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Year Round Production of Vegetables under Naturally Ventilated Poly House in Mid Hill Region of Kaski, Nepal

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Abstract

Year round production systems of high yielding vegetables inside the naturally ventilated polyhouse was evaluated at Horticulture Research Station, Malepatan, Kaski in fiscal year of 2020/21 and 2021/22. Year round production of high value vegetables is not profitable in open field thus development of technologies for protected structure is envisaged. The standard cultivation practices inside poly houses were followed for the crop cultivation period of major vegetables. The crops were grown in the defined area (m^2). Total yield and the marketable price per kilogram were recorded for evaluation. During 2020/21, the high yielding commodities were capsicum (18-20 t/ha) planted in second week of May, tomato (50-60 t/ha) planted in second week of June, pole bean (50-55 t/ha) planted in first week of August, cucumber (80 t/ha) planted in the last week of December. Similarly during 2021/22, capsicum (20 t/ha) planted in first week of May, tomato (50-60 t/ha) planted in third week of June, pole bean (50-55 t/ha) planted in first week of August, Broad leaf mustard (BLM) (40-50 t/ha) planted in first week of August, cucumber(80-100 t/ha) planted in last week of December and tomato (60-65 t/ha) planted in last week of February were high yielders. From the two year's result, cropping sequence of Capsicum/Tomato-Asparagus bean/French bean-Cucumber or Leafy vegetables (BLM)/Coriander-Tomato-French bean/Asparagus bean sequence were identified for proper utilization as well as to increase the income from protected structure in the mid hill region of similar climates.

Keywords: Poly house, Schedule, Cropping sequence, Vegetables, Profitable yield

Introduction

Greenhouse vegetable production is adopted in more than 115 countries in the world (Naved & Balraj Singh, 2013). Greenhouse crop production technology is adopted by all the continents and estimated 405,000 ha of land is covered by green house all over the world (FAO, 2013). According to Reddy (2016) more than 55 countries in the world used greenhouse technology for commercial vegetable production and the rate of using such technology is higher day by day. In Nepal the area of protected cultivation is about 703 ha and the area of protected cultivation (PC) in Nepal is also increasing every year due to attraction on such cultivation and subsidies provided by government on the construction of such structures (Atreya et al., 2019). The protected structure of naturally ventilated poly house covering an area of 4.53 ha is existed in Kaski which was built with the support of vegetable super zone (PMAMP, 2022).

Plant is grown under controlled or partially controlled environment resulting in higher yields than that is possible under open conditions (Navale et al., 2003). Different types of structures are being used for improving the productivity and profitability of horticultural crops throughout the year using green house, shade house, lath house, mist house etc. Favorable environment is the key point for the horticultural crop production (Trivedi & Singh, 2015). Negi et al (2013) reported that protected structure provides favorable environment for vegetable cultivation by controlling weather and regulates microclimate of structure. Despite having fertile land, the extreme temperature ranges from 0-48°C s is the main reason for unsuitable cultivation for year round production of vegetable in open field (Wani et al., 2011). Vegetable cultivation in open field has many constraints like heavy rain, thunderstorms, excessive solar radiation, temperatures and humidity levels (Max et al., 2009), high insect pest infestation (Nguyen et

al., 2009) and fungal attack (Sringarm et al., 2013). Environment is the most determinate factor for production of vegetables (Trivedi & Singh, 2015). To control the effect of environment on crop growth the use of protected cultivation is boon for the sustainable way of increment of yield. Besides, protection from adverse climatic condition, the produce has more yield and quality in terms of shape, size and colors (Sringarm et al., 2013). Cultivation of vegetables under protected condition will prolong its harvest period, increase in yield and quality and crop diversity (Trivedi &Singh, 2015). Protected cultivation is often used for high-value vegetables such as tomato, cherry tomato, colorful capsicum, parthenocarpic cucumbers, for off season cultivation (Singh et al., 2015).Greenhouse production should follow the market demands and consumer preferences as well as selection of right cultivar produce the profitable yield (Tuzel & Leonardi, 2009). Due to higher demand of Cucurbitaceae and Solanaceae family vegetables, parthenocarpic and indeterminate types of cucumber and tomato are necessary for green house cultivation to show their full genetic capacity (Kaddi et al., 2014). Plastic house technology is one of the viable alternatives for quality tomato production in the high hills (Chapagain et al., 2010). The yield obtained from plastic house tomato cultivation is very high as compared to national and regional productivity of tomato (CADP, 2008).

In Nepal, the highest coverage for fresh vegetables was Madhesh Province (83355 ha) followed by Province 1(50449 ha) and the production area of Gandaki Province was 22726 ha. But the productivity was highest in Province 1 (15.81 mt ha^{-1}) followed by Bagmati Province (14.57 mt ha^{-1}) and productivity of Gandaki Province was 12.43 mt ha^{-1}. The vegetable production area of Kaski district is 5376 ha with the productivity of 13.38 mt ha^{-1}.The total area of fresh vegetable production in Nepal is 284121 ha with the productivity of 14.05 mt ha^{-1} (MoALD, 2021). Year round production of vegetable crops helps to local or regional supply of quality produce. Production and productivity of quality vegetable can be increased under protected condition by creating conducive environment for vegetables to grow which will help for import substitution.

Protected Cultivation technology is a relatively new technology for our country. The total area covered under protected cultivation in our country is very low. Many farmers are not able to utilize the high tech protected structure built inside the Pokhara valley, Kaski due to lack of production technologies for protected cultivation. Selection of the proper cropping system and varieties is the challenge for the full utilization of the plastic houses for high profit. . Lack of proper cropping calendar and appropriate varieties under protected agriculture, farmers are unable to fetch high yield as well as quality produce which ultimately lower theirreturn. Farmers will be able to get more profit if they could harvest and sell the product that are not suitable to produce in open condition however they are possible under protected structure. . By the use of protected cultivation offers a great opportunity to grow vegetables in the off-season and also to lengthen the vegetable growing periods than open field conditions. Besides, small land holding farmers can also plan for commercial vegetable production with the help of protected structure. Therefore, this study aims to provide proper cropping system with appropriate varieties of different vegetables under protected structure for offseason production which ultimately give high returns to the farmers.

Materials and Methods

Experimental sites

The experiment was performed at Horticulture Research Station (HRS), Malepatan, Pokhara, Kaski district during the two consecutive fiscal years (2020/21 and 2021/22) under naturally ventilated poly house condition. The station is located at about 28°13'6.8" N latitude and 83°58'27.72" E longitude with an elevation of 848 masl. The station has sub-tropical humid type of climate. The protected structure was placed fully closed for November to February months whereas other duration the sides were opened for aeration. The soils are deep, well drained and sandy loam in texture (Table 1).

Table 1. Soil physico-chemical properties of the research site, HRS Malepatan, Kaski, Nepal, 2020

Details	Mean	Ratings
pH	5.8	Acidic
Total nitrogen (%)	0.16	Medium
Phosphorous (kg/ha)	219	High
Potash (kg/ha)	1416	High
Organic matter (%)	3.2	Medium

Source: Soil and Fertilizer testing laboratory, Pokhara, Gandaki Province

Naturally Ventilated Poly houses

This type of poly house has adequate ventilation and fogger system to prevent from extreme weather condition. The naturally ventilated poly house used in this studyis multi-span type having central height of 4.5 meter, gutter height of 2.5 meter and side ventilation of 1.5 meter with resistant to wind storm. There is provision of side ventilation with roll-able poly-cover with roof ventilation and double door entry system. Flap ventilators on the roof and rolling ventilators on the side wall were present on the structure. The roof was covered with plastic film and the side and front walls are covered with semi-rigid plastics. These arch-shaped multi span structures frames are normally made by galvanized steel. We had installed drip irrigation system for each plot and mulched with black and silver color plastic film for each crop. There was facility of misting during the high temperature. In Extreme winter from November15 to February 15 the side ventilation was kept close with plastic cover. Such poly houses are found suitable for year round production of vegetables according to climate specific location. The size of poly house was 750 m^2 (20 m width and 37.5 m length) having twenty rows of one meter width.

Crop diversity used and their cultural practices

For the evaluation of each crop and variety under protected structure, the following variety, spacing and Recommended dose of fertilizer **(**RDF) were used for the research plot. For every vegetable, 25 ton FYM per hectare was used during land preparation (Table 2).

Table 2. Crops grown in naturally ventilated poly house and their cultural practices

SN	Crops	Variety	Spacing (cm x cm= cm^2)	Recommended dose of fertilizer (RDF) (kg NPK/ha)
1	Broad Leaf Mustard	Manakamana, ZY no.2	25 x25	200:180:80
2	French Bean	Four season bean and Italy 38	50 x60	200:180:60
3	Cucumber	Brisma, Daddy 2231, Majesty, Bhaktapur Local	50 x 60	200:100:100
4	Tomato	Srijana (F1)	50 x 60	200:180:150
5	Capsicum	California Wonder	50 x 60	200:100:100
6	Radish	Mino Early	30 x 20	200:180:60
7	Coriander	Kalami	25 cm row to row and P to P continuous	100:100:100
8	Asparagus Bean	ASB008, Chandra OP	50 x30	80:120:40
9	Carrot	New Koroda	20 cm row to row and P to P continuous	100:100:100
10	Spinach	All Green	25x25	200:180: 80 kg NPK/ha
11	Sponge Gourd	New Narayani (F1)	50x120	200:100:100
12	Okra	ArkaAnamika	50x25	200:180:60

Experimental design

The experiment was conducted in non replicated design. The plot size was maintained according to the specific crop geometry for each crop. Each plot was laid down in one meter width and length was maintained at 17 meter. Plant parameters were collected from 5 sample plant and each defined plot for the respective crop.

Data observation

The parameters like days to first flowering, days to first harvesting, number of harvesting, last date of harvesting, yield per plant and yield per plot were recorded from the five sample plants from each plot. The fruits were evaluated based on the fruit weight, fruit length, diameter and the number of fruits per plant. Multiple harvesting was performed for each crop from the date of first harvest and the estimated yield was calculated by adding each times yield in per plot.

Results

During 2020/21, the production period and status of vegetables grown under naturally ventilated poly house was shown in the Table 3. The evaluations were started from April, 2020 to the March, 2021 by growing different crops with a purpose of off-season production to catch the higher market price. Among the crop grown in this protected

structure, the high yielding crops were recorded for the Cucumber followed by Tomato, French bean and Broad leaf mustard. The high yielding commodities were capsicum (18-20 t/ha) planted in second week of May, tomato (50-60 t/ha) planted in second week of June, pole bean (50-55 t/ha) planted in first week of August, cucumber (80 t/ha) planted in the last week of December. The high yielding crops were recorded for the Cucumber from 8-15 kgm^2 which means the yield ranges from 50-100 t/ha according to respective planting season. The highest yield was obtained when planting one month old seedlings in December and achieved 80-100 t/ha fresh cucumber from the date of February. The late planting of cucumber yield less compared to earlier one. The production of Broad leaf Mustard (BLM) was found successful under naturally ventilated poly house structure. The direct seed sowing of BLM in the first week of August started to harvest by root uproot after 40 days after sowing and yielded up to 40-50 t/ha in the respective growing period. The productive length of Tomato under naturally ventilated poly house was longer than other tested vegetable crops. Generally, six month duration was productive period from the date of planting under such protected structure and produced more than 50 t/ha. The production of coriander starting from the August was also produced 10-12 t/ha fresh leaves by multiple harvesting.

Table 3. Crop duration and yield evaluation ofdifferent vegetables under naturally ventilated poly house at HRS, Malepatan in 2020/21

Crop	Date of seed sowing	Date of transplanting	Date of 1st harvest	Yield/m^2 (kg)	Yield(t/ha)
Capsicum	Apr-17,2020	May-18,2020	July-28,2020	2.5	15-20 ton
Tomato (Srijana F1)	May-18,2020	Jun-19,2020	July-30,2020	8	50-60
BLM (Manakamana)	Aug-2,2020		Sep-14,2020 (43 DAS)	6.03	40-50
Bush Bean	Aug-2,2020		Oct-2,2020 (61 DAS)	2.02	15-18
Pole Bean (Four season)	Aug-2,2020		Oct-2,2016 (61 DAS)	8.2	55-50
Radish (Mino Early)	Aug-2,2020		Sep-30,2020 (59 DAS)	1.8	12
Radish (40 days)	Aug-2,2020		2077/06/04 (49 DAS)	1.5	10
Okra	Aug-2,2020		Sep-20,2020 (59 DAS)	1.2	7-8 ton
Asparagus Bean (ASB008)	Aug-2,2020		Sep-25,2020 (59 DAS)	2.6	15-16
Coriander	Aug-2,2020		Oct-9,2020 (68 DAS)	1.8	10-12 ton
Carrot (New Koroda)	Aug-2,2020		Nov-5,2020 (95 DAS)	1.9	10-12 ton
Asparagus Bean (ASB008)	Dec-7,2020		Apr-19,2021	2.8	18
French Bean (Four season bean)	Dec-7,2020		Mar-24,2021	4.8	28-30
Cucumber	Nov-29,2020	Dec-29,2020	Feb-25,2021	15	80-100
Sponge Gourd (New Narayani)	Dec-9,2020		Apr-7,2021	5	30-35
Tomato (Srijana F1)	Nov-26,2020	Jan-27,2021	Apr-26,2021	9.85	60-65
Cucumber	Dec-17,2020	Jan-24,2021	Mar-7,2021	10	60-65
Radish (Mino Early)	Dec-11,2020		Jan-18,2021	10	60
Carrot (New Koroda)	Dec-11,2020		Mar-24,2021	6	40
Cucumber	Jan-4,2021		Mar-24,2021	8.5	50-55
Broad Leaf Mustard (Manakamana)	Jan-8,2021		Mar-14,2021	8	45-50
Spinach	Jan-8,2021		Mar-14,2021	4	20-25
Cucumber	Jan-29,2021		Mar-30,2021	9	60
Capsicum (California Wonder)	Feb-8,2021	May-2,2021	May-30,2021	3	20
Cucumber	Feb-22,2021		Apr-19,2021	3	20
Tomato	Feb-19,2021	Mar-21,2021	June-3,2021	8	50-55
Asparagus Bean (ASB008)	Mar-25,2021		Jun-6,2021	2.09	12-15 ton
French Bean (Four season bean)	Mar-25,2021		Jun-3,2021	3.9	25

Similarly during 2021/22, the production period and status of vegetables grown under naturally ventilated poly house was shown in the Table 4. The evaluation was started from Aug, 2021 to the Aug, 2022 by growing the different crops. The September planting of Capsicum produced 10-12 t/ha under poly house condition and tomato gave up to 70 t/ha. Different crops viz. Asparagus beans, French bean, Broad leaf mustard, Coriander and Sponge gourd were

evaluated in the month of August. These crops were chosen for the off-season production. The French bean variety Italy 38 produced 25-28 t/ha which was more consumer appealing than Four Season French bean which gave 16-20 t/ha yield. Broad leaf mustard was harvested by direct plucking of whole plant and also by leaf plucking to sell early in the market. Some plot of BLM left for continuous leaf plucking over the growing period and produced up to 25-40 t/ha fresh leaves of BLM. The Chinese variety ZY no.2 produced more yield than Manakamana variety of BLM under poly house. The yield of normal season Spinach was 18-20 t/ha which were harvested from January to March. The early planting of Cucumber on third week of January produced 90-100 t/ha which were harvested from March to May but late planted cucumber gave lower yield. The one month old seedling of tomato planted in second week of March produced yield up to 80 t/ha. The French bean produced 20 t/ha planted in the February and April planted Capsicum produced 12-15 t/ha. From the year round evaluation of vegetables, capsicum (20 t/ha) planted in first week of May, tomato(50-60 t/ha) planted in third week of June, pole bean (50-55 t/ha) planted in first week of August, Broad leaf mustard (BLM) (40-50 t/ha) planted in first week of August, cucumber (80-100 t/ha) planted in last week of December and tomato (60-65 t/ha) planted in last week of February were high yielders.

Table 4. Table: Crop duration and yield evaluation of different vegetables under naturally ventilated poly house at HRS, Malepatan in 2021/22

Crop	Date of seed sowing	Date of transplanting	First harvest/Last harvest	Yield/m^2 (kg)	Yield (t/ha)
Capsicum	Aug-6,2021	Sept-27,2021	Nov-28,2021/Feb-6,2022	1-2	10-12
Tomato	Aug-19,2021	Sep-16,2021	Nov-15,2021/Jan-31,2022	10.52	70
Asparagus Bean	Aug-9,2021		Sep-28,2021/Nov-8,2021	1.56	12
French bean	Aug-9,2021		Sep-27,2021/Nov-8,2021	2.76	16-20
French Bean	Aug-9,2021		Sep-27,2021/Nov-8,2021	3.84	25-28
BLM	Aug-4,2021		Sep-15,2021 (root uproot)	1	5
BLM (Manakamana)	Aug-4,2021		Sep-22,2021/Jan-3,2022(leaf)	3.52	25
BLM (Chinese ZY no.2)	Aug-4,2021		Sep-22,2021/Jan-3,2022(leaf)	5.36	35-40
Sponge gourd	Aug-20,2021		Oct-17,2021/Jan-3,2022	5.14	40
Coriander (Kalami)	Aug-20,2021		Oct-19,2021/Jan-3,2022	1.18	8-10
Coriander	Oct-1,2021		Nov-17,2021/Mar-7,2022	2.69	16-18
Spinach	Dec-3,2021		Jan-26,2022/Mar-7,2022	2.8	18-20
Carrot (New Koroda)	Nov-22,2021		Mar-7,2022	3.5	25
Carrot (Chinese)	Nov-22,2021		Mar-7,2022	3.2	20
French bean (Four season)	Dec-7,2021		Mar-25,2022/May-25,2022	6.3	40
French bean (Four season)	Jan-10,2022		Apr-4,2022/Jun-10,2022	3.9	26
French Bean (Italy 38)	Jan-10,2022		Apr-4,2022/Jun-10,2022	5	32-35
Asparagus Bean (Chandra OP)	Jan-10,2022		Apr-20,2022/May-2,2022	0.88	6-8
Cucumber (Brisma, Majesty)	Jan-1,2022	Jan-21,2022	Mar-11,2022/May-18,2022	15	90-100
Cucumber		Feb-17,2022	Apr-1,2022/May-18,2022	8.5	55-60
Cucumber		Mar-18,2022	Apr-19,2022/Apr-1,2022	3.5	25
Cucumber (Bhaktapur Local)		Mar-10,2022	Apr-19,2022/Apr-1,2022	2	15
Tomato		Mar-14,2022	May-24,2022/Aug-10,2022	12	80
Asparagus Bean (Chandra OP)	Feb-7,2022		Apr-25,2022/May-20,2022	1-2	6-8
French Bean (Four season)	Feb-6,2022		Apr-20,2022/May-28,2022	3.1	20
Capsicum		Apr-3,2022	Jun-22,2022/Aug-5,2022	1.9	12-15

From the two year's result, crop evaluation under naturally ventilated poly house in terms of yield, their market price and the demand of the commodities. we can follow the production cropping sequence of Capsicum/Tomato(Aug-Jan)-Asparagus-bean/French, bean(Jan-Apr)-Cucumber (Mar/April-May/June/July) or Leafy vegetables (BLM)/ Coriander (May/Jun-Sept)-Tomato (Sep-Feb)-French bean/Asparagus bean (Feb-May)

sequence were identified for proper utilizationas well as to increase the income from protected structure in the mid hill region of similar climates (Table 5).

Table 5. Possible best combination identified from two year result for the year round production of major high value vegetables under naturally ventilated poly house in Pokhara, Kaski, Nepal

Sequence 1	Sequence 2	Sequence 3	Sequence 4
Capsicum (Apr/May/Jun-Sep/Oct/Nov)	Tomato (Apr/May/Jun-Sep/Oct/Nov)	Rayo for uproot (Apr/May/Jun–Jul/Aug/Sep)	Coriander (Apr/May/Jun–Jul/Aug/Sep)
French Bean/Asparagus Bean (Oct/Nov/Dec-Jan/Feb/Mar)	Asparagus Bean (Oct/Nov/Dec-Jan/Feb/Mar)	Rayo for transplant (Aug/Sep-Oct/Nov/Dec)	Tomato (July/Aug/Sep-Nov/Dec)
Cucumber (Jan/Feb/Mar-Apr/May/Jun)	Cucumber (Jan/Feb/Mar-Apr/May/Jun)	Sponge gourd (Nov/Dec- Apr/May)	French Bean (Nov/Dec-Jan/Feb)
			Asparagus Bean (Jan/Feb-Apr/May)

Table 6. Normal season planting of major vegetables for the mid hill condition of Pokhara, Kaski region

Crop	Normal season planting	Time of harvesting (days after sowing[DAS]/days after planting [DAP]
Tomato	Feb-May	75-80 DAP
Capsicum	Feb-March	75-80 DAP
French Bean	Feb-Apr and July/August	60 DAS
Asparagus bean	Apr and July August	60 DAS
Broad leaf mustard	Sep-Dec	30 DAP
Coriander	Sep-Dec	50-55 DAS
Cucumber	Feb-Jun	50 DAP

Source: Package of Practices for vegetable crops, NARC, 2021

Cost of cultivation analysis for major vegetables

The cost calculation for the production of major fresh vegetables 0.05 ha (500 m^2area of land) was mentioned in Table 7. The highest production cost 43 Rs/kg was found for the French bean followed by tomato (31 Rs/kg) and hot pepper (23 Rs. /kg).

Table 7. Cost Economics for vegetable cultivation in Pokhara Metropolitan city, Kaski, Nepal

Particulars	Crops				
	Cucumber	Tomato	Beans	Broad Leaf Mustard	Hotpepper
Land type	Open field	Rain out shelter	Open field	Open field	Open field
Total Cost	28735	65140	19350	16390	28760
Total variable cost	90%	48	79	75	86
Total Fixed cost	10%	52	21	25	14
Yield (Per 500 m^2 Land)	1500 kg	2100 kg	450 kg	1400 kg	1250kg
Production Cost per kg (Rs.)	19	31	43	12	23

Source: Pokhara Metropolitan city, Research report, 2022,

Vegetable market price situation

The year round market prices of major vegetables were presented on Table 8 and Table 9. From the data of vegetable wholesale market of Pokhara, The price of hotpepper was higher than 100 rupees per kg from July to December. The price of BLM (70 Rs/kg) was found higher from July to October than other growing periods. The price of coriander (more than 300 Rs/kg) was found higher from July to November than other growing periods. The wholesale price of French bean was found quite impressive throughout the year while the price from August to December was found higher than other growing seasons. The price of tomato from August to December also got higher price than other crop season.

Table 8. Market price list of major vegetables in wholesale market of Pokhara Metropolitan city, Kaski, Nepal in 2020/21 and 2021/22

Month	Hot pepper green		Sweet Pepper		Broad Leaf Mustard		Coriander leaf	
	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
Apr/May	94.20	85.00	95.87	100.00	38.49	27.50	32.13	45.00
May/June	108.80	85.00	67.26	90.31	25.89	27.34	101.79	69.38
June/July	71.21	105.00	133.33	120.00	32.21	40.00	306.21	260.00
July/Aug	113.26	136.79	167.83	130.00	70.98	72.50	516.30	283.93
Aug/Sep	139.66	136.00	139.31	123.00	71.03	76.88	282.76	448.75
Sep/Oct	177.04	133.00	159.81	187.00	80.19	96.00	400.00	435.00
Oct/Nov	168.00	131.15	179.00	204.62	37.25	75.58	342.50	229.62
Nov/Dec	112.29	107.69	105.00	140.00	32.81	44.81	265.63	164.42
Dec/Jan	76.67	91.48	78.57	128.70	36.79	28.15	98.57	134.26
Jan/Feb	80.23	96.67	76.14	110.00	35.34	17.50	86.82	111.11
Feb/Mar	92.90	151.79	87.26	140.71	35.32	20.36	83.71	77.14
Mar/Apr	96.88	160.25	100.83	118.00	46.04	33.88	77.92	49.13

Source:bajar.pokharakrishi.com

Table 9. Market price list of major vegetables in wholesale market of Pokhara Metropolitan city, Kaski, Nepal in 2020/21 and 2021/22

Month	French Bean		Asparagus bean		Cucumber (Local)		Tomato	
	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
Apr/May	60.16	75.00	59.10	65.00	64.63	85.00	35.58	39.90
May/June	53.04	70.63	49.82	66.88	38.30	84.06	47.03	48.50
June/July	64.74	75.00	52.33	55.00	28.97	75.00	38.72	39.61
July/Aug	120.65	78.21	102.83	53.93	57.61	76.07	66.86	46.13
Aug/Sep	145.17	94.75	110.86	88.00	64.66	76.00	94.27	37.15
Sep/Oct	119.63	113.00	108.70	125.00	70.37	79.00	96.16	70.07
Oct/Nov	77.00	139.62	87.50	156.54	78.00	74.62	72.53	104.88
Nov/Dec	116.88	110.58	76.04	125.58	99.35	75.58	64.65	108.67
Dec/Jan	83.33	102.59	92.38	99.07	30.24	40.37	52.10	61.62
Jan/Feb	38.86	111.94	10.00	48.61	55.00	57.00	45.71	41.84
Feb/Mar	91.94	95.00	6.45	0.00	73.06	70.00	25.99	53.66
Mar/Apr	95.42	73.63	140.63	113.25	102.29	78.75	45.43	71.14

Source: bajar.pokharakrishi.com

Discussion

Green house, polyhouse, shade net house & low tunnels are different types of protected cultivation structures which provide favourable condition for higher yield and quality. For extreme winter, green house is the best option to cultivate vegetables (Santosh et al., 2016). The productivity under protected condition was 5 to 8 folds higher than open field condition that depends on the nature of crop (Jethi et al., 2012; Negi et al., 2013; Reddy, 2016).

Ummyiah et al. (2017) stated that the production of vegetables in protected structure can be doneto produce off-season, can be made available early than normal season as well as vegetable growing period can be extendedthan in open field. Likewise, Kumar and Kumar (2020) reported that by using net house/poly house year round cultivation of capsicum, tomato, okra, cauliflower, cabbage, brinjal, beans, parthenocarpic cucumber and other cucurbits is possible with lower incidence of insect-pest and diseases. Pachiyappan et al.(2022) reported that the cultivation of flowers and vegetables under protected cultivation was highly profitable with high rate of investment. Also, in comparison with open field condition, the cultivation cost for Capsicum under protected conditionwas 300 %, gross return was 250% and net return was 190 %..To produce off season vegetables and to catch the higher prices for

produce, the protected cultivation is the viable option. Protected cultivation lets farmers to produce crops off season and fetch higher prices (Sabir & Singh, 2013; Singh, 2014). Heuvelink (2005) reported that the facility of high tech protected structure in Netherlands produced 550 metric tons ha^{-1} $year^{-1}$ of fresh tomato which is the number one productivity in the world.

Tomato, bell pepper and cucumber are the mostly cultivated vegetables under greenhouses to get higher returns in terms of yield and monetary value (Chandra et al.,2000).To produce the off season vegetable, use of cost-effective plastic greenhouses helps to meet year-round supply of fresh vegetables with efficient resource use (Sharma et al., 2009).Talukdar et al. (2003) reported the use of protected cultivation has higher productivity, better quality of goods, disease and pest free, early maturity and helps to produce year round fresh vegetables having hostile environment in open condition. Due to excessive rainfall in Pokhara region, the cultivation of Capsicum is almost impossible for the commercial production. In the protected structure of HRS, Malepatan produced 10-15 t/ha of fresh Capsicum which is supported by Reddy(2016) who reported that the various trials conducted at agro-research centers in northern India shows that capsicum (planted in mid- September), cucumber (planting in mid- October) and tomato (planted in November) under the polyhouse gives higher yield than open field, longer crop duration for harvest and the price was higher 2-4 times than normal season.

Coriander and Broad leaf mustard sown in the month of August gave the profitable yield under the protected structure at HRS, Malepatan. Leafy vegetables have also the potentiality of production under protected environment (Sabir & Singh, 2013). July-August planting of Capsicum and Tomato is the off-season for these crops in the rainy season in normal condition. With the provision of protected environment from excessive rainfall, the production under naturally ventilated polyhouse gave the significant yield and achieved the high price during the harvesting period. The used variety for Tomato was indeterminate type hybrid variety. Vegetables are more common crops in polyhouses and useful for production of high-value vegetables, such as capsicum and tomato in year round production including off-season (Murthy et al*.,* 2009). Singh et al.(2015) also reveals that in Northern India, high-value vegetables such as tomato, cherry tomato, colorful capsicum, parthenocarpic cucumbers, pole type French beans, winter watermelon, muskmelon and strawberries can be cultivated out of season in poly houses/ walk-in tunnels. Likewise, hybrid cultivars having indeterminate growth habit are ideal for greenhouse. Bhatnagar et al. (1990) found that higher yield and earliness in tomato in green house and Capsicum cultivated in the naturally ventilated polyhouse produced four times more yield than open field condition.

In the protected condition at HRS, Malepatan, the used variety of Cucumber were gynoecious line and parthenocarpic lines, The gynoecious lines of Brisma (F1) and Majesty (F1) gave the highest yield during the growth period. The Daddy 2231 was parthenocarpic line which was used for production of mini cucumber. These findings are in accordance with Singh (2018) who stated that in modified naturally ventilated polyhouse in India, tomato, Capsicum and Parthenocarpic cucumber were produced for 8-10 months in plains and low hills.

Fernandez et al. (2018) reported that Cucurbitaceae and Solanaceae are the dominant species in greenhouses due to higher demand and well adapted to changing climatic conditions and there is chance of monoculture. Fernandez et al. (2018) mentioned that Use of naturally ventilated polyhouse helps to maintain the greenhouse microclimate (temperature, humidity and CO2). Sindhu and Chatterjee (2020) reported that use of poly house for growing summer crops in winter, growing winter vegetables in summer month by using shade net and growing winter vegetables in rainy season by using rain shelter are the ways for off-season production of the vegetables under protected condition. Growing of leguminous crop under the protected structure has many benefits like soil amendments, crop rotation as well as the yield of these crops. French bean is the potential crop to cultivate in all season under protected condition and the price of these products were always higher in the market and it will improve the soil condition by effective crop rotation as well as increase the yield and income of farmer (Preissel et al., 2015).

Conclusion

The cultivation of high value vegetable crops under protected structure (naturally ventilated poly house) is highly fruitful in terms of economic and environmental perspectives by providing higher quality and yield in the adverse as well as in the normal growing condition. Production of high value vegetables like tomato, Capsicum, French bean,

Coriander under poly house gave higher yield and also fetched good price. From the two year's result, in terms of yield and profit possible cropping sequence could be Capsicum/Tomato-French bean/Asparagus bean-Cucumber, Leafy vegetables (BLM/Coriander)-cucurbits and Coriander leaves-Tomato- French bean/Asparagus bean. Hence to obtain a good quality produce and production during off season, there is a need to cultivate high value crops under protected condition such as naturally ventilated poly house or green houses. Use of leguminous crop in the cropping sequence also adds the soil health other than fresh yield. Year round cultivation of fresh vegetable is possible under such type of protected structure if appropriate selection of variety, crops and seasons for increment of yield and income.

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Authors' contributions

S Lohani was directly involved in the research design and in the conduction of field experiment, data recording, analysis of data and draft preparation of manuscript while LN Aryal and S Adhikari were involved as helping hands for research concept, design and field experiment as well as data recording and analysis. YR Bhusal and S Aryal had contribution on guideline for proper research design and correction of manuscript.

Conflicts of interest

The authors have no relevant financial or non-financial interests to disclose.

References

Atreya, P. N., Kafle, A., Suvedi, B. D. & Shrestha, S. B. 2019. Precision and Protected Horticulture in Nepal. Proceeding of 10 th National Horticulture Seminar, 2019.

Bhatnagar R. R., Vedprakash, R. C. & and Srivastav, R. C. (1990). Production of vegetables in polyhouse greenhouse during winters in mid hills of Uttar Pradesh. Prog. Hort., 22 : 97-100.

CADP. (2008). Final value chain report of tomato. Commercial Agriculture Development Project. Ministry of Agriculture and Cooperaives, Biratnagar, Nepal. www.cadp.gov.np/Documents_Uplaods/ Reports.

Chandra, P., Sirohi, P. S., Behera, T. K. & Singh, A. K. (2000). Cultivating vegetables in polyhouse. Indian Hort 45:17–25

Chapagain, T. R., Piya, S., Mandal, J. L. & Chaudhary, B. P. (2010). Up-scaling of polyhouse tomato production technology in mid and high hills of eastern Nepal. In: Proceedings of ninth nationaloutreach research workshop (June 7-8, 2010), Kathmandu (Eds. M. N. Paudel, T. P. Barakoti and Y. N. Ghimire). Outreach Research Division, Nepal Agriculture Research Council, Kathmandu. pp. 116-120.

FAO. (2013). Good agricultural practices for greenhouse vegetable Crops. FAO plant production and protection paper 217. Food and Agriculture Organization of the United Nations, Rome

Fernández, J. A., Orsini, F., Baeza, E., Oztekin, G.B., Muñoz, P., Contreras, J. & Montero, J. I. (2018). Current trends in protected cultivation in Mediterranean climates. Eur. J. Hortic. Sci. *83*(5), 294–305

Heuvelink, E. (2005). Tomatoes, vol 13. CABI.

Jethi, R.; Srinivas, K. &Bisht, J.K. (2012). Economics of production of tomato under open and protected field conditions in hills of Uttarakhand. Indian J. Ext. Educ. 2012, 48, 13–16.

Kaddi, G., Tomar, B. S., Singh, B. & Kumar, S. (2014). Effect of growing conditions on seed yield and quality of hybrid Cucumber (*Cucumissativus*). Indian Journal of Agricultural Sciences. 84(5): 624-7.

Kumar, D. & Kumar, S. (2020). Vegetables cultivation under the protected conditions .The Pharma Innovation Journal 2020; 9(8): 277-280

Max, J.F.J., Horst, W.J., Mutwiwa, U.N. &Tantau, H.J. (2009). Effects of greenhouse cooling method on growth, fruit yield and quality of tomato (*Solanumlycopersicum*L.) in a tropical climate. *Sci.Hortic*. 122(2): 179-186.

MoALD. (2021). Statistical information on Nepalese agriculture. Ministry of Agricultural Development. Agri-Business Promotion and Statistics Division, Singh Durbar Kathmandu, Nepal.

Murthy, D. S., Prabhakar, B. S., Hebbar, S. S., Srinivas, V. &Prabhakar, M. (2009). Economic feasibility of vegetable production under poly house: A case study of capsicum and tomato. *Journal of Horticulture Science* 4:148-52.

Navale, A. V., Nandagude, S. B., Pawar, A. G., Ghodke, H. M. &Bhosale, A. D. (2003). Comparative study of skirting and top covering effect in low cost greenhouse. Proc. of All India on Seminar Potential and Prospects for Protective Cultivation, organized by the Institute of Engineers, Ahmednagar, December 12-13, 2003, p. 97.

Naved, S. &Balraj Singh, A. D. (2013). Protected cultivation of vegetables in global arena: review Indian Journal of Agricultural Sciences 2013;83(2):123-35. February 2013/Review article

Negi V. S., Maikhuri, R. K., Rawat, L. S. &Parshwan D. (2013). Protected cultivation as an option of livelihood in mountain region of central Himalaya, India. International Jouranl of Sustainable Development and World Ecology, 20(5) :416–425. https://doi:10.1080/13504509.2013.79910*38T*.

Nguyen, T. H. N., Borgemeister, C., Max, J. & Poehling, H.M. (2009). Manipulation of ultraviolet light affects immigration behaviour of Ceratothripoidesclaratris (Thysanoptera: Thripidae). *J. Econ. Entomol.* 102(4): 1559-1566.

Pachiyappan, P.; Kumar, P.; Reddy, K.V.; Kumar, K. N.R.; Konduru, S.; Paramesh, V.; Rajanna, G.A.; Shankarappa, S.K.; Jaganathan, D. & Immanuel, S. (2022). Protected Cultivation of Horticultural Crops as a Livelihood Opportunity in Western India: An Economic Assessment. Sustainability, 14, 7430. https://doi.org/10.3390/su14127430

PMAMP. (2022). Annual Report. Prime Minister Agriculture Modernization Project, Program Implementation Unit, Kaski

Pokhara Metropolitan city Research report, 2022, Minimum support price declaration of major agricultural products, Agricultural and livestock development division, Pokhara Metropolitan City, Kaski

Preissel, S., Reckling, M., Schläfke, N., & Zander, P. (2015). Magnitude and farm-economic value of grain legume pre-crop benefits in Europe: a review. Field Crops Research, 175, 64–79.

Reddy, P. P. (2016). Sustainable Crop Protection under Protected Cultivation. Springer Publication. ISBN 978-981-287-950-9, ISBN 978-981-287-952-3 (eBook) DOI 10.1007/978-981-287-952-3

Sabir, N. & Singh, B. (2013). Protected cultivation of vegetables in global arena: A review. *Indian Journal of Agriculture Science* 83:123-35.

Santosh, D. T., Tiwari, K.N. & Singh, V. K. (2017). Influence of different protected cultivation structures on water requirements of winter vegetables.International Journal of Agriculture, Environment and Biotechnology (IJAEB): 10(1): 93-103, DOI: 10.5958/2230-732X.2017.00004.3

Sharma, M., Negi, S. & Kumari, S. (2009). Effect of different growing media and fertigation levels on production of cucumber (*Cucumissativus*L.) under protected conditions in the hills. Indian J AgricSci 79(10):853–856

Sindhu, V. & Chatterjee, R. (2020). Off-Season Vegetable Cultivation under Protected Structures: A Promising Technology for Doubling Farmers Income. *International Archive of Applied Science and Technology* Vol 11 **4**: 208-14.

Singh J., Nangare, D. D., Meena, V. S., Bhushan, B., Bhatnagar, P. R. & Sabir, N. (2015). Growth, quality and pest infestation in tomato under protected cultivation in semi-arid region of Punjab. Indian Journal of Horticulture 72:518-22.

Singh, B. (2014). Protected cultivation of horticultural crops in India: Challenges and opportunities. In Proceedings of the 2014 Conference Third International Conference on Agriculture and Horticulture, Hyderabad, India, 27–29 October 2014.

Singh, B. (2018). Greenhouse Production Systems in India: Opportunities and Challenges. In: Kumar, S., Patel, N. B., Saravaiya, S. N. & Patel, B. N. (Eds). (2018). Technologies and sustainability of Protected cultivation for Hi-valued vegetable crops. Navsari Agricultural University, Navsari, Gujarat, India. February 01-03,2018.494p.

Singh, V. K., Rajan, S., Singh, A. & and Soni, M. K. (2015). Protected Cultivation of Horticultural Crops. Technical Bulletin. Precision Farming Development center.ICAR- Central Institute for subtropical horticulture.Lucknow.

Sringarm, K., Max, J., Saehang, S., Spreer, W., Kumpiro, S. & Müller, J. (2013). Protected Cultivation of Tomato to Enhance Plant Productivity and Reduce PesticideUse. [Online]. Available: 38Thttps://www.researchgate.net/publication/ 25809888838T.

Talukdar, M. C., Sarma, B., Das, S.&Mahanta, S. (2003). Evaluation of spray chrysanthemum cultivars under open and polyhouse conditions. In: National symposium on recent advances in Indian floriculture, Kerala Agricultural University.

Trivedi, A. K. & Singh, V. K. (2015). Potential for improving quality production of temperate horticulture crops under protected cultivation. *(In)* National workshop cum seminar on emerging prospects of protected cultivation in horticultural crops under changing climate. Precision farming development center Lucknow.

Tuzel, Y. & Leonardi, C. (2009). Protected cultivation in Mediterranean region: trends and needs. *J. Ege Univ. Fac. Agric*. 46(3): 215–223.

Ummyiah, H. M., Wani, K. P., Khan, S. H. &Magray, M. M. (2017). Protected cultivation of vegetable crops under temperate conditions. Journal of Pharmacognosy and Phytochemistry 2017; 6(5): 1629-1634

Wani, K.P. Singh, P. K., Amin, A., Mushtaq, F. & Dar, Z. A. (2011). Protected cultivation of tomato, capsicum and cucumber under Kashmir valley conditions. *Asian Journal of Science and Technology Vol*. 1 4:56-61.