Strategies for Protected Cultivation for Small and Marginal Farmers in India

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ABSTRACT

Protected cultivation is one of answer to most of the burning issues facing Indian Agriculture including adversities due to uncertain and varying climatic conditions, climate change, improper uses and low productivity of natural resources, nutritional security in topographic and climatic disadvantaged areas, environmental pollution due to pesticide use, etc. It generally refers to providing congenial conditions for better plant growth and enhancing the production level through artificial means. It makes possible by controlling the climatic conditions by providing full or partial covering surrounding the plant so that plant does not experience higher or low temperatures or humidity, while getting enough light for photosynthesis, optimum fertilisation and watering, and other factors for best growth and production. In the present day context, the interventions include polythene covered greenhouses (polyhouses), shadenet houses, insect net houses, low plastic tunnels, row covers, plastic film mulching, etc.

Such interventions have potential to enhance the productivity of any crop to several folds along with enhancing quality to very high level which is not expected normally in open conditions. It increases the land, water and fertiliser productivity alongwith reduction in pesticide use. But such interventions are associated with very high initial cost. Although, it is linked with several Government Schemes in India and have 50-90% of subsidies depending on intervention, status / socio-economic condition and policy of State and Central Government. But, still such efforts are not appreciated by small and marginal farmers and they are still deprived of their benefits at large. The ICAR funded All India Coordinated Research Project (AICRP) on Application of Plastics in Agriculture (APA) operative at eleven centres at different locations in India, is making intensive efforts to develop location specific - cost effective strategies for Protected Cultivation which is suitable for small and marginal farmers. Such efforts have been successful in raising the income and livelihood of resource poor farmers at different locations which is described in this paper.

Keywords: Protected cultivation; AICRP; Application of plstics in Agriculture; Polyhouses; Plastic film mulch; Shadenet house.

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1. INTRODUCTION

Application of plastics in agriculture, known as "Plasticulture" has enoromous potential to enhance the productivity of natural resources which has been realised in western countries since 1940s and onwards. Protected cultivation is one of the intervention of plasticulture which is highly promising to provide solution to most of the burning problems faced by agricutlure all over the world. In Indian context, the plasticulture was explored to enhance the productivity of different agricultural production systems, mostly after 1980s after establishment of National Committee on use of Plastics in Agriculture (NCPA). As an important constituent of NCPA, the Indian Council of Agricultural Research was assigned the task for research on the issue, and as a result the All India Coordinated Research Project (AICRP) on Application of Plastics in Agriculture was started in 1988 by ICAR. At present the AICRP is being operated at eleven centres located in different agro-ecologic areas and contributing in research and development on different plasticulture issues as per need and conditions prevailing in mandated areas of the centres.

Protected cultivation enables cultivator to produce several fold of good quality production which is difficult in normal conditions due to climatic and other constraints. If the recommended and needful package of practices is adopted skilfully with exactness, the any crop can be grown in any season, at any place using protected cultivation technique. It enables to control climate (temperature, humidity, wind, light intensity, etc), atmospheric gas composition (mainly CO_2 concentration), fertilisation, watering, pest and diseases, etc which results in better plant growth, better reproduction, minimised harmful effects of different factors (climate and agronomy) and higher production with better quality of produce.

The protection from different adverse factors may have different levels. Plastic mulching is provided to control climatic conditions in root zone, shadenet control temperatures and light intensity only, insect net house has additional insect & pest control, and greenhouses have fully covered structure with a transparent glazing film of suitable material with varying level of controls. Hence, the productivity and quality enhancement of any produce largely depends on level of protection and congenial conditions available to plants. However, it is a matter of cost which decides to what extent climatic and other conditions are controlled.

Due to the higher initial and operating cost and higher level of skill requirement, the interventions of the Protect Cultivation is mostly adopted by rich farmers and entrepreneurs, while it still remains far distant dream for small and marginal farmers in spite of several Governmental schemes and subsidies. Hence, the team of the scientists under the aegis of AICRP on Application of Plastics in Agriculture are engaged in developing simple and cost effective techniques for protected cultivations which can easily be adopted by the small and marginal farmers who are mostly resource poor and have less risk taking capacity. In this paper, we discuss few of the such efforts made at different locations and success obtained through working with farmers in their own conditions.

2. HISTORY OF PROTECTED CULTIVATION

From the ancient times, man strived to modify the environment through the use of devices such as windbreaks, shading, irrigation, drainage, fertilisers, and other cultural practices to improve the cultivation of different crops under varying conditions. All such efforts were to modify the environment but has little control on climate and other factors which is responsible for the crop production. Attempts to adapt crop production to the environment with protective devices to practices dates back to ancient times. Structures for crop protection began in early part of Roman Empire (14-37 AD), which have movable beds of cucumbers or other crops, placed outside on favourable days and inside during inclement weather. Transparent slate like plates or sheets of mica or alabaster were used as covers (Wittwer and Castilla, 1995). During late 15th to 18th centuries that the precursors of greenhouses appeared, primarily in England, Holland, France, Japan, and China. Later oiled translucent paper and glass were used to grow and warm plants against severe cold (Jensen & Malter, 1994). After 1600 AD, glass was the major covering material. Polythene film was developed in the late 1930s. The polythene film was first used to cover greenhouse to replace expensive glass panels in 1948 by Prof. E.M. Emmert in University of Kentucky to reduce the cost of construction (Espi *et al.* 2006). After that it is adopted all over world and almost replaced the glass panels except for special purpose greenhouses. However, plastic rigid panels are also being used in place of glass panels with similar results.

Bamboo and wooden sticks were the popular material for construction of frame of the structure in 15-19th century which was slowly replaced with metallic channels or pipes. Presently, all over the world, GI pipes or channels are most preferred material with varying specifications, while MS pipes angles are also being used at some locations with required paints / coatings.

3. DESIGN AND TYPES PROTECTED CULTIVATION STRUCTURES

The protected cultivation structure has three main components, viz. frame, cladding material and ventilation / climate control systems. Frame needs to be constructed strong enough to sustain against different types of damaging factors e.g. wind, rain / snow, soil / climatic moisture, physical / chemical deteriorations, etc. The cladding material should be transparent enough to provide required photo synthetically active radiation (PAR), entrap enough heat during cold weathers, and protect the plants from outside conditions. The ventilation / climate control system should be designed to provide congenial climatic conditions for better plant performance with reasonable compromise.

Design of a polyhouse involves determining its dimensions, ventilation / climate control requirement, and stability against adverse forces like winds, snow, heavy rains, hailstorm, etc. BIS standards (IS 14462:1997) provides guidelines to determine the design load from different sources, e.g. dead load due to fixed service equipments (heating, ventilation, air circulation, electrical, lighting, watering, etc.), live load (temporary load including repair crews and hanging plants, etc), snow load, and wind load. Some real time models developed for structural designs may also be employed to design various components of the structures.

The cost of construction is influenced mainly by design and material used for frame, and climate control system / ventilation used, while cladding material has less influence as it is fixed material which may vary a bit in quantity depending on structural design. Hence, to make the structure cost effective or cheaper, the material for the frame needs to be selected cheaper, locally available and easy to use for fabrication, but should be strong enough to withstand against normally occurring high wind pressure and corrosion or weathering in soil and climatic moisture.

Keeping view of such aspects in view, the project team has developed several designs which involve very low cost for construction and maintenance, while resource poor farmers can adopt and manage with moderate level of skill. Locally available bamboo or wooden material fetched from forest or purchased locally is mostly used for the construction of the frame, while only cladding material (UV stabilized 200 micron LDPE) is to be brought from outside. The local entrepreneurs have been trained to construct as well as maintain the structures. Such framed structure has life of 4-5 years or may be extended with appropriate measures upto 8-10 years. Such polyhouses (greenhouses covered with plastic film) are very cheap and easy to construct (Rs 200-300 / m^2 floor area) and found very effective as entry level structure to train and acquaint poor farmers to enhance the overall productivity of their small patch of land owned and can earn good livelihood. Once such farmers realize the benefits of the protected cultivation, then they go for relatively better structures with frame made of GI pipes having longer life (15-20 years). Cost effective designs have been developed using GI pipe frames and methodology of construction have been standardized at several locations. Several success stories are there in this respect and more than 150 units have been constructed in the states of Uttarakhand, Meghalaya, Kashmir & Ladhakh valley, and Himachal Pradesh, while the pertinent design have been demonstrated at other locations. Few of the studies in participatory mode undertaken at different locations are discussed below.

4. STUDIES ON COST EFFECTIVE POLYHOUSES IN HILLY AND OTHER AREAS

Strategic studies have been carried out in participatory mode at different locations to evaluate and demonstration of strategies to achieve better production from a small patch of land and limited natural resources. Active involvement of farmers and other stakeholders were ensured to better understanding of the strategies and technologies for lasting adoption and better realization of benefits by stakeholders.

4.1 Bamboo Greenhouse Technology in Farmer's field

A study was conducted in 2007, in two villages namely - Dhaspad and Palauali in Almora district, located in mid-hills of NW Himalayas (altitude 1800 m). A base-line survey on socio-economic condition of the inhabitant farmers was conducted and 6 and 4 farmers were selected from two villages, respectively. The bamboo framed greenhouse structures (40 to 80 m^2 floor area, even shaped with length:width ratio more than 2.2 with length along east west) were suitable considering the investment capacity of the farmers. The ventilation comprised of doors and windows covered with shade nets (75%). The farmer contributed construction of bamboo frame including fixing and labour, while the UV stabilized film (200 micron and 200 gsm) was provided by the project. The average structural cost was Rs 86/m^2 of floor area which includes 29% bamboo frame (Rs 25/m^2) contributed by farmer. The off-season vegetable crop sequences were selected to get maximum benefit, i.e. vegetable pea (December-March; season I) - summer squash (March-June; season II), Tomato (July – November; season III). The annualized fixed cost and input cost were considered as the investment in the current year. The B-C ratio varied between 1.67 and 2.2 for different greenhouses. The study suggested that the bamboo based greenhouse should have at least 80 m^2 floor area to realize better profit in the prevailing climatic conditions of NW Himalaya and socio-economic conditions of the farmers living in the region. The typical dimension of the greenhouse can be recommended as 16 x 5 m.

4.2 Environmental Control for Greenhouse in Hot humid climate

Development of appropriate greenhouse designs for arid and semi arid regions using natural ventilation and shading is very important for saving in energy and cost for environmental control. Efforts were made at JAU, Junagadh centre to study the climatic variations, techno-economic performance for flower and vegetable cultivation, in a GI pipe framed greenhouse (12.0 x 4.8 m). Various cooling and controlling devices and operating systems like mechanized natural ventilation, exhaust fan with VFD, excelsior cooling pad, wind pump water delivery and micro tube irrigation system, microprocessor based greenhouse controlling system, foggers cooling and different pumping units were installed. Based on the study, a schedule for operating different cooling system was prepared for handy use by farmers, as given in Table 1. In first fortnight of March, use evaporative cooling, and shading may help to reduce 1 to 2 hours evaporative cooling period. During second fortnight, use shading with forced evaporative cooling methods to bring down inside air temperature below optimum range (25+ 5°C). Natural ventilation is enough during night hours. In April, suitable night cooling is also needed in addition to shading with forced cooling during day hours. During the month of May and June, forced cooling with shading is needed in the greenhouse to bring down the temperature within the good production range.

The monthly average daily heating and cooling load required in kWh during winter (January, February and March) and summer (April, May and June) months to maintain inside favorable temperature i.e. T_{day} = 25°C and T_{night} = 17°C for growing roses and gerbera calculated on the basis of average of daily load from January to June. The daily cooling load requirement from January to June was estimated to be between 5.0 to 16.9 kWh along with a small requirement of heating during January (0.10 kWh) and February (0.16 kWh). It is concluded that in order to reduce cooling load shading may be adapted from March to June with appropriate ventilation system.

Table 1 Schedule of operating cooling devices in manually operated polyhouse in Junagadh, Gujarat.

Month	Treatment	Time of operation
March	Natural Ventilation	8.00-10.00 /19.00-21.00
	Fogging & Natural Ventilation	10.00-11.00/17.00-19.00
	Fogging & Fan Ventilation /Fan & Pad Ventilation	11.00-17.00
	Without ventilation	21.00-8.00
	Shading	Required
April	Natural Ventilation	7.00-8.00 /22.00-23.00
	Fogging & Fan Ventilation	8.00-10.00/19.00-22.00
	Fan & Pad Ventilation	10.00-19.00
	Without ventilation	23.00-7.00
	Shading	Required
May	Natural Ventilation	22.00-24.00
	Fogging & Fan Ventilation	8.00-11.00/19.00-22.00
	Fan & Pad Ventilation	11.00-19.00
	Without ventilation	0.00-8.00
	Shading	Required
June	Natural Ventilation	22.00-24.00
	Fogging & Fan Ventilation /Fan & Pad Ventilation	8.00-22.00
	Without ventilation	0.00-8.00
	Shading	Required

4.3 Low cost bamboo polyhouse and rain-shelters in Meghalaya

One low-cost bamboo polyhouse and one rainshelter covering land area of 148 m^2 and 172 m^2, respectively were constructed in farmers' field at Umdohbyrthih and Umkhteih village in Ri bhoi district, Meghalaya for conducting field trials and demonstration in 2008. Bamboo frame with arch type roof was covered by UV stabilized (200 μ) film, with average cost of polyhouse and rainshelter as Rs. 142 and 92/m^2. Farmers used the structures for growing vegetable crops, nursery raising, and strawberry cultivation. The results shown that 1) for nursery raising, the tomato and brinjal seedling, sown in April, were ready for transplanting about 10-12 days early along with 38% and 32% more seedlings, respectively, from the polyhouse than outside condition (1120/m^2 and 1220/m^2, respectively for the two crops). Less temperature and frost may be the reasons for slow growth and less survival percentage in open condition. 2) A bamboo framed rain shelter constructed was used for strawberry cultivation. Strawberry seedlings were planted in 9" dia polythene sleeves in September, fruiting started in December and continued upto April next year. A 12 to 15% fruits in the open area were damaged either by disease, bird bite, black spot or frost. Average number of fruits/plant, weight/fruit, and fruit weight/plant was 47, 14.5 and 682 g, respectively inside the rain shelter, as compared to 41, 11.3 and 360 g, respectively in open area. The cost of construction of the rain shelter was Rs 146 per m^2 which increased the yield of strawberry by 1.10 kg per m^2 along with better quality that fetch more prices in the market.

4.4 Agro-techniques for strawberry cultivation under greenhouses in Kashmir valley

Strawberry was grown successfully in the Kashmir valley, but its production in April coincides with other temperate fruits which make it less remunerative. Study have been undertaken to investigate the possibility of off-season cultivation of the strawberry under greenhouse condition and to develop agro-techniques for greenhouse cultivation of strawberry with mulching and drip irrigation. A walk – in – tunnel type polyhouse (17.5 x 3.5 x 2.2 m) was constructed in Srinagar after lot of efforts to standardize the design to sustain under snow load and high wind pressure. The runners of strawberry (cv. *Canfutra*) were transplanted 15th October 2005. The first fruit inside polyhouse was harvested on 17th March 2006, about 45 days early than in open field (2nd May 2006). The peak harvesting started under polyhouse from 27th March while open field gave peak harvesting on 4th of May. Average yield per plant inside the polyhouse was about 2.5 times than obtained in open field (5.22 t/ha) with black polythene mulch and drip irrigation. The black plastic mulch also improved the yield as compared to no mulch (36% in open field and 22% in greenhouse). More than 54% fruits of uniform medium size were harvested from inside the polyhouse, which had better market value than only 48% obtained in open field condition. The largest fruit in open field was 47 gm, while 39 gm in walk-in tunnel. In term of quality, fruit harvested from inside had 7.75 and 4.78% of TSS and sugar, respectively, while 8.44% of TSS and 7.71 % sugar was in fruits from the open field.

4.5 Round the year Cultivation of Off-Season Vegetables under naturally ventilated greenhouses

The cost of creation of covered cultivable area under the greenhouse is very high and hence, careful selection of vegetable crops with off-seasonality for a given location is very important to realize benefits from the system. Efforts has been made on most of the centres to make recommendations for type of vegetables to be grown during different period in a year with strategies for efficient utilization of the space under the greenhouse.

For Punjab: Tomato and capsicum being the important vegetables in Punjab, they were planted with lettuce inside the greenhouse for economical vegetable production. Experiments having tomatoes (Var. Naveen F1) and Capsicum (Var. Bharat Hybrid) as main crops and lettuce as an inter crop was cultivated in the green house with different planting geometries in a plot of 3.0 m^2 and replicated thrice. The results indicated that growing of one or two rows of lettuce as an inter crop had no deleterious effect on yield of main crop. One row of lettuce as an inter crop resulted in very low yield whereas two rows gave lettuce yield which was about 25% of the yield obtained as pure crop. Lettuce transplanted on 22 November became ready for harvest just in less than 40 days and produced reasonable yield before main crop of tomato or Capsicum became ready for picking.

For Uttarakhand: Five vegetables cropping sequences were tested under protected cultivation in mid-hills of Uttarakhand in naturally ventilated polyhouse. The yield obtained during 2006-07 under different cropping system is given in Table 2. First crop of each sequence is transplanted during end of February to first week of March. During May-July, temperature inside polyhouse increased beyond 40^0 C. This had adverse effects on second crop of the rotation. This results in complete failure of cucumber in cropping system 2^{nd} and less yield under other crops. Cropping systems CS1 and CS4 were found more profitable under naturally ventilated polyhouse with net returns of Rs. 11, 358 and 6, 670 per 100 m^2 and B-C ratio of 3.94 and 2.57, respectively.

For Himachal Pradesh: The sequence of capsicum-cabbage-green onion and capsicum-cucumber-frenchbean gave the maximum production of 13.28 and 10.42q/100m^2/ year in greenhouse, but the B-C ratio showed reverse trend due to variation in vegetables prices. Capsicum-capsicum cropping

Table 2. Selected cropping system in greenhouse in Uttarakhand and yield (q/ha) given in parenthesis.

Cropping System	Feb	May	Aug	Dec
CS1	Capsicum (703)	Tomato (340)	Spinach (120)	
CS2	Tomato (535)	Cucumber (nil)	Frenchbean (109)	Coriander (83)
CS3	Broccoli (58)	Capsicum (243)	Squash (194)	Fenugreek (80)
CS4	Squash (959)	Frenchbean (57)	Tomato (425)	Spinach (92)
CS5	Cucumber (461)	Frenchbean (110)	Frenchbean (119)	Spinach (225)

sequence recorded highest B-C ratio of 5.20 followed by capsicum-cucumber-frenchbean (4.95). Capsicum-Tomato-Frenchbean recorded the lowest benefit:cost ratio of 3.09.

Meghalaya hills: Two cropping sequences: capsicum-tomato-lettuce, and tomato-french bean-cabbage were tried in a bamboo greenhouse which was constructed using bamboo at a cost of Rs 156.40 /m^2. Total value of produce from capsicum-tomato-lettuce was worked out as Rs. 1964 and from Tomato-french bean-cabbage Rs. 1368 that amount to the net annual income of Rs 109.10 and Rs 76.0 per m^2, respectively from the two sequences. Adopting discounting technique and 5 yr life with major repair in 3rd year, the B-C ratio was estimated as 2.1 and 1.7 for the two cropping sequences, respectively.

5. CONCLUSIONS

The opportunities existing with the Protected Cultivation to improve the overall productivity and profitability of agriculture, must be realized by small and marginal farmers as well, who are deprived of such issues because of lake of financial resources, lack of information, and fear of approaching Governmental agencies / or financial institutions. The efforts to make them acquainted about the benefits and opportunities associated with Protected Cultivation through small scale and low investment requiring technologies, such farmers are slowly getting into the interventions and improving their income from small patch of lands owned by them, especially in hilly areas of Himalayan region. More efforts are being undertaken in this direction at other places too including eastern plateau, Aravali, indo-gangetic plains and other areas. This will not only help to improve the livelihood of the poor farmers, but provide nutritional security in far reaching areas too.

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