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CULTURAL RESPONSES AS A BASIS FOR THE INTERPRETATION OF THE AGRONOMIC VALUE OF WINDBREAKS IN THE CARIBBEAN ZONE

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INTRODUCTION

Trade winds are among the determinants of climate in the Caribbean area through their mechanical effects and their effects on evapo-transpiration. Only (the effects on) evapo-transpiration will be considered in this paper.

Trade winds markedly increase the water requirement of plants for transpiration and thus affects the "potential evaporation" (ETP) (†). Several authors including the bioclimatologists of INRA (1964) have investigated the effect of ETP on plant production. It was observed that too high a level of ETP can reduce the instantaneous photosynthetic activity of plants. It can be argued, therefore, that in tropical countries, where high solar radiation at mid-day, short days and one of the highest instantaneous ETP throughont the world exist, these factors act as limiting factors to photosynthesis. The acceleration of the exchange of water between the plant and the air increases the need for water, of plants grown in such climates.

It is reasonable, therefore, to expect that the establishment of windbreaks leading to a decrease in the EPT values, would result in an increase in the photosynthetic activity. These experiments were done along similar lines as those done by Guyot in France (1964).

Semi-permeable artificial windbreaks were erected in Guadeloupe as parallel curtains set perpendicularly to the predominant direction of the trade winds.

II. CULTURAL RESPONSES

II.I. French Bean, Cucumber, Melon

These vegetables have responded favourably to the inclusion of windbreaks. First, earliness is enchanced. Seed germination may be advanced by 3 or 5 days. Early growth is faster, while later growth could be more vigorous in some instances. Normal size may not be attained if growth is retarded or delayed.

Next, this early advantage given to plants on the leeward side of the windbreak is maintained during the late stages of development, the leaves are usually wider and more in number. The leaf area was 25 per cent greater on plants on the leeward side. Plants on the windward side of the windbread exhibited xerophytic features; for example, melon leaves developed a marked pilosity.

Last, fruit setting is higher and lead to a yield greater than that of the control.

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*INRA: Institute National de la Recherche Agronomique (France).

†In this paper we differentiated ETP on a day scale and instaneous ETP on some minutes scale.

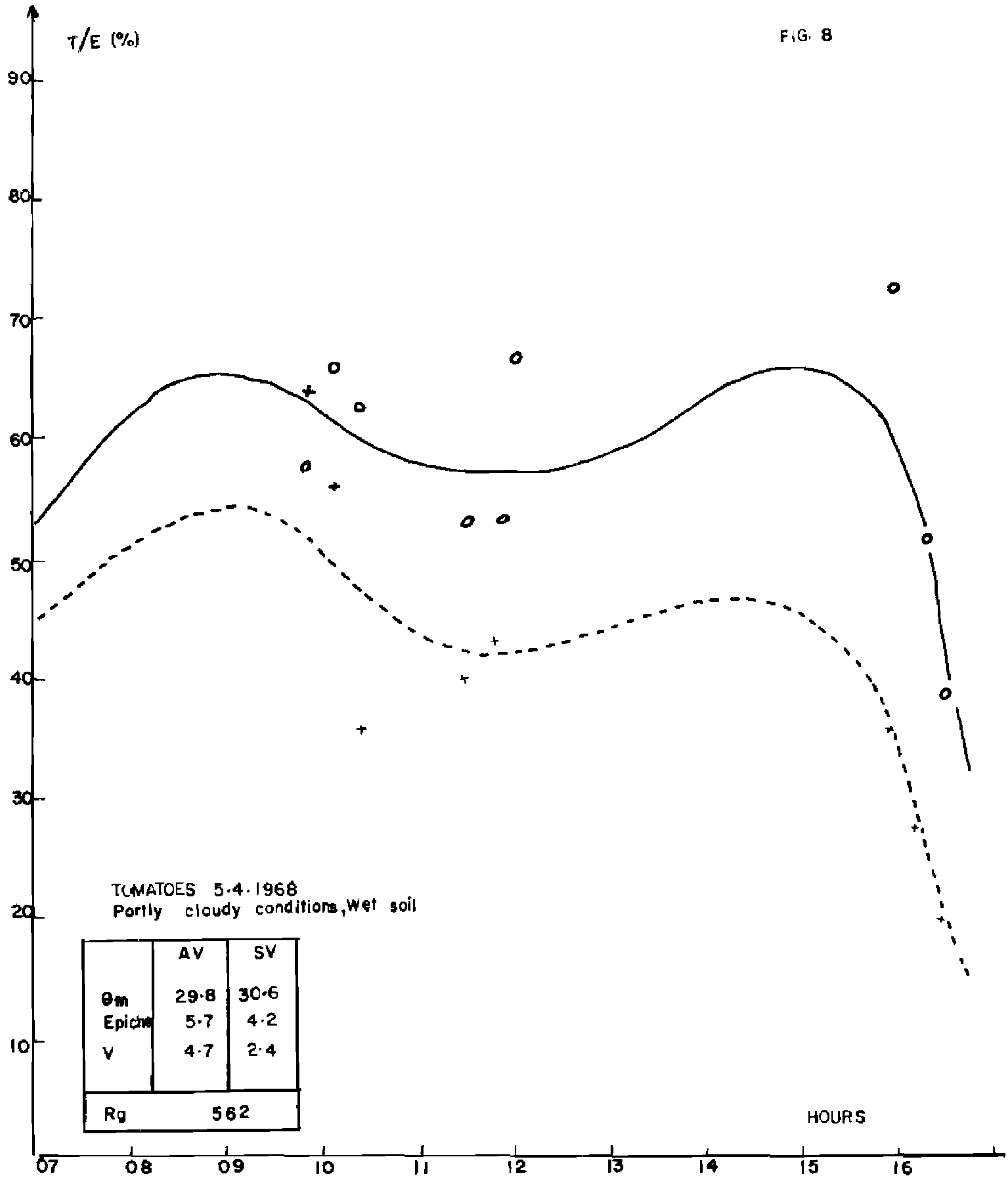

T/E (%)
90
80
70
60
50
40
30
20
10
TOMATOES 5·4·1968
Partly cloudy conditions, Wet soil
AV
SV
θm
29·8
30·6
Epich
5·7
4·2
V
4·7
2·4
Rg
562
HOURS
07
08
09
10
11
12
13
14
15
16

FIG. 8

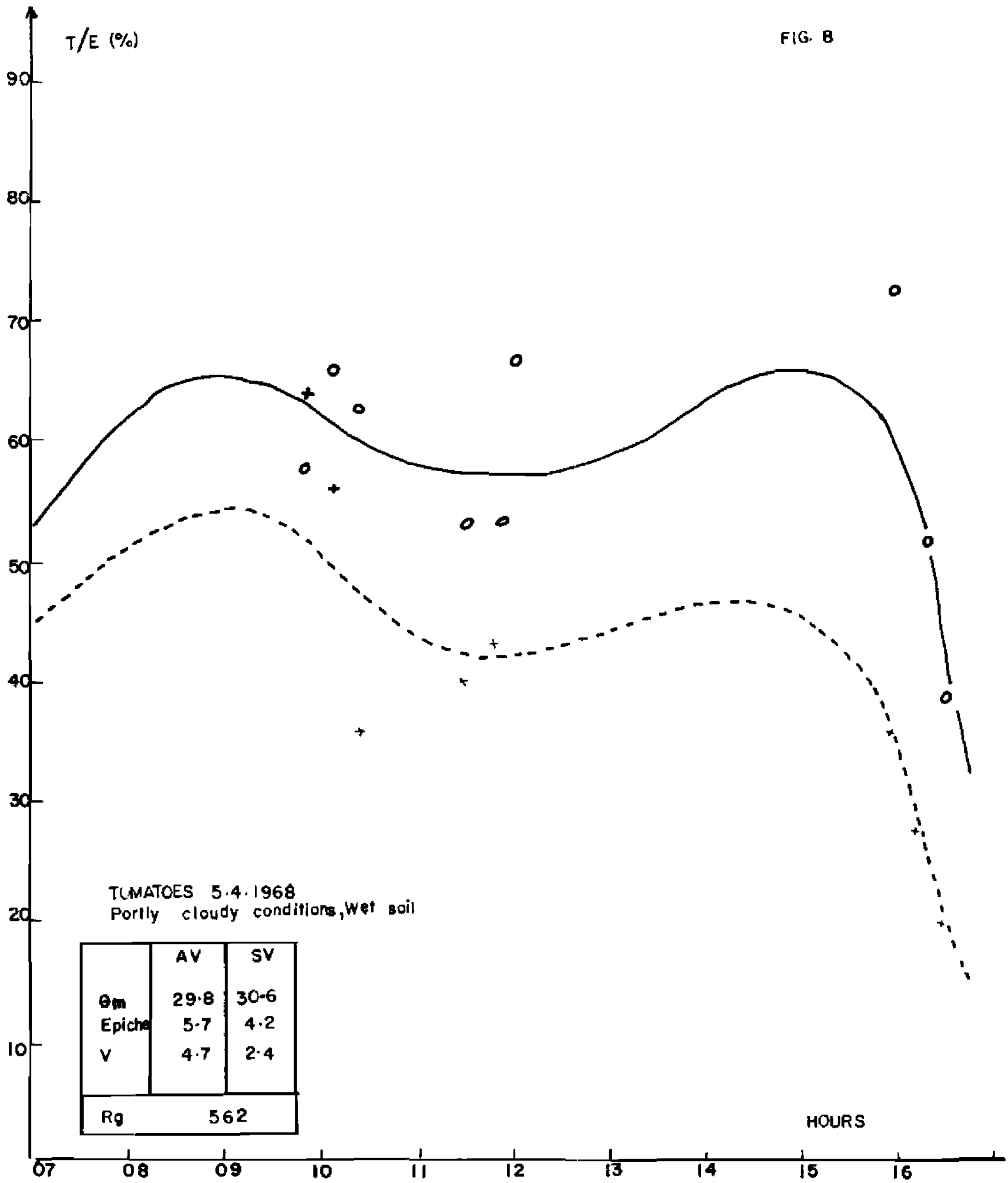

T/E (%)
90
80
70
60
50
40
30
20
10
TUMATOES 5·4·1968
Portly cloudy conditions, Wet soil
AV SV
θm 29·8 30·6
Epicha 5·7 4·2
V 4·7 2·4
Rg 562
HOURS
07
08
09
10
11
12
13
14
15
16

FIG. 8

II.2. Sweet Potatoes

Experiments conducted on sweet potatoes have shown a noticeable increase of foliage (20 per cent about), but increases in tuber yield only occurred in a limited number of cases. It may be that, with irrigation food reserves which are enchanced by the application of windbreaks, could be orientated between the foliage or nnder gronnd parts.

II.3. Tomatoes and Lettuce

Less success has been obtained with tomatoes. There is some difficulty, experienced in leeward culture, and the leaves do not grow better than those on the windward side; bunches are thus a little poorer and the fruit number is less. The fruits themselves are somewhat bigger at harvest and thus yields are similar.

With lettuce we observe a starting growth and an increased leaf area in leeward culture, while the control progresses very slowly. At the end of the cultivation cycle, a propensity toward flowering is exhibited in leeward culture and lead to the harvesting of badly headed plants, though well furnished with wide and thin leaves. Growth in the windward culture continues longer and its vegetative performance is better. Yield increases from leeward culture is 10 per cent greater but this short superiority is balanced by leaving the plants under windward culture 5 days longer in the field.

For these two crops, modification of growth and yield are not experienced with the use of windbreaks.

Differences in the responses of plants to windbreaks can be explained by their sensibility to microclimatic factors. The chief climatic factors essential for photosynthesis are light energy, temperature, carbon dioxide and water. It can be argued that light energy is not an important consideration when dealing witb windbreaks except in immediate proximity to it. It is often admitted that carbon dioxide concentrations in localised areas are increased at night by the use of windbreaks. (GUYOT 1964). Moreover, windbreaks, by diminishing exchange ability, increases the resistances of diffusion of gases at leaf level. Though CO_2 interactions need to be thoroughly studied as far as they affect natural vegetative conditions, this seems to be less important than temperature and water interactions.

III. Windbreak effects and the relative Transpiration of the Leaf (T/E)

Observations on the cultural responses of plants to the application of windbreaks have shown that the most promising experimental approach to the study of favourable plant reactions to ETP reduction may be through measurements of the relative transpiration of the leaves.

III.1. Working Hypothesis

It is well known that leaf cells keep an amount of water that depends upon the supplying capacity of the plant, the environmental situation and the plant species.

A part of this water is available for evaporation from the external surfaces which correspond to the transpiration process. If the supplying of water is deficient the cell turgor is lowered and may lead to stomatal closure and stopping of photosynthesis. As said before, in the Caribbean zone, where mid-day hours may also be the most windy, windbreaks must be used to reduce the mid-day depression which is responsible for the decrease in dry matter production at the time when light is at its best.

Photosynthesis may be therefore linked with transpiration since the mid-day depression is more important on the former than on the latter ((DE PARCEVAUX 1.64). The leaf transpiration value cannot be understood except as a physical model steadily bound to variations in the climatic conditions. For instance, comparing a leaf transpiration (T) with the evaporation (E) of an evaporometer PICHE disk, leads to an estimate of relative transpiration (T/E) that approaches unity as the opening of stomata get larger. Then it is possible to follow through-out the day the relative transpiration fluctuation and, admitting that other limiting factors do not operate, to compare these with photosynthetic variations.

111.2. Technical Procedure

The technical procedure is that of DE PARCEVAUX (1964). Measures of T/E have been done simultaneously on both sides of the windbreak with leaves of melon, French bean, and tomatoes. Thus, absolute values which lead to some errors are not used, but relative ones are used instead.

III.3. Interpretation of T/E Measure from Windbreak Trials in Guadeloupe

Interpretation of T/E values from ETP reduction by the use of windbreaks must result in a greater approach to unity for T/E value in the leeward zone.

The results shown (figure 2 to figure 8) were taken on days with rather homogeneous weather conditions has been confirmed by other measures. The indicated extrapolations specially for the beginning and the end of the day-time, had been also checked.

III.3.2 Relative transpiration of melon

Three cases have been studied. They had in common: high total radiation, windy and sunny weather. They differed in the soil water supply.

In the first case (figure 2) on the 5th of April, 1968, with a good soil water supply, T/E was increasing by mid-day on the protected side, while, on the contrary, the open side showed a slight decrease. The difference is noticeable the more since the leaf area index are also highly different. Observed evaporation in the leeward zone which exhibit a high leaf area index is far over the control one.

Some days later (figure 3) on the 9th of April, soil water supply was markedly lower in the leeward zone, in contrast to the windward zone which still showed a rather saturated value. T/E measures on this day showed a better value for the protected zone, but the difference is less, and the mid-day decrease is effective in both situations.

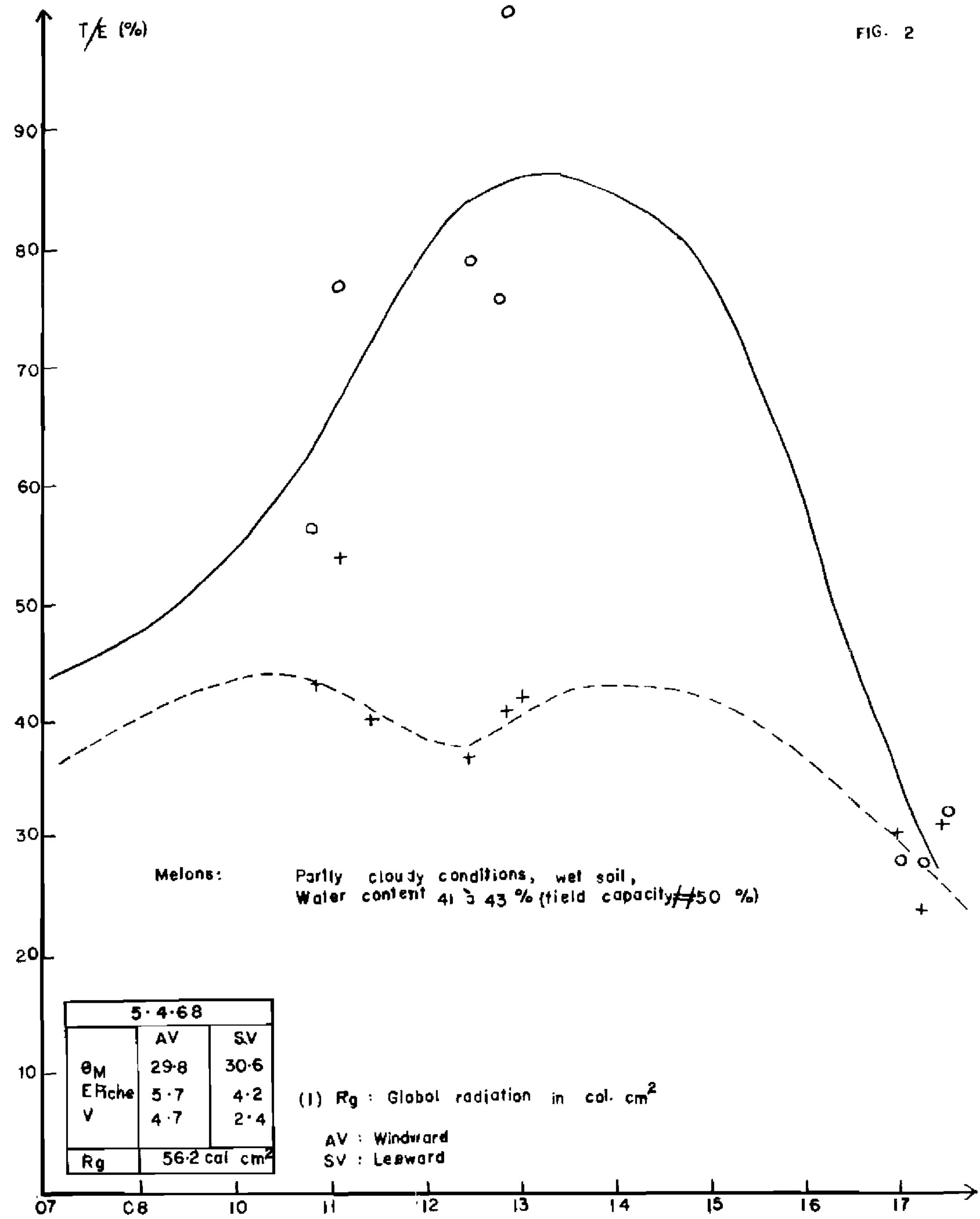
With a dry soil, as on the 5th of July (figure 4), after high T/E value in the morning a marked decrease in leaf turgor is observed which leads to a visible wilting. Inferior values of T/E can be seen at times in the protected zone, a reverse situation which is not significant when considering the whole crop cycle. This inversion disappeared at the beginning of the afternoon and came back later but the increases were comparably less than the morning ones.

With a soil poorly supplied with water, windbreaks result in adverse conditions.

III.3.3. Relative transpiration of French bean

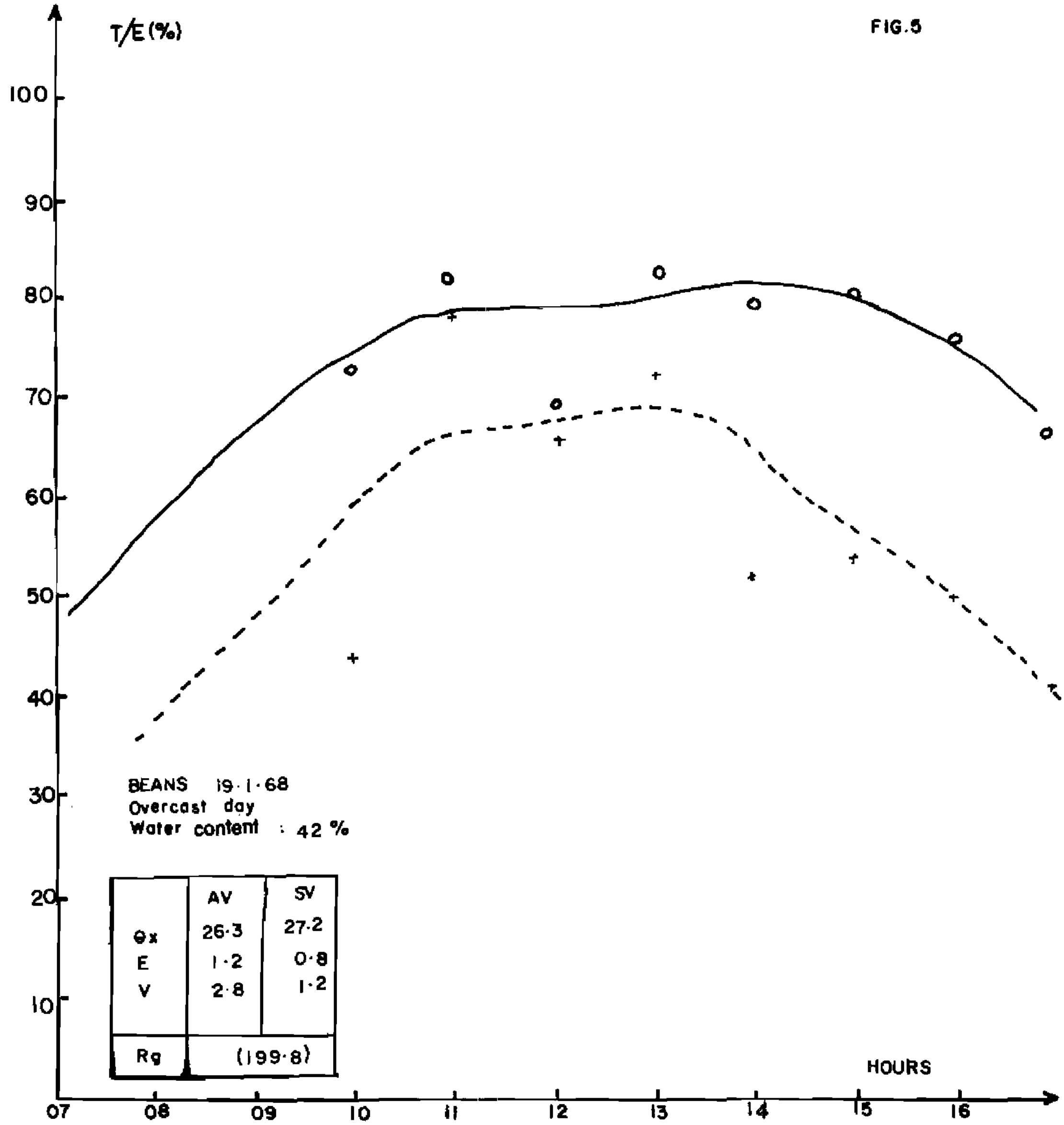
The trial was conducted during that part of the year when gross radiation, day length and therefore ETP, are at their weakest level.

FIG. 2

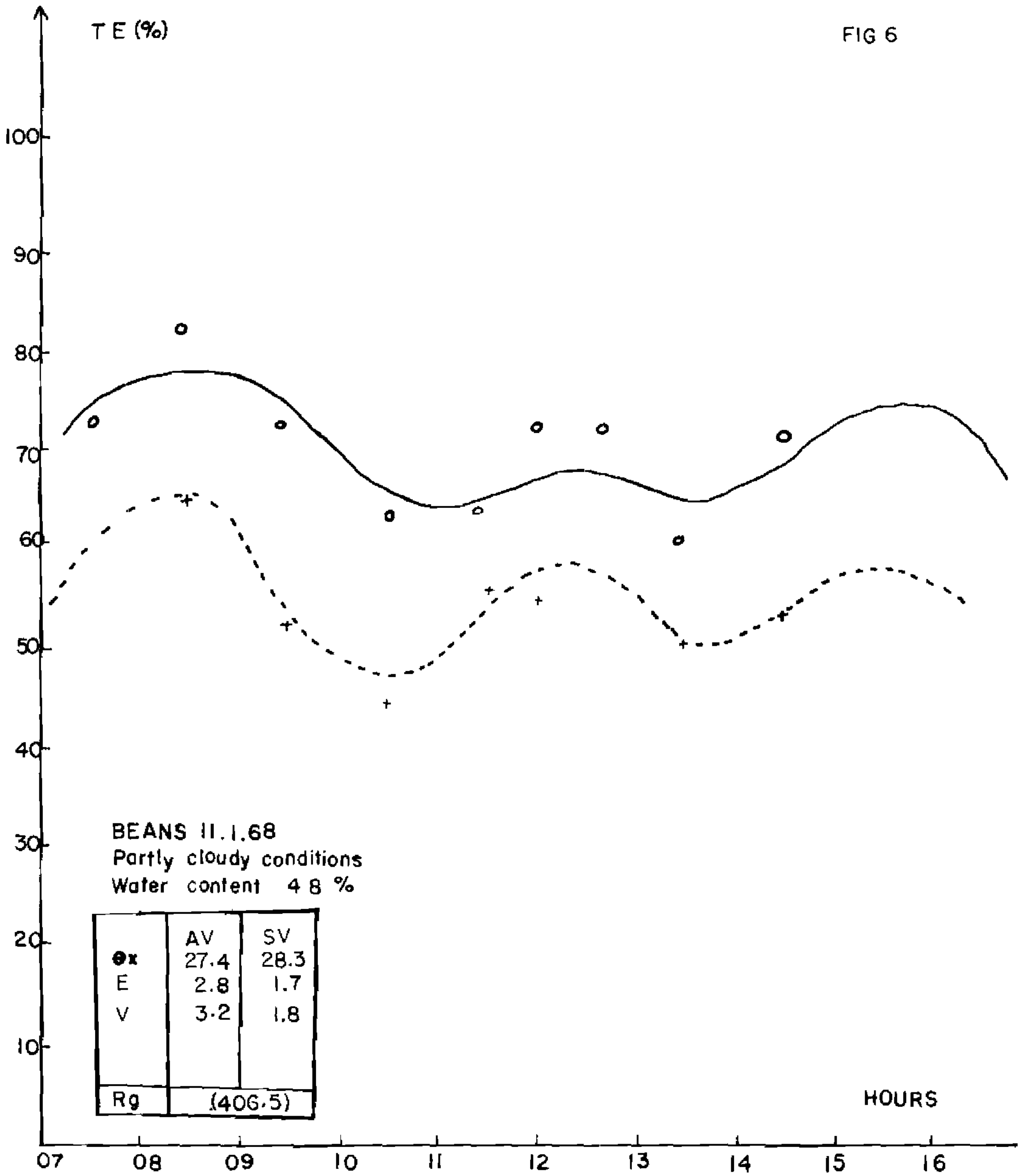


T/E (%)
90
80
70
60
50
40
30
20
10
07
08
10
11
12
13
14
15
16
17
Melons: Partly cloudy conditions, wet soil,
Water content 41 à 43 % (field capacity ≠ 50 %)
5·4·68
AV
SV
θM
ERche
V
29·8
5·7
4·7
30·6
4·2
2·4
Rg
56·2 cal cm2
(1) Rg : Global radiation in cal. cm2
AV : Windward
SV : Leeward

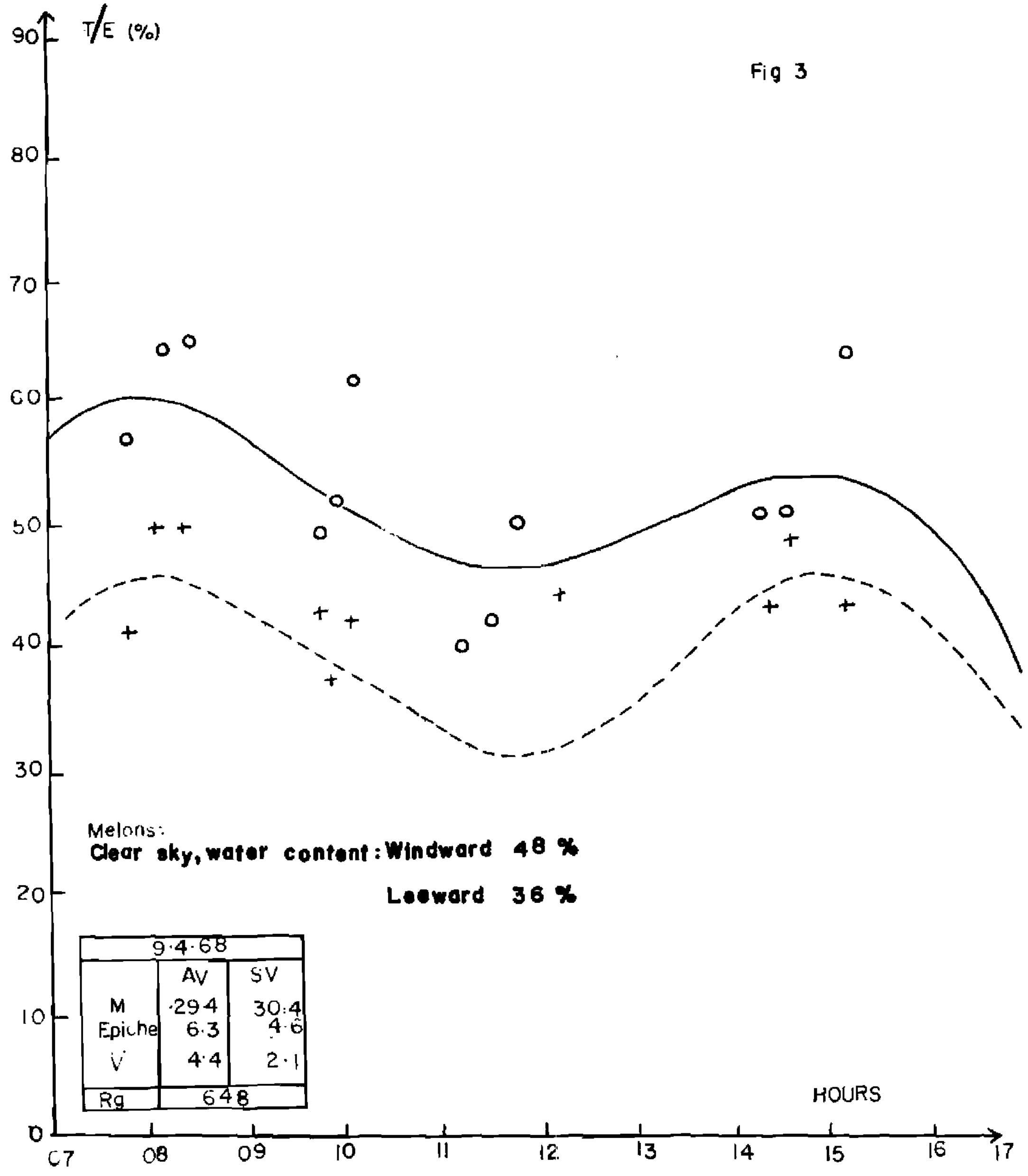
FIG.5



T/E (%)
100
90
80
70
60
50
40
30
20
10
BEANS 19·1·68
Overcast day
Water content : 42 %
AV
SV
θx
26·3
27·2
E
1·2
0·8
V
2·8
1·2
Rg
(199·8)
HOURS
07
08
09
10
11
12
13
14
15
16



T E (%)
FIG 6
100
90
80
70
60
50
40
30
20
10
BEANS 11.1.68
Partly cloudy conditions
Water content 48 %
AV
SV
Θx
27.4
28.3
E
2.8
1.7
V
3.2
1.8
Rg
(406.5)
HOURS
07
08
09
10
11
12
13
14
15
16



T/E (%)
Fig 3
90
80
70
60
50
40
30
20
10
0
Melons:
Clear sky, water content: Windward 48 %
Leeward 36 %
9·4·68
AV
SV
M
·29·4
30·4
Epiche
6·3
4·6
V
4·4
2·1
Rg
648
HOURS
07
08
09
10
11
12
13
14
15
16
17

The soil being well supplied with water, the only limiting factor is solar energy. The curves (figure 5) obtained from a cloudy weather shows T/E 10 to 20 per cent higher iu the protected zone. Maximum values found around mid-day, perhaps is due to limiting light values at both extremities of the day. During sunny weather, on the contrary, best results are obtained in the middle of the morning and the afternoon. On the hottest "summer" days, more important decreases should be observed or even, inversion between the two curves, indicating a possible decreasing effect of windbreaks at the time of the highest instantaneous ETP.

Within the limits of the experiments the effects of windbreaks were a clear increase of T/E in the protected zone.

III.3.4. Relative transpiration of tomatoes

The curves obtained for T/E with tomatoes (figures 7 and 8) during sunny weather with or without passing clouds and with the soil being well supplied with water, give a strong collaboration to the results found with French bean. The activity is the greatest between 8 and 10 a.m. and between 3 and 4 p.m., with a noticeable decrease between 11 and 12 p.m. The leeward and windward curves become parallel but the leeward one remains very clearly above the other (10 to 30 per cent difference). The depression is more accentuated on the 9th than on the 5th of April because of the higher instantaneous total radiation. A less marked sensibility in the protected zone would be expected in the hottest time depression, but very likely the increase observed behiud the windbreak can account for the partial inefficiency of the slowing of the wind as against instantaneous ETP.

To sum up, the analysis of the T/E evolution curves during day-time leads to the following conclusions:—

Control of water supply is a key factor in determining the benefits to be derived from the use of windbreaks.

Windbreaks are highly efficient with some crops in well watered soil. Its advantages are less obvious when a shortage of water supply is present and the responses occur at random in dry soil.

The effects of windbreaks on the plant on well watered soils are expressed at the leaf transpiration level, through better ability to respond to climatic changes and thus result in better conditions for dry matter accumulation.

Responses depend upon the characteristics of the plant. Melon is markedly and positively sensitive. French bean, though somewhat less sensitive, reacts favourably, at least in our experiments. Tomatoes react in the same direction but even less.

If considered together, T/E measures and yield, exhibit a fair relationship in melon and French bean crops. On the contrary, the improvement of the relative transpiration of tomato leaves behind windbreaks does not express itself through a yield increase. The reason for this is the negative intervention of the high temperature associated with the use of windbreaks.

IV. VARIATION BETWEEN CULTIVATED PLANT RESPONSES AND INCREASE IN TEMPERATURE

Depending upon season and windbreak porosity, the air temperature during the hottest time of the day increases by 1 or 3° C, bare soil temperatures being also increased by 1 or 2° C. This last fact could account for early germination and difficulties in cuttings rooting and may cause complicated modifications in water diffusion and absorption at roots level.

Diurnal increases of air temperature leads to the more important loss of dry matter from respiration. This loss can counteract the gain resulting from the better gross photosynthesis brought about by ETP reduction. It is known (COSTES et al, 1967) that this is related to the species of plant. Among the species we tested in Guadeloupe, tomatoes and lettuce are some of the most sensitive to high temperatures. For instance, a number of species of tomatoes show, in green-houses, an optimum net photosynthesis at 20° C. As for French beans, the optimum occurs at 30° C and for cucumber and melon between 30 and 35° C.

The temperatures in the shade during peak temperatures in Guadeloupe being between 27 and 31° C it is obvious that a shift of 1° or 2° C has no effect with melon and cucumber, while it has a depressive effect with tomatoes and lettuce. If we also consider the fact that the leaf temperature differences can be of 4° or 5° C between open and protected zones when measured in French bean and tomatoes, it is clear that the depressive effect of high temperatures could lead, in cultivated species poorly adapted to Guadeloupe, to random or even negative effects with windbreaks.

V. CONCLUSION

The agronomical interest of windbreaks in the trade wind tropical zone and specially in the Caribbean Area is undeniable. A considerable increase in productivity of some vegetables well adapted to high temperatures can be expected. Somewhat less may come from root crops for which a model of the method of interaction appears to be more complicated.

Increase in temperature seems to limit the value of windbreaks for a number of sensitive plants like tomatoes and lettuce. More interpretative data are needed with them. The use of a windbreak having a greater porosity than the semi-permeable one, which was used in this study, to observe the effects of a decrease of heat combined with a determined reduction of ETP upon the relative transpiration of the leaves.

Research has therefore to proceed toward a better appraisal of the possibility of the use of windbreaks which should improve the agronomic response of a great number of cultivated plants of the tropical zone.

JULY, 1968

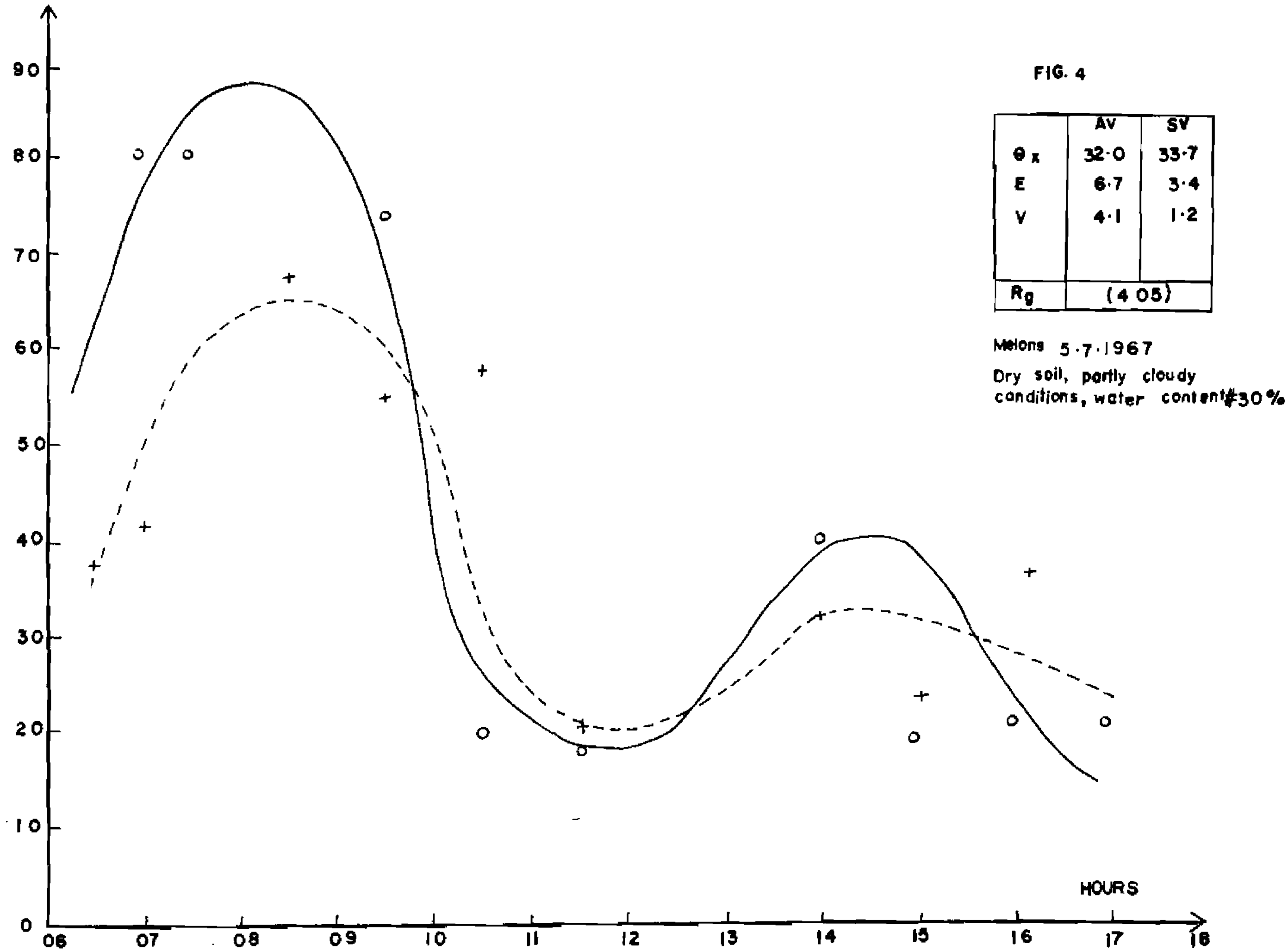
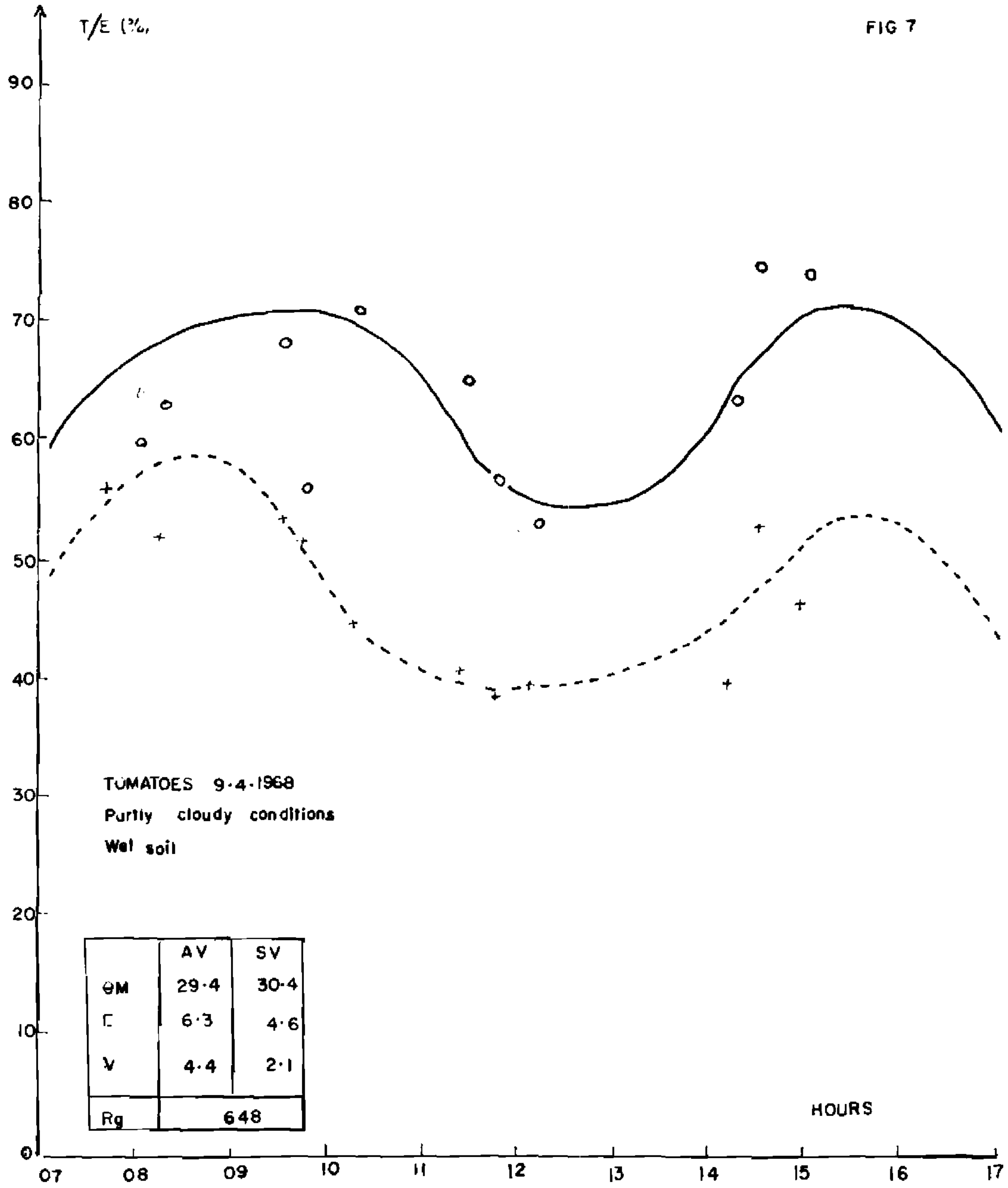


FIG. 4
AV SV
θx 32·0 33·7
E 6·7 3·4
V 4·1 1·2
Rg (4 05)
Melons 5·7·1967
Dry soil, partly cloudy
conditions, water content≠30%
HOURS
0
10
20
30
40
50
60
70
80
90
06
07
08
09
10
11
12
13
14
15
16
17
18

FIG 7



T/E (%)
90
80
70
60
50
40
30
20
10
0
TOMATOES 9·4·1968
Partly cloudy conditions
Wet soil
AV
SV
θM
29·4
30·4
E
6·3
4·6
V
4·4
2·1
Rg
648
HOURS
07
08
09
10
11
12
13
14
15
16
17

TABLE I

Windbreak experiment in Guadeloupe Choice of cultural result

Crops	Windward				Leeward				Rdt B/A
	V	Ox	ETP	Rdt	V	Ox	ETP	Rdt	%
French Bean: December 1967–February 1968 ...	3.0	27.9	4.7	10.0	2.0	28.5	5.3	15.0	150
Cucumbers: June 1967–August 1967 ...	3.2	29.6	4.8	23.0	2.3	30.2	3.6	40.0	174
Melons: March–May 1968 ...	3.5	30.0	6.3	23.4	1.6	30.7	4.6	34.3	146
Sweet potatoes: July-October 1967 ...	2.7	29.8	4.7	12.3 26.0	—	30.4	3.8	13.2 30.5	107 117
Tomatoes: March–May 1968 ...	3.5	30.0	6.3	35.0	1.6	30.7	4.6	28.5	80
Lettuce: March–April 1968 ...	2.1	27.8	4.1	36.7	0.7	29.5	3.0	33.3	90

V = Mean wind speed: m. $s.^{-1}$
O_X = Mean maximal temperature at 1 m: °C.
ETP = Potential evapotranspiration: mm by day
Rdt = Production: t. ha^{-1}. For sweet potatoes,
—First value: tuber weight
—Second value: aerial parts weight.

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