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Original Article

Climate versus Productivity

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Abstract

The relation between climate and agricultural productivity starts from that of carbohydrates dependent on photosynthetic activity and as such any relation between climate and productivity is primarily linked to the relation between photosynthetic yield and the climatic parameters This is the essence of Devanathan 'concept on the relation between climate and productivity On this basis productivity model has been developed and presented. This has been so widely tested by Ranganathan in tea and other crops in India and Sri Lanka as Consultant to IMT technologies Ltd., Pune.

Keyswords

Climate; Agricultural productivity; Photosynthetic activity.

Introduction

The important considerations deciding the relation between climate and productivity are:

1 Carbohydrate yield – function of photosynthesis

2 Bio-mass conversion and expression in terms of growth and recognition of time lag between carbohydrate production and expression of it in growth.

Devanathan's[1] concept and improvements there on by Ranganathan lead to generalized model for growth as given below:[2]

PART - A

The plant factors relating to water resistance to transportation mechanisms and evapo - transpiration to dissipate heat and adaptations to drought resistance are included in constant 'K 'along with the effects of crop husbandry practices which finally express themselves in terms of harvest index.

Soil Factors Relate to it

1. It's capacity to store water and supply it to plants
2. The path ways and the rates of repletion through rain fall and ,or irrigation against depletion through evapo-transpiration and plant uptake
3. Depletion/Repletion Pattern

Water Storage is Determined by

1. Soil structure expressed in terms of porosity (around 60 %) and bulk density (around 1.1) – the water held in micro-pores sustained by humic acids binding, and aeration, permeability and bio- activity maintained by meso and macro pores sustained by calcium aggregation and mechanical

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Generalized Model for Growth

Agro-climatic Potential φ = Ft *R * (S+1) * R *T * K
A B C

A -Photosynthetic yield
Ft-Temperature coefficient of photosynthetic process(Baldry, Buckeland Walker, 1966 Table-1) based on the rates of photosynthesis on isolated chloroplasts under saturated light and unlimited supply and moisture using labeled carbon under ideal conditions
R – Rainfall /irrigation efficiency factor (discussed in detail below in PART-A) Represents the probability of the length duration ,the water supply system maintains leaf water potential at and above critical level (88 % of the optimum level) during illumination
S+1 - Sunshine hours per day above limiting light saturation ; correction given for diffused light and unrecorded sun shine at boundaries at critical light saturation by adding +1

B- Bio-mass production and expression in terms of growth
Utilization of carbohydrates for biomass production interms of growth ,all reactions taking place in water medium The entire gamut of bio- chemical reactions involved are water and temperature dependent
R- Rainfall /irrigation water use efficiency or water use efficiency
T- temperature use efficiency –Effective use of available day degrees for growth (discussed in part-B)

C -Plantfactors and agronomic practices
Variations in transport mechanisms of carbon-di-oxide to mesophyll cells, transport resistance to water and , photosynthetic sites per unit area etc, and finally manifest in practical terms as HARVEST INDEX

Table1: Rates of Photosynthesis at Various Temperatures Relative to 25 p c (after Baldry, *et al* 1966) at Unlimited Supply of Carbon-di-oxide and Water 'Devanathan MA.W. (1976). The Quantification of Climatic Constraints on Plant Growth (Tea Quarterly 45: 43-72.)

t°c	Ft	t°c	Ft	t°c	Ft	t°c	Ft
0	3.4	10	31.1	20	75.4	30	126.8
1	4,5	11	35.2	21	80.4	31	132.9
2	5.0	12	39.8	22	85.1	32	138.9
3	7.6	13	44.3	23	90.1	33	145.0
4	9.9	14	48.8	24	94.9	34	151.2
5	12.3	15	53.0	25	100.0	35	157.7
6	15.2	16	57.5	26	105.0		
7	18.9	17	62.2	27	110.1		
8	22.6	18	66.7	28	115.1		
9	26.7	19	71.2	29	120.9		

t°c temperature Ft Relative rate of photosynthesis

composition of soils (texture).

2. Soil depth – for effective root penetration and volume of storage medium.

Water Storage Available to Plants is Calculated as Follows :

1. Soil depth : It is taken as the depth of the soil up to which 90 % of the root distribution is seen
2. Moisture at 1/3 atmospheres or 60 to 70 % of Water holding capacity is taken as available water for plants
3. Efficiency of moisture utilization is 100 % at top one third Soil depth and 50% at lower two thirds of soil depth or 70 % on an average

The Water Storage at any Given Time Units (Say Month) is Equal to:

F# = Fm +Rm – Etmwhere

'Fm' is the storage of water at the beginning of the month'.

1. 'Rm' the rain fall or quantum of irrigation for the month, 'Etm' the evapo -transpiration losses for the month.
2. 'F#' is the available moisture for the month.
3. 'Fm' at the beginning of the time unit is the 'F#' calculated at the end of previous time segment or 'F', the water storage capacity of the soil whichever is lower, or in other words 'Fm' is limited to maximum of 'F'

values.

$$R = 1 - e^{-(Fm + Rm - ET)/F}$$

Where 'R' is the probability of leaf water potential maintained at or above critical level and represents rain fall or irrigation use efficiency.

PART – B

Growth is a function of transpiration (250 kg of water is transpired to manufacture one kg of biomass) and temperature. Water available is determined by depletion /repletion balance of water storage system. Hence it is represented by 'R' rain fall / irrigation water use efficiency factor.

All reactions are temperature dependent. Night temperature below 14 ^{0}C retards growth and the probability of number of days with night temperature falling below 14 ^{0}C is related to daily mean temperatures

Day degrees above the critical minimum temperature for growth i.e., 12.5 ^{0}C for tea determines the rate of biomass production for growth ; but the increase is exponential reaching a maximum value around 28 ^{0}C because losses due to respiration increases at a much faster rate than the gains through photosynthesis at temperatures above 30 ^{0}C

Hence the effect of temperature is given as below:

$$T = 1 - e^{-(12.5 - t')/17.5}$$

Where 12.5 is the minimum critical temperature for growth, t' is the mean temperature and 17.5 is the day degrees between the minimum critical temperature for growth and the temperature above which the net photosynthesis falls rapidly (that is 30 ^{0}C)

Other considerations

1. Time lag between photosynthetic yield and expression in terms of growth is about 5 weeks in the pruned year and 4 weeks in other years. To-day's crop is a reflection of photosynthetic yield obtained 4 to 5 weeks ago and the prevailing growing condition .
2. Hence, φ_p Agro- climatic potential of the previous month and ' φ_c' agro climatic potential of the current month are taken for correlating with yield. Prediction value is 94 % with Malawi data under constant management and non limiting fertilizer management ; 85 % with Sri Lankan Data with good distribution of rain water; and 70 % in South India with data involving wide variety of management practices and climatic Zones
3. Theoretically yield is represented by:

$$Y = (k_1 * \varphi_p + k_2 * \varphi_c) CF$$

Table 2: Water storage available to plants in different regions

	NE India	S India	Sri Lanka
Soil depth (90% root distribution),	75 cm	150 cm	150 cm
Water holding capacity	45 %	48 %	45 %
Bulk density of the soil	1.20	1.05	1.10
Water storage capacity (as rainfall equivalent)	20 cm	36 cm	36 cm
Evapo-transpiration cm /month	7-14	6-9	7-10
Drought tolerance	1-2 months	3-6 months	3-6 months

Table 3: Agro- Climate of some tea growing areas

AREA	t' °C	RF cm	SS,h	ft	R	T	φ_p
Anamallais, SI	20.3	400	5.2	0.77	0.73	0.36	0.83
N.Wynaad	21.8	201	6.4	0.84	0.69	0.41	1.24
Vandiperiyar	22.4	211	6.4	0.88	0.66	0.44	1.14
Assam	23.4	206	5.6	0.93	0.69	0.44	1.29
Malawi	21.8	177	6.7	0.85	0.65	0.41	1.13
KANDY	23.5	164	6.8	0.93	0.66	0.47	1.26

Where k_1 and k_2 are relative contribution of φ_p and φ_c for the current crop; CF is the correction factor which is related to 'harvest index' and factors influencing it.Agro- Climate of some tea growing areas are given in Table 3.

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