayed plots (Fig. 3). However, four late applications beginning at 42 days did keep rust incidence markedly below that in check plots until last day of evaluation. Tridemorph applied as late as 54 days reduced rust incidence late in the growing phase but it was not superior than one to two late spray application and had significantly more rust than 4 late sprays which were commenced at 42 DAS.

4.3 <u>Effect on rust severity</u> :

Severity of rust measured in terms of number of pustules per compound leaf was converted into log x/1-x and plotted against time of observation. The data for early sprays (5) and late sprays (4) are presented in Fig.4 and Fig.5, respectively.

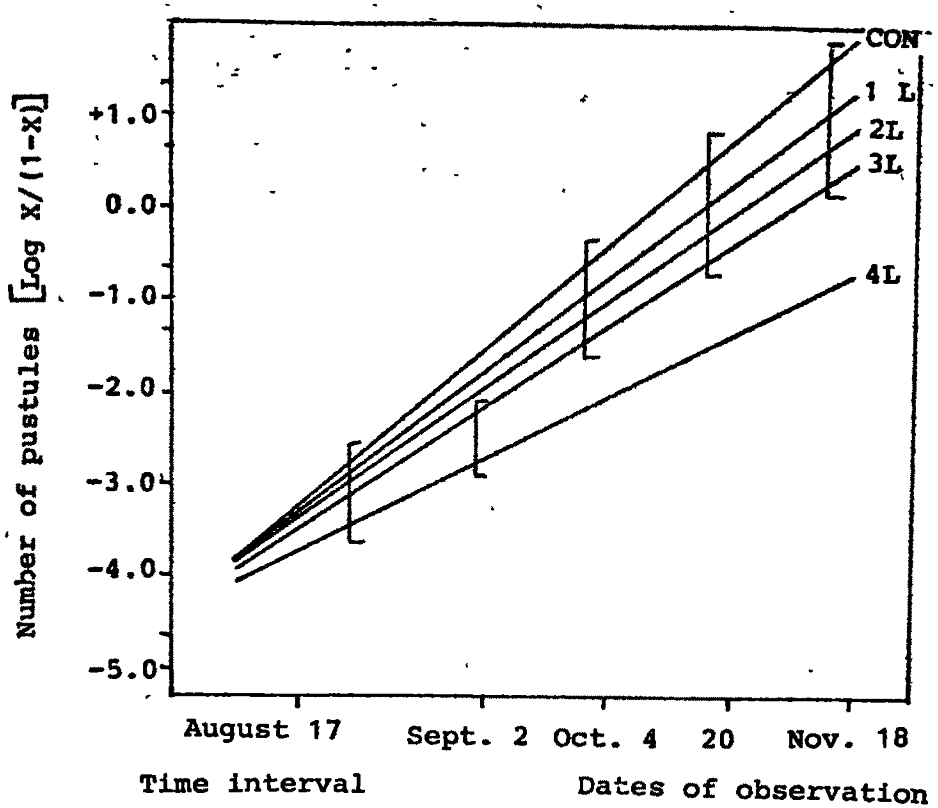
Tridemorph reduced rust severity on SB XI groundnut when applied at 30 DAS and this was enough to keep rust levels significantly below that in unsprayed check plot. An additional spray at 42 DAS brought down the severity further below but was statistically at par with one spray given at 30 DAS. Three sprays beginning from 30 days, were highly effective in reducing the number of pustules over two sprays and control, provided they were commenced at 30 days. The effectiveness of three sprays lasted till harvest. Plots receiving four and five sprays reduced the rust pustules drastically and significant reduction was noticeable upto 84 days. Subsequently, however, the additional sprays given at 66

Fig. 4. Rust severity as influenced by five sprays of tridemorph



CON = Unsprayed
5 E = 5 early sprays
4 E = 4 early sprays
3 E = 3 early sprays
2 E = 2 early sprays
1 E = 1 early spray

Fig. 5. Rust severity as influenced by four sprays of tridemorph



CON = Unsprayed

4 L = 4 late sprays

3 L = 3 late sprays

2 L = 2 late sprays

1 L = 1 late spray

and 78 DAS were at par with only three sprays given earlier i.e. at 30, 42 and 54 DAS (Fig. 4).

When tridemorph application was delayed and sprays started at 42, 54, 66 and 78 DAS, the severity of rust was less affected as compared to early sprays. If only one spray was given at 78 DAS (i.e. highest delayed) it had no impact on rust severity at all. When two sprays were given beginning from 66 DAS, then rust severity declined but only after 84 DAS and it was at par with only one spray at 78 DAS (Fig. 5). The rust development under late sprays indicated that substantial reduction in severity was possible only when four sprays were given beginning at 42 DAS. If the first spray is delayed upto 54 DAS, the severity declined but was never better than any earlier sprays. The data further revealed that 3 early sprays were comparable to 4 late sprays in terms of reducing the rust severity.

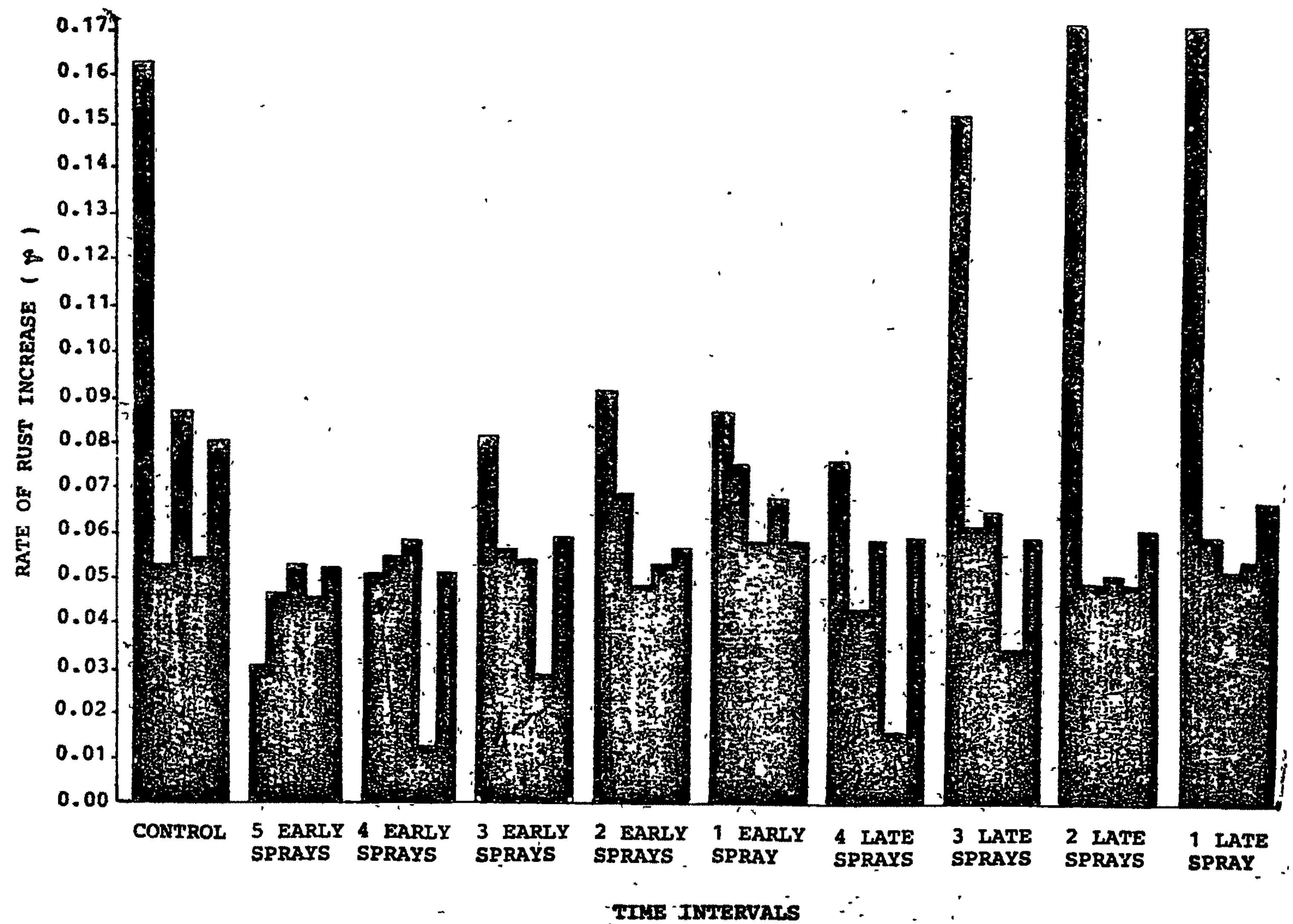
4.4 <u>Effect on apparent infection rates</u> :

Periodical infection rates (r) over the observation intervals were calculated from the severity data to know at what levels the rust severity slowed down. The data are presented in Table 2.

Table 2 : Periodical infection rates of rust based on the pustule development

No. of spray	Spray DAS	Infection rates (r) units/day between DAS				
		36-52	52-68	68-84	84-100	100-188
Water spray	Control	0.144	0.052	0.086	0.054	0.078
5	30-78	0.031	0.040	0.052	0.044	0.051
4	30-66	0.050	0.053	0.058	0.012	0.050
3	30-54	0.080	0.054	0.053	0.027	0.059
2	30-42	0.090	0.069	0.048	0.052	0.056
1	30	0.084	0.073	0.056	0.066	0.057
4	42-78	0.075	0.041	0.058	0.016	0.058
3	54-78	0.130	0.058	0.063	0.034	0.057
2 2	66-78	0.160	0.046	0.049	0.048	0.058
1	78	0.168	0.059	0.050	0.052	0.074

Fig. 6. Apparent infection rates (r) of *P. arachidis* as influenced by tridemorph spray application.


RATE OF RUST INCREASE (r)
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
CONTROL
5 EARLY SPRAYS
4 EARLY SPRAYS
3 EARLY SPRAYS
2 EARLY SPRAYS
1 EARLY SPRAY
4 LATE SPRAYS
3 LATE SPRAYS
2 LATE SPRAYS
1 LATE SPRAY
TIME INTERVALS

The infection rates of rust were very high between 36-52 DAS specially in unsprayed plots. Similarly, the overall infection rates in unsprayed plots were higher than treated plots. The value of 'r' were similarly very high in plots receiving one to three late sprays.

Four to five applications of tridemorph (beginning at 30 days) reduced the early infection rates substantially (from 0.168 or 0.144 to 0.031 or 0.050 units per day).

The data of infection rates are graphically presented in Fig.6. for better comparison. This clearly brings out the impact of 4 and 5 early sprays on reduction of infection rates during early disease development. Late in the growing season, however, the apparent infection rates did not vary and occasionally they were as high as those in the unsprayed plots. Three early sprays also effectively reduced the infection rate during 36-52 days, but it was not as effective as 4 and 5 sprays. In respect of late sprays only 4 sprays beginning at 42 days were as effective as 3 early sprays but subsequent delaying in the spraying had no impact.

The disease situation in respect of incidence, intensity and infection rate is summarized in Table 3 for the final observation before harvest. It is evident plots

Table 3 : Effect of tridemorph spray schedules on incidence, intensity and infection rate of rust of groundnut

No. of spray	Spray DAS	Total quantity (Lit/ha)	Final disease evaluation: % incidence (arc sine)	Intensity (Pustules/leaf)	Infection rate (r) units/day
Water spray	Control	0.0	90.0	20.67	0.088
5	30-78	2.8	56.1	11.6	0.045
4	30-66	2.2	55.9	11.9	0.046
3	30-54	1.6	70.3	12.3	0.048
2	30-42	1.0	81.3	15.9	0.063
1	30	0.5	85.3	16.7	0.059
4	42-78	2.3	60.3	12.5	0.049
3	54-78	1.8	81.6	17.0	0.069
2	66-78	1.2	86.2	17.9	0.072
1	78	0.6	87.8	19.0	0.079
SE ±			3.1	0.38	
CD at 5%			9.3	1.14	

from the data that the rust reached high levels in unsprayed plots as well as in plots those received late one to three sprays or only 1 early spray. Further, it was noted that number of sprays could be reduced if sprayings were undertaken early in the growing season. Four late sprays were as effective as three early sprays or even one early spray was comparable to three late sprays in respect of disease management.

4.5 Effect on groundnut yield :

4.5.1 Pod yield :

The data in respect of pod yield are given in Table 4. Except one late application of tridemorph at 78 DAS, all the spray schedules increased the pod yield of groundnut. However, a minimum of three early applications were found necessary to obtain highest yield. When one early application of the fungicide was ommited, four late sprays resulted in yields as high as that obtained in two early application spray treatments. Highest pod yield was obtained in five spray schedule treatment. It was at par with four and three early applications. Four late sprays gave pod yield equal to two early sprays while one spray gave pod yield as high as that obtained in two late sprays.

Table 4 : Dry pod yield of SB XI groundnut in various spray schedule treatments

No. of spray (early)	Spray DAS	Yield (Kg/ha)	No. of spray (late)	Spray DAS	Yield (Kg/ha)
5	30–78	1414	4	42–78	1088
4	30–66	1334	3	54–78	972
3	30–54	1346	2	66–78	620
2	30–42	1083	1	78	398
1	30	528	Water spray control		303
SE ±		81	C.D. at 5%	244	

4.5.2 100-kernel weight :

The net weight of the shelled nuts obtained from various treatments are given in Table 5.

The 100-kernel weight significantly improved in sprayed plots over unsprayed one except in case where the sprays were delayed 66 days onward. Three sprays were as effective as four to five sprays in increasing the kernel weight. Four late sprays were at par with three to four early sprays but was significantly lower than the weight obtained in plots receiving five early sprays. It was, however, superior to all other treatments.

4.5.3 Losses in yield :

Heavy losses in pod yield and kernel weight occurred in unsprayed plots when yields obtained from plots receiving five sprays were considered the maximum. Relative to this pod yield losses in other treatments ranged from 4.8 to 71.9% while losses in 100-kernel weight were in the range of 1.6 to 34.1%

In the unsprayed plots 79% losses in pod yield occurred, while 33.3% losses in kernel weight were evident (Table 6). As the number of sprays increased the losses proportionately declined. When only one spray was given at

Table 5 : 100-kernel weight of SB XI groundnut in various spray schedule treatments

No. of spray (early)	Spray (DAS)	100-K weight (g)	No. of sprays (late)	Spray (DAS)	100-K weight (g)
5	30-78	37.5	4	42-78	34.1
4	30-66	36.9	3	54.78	26.1
3	30-54	35.1	2	66-78	28.0
2	30-42	39.5	1	78	24.7
1	30	27.7	Water spray		Control
SE ±		1.2	CD at 5%		3.2

Table 6 : Effect of tridemorph spray schedules on pod yield of groundnut and yield loss under various rust intensities

Treatments		Total tridemorph* (l/ha)	Pod yield (kg/ha)	100-kernel weight (g)x	Yield loss expressed as % of five sprays	
Number of sprays	Spray applications days after planting				Pod yield	100 kernel wt.
Un-sprayed	control	0.0	303 d	25.0 d	78.6	33.3
5	30-78	2.8	1414a	37.5 a	-	-
4	30-66	2.2	1334a	36.9 ab	5.7	1.6
3	30-54	1.6	1346a	35.1 ab	4.8	6.4
2	30-42	1.0	1083b	29.5 c	23.4	21.3
1	30	0.5	628c	27.7 c	55.6	26.1
4	42-78	2.3	1088b	34.1 b	23.1	9.1
3	54-78	1.8	972b	26.1 c	31.3	30.4
2	66-78	1.2	620c	28.0 cd	56.2	25.3
1	78	0.6	398a	24.7 d	71.9	34.1

* sprays were given at the interval of 12 days.

x The treatment means followed by the same letters are not significantly different ($P = 0.05$).

30 DAS, 56% losses in pod yield and 26% losses in kernel weight were observed. When an additional spray was given at 42 DAS, losses reduced to the 23% and 21% in pod and kernel weights, respectively.

Pod yield losses in four late sprays were nearly equal to the losses that were evident in two early sprays. However, the kernel weight losses were only 9.1% in plots receiving four late sprays and were comparatively low than two early sprays.

4.5.4 Effect on dry matter content of plant :

The data regarding per cent dry matter and dry matter per plant are presented in Table 7. Dry matter per plant drastically reduced in unsprayed plots and in plots receiving one to two late sprays. Significantly higher dry matter per plant was evident in plots that received three to five sprays, preferably early.

The per cent dry matter, however, was found more in unsprayed plants as also in one late sprayed plot. The differences between other treatments were negligible.

4.5.5 Mature pods :

The number and weight of mature pods per plants was highest in the treatment of five spray applications.

Table 7 : Effect of tridemorph spray application on dry matter and mature pod yield

No. of sprays	Sprays (DAS)	Dry matter per plant (g)	% dry matter at harvest	No. of mature pods/ plants	Wt. of mature pods/ plants (g)
Water spray	Control	9.37	37.72	8.0	5.0
5	30-78	10.17	31.15	15.7	12.1
4	30-66	19.87	33.13	15.5	11.0
3	30-54	18.70	33.65	16.8	11.3
2	30-42	10.90	33.19	14.6	9.6
1	30	10.67	33.53	12.1	8.6
4	42-78	15.83	33.80	15.1	10.4
3	54-78	10.60	33.14	10.7	7.0
2	66-78	9.50	34.14	10.5	6.8
1	78	8.50	34.73	9.9	5.9
SE ±		0.88	1.07	1.3	0.8
CD at 5%		2.60	3.20	3.7	2.4

They were significantly higher in this treatment over unsprayed control and over those treatment where only one to three late sprays or two or three early sprays were administered (Table 7).

4.5.6 Immature pods :

The differences in number of immature pods between sprayed plots were non-significant and even the less number of pods observed in control plot were statistically at par with spray treated plots.

However, the weight of immature pods was found significantly high in early sprayed plots over the control as well as over one to two late application spray plots. The weight of immature pods in treatments with early sprays and four late sprays given any time were superior to other treatment (Table 8).

4.6 Correlations between yield and disease :

Rust incidence (% INC) on all the evaluation dates were significantly negatively correlated with pod yield. Pustule counts (PC) on all but the first two evaluation dates (36 and 52 DAS) were similarly negatively correlated (Table 9). As against this, foliage retained by the groundnut plant on all but the first evaluation date was significantly positively correlated with pod yield.

Table 8 : Effect of tridemorph spray applications on immature pod number and weight

Number of sprays	Sprays (DAS)	Number of immature pods per plant	Wt. of immature pods/plant (g)	Immature to mature pod ratio
Water spray	Control	5.3	0.23	1:1.5
5	30-78	7.0	0.83	1:1.2
4	30-66	6.4	0.60	1:2.4
3	30-54	6.2	0.47	1:2.7
2	30-42	6.3	0.43	1:2.3
1	30	6.5	0.36	1:1.9
4	42-78	7.5	0.90	1:2.0
3	54-78	7.4	0.53	1:2.4
2	66-78	7.3	0.43	1:1.4
1	78	6.3	0.23	1:1.6
SE ±		1.0	0.08	
CD at 5%		NS	0.24	

Table 9 : Correlation coefficients between the rust disease evaluation parameters recorded on six different days after planting (DAP) with groundnut pod yield

Rust observations (DAP)	Correlation coefficients (r)[a]		
	Rust incidence (% INC)	Pustules/compound leaf (PG)	Compound leaves/plant
36	-0.581**	-0.126 NS	0.398
52	-0.680**	-0.105 NS	0.559*
68	-0.766**	-0.638**	0.728**
84	-0.698**	-0.641**	0.627**
100	-0.728**	-0.686**	0.867**
118	-0.660**	-0.616**	0.944**

*

[a]NS = not significant (P 0.05) Double asterisk (**) or single asterisk (*) indicate correlation coefficients significant at P = 0.01 or 0.05, respectively.

Greatest correlations between the rust evaluation parameters and pod yield were observed during evaluations after 68 DAS. The number of leaves on plants protected from defoliation upto harvest were observed to have maximum positive correlation with yield.

4.7 Spray schedule decision model :

These data further revealed that two early sprays were as effective as that of three to four late sprays and one early spray was as effective as two late sprays, suggested a differential impact of conditional spray schedules at different growth stages on crop yields. Therefore, the yield eqation obtained was converted into linear programming i.e. activity analysis (eg. 5) for getting the optimum solutions for conditional maximization of profit under given constraint situations. The resultant functions were;

$$Y = 363.1 + 325.5\, x_1 + 385.\, x_2 + 307.5\, x_3 + 105.0\, x_4 + 87.5\, x_5 \quad - (4)$$

$$P = 252.4 + 1277\, x_1 + 1067\, x_2 + 1155\, x_3 + 345\, x_4 + 230\, x_5 - (5).$$

The test statistics of yield function (eq.4) revealed that the fit was good and significant. It precisely estimated the yields (S.E. ± 114.14 kg/ha) and represented the observed yields to the extent of 95.96 per cent. The

Table 10 : Resource availability, schedule priority and it's maximum profit

Category	Resource availability (Rs/ha)	Schedule priority (DAS)	No.of sprays	Resource balance (Rs/ha)	Maximum profit (Rs/ha)
A	1700	30,42,54,66,78	5	225	4321
B	1500	30,42,54,66, *	4	0	4091
C	1450	30,42,54, * *	3	25	3746
D	1400	30, * 54, * *	2	50	2679
E	1350	30 * 54, * *	2	0	2679
F	1300	30 * * * *	1	25	1524
G	1200	* * * * *	0	0	252

* denotes the spray to be deleted.

regression coefficients of yield function showed that the spray scheduled at X_1 (30 DAS) had highest impact on yield subsequently followed by X_3 (54 DAS), X_2(42 DAS) X_4 (66 DAS) and X_5 (78 DAS) in order of merit. Similar trend was noticed in proft function (eq. 5) . The solution of profit function under uncostraint conditions gave maximum profit of Rs. 4321/ha on five spray applications. However, under constraint conditions, the profit reduced due to resource limitations (Table 1J). These data revealed that the activity analysis solutions have satisfied the boundry conditions and gave optimum solutions for maximum possible profits under given constraints. Where the availability of resources (funds) have posed limitations on the number of sprays to be applied, the role of decision making would operate. In cases of 'D' and 'E' funds are sufficient for applying only two sprays. Under such circumstances the appropriate decision shall have to be to miss the second spray at 42 days and apply it at 54 days. Second spray at 42 instead of 54 will reduce the profit by Rs. 83/ha. Similarly if only one spray is admissible in the budget then it should be given at 30 DAS as it will give the highest profit than it's application at any other stage.

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DISCUSSION

CHAPTER - 5

DISCUSSION

The systemic fungicide, tridemorph, commercially available in India as Calixin EC 80 EC is a morpholine derivative (2,6-dimethyl-4-tridecylmorpholine) with molecular weight of 297.5 deltons ($C_{19}H_{39}N_{O}$). This is a colourless faint yellowish liquid having characteristic odour. It is quite stable and can remain active for 7 years under storage. Basically this chemical was developed by BASF (West Germany), under the code No BAS 220 05F and subsequently marketed as Calixin either 75 or 80 EC. Activity range of this chemical has been reported only towards powdery mildew fungi and Exphasidium vexans which cases blister blight of tea. (Nene and Tapliyal, 1972; Marsh, 1972). It is also claimed that this compound is freely translocated through xylem tissues upqard and provide systemic protection for three to four weeks.

In a series of experiment Mayee and associates at MAU, Parbhani for the first time demonstrated the selective inhibition of P. arachidis infecting groundnut by tridemorph at the rate of 0.07%. They found that it had no greater impact on the early and late leaf spots of groundnut which were selectively inhibited by carbendazim. (Mayee et al., 1977a; Mayee et al., 1977b; Mayee et al., 1978; Mayee et al., 1979a; Mayee *et al*., 1979b; Ghuge *et al*., 1980; 1981; Mayee *et al*., 1982). The efficacy of tridemorph against rust was confirmed in the All India Co-ordinated Research Programme on Oilseeds (Anonymous, 1983) in a multilocational and multi years trials. Subrahmanyam *et al*. (1980) used tridemorph for selective control of groundnut rust in a trial on estimation of losses due to rust.

The present studies confirmed the earlier findings and revealed that the chemical can protect groundnut plants against rust for nearly, thirty to thirty two days if applied early during the crop growth (*ca*. 30 DAS). The protection, however, by the chemical was limited and repeated applications were necessary to contain the epidemic and prevent subsequent damage.

Although tridemorph did not eradicate the rust pathogen once infection was fully established, new foliage was partially prevented from secondary infections. Five applications of the spray were highly effective in keeping the rust at low magnitude and increased the pod yield. However, when applied immediately after early appearance of the pustules, three applications at an interval of 12 days were optimum enough to obtain pod yields at par with that can be harvested with five applications.

Several chemicals have been reported to affectively control rust of groudnut. Increased pod yields attributable be effective management of foliar diseases have also been demonstrated by various workers in several countries (Smith and Littrell, 1980; Subrahmanyam and Mc Donald, 1983; Mayee, 1983). Because of its effectiveness against rust tridemorph has been recommended for rust management in India. This chemical also finds place in the plant protection schedule published by the Agricultural Department and Extension agencies, of the various groundnut growing areas. However, specific recommendations about the rates, scheduling of applications differ widely among the production areas and among growing seasons in a particular locality. Tridemorph being costly fungicide it was considered highly essential to optimise the spray schedules with a view to protect maximum crop losses by suppressing the epidemic build up of the disease. Breeding for resistance to foliar diseases of groundnut is under way at several locations in India and other countries but release of agronomically acceptable foliar disease resistant cultivar within the next few years in unlikely. (Smith and Littrell, 1980). In this context the prospects for refining chemical strategies for suppressing foliar diseases like rust will have to be vastly improved in the near future.

The results of the present investigation indicated that tridemorph can be effectively reduce rust disease in groundnut and increase pod production. This confirmed the earlier findings about the fficiency of the chemical at Parbhani as well as by several other workers in different states of the country (Anonymous, 1983).

One early application of tridemorph at 30 DAS was sufficient to prevent defoliation upto pod formation stage. However, late applications were not effective in controlling the defoliation. Two to three early applications or four late applications prevented heavy defoliation. Rust normally bring about heavy defoliation when accompanied by leaf spots and thus hastens crop maturity (Harrison, 1967; Mayee et al., 1977b). Yield losses are usually greater when defoliation begins early in the growing season and progresses rapidly. Therefore, initiation of a fungicidal spray programme early in the season, either before or at first appearance of symptoms is highly crucial in preventing substantial crop losses. The results have depicted that as the defoliation rate was reduced there was substantial increase in the yield.

Tridemorph reduced rust severity on groundnut applied at 30 DAS. One early spray was sufficient to keep the disease levels below those that in unsprayed check plot upto 66 days. An additional application at 42 days resulted in additional reduction but it was not markedly below the levels achieved with one early spray. The effectiveness of one or two early sprays lasted for about 32 days, after which rust increased significantly above that in plots that received no applications. This clearly demonstrated that the spray at 42 days was not a very useful proposition.

Third spraying at 54 days kept rust incidence significantly below that in check plot and also below those that received only one or two early sprays until last evaluation at 118 DAS. Plots with four to five applications of the chemical has significantly less rust severity over other treatments. This suggested clearly that the application at 54 days was probably most crucial in reducing the rust damage.

When tridemorph application was delayed until 66 DAS, one additional application at 78 DAS was not sufficient to keep rat levels significantly below that in unsprayed plots. However, four late applications beginning at 42 days did keep rust markedly below that in check plots untill last day of evaluation.

Tridemorph is a known systemic fungicide and it is absorbed into the plant system and translocated (Marsh, 1972). It is also known that it has greater impact on the germination, germ tube elongation and hestorial formation of powdery mildew pathogen. It is, therefore, both prophylactic as well as culrative in action. The trend of rust inhibition here indicated that its prophylactic action was more pronounced and that it did became systemic as the early spray given at 30 days prevented the groundnut plants from damage by rust for a sufficiently longer time. However, the effect did not last till harvest because the concentration of the chemical might have gone down and further sprays were necessary to keep up the levels of the toxicant in the plant.

The apparent infection rates are considered to be the speedometer of the epidemic(Van der Plank, 1975; Kranz, 1978). Reduced infection rates were observed in sprayed plots because tridemorph delayed further spread of rust, while newly emerged leaves supported less pustular development. Quick decline in infection rates during early growth period de to fungicide application has subsequently reduced the epidemic. Stranburg and White (1978) obtained negative infection rate of <u>Cercospora appii</u> in celary due to new growth and slower disease development during the cool and dry conditions in winter months. Amin and Ullasa (1981) found that infection rates of colletotrichum lagenarium on watermelon decreased when uninfected plant parts decreased with increased disease intensity with time. The results of present study also indicated that infection rates were decreased substantially during the early disease development with time.

Yield loss was greater in early infected plots where tridemorph applications were delayed than late infected plot, where the sprayings were early. Smith and Littreell (1980) reported that in the peanut producing area of southern Texas, U.S.A. early planting avoided rust epidemics because early planted crop was usually exposed to rust for less than a month and sucha brief exposure precludes crop losses attributable to peanut rust. Groundnut pod yield decreases with increase in rust incidence and pustule count. However, greater the foliage retained by plant, higher were the pod yields. Maximum correlations between disease evaluation parameters and pod yield were observed after 68 DAS which coincided with the pod development stage in SB XI groundnut, a spanish bunch type variety.

From the above discussion, it is clear that the application of tridemorph early in the growing season increases the pod yield as the number of applications were increased. Although five applications resulted in the highest yield they were at par statistically with three applications. However, the limitations of finance of groudnut growers in the semi-arid tropics in which groundnut is mostly grown (Gibbons, 1980) imposes certain restrictions over the number of spray applications. To derive maximum benefit out of a minimum spray input for management of rust, would be the most acceptable strategy. An analysis of the profit function indicated that the dicision making could be made operative under conditions of resource constraints where the sprays at critical stages shall give maximum profits. When resources do not permit for undertaking even three sprays and only permits for two spray applications, it would be highly profitable to undertake these sprays at 30 and 54 DAS to derive highest profits. The priority of sprays scheduled at 30 days followed by 54, 42, 66 and 78 DAS in order of preference depending upon the resource availability shall be remunerative.

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S U M M A R Y

CHAPTER - 6

SUMMARY

Artificial epidemics of rust (*Puccinia arachidis* Speg.) of groundnut caused losses upto 79% in pod yield. By reducing the kernel weight to the tune of 33%. Tridemorph (Calixin 80 EC) sprays applied during early disease development enhanced the retaintan of green compound leaves per plant and reduced rust incidence and severity on SB XI.

One or two early sprays (30 DAS, 42 DAS) of tridemorph protected the plants from the infection by *P. arachidis*, but did not eradicate the pathogen from established pustules. Early infection (upto 52 DAS) resulted in high incidence, more pustule count, less retention of foliage and substantial yield losses.

A minimum of two early sprays increased the foliage tetention and reduced the rast incidence and severity significantly over no spray treatment. An additional third spray given at 54 DAS further reduced the rust severity and increased the foliage retention over one or two sprays.

When tridemorph application was delayed upto 78 days, it had no effect on rust incidence as well as severity. When the application was delayed untill 66

DAS, an additional spray at 78 DAS was not adequate to keep disease level significantly below that in un-sprayed plots. However, four late application beginning at 42 days did keep the rust incidence and severity markedly below that in the check plot untill last day of evaluation. If the first spray was commenced at 54 DAS the rust incidence and severity was not significant reduced and was comparable to any other late spray treatment.

The infection rates of rust were very high between 36 to 52 DAS specially in unsprayed plots. Four to five applications of tridemorph (beginning at 30 DAS) reduced infection rates (r) from 0.168 units per day to 0.031 units per day.

A minimum of three early sprays enhanced pod yield by improving the number of matured pods per plant and also by improving the hundred kernel weight. Four late sprays (beginning 42 DAS) were as effective as two early spray (30 and 40 DAS). Correlation coefficient between rust severity and pod yield were negative and significant ($\underline{P}$ = 0.05). High correlation were found between yield loss and disease incidence and pustule counts taken after pod formation stage. As against this highest positive correlations were observed between pod yield and total foliage retained by the plant after pod development stage.

The differential response of spray schedules on the pod yield was clearly evident by the application of early and late sprays. Therefore, activity analysis was done which revealed that decision making could be made operative under conditions of constrains. If the resources of a grower permit only two sprays depending on the budget, applying them at 30 and 54 DAS should give maximum profit. A second spray at 42 DAS instead of 54 DAS may reduce the profit by Rs. 83 per hectare.

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LITERATURE CITED

LITERATURE CITED

Amin, K.S. and Ullasa, B.A. (1981). Effect of thiophananate on epidemic development of anthracnose and yield of Watermelon. Phytopathology 71: 20-22.

Anonymous (1983). Pro. of the kharif Workshop of All India Coordinated Research Project on Oilseeds held at Telhan Bhavan, Hyderabad 22-25 April 1983, I.C.A.R., Directorate of oilseeds Research, Rajendranagar, Hyderabad.

Arneson, P.A. (1970). Chemical control of rust and tikka leaf spot of peanut in Hondurus and Niearagua. Phytopath. 60: 1539 (Abst.).

Barve, S.M. (1980). Bioefficiency of nickel chloride against major foliar pathogens of groundnut. M.Sc. thesis, Marathwada Agril. Univ. Parbhani.

Chahal, B.S. and J.S. Chohan. (1971). Puccinia rust on groundnut. Plant Prot. Bull. 19:30.

Durairaj, P. and Mohan, R. (1978). Evaluation of fungicides for the control of groundnut rust. Madras agric. J. 65(10): 692.

Felix and Ricaud (1977). Revue Agricole et Sucriere de & I' lle Maurice 56: 110.

Gangwal, K.V. (1980). Groundnut rust progress in various agro-practices. M.Sc. thesis, Marathwada Agril. Univ. Parbhani.

Ghuge, S.S., Mayee, C.D. and Godbole, G.M. (1981). Assessment of losses in peanut due to rust and tikka leafspots. Indian Phytopath. 34: 179-182.

Ghuge, S.S., Mayee, C.D. and Godbole, G.M. (1980). Development of rust and leafspots of groundnut as influenced by foliar application of carbendazim and tridemorph. Pesticides. 14(6): 16-19.

Gibbons, R.W. (1980). Groundnut improvement research technology for the semiarid tropics. pp. 27-37 in Proc. Int. Symp. Development and transfer of technology for rainfed Agriculture and the SAT farmer. 28 August 1 Sept. 1979. ICRISAT, Patancheru, A.P., India..

Hammons, R.O. (1977). Groundnut rust in the united states and the caribbean. PANS 23:300-304.

Harrison, A.L. (1967). Some observations on peanut leaf rust and cercospora leafspots in Texas. Plant Dis. Reptr. 51: 687-89.

Harrison, A.L. (1971). Peanut leafspot and rust control on peanuts. Journal of American Peanut Research and Education Association Inc. 3(1): 96-101.

Harrison, A.L. (1973). Control of peanut leaf rat alone. or in combanation with Cercospora leaf spots. Phytopath. 63(6): 668-673.

James, W.C., Shih, C.S., Hodgson, W.A. and Callbeck, L.C. (1972). The quantitative relationship between late blight of potato and loss in tuber yield. Phytopathol. 62: 92-96.

Kranz, J. (1978). Comparative anatomy of epidemics in plant disease Vol. II Ed. Horsfall, J.G. and cowling, E.B. Academic Press New York p. 33-62.

Lin, K.H. and Cheng, Z. (1980). Efficacy of sulphur fungicides against groundnut rust. Journal of the South China Agril. College, 1:73.

Marsh, R.W. (1972). Systemic fungicides. Ed. Longman Willian Clowes and Sons Ltd. London pp. 321.

Mayee, C.D., Godbole, G.M. and Patil, F.S. (1977). Appraisal of groundnut rust in India. Problems and approach. PANS 23(2): 162-165.

Mayee, C.D., Patil, F.S. and Rab, K.G. (1978). Evaluation of groundnut cultivars for resistance to rust and possible existance of races. Indian Phytopath. 31(1): 121 (Abstr.).

Mayee, C.D., Patil, M.A., Godbole, G.M., Kide, D.S. and Patil, F.S. (1979). Fungicidal control of groundnut rust. Pesticides, 13:13-14.

Mayee, C.D. (1982). Groundnut rust: A review, Indian bot. Reptr. 1(2): 75-83.

Mayee, C.D., Ghuge, S.S. and Godbole, G.M. (1982). Chemical management of foliar diseases of groundnut. In Ist National Symposium on systemic fungicides in plant disease control in Indian agriculture held at JNKVV, Jabalpur, pp. 17. (Abstr.).

Mayee, C.D. (1983). Final Report of the ICAR Scheme on "Epidemiology and forecasting of grooodnut rust in Marathwada region". Department of Plant Pathology M.A.U. Parbhani pp. 72.

Nene, Y.L. and Thapliyal, P.N. (1979). Fungicides in plant disease control, 2nd edn., Oxford & IBH Pub. Co., New Delhi, pp. 507.

O'Brian, R.G. (1974). Peanut rust on the Atherton Tableland. Queensland Afric. J. 100(3): 108-110.

O'Brian, R.G. (1977). Observations on the development of groundnut rust in Australia. PANS. 23(3):297-299.

O'Brian, R.G. and Davis, R.D. (1977). Peanut leafspot and rust control on the Ahterton Tableland. Queensland Agricultural Journal, 103(2): 113-115.

Padmanabhan, D., Visvanathan, A.R. and Durairj, P. (1977). Study of the incidence and control of groundnut rust in Tamil Nadu, Pesticides, 11(4): 42-44.

Patil, B.P. and Kalekar, A.R. (1974). Effect of seven fungicides and antibiotics on the intensity of leaf rust of groundnut (Puccinia arachidis Speg.). Pesticides, 8: 23-25.

Patil, M.B., Wani, P.V. and Patil, G.D. (1979). Evaluation of fungicides for control of groundnut leaf rust (Puccinia arachidis Speg.). Pesticides, 13(3): 24-25.

Ponniah, S., Sachithanathanam, K., Rao, S.M. (1982). Evaluation of fungicides against tikka and rust diseases of groundnut. Pesticides 16(11): 27-28.

Prasad, K.V. and Vyas, S.C. (1981). Some high yielding varieties of groundnut resistant to rust and leaf spots. Seed Farms, 7(12): 19-20.

Quebral, F.C., Garcia, O.A., Punzalan, F.L. and Cagampang C. (1975-76). Evaluation of fungicides for leaf spot control of peanut. Phillipine Agriculturist 59(7/8): 313-316.

Raemakers, R. and Preston, G. (1977). Groundnut rust occurence and foliar disease control in Zambia. PANS. 23(2): 166-170.

Schiller, J.M. and Indhaphaun, P. (1978). Control of Cercospora leaf spot and rust in rainfed peanut production. Thai J. Agric. Sci. 11(3): 149-164.

Schiller, J.M. and Sampoapol, R. (1981). Foliar diseases and their control in rainfed groundnut production in Thialand. Tropical Pest Management. 27(1):13-23.

Siddaramiah, A.L.? Hiremath, R.V. and Krishna Prasad, K.S. (1977). Control of tikka disease of groundnut with Duter, Indian J. Pl. Prot. 5(2): 193-194.

Smith, D.H. and Littrell, R.H. (1980). Management of peanut foliar diseases with fungicides. Plant Disease. 64(4): 356-361.

Strandberg, J.O. add White, J.M. (1978). Cercospora apii damage of celery-effects of plant spacing and growth on raised beds. Phytopathology. 68:223-226.

Subrahmanyam, P., Reddy, D.V.R., Gibbons, R.W., Rao, V.R. and Garren, K.H. (1979). Current distribution of groundnut rust in India, PANS 25: 25-29.

Subrahmanyam, P., Mohan, V.K., Nevill, D.J. and McDonald,D. (1980). Research on fungal diseases of groundnut at ICRISAT. Proc. Int. Workshop on groundnuts, 13-17 October, 1980, Pantancheru, A.P. India p. 193-202.

Subrahmanyam, P. and McDonald, D. (1982). Groundnut rust - its survival and carryover in India. Procee-dings of the Indian acadamy of sciences (Plant Sciences) 91: 93-100.

Subrahmanyam, P. and D. McDonald (1983). Rust disease of groundnut. Information Bulletin No.3. ICRISAT, Patancheru P.O., p. 15.

Vander Plank, J.G. (1975). Principles of plant infection. Academic Press, New York. pp. 216.

Wankhede, P.S. and Mayee, C.D. (1980). Development of rust in susceptible vaiety of groundnut as influenced by seed, capsule and granule applications of five systemic fungicides. Pesticides. 14(5): 18-20.

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