SYNOPSIS

Tea is the only organised agricultural industry in India that has long standing, being planted in about 0.4 million hectares in India and supporting about two million people. India produces 655 million kg. of made tea, about 29.1 per cent of the world production (2254 M kg). There is growing threat on Indian tea export as more and more areas are brought under tea elsewhere. To keep India in its position, production must be maximized. A highly ambitious plan of the Government of India to increase the production by 16 per cent by the end of the 7th plan is only possible by better management rather than extensive cultivation due to the paucity of land.

Major amount of tea is produced in North-Eastern India in Assam, Dooars, Darjeeling, Terai and Cachar. A general survey shows that most of the gardens depends on mercy of rain for their production. Tea being a perennial crop, needs lot of water. But an uneven distribution of rain which often happens in the region has a very adverse effect on tea. Fertilizer is another important resource responsible for better tea production.

Tea Research Association, the pioneer research organisation for tea in North-Eastern India, has carried out some studies on the effect of fertilizer and irrigation on tea production. But a comprehensive study has not been carried out on the resource management which maximizes the tea production and minimizes the cost.

Keeping these objectives in view an experiment was formulated. The area taken for the experiment was in two sections of Tinkharia Tea Estate (Latitude: 26° 43' 13" N, Longitude: 92° 26' 35" E). The variables and the levels conceived for experimentation are :

(i) Water application in terms of available moisture depletion, I(6) :

I_1 = 10 per cent

I_2 = 20 per cent

I_3 = 30 per cent

I_4 = 40 per cent

I_5 = 50 per cent

I_0 = control (rainfed irrigation)

(ii) Fertilizer dose F(5) :

F_1 = split dose 110-20-40 N P K

F_2 = single dose 135-40-80 N P K

F_3 = split dose 135-40-80 N P K

F_4 = single dose 160-40-160 N P K

F_5 = split dose 160-40-160 N P K

(iii) Age (2):

Planted in 1931

Planted in 1954

(iv) Replication (3) :

Each treatment was replicated thrice.

Irrigation levels were changed in the second year in one of the sections to establish optimum depth. The irrigation period was devided into three parts viz. 21st October to 31st January, 1st February to 31st March and 1st April to 14th June. The levels in the periods were fixed on the basis of IW/CPE ratio as follows :

I_1 = 0.5, 1.0 and 1.0

I_2 = 0.5, 0.9 and 0.9

I_3 = 0.5, 0.75 and 1.0

I_4 = 0.6, 0.6 and 0.6

I_5 = 0.5, 0.5 and 0.5

I_0 = control (rainfed irrigation)

Split-split-plots design was used taking plant age as the main plot, water as the subplot and fertilizer as the sub-subplot. There were 90 plots in each of the two sections. The size of each of the plots has been decided taking the uniformity of the sprinkler into consideration. Each plot is 18 m long and 6 m wide with buffer zone differentiating one plot from the other.

Soil analysis showed that soil is of sandy loam type with low amount of Nitrogen, Potash content and high amount of Phosphorus and Carbon content. Average rainfall of the area is 2021 mm with almost 81 per cent of the rain concentrated between May and September. Rainfall during monsoon is more than sufficient to sustain growth. Probability analysis showed that the rainfall in warm season, which is very important for an early

crop is erratic and highly unpredictable. Evaporation rate during March and April is very high creating maximum need of irrigation.

Crop factor under different irrigation levels were measured by drum culture technique, which shows that this factor is minimum (0.41) during December and gradually increases with time and become maximum in April (0.91). Crop factor decreases as the available moisture depletion decreases.

The experiment was conducted during 1985-86 and 1986-87. Yield from the indivisual plots showed that young plants yield much better production than the old plants.

Effect of irrigation was found to be highly significant on production. Irrigation reduced the dormancy period. An early crop of about 17.4 per cent of the total production was harvested on an average while non-irrigated plots not only delayed the first flush but brings in huge amount of green leaf creating management problem. In all other rounds of plucking irrigated sections invariably gave better production than the non-irrigated ones. Yield records clearly indicates maximum production from I_2 (20 per cent depletion) level of irrigation in both the sections irrespective of fertilizer level. Otherwise the general trend of yield decreased with increase in moisture depletion. Though I_1 (10 per cent depletion) level of irrigation maintains minimum stress the ultimate annual production is less than that produced by I_2 level of irrigation.

With the modifed status of irrigation level in Section 43 during 1986-87 the yield record indicates that maximum production is possible with I_2 level of irrigation. In other words maintaining IW/CPE ratio of 0.5 during winter upto the end of February and there on a ratio of 0.9 achieves maximum production.

Yield response to fertilizer indicated a clear advantage of split dose over single dose. Higher production is possible with a higher level of fertilizer. However, F-test on the yield data showed that the effect of fertilizer is not statistically significant unlike the effect of irrigation which is highly significant.

Mathematical relationships were developed between cumulative production and time. The relationships were found to be almost linear. It shows that first flush is delayed with soil stress. Relationships were also established between soil moisture depletion and production for both the sections during 1985-86 and for Section 45 during 1986-87. Third order polynomial equations were found to have explained the relationships. Same degree of equation was also found to be best fitted for the relationships between total depth of irrigation water and production for the yield record of Section 43 during 1986-87. Relationships were also established to find out the combined effect of fertilizer and irrigation on yield, based on yield record of Section 43 during 1986-87. The following are the established relationships :

$$Y = 0.015 + 7.961\ I - 0.334\ N + 0.161\ IN - 0.038\ I^2 - 4.553\ N^2$$

$$Y = -0.002 + 8.868\ I - 5.457\ P + 0.030\ IP - 0.038\ I^2 - 0.043\ P^2$$

$$Y = 1.102 + 8.487\ I - 1.222\ K + 7.911\ IK - 0.035\ I^2 + 0.002\ K^2$$

where, Y = Yield, made-tea, kg/ha,

N = Nitrogen, kg/ha,

P = Phosphorus, kg/ha,

K = Potash, kg/ha and

I = Depth of irrigation, mm

Classical optimization technique was used to find out the optimal depletion rate using the production functions obtained from the experimental data. The optimum value of the rate was found to be 18.44 per cent. Using the same technique, an optimum depth of irrigation ranging from 134.15 mm to 148.80 mm was obtained depending on fertilizer level. The optimum depth of irrigation is less in case of split dose application of fertilizer with a minimum at F_5 (160-40-160 N P K) level.

Utilizing the best moisture status for maximum production two plans were developed considering 20 and 30 per cent risk factors. In addition irrigation schedule on fortnightly basis with 25 mm has been worked out. It was found that during the early flush period additional quantity of water needs to be applied to maintain optimum moisture content. A case study was taken up for Tinkharia Tea Estate to demonstrate the application of the models. Irrigation sets required considering 30 per cent risk and the 25 mm depth of irrigation for most of the time was worked out. The number of extra hours to be run by the sets was

also incorporated in the irrigation schedule.

Economics of irrigation based on prevailing rates have been worked out consulting leading firms, knowledgible indivisuals and planters. Economics have been worked out for different systems of irrigation currently practised in the gardens. The extra benefits due to irrigation works out to be Rs. 9580 per hectare.

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CHAPTER I

INTRODUCTION

Tea (Camelia sinensis), the beverage for poor and rich alike, has been known to be used as a drink in south-east China before AD. The natural home of the tea plant is considered to be within the fan-shaped area between the Naga and Lushai hills along Assam-Burma border, in the west, through the Che-kiang province of China, in the east. The east-west axis is about 2400 km long, extending from 95° to 120° E. The north-south axis is about 1900 km, from 29° to 11° N. Tea was planted in Assam in the year 1839 (Eden, 1976). It was later on extended to other parts of the world, with a net world tea production of 2254 M kg by 1986. India produced 655 M kg, about 29.1 per cent of the world production.

Tea is the only organised agricultural industry in India that has long standing. It is employing about a million persons directly, and supporting another million through the subsidiary industries. Tea is planted in 3,94,900 ha in the states of Assam, West Bengal, Karnataka, Tamil Nadu and Kerela. The internal consumption of tea in India is about 480 M kg and is increasing steadily at a rate of 4 to 5 per cent per annum. Tea is the second highest foreign exchange earner for India, Which is the largest exporter of tea in the World.

Because of stiff international competition posed by countries like China, Sri Lanka, Japan, Malayasia, etc, there is

strong need to increase the cost effectiveness of tea production in India. The highly ambitious plan of the Government of India to produce 760 M kg of made-tea by the end of the seventh plan, aiming at an export of 281 M kg is impossible with an extensive cultivation due to paucity of land. For maximising the production from the existing resources it is necessary to produce plants with inbuilt characteristics for high growth, better quality and protection from the attack of various diseases, pests, etc. Secondly, the use of the plant nutrients and the plant protection materials have to be optimised to cut down the cost. Thirdly, radical changes have to be brought about in the methods of tea production to retain and optimise the characteristics responsible for the quality and flavour as also to enhance cuppage. Fourth and the most important aspect is to optimise the inputs to maximize the production from the same land. Irrigation and fertilizer are the most important inputs in the tea industry. Tea in many areas of India are left to the mercy of rain. Tea is a perennial crop needing huge amounts of water throughout the year. So irrigation is highly essential not only as an insurance against drought but also as a means of producing higher amounts of tea and reducing the seasonal dormancy. Moreover, successful irrigation is more than just water, it is a complex interaction of soil, water, agronomics and application, all of which are continuously evolving with new technology. Both "over irrigation" and "under irrigation" not only affect the soil moisture status in soil but also directly interfere with total cost of irrigation. Hence benefits accrued will be nullified to a great extent unless the optimum quantities are applied at proper time.

With the increase in the fuel cost and irrigation equipment a proper design is of paramount importance. Fertilizer need is the maximum single capital expenditure as an input in tea industry. Thus judicious application must be aimed at maximizing the production and minimizing the input itself. Keeping the above problems in view, the research project was formulated with the following specific objectives :

1) To find out the effect of variation in fertilizer and irrigation on the production of tea.

2) To develop production functions taking fertilizer and irrigation parameters as variables.

3) To develop an optimal planning for a given area under limited resource.

4) To work out the economics of irrigation under optimal planning.

A small metereological observatory provides vital data for rainfall, evaporation, temperature and relative humidity of the experimental area. Moreover, the ground water fluctuation and the soil temperature were recorded during the period of the experiment. A split-split-plot design was proposed with the age of the plant as main plot, irrigation as the subplot and fertilizer as the sub-subplot. The levels of fertilizer and irrgation were decided in consultation with agronomists and planters. The effect of different levels of resources were recorded in 1985-86 and the same experiment was continued in 1986-87 one of the sections for confirming the previous year's result. The irrigation levels were changed in one of the sections

to establish optimum depth. The irrigation experiment indicated the optimum level of irrigation and fertilizer. Practical viavility of the optimum application were studied and a more practical irrigation schedule was proposed to give similar result.

Production function models were developed using a developed program on computer by the least square method taking fertilizer level and irrigation level as variables. Optimum quantities were obtained using classical optimization techniques. The third objective was achieved by taking a case study for the experimental garden with its existing water resource.

The money to be invested for irrigation was calculated using the recent cost of irrigation equipments along with the running costs. The expected net return due to this extra investment in the way of irrigation was calculated. The results clearly justify the additional investment and future planning.