Protected Cultivation and Drip Fertigation Technology for Sustainable Food Production

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Abstract

Protected cultivation is one of the most promising areas of agriculture in the current context. It is an upcoming and alternative production system involving high-tech and intensive practices mainly for urban and export demands of horticultural and ornamental crops for food, nutrition and economic security. Burgeoning population, fragmentation of land holdings, depletion and erosion of natural resources are all adversely affecting agricultural productivity. The main purpose of protected cultivation is to create a favourable environment for the sustained growth of the crop so as to realize its maximum potential even under adverse climatic conditions. Protected cultivation technology, using different structures offers several advantages to produce vegetables, flowers, hybrid seeds and plants of high quality with minimum risks due to uncertainty of weather and also ensuring efficient use of land, water and other resources. Area under protected cultivation in India is about 50,000 hectares only. Maharashtra is leading state in India, followed by Karnataka and Himachal Pradesh. Apart from protected cultivation Drip irrigation, is also the best available technology for the efficient use of water for growing horticultural crops in large scale on sustainable basis. Irrigation water savings ranging from 36-79% can be affected by adopting a suitable drip irrigation system. At present, there is a large gap between the demand and production of these crops to meet both quantitative and qualitative needs of domestic and export markers which are difficult to be bridged with the traditional cultivation practices. Thus protected cultivation and precision farming of horticultural crops has great potential to enhance the income especially of small farmers if appropriate technology interventions are made.

Keywords: Protected cultivation, drip irrigation, horticultural crops

1. Background

The crop productivity is greatly influenced by the growing environment and management practices. Under the open field cultivation it is not possible to control the growing environment of plants, thereby affecting the quality and productivity of the crop. The main purpose of protected cultivation is to create a favorable environment for the sustained growth of the crop so as to realize its maximum potential even under adverse climatic conditions. Protected cultivation technology, using different structures offers several advantages to produce vegetables, flowers, hybrid seeds and plants of high quality with minimum risks due to uncertainty of weather and also ensuring efficient use of land, water and other resources. This becomes relevant to farmers having small land holding who would be benefited by a technology, which helps them to produce more crops each year from their land, particularly during off-season when prices are higher. This kind of crop production system could be adopted as a profitable agro-enterprise, especially in various peri-urban areas of the country. Vegetables and flowers production under location specific and cost-effective structures may accrue substantial benefits even to small growers. Similarly the basic objective of precision farming is to increase the productivity decreasing production costs and minimizing the environmental impacts of farming. Rapid socio-economic charges in some developing countries including India are creating new scopes for application of precision farming.

At present, there is a large gap between the demand and production of these crops to meet both quantitative and qualitative needs of domestic and export markers which are difficult to be bridged with the traditional cultivation practices. Thus protected cultivation and precision farming of horticultural crops has great potential to enhance the income especially of small farmers if appropriate technology interventions are made.

2. Protected Cultivation Technology

Protected cultivation is one of the most promising areas of agriculture in the current context. It is an upcoming and alternative production system involving high-tech and intensive practices mainly for urban and export demands of horticultural and ornamental crops for food, nutrition and economic security. Burgeoning population, fragmentation of land holdings, depletion and erosion of natural resources are all adversely affecting agricultural productivity. The protected cultivation offers several advantages to grow high-value crops with improved quality even under unfavourable and marginal environments. It has the potential of fulfilling the requirements of small growers as it can increase the productivity. The crops can also be grown round the year, including off-season with increased profitability. The technology has already been adopted in many parts of the country. On the contrary, increasing trend of entrepreneurial mindset and commensurate opportunities of respectable business for educated youth among progressive farmers is opening up an exciting combination of brighter sides of agriculture in India vis-à-vis protected cultivation. Besides, protected cultivation is one area where Government initiatives have been far more forthcoming though not as complimentary for human resource development and technical support to the farmers adopting protected cultivation. In these contrasting scenarios, it is critically pertinent to have credible interface of growers, academicians, administrators, policy-makers, entrepreneurs and industry to share ideas and opportunities on some common platform. Protected cultivation or greenhouse cultivation or controlled environment agriculture is the most contemporary approach to produce mainly horticultural crops which is highly productive, conservative of water and land, and also protective to the environment. This involves manipulation of plant growth conditions to yield higher and quality produce during on and off-season or round the year. Off-season production of horticultural crops is one such area the importance of which can hardly be emphasized as it satisfies almost all stakeholders.

Water is one of the most important and critical input for agricultural production system. The demand for food grains, vegetables, fruits and flowers is increasing day by day due to increasing population. The total geographical area of our country is 2.3% of the world area and 17% of the total world population but the total fresh water resource is only 4% of the world. Agriculture consumes about 80% of the total water resources of the country. The irrigated agriculture provides the crop water productivity of about 2.5 t ha^{-1} and the overall irrigation efficiency is only about 30% as compared to world average of 4 t ha^{-1}. In the above scenario it is necessary to have the irrigation system in which both the crop water productivity and irrigation efficiency increase considerably. Moreover the food habits are changing throughout the world as people want more quality fruits and vegetables as dietary supplement. Drip irrigation and fertigation have become the most viable and efficient technology options in such a situation. It provides several advantages in the context of crop agronomy, water and energy conservation. Drip irrigation and fertigation has the potential to achieve the crop water productivity to a desired level of 4 t ha^{-1} and simultaneously maintain the irrigation efficiency above 80%. It helps in producing high value nutritional crops in open field and protected cultivation. The total coverage of micro irrigation in the Xth Plan was only about 2 million hectare. The task force on micro irrigation (2004) has indicated a potential of 69 million hectare for our country. Hence there is a tremendous potential available and the coverage of drip irrigation has to be increased to cover more crops across newer areas.

3. Current Status of Protected Cultivation Technology

Area under protected cultivation in India is about 50,000 hectares only. State wise area of protected cultivation under different crops is presented in Table 1. Maharashtra is leading state in India with 15,000 hectares area under protected cultivation. Mainly carnation, gerbera, rose, capsicum crops are under practices in greenhouse. Karnataka is at second position with 10,000 hectares area under protection cultivation followed by Himachal Pradesh which has area of 5000 hectares. Other states which have area under protected cultivation are Punjab, Uttarakhand, Haryana, U.P., Gujarat, Rajasthan, Jharkhand, J&K, Delhi, West Bengal, Orissa, Bihar, M. P. etc. Farmers are growing generally roses, gerbera, carnation under flowers and capsicum, tomato, cucumber under vegetables crops below table.

Table 1: Leading States in Protected Cultivation

Sl. No.	State	Area (ha)	Crops
1.	Maharashtra	15,000	carnation, gerbera, rose, capsicum
2.	Karnataka	10,000	roses, gerbera, carnation, seed ,nursery
3.	Himachal Pradesh	5000	capsicum, carnation, gerbera, tuberose
4.	Punjab	4000	vegetable crops
5.	Uttarakhand	3000	gerbera, capsicum
6.	Tamil Nadu	2100	floricultural crops
7.	North-Eastern	2000	floricultural and vegetable crops

Other States – Haryana, U.P., Gujarat, Rajasthan, Jharkhand, J&K, Delhi, West Bengal, Orissa, Bihar, M. P.

4. Protected Structures

Protected cultivation technologies cover climate control or high-tech greenhouses, poly or net-houses, naturally-ventilated green or polyhouses, hydroponics, aeroponics, plasticulture, drip irrigation, fertigation, mulching, integrated greenhouse pest management, lowcost protected structures like nethouses insect-proof and shade houses, hydroponics, aeroponics and vertical farms. At present, in our country, we are not in a position to provide power to manipulate and regulate climate in protected structures with the help of sensors and nano materials, and inputs. In our research and developmental programmes, we actually accord priority to it but for this purpose we have to outweigh the returns to justify high cost involved. For example, use of high-tech or climate controlled greenhouses for propagation of horticultural crops to multiply disease free planting material will go a long way to improve the production and productivity of these crops. The single use of this high-tech horticulture by establishing climate controlled disease-free nursery production centers can simply double production of horticultural crops.

5. Returns under Protected Cultivation Technology

It is estimated that annual returns per unit area from protected cultivation could be 10-100 times than those of open field cultivation. Protected cultivation ensures reduced use of water and land and it is becoming extremely important under current scenario of climate change. Protected cultivation is friendly to marginal farmers, to the environment, to unemployed youths, to meet requirements of fresh produce like vegetables, fruits and flowers round the year, urban and peri-urban farming and one and all interested in this farming. The country's vision on protected cultivation should be to target the potentialities and convert them into reality with the help of stakeholders, including private sector through public private joint programmes.

Drip fertigation is taken up under two conditions i.e. open field where fruits, vegetables, cotton and sugarcane are mostly grown and other is protected cultivation where vegetables and flowers are grown under protected structures like greenhouse, net house, shade net and nursery. Of late farmers are also growing crops like sunflower, groundnut, and maize in a limited way under drip fertigation. Protected cultivation technology provides the option for round the year production by combating biotic and abiotic stress. The crop water requirement under protected cultivation is less than in open field condition and there is precise requirement of nutrients and micro nutrients. Drip irrigation and fertigation under protected cultivation provides efficient use of water and nutrient and increases the yield and improve quality of the produce. Fertigation scheduling refers to timely application of water and nutrients as per crop stages through drip fertigation. It is the most important aspects of drip fertigation to know exactly the quantity of water and fertilizers to be applied through drip fertigation on daily and monthly basis for different horticultural crops. This information need to be made available to the farmers in the user friendly form. Very complex mathematical formulae and models are available to calculate the fertigation scheduling for different horticultural crops. Therefore, an attempt has been made to compile all the data related to the fertigation scheduling works done during the last ten years for various horticultural crops grown in open field and protected cultivation at Centre for Protected Cultivation Technology (CPCT), IARI New Delhi. Indian Farmers Fertiliser Cooperative Limited (IFFCO) has indigenously developed 100% water soluble fertiliser urea phosphate (17:44:0) which is suitable for drip fertigation for different horticultural crops. An attempt has been made to prepare crop wise monthly fertigation scheduling in a very user friendly way for different horticultural crops.

6. Drip Irrigation System

Drip irrigation is the best available technology for the efficient use of water for growing horticultural crops in large scale on sustainable basis. Drip irrigation is a low labour intensive and highly efficient system of irrigation, which is also amenable to use in difficult situations and problematic soils, even with poor quality water. Irrigation water savings ranging from 36-79% can be affected by adopting a suitable drip irrigation system. Drip irrigation or low volume irrigation is designed to supply filtered water directly to the root zone of the plant so as to maintain the soil moisture near to field capacity level for most of the time, which is found to be ideal for efficient growing of horticultural crops. This is due to the fact that at this level the plant gets ideal mixture of water and air for its development. The device that delivers the water to the plant is called dripper. Water is frequently applied to the soil through emitter placed along a water delivery lateral line placed near the plant row. The principle of drip irrigation is to irrigate the root zone of the plant rather than the soil and getting minimal wetted soil surface. This is the reason for getting very high water application efficiency (90-95%) through drip irrigation. The area between the crop row is not irrigated therefore more area of land can be irrigated with the same amount of water. Thus, water saving and production per unit of water is very high in drip irrigation.

A distinction is made between the two principal micro-irrigation methods, namely, the sprayer or micro-sprinkler, and the drip irrigation system. Sprayers and micro-sprinklers spray the water through the atmosphere and are designed principally to wet a specific volume of soil around individual trees in an orchard. Drip irrigation, on the other hand, represents a point source of water, and wets a specific volume of soil by direct application of water to the root zone of the plant. The type of drip emitter from the aspect of its discharge and the distribution of the emitters throughout the plot (distances along the drip lateral and between the drip laterals) is dependent on the soil texture and the crop. The drip system is suitable for irrigation of row crops (vegetable and industrial crops) and orchards.

7. Fertigation for Open Field and Protected Cultivation Technology

Fertigation is the process in which fertilizers can be applied through the system with the irrigation water directly to the region where most of the plant roots develop. It is done with the aid of special fertilizer apparatus (injectors) installed at the head control unit of the system, before the filter. The element most commonly applied is nitrogen. However, application of phosphorous, potassium and other micro-nutrients are common for different horticultural crops. Fertigation is a necessity in drip irrigation. The main objectives of fertigation are;

1. Uniform and timely application of fertilizers.
2. Water and nutrient saving.
3. Optimizing yield.
4. Quality improvement.
5. Minimizing pollution

8. Fertigation Scheduling for Horticultural Crops

Nutrient management in fertigation is important for increasing the crop productivity and also quality of produce. Plant needs nutrients throughout their growth stages. For the newly planted fruit trees the dosage for first year fertigation is 10% of the recommended dose of fully mature fruit trees and it will gradually increase by 20% of the dosage for the succeeding years. In horticultural crops, these stages vary from crop to crop viz initial and final stage, vegetative stage, flowering stage, flowering and fruiting stage etc (Table 1).

Table 1: Crop evapotranspiration, yield and water use efficiency for food commodities

Crop or food	Evapotranspiration (mm)	Yield ($t\ ha^{-1}$)	Water use efficiency ($kg\ m^{-3}$)
Wheat	627	5.4	0.86
Rice	1200	8.5	0.71
Maize	696	9.8	1.41
Potato	425	40.4	9.51
Sugarcane	2491	97.4	3.91
Onion	711	49.2	6.94
Tomato	622	47.8	7.69
Orange	973	25.7	2.65
Banana	1597	32	2
Groundnut	655	2.6	0.39
Cotton	873	2.2	0.25
Beans	548	2.7	0.59
Soyabeen	803	2.6	0.32
Sugarbeet	1112	57.6	5.18
Lemon	973	28.3	2.91
Grape fruit	935	32.6	3.49

The nutritional water productivity is very high for potato, maize, wheat and groundnut crops and low for banana, soybean and citrus crops. It is significantly low for beef, pork, poultry etc as shown in Table 2.

The crop water productivity is very high for tomato, cucumber, capsicum and flowers grown inside greenhouse with drip fertigation as shown in Table 3 and 4 respectively. The crop

Table 2: Nutrient content and nutritional water productivity of some of the main food commodities

Food	WI	P	Nutritional water productivity			
			E	P*	F	C
Wheat	1159	0.863	2279	74	9	279
Rice	1408	0.71	1989	49	5	132
Maize	710	10408	3856	77	17	63
Potato	105	9.524	5626	150	9	543
Pulses	2860	0.35	1188	76	4	473
Grounnut	2547	0.393	2382	111	206	296
Soyabean	15240	0.66	547	0	62	0
Tomato	130	7.692	1416	65	11	200
Onion	147	6.826	2259	85	0	1673
Banana	499	2	432	11	0	29
Lemon	344	2.9	504	0	0	423
Beef	13500	.074	102	10	7	3
Pork	4600	0.217	408	21	35	7
Poultry	4100	0.244	330	33	21	14
Egg	2700	0.37	519	41	36	166
Milk	790	1.266	659	40	38	1233
Butter	18000	0.056	404	1	45	11

WI: Water input kg^{-1} (liter); P: Productivity ($kg\ m^{-3}$); E: Energy ($Kcal\ m^{-3}$); P*: Protein ($g\ m^{-3}$); F: Fat ($g\ m^{-3}$); C: calcium ($mg\ m^{-3}$)

Table 3: Crop water productivity for vegetables grown with drip fertigation

Crop	Growing place	Growing period	TWU	Total yield ($t\ ha^{-1}$)	CWP
Tomato	GH	Sept-May	3200	250	78
Capsicum green	GH	Sept-May	2440	90	37
Capsicum color	GH	Sept-May	2440	60	24.6
Cucumber	GH	Aug-Oct	1550	60	38.7
Cucumber	GH	Feb-May	2010	80	39.8
Brinjal	OF	Sept-April	2200	25	11.3
Tomato	OF	Sept-dec	2885	60	20.8

TWU: Total water use ($m^3\ ha^{-1}$); CWP: Crop water productivity ($kg\ m^{-3}$) ($g\ l^{-1}$);

Table 4: Crop water productivity for Flowers grown in greenhouse

Crop	GP	Growing period	TWU	Total Yield (stem ha-1)	CWP
Rose soilless	GH	Yearly	15000	2700000	180
Rose soil	GH	Yearly	5000	2100000	420
Chrysanthe-mum	GH	Yearly	2800	1160000	414

GP: Growing place

water productivity of tomato grown inside greenhouse is four times higher than the open field grown tomato. The crop water productivity of green capsicum is higher than colored capsicum grown inside greenhouse.

Greenhouse production with drip fertigation has tremendous potential of increasing the crop and nutritional productivity. It is the need of the future to produce quality crops round the year having maximum nutritional value with minimum quantity of water. Protected cultivation in the greenhouse gives the opportunity to maximize the crop water as well as crop nutritional productivity to a great extent.

9. Conclusion

Protected cultivation technology, using different structures offers several advantages to produce vegetables, flowers, hybrid seeds and plants of high quality with minimum risks due to uncertainty of weather and also ensuring efficient use of land, water and other resources. Area under protected cultivation in India is about 50,000 hectares only. Drip irrigation is the best available technology for the efficient use of water for growing horticultural crops in large scale on sustainable basis. Irrigation water savings ranging from 36-79% can be affected by adopting a suitable drip irrigation system.