Agricultural Development & Advisory Service

Report to: Mr E J Kennedy
Horticultural Development Council
18 Lavant Street
Petersfield
Hants
GU32 3EW
Tel: 0730 63736

ADAS Contract Manager Dr T M O'Neill
Government Buildings
Brooklands Avenue
Cambridge CB2 2DR
Tel: 0223 455852

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CONTRACT REPORT

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Tomato -
Control of powdery mildew
Undertaken for the HDC

COMMERCIAL IN CONFIDENCE

PRINCIPAL WORKERS

T M O'Neill	MA, PhD, Plant Pathologist (author of report)
C. Nicholls	
A. Jones	H Tech, (Applied Biology)
C. Hewett	

AUTHENTICATION

I declare that this work was done under my supervision according to the procedures described herein and this report represents a true and accurate record of the results obtained.

T.M. O'Neill

T M O'Neill
Contract Manager

Date 15 January 1991

Report authorised by D J Yarham

D J Yarham
Head of Plant Pathology
Block C
Government Buildings
Brooklands Avenue
Cambridge
CB2 2DR

Tel: 0223 455847

Date 15 Jan 1991

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TOMATO: CONTROL OF POWDERY MILDEW

Summary

Seven fungicide spray programmes were compared with an untreated control in 2 commercial crops of cv Gardener's Delight. Powdery mildew was first observed in one crop in late July and the first sprays were applied in early August. Disease levels increased and by early October affected more than 50% leaf area of some untreated plants ; stems were also severely affected on untreated plots. All programmes gave very good disease control and there were no significant differences between fungicide treatments. Powdery mildew occurred in the second crop in late September and increased to low levels by early November. All programmes again gave very good control. Nimrod and Rubigan caused a slight leaf scorch and Repulse and Elvaron left a white deposit on fruit. No fruit browning was seen in plots treated with Rubigan. Long periods of high relative humidity (≥ 12h at ≥ 80%) were frequently recorded in both crops. Methods to determine fungicide sensitivity were investigated using detached leaves and young plants. It was found difficult reliably to establish mildew isolates on test leaves and only a limited number were tested. Mildew developed on leaves treated with Rubigan and Nimrod at one tenth normal spray rate but not on leaves treated with these products at half normal rates or greater concentrations.

Introduction

Powdery mildew caused by Erysiphe sp, is a relatively new disease to affect tomatoes in England and is increasing in importance. Some crops, both round and cherry tomatoes, have been severely affected. The disease may progress rapidly, causing leaf yellowing and necrosis and a consequent reduction in fruit yield. Infection may occur as early as January, although it usually appears later in the year.

Grower experience in 1988 and 1989 indicates that, in some cases, 2 or 3 well-timed sprays of a fungicide can be sufficient to eliminate powdery mildew for the season. On other nurseries, many sprays may be required to get the disease under control. Identification of suitable spray sequences would minimise fungicide input (and thereby save costs), and allow more rapid disease control (and thereby minimise loss caused by the disease). Without treatment the disease usually continues to develop, and may cause death of plants within 3-4 weeks.

Off-label approvals (OLA) have been approved for Rubigan and Nimrod, and these have proved reasonably successful; the new OLA for Rubigan allows 3 treatments per crop at 28 day intervals; the OLA for Nimrod allows up to 6 treatments per crop. An off-label approval for Thiovit was listed in January 1990. A summary of fungicides which are known to have activity against powdery mildew diseases and which also have a recommendation or OLA for use on tomato is given in Table 1.

On cucumber, frequent use of certain fungicides to control powdery mildew has resulted in reduced fungicide sensitivity and poor disease control (Schepers 1983; 1985). The same reduction in fungicide efficacy may occur on tomato as powdery mildew becomes more common and fungal populations are increasingly subjected to fungicide treatment. It is important to determine the baseline sensitivity of tomato powdery mildew now so that reduced sensitivity can be investigated as a possible cause should there be instances of poor disease control in the future. Determination of fungicide sensitivity is not straightforward due to the fact that powdery mildews are obligate parasites (ie they grow only on living plant material and cannot be cultured in vitro).

The effect of glasshouse environment on development of powdery mildew is not fully understood. CSG funded work by ADAS is currently investigating the effect of different temperature and humidity regimes on various stages of the disease cycle from germination through to spore production and release. Identification of limiting factors may enable a more directed manipulation of glasshouse environments so as to reduce the risk of rapid mildew development. Information on conditions necessary for rapid mildew development may also be gained by monitoring the glasshouse environment when mildew is developing.

The objectives of the work described here were:

(i) To compare the efficacy of 7 different fungicide spray programmes in controlling powdery mildew.

(ii) To investigate a technique for determining the sensitivity of powdery mildew isolates to bupirimate (Nimrod) and fenarimol (Rubigan), and to examine some isolates from commercial crops for sensitivity/resistance to these fungicides.

(iii) To monitor the glasshouse environment (temperature and relative humidity) to try to relate disease development to environmental conditions.

TABLE 1. Fungicides active against powdery mildew

Product	Maximum rate	Maximum No sprays	Spray interval (days)	Harvest interval (days)	Comment
Bavistin	100g/100l	-	14	0	
Benlate	100g/100l	-	-	0	
Elvaron	100g/100l	-	14	3	
Nimrod	200 ml/100l	6	-	2	OLA 969/88
Repulse	220ml/100l	-	7-14	½	
Rubigan	18ml/100l	3	28	2	OLA 305/90
Thiovit	200g/100l	-	14	2	OLA 39/90

Notes

1. None of the products has a label recommendation for control of powdery mildew.

2. Off label approvals (OLA) are used entirely at a grower's own risk.

Materials and Methods

Crop Details

The 2 spray trials were carried out in commercial crops of cherry tomato cv Gardener's Delight, at Newbourn, Woodbridge, Suffolk. Both crops were soil grown, in aluminium glasshouses. The crop at site A was planted on 2 March 1990 and plants were trained by layering. The crop at site B was planted in mid-June 1990 and plants were trained vertically.

No fungicides were applied by the growers to the trial areas. Pest control was achieved using Encarsia for whitefly and Phytoseiulus for red spider mites; no insecticides were applied. The surrounding crops were sprayed for control of mildew with Nimrod on 3-4 August (Site A), and Repulse om 14 October (Site B). A minimum night temperature of 60°F was maintained at site A; the crop at site B was unheated.

Trial Design

Both trials consisted of 8 treatments x 4 replicates arranged in a randomised block design; there were 14 plants (a double row of 7) in each plot, and the central 5 plants in each run of 7 were assessed. Rows adjacent to the trial areas were left unsprayed by fungicide.

Fungicide Treatment

Treatments were applied by spraying leaves and stems to run-off using a handheld 5 litre pressured sprayer ('Kilaspray'). Plots were treated from both sides of the double row. Treatments were as follows:

A. Untreated
B. Rubigan at 28 day intervals, to a maximum of 3 sprays
C. Nimrod at 28 day intervals, to a maximum of 6 sprays
D. Thiovit + Agral at 14 day intervals
E. Elvaron at 14 day intervals
F. Repulse at 14 day intervals
G. Rubigan alternating with Nimrod at 14 day intervals (Maximum of 3 Rubigan sprays).
H. Rubigan followed by Nimrod after 14 days then Repulse at 14 day intervals.

A list of products, active ingredients and application rates is given in Table 2. The dates of spray application are shown in Table 3.

Table 2. Fungicide rates and active ingredients

Product	Active ingredient	Rate of application
Elvaron	dichlofluanid (50% wp)	100g/100l
Nimrod	bupirimate (27% ec)	200ml/100l
Repulse	chlorothalonil (40% ec)	220ml/100l
Rubigan	fenarimol (12% ec)	18ml/100l
Thiovit*	sulphur (80%)	200g/100l

* Agral was added at 6ml/100l

Table 3. Date of Spray application[a]

Treatment	1	2	3	4
Site A				
B. Rubigan (R)	9/8	-	6/9	-
C. Nimrod (N)	9/8	-	6/9	-
D. Thiovit	9/8	23/8	6/9	20/9
E. Elvaron	9/8	23/8	6/9	20/9
F. Repulse	9/8	23/8	6/9	20/9
G. R/N/R/N	9/8	23/8	6/9	20/9
H. R/N/Rep	9/8	23/8	6/9	20/9
Site B				
B. Rubigan (R)	4/10	-	1/11	
C. Nimrod (N)	4/10	-	1/11	
D. Thiovit	4/10	18/10	1/11	
E. Elvaron	4/10	18/10	1/11	
F. Repulse	4/10	18/10	1/11	
G. R/N/R/N	4/10	18/10	1/11	
H. R/N/Rep	4/10	18/10	1/11	

[a]Powdery mildew was first observed in the trial area at Site A on 1 August and at Site B on 30 September.

Full Disease assessments were made 2 weeks after the final sprays were applied (4 October at Site A, 15 November at Site B). An additional assessment was made at Site A on 20 September.

Disease assessment

The level of mildew was assessed by estimating the % leaf area affected on the upper leaf surface at 3 positions (upper, mid and bottom) in the crop canopy. Ten plants per plot were individually assessed and a mean score calculated for each plot.

Mildew on the stems was assessed on a 0-3 scale as follows: 0 - absent; 1 - up to 33% stem surface affected, 2 - 34 to 66% stem surface affected 3 - >66% stem surface affected.

An assessment was also made of the number of stems affected by grey mould (*Botrytis cinerea*), and the total number of botrytis stem lesions per plot.

Observations on the level of mildew were made at the time of each spray application. Full disease assessments were carried out 2 weeks after the third spray (Site A) and 2 weeks after the final spray (both sites). Further assessments were not possible as the crops were then pulled out.

Glasshouse environment monitoring

Two Kane and May KM 1204 temperature and relative humidity (rh) recorders were calibrated against known standards and then programmed to record at 60 minute intervals. The recorders were placed within rows and at opposite ends of the trial, with sensors suspended at 1.5m height. Batteries and tapes were changed as required.

Investigation of fungicide sensitivity

Isolates were collected from commercial crops and tested as described below.

A) Detached leaf technique

Tomato leaflets freshly collected from plants not affected by mildew were treated with fungicide and placed on Petri plates of tap water agar containing benzimidazole at 100 ppm ai; the benzimidazole was added as an anti-senescence chemical to maintain the leaves green for the period of the test. Leaflets were dipped in Nimrod and Rubigan at a range of concentrations, or in water (control), and then immediately placed on agar plates, and inoculated with the test isolate of mildew, and incubated. There were 3 replicate leaflets per test with 1 leaflet per plate, upper surface topmost; non-inoculated leaves were incubated as a control. Several inoculation techniques were compared, namely:

1. Tap and Scratch inoculation

A set of prepared leaves on Petri plates were placed at random in a sterilised air-flow cabinet with the fan switched off. Tomato leaves affected by the test mildew isolate were held c. 10cm above the prepared leaflets and tapped and then scratched with a sterile needle to detach conidia to fall onto the test leaflets. The cabinet was sterlised between each test.

2. Direct contact inoculation

Plates containing leaflets were prepared as previously and then inoculated with a square (1 x 1cm) of tomato leaf affected by mildew, placing the mildew in direct contact with the test leaflet.

3. Cotton bud inoculation

Mildew spores were collected and transferred by rolling a cotton bud backwards and forwards (once) over an affected leaf, and then over the test leaflet (Sadasivan Nair and Ellingboe, 1962). A new cotton bud was used for each transfer.

Inoculated leaves were incubated on the laboratory bench out of direct sunlight and examined after 7, 14 and 21 days for evidence of mildew growth. The effect of temperature on success of mildew transfer was examined by incubating plates in illuminated incubators at 20 and 27° C for 3 days before transfer to the laboratory bench. The effect of leaf moisture was investigated by gently spraying inoculated leaflets with water at 3 and 7 days after inoculation.

B) Whole Plant technique

Pot-grown plants of cv Calypso, approximately 30cm in height, were sprayed with fungicide or water and allowed to dry. Plants were then inoculated with mildew by placing small squares (1 x 1cm) of affected leaf tissue onto the treated plant. There were 3 replicate inoculation sites per plant (a top leaf, a middle leaf and a bottom leaf), and 1 plant perfungicide treatment. Plants were sprayed lightly with water immediately before inoculation. Plants were then covered with a clear polythene bag, lightly tied around the base to maintain a high humidity, and placed in partial-shade on a glasshouse floor. Polythene bags were removed after 24h and plants placed on a glasshouse bench. Each set of plants inoculated with the same test isolate, together with an un-inoculated control, were placed in separate glasshouse compartments. Plants were examined for mildew 14 and 28 days after inoculation.

Statistical analysis

The results of mildew assessments were examined by analysis of variance and means were separated using Duncan's New Multiple Range Test. Anovar was performed on angular transformed data; non-transformed data are also shown in the tables.

Results

Comparison of fungicide programmes - Site A

Rubigan sprays at this site, and the first spray at site B, were inadvertently applied at an incorrect rate and therefore these results should be interpreted with caution.

When the first spray was applied mildew was evident in 3 blocks, albeit in single plots in each block, and affected <5% leaf area. Two weeks after the first spray mildew was not found in any of the treated plots, and was present, at trace levels only, in 1 of the 4 untreated control plots (Table 4). After a further 2 weeks, mildew was found relatively easily in 3 of the untreated plots and was also found, at trace levels, in treatment C (Nimrod applied 1 month previously).

A full disease assessment on 20 September (Table 5) revealed significantly higher levels of mildew in the mid and lower leaf canopies of untreated plots than in any of the treated plots. (A) There were no significant differences between fungicide treatments. Treatments C (Nimrod) and G (alternating programmes of Rubigan and Nimrod) appeared best, with no disease found on leaves, although the level of mildew did not exceed 1% leaf area in any of the treatments.

Two weeks after the final spray mildew affected a mean of 12.6% leaf area of the lower canopy in untreated plots, and not previous in any of the treated plots, apart from trace levels in treatment C (Nimrod). Untreated plots were easily distinguished in the trial at this stage because leaf yellowing was more advanced in them than in adjacent plots. (B) All treatments significantly reduced the level of mildew, with no significant differences between treatments.

The greatest levels of mildew (up to 50% leaf area affectedon some plants) were found in the 2 outer rows of the trial area. Rows immediately adjacent to the trial had been left unsprayed by the grower to avoid spray drift onto the trial, and consequently these rows became affected and acted as close sources of inoculum to the outer rows of the trial.

Development of mildew on stems was superficial and caused no associated yellowing or tissue softening. There was significantly more mildew on stems of plants in untreated control plots than all other treatments (Table 5). No mildew was found on stems in 4 treatments.

Botrytis affected up to 50% of stems, with up to 7 stem lesionsper plot (10 plants). Fungicide treatments had no significant effect on the incidence of stems lesions.

A slight white deposit was observed on some fruit in treatments E (Elvaron) and F (Repulse). No fruit browning was observed following Rubigan treatment, and no leaf scorch symptoms were observed.

Table 4 Observation on levels of powdery mildew

Site A		Site B	
1st Spray		**1st Spray**	
9/8	Low levels in 3 blocks, in plots distant from the doorway	4/10	Trace to 2% in all blocks
2nd Spray		**2nd Spray**	
23/8	Not observed in treated plots. Trace levels in 1 of 4 untreated plots	18/10	Trace levels on untreated plots. Not found in any of the treated plots
3rd Spray		**3rd Spray**	
6/9	Trace levels in 1 Elvaron treated plot and 2 Nimrod treated plots (treatment C). Low level in 3 out of 4 untreated plots	1/11	No mildew found on treated plots. Trace to low level in untreated plots (1-3% leaf areas)
4th Spray		**Final assessment**	
20/9	Trace levels in all treatments except C (Nimrod) and G (Rubigan/Nimrod). Moderate level in untreated plots. Full details - Table 5.	15/11	Trace level in treatments B (Rubigan) and D (Thiovit). Moderate level in untreated plots. Not found in other treatments. Full details - Table 6.
Final assessment			
4/10	Trace level in C (Nimrod). Moderate level in untreated. Not found in other treatments Full details - Table 5.		

Table 5 Effect of fungicide sprays on severity of powdery mildew - Site A

	Treatment	Mean % leaf area affected: Top leaves	Mid leaves	Bottom leaves	Stem mildew (0-3)
		20 September			
A	Control	1.2 (4.2)^{b}	2.8 (7.8)^{b}	6.5 (12.3)^{b}	
B	Rubigan (R)^{c}	0.0 (0.0)^{a}	0.3 (1.4)^{a}	0.0 (0.0)^{a}	
C	Nimrod (N)	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	
D	Thiovit	0.0 (0.0)^{a}	0.4 (3.2)^{a}	0.8 (4.9)^{a}	
E	Elvaron	0.0 (0.0)^{a}	0.1 (1.1)^{a}	0.3 (2.8)^{a}	
F	Repulse (Rep)	0.0 (0.0)^{a}	0.2^{a} (2.5)^{a}	0.8 (5.2)^{a}	
G	R/N/R/N	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	
H	R/N/Rep	0.1 (0.9)^{a}	0.5 (3.8)^{a}	0.6^{a} (3.7)^{a}	
	VR	(2.05)^{ns}	(3.65)**	(5.23)*	
	SED	(1.43)	(1.88)	(2.56)	
	CV(%)	(307)	(108)	(100)	
		4 October			
A	Control	1.7 (5.1)^{b}	6.1 (10.3)^{b}	12.6 (15.0)^{b}	1.8 (6.4)^{b}
B	Rubigan (R)	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0 (0)^{a}
C	Nimrod (N)	0.0 (0.0)^{a}	0.1 (0.7)^{a}	0.1 (1.0)^{a}	0.3 (2.0)^{a}
D	Thiovit	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0 (0)^{a}
E	Elvaron	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0 (0)^{a}
F	Repulse (Rep)	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.3 (1.4)^{a}
G	R/N/R/N	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0 (0)^{a}
H	R/N/Rep	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0.3 (1.4)^{a}
	VR	(2.75)*	(3.10)*	(2.81)*	
	SED	(1.54)	(2.91)	(4.43)	
	CV(%)	(327)	(300)	(314)	

Figures in parenthesis are angular transformed values.
ns - not significant
* - significant at P = 0.05 ** - significant at P = 0.01

Comparison of fungicide programmes - Site B

Mildew did not occur in the house until the end of September, and subsequent development was less than at site A. When the first sprays were applied on 4 October the disease was present throughout the trial area at trace levels to 2% leaf area affected. Two weeks after the first spray, mildew was observed at trace levels on untreated plots and was not found in any of the treated plots. After a further two weeks the disease had increased slightly on untreated plots and was still not found on any of the treated plots (Table 4).

Two weeks after the final spray mildew affected an average 5.6% leaf area in the mid-leaf canopy of untreated plots and was absent from all other treatments apart from B (Rubigan) and D (Thiovit), where very low levels were detected (Table 6). All treatments significantly reduced the level of mildew, with no significant differences between treatments.

A slight leaf scorch was observed on plots following Rubigan and more particularly Nimrod treatment, and a slight white deposit was observed on some fruit following treatment with Elvaron and Repulse.

Glasshouse temperature and humidity

A summary of glasshouse temperature and humidity as recorded by the in-crop recorders is given in Tables 7-9. Full daily charts are shown in Appendix 3. One machine ceased to function from late September and therefore readings were taken from only one position in the trial at site B. The two recorders at Site A showed very similar patterns of relative humidity and temperature change.

Long periods (≥12h) of high relatively humidity (≥80%) frequently occurred in both crops. Initially such periods were at night, and from early October often extended into the day.

Table 6 Effects of fungicide sprays on severity of powdery mildew - Site B

Treatment		Mean % leaf area affected 15 November		
		Top leaves	Mid leaves	Bottom leaves
A	Control	0.1 (1.4)^{b}	5.6 (13.4)^{b}	0
B	Rubigan (R)	0.0 (0.0)^{a}	0.1 (0.5)^{a}	0
C	Nimrod (N)	0.0 (0.0)^{a}	0.0 (0.6)^{a}	0
D	Thiovit	0.0 (0.0)^{a}	0.9 (0.0)^{a}	0
E	Elvaron	0.1 (0.5)^{a}	0.0 (3.2)^{a}	0
F	Repulse (Rep)	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0
G	R/N/R/N	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0
H	R/N/Rep	0.0 (0.0)^{a}	0.0 (0.0)^{a}	0
	VR	(4.80)**	(18.02)***	-
	SED	(0.313)	(1.547)	-
	CV(%)	(195)	(99)	-

** - significant at P = 0.01
*** - significant at P = 0.001

Fungicide sensitivity tests

Preliminary experiments in 1989 with several isolates of cucumber powdery mildew inoculated onto cucumber leaf pieces and 3 isolates of tomato powdery mildew inoculated onto tomato leaflets indicated that inoculation of detached leaflets on agar plates would be a suitable method for testing fungicide sensitivity. However, in experiments with 14 isolates in 1990 using the same and modified inoculation and incubation procedures, the disease failed to establish even on non-fungicide treated leaflets (Table 10). Dipping leaves in Nimrod at twice the recommended rate caused leaf necrosis; Rubigan at twice the recommended rate cause no leaf necrosis.

Using young whole plants, one mildew isolate was established and grew at all inoculation sites on untreated plants and also on plants sprayed with Rubigan and Nimrod at 1/10 recommended spray rates, but not at 1/5 or higher concentrations (Table 10).

In a separate experiment designed to investigate the effect of different incubation conditions on mildew development, leaves not treated with fungicide were incubated at ambient, 20 and 27°C. Mildew developed in all three treatments, most consistently so at 20°C. Lightly spraying with water reduced mildew development at 20°C and ambient incubation.

Table 7 Summary of temperature and relative humidity measurements

	Temperature (°C)		Relative humidity(%)		
	Max	Min	Max	Min	Frequency ≥80%
Site A					
24 Aug - 2 Sept	31.7	11.8	101.7	37.1	Most nights to 9am
7 Sept - 20 Sept	31.7	6.6	101.7	21.2	As above; and some short day periods
21 Sept - 3 Oct	29.3	1.7	102.1	21.4	As above; increasingly in day time too
Site B					
5 Oct - 18 Oct	29.3	6.1	102.2	34.8	Frequent except from 11.30am - 4.30pm
19 Oct - 1 Nov	26.2	5.1	102.2	83.5	Rarely below 80%
21 Nov - 15 Nov	22.7	3.2	100	75.4	Rarely below 80%

Table 8 Relative humidity and temperature records - Site A (Heated crop)

Date	Hours RH ≥ 80 %	Temperature (°C) Max	Min	Mean (24h)	Mean (6am - 6pm)
Aug 24	13	30.4	14.7	22.0	26.2
25	18	29.3	13.3	19.8	23.3
26	17	28.7	13.2	19.0	22.5
27	17	27.7	12.0	19.2	23.1
28	13	28.8	13.0	20.5	24.6
29	11	31.1	15.2	22.7	27.2
30	10	25.5	12.7	18.1	20.7
31	11	26.5	7.9	17.4	21.2
Sept 1	15	29.5	15.3	19.6	22.1
2	13	27.2	15.4	20.3	23.0
3	-	-	-	-	-
4	-	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	8	26.5	11.8	16.2	19.3
8	13	26.2	10.4	15.5	19.5
9	14	27.4	5.9	20.0	21.7
10	13	27.1	9.2	16.2	20.4
11	16	24.2	10.9	16.2	19.2
12	13	25.0	9.2	15.9	20.4
13	16	30.6	7.7	14.8	20.3
14	14	26.5	6.7	14.3	19.2
15	9	27.2	11.4	15.8	17.4
16	8	21.1	11.8	14.7	16.8
17	22	18.2	7.2	12.8	15.0
18	14	24.4	8.7	15.6	19.0
19	11	32.1	11.7	18.6	22.6
20	23	20.9	9.3	13.7	16.5
21	11	22.5	8.4	14.0	17.0
22	16	20.9	9.5	13.0	15.3
23	17	22.6	8.6	13.3	17.2
24	16	29.3	7.0	13.4	18.2
25	15	22.1	6.1	12.8	16.7
26	15	23.6	3.7	11.1	15.6
27	14	23.5	1.7	10.4	12.7
28	11	28.7	4.8	14.1	20.0
29	23	17.3	9.1	13.2	14.5
30	22	26.0	11.3	17.3	20.0
1	21	24.3	6.7	13.9	17.6
2	21	22.1	5.2	13.7	17.1

Table 9 Relative and temperature records - Site B (unheated crop)

Date	Hours RH ≥ 80%	Temperature (°C) Max	Min
Oct 5	24	19.3	9.1
6	24	20.8	10.7
7	22	26.2	8.0
8	18	28.7	5.6
9	24	24.7	7.0
10	23	27.2	9.9
11	23	29.3	10.5
12	20	27.7	7.5
13	21	25.4	12.7
14	24	22.3	14.2
15	24	26.3	11.8
16	18	23.2	9.8
17	24	20.6	11.0
18	24	23.8	12.1
19	24	21.6	11.7
20	24	23.5	12.0
21	24	16.0	10.4
22	24	20.5	9.2
23	24	23.8	9.2
24	24	26.2	10.6
25	24	21.5	12.0
26	24	15.8	10.0
27	24	21.0	9.3
28	24	19.5	7.6
29	24	21.3	5.1
30	24	21.8	5.5
31	24	19.1	7.8
Nov 1	24	22.7	7.0
2	24	22.0	6.1
3	24	19.2	5.3
4	24	13.5	6.0
5	24	21.3	4.3
6	24	21.1	3.0
7	24	13.6	3.2
8	24	12.3	8.3
9	24	18.1	5.1
10	24	14.8	10.0
11	24	20.3	5.9
12	24	14.2	4.7
13	24	17.6	11.3
14	24	17.8	9.0

Table 10 Summary of fungicide sensitivity tests

Experiment	Year	Inoculation method	Incubation method	N° isolates tested	N° isolates growing on control	Maximum fungicide rate allowing growth: Rubigan	Maximum fungicide rate allowing growth: Nimrod
Detached leaves							
1	1989	Tap and scratch	Lab bench	6	6	0[a]	0[a]
2	1989	Tap and scratch	Lab bench	3	3	0.1[a]	-
3	1990	Tap and scratch	Lab bench	5	0	-	-
4	1990	Direct contact	20°C, then lab bench	6	0	-	-
5	1990	Cotton bud	20°C, then lab bench. Sprayed with water	3	0	-	-
Whole Plants							
1	1990	Direct contact	Glasshouse	3	1	0.1[b]	0.1[b]

a No growth at 0.5, 1 or 2 x normal spray concentration
b No growth at 0.5 or 1 x normal spray concentration

Results and

Discussion

All fungicide programmes at both sites gave good control of mildew and there were no significant differences between treatments. The 3 and 4 spray programmes using protectant fungicides (Thiovit, Elvaron and Repulse) were as good as the 2 - spray programmes of eradicant fungicides (Nimrod and Rubigan), and the alternating Rubigan/Nimrod programme. If mildew had occurred in the trial houses earlier in the season and developed over a longer period of time it is possible that differences in efficacy between the programmes may have emerged.

Rubigan has, on occasion, been reported to cause a brown fruit marking and fruit cracking when applied for control of mildew. No fruit symptoms were seen in these trials, even when Rubigan was applied at higher than the recommended rate.

Rubigan and Nimrod are both fungicides known to have good activity against mildew diseases and therefore are often the first choice for control of mildew in a tomato crop. The experimental results presented here indicate that sprays of the protectant fungicides Elvaron, Repulse and Thiovit plus Agral can equally well provide good disease control, provided that first sprays are applied when the disease is at a low level. Thus, use of a chlorothalonil product (eg Bravo 500, Repulse, Jupital) against botrytis leaf and stem rot, or of Elvaron against ghost spot, should help protect a crop against rapid development of mildew.

Thiovit is permitted in organic tomato crops grown to UKROFS standards and should provide control of mildew where the disease occurs. For production to Soil Association Standards a grower will require permission from the Certification Committee before making routine use of sulphur. The wetter Agral is not appoved by UKROFS and use of sulphur without a wetter may be less effective against mildew.

Monitoring of relative humidity showed that extended periods of high humidity, the conditions thought to be required for mildew spores to germinate on a leaf surface and infect epidermal cells, are often found in cherry tomato crops in the autumn months. Low temperatures at Site B (late, unheated crop) probably account for the slower development of mildew at this site compared to Site A.

No isolates resistant to the DMI fungicide fenarimol (Rubigan) or the hydroxy-pyrimidine fungicide bupirimate (Nimrod) were detected. On cucumber however, frequent use of certain DMI fungicides to control cucumber powdery mildew has resulted in reduced fungicide sensitivity and poor disease control (Schepers, 1983; 1985); reduced sensitivity to bupirimate has also been recorded. It would therefore be a wise precaution not to overuse Rubigan and Nimrod for control of tomato powdery mildew; one or more of the protectant products described above should also be used in a spray sequence aimed at controlling powdery mildew.

Conclusions

1. Powdery mildew occurred in both trials and developed to a moderate level in untreated plots in the first trial (Aug - Oct) and to a low level in the second trial (Oct - Nov).

2. All fungicide programmes gave good disease control and there were no significant differences in efficacy of control between treatments.

3. Spray sequences of both protectant products (Elvaron, Repulse, Thiovit) and eradicant products (Nimrod, Rubigan) gave good disease control; the first sprays were applied when the disease was at a low level.

4. Nimrod, and to a lesser extent Rubigan, caused a slight leaf scorch. No fruit symptoms were seen associated with use of these products. Elvaron and Repulse left a white deposit on some fruit.

5. Extended periods of high relatively humidity were frequently recorded in cherry tomato crops, from August to November.

6. Isolates of powdery mildew grew on detached tomato leaflets and young tomato plants treated with Nimrod and Rubigan at one tenth recommended spray rates but not at one fifth recommended rates or higher concentrations.

Recommendations

1. Growers should be made aware of the efficacy of protectant fungicides against mildew and how these products may be used in a sequence to control the disease.

   [An article entitled Sprays Programme for Tomato Powdery Mildew for publication in ADAS Glasshouse Technical Notes has now been prepared and is appended].

2. In order to investigate further any differences in activity between products a comparison should be made in a crop where the disease occurs earlier in the season and develops over a longer period of time. The effect of single sprays of some of the products used in these trials was recently described by Fletcher et al (1989).

3. Further work is required to identify the precise temperature and humidity conditions required for the various stages of the disease cycle and the succession of conditions required for rapid development.

   [CSG - funded work investigating these aspects is in progress at ADAS Reading (Mr D Ann, Plant Pathology Dept.)]

4. A simple and reliable technique needs to be established before further fungicide sensitivity monitoring work is undertaken. Results from (3) should help to identify such a technique.

5. Control of powdery mildew without the use of fungicides should be investigated. Possible areas for investigation include water sprays (see: Jarvis and Slingsby 1987; Yarwood 1930), antagonistic fungi, nutrient sprays to encourage antagonistic fungi, and manipulation of glasshouse humidity and temperature.

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Yarwood C E (1939). Control of powdery mildews with a water spray. Phytopathology 29, 288-290.

Acknowledgements

We sincerely thank Mr H Hammond and Mr L Risdale for allowing us to carry out the experiments in their crops; David Stokes, ADAS Huntingdon for helping to co-ordinate the trials and making observations on phytotoxicity and spray deposits; Peter Hancocks, ADAS Worcester, for collecting samples of mildew from crops for sensitivity testing; and to several growers who allowed us to collect samples of affected leaves from their crops.

Storage of Data

The raw data will be stored by the ADAS Regional Plant Pathologist, Block C, Government Buildings, Brooklands Avenue, Cambridge CB2 2DR for a period of 10 years. The Horticultural Development Council will be consulted before disposal.

SPRAY PROGRAMMES FOR TOMATO POWDERY MILDEW - 1991

Powdery mildew need not be a problem in your tomato crop this season.

ADAS experiments sponsored by the HDC during 1990, together with observations in other crops, show that this potentially damaging disease is well controlled by several fungicides where the products are applied in good time. A single spray with some products, if applied promptly, appears to give persistent protection for several weeks. However, once mildew is well established and very obvious in a crop a single spray is usually insufficient and 2 or 3 sprays may be required to bring the disease under control. With an intensive spray programme there is a possible consequential disruptive effect on biological pest control disruption of picking due to harvest interval restrictions, and an increased risk of fungicide resistance developing. Hence the need for constant vigilance, and timely action when the disease is found.

Symptoms

The disease is usually first seen as small white blotches or floury deposits, mainly on the upper leaf surface; affected areas may spread and coalesce so that all of the leaf surface is covered. In some cases the fungus develops as a fine growth over the leaf surface, more difficult to see than the discrete blotches. Symptoms on the lower leaf surface and stem are less common, and fruit are not affected, although the calyx may be. The disease may initially appear to be causing little damage but without treatment it can suddenly develop to affect most of a crop, causing serious leaf yellowing, defoliation and loss of yield. Some untreated crops in 1990 were pulled out up to a month early because of mildew.

HDC Trials 1990

Programmes of the following products all gave very good control:

Rubigan (at 28 day intervals)
Nimrod (at 28 days)
Repulse (at 14 days)
Elvaron (at 14 days)
Thiovit + Agral (at 14 days)

The first sprays were applied shortly after mildew was found in the crop. The disease spread and eventually reached up to 50% leaf area affected on untreated plants and less than 5% in any of the treated plots. The best control was given by Nimbrod and Rubigan. It is interesting to note that Repulse, Elvaron and Thiovit applied when the disease was still at a very low level all gave good disease control. Earlier trials have shown that Repulse is less effective than Rubigan and Nimrod when applied several days after infection has occurred, particularly for control of the disease on lower leaf surfaces.

A summary of fungicides with activity against powdery mildew is shown in the table below:

Fungicides active against powdery mildew

Product	Maximum rate	Maximum No sprays	Spray interval (days)	Harvest interval (days)	Comment
Bavistin	100g/1001	-	14	0	
Benlate	100g/1001	-	-	0	
Elvaron	100g/1001	-	14	3	
Nimrod	200ml/1001	6	-	2	OLA 969/88
Repulse	220ml/1001	-	7-14	½	
Rubigan	18ml/1001	3	28	2	OLA 305/90
Thiovit	200g/1001	-	14	2	OLA 39/90

Notes

1. None of the products has a label recommendation for control of powdery mildew.

2. Off label approvals (OLA) are used entirely at a grower's own risk.

Spray Programmes for 1991

Some suggested programmes for different situations are listed in the table below. All treatments shown are at 2 week intervals.

These suggested programmes are an outline scheme only and there are many other sequences which could be used, and other modifications which could be made. ADAS Plant Pathologists and tomato advisers will be pleased to discuss spray programmes for individual nurseries and how best to integrate control of powdery mildew with control of other diseases (eg botrytis), and with the use of biological pest control agents.

It is difficult to use a preventative programme sensibly because the disease may occur at any time - in 1990 outbreaks occurred on some nurseries as early as January or February and on others not until August or September - and once a preventative programme is started it needs to be continued in order to be certain it will be effective.

An alternative approach is to make careful observations regularly in all crops so that the first few spots of disease are recognised - and an eradicant fungicide such as Nimrod or Rubigan should then be used for the initial spray. Be especially vigilant for symptoms and prepared for immediate treatment if you know that crops close-by are affected, particularly if your nursery is downwind of an affected crop. It is preferable to spray a whole block rather than to spot-treat. When symptoms are visible in one area spores are already spread elsewhere in the house.

Experience to date indicates that 2 or 3 suitable sprays are sufficient to provide control provided the first treatment is applied as soon as the disease is found.

For growers who may wish to apply protectant sprays during high risk weather periods (high humidity, in late summer and early autumn), or when the disease is very close-by, it would be preferable to use products such as Repulse (a good protectant) and to reserve the eradicant materials lest the disease does occur.

<u>Spray Programmes for powdery mildew</u>

Preventative	Low levels of disease	Widespread & obvious in a crop
Repulse*	Rubigan	Rubigan
-	Repulse	Nimrod
Repulse*	Rubigan	Rubigan
-	-	Repulse
Repulse*	-	-
-	-	-

* Or equivalent product - no spray

- Carefully follow instructions on product labels and Off-Label Approval documents. Some of the product information is summarised in the first table.

- Note that in some situations Rubigan may cause fruit marking and Nimrod may cause leaf marking.

- Nimrod may temporarily disrupt whitefly control where Encarsia parasites are used.

- Information on effects of fungicides on pollinating bees is limited; there are some reports that MBC fungicides and possibly Nimrod may be harmful.

Summary

Check now around the nursery and within cropping houses for weed tomato plants. Destroy any found.

Use heat and ventilation to reduce high humidity and thereby reduce the risk of infection. Inspect crops carefully during high risk weather periods, especially in late summer and early autumn.

Be vigilant for symptoms in your crop and apply an eradicant spray treatment as soon as symptoms are found.

Tim O'Neill
Plant Pathology
Cambridge

APPENDIX 2

Contract between ADAS (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for a research/development project.

PROPOSAL

1. TITLE OF PROJECT Project Number PC 26

TOMATO: CONTROL OF POWDERY MILDEW

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Powdery mildew is a relatively new disease to affect tomatoes in England and is increasing in importance. Some crops, both round and cherry tomatoes, have been severely affected. The disease may progress rapidly causing leaf yellowing and necrosis and a consequent reduction in fruit yield. Infection may occur as early as January, although it usually appears later in the year.

Off-label approvals have been approved for Rubigan and Nimrod, and these have proved reasonably successful; the new OLA for Rubigan allows 3 treatments per crop at 28 day intervals. An off-label approval for sulphur was listed in January 1990.

On cucumber, frequent use of certain fungicides to control powdery mildew has resulted in reduced fungicide sensitivity and poor disease control (Schepers 1983; 1985). The same reduction in fungicide efficacy may occur on tomato as powdery mildew becomes more common and fungal populations are increasingly subjected to fungicide treatment. It is important to determine the baseline sensitivity of tomato powdery mildew now so that reduced sensitivity can be investigated as a possible cause should there be instances of poor disease control in the future.

The commercial objectives of the investigation proposed here are:

(1) identification of effective fungicide spray treatments.

(2) to determine the current sensitivity of powdery mildew to selected fungicides.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

Grower experience in 1988 and 1989 indicates that in some cases 2 or 3 well-timed sprays of a fungicide can be sufficient to eliminate powdery mildew for the season. On other nurseries many sprays be required to get the disease under control. Identification of suitable spray sequences would minimise fungicide input (and thereby save costs), and allow more rapid disease control (and thereby minimise loss to the disease). Without treatment the disease usually continues to develop, and many cause death of plants within 3-4 weeks.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

(i) To compare the efficacy of different fungicide spray treatments and programmes in controlling powdery mildew.

(ii) To monitor the glasshouse environment (temperature and relative humidity) to try and relate disease development to environmental conditions.

(iii) To determine the sensitivity of powdery mildew isolates to bupirimate (Nimrod) and fenarimol (Rubigan).

5. Closely related work-completed or in progress

A controlled comparison of the 3 fungicides with OLA for tomato powdery mildew has not so far been made.

Dr J Fletcher (ADAS, Wye) has investigated the effects of single sprays of various fungicides as preventative and curative treatments in glasshouse experimental work (Fletcher et al, 1989), and is continuing to investigate tomato powdery mildew. The work here would be done in collaboration with him.

6. Description of proposed work

1. Comparison of fungicide programmes

Randomised block trials would be set up on two commercial nurseries, probably on cherry tomatoes where the disease has occurred in many crops in the past two years. Treatments would be started soon after the disease is first observed (probably in mid-summer). Levels of disease (% leaf area affected in top, mid and lower leaf canopy) would be assessed at the start of the trial and at regular intervals thereafter. Sprays would be applied by knapsack sprayer. Running the trial on 2 nurseries will (a) provide an indication of the reliability of results obtained and (b) reduce the travel time per trial as the proposed sites are in the same area.

Plants would be examined for phytotoxic or other symtoms on leaves and fruit, and any gross effects on pest levels (detailed pest assessments would not be made), and other diseases (eg. botrytis).

Treatments would include

A. Untreated
B. Rubigan at 28 day intervals, maximum of 3 sprays
C. Nimrod at 28 day intervals
D. Sulphur + Agral at 14 day intervals
E. Elvaron at 14 day intervals
F. Repulse at 14 day intervals
G. Rubigan alternating with Nimrod at 14 day intervals
H. Rubigan followed by Nimrod (14d), then Repulse (14d)

Trials would depend on co-operation of participating growers. Two growers have given provisional agreement for the trial. If other diseases or obvious crop detrimental effects appear, some treatments may need to be curtailed prematurely.

2. Investigation of fungicide sensitivity

Isolates of powdery mildew will be collected from crops and examined for sensitivity to bupirimate (Nimrod) and fenarimol (Rubigan) by inoculating leaves following treatment with each fungicide at a range of concentrations. The greatest concentration at which each isolate is able to grow will be recorded.

7. COMMENCEMENT DATE AND DURATION

June 1990, for 1 season initially; possible further trials in 1991 according to the results obtained this year.

The trials would be written up by December 1990.

8. STAFF RESPONSIBILITIES

Project Leader: Dr T M O'Neill, ADAS Plant Pathology, Cambridge RO

Other Staff: D Pye, ADAS Cambridge
Mrs C Nicholls, ADAS Cambridge
D Stokes, ADAS Cambridge

9. LOCATION

Two cherry tomato crops (cv Gardener's Delight) in East Anglia, probably at Newbourn, Suffolk.

11. PAYMENT

On each quarter date the Council will pay the Contractor in accordance with the following schedule:

QUARTER/YEAR	1990
1	
2	
3	
4	

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor (s) Signature..........................

Position. R&D. Programme Manager

Date.........9.7.90..........

Signed for the Contractor (s) Signature..........................

Position..........................

Date..........................

Signed for the Council Signature..........................

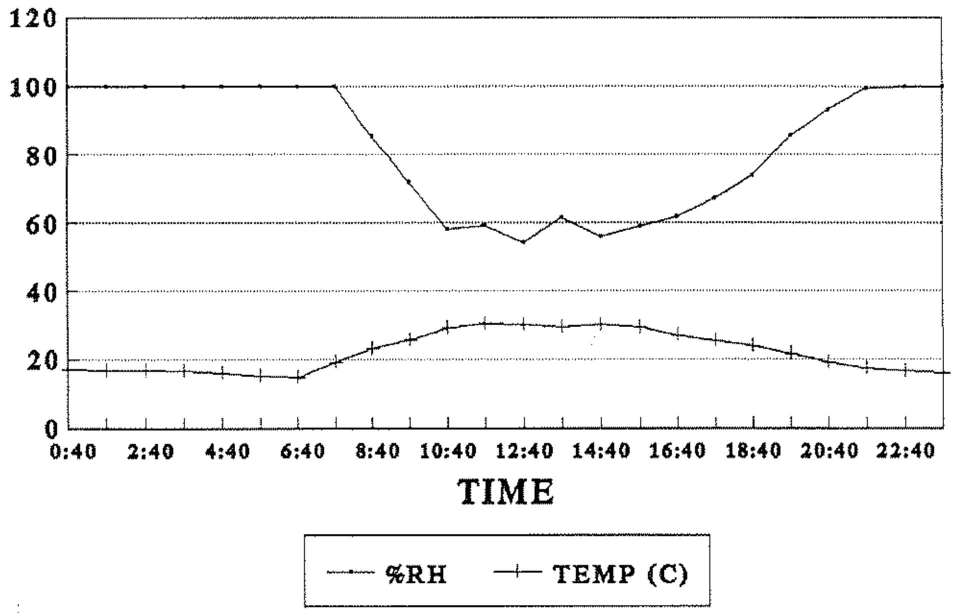
Position..........................

Date.........3.7.90..........

Temperature and Relative Humidity Records

1.	Site A	Recorder distant from doorway August 24 - October 3
2.	Site A	Comparison of recorders September 7 - September 19 Upper chart is distant from doorway
3.	Site B	October 5 - October 30

RH AND TEMPERATURE CHANGES
SITE A



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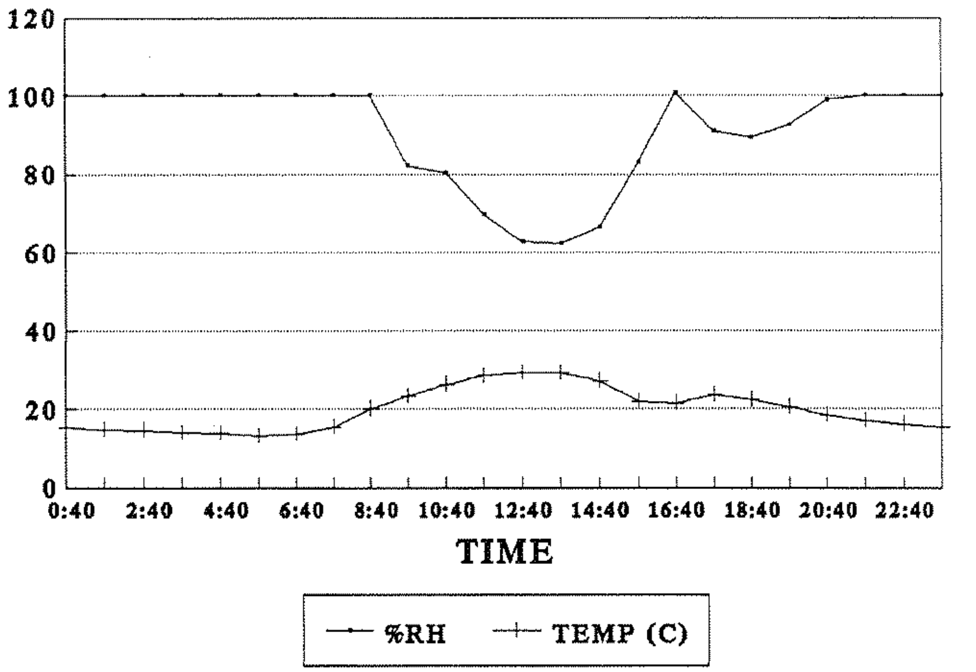

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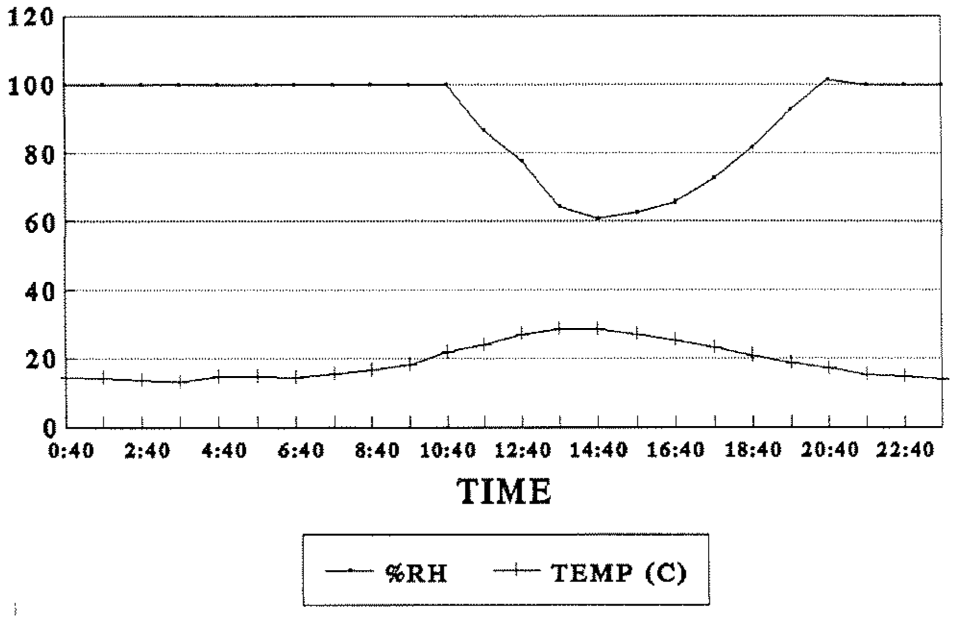

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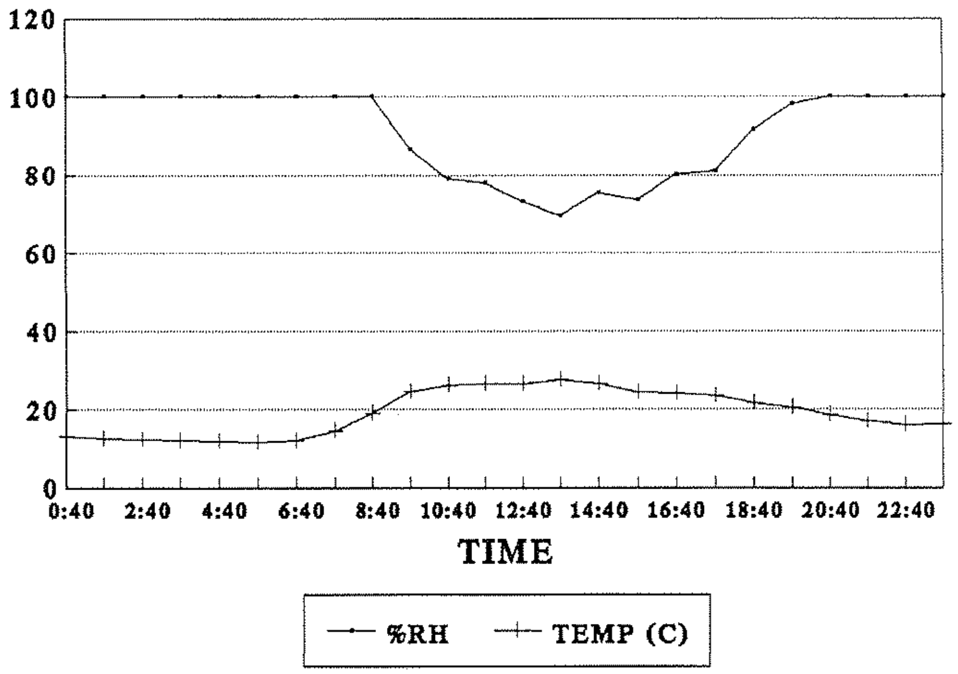

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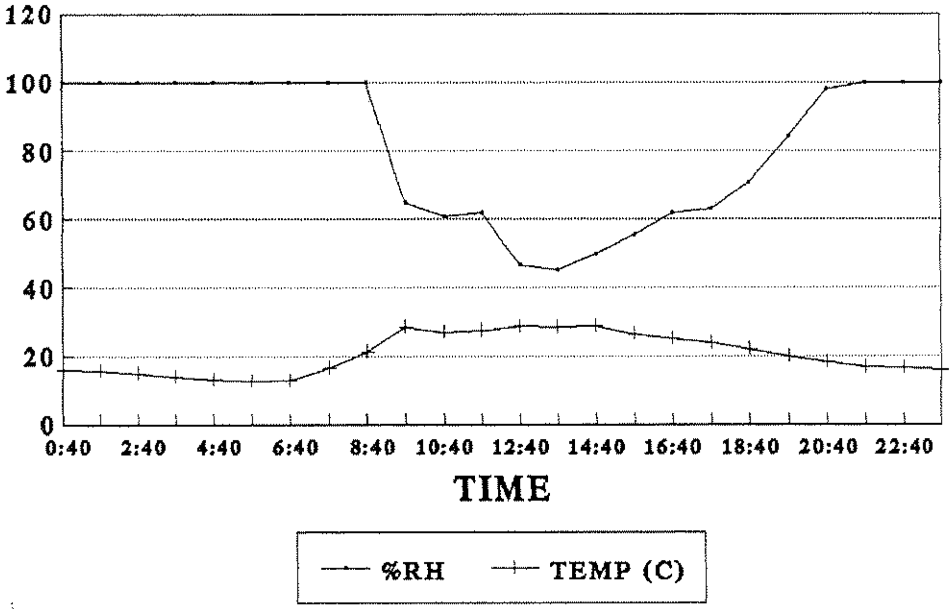

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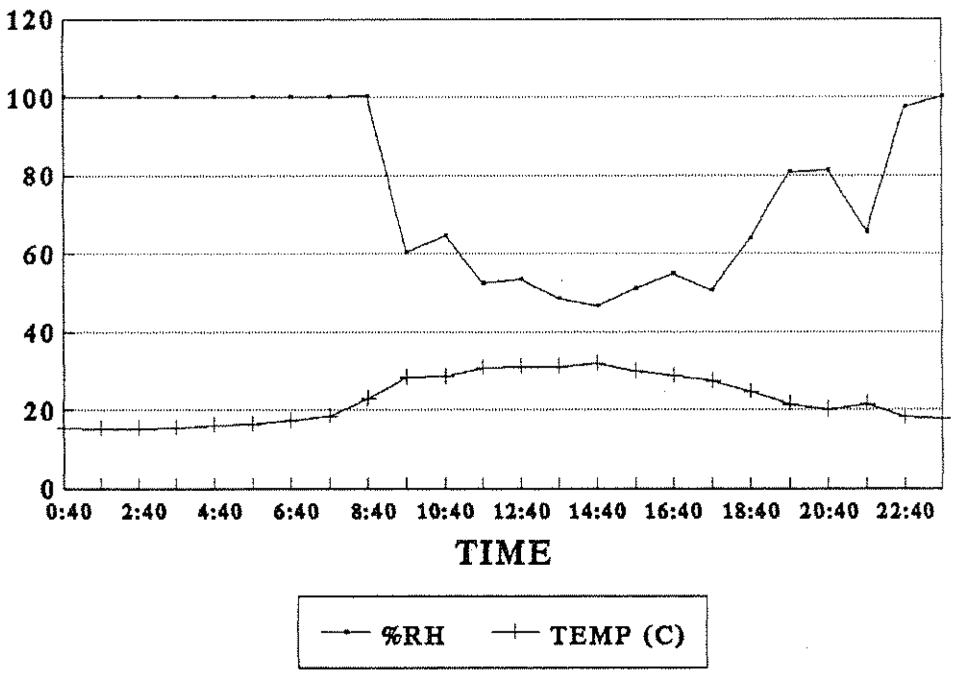

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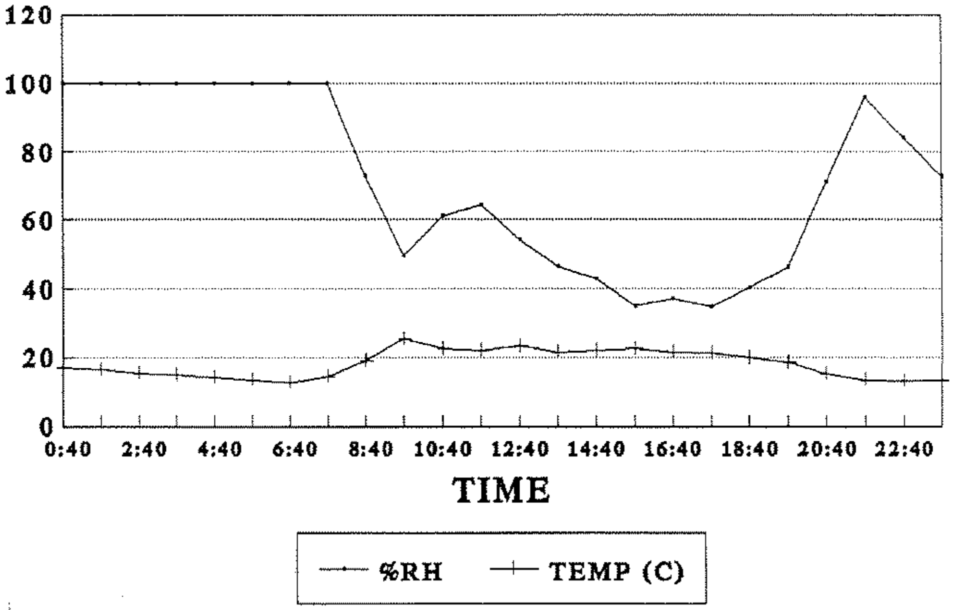

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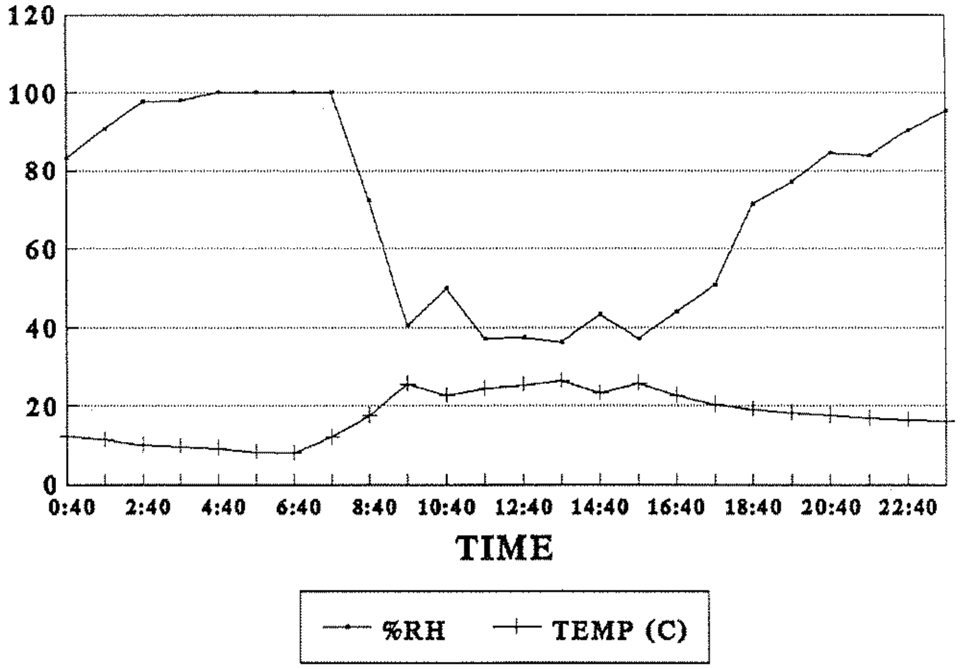

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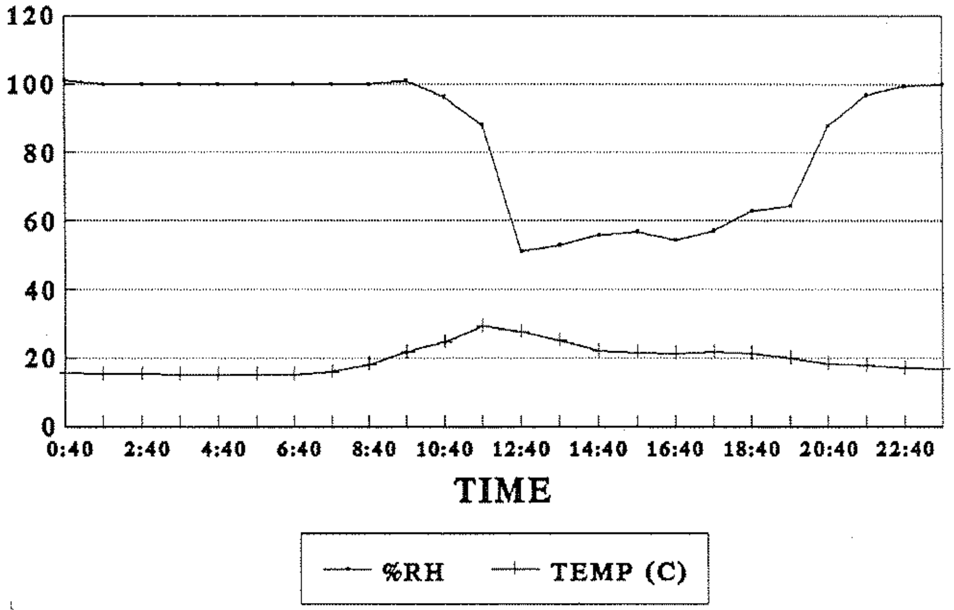

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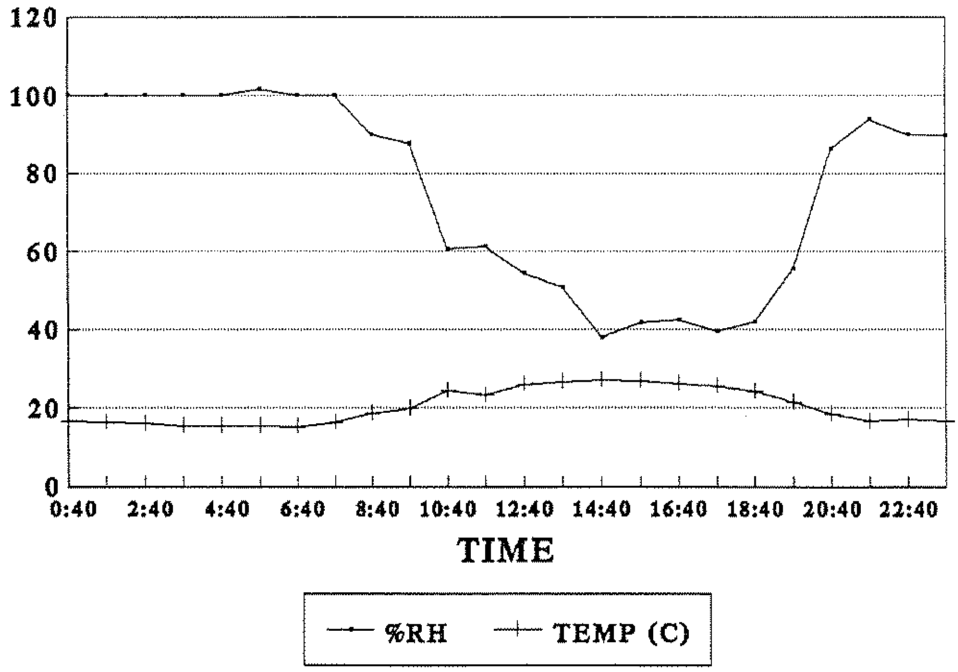

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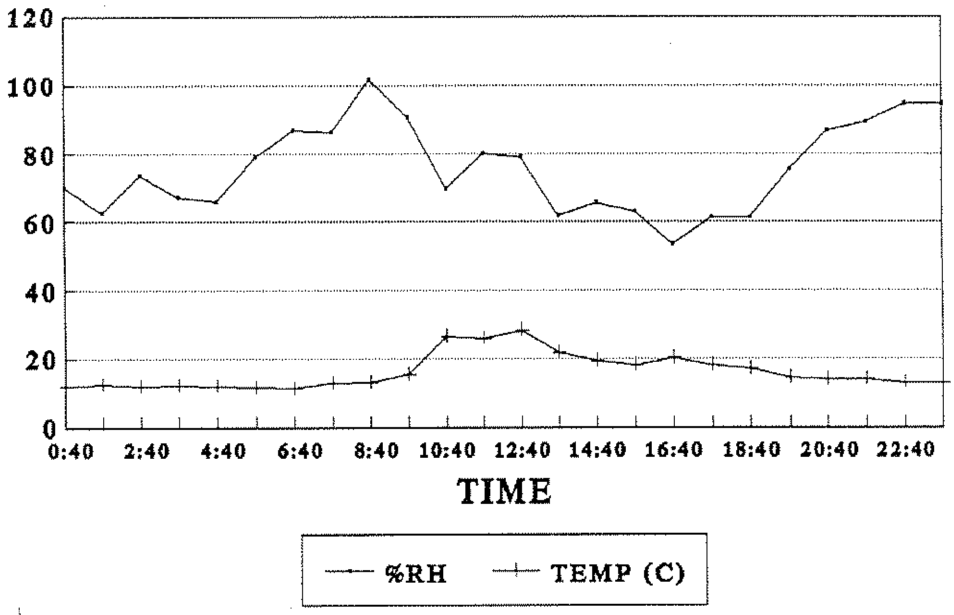

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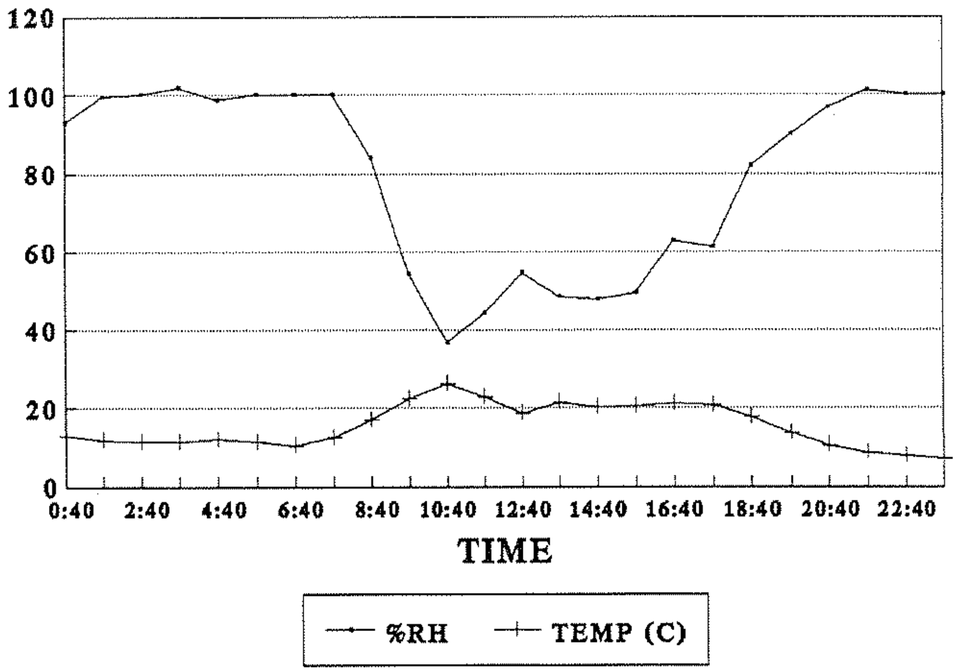

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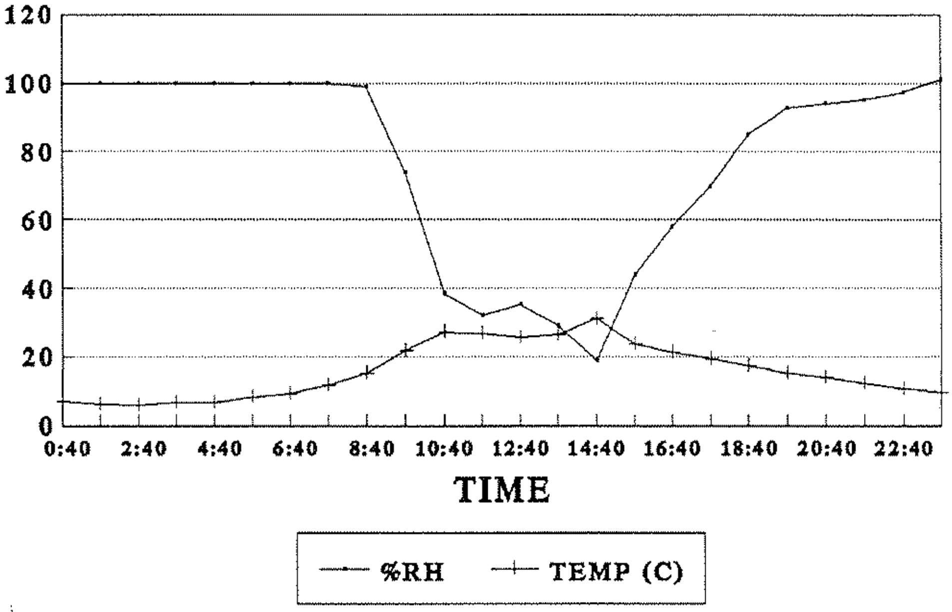

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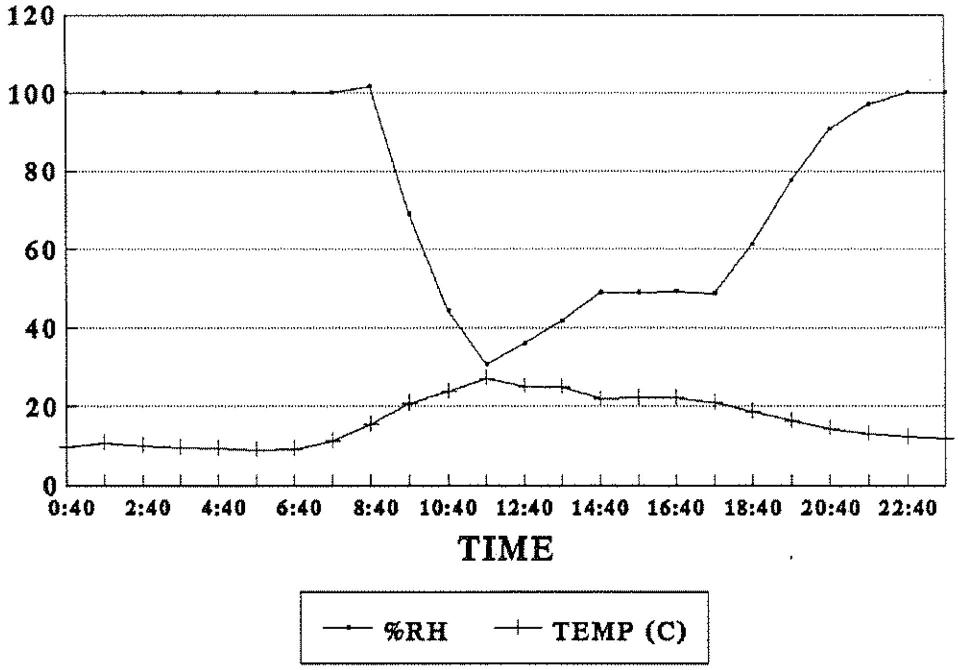

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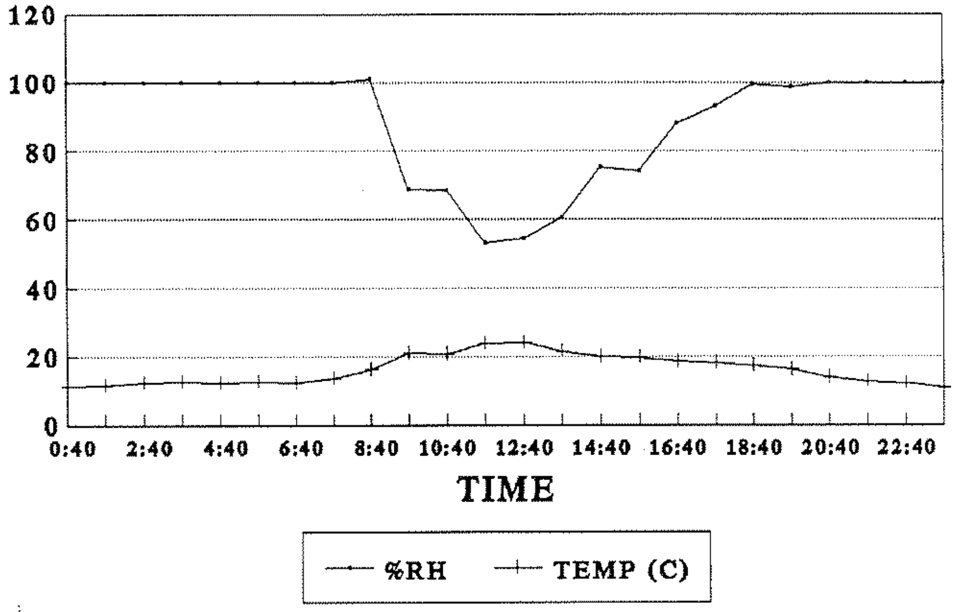

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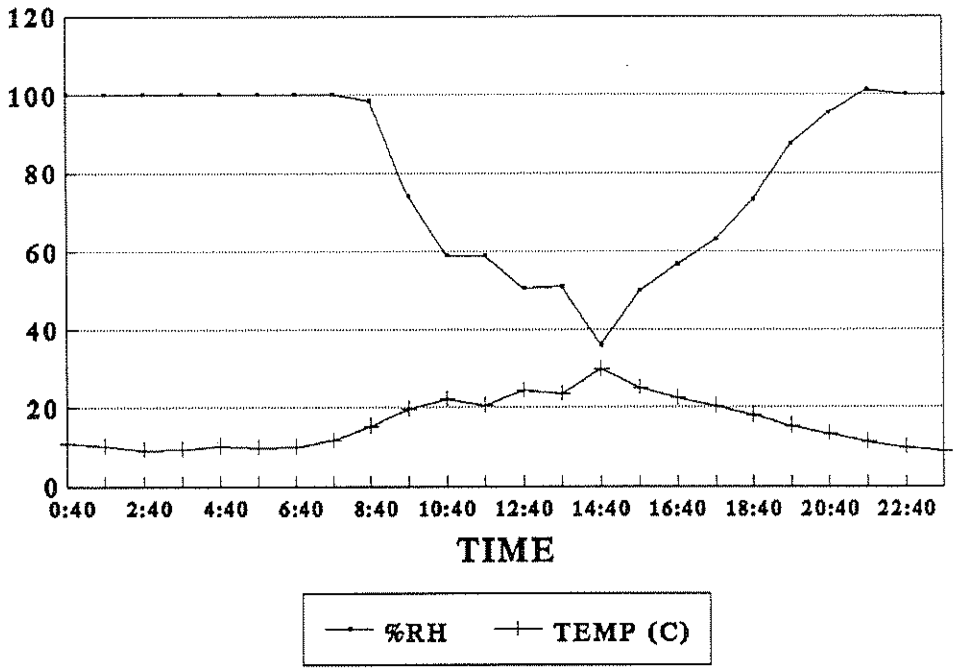

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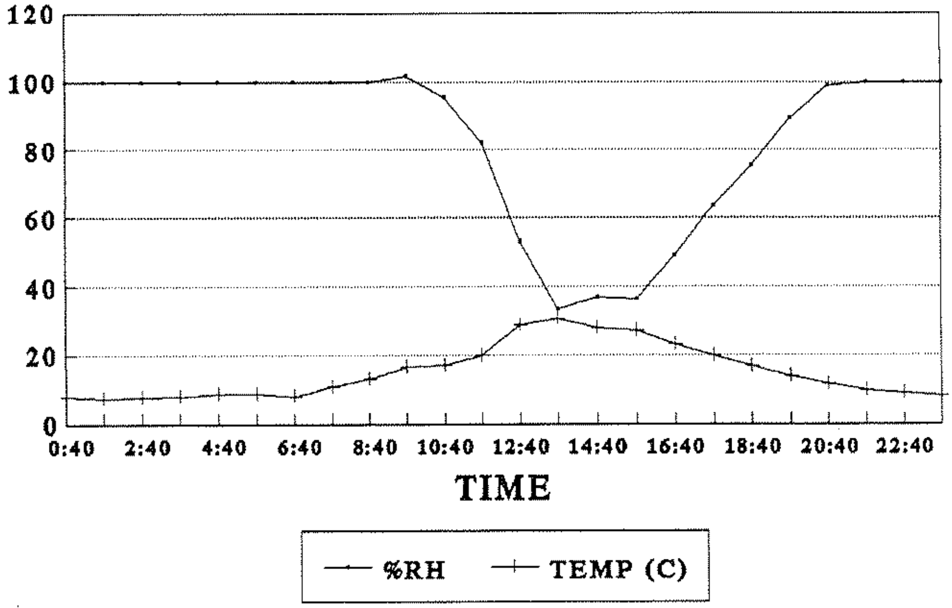

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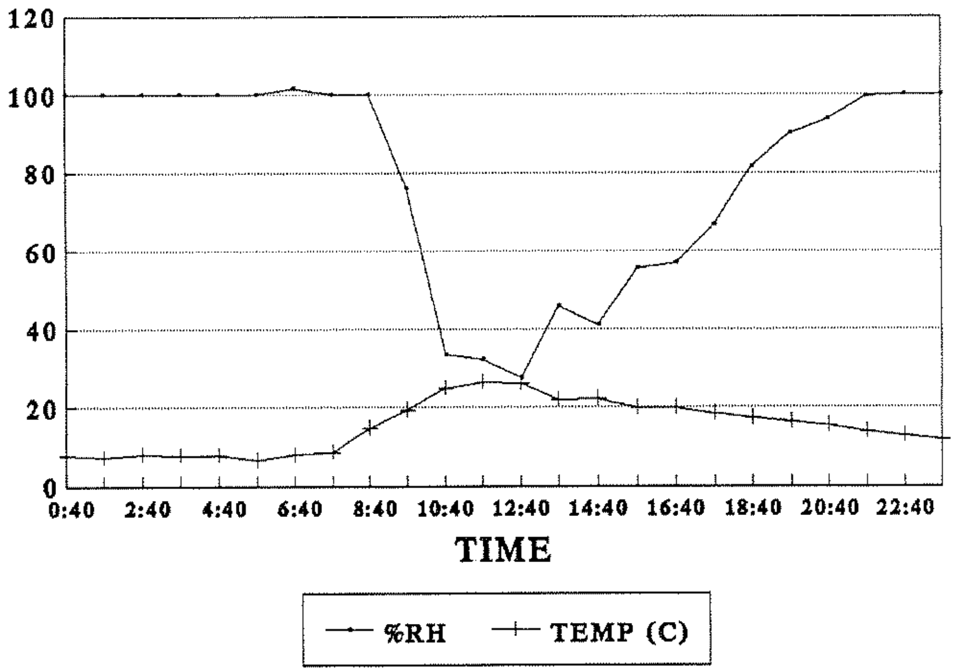

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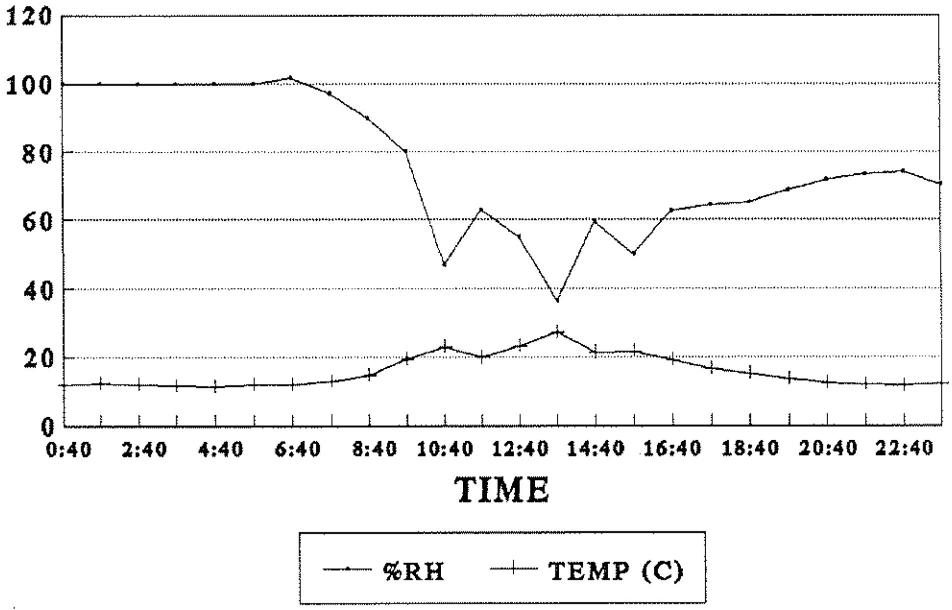

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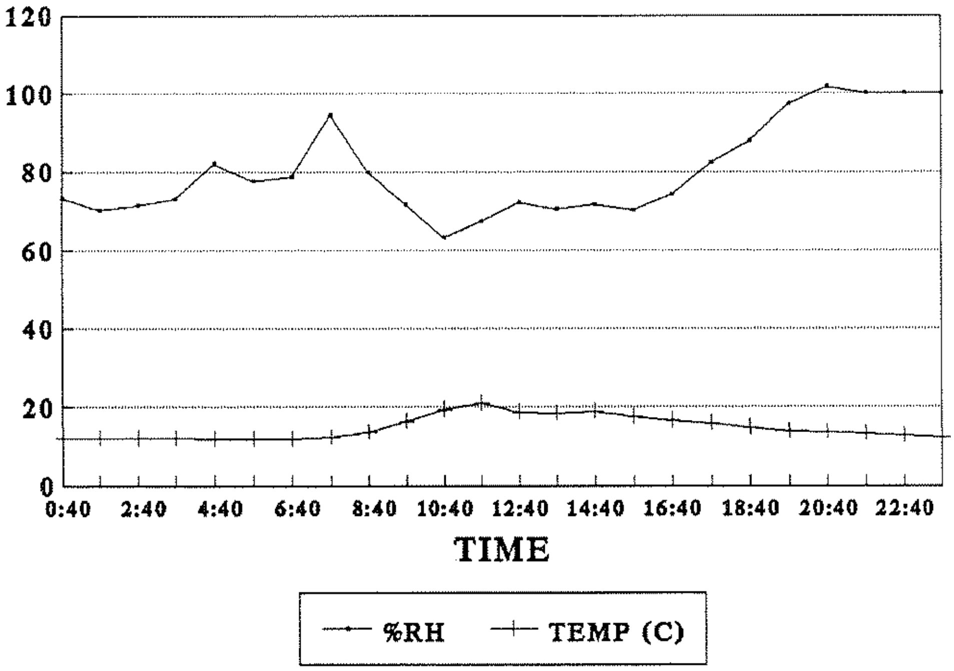

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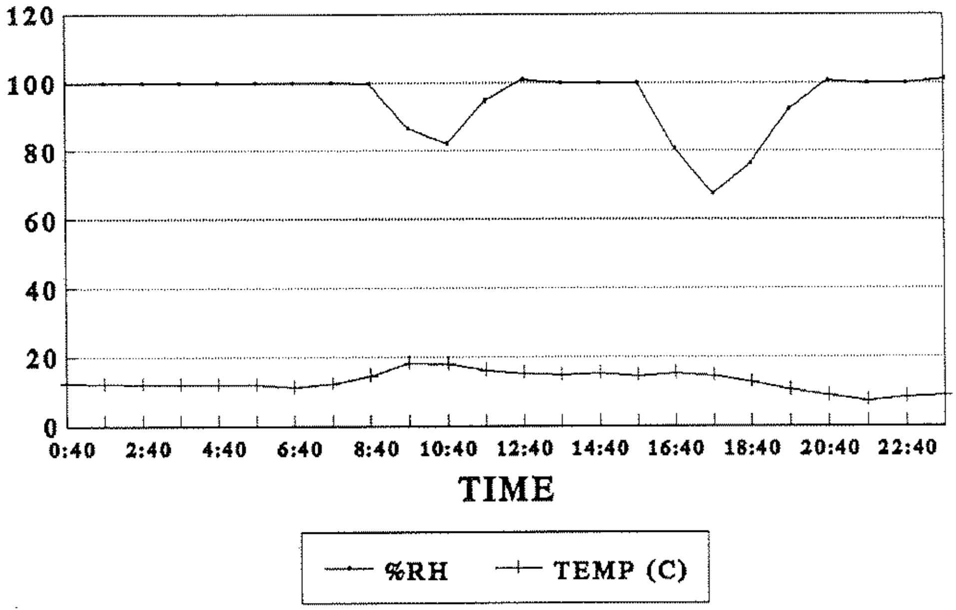

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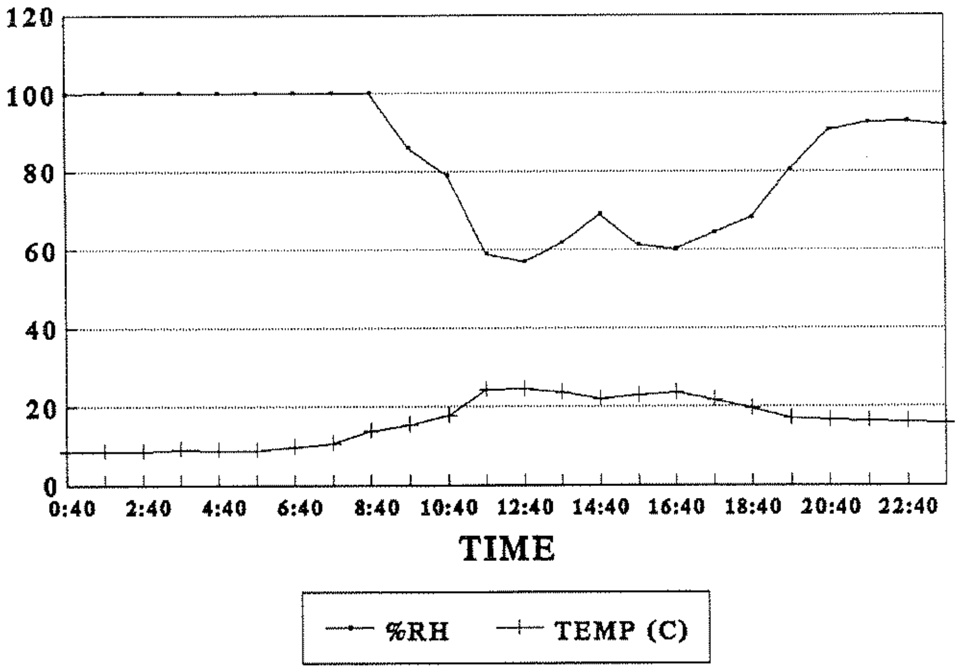

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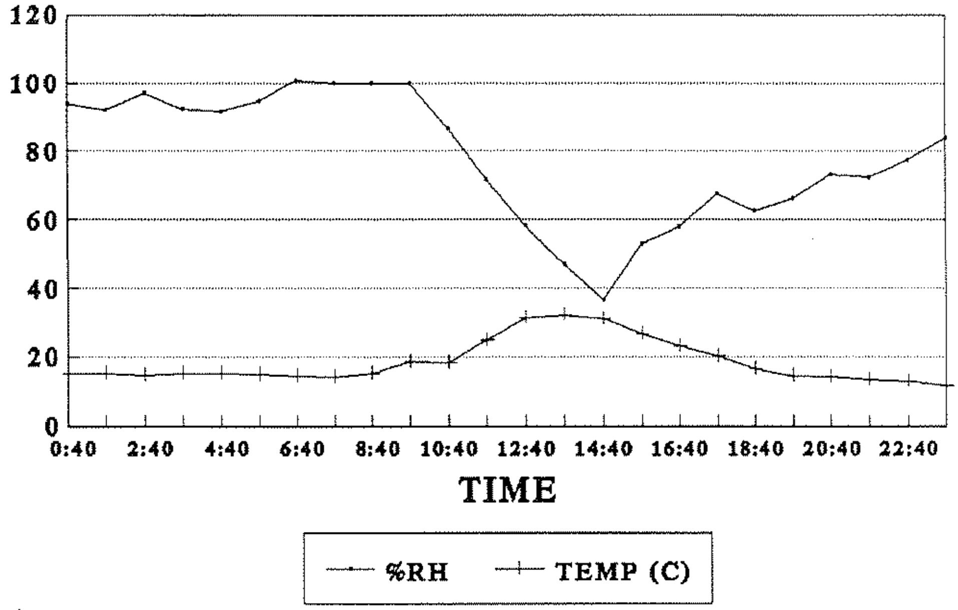

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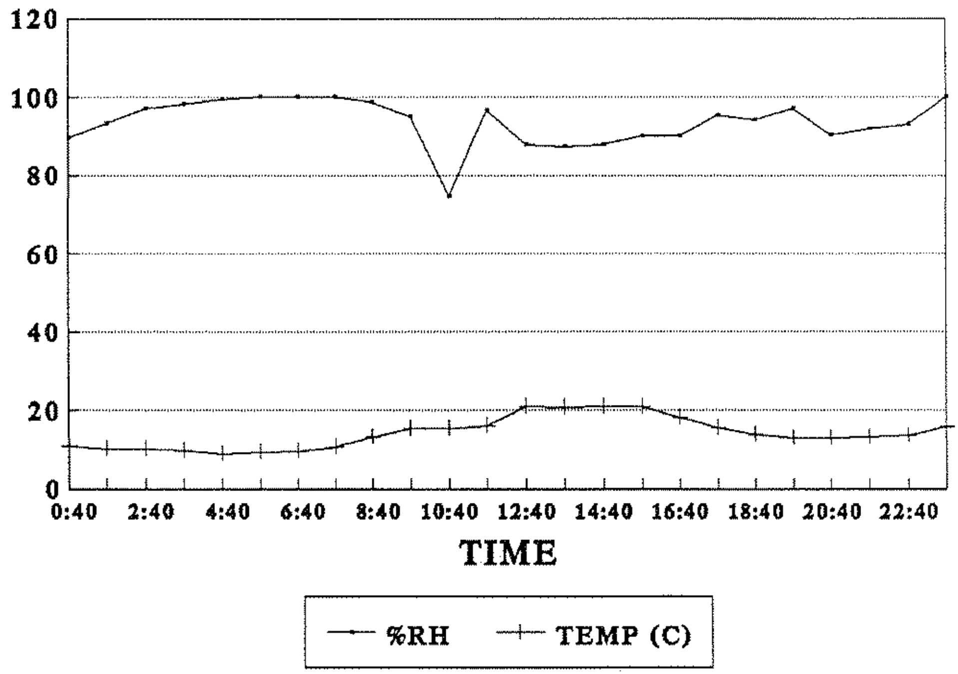

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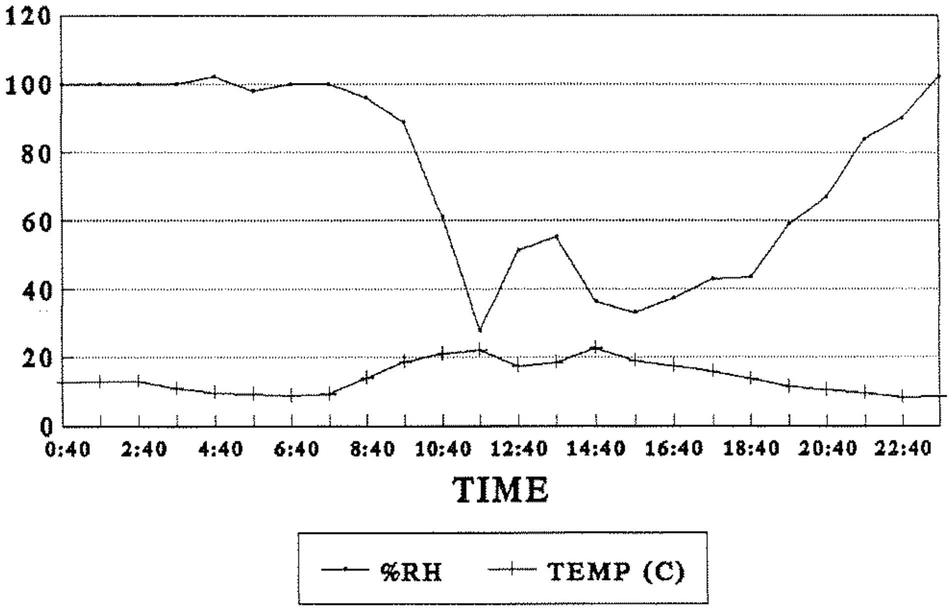

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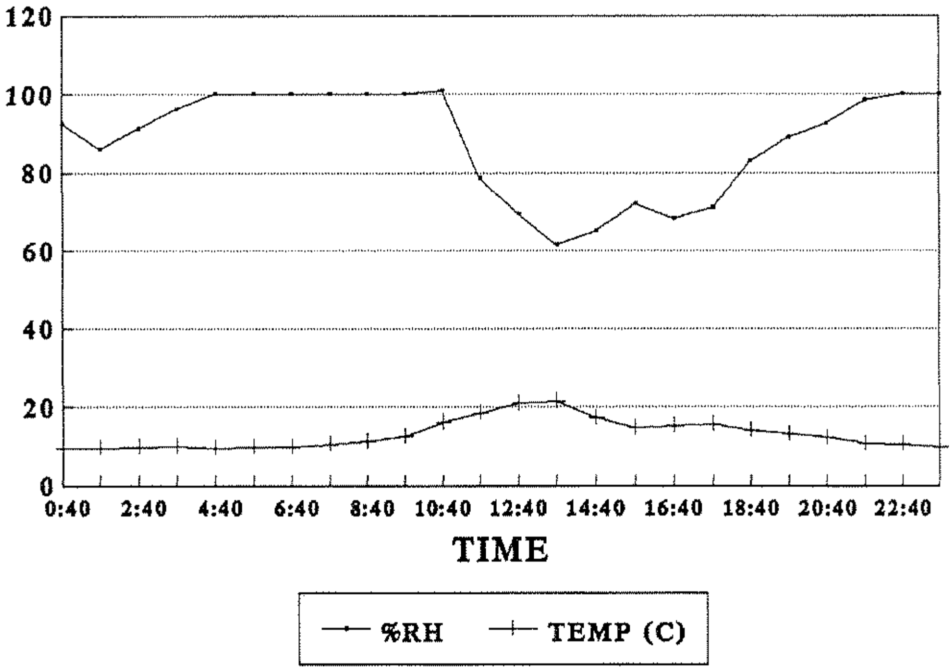

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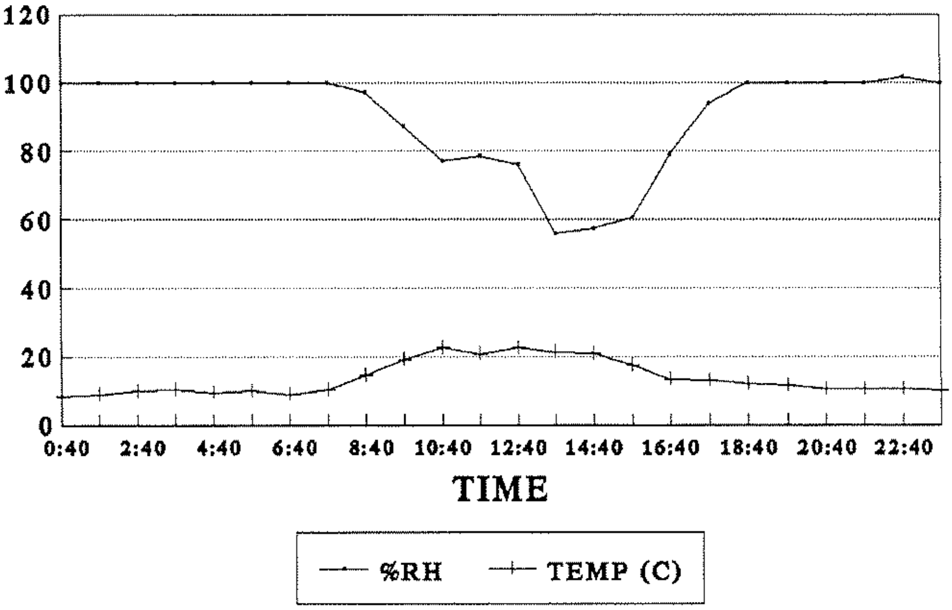
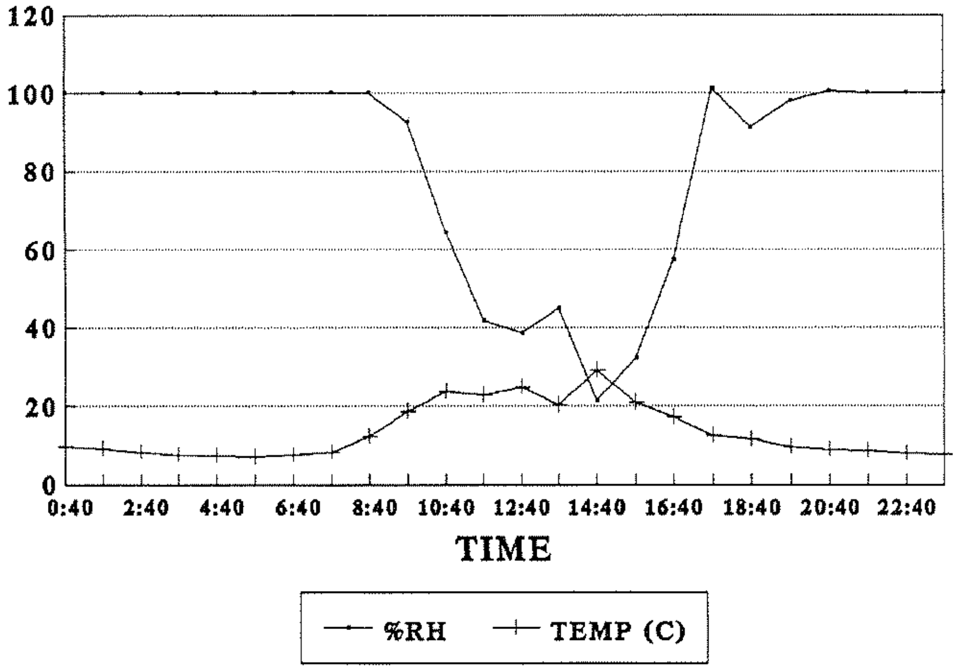
RH AND TEMPERATURE CHANGES
SITE A

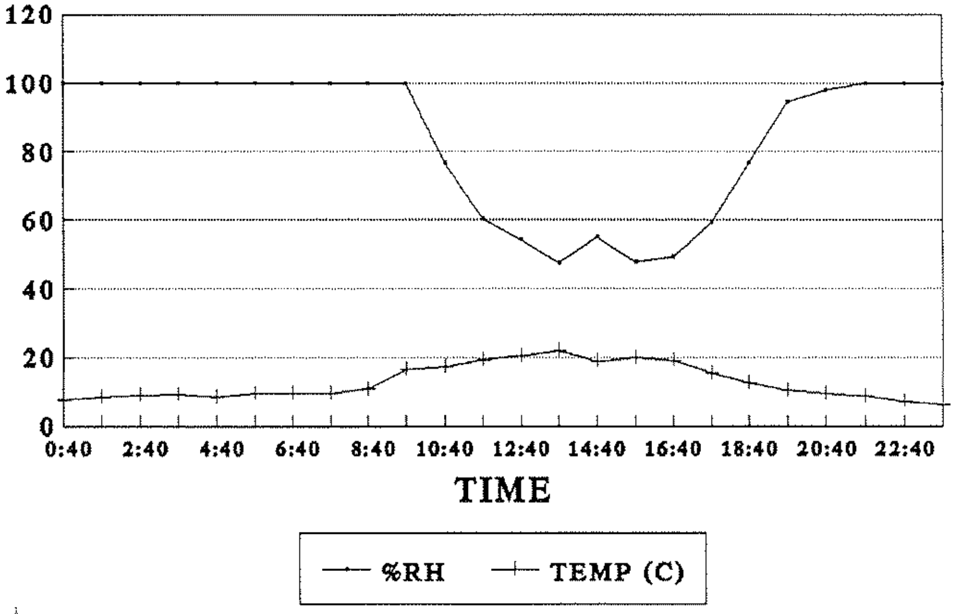


23/09/90

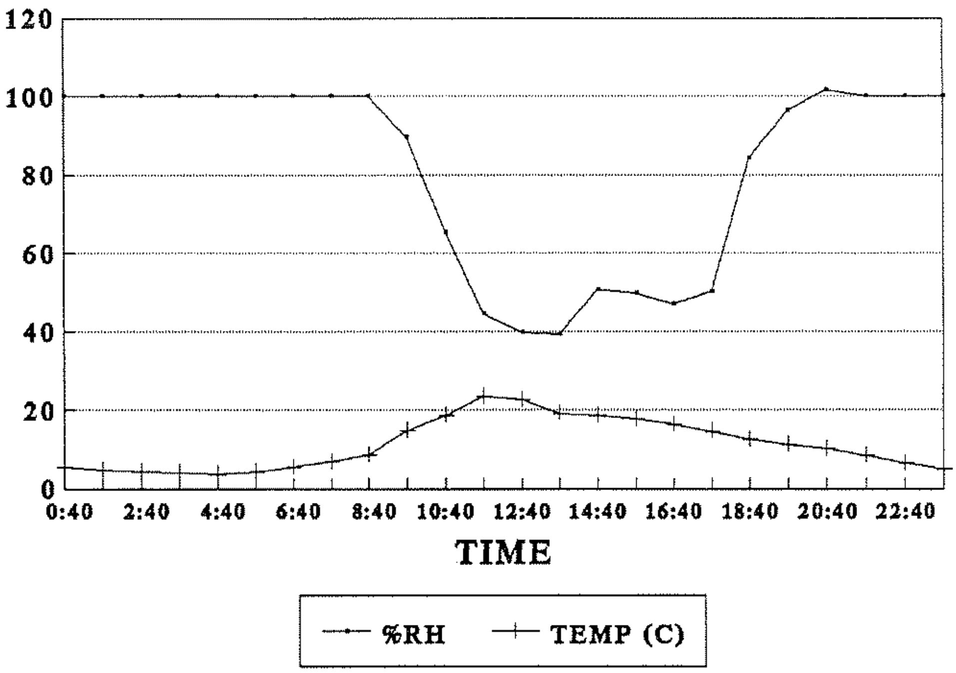


24/09/90

RH AND TEMPERATURE CHANGES SITE A

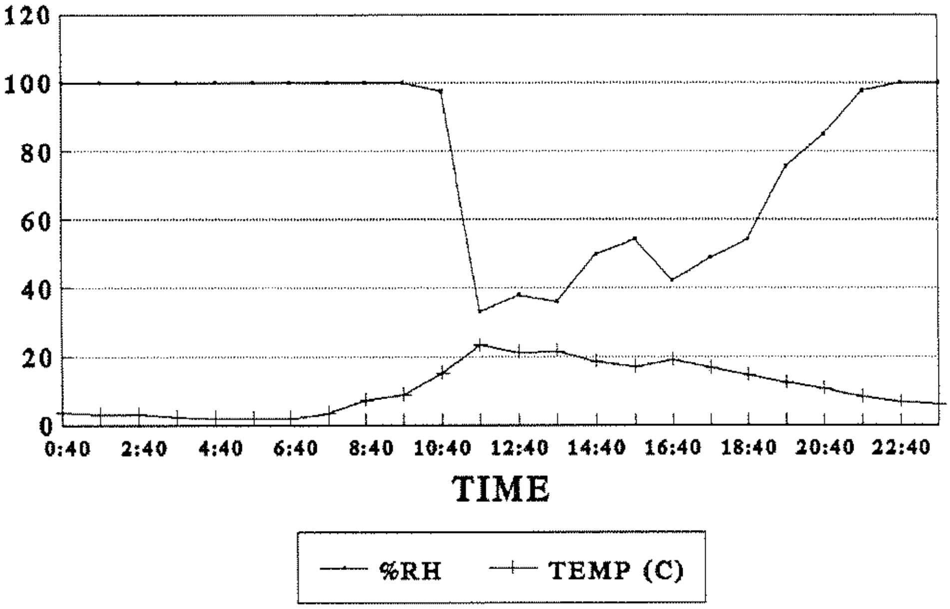


25/09/90

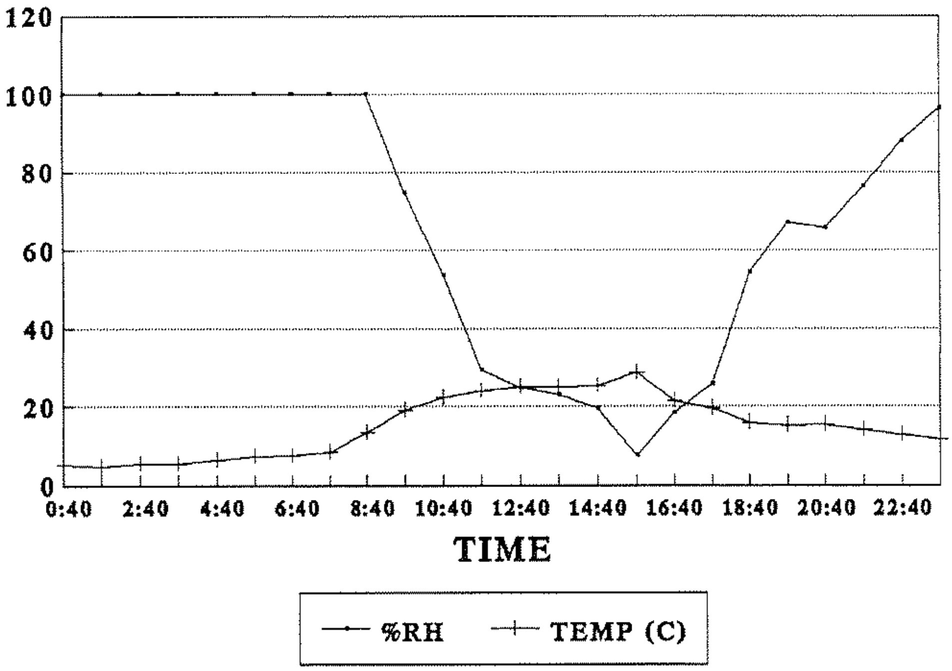


26/09/90

RH AND TEMPERATURE CHANGES SITE A

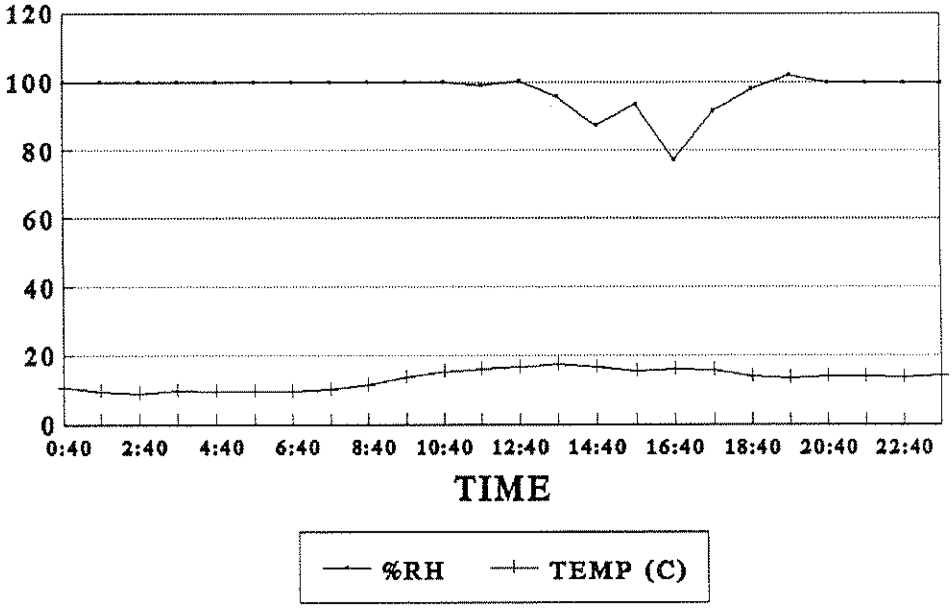


27/09/90

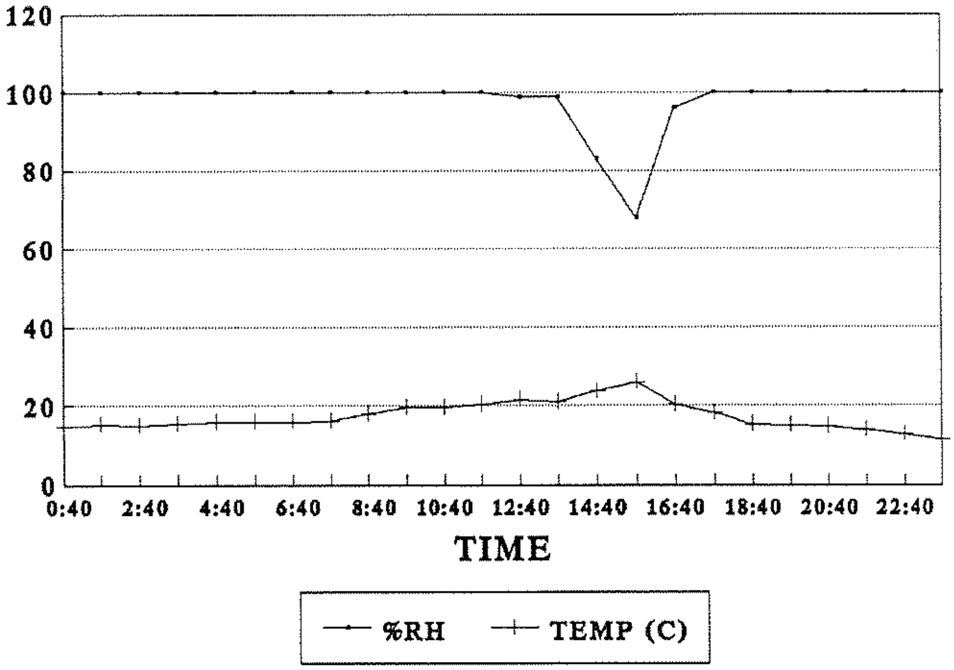


28/09/90

RH AND TEMPERATURE CHANGES
SITE A

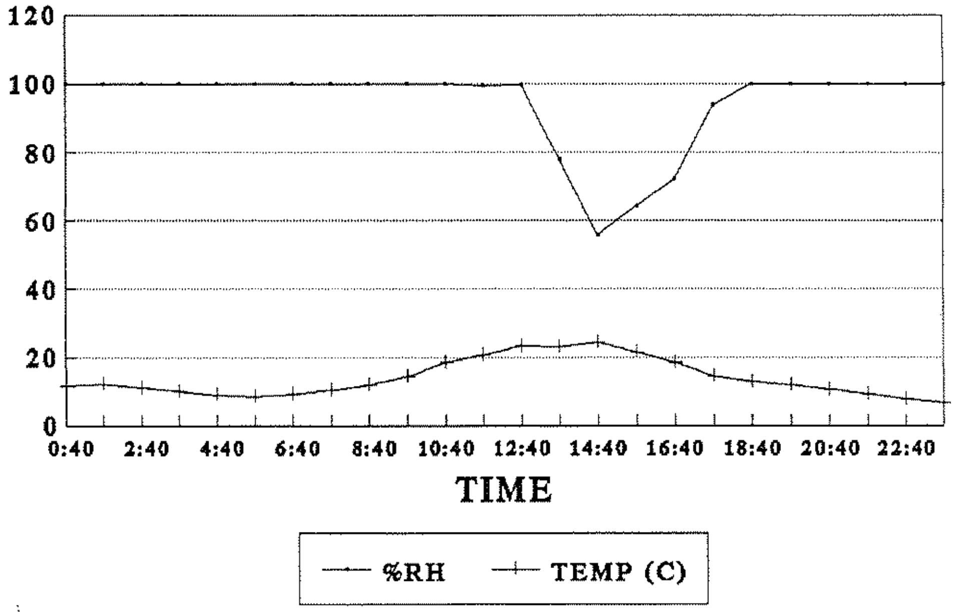


29/09/90

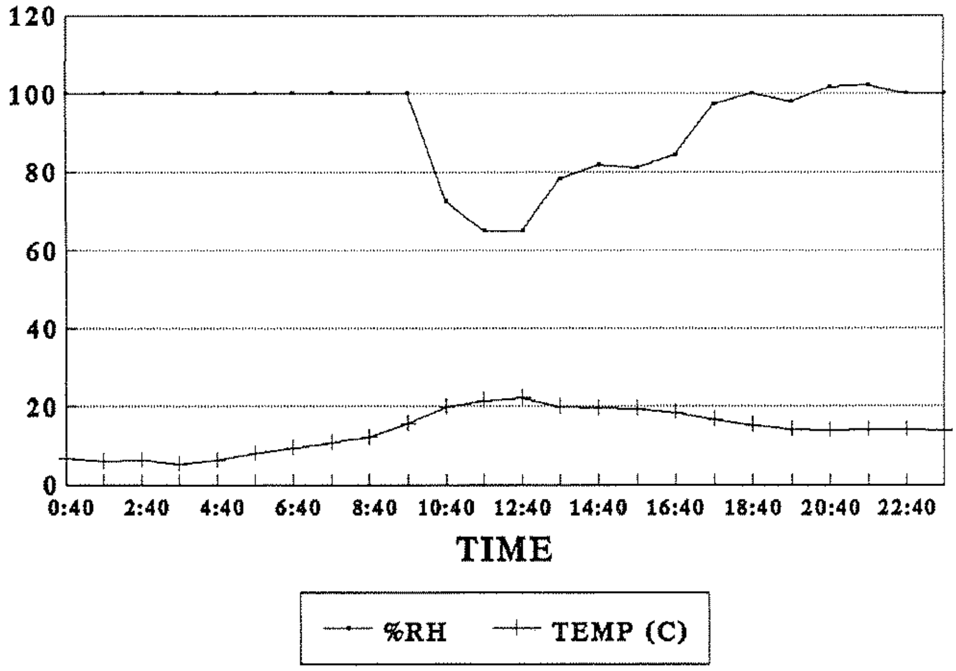


30/09/90

RH AND TEMPERATURE CHANGES
SITE A

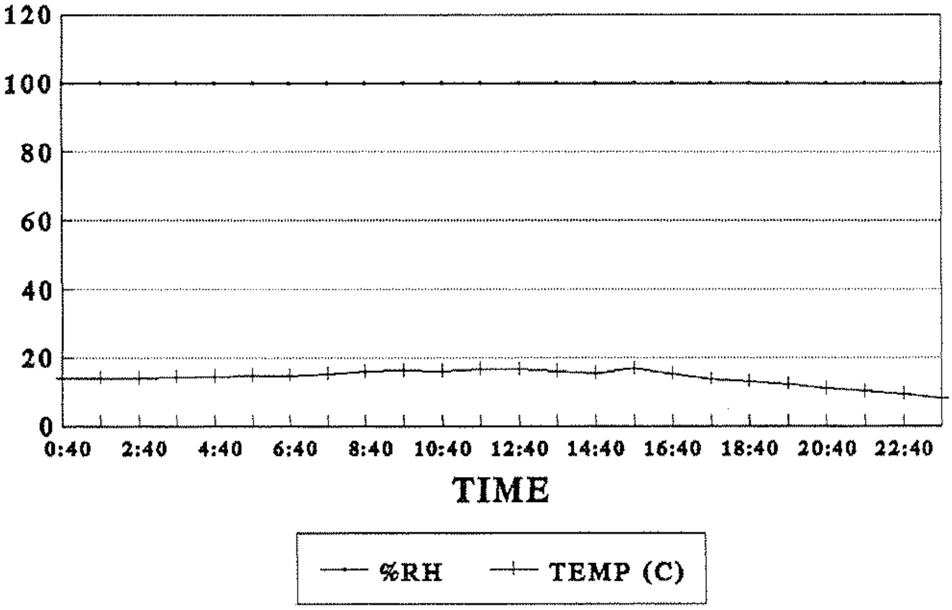


01/10/90



02/10/90

RH AND TEMPERATURE CHANGES
SITE A



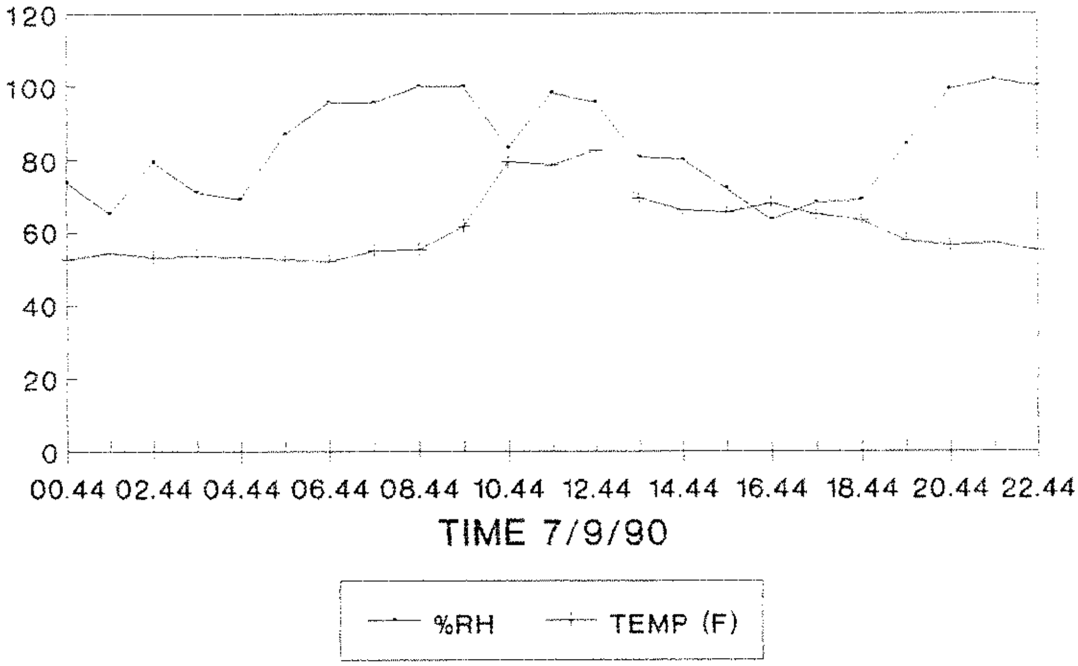
03/10/90

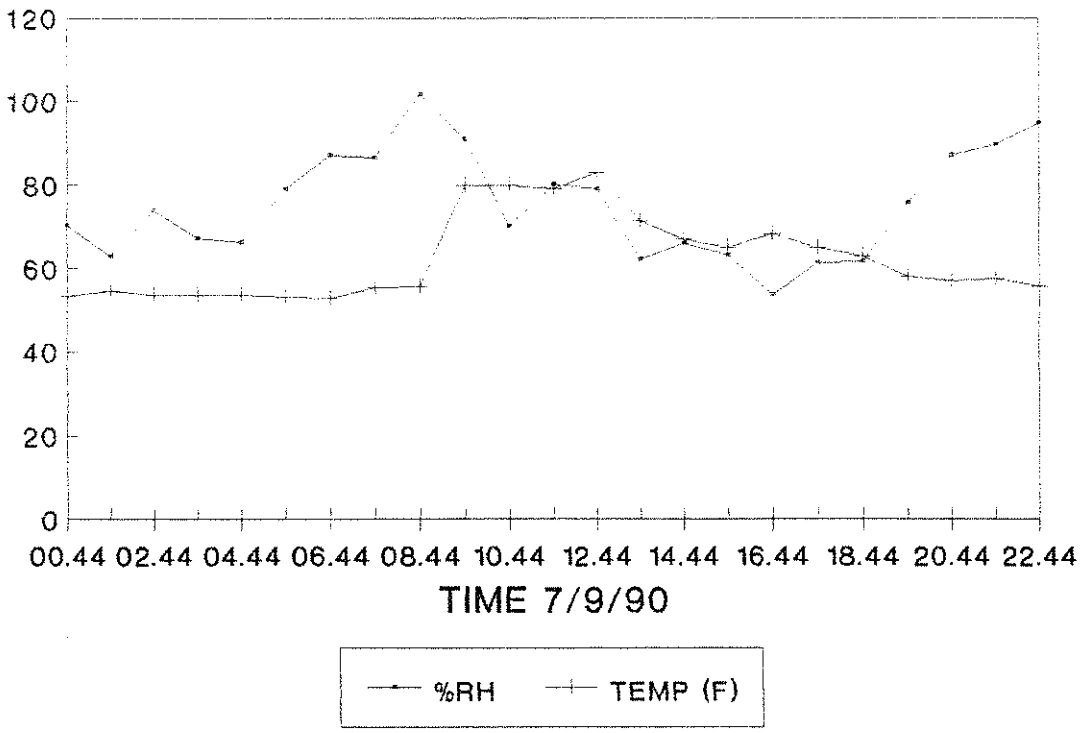
2. Site A : Comparison of recorders

7 September - 19 September

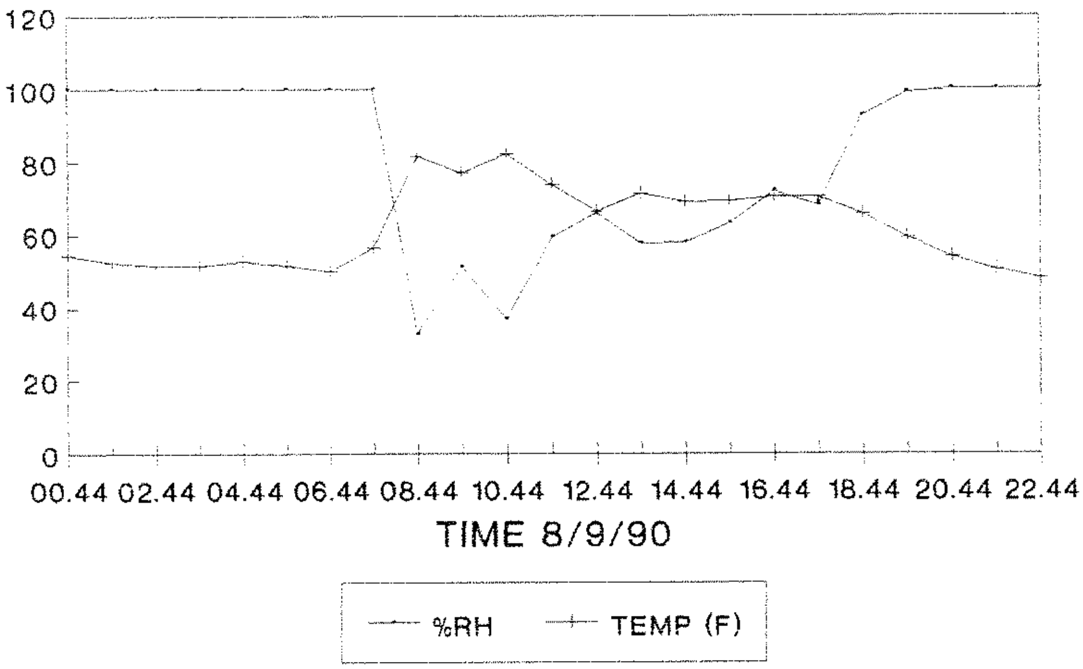
Upper chart is recorder distant from doorway

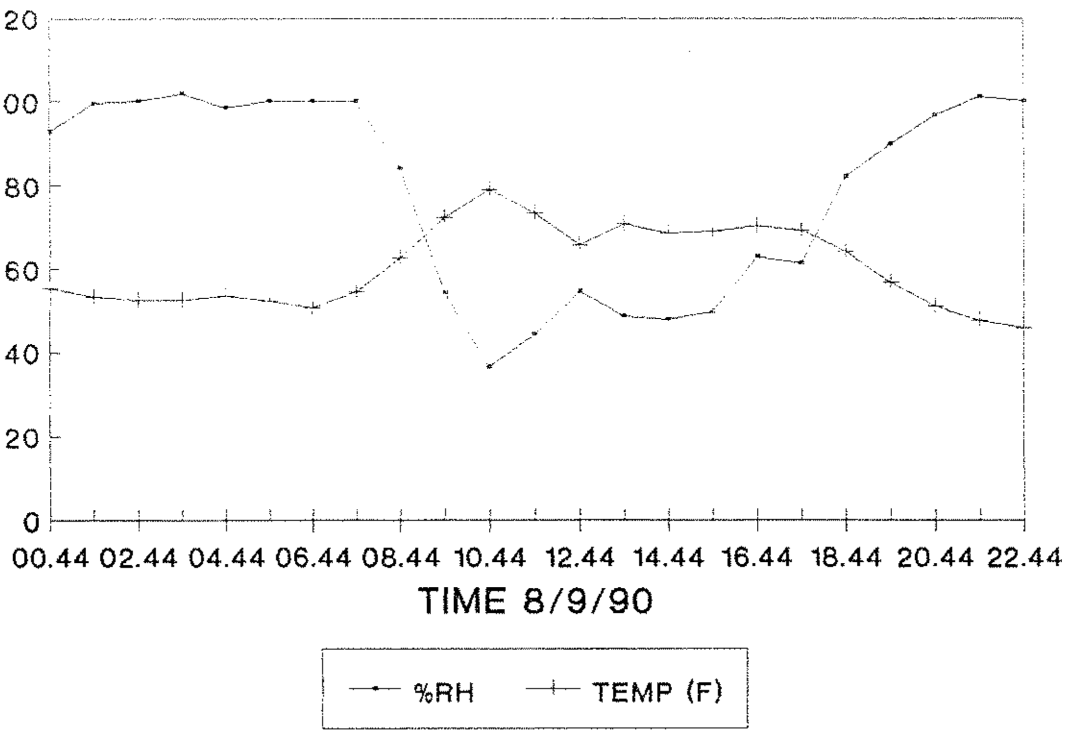
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



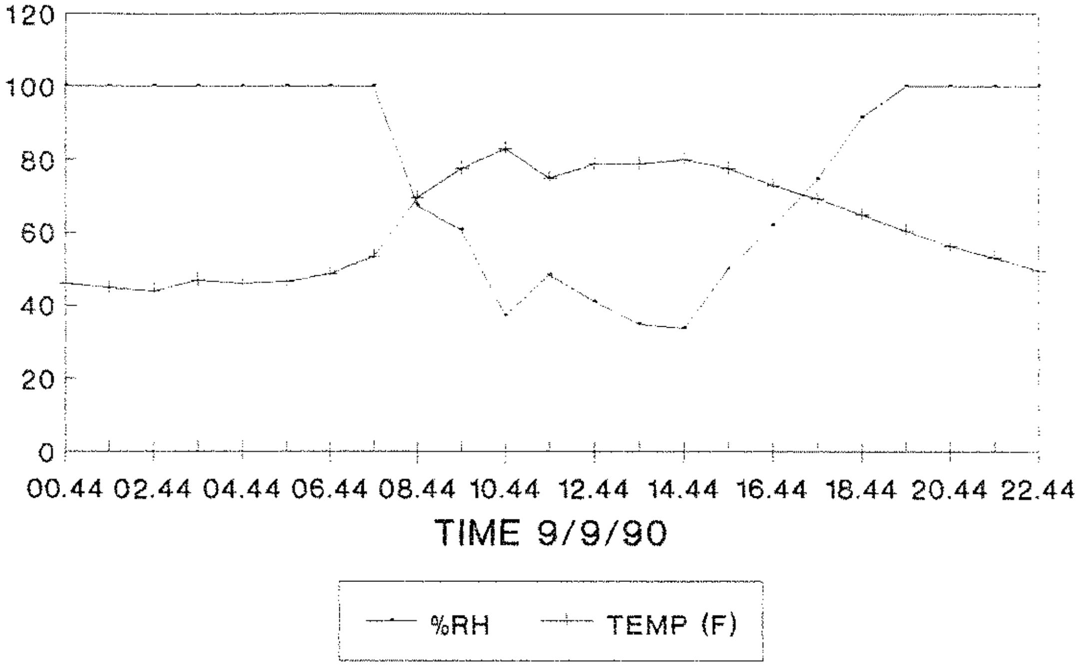


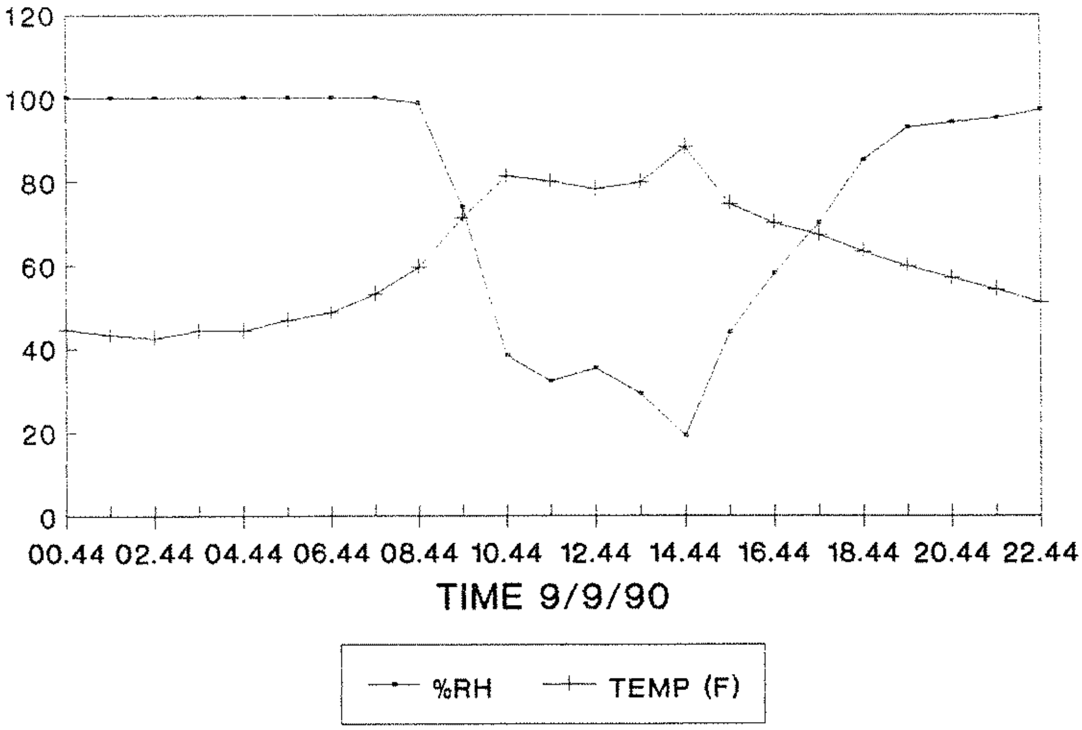
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



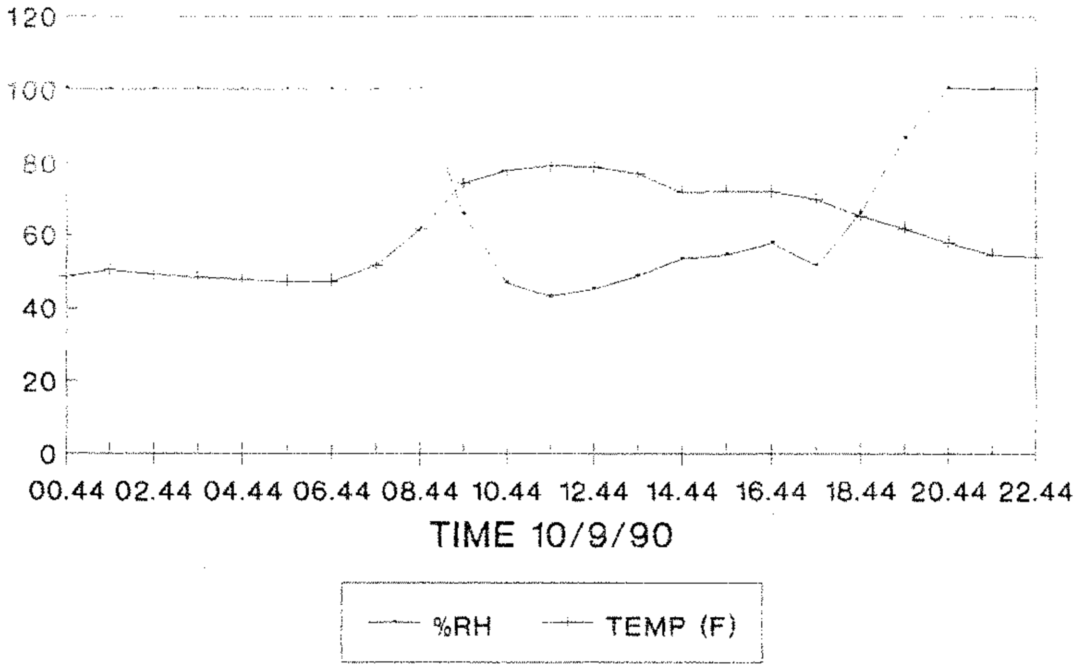


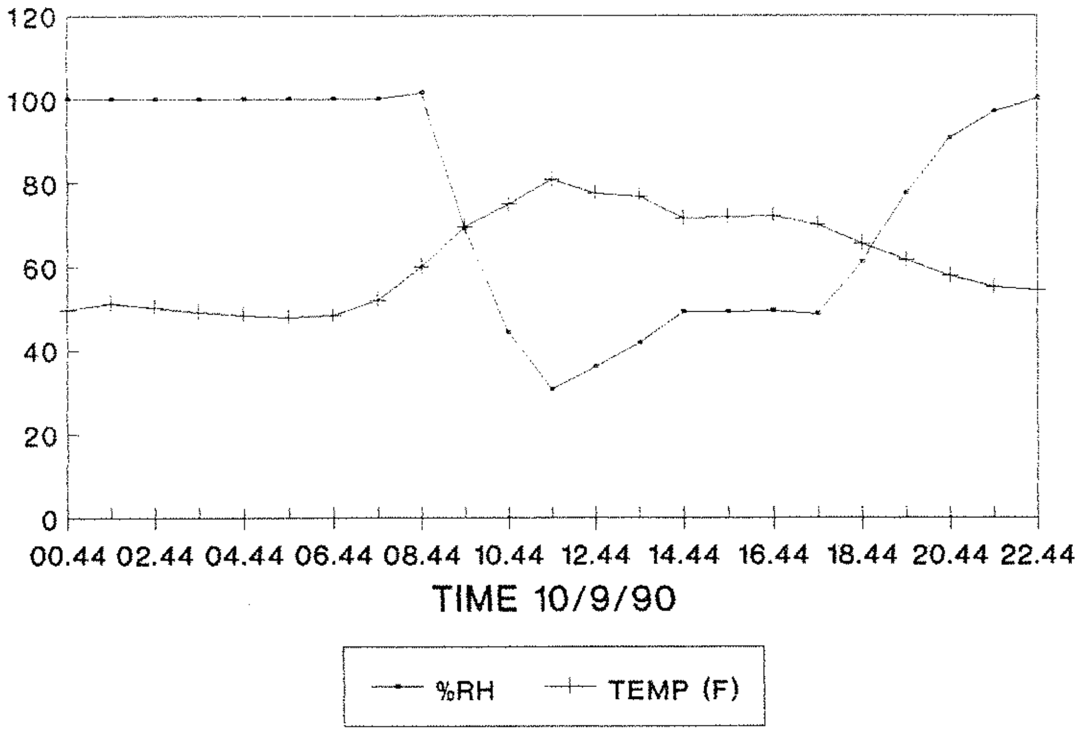
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



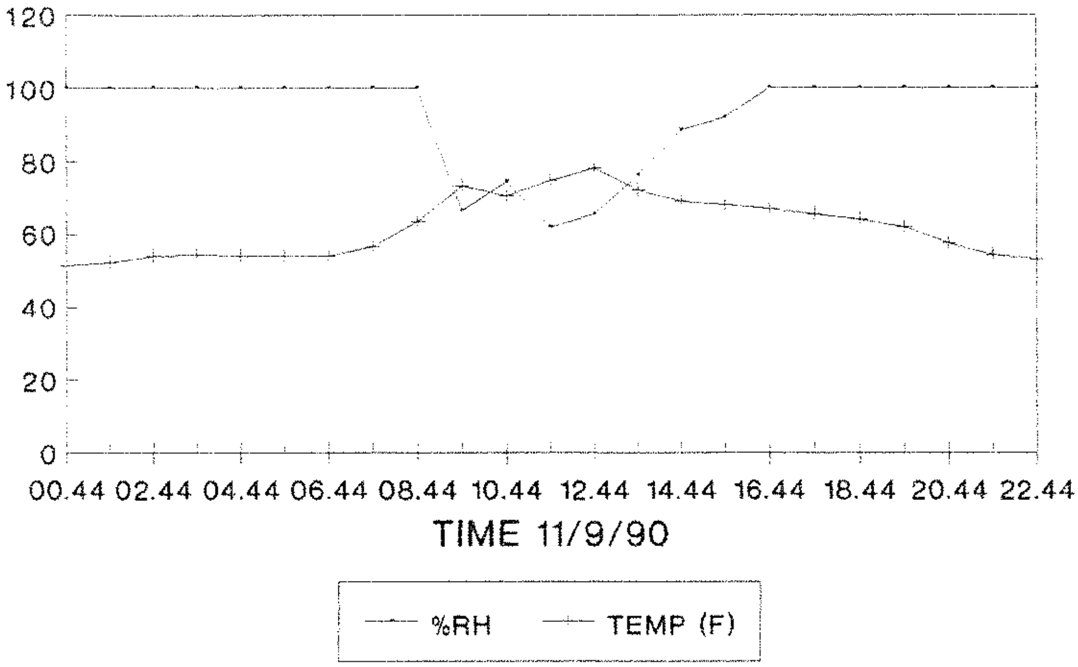


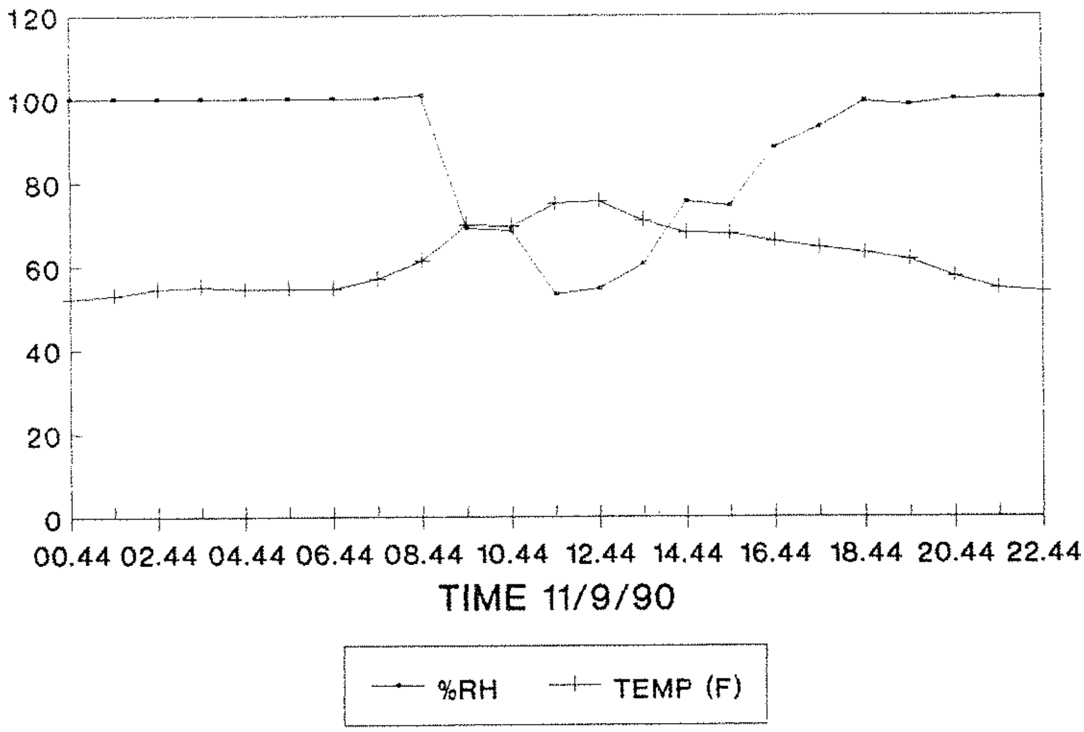
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



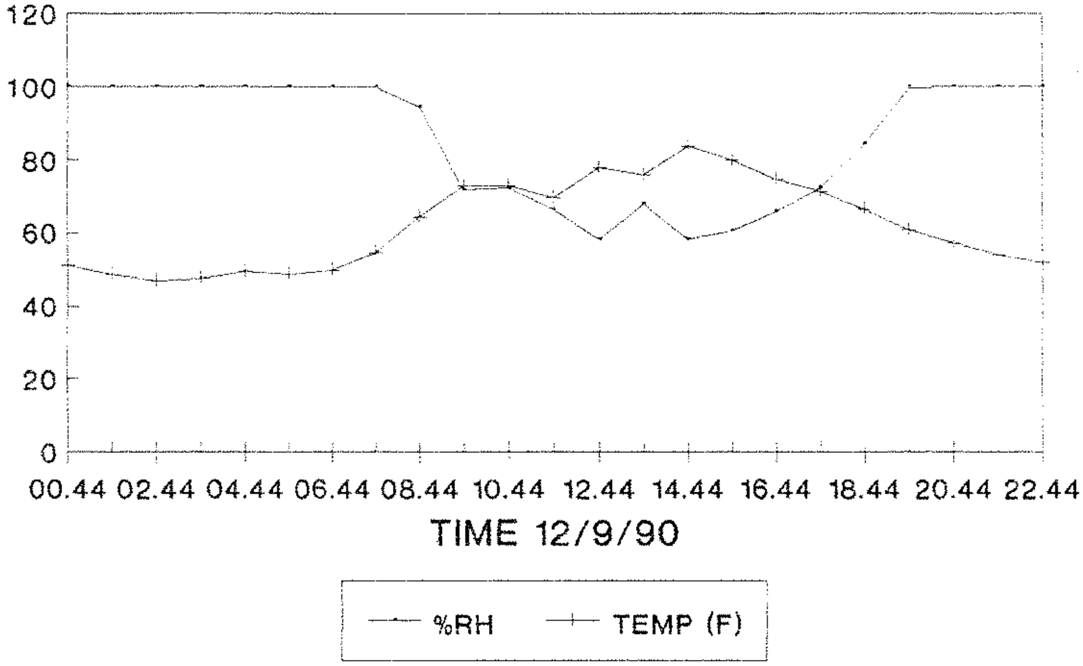


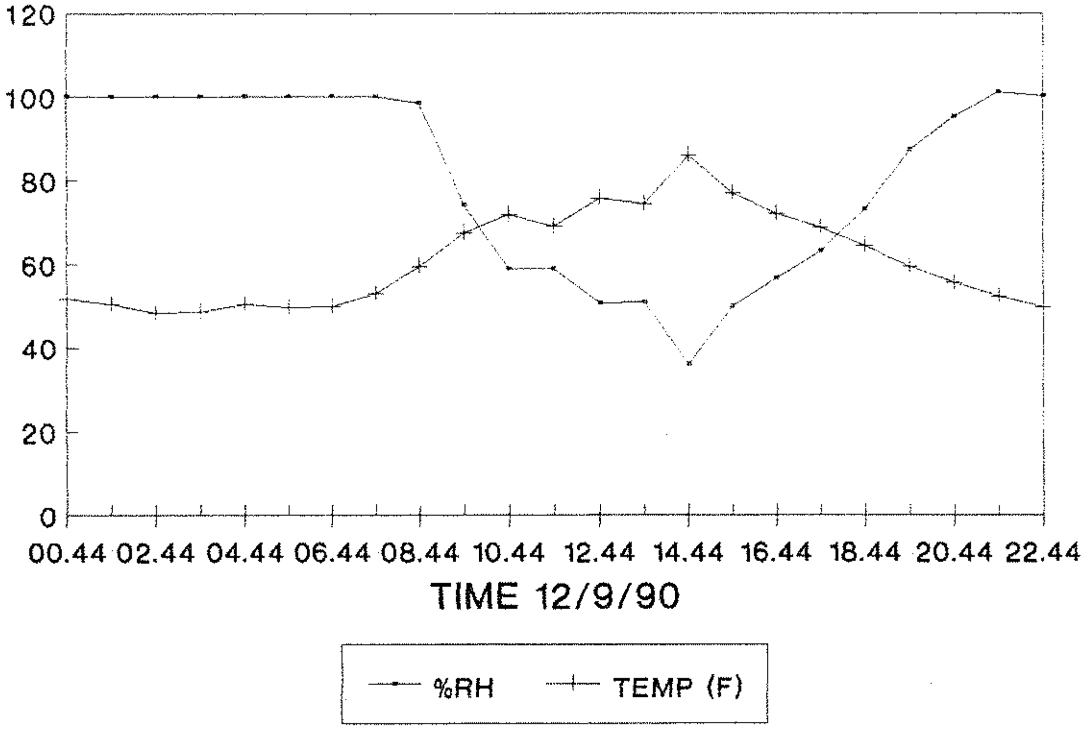
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



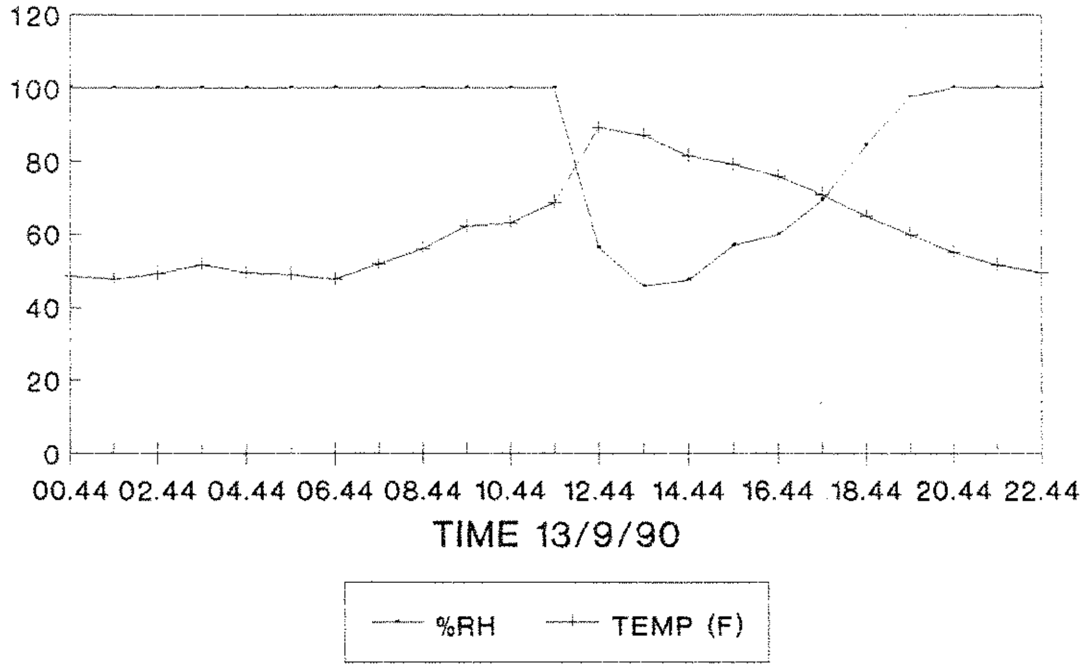


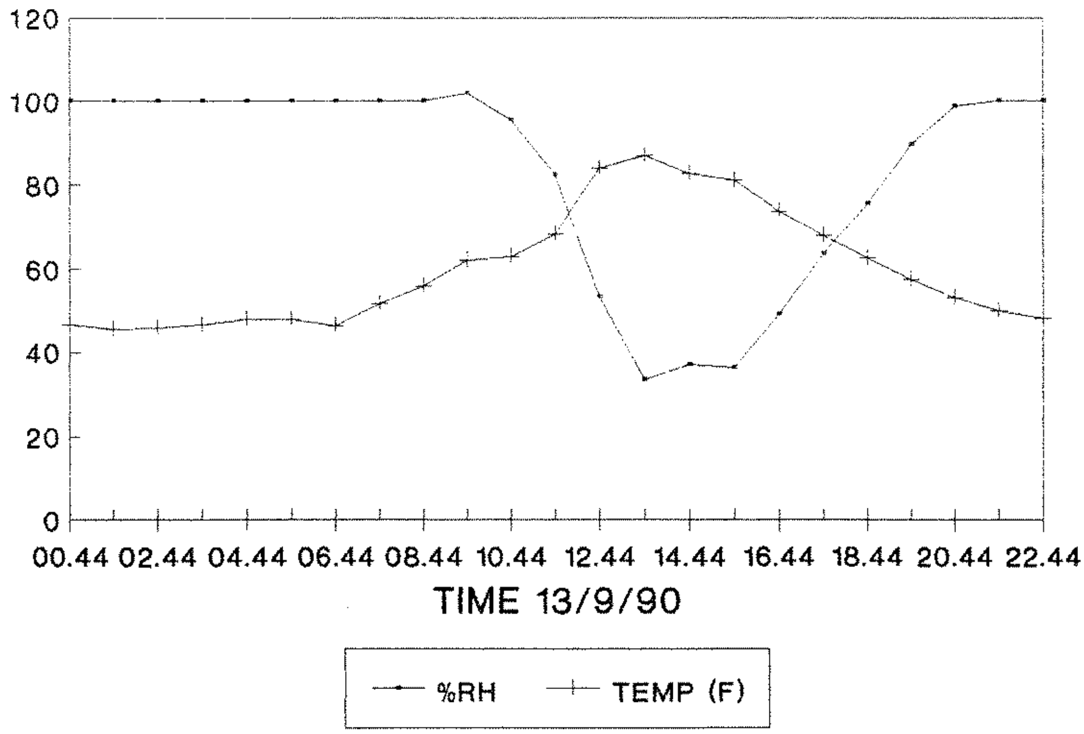
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



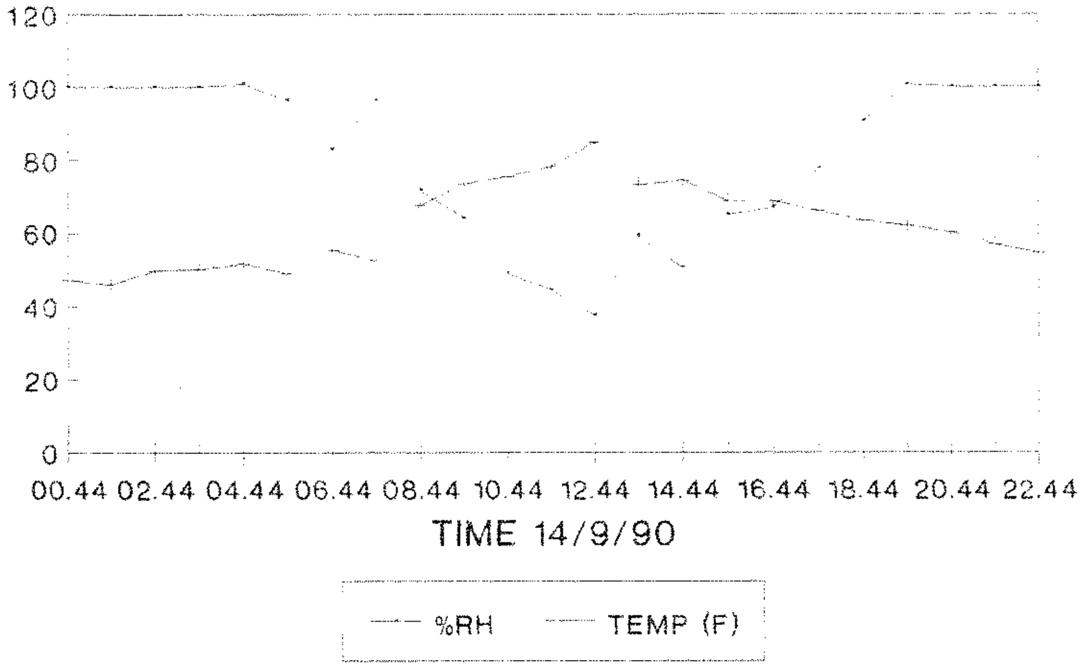


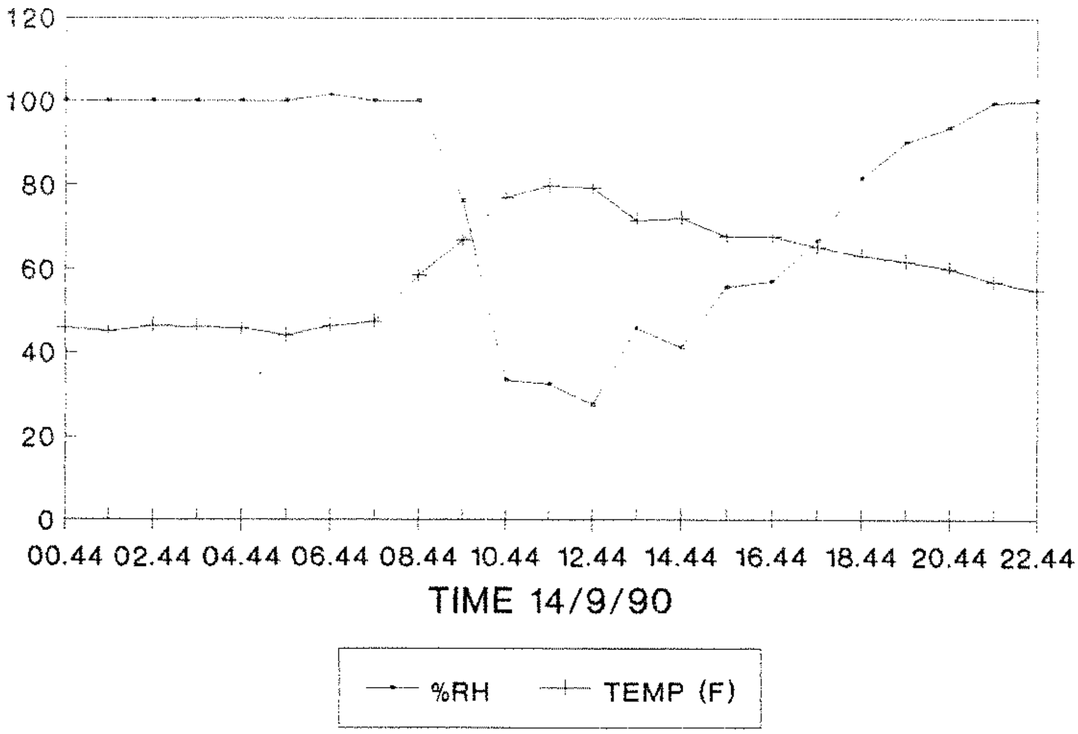
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



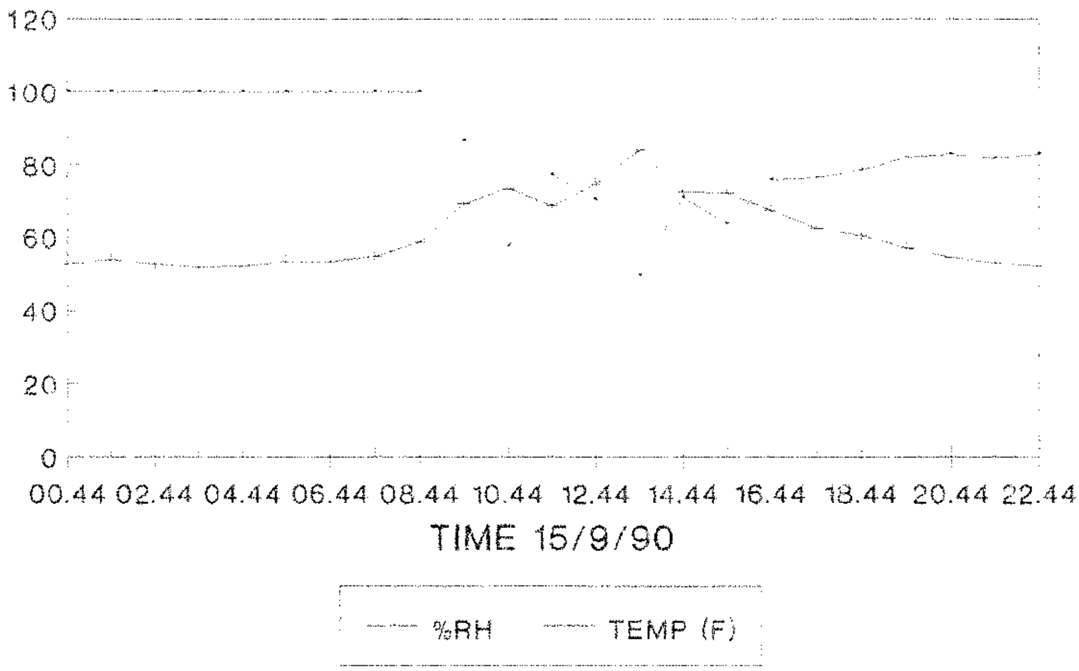


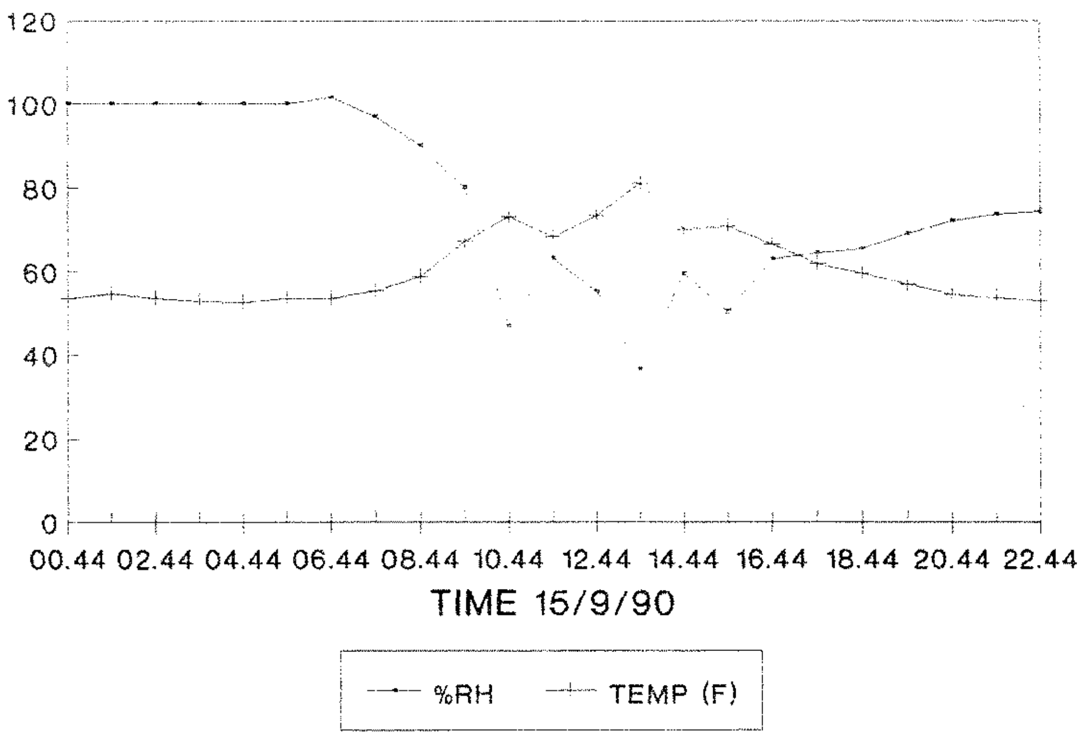
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



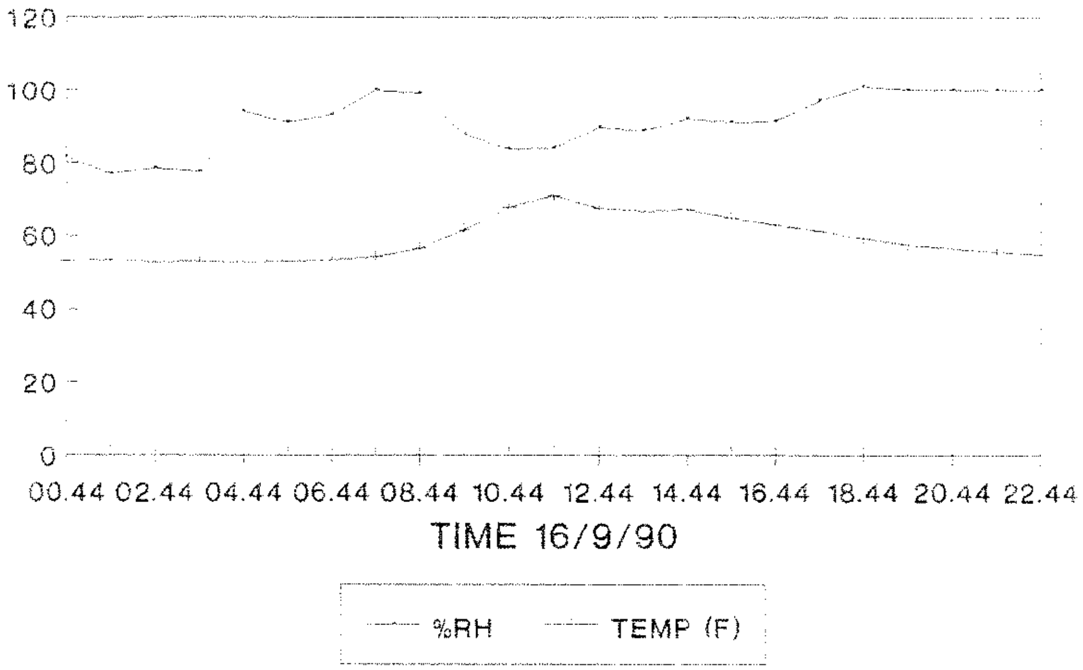


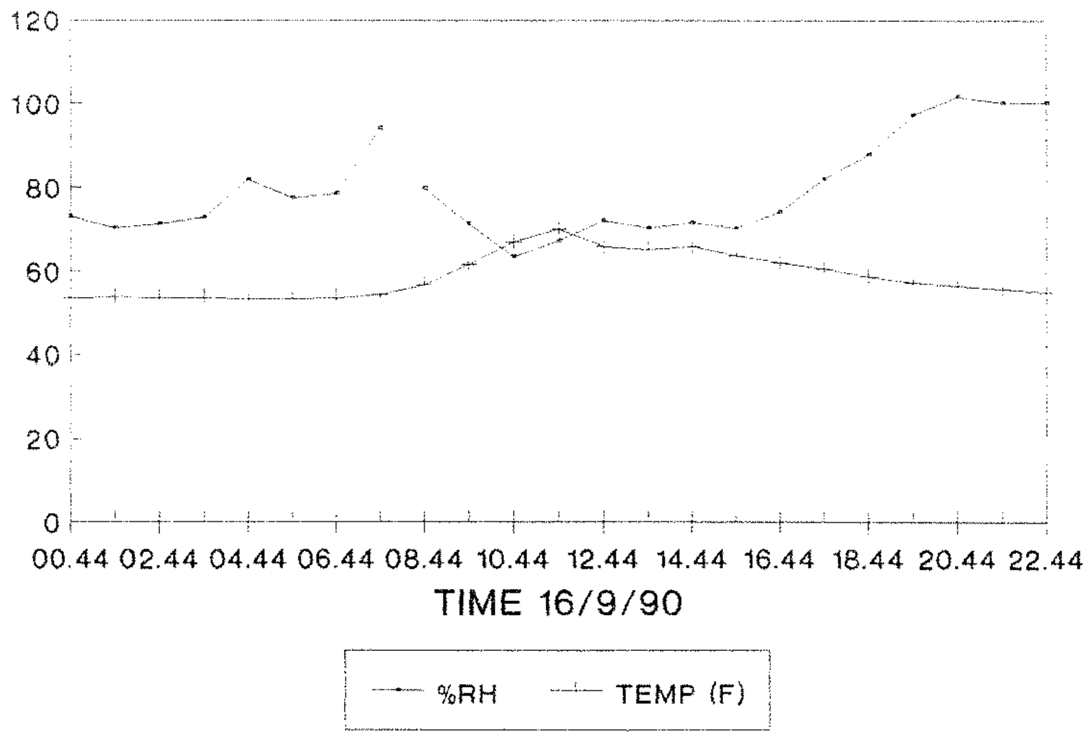
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



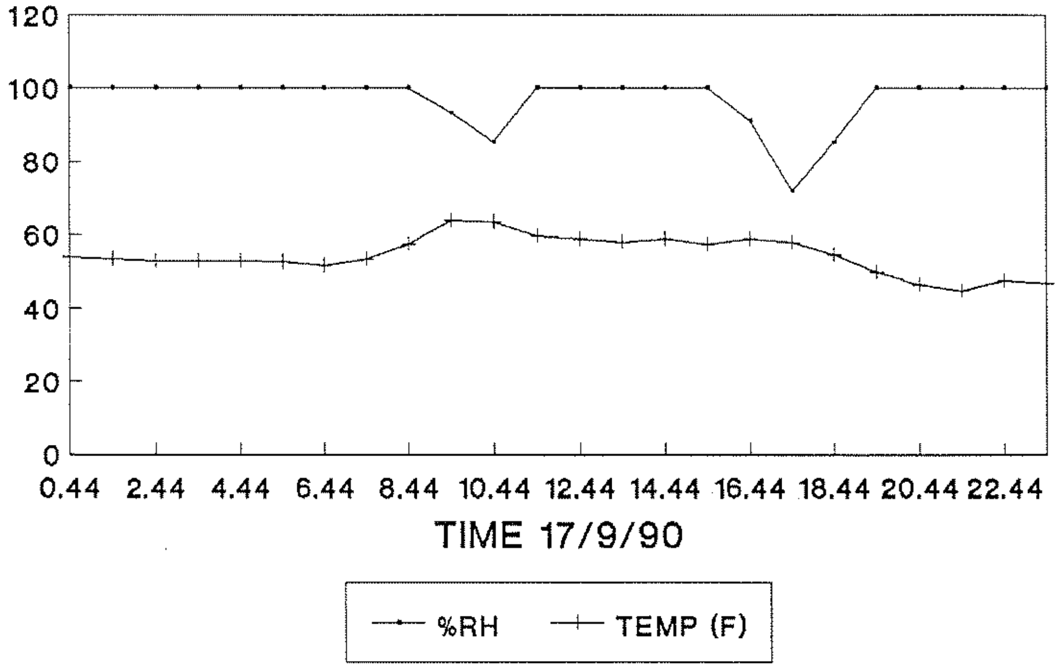


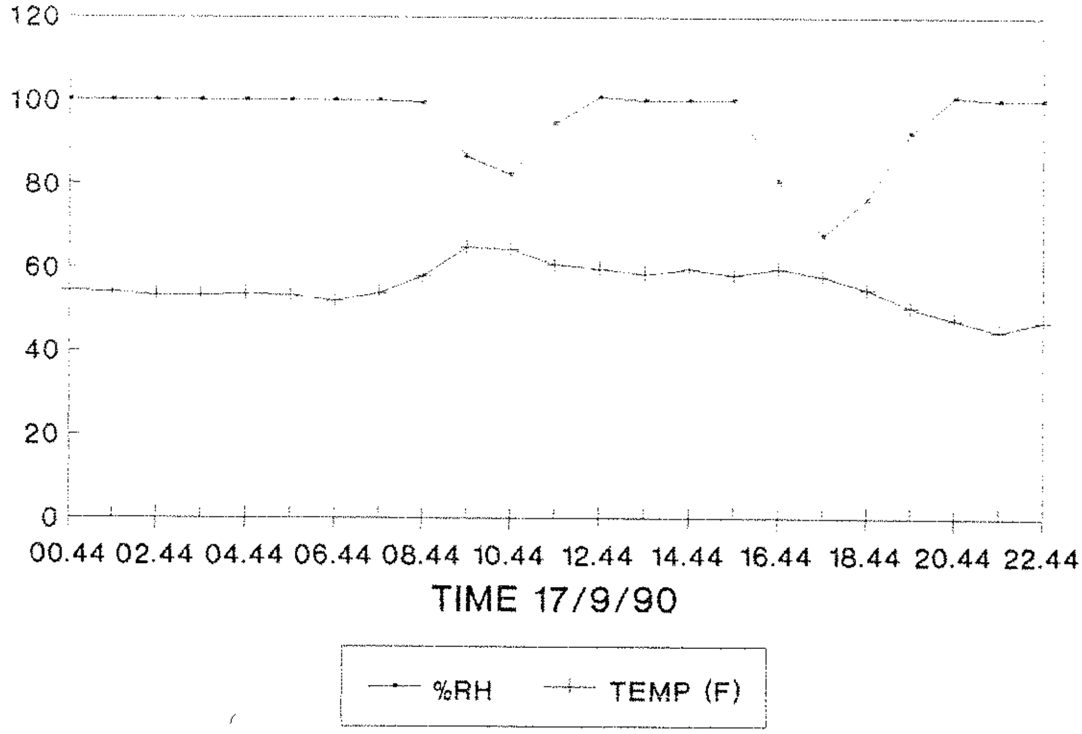
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



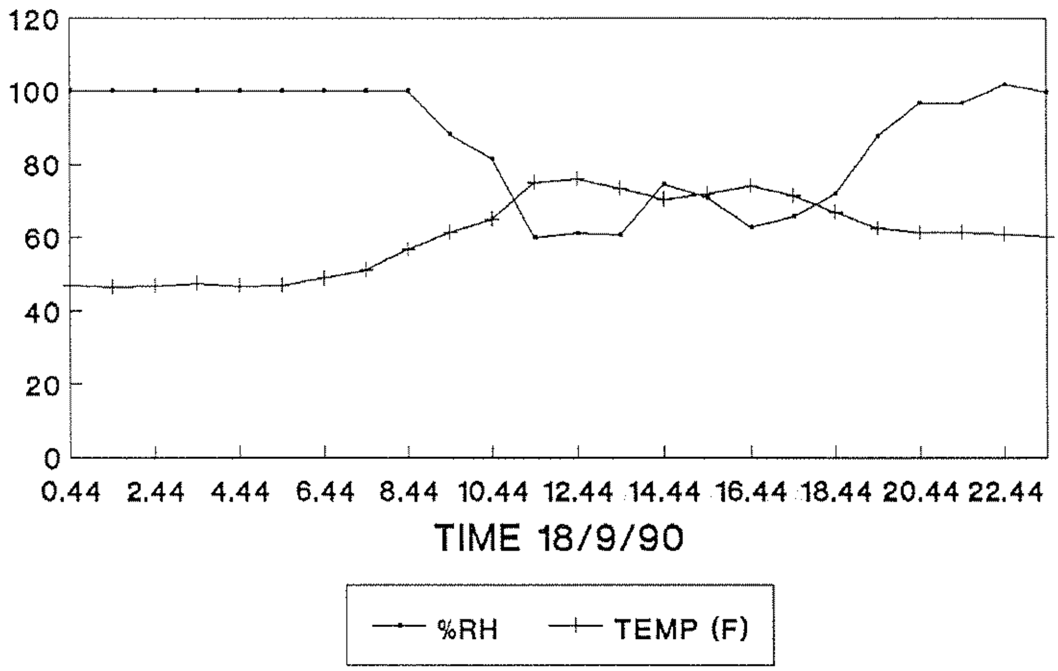


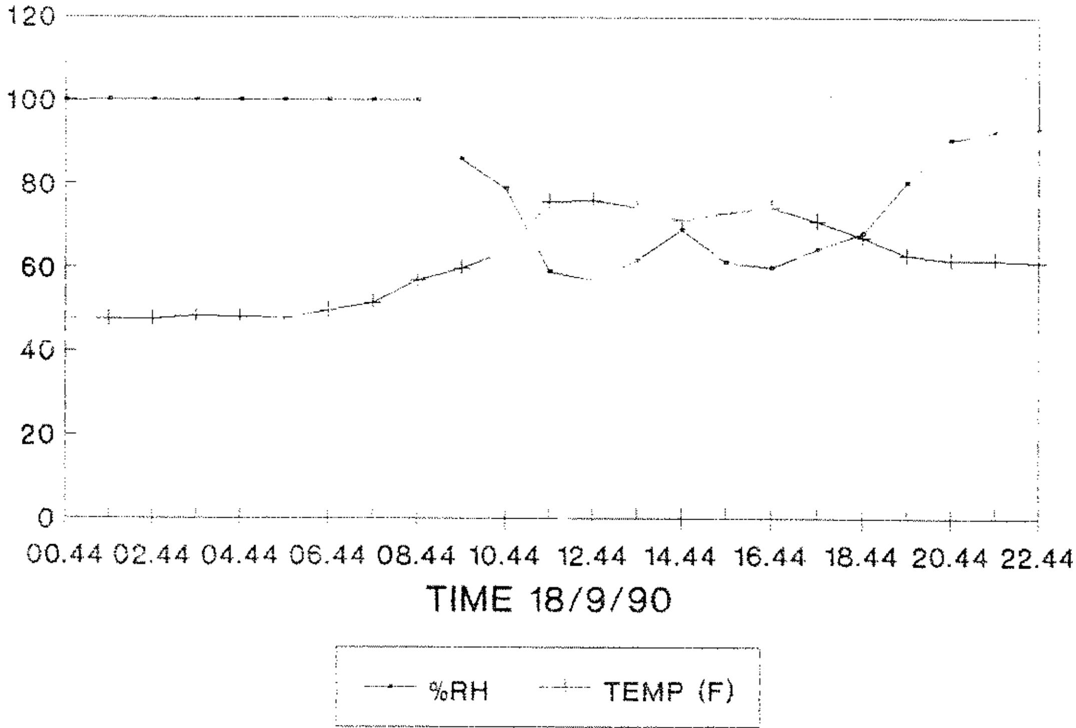
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL



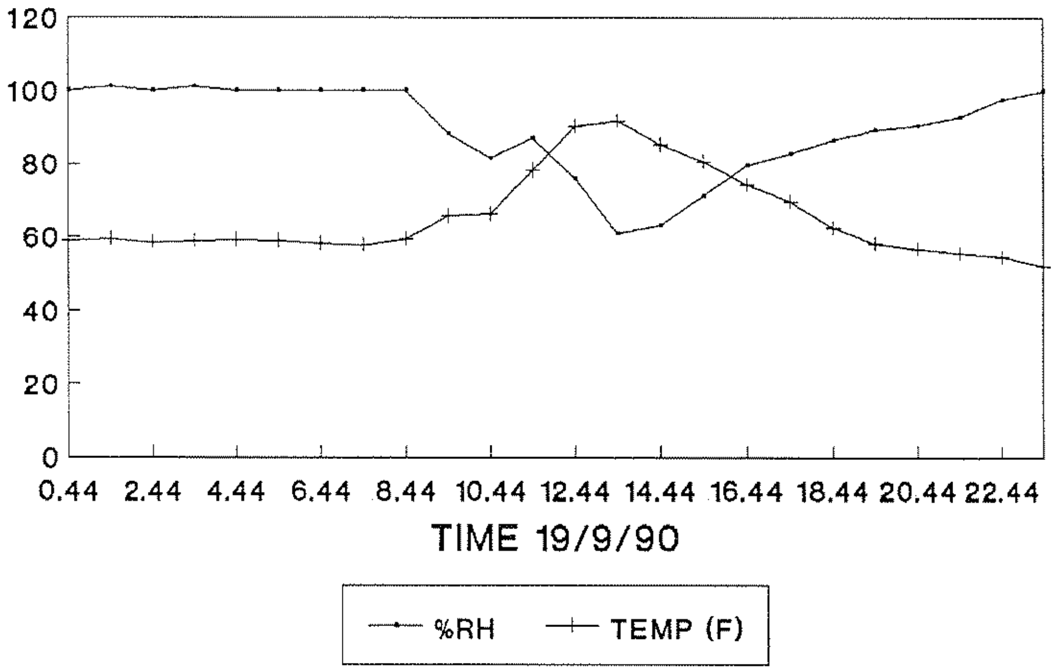


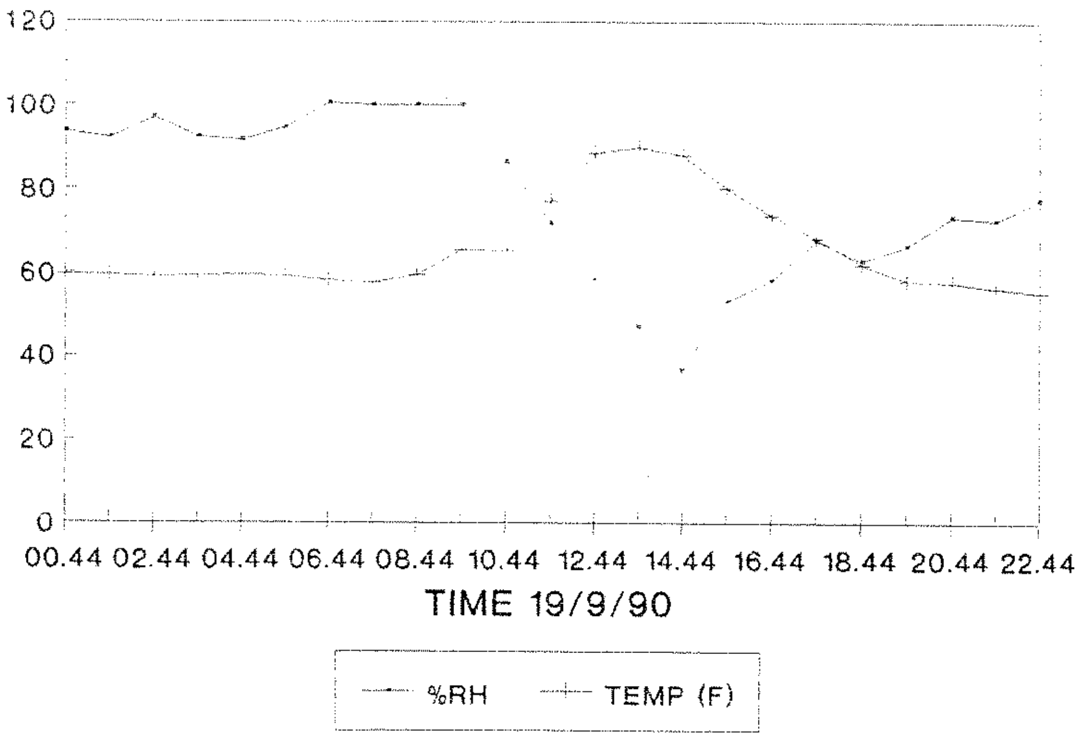
%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL





%RH AND TEMP CHANGES
TOMATO MILDEW CONTROL

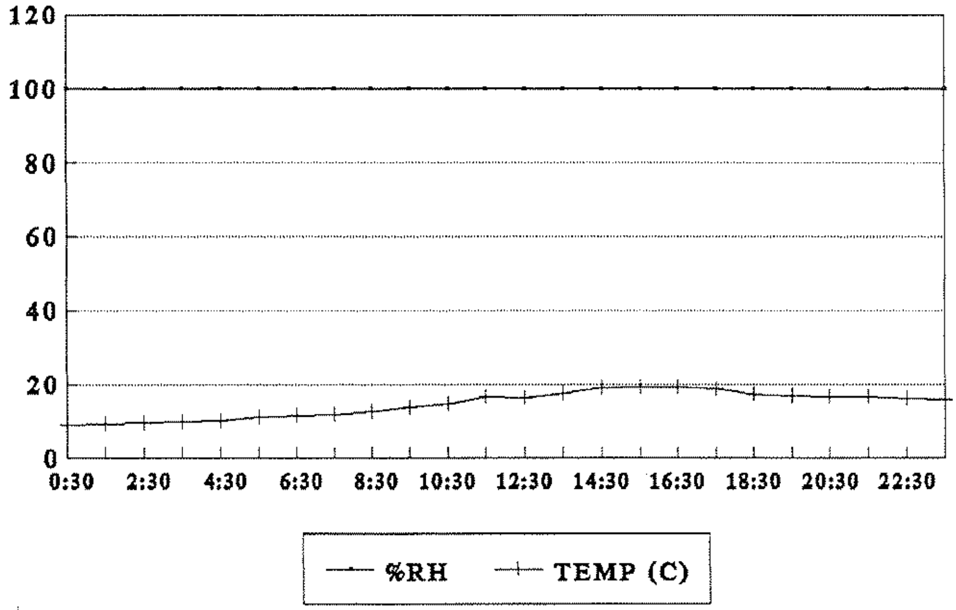




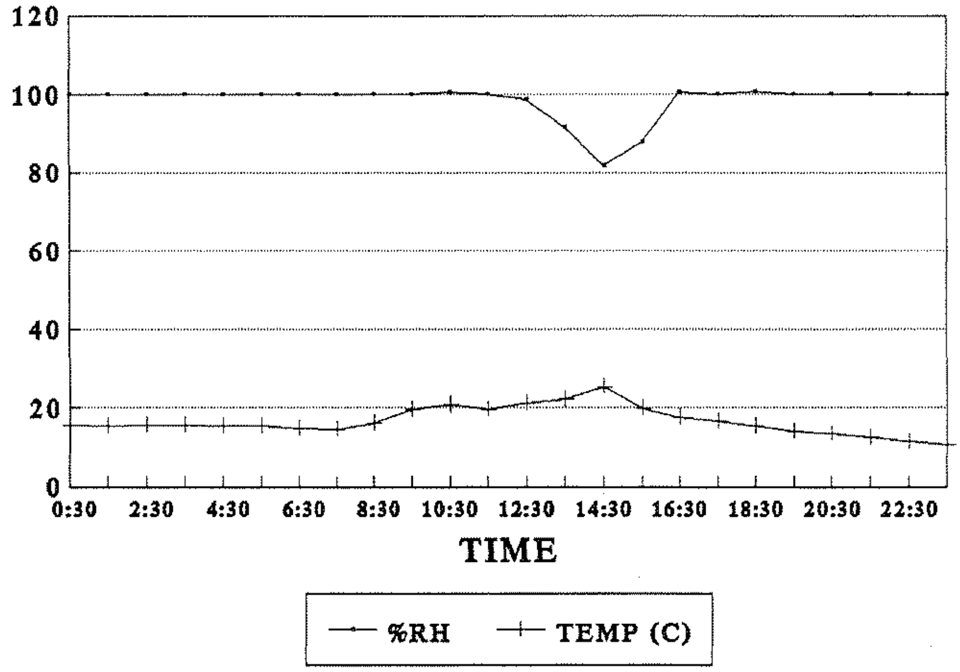
3. <u>Site B : 5 October - 30 October</u>

Untreated crop

%RH AND TEMPERATURE CHANGE
SITE B

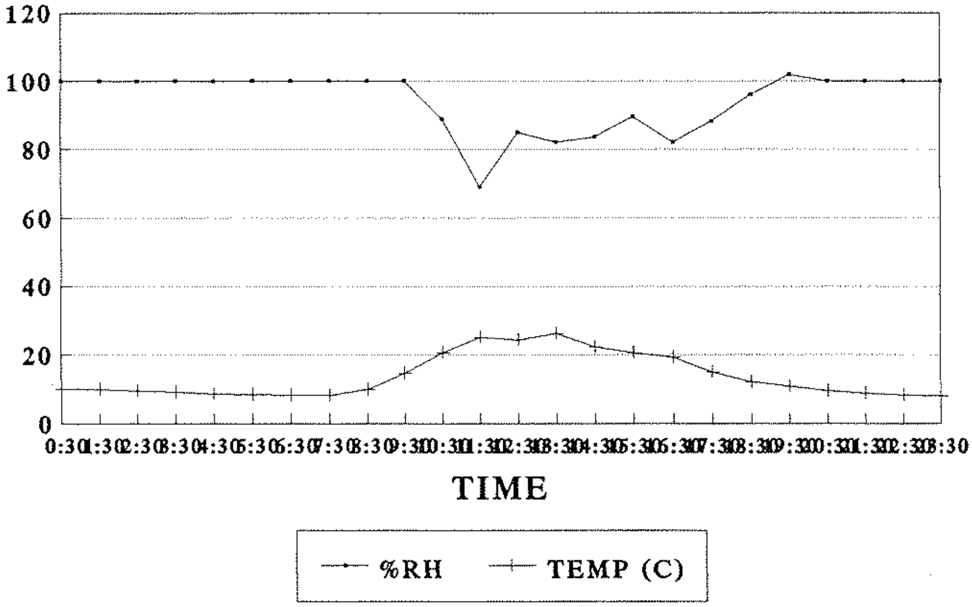


05/10/90

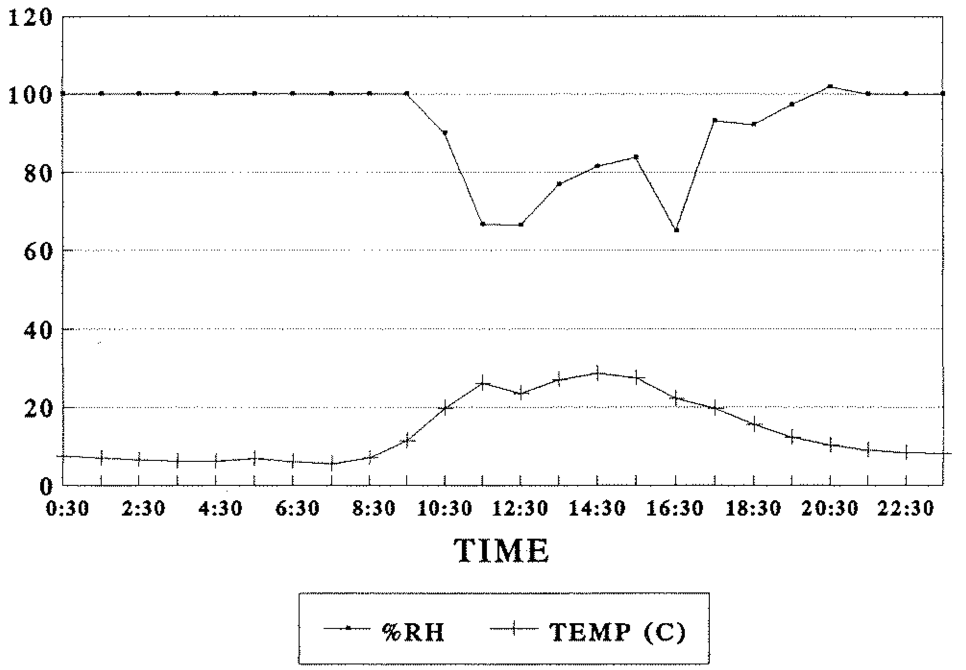


06/10/90

RH AND TEMPERATURE CHANGES
SITE B

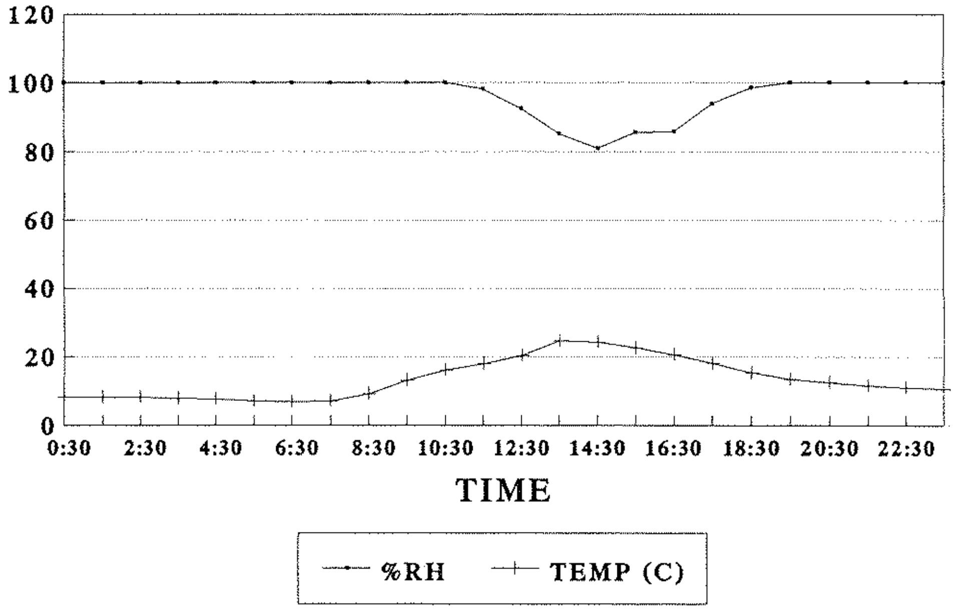


07/10/90

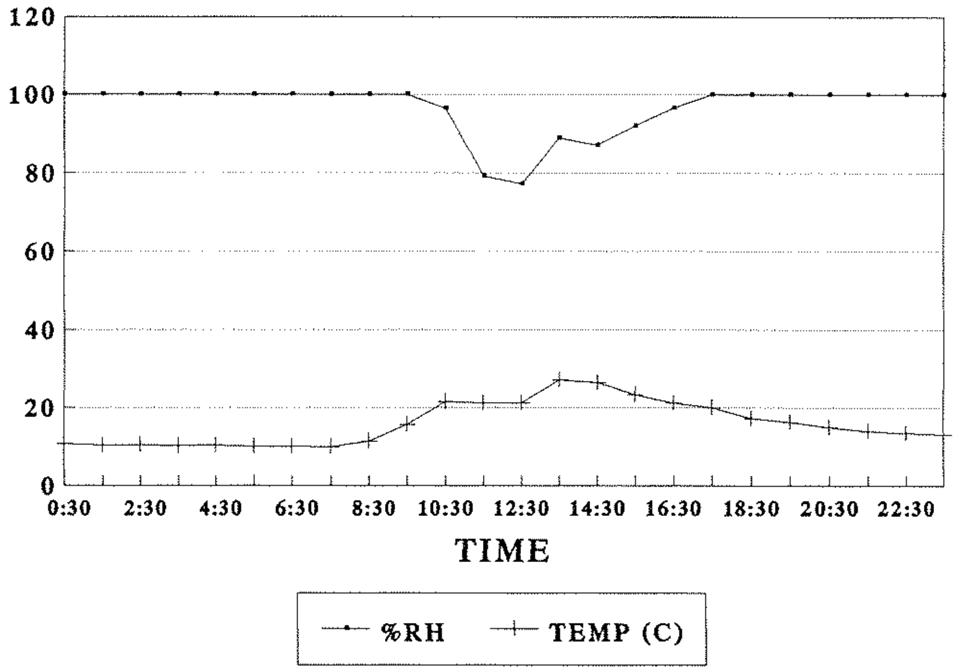


08/10/90

RH AND TEMPERATURE CHANGES SITE B

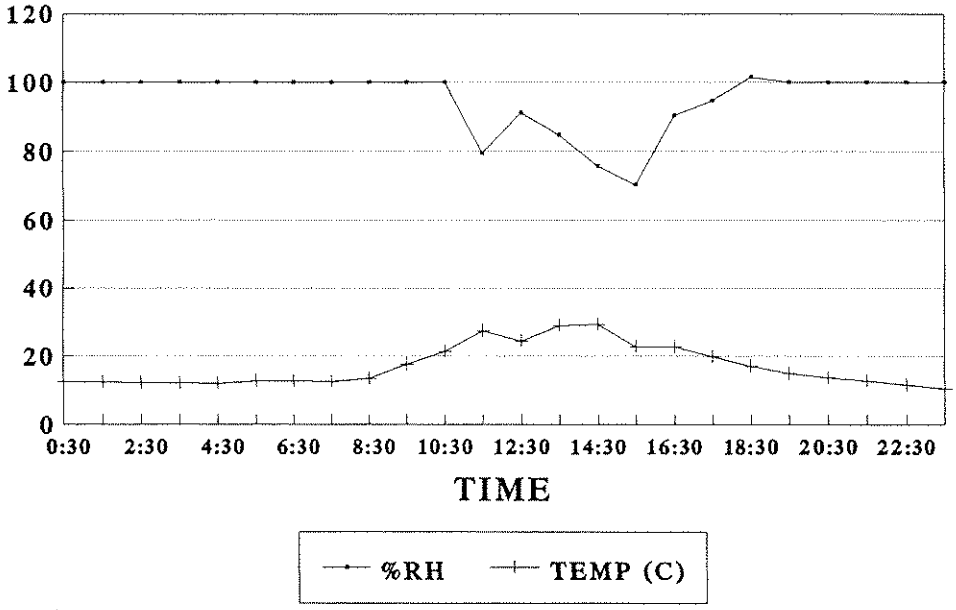


09/10/90

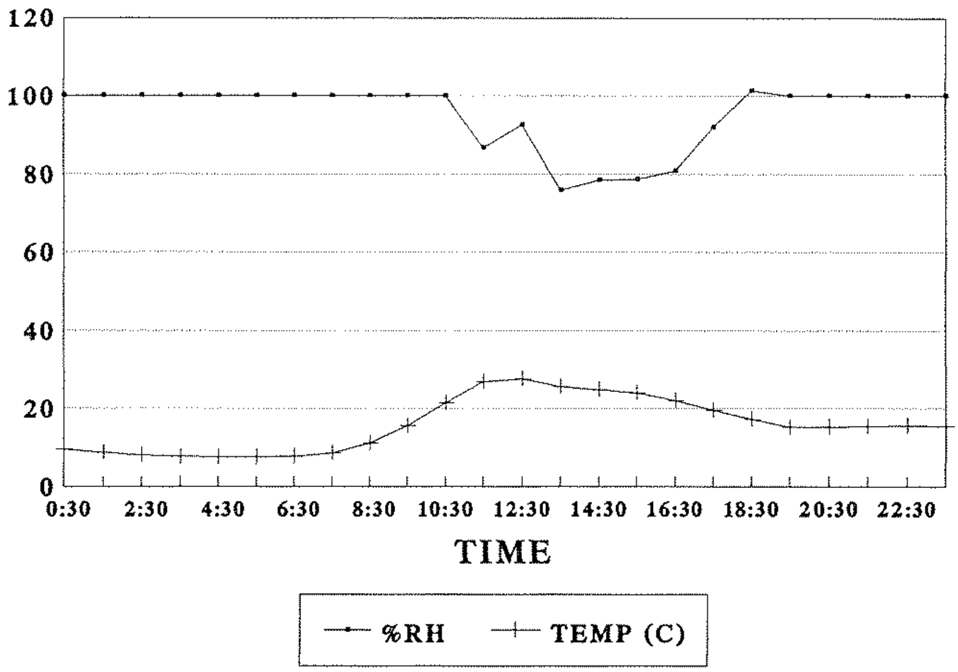


10/10/90

RH AND TEMPERATURE CHANGES
SITE B MILDEW CONTROL

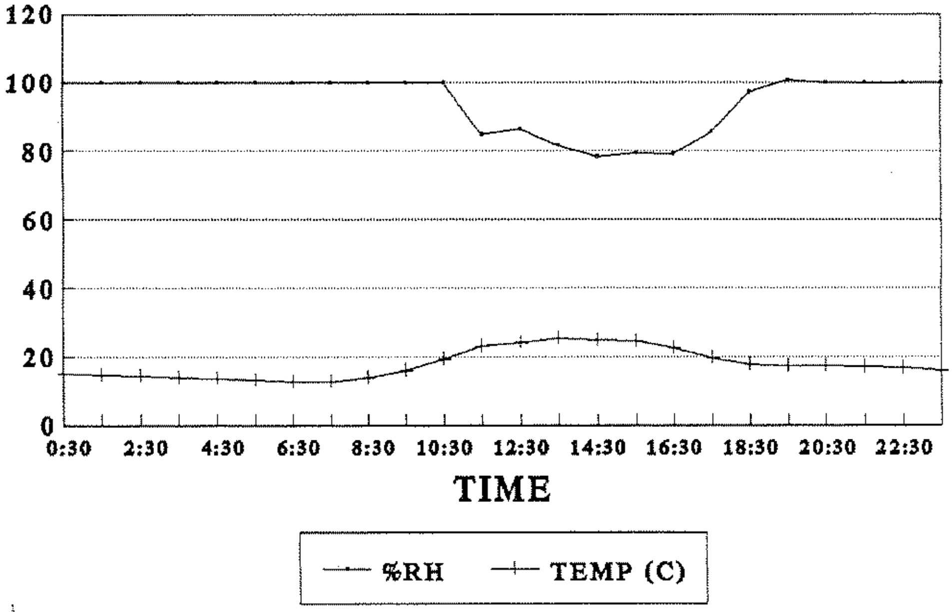


11/10/90

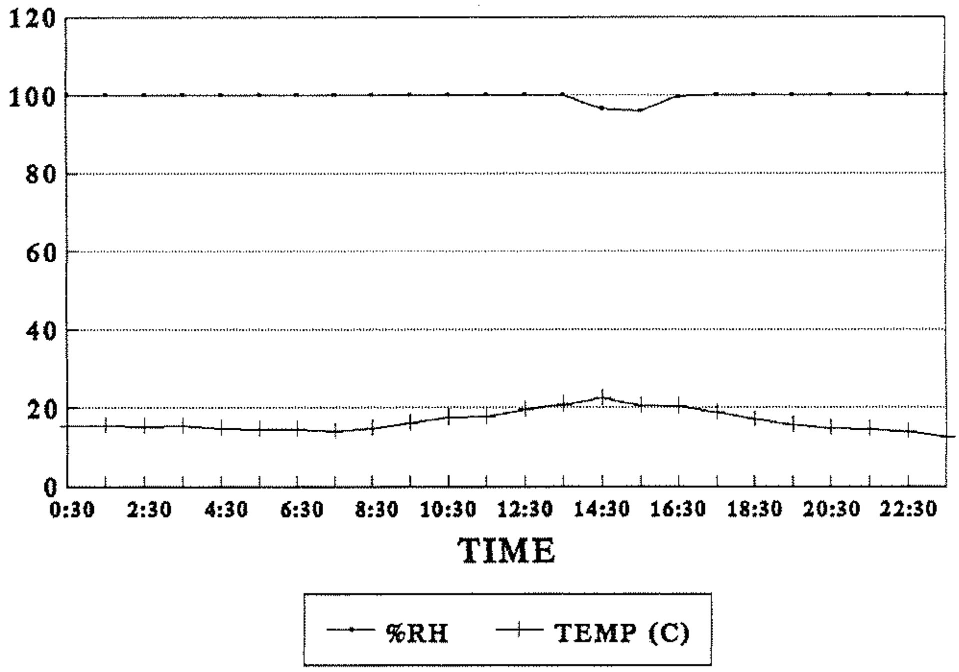


12/10/90

RH AND TEMPERATURE CHANGES
SITE B

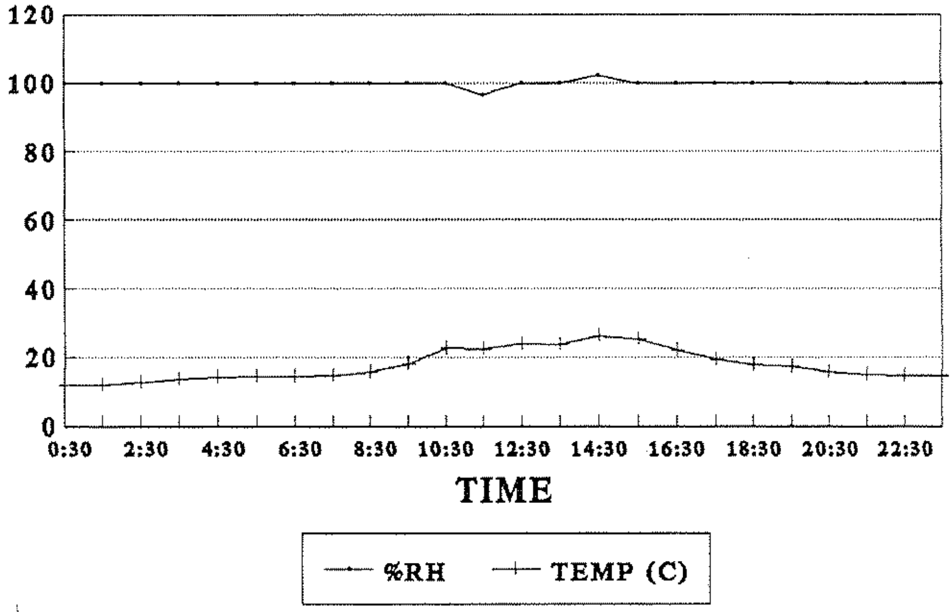


13/10/90

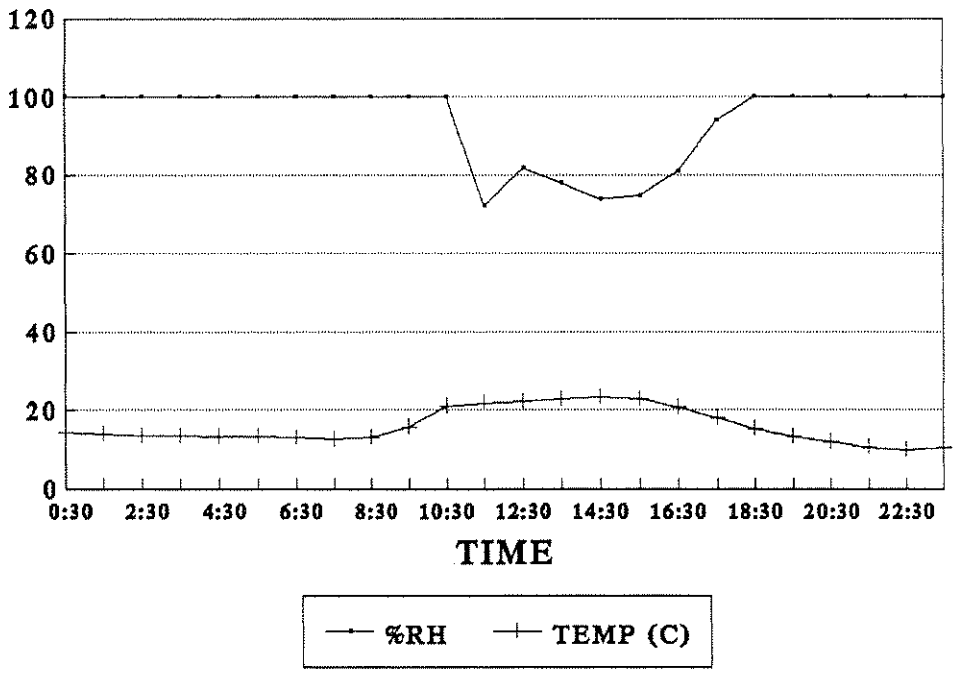


14/10/90

RH AND TEMPERATURE CHANGES
SITE B

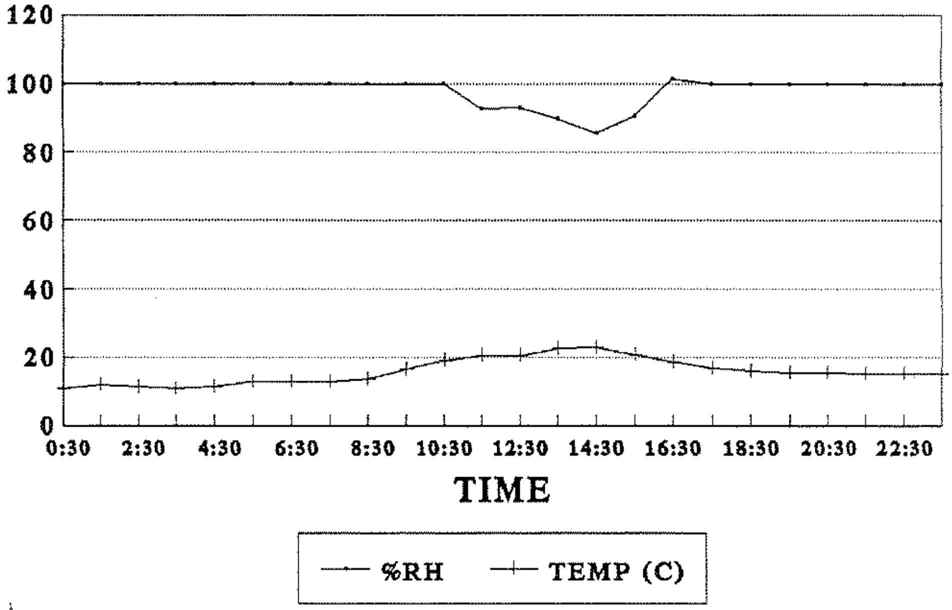


15/10/90

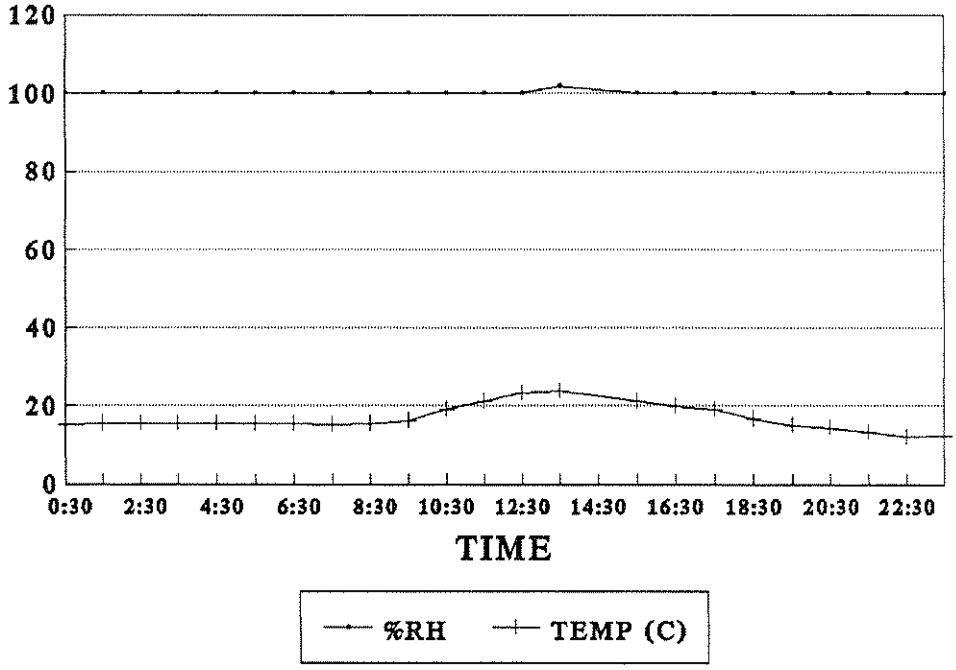


16/10/90

RH AND TEMPERATURE CHANGES
SITE B

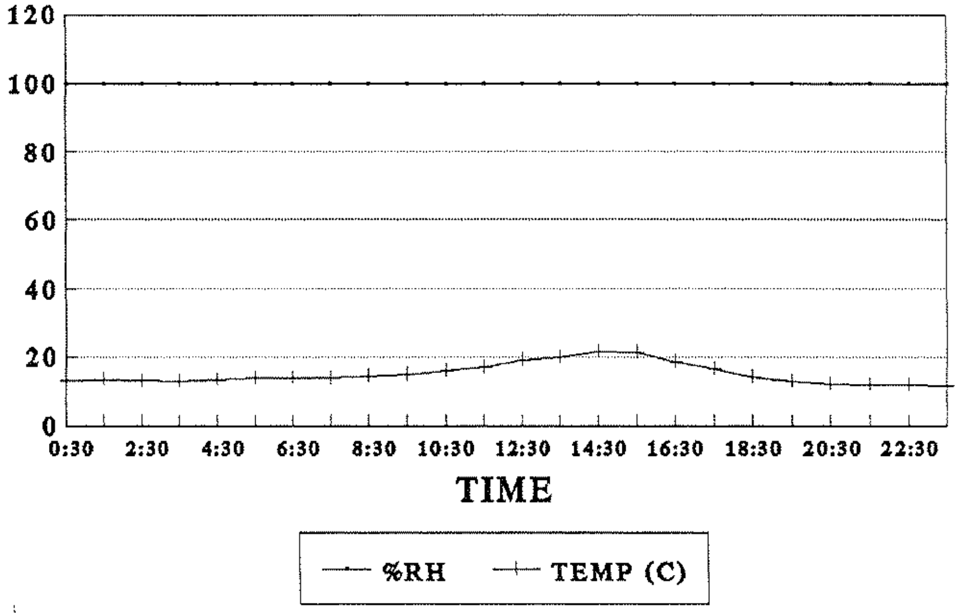


17/10/90

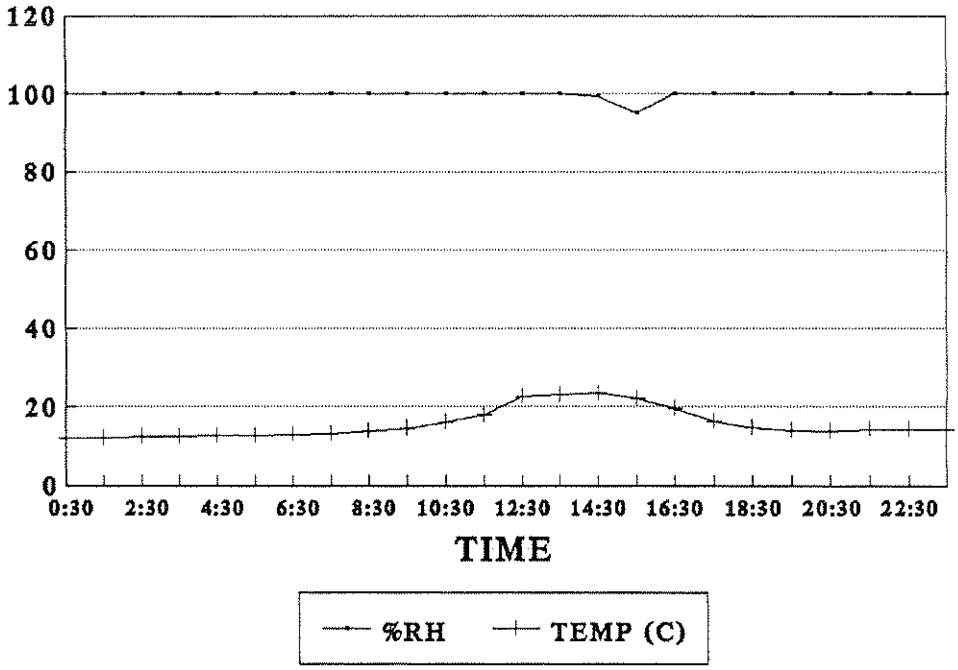


18/10/90

RH AND TEMPERATURE CHANGES
SITE B

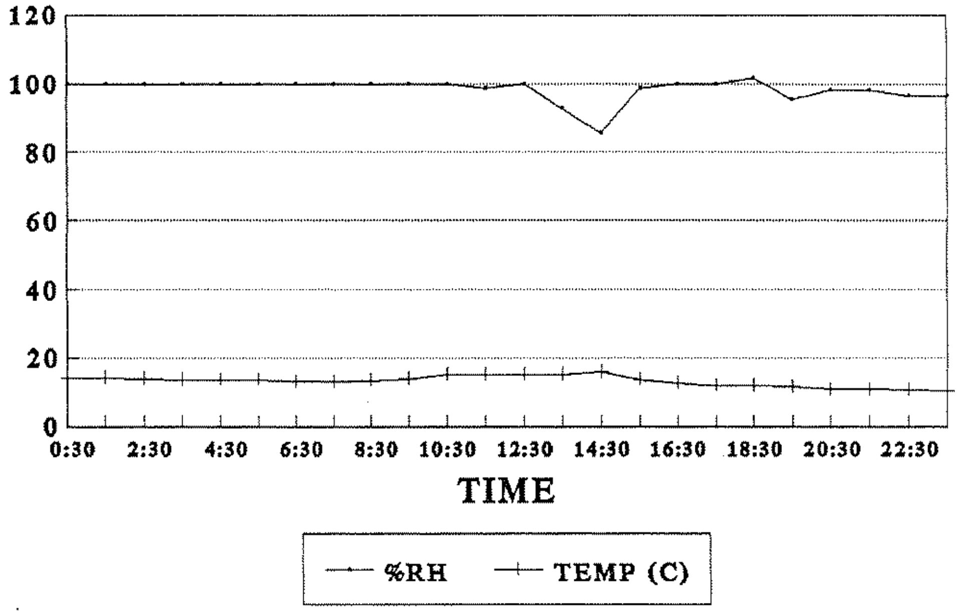


19/10/90

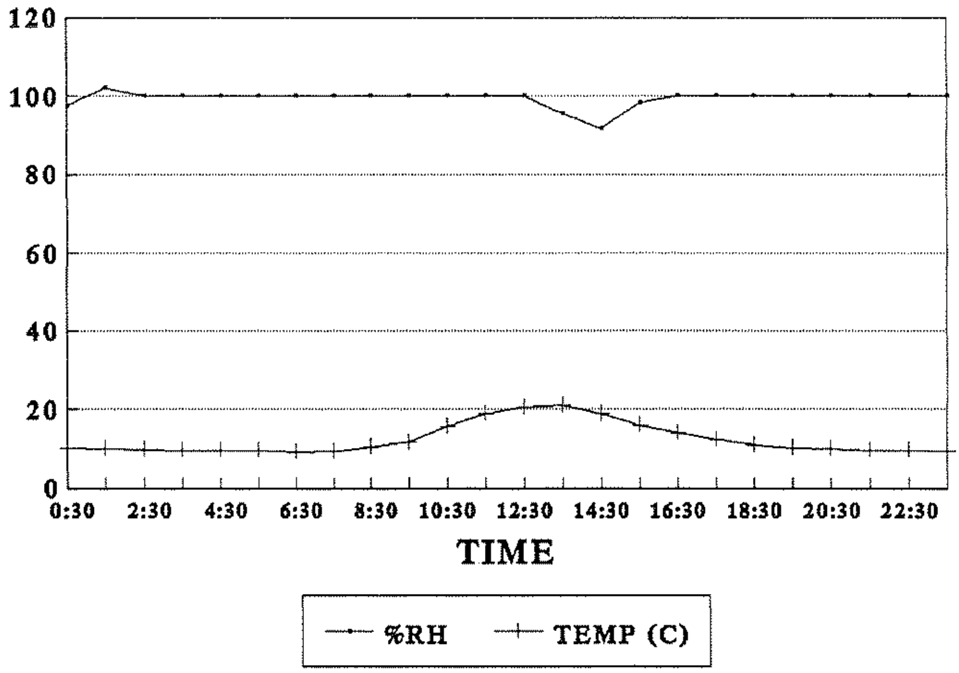


20/10/90

RH AND TEMPERATURE CHANGES
SITE B

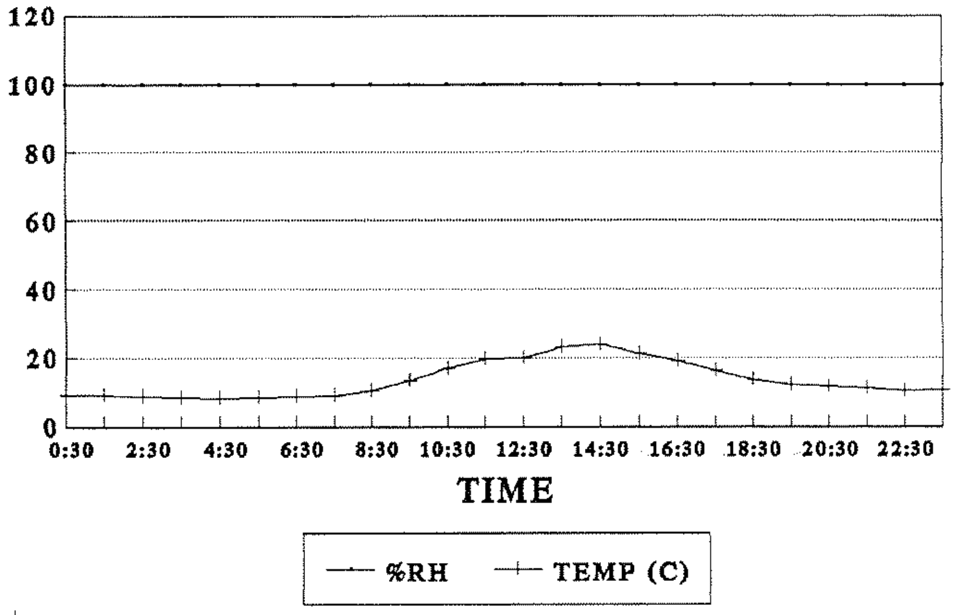


21/10/90

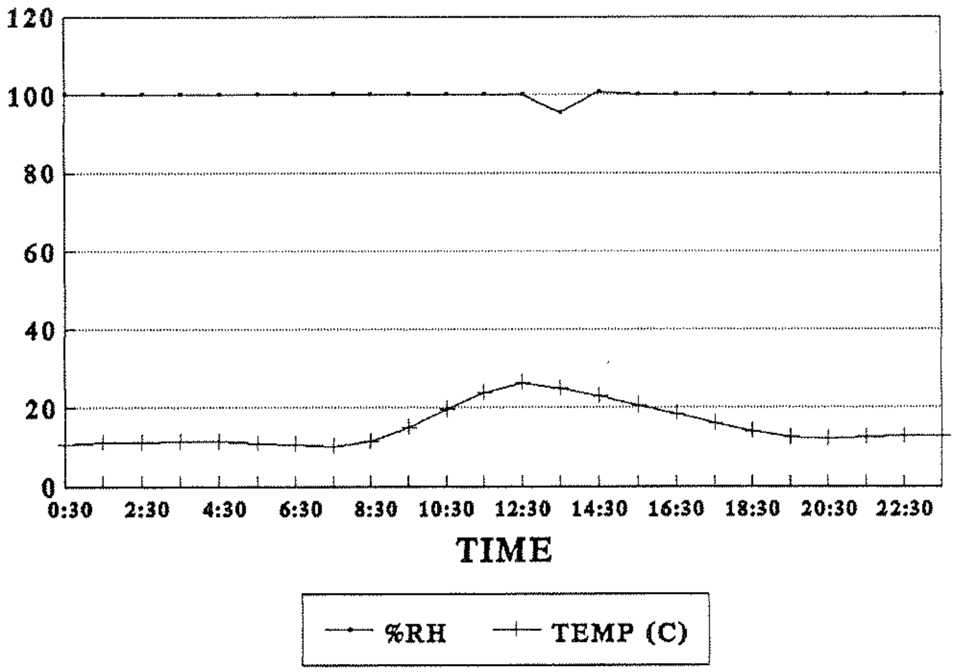


22/10/90

RH AND TEMPERATURE CHANGES
SITE B

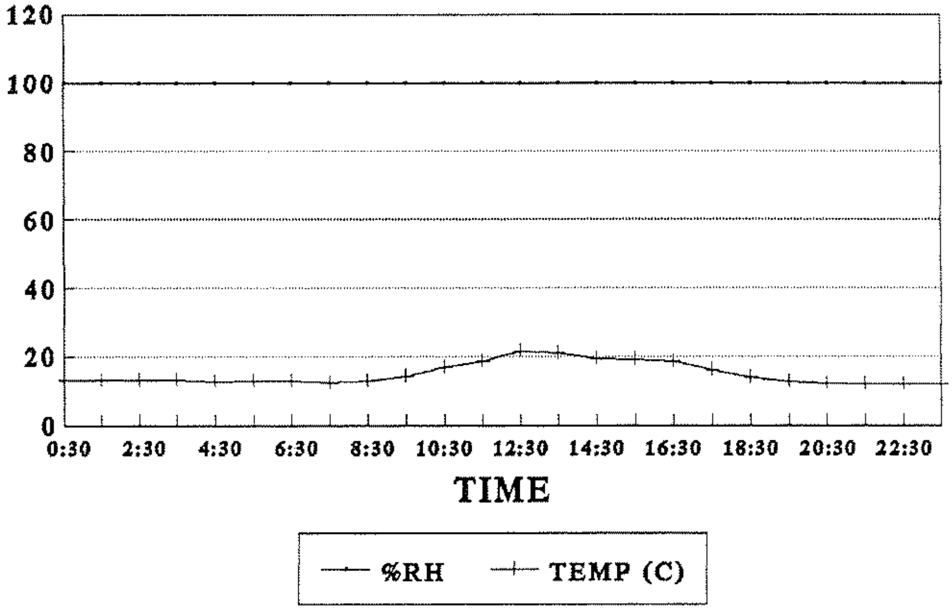


23/10/90

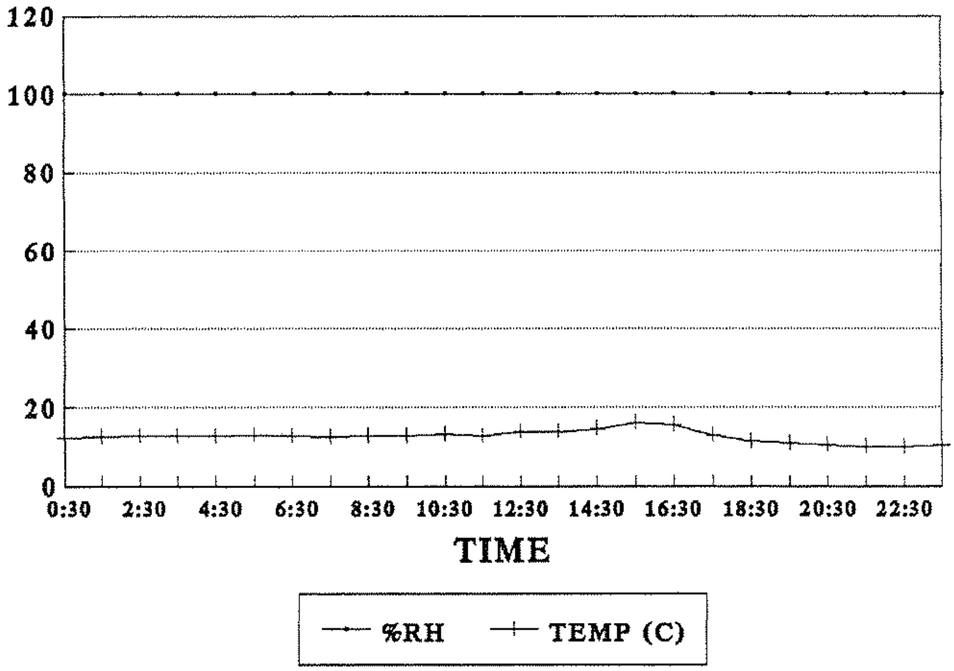


24/10/90

RH AND TEMPERATURE CHANGES
SITE B

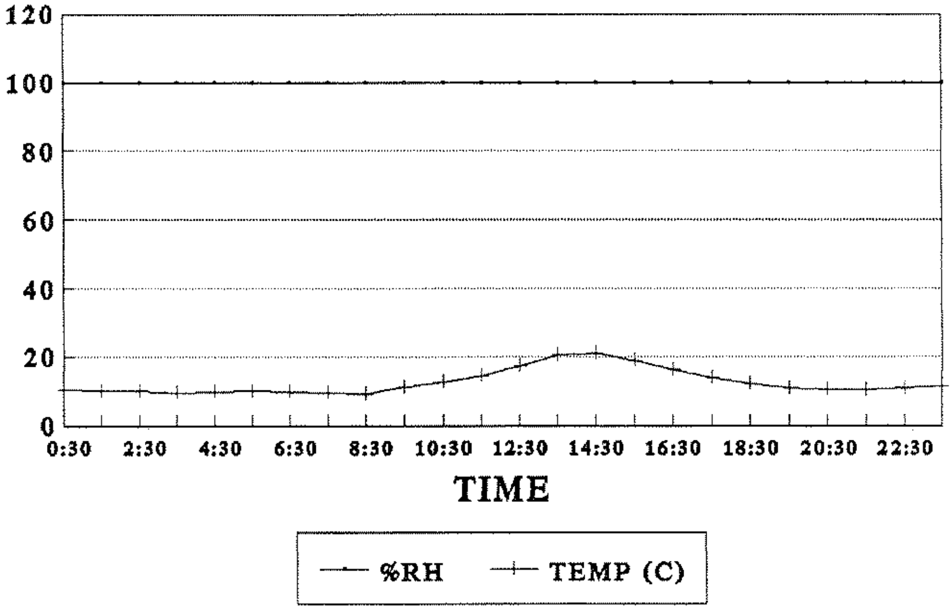


25/10/90

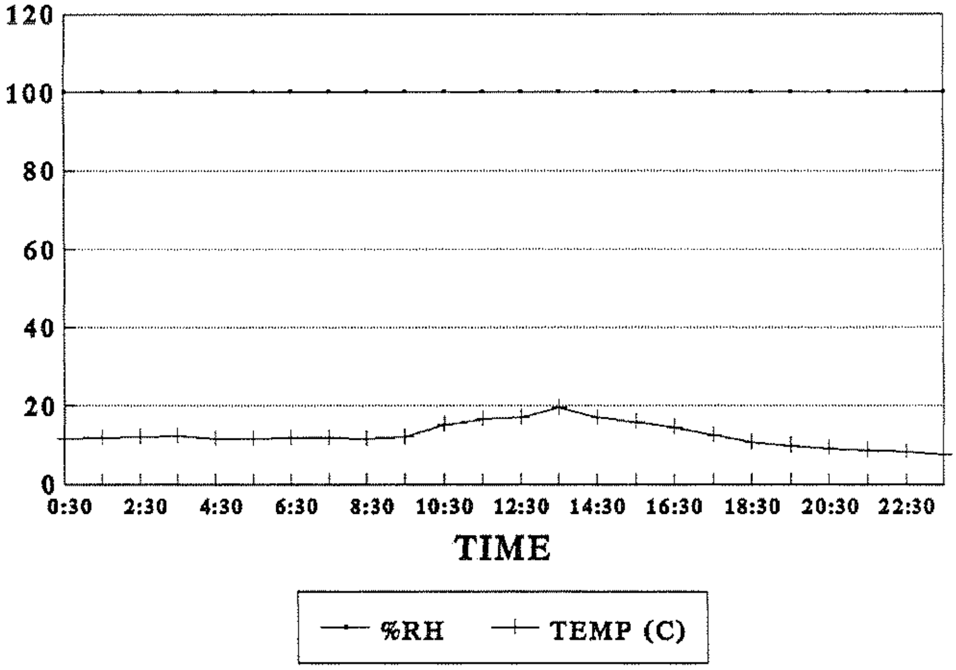


26/10/90

RH AND TEMPERATURE CHANGES
SITE B

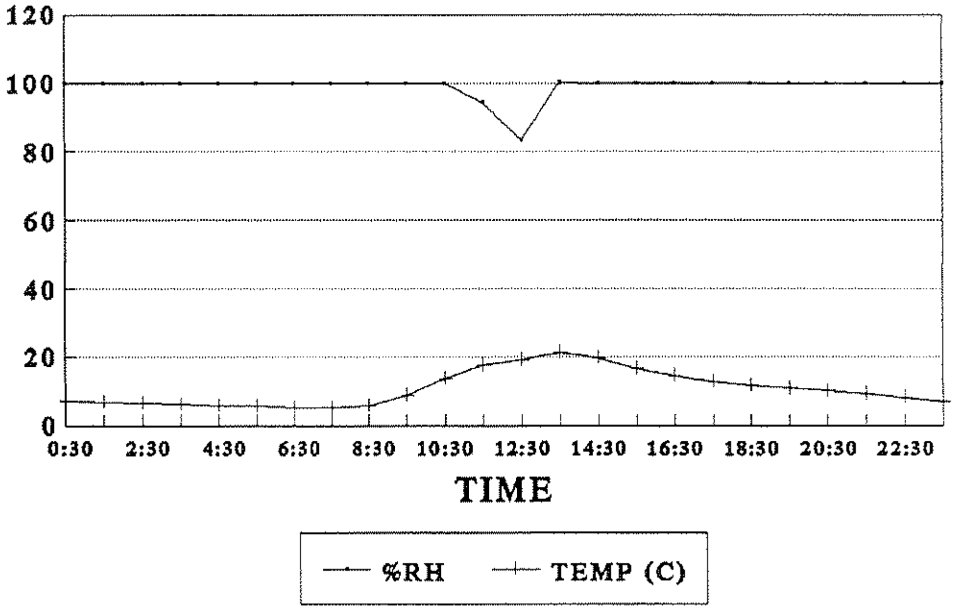


27/10/90

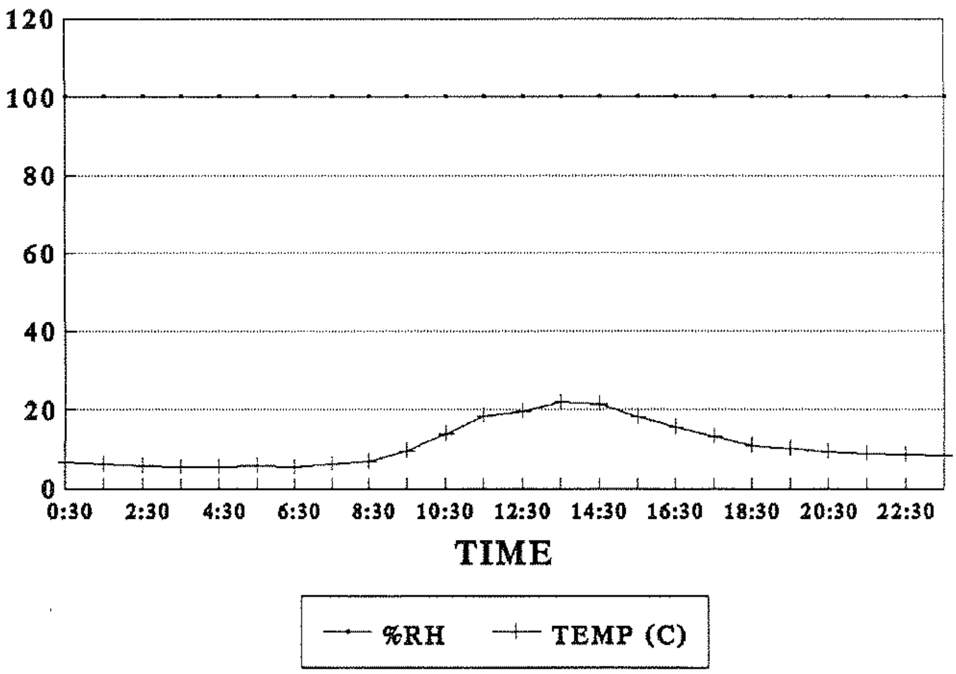


28/10/90

RH AND TEMPERATURE CHANGES
SITE B



29/10/90



30/10/90