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Prospects of Yield Enhancement in Greenhouse Cultivation through IoT based Micro-climate Management

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The dynamic behaviour of the greenhouse micro-climate plays a major role in the productivity of a plant crop. Maintaining an optimum microclimate is a prerequisite for higher crop production. Unscientific manual monitoring and resultant faulty treatments lead to a suboptimal yield. To this effect, an experiment was conducted in 5 nos. of Gerbera greenhouses in which Agrithink's Smart Micro-climate Monitoring and Control System (a patented system) was installed. Another 5 normally maintained Gerbera greenhouses of uniform dimensions and specifications were taken for comparative analysis. The study lasting a year revealed that all the plant characteristics, and the yields in the greenhouses equipped with Smart Micro-climate Monitoring and Control System (SMMCS), were significantly superior over normally maintained(NM) greenhouses. The sale of Gerbera from the first case with SMMCS also showed a highly significant return over the return from normally maintained greenhouses.

Introduction

Gerbera (*Gerbera jamesonii* L.) is an important high-value cut flower, used as fresh and dry flowers, as aesthetic decoration, and in the making of bouquets. The gerbera cut flowers have a high demand in the domestic as well as export market (Singh *et al.*, 2017a). It is a leading flower and ranks among the top ten cut flowers in the world with wider applicability in the flower industry as a cut flower and potted plant (Maitra *et al.*, 2020). The recent boom in the global floriculture market has necessitated technological interventions for enhancing the yield and quality of cut flowers. Speciality flowers like gerbera give better yield under protected cultivation than in the open field. Therefore, technological invasions have to be encouraged and implemented to improve the quality of farming and the farming community (Indumathi, 2020). The IoT-based monitoring and control of greenhouse cultivation can play a key role in bringing a breakthrough in production and return.

The microclimate of greenhouses is important for better plant growth and greater yield. Greenhouse automation is all about the utilization of all available natural resources, recycling the information within the system, and claims higher productivity, higher returns, and better quality while remaining environmentally-friendly (Jain *et al.*, 2017). IoT can make agricultural and farming industry processes more efficient by reducing human intervention through automation (Madushanki *et al.*, 2019). An effective IoT-based solution incorporates the use of wireless sensors and mobile applications for displaying, processing, and analyzing data in real-time from remote locations using cloud services which together provide new insights and recommendations for better decision-making (Shamshiri *et al.*, 2021). Farmers can remotely monitor their crops by smart devices with IoT-aided systems, (Puneeth *et al.*, 2018) and control them accordingly. This enhances production and higher return over conventionally maintained greenhouses.

Materials and Methods

Field experiments were conducted on Gerbera (*Gerbera jamesonii* L) in different Greenhouses at Sikkim and Assam in the year 2020-2021. Ten nos. of greenhouses were considered for observation of the effects of the applied treatments. Smart Micro-climate Monitoring and Control system developed and patented by Agrithink Services was installed in five greenhouses marked as treatment 1 and named T1SMMCS while the other 5 Greenhouses which were normally maintained (NM) were taken as treatment 2 and named T2NM for ease of analysis. Agrithink's Smart Micro-climate Monitoring and Climate System is an IoT, cloud-based patented technology. This technological intervention is designed to monitor the microclimate parameters prevailing inside Greenhouses and other indoor production systems to harvest the estimated production target. The system uses five types of sensors viz. temperature sensor, humidity sensor, UV light, light sensor and moisture sensor. The real-time data collected by the network of sensors are stored using server-aided cloud computing. The cloud-processed data is provided to the greenhouse owner in any smart device through the patented application which the user can access with a given log-in credential. The system is also provided with in-built control of temperature, humidity and light with on/off features. Remote auto control of irrigation based on real-time moisture reading is a prime feature of the device/model. Added to the efficient soil management within a cultivation unit, the system has an attached plug-and-play pH sensor. The real-time customizable system which has remote monitoring and control facility can also be operated by renewable (Solar) energy. Periodic interactions with Greenhouse owners were conducted during the experiment. Data from both treatments were recorded. Yield and relative income from the two treatments were compared at the end of one year. The wholesale price of the Gerbera cut-flower realised by the farmer was Rs. 6.00 per stick which was used to extrapolate the returns from the sales. The Data thus obtained, were tested statistically for significance using standard procedure and analysed accordingly.

All other operations were similar in the two treatments. Standard packages of practice were followed uniformly.

Results and Discussion

It was found that plant height recorded a mean of 30.52cm in plants in greenhouses where SMMCS was installed (T1SMMCS)whereas in the normally maintained greenhouses(T2NM) the mean plant height was 26.0cm showing a significant difference between the treatments(P=0.0012). A similar result was found in other plant characteristics viz. no. of leaves (P<0.0001) and no. of suckers (P <0.0001) showing a highly significant difference between the two treatments which are presented in Table 1. As evident from Table 2, the mean production of flowers in treatment 1(T1SMMCS) was 33.37nos./plant while in treatment 2(T2NM) mean yield was 24.28 nos. of flowers/plant. A very significant difference was found in flower production between the two treatments (P=0.001).

The significantly better performance of Gerbera in the greenhouses with SMMCS in the present experiment was due to real-time data generation of temperature, humidity, soil moisture and light intensity which enabled the adoption of optimum management practices. The use of monitoring and automation in Gerbera greenhouses is also supported by Jain *et al.,* (2017) who revealed that the cost of growing inside a greenhouse is generally greater than growing in the field; therefore monitoring and automotive control of important environmental parameters such as air temperature, relative humidity (RH) is necessary to achieve high yield at low expense and to keep the environment competitive. In the present experiment, the IoT-based system recorded the real-time value of the critical factors and managed it accordingly which led to a luxurious yield. Earlier reports suggest that the average water requirement of Gerbera is about 500 – 700 ml/day/plant (TNAU Agritech Portal). Silva *et al.,* (2021) also found that 66-68 lit water per plant was required for optimum yield of Gerbera. Preferably, gerbera is irrigated before noon (Maitra *et al.,* 2021). Need-based automated irrigation through Agrithink's app following guidelines for Gerbera was a major yield booster in this treatment. The optimum humidity inside the gerbera greenhouse should be 70-75% (Maitra *et al.,* 2020) while light intensity above the canopy level must be maintained as per the crop's requirement.

Generally, gerbera plants require 35,000 to 40,000 lux light intensity (Maitra *et al.,* 2020). De and Kurnar (2007) reported that the sunlight requirement is around 400 watts/sq m for growth. Required humidity level and favourable light intensity were also maintained in treatment 1(T1SMMCS) as par real-time data which enhanced production.

For Gerbera, the optimum temperature ranges between 20-30°C, and when the temperature falls below 12°C and reaches more than 35°C, flower production is adversely affected (Maitra *et al.,* 2020). The better yield of Gerbera in treatment 1(T1SMMCS) is also attributed to real-time monitoring and control of temperature based on real-time value. The optimum soil pH should be between 5.5 and 6.5 to get maximum efficiency in the absorption of nutrients (Maitra *et al.,* 2020). The pH sensor-enabled time-to-time management of pH which is another important factor in crop production.

On the other hand, it was seen that the greenhouse owners in treatment 2 (T2NM) applied irrigation based on a schedule made by them depending on the availability of water, a suitable time for the workers and sometimes they start irrigating when the plants already show drying symptoms. This had led to a decline in yield as water management is one of the most important aspects of crop production. Also as there was no real-time monitoring of temperature, light intensity, humidity and pH. Greenhouse owners depended on natural maintenance inside the polyhouse and carried out a few management practices based on assumptions which were neither regular nor need-based. This led to below the potential yield under treatment 2 (T2NM).

It is revealed from Table 2 that, the mean return from the sale of Gerbera in T1(SMMCS) was Rs.7,00,770/- while in T2(NM) mean return from the sale was found to be Rs.5,09,880/. A highly significant difference was found between these two treatments.

Further analysis showed a very significant difference (P=0.0132) in return from flower sales even when each SMMCS costs Rs. 70,000/-. A significantly higher mean net return (Rs.6,30,770/-) was found after deducting the system cost in T1(SMMCS). This could be traced back to a significantly higher yield of T1 over T2. IoT as a driving force for cost-effectively increasing agricultural production was also reported by Saidiku *et al.,* (2021).

Table.1 Yield Attributing Characters of Gerbera in Treatments

Treatment	T1(SMMCS)	T2(NM)	T1(SMMCS)	T2(NM)	T1(SMMCS)	T2(NM)
	Plant height (cm)	**Plant height (cm)**	**No. of leaves/plant**	**No. of leaves/plant**	**No. of suckers/plant**	**No. of suckers/plant**
	33.20	25.45	23	14.8	5.66	3.33
	34.13	24.60	28	15.2	5.23	3.35
	29.37	28.20	21	12.33	4.53	3.70
	31.10	27.40	25	11.93	5.4	3.53
	30.52	26.00	26	10.37	4.67	3.40
Mean	**31.66**	**26.33**	**25.08**	**12.93**	**3.46**	**4.87**
SD	**1.97**	**1.45**	**2.74**	**2.03**	**0.15**	**0.41**
SEM	**0.88**	**0.65**	**1.22**	**0.91**	**0.07**	**0.18**
P value	**=0.0012**		**< 0.0001**		**< 0.0001**	

Table.2 Yield of Gerbera Cut flower and Return from Sales (INR)

Treatment	T1 (SMMCS)	T2 (NM)	T1 (SMMCS)	T2 (NM)	T1 (SMMCS)	T2 (NM)	Cost of SMMCS (INR)	T1 (SMMCS)	T2 (NM)
	No. of flowers /plant	**No. of flowers/ plant**	**Return from sale (INR)**	**Return from sale(INR)**	**Returns from sale (INR)**	**Return from sale (INR)**		**Net Return (INR)**	**Net Return (INR)**
	36.30	25.40	217.80	152.40	7,62,300.00	5,33,400.00	70,000	6,92,300.00	5,33,400.00
	33.25	23.80	199.50	142.80	6,98,250.00	4,99,800.00	70,000	6,28,250.00	4,99,800.00
	34.50	26.60	207.00	159.60	7,24,500.00	5,58,600.00	70,000	6,54,500.00	5,58,600.00
	35.40	24.40	212.40	146.40	7,43,400.00	5,12,400.00	70,000	6,73,400.00	5,12,400.00
	27.40	21.20	164.40	127.20	5,75,400.00	4,45,200.00	70,000	5,05,400.00	4,45,200.00
Mean	**33.37**	**24.28**	**200.22**	**145.68**	**7,00,770.00**	**5,09,880.00**		**6,30,770.00**	**5,09880.00**
SD	**3.52**	**2.02**	**21.14**	**12.14**	**73,976.95**	**42,480.25**		**73976.95**	**42,480.25**
SEM	**1.57**	**0.90**	**9.45**	**5.43**	**33,083.50**	**18997.75**		**33,083.50**	**18997.75**
P value	**= 0.001**		**= 0.0010**		**=0.001**			**=0.0132**	

The comparative analysis of yield and income from gerbera cultivation under IoT aided Micro-climate management and normal greenhouse maintenance approach established that real-time management of greenhouses can enhance profitability by increasing production. Though IoT based Micro-climate management system increases the expenditure, the marked increase in production contributes gracefully to the economic return of the greenhouse owner.

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