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Sequential vegetable production under protected condition in temperate humid region

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Crop intensification through cropping sequence is not only productive and profitable but also sustainable. Moreover it entails efficient utilization of natural resources (Prasad *et al*. 2011, Saroch *et al*. 2005). In spite of quantum improvement in the production, vegetable has been plagued by weather extreme and technological accessibility which widened the gap between availability (220g/day/person) and requirement (300g/day/person). In the era of market-driven production system, suitable cropping sequence of high value vegetables is the most important aspect to get more benefit per unit of area particularly in temperate region. North-eastern Himalayan regions are blessed with varied agro-climatic conditions which favour cultivation of varieties of vegetables. However weather extremities limit the production potential and in turn profitability. Protected cultivation of vegetables is a vital tool to cultivate vegetables even during weather extremities. Moreover a viable cropping sequence will play significant role in making farming more profitable particularly for small and marginal farmers (Srivastava *et al*. 2002). In this background, the present investigation was undertaken to evaluate the performance of off-season vegetable-based cropping sequence under low-cost protected cultivation to determine the best cropping sequence, to enhance the profitability of vegetables under mid hills of north-eastern Himalayan regions.

Experiment was conducted at ICAR research farm, Tadong, Gangtok, East Sikkim (27° 20' N, 88° 4' E, altitude 1300 m amsl) during 2008, 2009 and 2010. The experiment was carried out inside 3 greenhouses (120 m^2 each, quonset-shape, GI pipe-made, top covered with UV stabilized polythene 200 µ, and side with 25% agro-shed net). Soils of experimental sites were sandy clay loam with pH 5.5, available N 231.5, P 14.8 and K 188.5 kg/ha, respectively. Treatments were consisted of six cropping sequences each with 400% cropping intensity which were evaluated in randomized complete block design and replicated three times. Crop combinations were taken by considering their off-seasonality and market price. Cropping sequences (CS) were; CS1: tomato (*Solanum lycopersicum* L.) – frenchbean (*Phaseolus vulgaris* L.) - coriander (*Coriandrum sativum* L.) - bitter gourd (*Momordica charantia* L.), CS2: capsicum (*Capsicum annum* L.) – carrot (*Daucus carota* L.) – coriander - cucumber (*Cucumis sativus* L.), CS3; tomato - pea (*Pisum sativum* L.) – carrot – cucumber, CS4: pea - broccoli (*Brassica oleracea var. italic* L.) – carrot – cucumber, CS5: pea – coriander –frenchbean - bitter gourd and CS6: pea – tomato – coriander – bitter gourd. The first crop of the cropping sequence was transplanted during February and all crops were grown with organic package of nutrient and pest and disease management. Micrometeorological parameters like air temperatures and relative humidity (RH) inside the polyhouse were recorded with portable weather tracker (Kestrel 4000) and monthly mean weather data were worked out.

The weather data (temperature, humidity and rainfall) of the site were collected from meteorological station located at ICAR Tadong farm. Varieties selected for experimentation were Avinash (tomato), Indra (capsicum), Arka Ajit (pea), Arka Komal (French bean), Indam multicut (coriander), Pusa Kesar (carrot), Arka Harit (bitter gourd), Everest (broccoli) and Snow white (cucumber). During experimentation, a set of plots were maintained in open field to compare the yield advantage of vegetables grown under different cropping sequences inside polyhouse. Seeds and nursery plots were treated with recommended doses of biofertlizers (*Azotobacter* and PSB culture) and *Trichoderma virdi* culture. Vegetables were planted at recommended spacing inside polyhouse and in open field. Input cost and return were calculated as per the prevailing wholesale local market price. While calculating production cost, annual cost of polyhouse was also considered which was worked out by considering initial cost, unacost

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(uniform end of year annual amount) salvage value, life span and floor area and consequently, benefit: cost ratio (BCR) under each cropping sequence was worked out (Tiwari and Goyal 1998). Per day profitability in 100m^2 area was also calculated for better understanding of economic viability of different cropping sequences. Data were subjected to analysis of variance (ANOVA) and Duncan multiple range test (DMRT) at P<0.05 to compare the means of variables on the basis of critical difference (CD) by using SPSS statistical package (11.5 version).

Crop yield and production efficiency of cropping sequences in polyhouse (Table 1) and open condition (Table 2) showed significant difference. Tomato, cucumber and bitter gourd were the major determinants for yield, whereas coriander had the minimum yield potential under both the conditions. Under polyhouse, the highest production (1045.5 kg/100m^2/year) and production efficiency (2.86 kg/100 m^2/day) were recorded in the CS3; tomato-pea-carrot-cucumber followed by CS6; pea-tomato-coriander-cucumber (Table 1). Whereas, pea - coriander - frenchbean - bitter gourd sequence (CS5) gave the lowest cumulative yield (595.0 kg/100m^2/year) and production efficiency (1.63 kg/100 m^2/day). There was no significant difference in production potential of capsicum-carrot-coriander-cucumber (CS2) and pea – broccoli – carrot - cucumber sequences (CS4).

Similar trends of production and production efficiency under different cropping sequences were recorded under open field condition (Table 2), however, yield and production efficiency were approximately half than that of protected condition. The yield advantage under polyhouse condition may be attributed to the prevalence of congenial microclimate in terms of temperature and relative humidity (Fig 1) which might have improved soil moisture status and duration of fruiting. Variation in the microclimate of polyhouse due to the variation of temperature and humidity was also reported by Kumar *et al.* (2009a) and Parvej *et al.* (2010). The findings on enhanced production under protected condition are in agreement with Singh *et al.* (2011) and Cheema *et al*. (2004) who recorded higher yield of vegetables under protected condition. On the other hand, low yield under open field condition in different cropping sequences was due to high soil moisture (Fig 2) and variation in temperature (Fig 1) which might have aggregated disease (late blight and powdery mildew) and pest (fruit/pod borer) incidence in different crops. The rainfall pattern is very important determinants for crop productivity as crop yield under open field condition gets reduced due to very high soil moisture which invites diseases and pests and moreover affect pollen viability. These problems are well addressed under protected cultivation technology. The statement is further strengthened by the

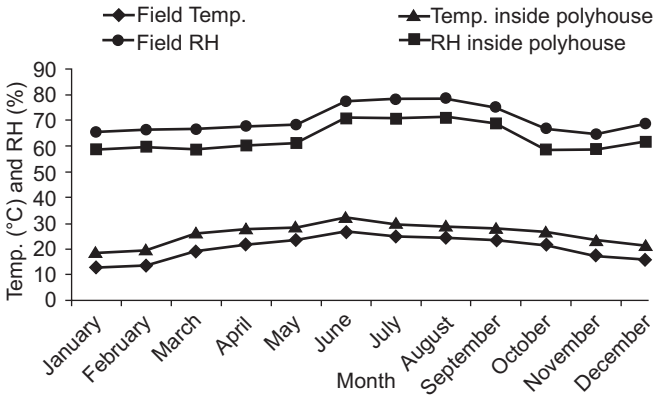

Fig 1 Mean temperature and relative humidity under open field condition and polyhouse

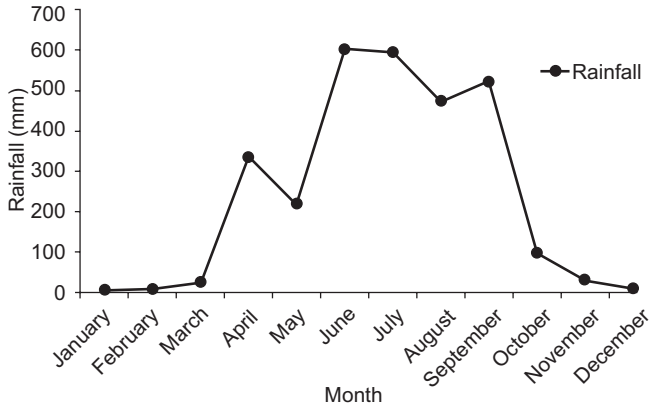

Fig 2 Monthly rainfall at the experimental site

Table 1 Yield and production efficiency of vegetable-based cropping sequence under protected condition

Cropping sequence	Mean yield (kg/100 m^2)				Total production	Production efficiency
	1st crop	2nd crop	3rd crop	4th crop	(kg/100m^2/year)	(kg/100m^2/day)
CS1	350.4	103.5	64.1	288.5	806.5	2.20
CS2	148.3	222.4	56.8	327.4	754.9	2.06
CS3	340.5	119.8	221.1	363.1	1045.5	2.86
CS4	140.6	84.1	210.2	299.9	734.7	2.01
CS5	141.0	60.7	91.6	301.7	595.0	1.63
CS6	143.0	371.6	62.1	284.2	860.9	2.35
CD (*P=0.05*)	4.8	6.4	5.1	4.8	45.8	0.29

Table 2 Yield and production efficiency of vegetable-based cropping sequence under open field condition (poled data of 2008-10)

Cropping sequence	Mean yield (kg/100 m^2)				Total production	Production efficiency
	1st crop	2nd crop	3rd crop	4th crop	(kg/100m^2/year)	(kg/100m^2/day)
CS1	143.6	61.6	44.6	172.0	421.8	1.15
CS2	72.8	136.6	40.8	196.0	446.2	1.22
CS3	137.4	67.3	142.6	205.2	552.5	1.51
CS4	128.2	50.1	125.1	179.4	482.8	1.32
CS5	58.4	40.7	57.1	164.7	320.9	0.88
CS6	72.5	164.1	42.1	170.7	449.4	1.23
CD (*P=0.05*)	5.3	6.2	4.9	3.6	11.6	0.18

findings of Singh *et al.* (2005) who observed high incidence of biotic stress and in turn plant mortality in open field in comparison to protected condition. The highest production efficiency in CS3; tomato – pea – carrot - cucumber sequence was mainly due to high tonnage of tomato, carrot and cucumber, whereas, low yield potential of pea, coriander and french bean resulted lowest production efficiency in pea – coriander - french bean - bitter gourd sequence (Table 1).

Results clearly indicated the variation in the cost of cultivation with crop and growing conditions (Table 3 and 4). Cropping sequence with tomato or capsicum increased the cost of cultivation due to seed cost, while in other cases cost of cultivation was relatively less. Furthermore, owing to the investment involved in polyhouse, production cost increased about 50% under polyhouse than that of open field condition. Returns were significantly influenced by cropping sequence under both the conditions. The highest return (₹ 16 620.9/100m^2/year) was recorded in pea – tomato – coriander - bitter gourd sequence (CS6) followed by tomato - french bean -coriander – cucumber sequence (CS3), while pea – coriander - french bean – bitter gourd sequence (CS5) gave the lowest return (12 121.0 100m^2/year, though return showed variation with year due to the difference in market price, yield and cost of cultivation (Table 3). Benefits under different cropping sequences exhibited similar trend as under return. The highest benefit (13 336.1/100m^2/year) was recorded in pea – tomato – coriander - cucumber sequence (CS6) followed by tomato - frenchbean – coriander - bitter gourd sequence (CS3). The minimum return (9 438/100m^2/year) was recorded in pea – coriander - frenchbean - bitter gourd sequence (CS5). Benefit : cost ratio an important indicator of profitability with respect to production cost, was highest (4.05) in pea – tomato – coriander - bitter gourd (CS6) followed by tomato – pea – carrot – cucumber (CS3), whereas minimum BCR (3.02) was recorded in capsicum – carrot – coriander - cucumber sequence (CS5), however B: C ratio showed variation with year. When day-wise profitability was worked out, it was observed that this parameter followed the trends of BCR with the highest (₹ 36.53/ 100 m^2/day) in pea – tomato - coriander - bitter gourd (CS6) and lowest (₹ 25.30/100 m^2/day) in pea – coriander - frenchbean - bitter gourd sequence (CS5). Date clearly indicated significant influence of cropping sequence on profitability (Table 3). Kumar *et al.* (2009b) evaluated the cropping sequences of vegetables inside polyhouse in the hills of north-western Himalayan region and reported that capsicum – tomato – spinach sequence gave the highest net return and BCR; however, maximum production efficiency was found in squash - - frenchbean – tomato – spinach sequence. Parvej *et al*. (2010) reported high number of flowers, fruit size, fruit weight and fruit yield/plant of tomato inside polyhouse and obtained 42% increase in yield of tomato over open field

Table 3 Cost of cultivation, return, benefit and benefit: cost ratio inside polyhouse (poled data of 2008-10)

Cropping sequence	Cost of cultivation (₹/100m^2/year	Gross return* (₹/100m^2/year)	Net return (₹/100m^2/year)	BCR	Profitability (₹/100m^2/day)
CS1	3270.5	13530.8	10260.3	3.12	28.10
CS2	3209.5	12952.6	9743.1	3.02	26.70
CS3	3316.5	15240.5	11924.2	3.59	32.66
CS4	2946.0	12840.9	9895.2	3.04	27.10
CS5	2883.1	12121.0	9238.0	3.20	25.30
CS6	3285.0	16620.9	13336.1	4.05	36.53
CD (*P=0.05*)	76.4	82.5	854.6	0.21	1.8

*Local market price (₹/q) tomato ₹ 1500, capsicum ₹ 2800, coriander ₹ 5000 cucumber 1000, bitter gourd ₹ 1200, carrot ₹ 1000 pea ₹ 3000/ q, French bean ₹ 1200, broccoli ₹ 2500

Table 4 Cost of cultivation, return, benefit and benefit: cost ratio in open field (Pooled data of 2008-10)

Cropping sequence	Cost of cultivation (₹/100m²/year	Gross return* (₹/100m²/year)	Net return (₹/100m²/year)	BCR	Profitability (₹/100m²/day)
CS1	2344.0	6475.5	4131.5	1.83	11.32
CS2	2244.0	7150.5	4906.5	2.18	13.85
CS3	2348.0	7777.0	5429.0	2.31	14.87
CS4	2032.0	6452.0	4339.5	2.10	11.90
CS5	1883.0	4517.5	2634.5	1.31	7.10
CS6	2388.0	8013.0	5625.0	2.33	15.41
CD (*P=0.05*)	46.5	69.8	72.9	0.19	0.9

*Local market price (₹/q) tomato ₹1500, capsicum ₹ 2800, coriander ₹ 5000 cucumber 1000, bitter gourd ₹ 1200, carrot ₹ 1000, pea ₹ 3000/q, French bean ₹ 1200, broccoli ₹ 2500

condition. Similarly Singh *et al*. (2011), obtained higher return of sweet pepper under polyhouse with minimal problem of bacterial wilt and blossom end rot.

Under field condition the average cost of cultivation was less as compared to polyhouse (Table 4) and varied between ₹ 1 883.0 – 2 388.0. The highest return (₹ 8 013/100 m²/year) and benefit (₹ 5 325.0/100 m²/year) were recorded in pea – tomato – coriander - cucumber sequence (CS6) followed by tomato – pea – carrot - cucumber sequence (CS3) and the lowest return (4 571.5/100m²/year) in pea – coriander - frenchbean - bitter gourd (CS5). The maximum BCR (2.33) was recorded in pea – tomato – coriander - cucumber sequence (CS6) and minimum (1.31) in pea – coriander - french bean - bitter gourd (CS5). Results clearly imply that high return and benefit ensure high BCR; however, cost of cultivation also determines the ratio. Data showed that (Table 4) profitability under open field condition was about 2-3 times less than that of polyhose condition; however maximum profitability (15.41/100m²/day) was recorded in pea – tomato – coriander – bitter gourd sequence and minimum in pea – coriander -frenchbean – bitter gourd (CS5).

SUMMARY

Under protected condition, tomato - pea- carrot - cucumber gave the maximum production production efficiency, return (₹ 13 336.1/100m²), BCR (4.05) and profitability (₹ 36.53/100m²/day). Whereas, pea - coriander - frenchbean – bitter gourd was least profitable. The production cost under polyhouse was about 1.5 times higher than that of open field; however return was about two times higher. Tomato, bitter gourd and cucumber were major determinants for production and profitability. Hence tomato - pea- carrot - cucumber cropping sequence was adjudged the most productive and profitable, which deserves adoption by farmers of mid hills of Himalayan region.

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