Fifth Indian Expedition to Antarctica, Scientific Report, 1988
Department of Ocean Development, Technical Publication No. 5, pp. 473-487

Prospects of Horticulture in Antarctica

M.C. JOSHI* AND B.K. BANERJEE**

*Defence Agricultural Research Laboratory, Almora-263602
**Defence Materials and Stores Research and Development Establishment
Kanpur-208013

Abstract

Horticultural experiments to cultivate some vegetables indoors were initiated during the Fifth Indian Expedition, at both Dakshin Gangotri and Maitree. Plants grew at both places well showing that the local soil is as good as the Indian soil. Preliminary surveys at DG and Maitree revealed that it is possible to obtain congenial indoor temperature. The indoor lighting and solar illumination were found to be inadequate. These, however, could be brought to the required level by doing the necessary adjustments.

Introduction

Antarctic flora, typical of a desert tundra, is mostly restricted to lichens, mosses and other lower forms, though totalling about 800 plant species (Benton, 1980) some of them growing as far poleward as 80°S. Vascular flora in Antarctica consists of only three species of flowering plants (Greene and Greene, 1963), growing mostly in Graham Land and its offshore islands, limited to the 64th parallel (Llano, 1962).

Little floral growth is possible at below-freezing temperatures (monthly means for all months) (Trewartha, 1954), as in most of Greater Antarctica (near 0°C in coastal areas in summer) (Phillpot, 1963). 'However, the temperature of bare ground where it exists (ca 0.05% of the whole Antarctic surface) can be considerably higher than that of the surrounding air when the sun shines, creating a microclimate to support existing flora. Additionally, the local average temperatures at Maitree, as per available data, are higher than those at Dakshin Gangotri, though with a broadly similar profile (Fig. 1). An apparent rising trend in the local temperature, as suggested by the receding snow cover in part of the Schirmacher hills (original landing strip of Novolazarevskaya station laid bare in about ten years), could well be the basis for an interesting experiment to grow trees behind the Priyadarshini lake at Maitree, perhaps with cold resistant seeds (Tikhomirov, 1962), or at least some lower vascular plants.

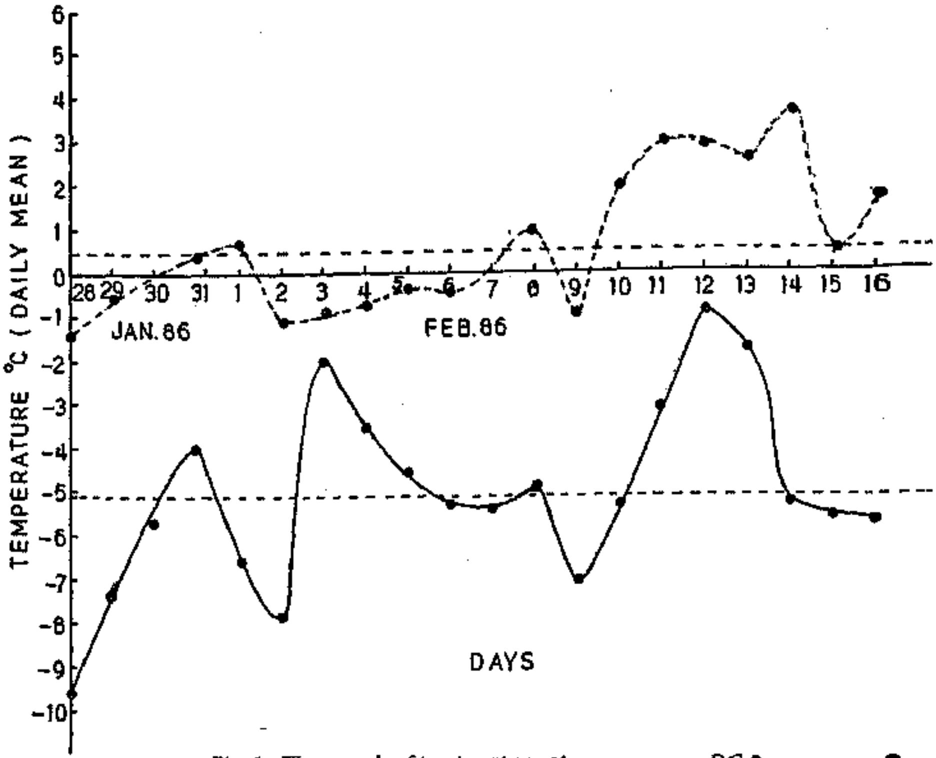

Fig. 1. The march of temperature at *DG* ●——● *Maitree* ■- - - -■

As a prelude to experiments to grow trees, more conservative experiments to grow vegetables (some salad crops, to start with) and flowers in Antarctica were planned in the Vth Expedition. Vegetable seeds (for indoor cultivation in Antarctica) were provided by the Defence Agricultural Research Laboratory (DARL), Almora. Cold resistant flower seeds (for sowing around the Priyadarshini lake), collected from high altitudes (12,000 - 15,000 feet) in the Himalayas, were unfortunately held up in India due to a transport breakdown and were not available for experiments in the Vth Expedition. The experiments on indoor cultivation described hereinafter were aimed at studying the suitability and adequacy (for plant growth) of local materials and under the existing conditions of temperature, illumination, and space at Dakshin Gangotri and Maitree. Accordingly, two experiments were carried out to grow some salad crops with: (a) Indian soil, snowmelt water, and Irish manure (as available) at Dakshin Gangotri Station (DGS) in artificial illumination and, (b) local soil, lake water, and manure at Maitree in sunlight.

The outcome of these experiments reveal encouraging prospects. Plants grew at both places, though they lacked vegetative development (apparently due to inadequate illumination). The local materials at Maitree were as congenial to plant growth as normal Indian materials. The observations resulting from these experiments throw useful light on horticultural experiments in Antarctica.

Materials and Method

Soil (ca 150 kg) from the Kodar farm near Ponda (Goa) was carried to Dakshin Gangotri for the experiment there. This soil, a sandy loam (typical coastal soil), contained an assortment of gravel (upto 3 cm); apparently it had a fair proportion of clay and held water well. The local soil at Maitree (from the bank of the Priyadarshini lake) contained a lot of sand besides a few gravel and very little clay (Table I). Its capacity to hold water was poor, though it was found to be very wet while digging up.

Table I. Some Physical characteristics of Maitree Soil

SI. No.	Composition	Content %
1.	Coarse sand	22.04
2.	Fine sand	42.00
3.	Silt	29.15
4.	Sand clay	5.87
SI. No.	**Property**	**Magnitude**
1.	Apparent density	1660 Kg/m^3
2.	Moisture content	24.66%
3.	Specific gravity	2.079
4.	Pore space	41.81%
5.	Volume expansion	NIL

Snow-melt water (central supply) was used for irrigation at DGS. Water from the Priyadarshini lake, freely used for cooking and drinking, was used for the experiment at Maitree; this water was found to be mildly acidic and contained a trace of some minerals (Table II).

Manures and fertilizer commonly used in India to augment yield were not available for the experiments in Antarctica. A different natural (organic) manure, viz., sphagnum or peat bog moss, was used instead. Some quantity of an imported Irish variety of this manure was available at DGS, and the naturally growing local variety, collected from the banks of the Priyadarshini lake was used for the experiments at Maitree.

The seeds used (Table III) were all (except cucumber) freshly raised in the cold environment of Almora by the DARL there with proved viability. Cucumber seeds came from the Novolazarevskaya station.

Table II. Analysis of Maitree Water (Soil)

Physical	
Colour	NIL (Nil)
Odour	NIL (Nil)
pH	6.8 (6.7)
Chemical	
TDS ppm	12 (25)
Total hardness ($CaCO_3$ ppm)	Trace (Trace)
Anions (ppm)	*Cations (ppm)*
Cl 2.8 (Trace)	NA^+ 1.00(-)
SO_4^{2-} -(-)	K^+ 1.00(-)
CO_3^{2-} -(-)	Ca^{2+} Trace (Trace)
HCO_3- 5 (7)	Mg^{2+} Trace (Trace)
F-0.05 (0.09)	Heavy Metals absent (absent)
NO_3- 0.05(5)	Iron absent (absent)

The experiment at DGS was performed on the A block mezzanine, right above the generator room and repair (mechanical and electrical) shops. There was no access to sunlight and no temperature control in the A block The

Table III. Particulars of vegetables for Horticulture

SI. No.	Vegetable	Variety (Cultivar)	Optimum temperature,°C	Season, days
1.	Radish	JWL	10-15	50-70
2.	Spinach	Arusel	12-18	40-50
3.	Methi (fenugreek)	Arusel	,,	30-40
4.	Methi (fenugreek)	Kashuri	,,	
5.	Tomato	BM-15	21-23	,,
6.	Cucumber	Novo	18-24	60-90
				80-100

experiment was carried out in artificial illumination (four 40W Cool White fluorescent lamps mounted in as two rows on a wall as possible under the circumstances. A coarse temperature control (effectively utilizing generator heat) was achieved (27.1.86) by erecting a makeshift enclosure around the plants and lights with the help of metal foil clad foam polystyrene blocks available at DGS. The temperature inside the enclosure was found to lie within a generally congenial range of 13°C to 21°C (Fig. 2) and the humidity varied from 16% to 30%, occasionally transgressing these limits in both directions.

The imported sphagnum manure was mixed with prepared (by eliminating gravel and evening out lumps) Indian soil in equal proportions (v/v) and spread into a 2-3 cm thick top layer over a bed (ca 15 cm deep) of similarly prepared soil in wooden packing cases and plastic bags, Radish was sown on ridges shaped on the soil in a packing case and the rest were sown on flat beds. Irrigation was done twice daily.

The experiment at Maitree, which lasted only 11 days, was carried out next to a glass paned window on the first floor of the kitchen hut so that sunlight was available for the growth of the plants. An oil fired bukhari and cooking

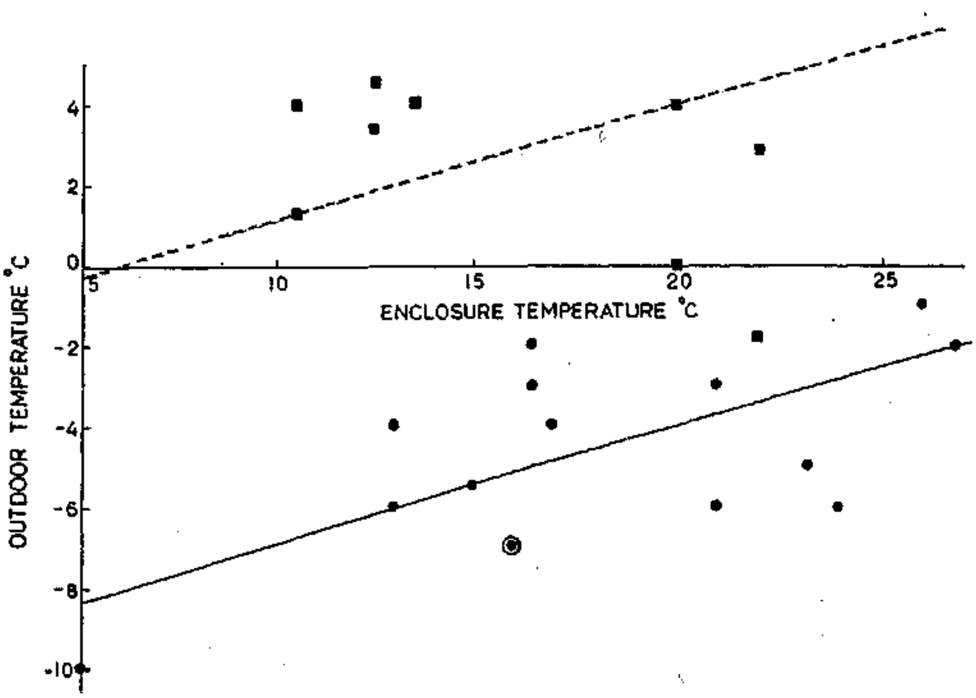

Fig. 2. ***Variation of enclosure temperature with outdoor temperature at*** ***DG*** ●——● ***Maitree*** ■- - - -■

gas oven on the ground floor kept the temperature at the cultivation site generally between 10.5°C and 22°C, though it used to be in the range of 7.5°C to 10°C, in the morning. The procedure followed at Maitree was the same as at DGS except that all seeds were sown on a flatbed of soil in plastic bags. After closure of camp at Maitree, all bags with seedlings (and sown seeds) were brought to DGS and kept inside the plants enclosure there. Almost 50% of the plants perished in the intense cold (-8°C) in transit but the survivors grew well at DGS.

Results and Discussion

All the seeds (except tomato and cucumber) sprouted within a week and progressed reasonably well at both places (Table IV). Tomato and cucumber both sprouted (the latter even grew two leaves) within 15 days at DG. The difference in the nature of illumination, soil, manure, and water employed at DGS and Maitree caused hardly any noticeable difference between the patterns

Table IV. Progress of Horticulture in Antarctica

DG

SI.No.	Vegetables	Sown on	Sprouted on	Seedling on	Harvested on
1.	Radish	16.1.86	20.1.86	21.1.86	3.5.86
2.	Spinach	22.1.86	27.1.86	30.1.86	,,
3.	Methi	2.2.86	5.2.86	8.2.86	,,
4.	Methi	2.2.86	3.2.86	4.2.86	,,
5.	Tomato	21.1.86 (20.2.86)	5.2.86 (-)	—	—
6.	Cucumber	21.1.86	31.1.86	5.2.86	—

MAITREE

SlNo.	Vegetables	Sown on	Sprouted on	Seedling on	Harvested on
1.	Radish	7.2.86	9.2.86	12.2.86	3.5.86
2.	Spinach	,,	14.2.86	17.2/86	,,
3.	Methi	,,	11.2.86	14.2.86	,,
4.	Methi	,,	9.2.86	12.2.86	,,
5.	Tomato	,,	28.2.86	—	—
6.	Cucumber	,,	28.2.86	—	—

of initial growth (11 days) of the plants at these two places (Figs 3 and 4). Signs of etiolation and poor vegetative growth (indicating insufficient illumination) (Went, 1959) were, however, distinctly discernible in the plants at both places. Spinach and the methis grew rickety stems and emaciated leaves as commonly attributed to deficient light (Audus, 1963), and at DGS, they showed a marked phototropic bending (Fig. 5) due to the unsymmetrical illumination there. Due to this abnormal morphogenesis, radish grew vestigial roots (25-30 mm X 1 mm) as found on uprooting a plant after 43 days, in spite of the luxuriant leaves (Fig 6). When harvested by the Wintering Party on 3rd May, 1986, for use in the kitchen, the radish roots are reported to have grown to a length of 35 to 40 mm with a width of about 3 mm. The cucumber seeding fell prey to a cold draught through the A block hatch, but four tomato seedlings are reported to have survived till May, 1986, growing to a height of 10 to 15 cm, and one of them flowered.

The deficiency of illumination received by the plants, as demonstrated by these results, are attributable to insufficient exposure (photo period restricted to ca 3 hrs daily by existing window size) at Maitree and to insufficient intensity (number of fluorescent lamps restricted by space and practical constraints) at DGS.

Plants have been shown to grow well (Porter, 1945; Withrow and Withrow, 1977; Cathey *et al* 1978), and salad crops are grown in a commercially competitive way in growth rooms (controlled environment agriculture), Downs (1975), in completely artificial illumination (photo-synthetic lighting with fluorescent lamps) (Arthur and Stewart, 1935; Bickford and Dunn, 1972; Cathey and Campbell, 1974).

However, a rough estimate (Appendix I) based on a well known method (Say, 1977) using available data (Croft *et ai,* 1981; Kaufman, 1981) shows (Table V) that the experimental enclosure at DGS would require 66 fluorescent lamps (supplemented by 6 100W gas filled clear incandescent filament lamps to fortify illumination in the red end i.e. 700—800 nm, of the spectrum) instead of the 4 actually used, for an initial illumination value of 2000 fc which reportedly gave very good plant growth (as in sunlight and faster).

For symmetry, economy, and simulating colour temperature of sunlight (Table VI), a combination of Cool White fluorescent lamps (96" lamps are commonly used for illumination levels upto 5000 fc) and incandescent filament lamps (or a combination of Plant Growth Lamps A and B, for better results) (Kaufman, 1981) may be mounted on the ceiling of the growth chamber to produce uniform illumination with the initial level as noted above, thereby eliminating the problems of etiolation and phototropic bending. Proper design of the growth chamber (Langhans, 1978) and more exact calculations could lead to a considerable reduction (more than 50%) in the number of lamps required to achieve the level of maintained illumination necessary for good plant growth (Table VII) (Luckiesh, 1924). Except for cucumber and tomato (both day neutral), the photoperiod would have to be adjusted to avoid early flowering and v'ining.

Table V. Specifications for Photosynthetic Lighting

Sl. No.	Specifications	Approximate Values			
1.	Type	Coolwhite	Coolwhite	Coolwhite	Incandescent
2.	Length	48"	60"	96"	55/16"
3.	Lamp current A	0.43	1.5	0.425	—
4.	Lamp volts	101	65	1.97	120
5.	Lamp watts	40	90	75	100
6.	Life hrs.	20,000	9,000	12,000	750
7.	Lamp lumen depreciation (LLD)	82%	85%	89%	
8.	Initial lumens	3150	6400	6300	1640
9.	No. for 2000 fc initial	66	32	33	6
10.	No. for 700 fc initial	23	12	12	2

After Say (1977) (p. 10-31) and Kaufman (1981) (Fig. 8-116. and 8-117)

Table VI. Approximate Correlated Colour Temperatures, K.

Blue sky	10,000-30,000
Overcast sky	7,000
Noon sunlight	5,250
Fluorescent lamps	
Warm White	3,020
Warm White Deluxe	2,940
White	3,450
Cool White	4,250
Cool White Deluxe	4,050
Daylight	6,250
100W incandescent filament lamp	2,900

After Croft et al. (1981) (p. 10-7), and Kaufman (1981) (Fig. 5-26)

Fig. 3. Pattern of initial growth inside the station at Dakshin Gangotri.

Fig. 4. Pattern of initial growth inside the station at Maitree.

Fig. 5. Phototropic bending of plants at Dakshin Gangotri Station

Fig. 6. Luxuriant leaves of plants.

Table VII. Photosynthetic and Photoperiodic Lighting for Growth Room

Sl. No.	Type of Work	Total effective light period, hrs.	Range of Irradiance mW/m^2	Range of illumination fc, (at 100 lum./W* and 25% cushion for LLD), approx.
1.	Professional horticulture	12 to continuous	6000-55000	75-700
2.	Amateur horticulture	10 to continuous	"	"
3.	Experimental horticulture	0 to continuous	0-400000	0-5000

*(After Luckiesh, 1924). The average illumination on the surface of the earth due to the sun at zenith is 10300 fc, falling to about 1000 fc when the sky is overcast. (Encyclopaedia Britannica, 17, p. 799, H.H. Benton, 1980).

The temperature recorded in the experimental enclosures varied roughly over the overall temperature range for optimum growth (Table III), in broad correspondence with local outdoor temperatures (spanning almost equal intervals, but about distinctly different means, at the two places). This general trend, as depicted by the slope and intercept of the regression lines (Hays, 1966) (Fig. 2), could be interpreted (assuming the bukhari to be a better heat source than the generator) to mean that the DGS enclosure is thermally better protected than the one at Maitree. Enclosure temperatures outside the generally congenial range appear to be outliers related either to the hot air blower or the side hatch in the A block at DGS, and to a dead bukhari and oven at Maitree. The humidity problem (recorded indoor RH 16-30%, as against a favourable range of 25-50%), endemic in the desiccated environment of Antarctica, has to be tackled by frequent irrigation as required.

The mildly acidic mineral soil (found, by analysis at DMSRDE, Kanpur, to contain normal bacterial flora as other Antarctic soil) and water of Maitree in combination with local sphagnum produced as good results as the mineral soil of Goa and snowmelt water combined with the Irish sphagnum.The apparent irregularities in the patterns of germination and seedling formation (Table IV) stem from the low ambient humidity which calls for sowing pre-soaked seeds.

The prospects of horticulture in Antarctica in the immediate future clearly belong to the growth chamber and the greenhouse. Indoor cultivation in sunlight, as is being done at present at Novolazarevskaya, can be carried out at Maitree either in a miniature greenhouse (like the East Germans) or next to a very wide transparent window in a living accommodation (like the Russians). One of the existing huts at Maitree can be conveniently converted to achieve the second option. Initially some short season radish (e.g. Early Scarlet Globe, and Comet, 21-25 days) could be tried to get a quick harvest and to establish the method. Cultivation of copious fruiting plants like tomato and cucumber, and flowers would be suitable for long-term work only. A generous supply of synthetic fertilizers to provide the mineral nutrients (macro; P, S, N, K, Ca, Mg, Fe, micro: B, Zn, Cu, Mn, Mo, Cl) is essential for good yield.

However, one particular -Himalayan high altitude flower, viz., the Brahm Kamal (Bamber, 1916; Hooker, 1904) (Saussurea Obvellata, Appendix II), appears to hold promise for outdoor cultivation around the Priyadarshini lake. Belonging to the outer fringe of the highland tundra, this flower has been found to grow above 15000 feet in the Himalayas, usually in rugged rocky terrain that lies under heavy snow cover for about seven months in a year, and often in just a pinch of sandy soil between rocks. The Brahm Kamal perhaps deserves the opportunity, denied to it by a transport breakdown, to prove that it is a serious contender for a place in the Schirmacher hills.

Acknowledgements

The authors are indebted to Dr. B.V. Ramani, Director, DMSRDE, Kanpur, for active help and guidance in bringing the work reported to a logical completion in Antarctica and subsequent analysis and assessment of results in India.

The help rendered by Shree M.K. Kaul, leader of the Vth Indian Scientific Expedition to Antarctica, in initiating the experimental work is gratefully acknowledged.

The cooperation extended by Lt. Col. P Kumaresh, and Dr. Vinod K. Dhargalkar, Commanders, DGS, and Lt. Col. R.P. Ahuja, Dr. N. Verlencar, Shree S.N. Misra, and Shree Channan Singh in continuation of experimental work is acknowledged with thanks. Shree Bhukan Lal of the IMD and Cdr. S.J. Singh of the Indian Navy must also be thanked for providing the outdoor temperature data for DGS and Maitree.

Thanks are due to Shree K.G. Sharma and Shree Gaonkar of the Zonal Agricultural Office in Ponda, Goa for providing the soil. Dr. N. Kumar and other agricultural scientists of the Pithoragarh, Almora, and Auli establishments must also be thanked for help in collection of high altitude flower seeds.

Acknowledgement is also due to Dr. Ram Gopal, Sc. 'E' of DLJ, Shree H.M. Dayal, Sc. *'B'*, and colleagues and Shree B.K. Gupta, Sc. 'B' DMSRDE, Kanpur for analysing Antarctic soil and water.

The authors are also grateful to Shree R.C. Gaur, Scientist, FRI for providing details of Brahm Kamal, Shree H.C. Pant, Sc. 'C', DMSRDE for many fruitful technical discussions, and Shree J.K. Chopra, JSO, DMSRDE, for help in preparing part of the material for publication.

References

ARTHUR, JOHN M., AND STEWART, W.D. (1935): Relative Growth and Dry Weight Production of Plant Tissue Under Mazda, Neon, Sodium, and Mercury Vapour Lamps, Boyce Thompson Institute, Yonkers, New York.

AUDUS, L.J, (1963): 'Plant Growth Substances', p. 363, Interscilnce.

BAMBER, C.J. (1916), Plants of the Punjab, p. 473, Govt. printing press, Lahore, Punjab.

BICKFORD, E.D., AND DUNN, S. (1972): 'Lighting for Plant Growth,' Kent State University Press, Kent, Ohio.

CATHEY, H.M., AND CAMPBELL, L.E. (1974): Lamps and Lighting, a Horticultural View, *Light Des. Appl*, 4, p. 41-52,

CATHF.Y, H.M., CAMPBELL, L.E., AND THIMIJAN, R.W. (1978): Plant Growth Under Fluorescent Lamps: Comparative Development of 11 species, *Florists' Rev.* p. 26-29, 67-69.

CROFT T., CARR, CLIFFORD, C, WATT, JOHN H., AND SUMMERS WILFORD I. (1981): American Electricians, Handbook, p. 10-31, tenth edition, McGraw Hill,.

DOWNS, R.J. (1975): "Controlled Environments for Plant Research", Columbia University Press, New York,.

ENCYCLOPAEDIA BRITANNICA (1980): 1, p. 956, H.H. Benton,.

GREENE, S.W., AND GREENE, D.M. (1963): Check List of the Sub-Antarctic and Antarctic Vascular Flora, *The Polar Record,* 11, No. 73, p. 411,.

HAYS, S. (1956): An Outline of Statistics; p. 119, 4th edition, Longmans,.

HOOKER, J.D. (1904): Flora of British India, iii, p. 365, Oxford.

KAUFMAN, JOHN E., Ed., (1981): 'IES Lighting Handbook' Application Volume; Illuminating Engineering Society, New York.

LANGHANS, R.W., Ed., (1978): 'A Growth Chamber Manual,' Cornell University Press, Ittaca, New York.

LLANO, G.A. (1962): The Terrestrial Life of the Antarctic, *Scientific American,* 207, p. 212-218,.

LUCKIESH, M. (1924): Light and Work, p. 92, D. Van Nostrand Co., New York.

PHILLPOT, H.R. (1963): Some Aspects of the climate of Antarctica, (SCAR Bulletin No. 15), *The Polar Record,* 11,.No. 75, p. 737.

PORTER, L.C. (1945): The Use of Artificial Light in Agriculture. General Electric Co., Cleveland,.

SAY, M.G. (1977): 'Electrical Engineer's Reference Book', p. 19-41, Newnes-Butterworths.

TIKHOMIROV, B.A. (1962): The Treelessness of the Tundra, *The Polar Record,* 11, No. 70, p. 24.

TREWARTHA, GLENN T. (1954): 'An introduction to Climate', p. 359, M,cGraw Hill.

WENT, F.W. (1959): Plant Physiology, 'Vistas in Botany" Turrill, W.B. Ed., vol. I. p. 525, Pergamon.

WITHROW, A.P., AND WITHROW, R.B. (1947): Plant Growth with Artificial Sources of Radiant Energy, Plant Physiology.

Appendix I

Computation of number of lamps required for desired illumination by the Lumen Method

The initial illumination produced on the work-plane by ceiling mounted light sources is given by

$$I = \frac{CU \times LL}{A} = \frac{CU \times (Np + nq)}{A}$$

Where I = initial illumination, fc
CU = coefficient of utilisation
LL = lamp lumens (initial)
N,n = no. of fluorescent, incandescent filament lamps
p,q = initial lumens of fluorescent, incandescent filament lamps
A = area, ft^2.

For a 8'× 5' enclosure with a source to work-plane distance of 4',

$$\text{room index} = \frac{\text{length} \times \text{breadth}}{(\text{length} + \text{breadth}) \times \text{heigth}} = \frac{40}{13 \times 4} = 0.8$$

For tentative ceiling- and wall-reflectances of 70% and 50% respectively, for batten mounted or bare fluorescent lamps, the CU is found (from tables) to be 0.37 corresponding to this room index of 0.8 Hence,

$$I = \frac{0.37}{40}(Np + nq) = \frac{1}{108}(Np + nq),$$

or, $N = \frac{1081-nq}{p}$, whence the N values of Table V (for arbitrarily chosen n and q values) follow.

Appendix II

Vern. : Brahm Kamal

Botanical Name : *Saussurea obvellata* (DC.) Edgew.

Pakistan to S.W. China. 3600—4500 m Rocky slopes, streamsides; rare in Nepal except in the extreme east around Topke Gola; prominent in 'The Valley of Flowers', Garhwal. Jul.-Sep.

A very striking perennial flower with large pale yellow boat-shaped papery bracts surrounding the dense cluster of purple flower-heads. Flower-heads several to many, in a dense umbel-like cluster, each 1.5-2.5 cm long and with involucral bracts with black margins and tips, hairless or nearly so. Encircling boat-shaped bracts several, overlapping, ovate, to 12 cm long, bristly-margined, translucent and conspicuously veined. Leaves oblong-lanceolate blunt, toothed, the lower stalked, the upper half-clasping with blade continuing in a wing down stem; stem stout, 15-45 cm.

FIFTH INDIAN SCIENTIFIC EXPEDITION

DAKSHIN GANGOTRI

ANTARCTICA

1985-1986

DEPARTMENT OF OCEAN DEVELOPMENT