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Research Paper

Impact of shade net and polyethene sheet on microclimate, growth and productivity of French bean (*Phaseolus vulgaris* L.) in Punjab, India

KOMAL RANI[1], K. K. GILL[1*], S. S. SANDHU[1] and RUMA DEVI[2]

[1]Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana, 141004, India
[2]Department of Vegetable Science, Punjab Agricultural University, Ludhiana, 141004, India
Corresponding Author email: kkgill@pau.edu

ABSTRACT

Modification of microclimate is a major factor that can affect growth and productivity of French bean. A study was conducted at Ludhiana, Punjab, India during winter (2021-22) and spring season (2022) to find out the effect of microclimatic modifications using polythene sheet and shade net on production of French bean. Four treatments were formulated i.e. Control, whole season covered, covered during vegetative stage and covered during reproductive stage of two varieties (FBP-1 and Kentucky wonder) of French bean. Structures on different treatments were installed after emergence of the crop. The crop took 60-70 days to attain physiological maturity during winter season while the crop matured in 60-65 days during spring season. Higher green pod yield (167.0 q ha^{-1}) was obtained for whole season cover conditions as compared to open conditions (130.7 q ha^{-1}) during winter season. Pod yield was recorded less during spring season, yield under cover condition (94.8 q ha^{-1}) was higher as compared to open condition (58.3 q ha^{-1}). Among the both varieties FBP-1 performed better than Kentucky wonder during both the seasons. Under covered condition higher chlorophyll content along with higher vegetative & reproductive growth and earliness of crop has been observed. During spring season due to rise in temperature less yield has been obtained.

Keywords: Microclimatic modification, Spring season, Winter season, French bean, Yield attributes

French bean is an important vegetable crop cultivated in every part of world. Development as well as growth of French bean mainly depends upon environmental condition. It is an annual and self-pollinated warm season crop. Several types of environmental factors that affect the crop growth are air temperature, soil temperature, rainfall, relative humidity and soil moisture availability (Saidi *et al.,* 2013). The optimum soil temperature of French bean for better growth is 16-24°C (Meena *et al.,* 2017). It does not germinate at <15°C soil temperature and growth of plant is dormant at <10°C. Temperature >35°C causes dropping of buds and reduces flowering. The optimum air temperature range is 20-25°C for its proper growth. The flowers, developing pods and branches are damaged below 5°C temperature. The flower drop is a serious problem at >30°C air temperature (Konsens *et al.,* 1991). Thus, sowing time becomes important factor affecting growth, development, yield and quality of French bean. It can be grown in two different seasons in a year. It can be sown in plain region during January-February and September- October (Dhillon and Kumar 2019).

Shade net covers have been reported to modify the crop micro-environment by maintaining higher soil moisture and reduced air temperatures as compared to open field and to protect the crop from frost and cold waves, polythene cover have been used (Khapte *et al.,* 2021; Samanta and Hazra, 2019). The available information on impact of different microclimatic modifications on performance of French bean is very limited. The objective of this study is to investigate the effect of microclimatic interventions in two different seasons. Therefore, a field experiment was conducted during two different seasons (spring and winter) with an objective to understand the impact of micro climatic modification through shade nets, polyethene covers.

MATERIALS AND METHODS

The field experiment was carried out during the winter and spring season of 2021-22 at the research farm of the Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. Ludhiana is situated in the Trans-Gangetic

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Table 1: Treatment details followed during the field experiment

Shading treatments	Details
Winter season	
P_1 (Control)	Open field
P_2 Polythene (Vegetative)	Covered with transparent polythene sheet during vegetative stage
P_3 Polythene (Reproductive)	Covered with transparent polythene sheet during reproductive stage
P_4 Polythene (Whole season)	Covered with transparent polythene sheet for whole season
Spring season	
P_1 Control	Control (open field)
P_2 Shade (Vegetative)	Covered with green shade net during vegetative stage
P_3 Shade (Reproductive)	Covered with green shade net during reproductive stage
P_4 Shade (Whole season)	Covered with green shade netfor whole season

agro climatic zone of India in the central plain region of Punjab with an elevation of 247 meters above mean sea level, at latitude 30° 54'N and longitude 75° 48'E. At Ludhiana, average annual rainfall is 760.0 mm, 80 percent of which is received through southwest monsoon from July to September. During summer season temperature rises over 38 °C and can even reach up to 51 °C, when there is a dry spell. Frost often occurs during December and January. The soil at the location was "loamy sand".

Treatments details

The field experiment was conducted in factorial randomized block design with three replications. Two varieties (FBP-1 and Kentucky Wonder) were used and both the varieties were of pole beans. There were four microclimatic modifications as given in Table 1. During winter season, clear polythene sheets of 200 micron were used which offers good light transmission and is relatively inexpensive. The shade nets of green colour (75% green colour & 150 GSM) were used to provide shade during spring season. Crop was covered with polythene and shade nets after 15 days of sowing for whole season and vegetative season covers. After flowering the covers were shifted from vegetative (P_2) to reproductive stage plots (P_4).The structures were removed after 40 days of sowing at vegetative stage cover. The plots were covered with polythene sheet with the help of iron pipes from three sides and one side was open for ventilation. Polythene sheet was buried in soil for maintain the structure. The same process was followed during spring season for shade net. The air temperature within the crop was recorded daily using maximum and minimum thermometers within both treatment and control plots, the thermometers were placed horizontally on a wooden stand within the plot. The observations were recorded twice a day daily.

Cultural operation

Sowing of French bean was done for both cultivars on 13th October, 2021 for winter season and 14th February, 2022 for spring season with seed rate of 100 kg ha^{-1}. The sowing was done on raised bed with 30 cm plant to plant spacing. Plots were covered with polythene sheet during the vegetative stage on October 28th, 2021 and during reproductive stage on November 20th, 2021 during winter season. During spring season, the crop was provided with shade on March 1st, 2022 during vegetative stage and on March 30th, 2022 during reproductive stage. First picking was done in second week of December and afterwards total three pickings were done at 10 days interval.

Observations recorded

The maximum temperature at 2:30 PM and minimum temperature at 7:30AM was recorded by thermometers from outside and inside the structure on daily basis. Phenological stages (start emergence, complete emergence, primary branching, secondary branching, flowering, pod development, pod filling and physiological maturity) were recorded by visual observations. The chlorophyll content was measuredfrom five leaves using Chlorophyll Meter Model M C 100 (Apogee instrument) portable leaf greenness meter at15 days intervals.

From each plot ten randomly chosen plants were selected for flower initiation. When 50% of the chosen plants had flowered, it was considered as initiation of flowering. Selected plants were observed for the growth and phenological stages and yield parameters.Green vegetable pod yield per plant was calculated by averaging the weights of pods from the five tagged plants from each individual harvests.

RESULT AND DISCUSSION

Air temperature above crop canopy

During winter season, the maximum temperatures decreased during the crop growing season from 31.9°C during emergence to 25.9**°C** during harvesting and the minimum temperature also decreased from 19.6°C to 11.6°C (Table 2) under the open field conditions. Similar decreasing trend was observed in shade treatments also, however, the average maximum temperature under polyethene cover was higher by 1.6°C during flowering and by 1.9°C at harvest as compared to control (open field) conditions. Similarly, the minimum temperature was higher by 0.7°C during flowering and by 1.3°C at harvest. The findings of Ngelenzi *et al.,* (2017) also suggested that using covers can improve crop microclimatic conditions.

In contrast to winter season, the temperatures during spring season, in general, had increasing trends during the crop growing season. The maximum temperature increased from 23.1**°C** during initial stages to 30.9°C during harvesting period while minimum temperature increased from 8.0°C to 15°C under open condition.

Table 2: Air temperature above crop canopy during winter and spring seasons

Phenological stages	Open field		Vegetative stage cover		Reproductive stage cover		Whole season cover	
	Temperature (°C)							
	Min	Max	Min	Max	Min	Max	Min	Max
Winter season								
Start emergence	19.6	31.8	19.6	31.8	19.6	31.8	19.6	31.8
Complete emergence	18.8	31.9	18.8	31.9	18.8	31.9	18.8	31.9
Primary branching	17.8	30.1	17.8	30.1	17.7	30.1	18.7	31.5
Secondary branching	16.1	29.4	17.4	31.0	16.1	29.4	17.4	31.0
Flowering	13.2	28.0	13.2	28.3	14.6	30.0	14.6	30.0
Pod development	12.9	27.6	13.0	28.0	13.8	29.4	14.0	29.7
Pod filling	12.3	26.9	12.7	27.1	13.5	28.9	13.7	29.3
Harvesting	11.6	25.9	12.0	26.4	13.0	28.2	13.3	28.8
Spring season								
Start emergence	8.0	23.5	8.0	23.5	8.0	23.5	8.0	23.5
Complete emergence	9.2	23.6	9.2	23.6	9.2	23.6	9.2	23.6
Primary branching	9.3	23.1	8.8	22.5	9.3	23.1	8.8	22.6
Secondary branching	10.7	24.3	9.9	23.4	10.7	24.4	9.9	23.4
Flowering	13.7	28.1	13.6	28.0	13.2	27.5	13.2	27.5
Pod development	14.1	29.1	14.0	29.0	13.6	28.5	13.7	28.6
Pod filling	14.4	29.9	14.4	29.7	14.0	29.3	14.0	29.3
Harvesting	15.1	30.9	15.1	30.5	14.7	30.3	14.8	30.1

The average maximum temperature under green shade net was lower by 1.5°C and 0.8°C during flowering and harvesting stages as compared to that under open conditions, respectively. Similarly, the average minimum temperature under green shade net was lower by 0.8°C during flowering and by 0.6°C during harvesting as compared to open conditions (Table 2).

Crop phenology

During the winter season, French bean emergence began in 6 days and was completed in 10 days. Primary branching started at 15 days for all treatments. Secondary branching initiated in 24-26 days while physiological maturity ranged from 58 to 70 days under different treatments (Table 3). The shortest duration was under P_4 (58-60 days), while the longest was in the open field (P_1) at 68-70 days. Phenological stages varied by variety and treatment. Overall, Kentucky Wonder took approximately three more days to complete its phenological stages than FBP-1.

In the spring season, French bean emergence started in 7 days and was completed in 11 days. Primary branches initiated in 17 days under control and under cover during reproductive-stage, but in 16 days under vegetative-stage or whole-season cover. Secondary branches appeared earlier under whole-season and vegetative-stage cover (25 days) compared to control and reproductive-stage cover (27 days). Flowering occurred at 44 and 46 days for FBP-1 and Kentucky Wonder, respectively, under control and reproductive-stage cover. Under whole-season and vegetative-stage cover, flowering took 45 and 47 days for FBP-1 and Kentucky Wonder, respectively. Pod development was observed after 50 and 52 days for FBP-1 and Kentucky Wonder under control and vegetative-stage cover, but after 51 and 53 days under reproductive-stage cover, and after 52 and 54 days under full-season cover, respectively. Pod filling was attained in 54 and 56 days under control and vegetative-stage cover, 55 and 57 days under reproductive-stage cover, and 56 and 58 days under full-season cover for FBP-1 and Kentucky Wonder, respectively. Physiological maturity for FBP-1 and Kentucky Wonder was reached in 60 and 62 days under control and vegetative-stage cover, 62 and 64 days under reproductive-stage cover, and 63 and 65 days under full-season cover. These results align with previous studies showing that polyhouses advance flowering and fruit development due to higher temperatures (Cheema *et al.,* 2004; Kang and Sidhu, 2005).

Chlorophyll content

In winter season (Table 4) the chlorophyll content (µmol $m^{-2}$of leaf area) was highest under polyethene cover during vegetative to physiological maturity whereas lowest was recorded in open field conditions. This is due to less light intensity, the leaves become thinner and rich in chlorophyll content as compared to open conditions. The increase in total chlorophyll content under less light was attributed to increased number and size of chloroplast and better grana development (Polthanee *et al.,* 2011). Maximum chlorophyll content (29.5µmol m^{2-}) was found under the treatment in which crop was covered with polythene sheet during whole season. Under this, at 60 days after sowing the crop had significantly higher chlorophyll content than rest of the treatments. In case of crop covered during reproductive and vegetative stage the chlorophyll content was found 27.1 and 24.4 µmol m^{2-}but under control conditions it was 22.6 µmol m^{2-}. Chlorophyll content increased during flowering stage to pod development for both cultivars. While the chlorophyll content decreased at maturity stage. Among the both cultivars, maximum chlorophyll content was recorded for FBP-1 (28.9 µmol m^{2-}) than for Kentucky Wonder (22.8 µmol m^{2-}) after 60 days of sowing. Similarly, in the springseason the chlorophyll content was highest in the whole-season covered treatment (29.5 µmol m^{2-}) and lowest in the control (23.1 µmol m^{2-}) at 60 days after sowing. The FBP-1 cultivar had more chlorophyll (29.3 µmol m^{2-}) than

Table 3: Crop phenology (days after sowing) of French beans under different treatments

Phenological stages	Open field		Vegetative stage cover		Reproductive stage cover		Whole season cover	
	FBP-1	Kentucky Wonder	FBP-1	Kentucky Wonder	FBP-1	Kentucky Wonder	FBP-1	Kentucky Wonder
Winter season								
Start emergence	6	6	6	6	6	6	6	6
Complete emergence	10	10	10	10	10	10	10	10
Primary branching	15	15	15	15	15	15	15	15
Secondary branching	26	26	24	24	26	26	24	24
Flowering	47	49	40	42	47	49	40	42
Pod development	54	56	47	49	53	55	46	48
Pod filling	61	63	53	55	58	60	51	53
Physiological maturity	68	70	60	62	65	67	58	60
Spring season								
Start emergence	7	7	7	7	7	7	7	7
Complete emergence	11	11	11	11	11	11	11	11
Primary branching	17	17	17	17	17	17	17	17
Secondary branching	27	27	25	25	27	27	25	25
Flowering	44	46	45	47	44	46	45	47
Pod development	50	52	50	52	51	53	52	54
Pod filling	54	56	54	56	55	57	56	58
Physiological maturity	60	62	60	62	62	64	63	65

Table 4: Chlorophyll content (µmol m^{2-} of leaf area) of French beans under different treatments

Treatments	Winter season					Spring season				
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS
Shading treatment										
Control	16.4	18.9	22.6	17.1	16.5	18.7	20.1	23.1	19.1	17.3
Vegetative	17.3	23.4	24.4	20.3	18.4	20.7	24.9	25.4	22.3	19.6
Reproductive	14.6	21.6	27.1	22.9	21.7	22.6	21.7	27.9	24.7	22.0
Whole season	17.1	23.6	29.5	25.2	24.0	23.7	26.4	29.5	27.2	24.5
CD (p=0.05)	NS	3.1	2.4	5.4	3.7	NS	3.9	1.9	5.1	3.5
Varieties										
FBP-1	17.8	24.6	28.9	25.4	22.4	24.3	25.8	29.3	27.3	23.3
Kentucky wonder	14.9	19.2	22.8	17.4	17.9	18.6	29.7	23.6	19.4	18.4
CD (p=0.05)	2.8	2.2	1.7	3.8	2.6	4.3	2.7	1.4	3.6	2.5

Kentucky Wonder (23.6 µmol m^{2-}). Chlorophyll content increased as light intensity decreased under cover, leading to higher levels as compared to open fields.

Yield and yield attributes

The data on yield attributes and yield of French bean during both seasons are presented in Table 5. Different type of microclimatic modification significantly affected the pod number per plant but showed non-significant result for pod length. During winter season significantly highest number of pods per plant (112.7) were obtained under the treatment in which crop was covered during the whole season that was statistically at par with that covered during the reproductive stagewith polythene sheet. During spring the number of pods per plant were significantly higher under the treatment in which crop was covered during the whole season (89.2) that was statistically at par with that covered at reproductive stage (77.4) with shade net. Among the cultivars FBP-1 (63.3) has significantly higher number of pods per plant than Kentucky wonder (54.8). Under shade net conditions pod formation was better as compared to open conditions but extreme higher temperature affect pod formation also under shade condition. Lesser number of pods were obtained in open condition. Mantur *et al.,* (2014) also reported that the number of pods per plant was higher under covered condition due to favorable environment for fruit development. The pod weight was also higher under covered conditions as compared to the open conditions. The numbers of pods were lesser in open condition. It has been reported that net covers advanced seedling emergence resulting in higher emergence percentage and plant growth also as compared to open conditions by Ngelenzi *et al.,* (2017).

Table 5: Yield and yield attributes of French beans under different treatments

Treatments	No of pods per plant	Pod length (cm)	No of seed per pod	100 seed weight (g)	Green pod yield (q ha^{-1})	Weight of pods per plant (g)
			Winter season			
Shading period						
Control	82.5	13.2	8.6	32.2	130.7	428.0
Vegetative	90.0	13.1	8.7	32.4	144.3	469.0
Reproductive	104.7	13.6	8.8	33.0	153.1	523.6
Whole season	112.7	13.7	8.9	33.5	167.0	532.4
CD (p=0.05)	7.1	NS	NS	NS	21.4	56.0
Varieties						
FBP-1	101.3	14.3	9.3	35.2	168.8	508.1
Kentucky wonder	93.6	12.5	8.2	33.3	128.7	468.3
CD (p=0.05)	5.03	NS	0.4	NS	15.1	39.6
Interaction	NS	NS	NS	NS	NS	NS
			Spring season			
Shading period						
Control	33.2	12.8	7.9	20.3	58.3	234.6
Vegetative	39.6	12.8	8.2	21.0	66.3	268.9
Reproductive	77.4	13.4	8.5	29.4	88.9	361.4
Whole season	89.2	13.6	8.6	32.5	94.8	384.1
CD (p=0.05)	17.2	NS	NS	3.6	13.9	55.0
Varieties						
FBP-1	63.3	14.0	8.8	28.1	86.2	349.0
Kentucky wonder	54.8	12.3	7.8	25.4	67.9	275.6
CD (p=0.05)	3.3	NS	0.4	NS	9.8	38.9
Interaction	NS	NS	NS	NS	NS	NS

Modifications of microclimate show no significant effect on 100 seed weight during winter season. Higher 100 seed weight (33.5g) was recorded fromwhole season cover followed by reproductive cover condition (33g) and lower (32.2 g) was recorded open condition that varied non-significantly with each other. 100 seed weight was recorded more in FBP-1(35.2 g) as compared to Kentucky Wonder (33.3 g). Number of seeds per pod varied non-significantly and was 8.9 under the treatment in which crop was covered during the whole seasonwhereas 8.6 under open field condition. FBP-1(9.3) showed significant difference with Kentucky wonders (8.2). The development of more fruits with larger lengths and diameters than those in the open field was related to higher pod yield in the polyhouse-grown plants over the plants grown in open space. Higher values of yield attributes and crop yield in the polyhouse compared to the open field were caused by taller plants and more branches due to the warmer temperature. During spring season 100 seed weight was overall reduced due to raise in temperature but was significantly higher under the treatment in which crop was covered with shade net during the whole season (32.5g) that was also statistically at par with that covered during reproductive stage (29.4g). Lower 100 seed weight was recorded under open condition (20.3g).

The green pod weight (g) per plant was significantly affected by modification of microclimate as well as among varieties during winter season. The higher green pod weight (532.4 g per plant) was found under the treatment which was covered during whole season but it statistically at par with that under cover during reproductive stage (523.6 g per plant). Less pod weight per plant was recorded under open condition (428 g per plant). FBP-1 has significantly higher pod weight (508.1 g per plant) than Kentucky wonder (468.3 g per plant). Number of pods was higher inside the cover as compared to open condition thus pod weight per plant was higher under cover conditions. During spring season pod weightper plant was found to be significantly higher under green shade net cover (384.1 gper plant) and that was statistically at par with that covered during reproductive stage (361.4gper plant). Pod weight per plantwas recorded very less under open condition (234.6gper plant) and vegetative cover condition (268.9gper plant) due to extreme temperature conditions the number of pod was less in spring season. Among the cultivar FBP-1 has significantly higher pod weight (349 g per plant) than Kentucky wonder (275.6 g per plant).

CONCLUSION

The study concluded that winter is the better growing season for French beans, yielding a higher green pod production of 167.0 q ha^{-1} compared to the spring season's 94.8 q ha^{-1}. Growing French beans in a polyhouse throughout the season led to better crop establishment, earlier pod formation, and higher yields than open-field conditions. During spring season sudden rise in temperature at the time of flowering caused more flowering but pod setting was not attained due to flower abortion which resulted in lesser yield.

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