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Performance of Vegetable Based Cropping Sequence under INM in Protected Conditions

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted in a naturally ventilated arched saw teeth polyhouse department of vegetable science, faculty of horticulture, BCKV, Kolkata, West Bengal. Vegetable crops were produced in appropriate cropping rotations under integrated nutrient management with acceptable cultural methods in the current study. Four different cropping sequences and five various levels of nutrition supplies were used in the experiment. With four replications, the experiment was set up in a Split plot design. Plant height [at first harvesting], number of leaves, number of primary branches, days required for first harvesting, fruit yield per plant and yield per square metre of component crops did not show any significant variation over the two-year cropping cycle, but observed a gradual improvement in consecutive years of cropping. All growth and reproductive characters of component crops in the cropping sequence differed statistically from the first to the second year cropping under the influence of different levels of combined nutrient management, with the highest values for these characters obtained under L1 (100 percent Recommended dose of fertilizer (R.D.) through inorganic source), but results are statistically comparable to L2 (application of 50 percent R.D. of NPK + Vermicompost) and L3 (application of

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50 percent R.D of NPK + FYM). However, there was no substantial variation in growth and yield parameters when cropping sequence and nutrient management were combined. It can be concluded Supplementation of organic fertilisers along suitable cropping sequences with short duration vegetable crops would be beneficial for long term soil fertility and crop vigour point of view.

Keywords: Cropping sequence; polyhouse; growth; yield, quality attributes; fertilizers; vegetables.

1. INTRODUCTION

Because of the drastic reduction in per capita land holdings owing to overpopulation, productivity must be increased vertically utilizing short-duration crops and rigorous input management is used to boost production and raise land use efficiency. In light of these issues, crop diversity is a viable strategy for accomplishing the goals of food security, poverty reduction, and long-term agricultural growth. To raise the agriculture sector's growth rate, cropping patterns must be diversified to include high-value crops, with a focus on short-duration vegetables that have the potential to increase production. To meet the following requirements, commercial vegetable crops might be included in the cropping sequence. Vegetable crops can also be cultivated on a small plot of land, and their inclusion in cropping systems can help restore the soil's nutritional potential, as vegetables are high in vitamins, minerals, and other health aspects, as well as provide a viable market for output. Vegetable crops are emerging as the most important horticulture crops in both domestic and international markets. India has made amazing progress in vegetable farming during the last few decades, contributing 14 percent of global vegetable production.

With an annual production of 175.008 million tonnes from a land area of 10.29 million ha, India remains the world's second largest producer of vegetables [1]. To satisfy the nutritional needs of an estimated 1200 million people by 2020 [2], our vegetable consumption has climbed to almost 220 million tonnes per year. However, substantial quantities of vegetables are still necessary to feed the rapidly growing population. Producing high-quality vegetables in the off-season by using a proper cropping sequence in a greenhouse allows for more efficient land management and improved productivity per unit area and time. The right cropping sequences of the vegetables may be playing a vital part in maximising the available space within the polyhouse [3]. The natural environment is adjusted in a protected setting to create ideal circumstances for plant growth, resulting in higher yields and improved crop quality, as well as higher returns, especially during the off-season. Cropping system refers to the type and sequence of crops cultivated on a certain piece of land over time. Cropping system represents the philosophy of greatest crop yield per unit area of land within a calendar year with minimal soil deterioration in vegetable crops competitions. Vegetable crops have a higher benefit-to-cost ratio and economic returns. Vegetables are usually followed by field crops, particularly pulses and cereals, although there are no specialized vegetable cropping sequences accessible under protected conditions. Crop diversification is an excellent approach for ensuring long-term crop production, but it is limited if it is not supported by family, roots depth, feeding habit, crop duration, commercial relevance, and local meteorological conditions. With respect to cropping sequence, there is room for a location-specific study on economic returns, output potential, variable costs, and soil fertility maintenance. In intensive cropping systems, the continuous and unbalanced use of chemical fertilisers has resulted in a loss in soil health and a drop in factor production [4].

The INM's core principle is to preserve soil fertility for long-term agricultural output while also lowering fertilizer input costs. Chemical fertilisers, organic manures, agricultural residues, and nitrogen-fixing crops such as pulses, grams, and other legumes are all used in the process. A well-thought-out integrated plant nutrient strategy, complete with balanced fertilizer and organic manure dosages, is a must for long-term crop performance and soil fertility restoration. Organic (FYM, vermicompost, chicken manure, and green manure) nutrients will be critical in the future decade for lowering fertilizer costs, supplementing nutrients, and sustaining soil health and eco-system stability for long-term crop productivity. According to Karchoo and Dixit [5], incorporating organics, particularly crop residues, enhances crop production, nutrient uptake, soil physicochemical and biological qualities, and provides a better environment for growth and development. One of the prerequisites of sustainable agriculture is the preservation of soil qualities as well as yield.

However, systemic study findings on cropping sequences involving the integration of organic and inorganic sources of plant nutrients in vegetables, particularly in protected conditions, are limited. Vegetable-based cropping systems in protected environments must prioritise the production of high-quality vegetables at a profit. Vegetable production under protected conditions is a new rising trend in West Bengal's plains for profitable market, although little research has been done on vegetable-based cropping sequences under cover. The majority of farmers are unaware of the importance of including suitable vegetables in cropping sequences.

1.1 Objectives of the Study

The main objective of the study is to standardize an effective cropping sequence with respect to productivity under polyhouse conditions. Meanwhile, the study was also focused on best combination of organic and inorganic sources of nutrients.

2. MATERIALS AND METHODS

The present experiment was conducted for two years at the main campus, Faculty of Horticulture, Bidhan Chandra Krishi Viswa Vidyalaya, Mohanpur, Nadia, West Bengal, in a naturally ventilated arched saw teeth type polyhouse. The experimental site is located at 23.50N latitude and 800E longitude, with an average elevation of 9.75m above mean sea level (MSL). The experimental site's topography falls inside West Bengal's Gangetic New Alluvial Plains. Before laying out the experiment, a composite sample of soil from 0 to 30 cm in depth was gathered at random from the field in twenty different locations. The soil samples were completely mixed, dried, and mechanical and chemical analysis was performed on them. The trial site is located in a warm, humid subtropical climate slightly south of the cancer tropic. As shown in the Table (2) Spring-Summer season (mid-February to mid-June); Summer-Rainy season (mid-June to mid-October); and Autumn-Winter season (mid-November to mid-December) were chosen as right time to grow various vegetable crops. During the summer, the average temperature is 25.9-36.50°C, and during the winter, the average temperature is 12-25°C, with an average rainfall of 1500 mm (Table-4&5). The attempt was performed by various vegetable sequences inside a polyhouse environment, in order to provide a diversity of vegetables to users throughout the year without affecting soil qualities by following appropriate cropping sequences. Different commercial vegetable crops were grown in sequences based on the family, rooting depth and feeding habit (Table - 1). The mentioned sequences were allotted with various combinations of organic and inorganic nutrients with acceptable cultural methods in the current study. As mentioned in Table (3) Four different Cropping Sequences and five various levels of nutrient sources, as well as their combinations, were used in the experiment. With four replications, the experiment was set up in a split pot design. During the statistical analysis, the cropping sequences were used as the main plot treatment and the degrees of plant nutrient delivery as the sub-plot treatment.

Table 1. Selection criteria of component crops with respect to particular sequence

Sequence	Character	Component crops		
Sequence 1		Palak →	Early Cauliflower →	Capsicum
	Family	Chenopodiaceae	Brassicaceae	Solanaceae
	Rooting depth	shallow	shallow	medium
	Feeding habit	light	medium	Heavy
Sequence 2		Coriander →	Cabbage →	Tomato
	Family	Apiaceae	Brassicaceae	Solanaceae
	Rooting depth	shallow	shallow	medium
	Feeding habit	light	medium	Heavy
Sequence 3		Tomato →	Palak →	Cucumber
	Family	Solanaceae	Chenopodiaceae	Cucurbitaceae
	Rooting depth	medium	shallow	Medium
	Feeding habit	Heavy	light	Medium
Sequence 4		Tomato →	Coriander →	Broccoli
	Family	Solanaceae	Apiaceae	Brassicaceae
	Rooting depth	medium	shallow	shallow
	Feeding habit	Heavy	light	medium

Table 2. Allotment of crops in Cropping sequences for different cropping seasons

Sequence	Seasons of sowing of component crops		
	Feb-March	**June-July**	**Oct-Nov**
S 1	Palak	Early cauliflower	Capsicum
S 2	Coriander	Cabbage	Tomato
S 3	Tomato	Palak	Cucumber
S 4	Tomato	Coriander	Broccoli

Table 3. The experiment's main details in terms of cropping sequence under various combinations of organic and inorganic fertilizers

Combination of nutrient level with sequence	Feb- March (Spring- Summer)				June-July (Summer- Rainy)				Oct-Nov (Autumn- Winter)			
	Component crops 1				Component crops 2				Component crops 3			
SD1	RDF through inorganic source (gm/plot)				RDF through inorganic source (gm/plot)				RDF through inorganic source (gm/plot)			
	Urea	SSP	MOP		Urea	SSP	MOP		Urea	SSP	MOP	
	RDF	RDF	RDF		RDF	RDF	RDF		RDF	RDF	RDF	
SD2	RDF through inorganic source (gm/plot) + VC (kg/plot)				RDF through inorganic source (gm/plot) + VC (kg/plot)				RDF through inorganic source (gm/plot) + VC (kg/plot)			
	Urea	SSP	MOP	VC	Urea	SSP	MOP	VC	Urea	SSP	MOP	VC
	50% RDF	50% RDF	50% RDF	1kg/ sq.m	50% RDF	50% RDF	50% RDF	1kg/ sq.m	50% RDF	50% RDF	50% RDF	1kg/ sq.m
SD3	RDF through inorganic source (gm/plot) + FYM (kg/plot)				RDF through inorganic source (gm/plot) + FYM (kg/plot)				RDF through inorganic source (gm/plot) + FYM (kg/plot)			
	Urea	SSP	MOP	FYM	Urea	SSP	MOP	FYM	Urea	SSP	MOP	FYM
	50% RDF	50% RDF	50% RDF	2.5 kg/ sq.m	50% RDF	50% RDF	50% RDF	2.5 kg/ sq.m	50% RDF	50% RDF	50% RDF	2.5 kg/ sq.m
SD4	RDF through inorganic source (gm/plot) + PM (kg/plot)				RDF through inorganic source (gm/plot) + PM (kg/plot)				RDF through inorganic source (gm/plot) + PM (kg/plot)			
	Urea	SSP	MOP	PM	Urea	SSP	MOP	PM	Urea	SSP	MOP	PM
	50% RDF	50% RDF	50% RDF	1kg/ sq.m	50% RDF	50% RDF	50% RDF	1kg/ sq.m	50% RDF	50% RDF	50% RDF	1kg/ sq.m
SD5	RDF through organic sources VC + FYM + PM (kg/plot)				RDF through organic sources VC + FYM + PM (kg/plot)				RDF through organic sources VC + FYM + PM (kg/plot)			
	VC	FYM	PM		VC	FYM	PM		VC	FYM	PM	
	0.5 kg/ sq.m	1.25 kg/ sq.m	0.5 kg/ sq.m		0.5 kg/ sq.m	1.25 kg/ sq.m	0.5 kg/ sq.m		0.5 kg/ sq.m	1.25 kg/ sq.m	0.5 kg/ sq.m	

2.1 Integrated Nutrient Management Levels (L)

Level -1 : 100% RDF of NPK through chemical sources
Level- 2 :50% RDF of NPK through chemical sources + Vermicompost 1kg /sq. m
Level- 3 : 50% RDF of NPK through chemical sources + FYM 2.5 kg /sq. m
Level- 4 : 50% RDF of NPK through chemical sources + Poultry manure 1kg /sq. m
Level- 5 : (Vermicompost0.5 kg/sq. m + FYM 1.25 kg/ sq. m + Poultry manure 0.5 kg/sq. m)

2.2 The Source of Nutrients of Different Organic and Inorganic Fertilizers –

- ✓ Inorganic source of Nitrogen – Urea
- ✓ Inorganic source of Phosphorus – Single super phosphate (SSP)
- ✓ Inorganic source of Potassium – Muriate of potash (MOP)
- ✓ Organic manure- Farm yard manure (FYM), Poultry manure and Vermicompost

2.3 Agronomic Practices

The experimental site's land was thoroughly prepared by ploughing multiple times to bring the soil to a fine tilth. The dirt was then pulverized to loosen it up and make it more friable. The area was left in the sun for a few days to eliminate any dangerous microorganisms or insect larvae that may have been present in the soil. Weeds, stubbles, and roots, among other things, were eliminated. The field was levelled and divided into plots by irrigation channels according to the treatments in each trial (Table 3).

According to general seed recommendations, the required amount of tomato, capsicum, cauliflower, cabbage, and broccoli seeds were sown first in the nursery, and then seedlings were transplanted to the main field in accordance with the crops and growing season, while maintaining the recommended spacing. In tests, the recommended doses of organic and inorganic sources of nutrients were used (Table 3). During the initial field application, the organic fertilisers FYM vermicompost and poultry manure were used. The first dose of nitrogen was applied as a basal treatment, and the second dose was applied 30 days following planting.As a basal dose, the complete phosphorus and potash dose was applied at the time of sowing. Light watering was applied immediately after fertilisers and vermicompost were added. Following that, irrigation was applied as needed by the crops during the growing season. Other cultural practices were followed in each experiment according to the standard and suggested packages of practices for each crop. All of the crops were harvested when they were fully mature and marketable. Throughout the experiment, observations were made on several personalities.

The data on growth characters, flowering, yield attributes, quality parameters, and plant tissue nutrient status of the component crops, as well as soil nutrient status, was statistically examined using the analysis of variation method and MSTAT software over the experimentation period. The 'F' and't' tests were used to make inferences at a 5% level of significance (Chandel, 1978). For comparison and comprehension, the mean results were expressed in tabular form with critical differences (C.D.). Land use efficiency, production efficiency, and the benefit-to-cost (B: C) ratio, on the other hand, have all been presented as such.

3. RESULTS AND DISCUSSION

3.1 Influence of Cropping Sequene

3.1.1 Growth parametrs of component crops

During two years of cropping cycle in vegetable-based cropping sequence under protected structure, the influence of cropping sequence on

Table 4. Weather data collected during the experiment's cropping cycle (2016-17)

Month	Temperature (^{0}C)		Relative Humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
February	29.8	16.05	98	56.96	3.73
March	33.21	19.58	93.12	51.45	0.85
April	38.21	23.73	89.9	48.33	0.11
May	35.35	22.61	91.35	65.22	5.44
June	34.54	23.91	93.56	74.2	5.36
July	32.37	24.16	96.41	87.06	12.86
August	32.62	24.14	96.38	82.22	13.93
September	33.53	24.16	93.7	78.46	4.04
October	32.29	21.63	94.41	68.54	5.39
November	36.83	15.33	92.9	58.16	0.57
December	26.24	10.9	96.77	57.7	0
January	25.4	8.54	96.32	46.51	0

Source: Department of Agricultural Meteorology and Physics, BCKV, Mohanpur

Table 5. Weather data collected during the experiment's cropping cycle (2017-18)

Month	Temperature (^{0}C)		Relative Humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
February	29.48	12.61	92.25	42.6	0
March	32.39	17.63	92.09	48.8	0.61
April	35.32	22.9	90.63	56.6	0.33
May	35.62	22.84	88.58	60.22	5.63
June	35.12	23.68	91.75	72	8.15
July	31.49	23.7	96.86	85.77	14.87
August	32.55	23.64	96.03	79.64	7.49
September	33.04	23.6	97.26	73.4	11.94
October	30.6	21.41	98	74.74	6.28
November	28.64	14.76	96.96	57.9	1.47
December	25.57	11.49	97.22	65.16	0.86
January	23.34	8.09	97.19	51.8	0

Source: Department of Agricultural Meteorology and Physics, BCKV, Mohanpu

growth characters such as plant height [at first harvesting], number of leaves, and number of primary branches per plant of component crops had no significant variation (Tables 6 & 7). This could be attributed to differences in soil physico-chemical characteristics and environmental conditions throughout these two cropping seasons. However, under the influence of cropping sequence, these features varied dramatically from the first to the second year of cropping. The improvement in component crop performance during the second year could be attributable to a long-term cropping sequence with crops with diverse rooting behavior, feeding habits, and life cycle lengths, which could have resulted in the soil maintaining its nutrient status. Noor et al. [7] found similar results from a field experiment on a tomato-okra-Indian spinach cropping pattern using a combination of chemical fertilisers and organic manures.

3.1.2 Reproductive parameters of component crops

The data in tables 8, 9, and 10 show that reproductive attributes, such as days to first harvest, yield per plant, and yield per square metre of component crops, did not show significant variation from the first to the second-year cropping cycle in vegetable-based cropping sequences, but that there was a gradual improvement from the first to the second-year cropping cycle. As a result of this finding, it can be concluded that farming the same vegetables in the same order for two consecutive years had no significant effect on the component crops' yield attributes. However, with the addition of vegetables as a component crop, the cropping sequence might be considered as a significant element in influencing production qualities in long-term research, as they belong to various families and have distinct feeding habits.

3.2 Influence of Integrated Nutrient Management

3.2.1 Growth parameters of component crops

Under the influence of different levels of combined nutrient management, all growth attributes of the component crops in the cropping sequence, such as plant height [at first harvesting], number of leaves per plant, and number of primary branches, differed statistically from first to second year cropping (Table-6 and 7). Plants applied with 100 percent Recommended dose of fertilizer (RDF) through inorganic source (L1) had the highest values for these characters, which differed significantly from plants applied with 50 percent R.D. of NPK+ FYM @ 2.50 kg sq m-1 (L3); 50 percent R.D. of NPK+ Poultry manure @ 1.00 kg sq m-1 (L4) and Vermicompost @ 0.50 kg sq m-1 + FYM @ 1.25 kg sq (L5).The fact that inorganic sources of nutrients provided more readily available nitrogen, which stimulated the growth of vegetative characters from the start, may account for the highest value of results for these characters under L1. However, the values obtained for these characters using a 50 percent R.D. of NPK + Vermicompost @ 1.00 kg. sq m -1 (L2) application were statistically comparable to the values obtained using L1. Palak performed better under integrated nutrient management (sewage sludge + inorganic fertilizer) than under solitary application of organic amendments, according to Roy et al. [8]. Sangeeta Shree et al. [9] and Tekasangla et al. [10] both reported increased cauliflower yields when organic and inorganic plant nutrients were used in tandem.

Table 6. Growth parameters of component crops in a vegetable based cropping sequence with integrated nutrient management under protected structures

Parameter/ Nutrient Level	Vegetable Based Cropping Sequence (Growth Parameters)																							
	Growth Parameters - Plant height (cm)																							
	Sequence1						Sequence 2						Sequence 3						Sequence 4					
	Palak		Early Cauliflower		Capsicum		Coriander		Cabbage		Tomato		Tomato		Palak		Cucumber		Tomato		Coriander		Broccoli	
L/Y	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**
L1	28.25	28.08	62.20	62.11	74.88	74.62	31.83	31.74	26.44	26.40	116.44	116.04	113.40	113.83	26.00	26.00	232.10	232.05	110.23	110.13	28.44	28.36	48.96	48.96
L2	27.13	27.52	61.88	61.95	72.43	72.88	31.38	31.42	26.06	26.06	113.65	113.77	109.30	109.76	25.00	25.15	225.78	226.15	106.49	106.55	28.01	28.05	47.46	47.50
L3	25.88	26.75	60.43	60.55	71.47	71.70	29.73	29.79	25.25	25.34	109.64	109.80	106.03	106.23	24.13	24.18	214.88	215.30	104.02	104.08	27.58	27.64	45.95	45.98
L4	26.25	27.25	61.85	61.85	72.02	72.28	30.09	30.11	25.74	25.76	112.78	112.91	111.15	111.28	24.50	24.63	219.65	219.80	106.29	106.31	27.88	27.90	46.85	46.87
L5	23.88	25.25	57.25	57.98	69.65	70.10	28.19	28.28	25.00	25.10	106.18	106.96	104.65	104.98	22.63	22.70	208.20	208.83	101.60	101.71	27.09	27.18	44.98	45.11
Mean																								
Test of Significance	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em . (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05
Year (Y)	0.190	N.S.	0.335	N.S.	0.568	N.S.	0.328	N.S.	0.100	N.S.	0.746	N.S.	1.118	N.S.	0.173	N.S.	0.259	N.S.	1.773	N.S.	0.095	N.S.	0.175	N.S.
Nutrient Level (L)	0.374	1.099	0.453	1.331	0.511	1.501	0.464	1.362	0.108	0.318	0.980	2.878	1.517	4.453	0.424	1.245	0.848	2.489	3.070	1.045	0.120	0.352	0.412	1.209
Y X L	0.425	1.681	0.749	2.164	1.270	N.S.	0.734	N.S.	0.223	0.542	1.668	N.S.	2.500	N.S.	0.388	N.S.	0.578	3.634	0.850	N.S.	0.213	N.S.	0.392	N.S.
LXY	0.510	1.621	0.664	2.241	0.860	N.S.	0.672	N.S.	0.170	0.600	1.447	N.S.	2.220	N.S.	0.564	N.S.	1.103	3.343	1.376	N.S.	0.179	N.S.	0.549	N.S.

Explanations: Sequence (1) =palak-early cauliflower-capsicum, Sequence (2) =coriander-cabbage-tomato, Sequence (3) =tomato-palak-cucumber, Sequence (4) =tomato-coriander-broccoli, Level (1) = 100% Recommended dose of NPK (inorganic fertilizers), Level (2) = 50% Recommended dose of NPK + Vermicompost@ 1.00 kg sqm-1, Level (3) = 50% Recommended dose of NPK+ FYM @ 2.50 kg sqm-1, Level (4) = 50% Recommended dose of NPK+ Poultry manure @ 1.00 kg sqm-1, Level (5) = Vermicompost@ 0.50 kg sqm-1 + FYM@ 1.25kg sqm-1 + Poultry manure @ 0.50 kg sqm-1, Sequence X Level(S X L) = Influence of L (nutrient level) for fixed cropping sequence (S), SequenceX Level (L X S) = Influence of S (cropping sequence) at a particular nutrient level (L)

Table 7. Growth parameters of component crops in a vegetable based cropping sequence with integrated nutrient management under protected structures

Parameter/ Nutrient Level	**Vegetable Based Cropping Sequence**																							
	Growth Parameters – Number of leaves & Number of primary branches																							
	Sequence1						**Sequence 2**						**Sequence 3**						**Sequence 4**					
	Palak		**Early Cauliflower**		**Capsicum**		**Coriander**		**Cabbage**		**Tomato**		**Tomato**		**Palak**		**Cucumber**		**Tomato**		**Coriander**		**Broccoli**	
	No. of Leaves		**No. of Leaves**		**No. of Primary branches**		**No. of Primary branches**		**No. of Leaves**		**No. of Primary branches**		**No. of Primary branches**		**No. of Leaves**		**No. of Primary branches**		**No. of Primary branches**		**No. of Primary branches**		**No. of Leaves**	
L/Y	**2016-17**	**2016-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**
L1	8.62	8.50	18.75	18.73	4.20	4.18	4.67	4.64	18.06	18.04	8.60	8.57	8.52	8.55	7.72	7.63	5.00	4.98	8.50	8.48	4.47	4.46	21.55	21.51
L2	8.25	8.47	18.68	18.73	4.05	4.05	4.53	4.57	17.79	17.85	8.38	8.43	8.24	8.30	7.50	7.56	4.85	4.90	8.23	8.24	4.35	4.38	20.61	20.92
L3	7.63	7.80	17.98	18.09	4.00	4.03	4.30	4.31	17.25	17.29	8.31	8.38	8.19	8.25	6.88	6.88	4.65	4.71	8.19	8.21	4.16	4.16	19.49	19.49
L4	7.95	8.18	18.53	18.63	4.03	4.03	4.44	4.48	17.56	17.60	8.37	8.41	8.32	8.36	7.14	7.15	4.80	4.83	8.29	8.32	4.26	4.28	20.00	20.03
L5	7.02	7.25	16.58	16.98	3.88	3.95	4.25	4.35	17.02	17.12	8.11	8.18	7.94	7.99	6.48	6.60	4.55	4.63	7.91	7.96	4.10	4.14	18.99	19.13
Mean																								
Test of Significance	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05
Year (Y)	0.015	0.071	0.154	N.S.	0.069	N.S	0.007	0.028	0.251	N.S.	0.009	0.039	0.011	0.049	0.029	N.S.	0.005	0.023	0.019	N.S.	0.025	N.S.	0.126	N.S.
Nutrient Level (L)	0.148	0.434	0.199	0.584	0.076	N.S	0.019	0.056	0.367	N.S.	0.027	0.078	0.054	0.158	0.131	0.384	0.046	0.134	0.037	0.108	0.031	0.091	0.164	0.480
Y X L	0.161	0.617	0.344	0.958	0.155	N.S	0.015	0.083	0.561	N.S.	0.039	0.124	0.057	0.240	0.064	N.S.	0.077	N.S.	0.044	0.166	0.056	0.151	0.283	0.788
LXY	0.188	0.553	0.295	1.005	0.118	N.S	0.025	0.077	0.528	N.S.	0.038	0.125	0.073	0.229	0.168	N.S.	0.067	N.S.	0.051	0.161	0.047	0.161	0.242	0.826

Explanations: Sequence (1) = palak-early cauliflower-capsicum, Sequence (2) = coriander-cabbage-tomato, Sequence (3) = tomato-palak-cucumber, Sequence (4) = tomato-coriander-broccoli, Level (1) = 100% Recommended dose of NPK (inorganic fertilizers), Level (2) = 50% Recommended dose of NPK + Vermicompost@ 1.00 kg sqm-1, Level (3) = 50% Recommended dose of NPK+ FYM @ 2.50 kg sqm-1, Level (4) = 50% Recommended dose of NPK+ Poultry manure @ 1.00 kg sqm-1, Level (5) = Vermicompost@ 0.50 kgsqm-1 + FYM@ 1.25kg sqm-1 + Poultry manure @ 0.50 kg sqm-1, Sequence X Level (S X L) = Influence of L (nutrient level) for fixed cropping sequence (S), Sequence X Level (L X S) = Influence of S (cropping sequence) at a particular nutrient level (L)

Table 8. Yield parameters of component crops in a vegetable based cropping sequence with integrated nutrient management under protected structures

Parameter/ Nutrient Level	Vegetable Based Cropping Sequence																							
	Yield parameters – Days required for 1st harvest																							
	Sequence1						Sequence 2						Sequence 3						Sequence 4					
	Palak		Early Cauliflower		Capsicum		Coriander		Cabbage		Tomato		Tomato		Palak		Cucumber		Tomato		Coriander		Broccoli	
	Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting		Days required for harvesting	
L/Y	**2016-17**	**2016-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**
L1	28.44	28.36	64.20	64.55	89.90	89.93	41.08	41.14	67.38	67.44	58.14	58.23	55.13	55.35	31.83	31.74	50.93	50.96	55.19	55.41	40.15	40.25	66.15	66.17
L2	28.01	28.05	61.38	61.33	87.47	87.36	42.59	42.57	65.32	65.28	54.81	54.74	52.43	52.26	31.38	31.42	47.55	47.48	52.53	52.50	41.28	41.27	61.10	61.05
L3	27.58	27.64	61.68	61.68	88.31	88.30	43.18	43.11	66.25	66.25	55.29	55.25	53.70	53.52	29.73	29.79	48.79	48.69	53.79	53.77	41.79	41.75	63.41	63.45
L4	27.88	27.90	61.25	61.21	87.67	87.50	42.77	42.74	65.63	65.60	53.84	53.72	51.80	51.57	30.09	30.11	48.51	48.43	51.95	51.90	41.47	41.45	61.72	61.75
L5	27.09	27.18	58.63	58.13	85.41	85.41	44.47	44.32	64.91	64.77	51.85	51.71	50.38	50.21	28.19	28.28	47.20	47.13	50.56	50.35	43.40	43.31	60.50	60.37
Mean																								
Test of Significance	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05
Year (Y)	0.095	N.S.	0.365	N.S.	0.292	N.S.	0.211	N.S.	0.184	N.S.	0.496	N.S.	0.130	0.607	0.328	N.S.	0.509	N.S.	0.255	N.S.	0.267	N.S.	0.120	N.S.
Nutrient Level (L)	0.120	0.352	0.390	1.145	0.245	0.718	0.437	1.283	0.270	0.792	0.345	1.013	0.337	0.990	0.464	1.362	0.318	0.933	0.387	1.138	0.366	1.075	0.380	1.115
Y X L	0.213	N.S.	0.816	1.956	0.653	1.297	0.472	N.S.	0.412	N.S.	1.109	1.908	0.291	1.470	0.734	N.S.	1.138	1.797	0.571	N.S.	0.597	N.S.	0.268	1.631
LXY	0.179	N.S.	0.614	2.177	0.425	1.595	0.592	N.S.	0.388	N.S.	0.661	2.582	0.446	1.375	0.672	N.S.	0.648	2.593	0.553	N.S.	0.535	N.S.	0.495	1.503

Explanations: Sequence (1) = palak-early cauliflower-capsicum, Sequence (2) = coriander-cabbage-tomato, Sequence (3) = tomato-palak-cucumber, Sequence (4) = tomato-coriander-broccoli, Level (1) = 100% Recommended dose of NPK (inorganic fertilizers), Level (2) = 50% Recommended dose of NPK + Vermicompost@ 1.00 kg sqm-1, Level (3) = 50% Recommended dose of NPK+ FYM @ 2.50 kg sqm-1, Level (4) = 50% Recommended dose of NPK+ Poultry manure @ 1.00 kg sqm-1, Level (5) = Vermicompost@ 0.50 kg sqm-1 + FYM@ 1.25kg sqm-1 + Poultry manure @ 0.50 kg sqm-1, Sequence X Level (S X L) = Influence of L (nutrient level) for fixed cropping sequence (S), Sequence X Level (L X S) = Influence of S (cropping sequence) at a particular nutrient level (L)

Table 9.Yield parameters of component crops in a vegetable based cropping sequence with integrated nutrient management under protected structures

Parameter/ Nutrient Level	Vegetable Based Cropping Sequence																							
	Yield parameters – Fruit yield /plant																							
	Sequence1						Sequence 2						Sequence 3						Sequence 4					
	Palak		Early Cauliflower		Capsicum		Coriander		Cabbage		Tomato		Tomato		Palak		Cucumber		Tomato		Coriander		Broccoli	
	Leaf yield gm/plant		Curd yield gm/plant		Fruit yield gm/plant		Leaf yield gm/plant		Head yield kg/plant		Fruit yield kg/plant		Fruit yield kg/plant		Leaf yield gm/plant		Fruit yield kg/plant		Fruit yield		Leaf yield		Head yield	
L/Y	2016-17	2016-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
L1	43.01	42.85	270.60	267.26	54.42	54.25	15.30	15.09	1.03	1.02	2.58	2.58	2.44	2.43	39.13	39.10	2.74	2.73	2.36	2.26	14.96	14.91	275.58	274.25
L2	42.58	42.77	334.40	335.55	58.39	58.91	15.03	15.10	1.18	1.18	3.01	3.02	2.73	2.74	38.83	38.92	3.68	3.69	2.49	2.54	14.67	14.70	345.20	348.38
L3	38.85	38.88	329.63	330.90	57.42	57.46	14.37	14.42	1.12	1.14	2.81	2.81	2.59	2.60	35.58	35.63	3.24	3.26	2.41	2.41	14.18	14.22	323.38	325.23
L4	40.03	40.39	331.26	331.86	58.24	58.50	14.89	14.88	1.16	1.17	2.90	2.91	2.67	2.67	36.78	36.85	3.47	3.48	2.39	2.55	14.49	14.51	333.98	336.43
L5	36.79	37.75	296.35	298.85	56.18	56.83	13.92	14.07	1.11	1.13	2.71	2.72	2.55	2.58	33.94	34.08	2.93	2.95	2.35	2.36	13.54	13.62	302.83	308.15
Mean																								
Test of Significance	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05
Year (Y)	0.461	N.S.	0.408	N.S.	0.372	N.S.	0.069	N.S.	0.002	0.010	0.006	N.S.	0.009	N.S.	0.206	N.S.	0.037	N.S.	0.015	N.S.	0.080	N.S.	1.179	N.S.
Nutrient Level (L)	0.399	1.171	0.932	2.738	0.519	1.524	0.114	0.335	0.004	0.011	0.013	0.039	0.020	0.058	0.250	0.735	0.061	0.180	0.020	0.060	0.177	0.519	1.893	5.559
Y X L	1.031	2.099	0.913	4.115	0.833	2.463	0.153	0.525	0.005	0.017	0.013	0.058	0.020	0.088	0.460	1.221	0.082	0.282	0.033	0.097	0.178	N.S.	2.636	8.763
LXY	0.683	2.544	1.248	3.895	0.755	2.533	0.160	0.520	0.005	0.017	0.018	0.056	0.027	0.083	0.378	1.302	0.086	0.279	0.030	0.100	0.237	N.S.	2.669	8.736

Explanations: Sequence (1) = palak-early cauliflower-capsicum, Sequence (2) = coriander-cabbage-tomato, Sequence (3) = tomato-palak-cucumber, Sequence (4) = tomato-coriander-broccoli, Level (1) = 100% Recommended dose of NPK (inorganic fertilizers), Level (2) = 50% Recommended dose of NPK + Vermicompost@ 1.00 kg sqm-1, Level (3) = 50% Recommended dose of NPK+ FYM @ 2.50 kg sqm-1, Level (4) = 50% Recommended dose of NPK+ Poultry manure @ 1.00 kg sqm-1, Level (5) = Vermicompost@ 0.50 kg sqm-1 + FYM@ 1.25kg sqm-1 + Poultry manure @ 0.50 kg sqm-1, Sequence X Level (S X L) = Influence of L (nutrient level) for fixed cropping sequence (S), Sequence X Level (L X S) = Influence of S (cropping sequence) at a particular nutrient level (L)

Table 10. Yield parameters of component crops in a vegetable based cropping sequence with integrated nutrient management under protected structures

Parameter/ Nutrient Level	Vegetable Based Cropping Sequence																							
	Yield parameters - yield kg / Sq. m																							
	Sequence1						Sequence 2						Sequence 3						Sequence 4					
	Palak		**Early Cauliflower**		**Capsicum**		**Coriander**		**Cabbage**		**Tomato**		**Tomato**		**Palak**		**Cucumber**		**Tomato**		**Coriander**		**Broccoli**	
L/Y	**2016-17**	**2016-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**	**2016-17**	**2017-18**
L1	1.96	1.95	1.52	1.50	1.61	1.59	0.697	0.687	4.13	4.08	6.19	6.19	5.85	5.83	1.78	1.78	8.23	8.20	5.66	5.42	0.681	0.679	1.54	1.54
L2	1.94	1.95	1.87	1.88	2.14	2.18	0.685	0.688	4.70	4.72	7.23	7.25	6.56	6.58	1.77	1.77	11.05	11.07	5.97	6.09	0.668	0.670	1.93	1.95
L3	1.77	1.77	1.85	1.85	2.07	2.09	0.655	0.657	4.49	4.54	6.74	6.75	6.21	6.23	1.62	1.62	9.73	9.77	5.77	5.78	0.646	0.648	1.81	1.82
L4	1.83	1.84	1.86	1.86	2.11	2.14	0.679	0.678	4.64	4.68	6.96	6.98	6.40	6.42	1.68	1.68	10.41	10.44	5.74	6.13	0.66	0.661	1.87	1.88
L5	1.68	1.72	1.66	1.67	1.80	1.93	0.634	0.641	4.43	4.50	6.51	6.53	6.12	6.19	1.55	1.55	8.79	8.84	5.63	5.65	0.617	0.621	1.70	1.73
Mean																								
Test of Significance	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05	S.Em. (±)	C.D. 0.05
Year (Y)	0.022	N.S.	0.002	N.S.	0.019	N.S.	0.003	N.S.	0.004	0.020	0.015	N.S.	0.022	N.S.	0.009	N.S.	0.109	N.S.	0.036	N.S.	0.003	N.S.	0.007	N.S.
Nutrient Level (L)	0.018	0.053	0.005	0.015	0.046	0.135	0.005	0.015	0.015	0.045	0.032	0.095	0.048	0.142	0.014	0.033	0.184	0.540	0.048	0.142	0.008	0.023	0.011	0.031
Y X L	0.049	0.096	0.005	0.023	0.043	0.201	0.007	0.023	0.019	0.069	0.034	0.144	0..048	0.213	0.021	0.056	0.244	0.845	0.081	0.231	0.008	N.S.	0.015	0.049
LXY	0.032	0.120	0.007	0.022	0.061	0.190	0.007	0.023	0.021	0.068	0.044	0.137	0.065	0.202	0.017	0.059	0.257	0.835	0.071	0.240	0.01	N.S.	0.015	0.049

Explanations: Sequence (1) = palak-early cauliflower-capsicum, Sequence (2) = coriander-cabbage-tomato, Sequence (3) = tomato-palak-cucumber, Sequence (4) = tomato-coriander-broccoli, Level (1) = 100% Recommended dose of NPK (inorganic fertilizers), Level (2) = 50% Recommended dose of NPK + Vermicompost@ 1.00 kg sqm-1, Level (3) = 50% Recommended dose of NPK+ FYM @ 2.50 kg sqm-1, Level (4) = 50% Recommended dose of NPK+ Poultry manure @ 1.00 kg sqm-1, Level (5) = Vermicompost@ 0.50 kg sqm-1 + FYM@ 1.25kg sqm-1 + Poultry manure @ 0.50 kg sqm-1, Sequence X Level (S X L) = Influence of L (nutrient level) for fixed cropping sequence (S), Sequence X Level (L X S) = Influence of S (cropping sequence) at a particular nutrient level (L)

3.2.2 Reproductive parameters of component crops

From one nutrient treatment level to the next, the yield attributing features of component crops in a vegetable-based cropping sequence showed significant variance (Table-8,9 and 10). Under the L1 type of nutrient application level (where nutrients were applied as 100 percent R.D.F through inorganic fertilizer), the greatest values for days required for first harvest, yield per plant, and yield per sq. m were obtained. Except for L2, where crops were applied with 50 percent R.D. of NPK + Vermicompost @ 1.00 kg sq. m-1, these results were significantly different from all other integrated nutrient application levels.This result could be due to the plants' more efficient utilization of absorbable nitrogen when an inorganic source of nitrogen is applied alone, or when an inorganic source of nutrients is applied in combination with vermicompost, rather than when fertilisers are mixed with different organic residues. Peyvast et al. [11] also observed similar findings (2008). This result could be explained by the fact that applying organic leftovers to the soil during crop cultivation increased the availability of phosphorus and potassium to the crop, causing yield metrics to accelerate. Tekasangla et al. [10] discovered that using vermicompost, pig manures, and FYM in conjunction with inorganic forms of NPK resulted in greater yield characteristics in vegetable-based cropping sequences.

3.3 Influence of Interaction of Cropping Sequence and Integrated Nutrient Management

3.3.1 Growth parametrs of component crops

Because of the interplay between a vegetable-based cropping sequence and integrated nutrient management systems, all growth characteristics of component crops in a vegetable-based cropping sequence varied dramatically. Plant height (at first harvest), number of leaves per plant, and number of major branches of component crops in a cropping sequence did not create any significant change when cropping sequence and integrated nutrition management were combined (Table-6&7). Plant height [at first harvesting], number of leaves per plant, and number of primary branches of a component crop in cropping sequence, however, all nutrient management levels except L1, which consisted of solitary application inorganic plant nutrients, showed gradual improvement from the first to the second cropping cycle.

3.3.2 Reproductive parameters of component crops

At fixed levels of both of these factors, the interaction of cropping sequence (Y) and integrated nutrient management (L) could not produce significant variation in yield attributing characters such as yield per plant (gm) and yield per m^2 (kg) of component crops in a vegetable-based cropping sequence (Table-8,9&10). Under different nutrient management levels, where plant nutrients were provided in the form of exclusively organic manures or organic manures combined with inorganic sources of plant nutrients, yield attributes improved gradually from the first-year cropping cycle to the second-year cropping cycle. However, in this case, small negative trends were observed when the plants were fed exclusively with inorganic nutrients. This could be due to the fact that the combined use of organic residue with inorganic sources of plant nutrients, as well as a systematic cropping cycle, increased the supply of available plant nutrients in the soil environment, resulting in significant yield improvements in subsequent cropping years.

4. SUMMARY

The performance is determined by the growth and reproductive attributes of component crops in cropping sequence with integrated nutrient management.

4.1 Growth Parameters of Component Crops

In most of the cases growth characters of component crops in the cropping sequence failed to produce any significant variation under the sole influence of cropping sequence. However, general observation reveals a gradual improvement of these parameters during the continuous cropping cycle (i.e. relatively better results obtained during second year compared to that of first year cropping). Nutrient management levels, involving sole and conjugal application of both organic and inorganic sources of plant nutrients, exerted remarkable influences over growth attributes of the component crops. In general, higher values with respect to growth characters were recorded with application of higher proportion of inorganic fertilizers during crop cultivation. On the other hand use of sole organic residues as plant nutrient resulted in maximum reduction in time requirement for reproductive development of the component crops followed by combined application of fertilizers and vermicompost.

The combined influences of cropping sequence and integrated nutrient management could not reveal much recognizable differences for the growth characters of the component crops. However, the general observation of the significant cases shows gradual and considerable improvement of these parameters from first year cropping to the second cropping with combined application of organic and inorganic manures during crop cultivation.

4.2 Reproductive Parameters of Component Crops

Reproductive parameters of the component crops under the individual influence of sequential cropping produced meagre amount of variation which most of the cases did not differ statistically. General observation on simple mathematical analysis of the data gives the impression of slight improvement of yield attributes from first year to second year cropping. The influence of sole and combined application of organic manures and fertilizers resulted significant variation for yield parameters of component crops under the present study. The yield attributes (especially for those crops, where reproductive growth of plants are considered as the economic plant parts) produced comparatively higher values, under crops cultivation with combined application of organic and inorganic manures.

The interaction of cropping sequence and nutrient management levels proved significantly influential over most of the yield parameters of the component crops during two seasons of cropping cycle. Statistically higher values for these parameters had been registered during both the years under combined application of fertilizer and vermicompost or FYM or poultry manure over solitary fertilizer application.

5. CONCLUSION

Growth and yield parameters of the component crops under the individual influence of sequential cropping created a little amount of variance that did not differ statistically in the majority of situations. A general remark based on a simple mathematical examination of the data suggests that yield qualities improved slightly from the first to the second year of cropping. Under the current study, the influence of sole or combined application of organic manures and fertilisers resulted in substantial variation in growth and yield characteristics of component crops. Under crops cultivation with a combined application of 50 percent recommended dose of plant nutrient through fertilizer + Vermicompost @ 1.00 kg sq m-1, the yield attributes (especially for those crops where reproductive growth of plants is considered as the economic plant parts) produced comparatively higher values. The integrated nutrient applications followed, with vermicompost being replaced by poultry manure and FYM, respectively. However, when solo organic residues (Vermicompost @ 0.50 kg sq m-1 + FYM @ 1.25 kg sq m-1 + Poultry manure @ 0.50 kg sq m-1) were used during crop cultivation, consistently improved outcome has shown. During two seasons of the cropping cycle, the interaction between cropping sequence and nutrient management levels had a substantial impact on most of the component crops' growth and yield metrics. Statistically higher values for these parameters were seen in both years when fertilizer and vermicompost or FYM or poultry manure were applied together rather than when fertilizer was applied alone.

6. FUTURE SCOPE OF RESEARCH

Evaluation of more cropping sequences with inclusion of more number of other component crops under poly house condition as per local market demand. Standardization of important location based cropping sequences through long term evaluation, to be the beast suited for protected condition, with special view to maintain environmental quality. Study of vegetable based cropping sequence with over all integration namely, with water management, pest management, weed management etc. under protected condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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