Do post-harvest losses affect the farmers' income? - Post-harvest loss estimation for major vegetables in South India

Abstract

Over the last two decades, India's food system with population surge has been undergoing a transformation with increase in demand for high value fruits and vegetables. However, farmers are not benefitted from these transitions as the post-harvest losses are fairly high due to poorly developed post-harvest management practices. The present study aims to estimate the nature and extent of losses and also analysed the determinants of post-harvest losses for major vegetables (gourds) in South India. Palakkad district of Kerala was chosen for the study as it contributes the most, for the state's vegetable area and production. Multi-stage random sampling techniques were adopted and the vegetables selected were based on their annual production in the study area. The total loss observed in bitter gourd at farm level was about 12.46 percent (34.53 qtl/ha). At trader level, the physiological loss contributed to almost 45 percent of the total losses. Hence, the total loss in bitter gourd was observed to be 21.88 per cent. Likewise in snake gourd, the extent of losses at farm level was found to be 9 percent (26.1 qtl/ha), where the highest losses (4.74 percent) were due to biotic factors like pests and diseases prevailing in the study area. Therefore, the total loss estimated in snake gourd was 13.89 percent which included 4.89 percent loss at trader level. Regression analyses delineated that in bitter gourd, area under cultivation, unfavourable weather conditions, pests and diseases and use of packing materials like jute sacks and wooden baskets were found as major determinants for losses. Whereas, area under cultivation, experience in farming and prevailing pests and diseases in snake gourd were found to affect the volume of post-harvest losses at farm level. The study found that adoption of proper post-harvest handling practices by farmers would help minimizing the losses to a remarkable extent. Besides, analysis of farmers' perception, brought out the fact that the farmers aware of losses incurred only to a limited extent.

Keywords: Post-harvest losses, vegetables, post-harvest handling, perception

1. INTRODUCTION

Vegetables are the excellent sources of vitamins particularly niacin, riboflavin, thiamin, vitamins A and C. They also contain a wide array of potentials and help combating the under-nourishments by providing proteins, carbohydrates and minerals like calcium and iron. They are the cheapest source of natural protective tools and are known as functional foods (ICMR-NIN, 2021). But, in the face of the surge in global agricultural production, 50 percent of the world's population continues to face difficulty in obtaining their daily vegetable portions. This can be attributed to a sizeable percentage of losses and wastages in vegetables (FAO, 1989). Post-

harvest losses of the agricultural commodities were observed higher in the under-developed and developing countries rather than in the developed countries. However in the recent times, efforts are being put-forth by experts from various fields for policy formulations in order to minimize the post-harvest losses at farm level, all along the supply chains of agricultural commodities. To ensure food security globally, these losses should be brought down, as they not only mean the wastage but also wastage of scarce resources used to produce them, human efforts, e*tc.*

1.1 Growth rate analysis of vegetables

Over the last two decades, India's food system with population surge has been undergoing a transformation with increase in demand for high value fruits and vegetables. In response to this demand hike, the area under vegetable cultivation and production in India has shown the increasing trend. Raghuvanshi (2018) studied the growth rates of area, production and productivity for vegetables in Chhattisgarh. He reported that growth rates of area and production and yield of okra, brinjal, tomato and potato have shown positive trend.

Manoj (2014) computed compounded growth rates of area, output and productivity of tomato in Jaipur, using exponential model and found that area under tomato was significant and showed increasing trend (8.32 per cent), whereas the output (-1.89 per cent) and productivity (-9.2 per cent) were found to be non-significant and declining. The overall growth rates in the state showed increasing trends with values 2.58, 2.96 and 0.37 per cent respectively.

1.2 Post-harvest losses

Post-harvest losses can be studied in various aspects that includes products, supply chains, factors involved in causing the damages (Mayienga and Cachia, 2021). These led the authors to adopt the suitable approaches in examining the losses for particular crop/commodities. Theoretically, the losses could be estimated by distinguishing between the initial and final causations and also, the location and times of losses (Bourne, 1977).

Post-harvest losses in vegetables are due to the low shelf-life and perishable nature as they are composed of living tissues. Fruits, vegetables and root crops are much less hardy and are mostly perishable, and hence utmost care should be taken during harvesting, handling and transport, else they will soon decay and become unfit for human consumption (FAO, 1989). Post-harvest loss can be defined as, "change in the availability, edibility, wholesomeness or quality of the food that prevents its consumption" (Troger *et al*., 2007). These losses can be due to pre-harvest factors at farm level and also because of post-harvest management practices such as grading, sorting, packaging, transportation, processing and distribution being performed by farmers and traders. Hodges *et al.* (2011) defined, "Post-harvest food loss as the measurable qualitative and quantitative food loss along the supply chain, starting at the time of harvest till its consumption or other end uses".

1.3 Status of post-harvest losses in Vegetables

1.3.1 Post-harvest losses - World Scenario

WVC (2018) explored that half of the onion produced under went post-harvest losses in Nigeria, due to improper handling and scientific storage. The main reason behind the losses was

lack of grading and sorting of onions before storage. The increased temperature inside the structure promoted bacterial growth and sprouting. Acedo and Easdown (2015) reported on post-harvest losses of vegetables in South-Asian countries. Based on the crops and intermediaries, Bangladesh was found to have average losses of about 11-33 per cent. The loss percentage of vegetables in Nepal accounted around 25-30. Pakistan with 6.1 lakh ha under vegetable cultivation faced losses of 15-40 per cent of total production. The reported losses of vegetables in Afghanistan were half of the total production and even more, due to farmer's unawareness on post-harvest practices. In Bhutan, the extent of post-harvest losses of major vegetables was estimated to be about 20-35 per cent whereas 16-40 per cent of the total vegetables in the country got wasted in Sri Lanka. In all these countries, tomato was estimated to account for the highest losses among vegetables. All of these losses were due to scarcity in post-harvest storage infrastructure facilities, transit issues, *etc.* Also, Alavi *et al.* (2012) consolidated the various post-harvest losses studies of FAO and concluded that Southeast Asia experienced around 10-37 per cent losses in rice value chains and 8-26 per cent in China. UNO in 2011 stated that relying on the different phases of the economic development of global nations, the extent of post-harvest spoilage of agricultural produce differs. Also, these notable losses were found to be in cradling stage of the agri-food chain and consumer levels in the developing and developed nations.

According to the report by World Bank, NRI and FAO (2011), the post-harvest losses in Sub-Saharan Africa valued to 4 billion US dollar annually, but the farmer's earnings were not more than 2 US dollars per day. Rathore *et al.* (2010) reported that UK's annual food consumption is equivalent to the India's annual food wastage. Nellemann and MacDevetter (2009) propounded that for the global nutrition security, post-harvest losses in the produce must be lowered to the possible extent.

1.2.2 Post-harvest losses - Indian Scenario

India with 188.91 million tonnes of vegetable production from 103 lakh hectare of area (GoI, 2020) stands second in the world, next to China. India's fresh exports of vegetables are worth ₹4,383.41 crores, whereas the processed vegetables account for ₹2,760.57 crores (APEDA, 2021). At the same time, India has reported that there is wastage 2 to 23 percent of the fresh vegetables and estimated mean of the losses is around 12 percent from farm to fork (IIHR, 2014). Kumar *et al.* (2004) pointed out that, minimizing the marketing losses would be the only possible means for increased vegetable production in India. Reddy (2004) suggested that, post-harvest wastage must be reduced or even avoided, to supply the vegetables, all round the year in markets. According to ASSOCHAM (2019), India is one of the biggest food wasters in the world, with an estimated spoilage of Rs. 900,000 million worth of fruits, vegetables and grains every year and year-on-year. It pointed-out that, Australia's annual wheat production was found equivalent to India's wheat wastage. Also, India tends to waste more fruits and vegetables than that consumed by the United Kingdom in a year.

1.3 Problem focus

As, post-harvest losses can occur at any stage in the distribution of produce, right from the harvest till they reach the final consumers, the major causes of occurrence of loss can be physical handling, physiological losses and losses due to biotic factors. The physical losses are generally quantitative in nature, where the handling damages, injuries at farm level such as harvest injuries followed by transportation losses include loading and unloading of the produce.

This type of losses may be found both at farmer level as well as trader level. Physiological losses are qualitative in nature *i.e.* quality deterioration of produce, which can be of malformed fruits, uneven size of tender fruits, over-ripened fruits, shrinkage due to loss of moisture and other physiological activities in harvested fruits. Sometimes, the tight packaging during the transport may cause the produce to undergo quality and quantity and even unfit for final consumption. The simple reason behind the larger loss in the quantity of produce could be the excess production *i.e.* bumper harvest and higher production in a season, where the surplus produce is found to have no buyer/trader in the market to transact. Losses due to the biotic factors like pests, diseases, rodents and birds are also found affecting the produce in both qualitative and quantitative aspects. These pre-harvest factors account for losses as the pest infected and diseased fruits would be sorted and graded into lower grades or sometimes, wastages as a whole and dumped into the field. Thus, the above mentioned factors cause the loss of the produce as well as the loss of all the efforts in producing them. Under this background, the present study was taken up to estimate the post-harvest losses in major vegetables.

2. METHODOLOGY

2.1 Study area and background

The present study was carried out in Palakkad district of Kerala in India. Besides, its economy is primarily agricultural and both food and cash crops are being cultivated. In Kerala, 13.52 percent of total vegetable area is being contributed by this district. During the year 2018-19, it has been reported that 41,809.11 ha was covered under vegetable cultivation, which is 4.42 per cent of total food crops area. Palakkad district contributed for 13.52 per cent (5651.78 ha) of total vegetable area. Hence, the district was chosen for the present study. And, it was observed that occurrence of farm level as well as transit losses (*w.r.t.* post-harvest losses) were very common. The Figure 1 shows the profile of study area.

2.2 Sampling technique

2.2.1 Selection of block and panchayats

Vegetable farmers were selected using multi-stage random sampling design. District followed by blocks and panchayats were selected based on the proportion of area under vegetable cultivation in the state. Palakkad district has thirteen blocks, of which two blocks *i.e.* Chittur and Nenmara were purposively selected, since they have maximum area under selected vegetables. Area occupied by bitter gourd and snake gourd in Chittur block were 26.1 ha and 14.3 ha respectively and in case of Nenmara, they were 284.9 ha and 181.3 ha respectively. And, four panchayats from two blocks (two of each) were purposively selected, since they have maximum area under cultivation. Nenmara and Elavanchery from Nenmara block and Perumaty and Vadakarapathy from Chittur blocks were the selected panchayats for the study.

2.3 Selection of vegetables

The selection of vegetables was done on the basis of total annual production of different vegetables in the district. Two major vegetables grown in the study area were bitter gourd and snake gourd and their annual production accounted for 3,593 tonnes and 2,874 tonnes respectively.

2.4 Selection of respondents

Fifteen farmers from each of the panchayats, for each of the vegetables were selected randomly. Thus, the total sample size formed was 120 for farmer respondents. Post-harvest losses estimation was also done at trader level through ten wholesalers and five retailers, using pre-structured and pre-tested interview schedules developed for the purpose. Though the farmers did not maintain any farm records, they were able to provide the necessary information. However, proper cross-checks were carried out to reduce memory recall bias. Figure 2 shows the sampling procedure. Survey of vegetable farmers, wholesalers and retailers was undertaken.

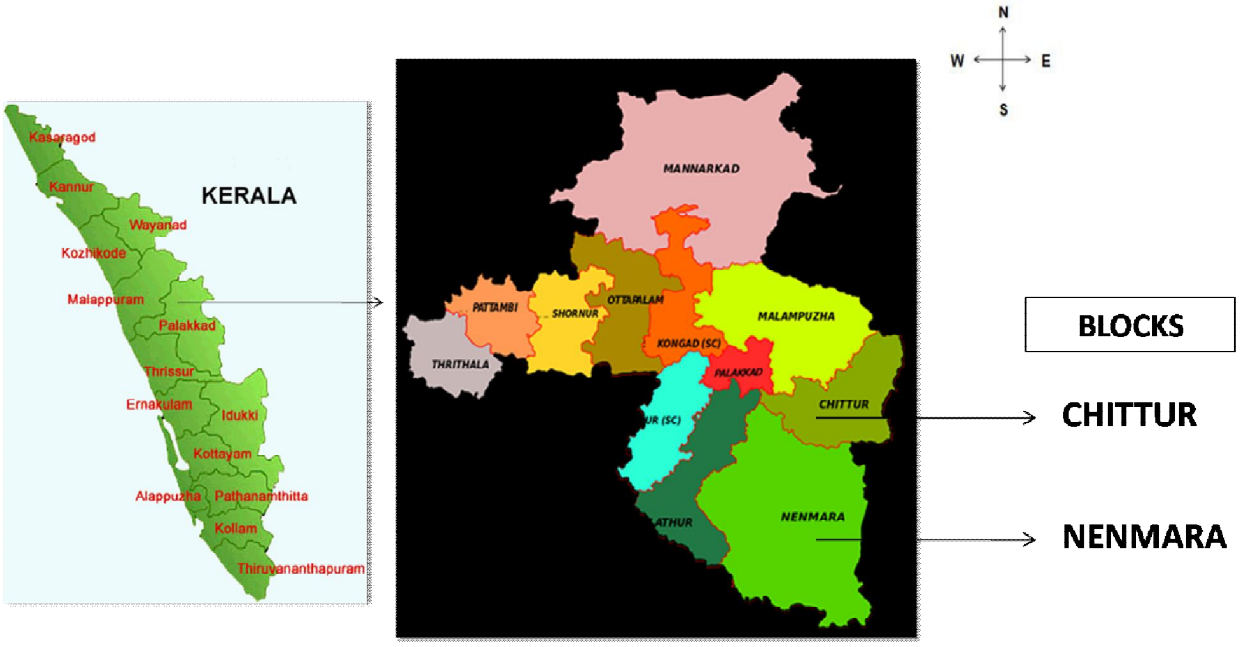
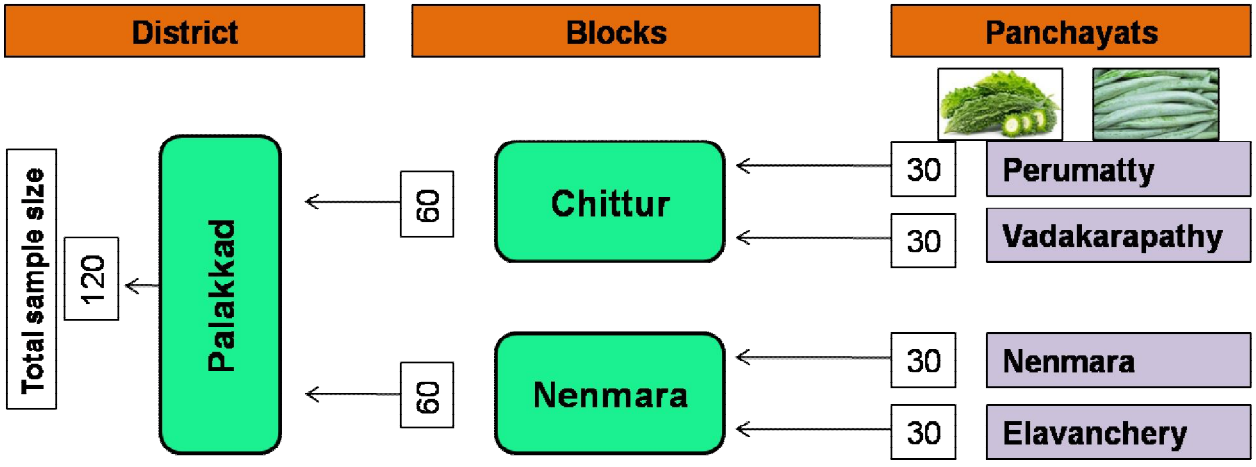


Figure 1 Map showing blocks of the study area - Palakkad district



Primary respondents

4 panchayats * 2 vegetables * 15 respondents = 120 farmers

10 wholesalers + 5 retailers

Figure 2 Classification of study area and respondents

2.5 Analytical Framework

The nature and extent of post-harvest losses in selected vegetables were assessed at different stages (farmer, wholesaler and retailer) using simple average, percentage and tabular analyses. The physical losses and monetary values for the same were also estimated. The losses were estimated in both qualitative and quantitative terms, where the physical losses incurred was based on decline in product values (second/third grade) due to deterioration and damages and monetary losses was assessed based on the quantity of discarded vegetables.

2.5.1 Growth rate analysis

The growth rates for area, production and productivity of vegetables in India and Kerala were calculated using compound annual growth rate analysis. The analysis was carried out using the functional form,

$$\mathbf{Y_t = ab^t}$$

Where,

Y_t : Area/ production/productivity of vegetables (in the year t)
a : Intercept
b : Regression coefficient
t : Number of years

Taking logarithms on both the sides,

$$\ln Y_t = \ln a + t \ln b$$

$$\mathbf{Y_t' = A + B}$$

The rate of change of area, production and productivity in unit time (yearly) is the compound annual growth rate. The value of the co-efficient (b) was estimated by the method of Ordinary Least Squares (OLS). The formula used to estimate CAGR in percentage is as follows:

Compound Annual Growth Rate (CAGR) = (Antilog B-1) × 100

Coefficient of variation

Co-efficient of variation (CV) was used to measure the variation over the years for the area, production and productivity using the formula,

CV = [Standard deviation / Mean] × 100

Standard deviation $= \sqrt{\frac{1}{n}} \sum (\mathbf{X} - \boldsymbol{X})^2$

Mean $= \frac{1}{n}[\sum \mathbf{Xi}]$

Where, $\sum Xi$ - Sum of observations and
n - Total number of observations

2.5.2 Percentage analysis

Descriptive statistics (percentage analyses) were used for analysing the major factors share to the total post-harvest losses taken in the study. To compute percentages, the particular factor's loss (f_i) was divided by the total losses and the value obtained was multiplied by 100.

2.5.3 Functional analysis

Multiple-linear regression model was fitted to delineate the determinants of post-harvest losses in the selected vegetables. The function was hypothesized by taking socio-economic aspects of farmers, favourable weather conditions, timely availability of labour, packing materials used and biotic factors (pests and disease infestations). The specified functional form is as follows:

$$\mathbf{Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + a_6X_6 + a_7X_7}$$

Where, Y - Post-harvest losses (Kg per quintal)
$\mathbf{a_0}$ is the intercept and
$\mathbf{a_2, a_3, a_4, a_5, a_6, a_7}$ are the regression coefficients
X_1 - Age (yrs)
X_2 - Area under vegetable production (hectare)
X_3 - Experience in farming (years)
X_4 - Favourable weather conditions
X_5 - Timely availability of labour
X_6 - Materials used for packing
X_7 - Biotic factors - pests and diseases

Age and experience of vegetable growers could help them in reducing the post-harvest losses. In addition to this, practices like harvesting the produce at proper stage using appropriate method and the crop protection measures undertaken would be considered as the adaptive measures followed by the farmers against the losses. While the determinants like favourable weather conditions, availability of timely labour and better packing materials would also help the farmers to minimize the qualitative losses to a considerable extent.

2.5.4 Knowledge, perception level and practices of farmers regarding the losses

In order to understand the farmer's knowledge, perception level and practices regarding the post-harvest losses, five-point Likert-type scale was adopted. The responses from the farmers were recorded using the score which ranges from five to one, indicating the knowledge and awareness regarding the losses as follows:

5 - Strongly agree
4 - Agree
3 - Neutral
2 - Disagree

1 - Strongly disagree

A set of statements were put-forth and respondents were asked to give their opinion based on the five-point scale. The perception scores were converted to percentage for each of the respondents. Based on the mean and standard deviation values, the respondents were categorized into three groups, *i.e.* high, medium and low level of perception. The maximum score expected would be 35 and minimum of 7.

3. RESULTS AND DISCUSSION

3.1 Growth rate analysis

3.1.1 Growth rate of area, production and productivity of vegetables in India

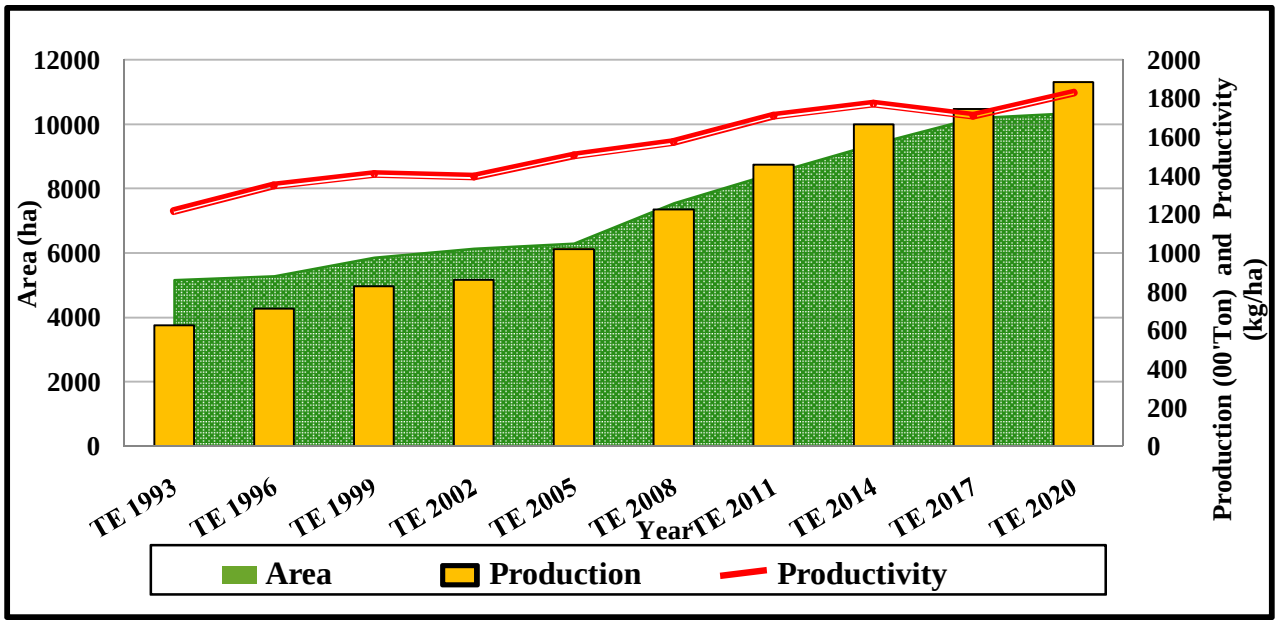
Area and production of vegetables in India has shown a two-fold increase from TE 1993 to TE 2020. With the help of time series data (1991-2020) of vegetables in India, growth rate analyses were carried out for area, production and productivity. Descriptive statistical tools and compound growth rates were used for showcasing their values in a meaningful manner (Table 1 and Figure 3). During the period of TE 1996 area, production and productivity of vegetables had an increased trend of 2.15, 13.73 and 10.66 per cent respectively. This period marks the drastic increase in productivity, which could be made possible with favourable weather conditions for vegetable production in India. Also, during the period of TE 1999, area under vegetables was observed to have increased by 10.91 per cent, and production and productivity rose by 16.17 and 4.6 per cent respectively. During the period of TE 2002, area and production had shown increasing trend of 4.65 and 3.9 per cent, but productivity showed a slight decline by 1.11 per cent.

Table 1 Area, production and productivity of vegetables in India (1991-2020)

S. No.	Period	Area ('000' ha)	Production ('000' MT)	Productivity (ton $ha^{-1)}$
1	TE 1993	5174.3 (NA)	62708 (NA)	12.19 (NA)
2	TE 1996	5285.3 (+2.15%)	71318 (+13.73%)	13.49 (+10.66%)
3	TE 1999	5862 (+10.91%)	82851 (+16.17%)	14.11 (+4.6%)
4	TE 2002	6134.7 (+4.65%)	86084 (+3.9%)	13.95 (-1.11%)
5	TE 2005	6306 (+2.79%)	101937 (+18.42%)	15.07 (+8.03%)
6	TE 2008	7547.3 (+19.68%)	122456 (+20.13%)	15.77 (+4.6%)
7	TE 2011	8489.7	145660	17.13

		(+12.49%)	(+18.95%)	(+8.63%)
8	TE 2014	9381 (+10.5%)	166602 (+14.38%)	17.76 (+3.68%)
9	TE 2017	10201 (+8.74%)	174794 (+4.92%)	17.13 (-3.53%)
10	TE 2020	10362 (+1.58%)	188562 (+7.88%)	18.32 (+6.93%)

Beginning from TE 2005 to TE 2017, all the three parameters depicted an increasing trend. This may be due to the implementation of the schemes under National Horticulture Mission which thereby also led to increase in production and supply of vegetables. There has been an area expansion of 5.18 per cent rise in production of 7.88 per cent and 6.93 per cent increase in productivity during the period of TE 2020. Vegetable cultivation is considered to be relatively more remunerative than food grains. West Bengal with 15.3 per cent share in Indian vegetable production leads among the states in the country, which is followed by Uttar Pradesh with 14.2 per cent.



Source: Horticultural Statistics at a Glance, Ministry of Agriculture

Figure 3 Area, production and productivity of vegetables in India (1991-2020)

It could be observed that growth rates for area, production and productivity were 2.94, 4.44 and 1.48 respectively (Table 2). It can thus, be concluded that India has shown positive and significant growth rates in vegetables over the years in area, production and productivity.

Table 2 Compound growth rates of area, production and productivity of vegetables in India (1991-2020)

Particulars	Area	Production	Productivity
Growth rate (%)	2.94	4.44	1.48
R^2	0.95	0.97	0.87

Coefficient of variation (CV) of area, production and productivity of vegetables in India are presented in the Table 3. It can be observed that CV was higher for production followed by area and productivity. These variations may be due to the factors like fragmentation of land, cultivation practices and technology adoption by vegetable growers and also, variations in climate.

Table 3 Coefficient of variation (CV) of area, production and productivity of vegetables in India (1991-2020)

Variable	Coefficient of variation (CV)
Area	26.13
Production	37.18
Productivity	13.28

3.1.2 Growth rate of area for vegetables in Kerala

Area under vegetable cultivation in Kerala had shown a declining trend till TE 2012, thereafter, it gained momentum and the area under vegetable increased. Vegetable and Fruit Promotion Council Keralam (VFPCK) was setup in 2001, to empower the vegetable and fruit farmers through quality production, value addition and marketing the produce for better prices without the interventions of intermediaries. Using time series data (2004-2020) of vegetables in Kerala, growth rate analysis for area was calculated.

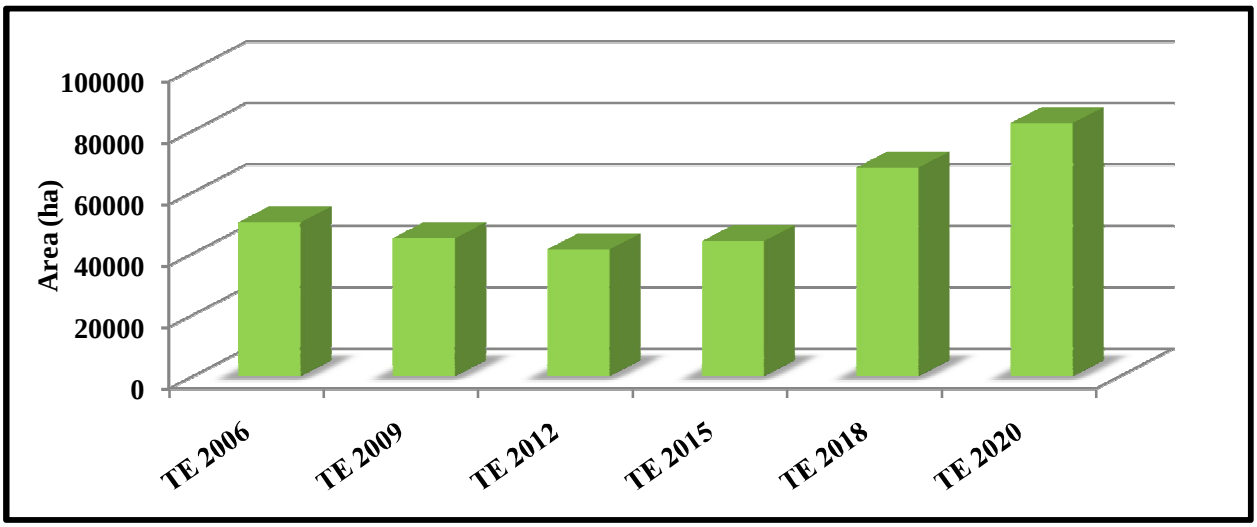
Triennium endings (TE) estimated for the period 2004-2020, are represented in the Table 4 and Figure 4. During the period of TE 2006, the area under vegetable cultivation was 50,185 ha, and it contracted by 10.33 per cent during the period of TE 2009. From the TE 2012 till TE 2020, it was found there was a sharp increase in the area under vegetable cultivation. In particular, the area expansion during TE 2018 was higher with 54.44 per cent.

With the efforts put-forth by the institutions like VFPCK and the state department of Agriculture through various schemes that were implemented might have been main reason behind the expansion of vegetable area in the state. The vegetable area in the TE 2020 was 82,508 ha, which accounted for 21.31 per cent increase. It is clear from the table that area under vegetable cultivation in the state has shown positive growth rate, which indicated increasing trend over the years (Table 5).

Table 4 Area under vegetable cultivation in Kerala (2004-2020)

S. No.	Period	Area (ha)
1	TE 2006	50185 (NA)
2	TE 2009	45001 (-10.33%)
3	TE 2012	41369.3 (-8.07%)
4	TE 2015	44040.7

		(+6.46%)
5	TE 2018	68014.3 (+54.44%)
6	TE 2020	82508.7 (+21.31%)



Source: Agricultural Statistics, DES, GoK

Figure 4 Area under vegetable cultivation in Kerala (2004-2020)

The Table 6 depicts the coefficient of variation of area for vegetables in the state. It can be interpreted that there existed variation to the extent of 30.7 per cent in the vegetable cultivation area, and this can be attributable to change in cropping pattern followed in the vegetable growing tracts of Kerala.

Table 5 Compound growth rates in Kerala (2004-2020)

Particulars	Area
Growth rate (%)	+3.11
R^2	0.27

Table 6 Coefficient of variation (CV) in Kerala (2004-2020)

Variable	Coefficient of variation (CV)
Area	30.67

3.2 Socio-economic profile of the vegetable farmers

Sixty farmers from each of the vegetables were surveyed and the data collected constitute information on socio-economic characteristics *i.e.* age, education status, annual income, income sources, sources of farming credits, land holding pattern, area under vegetable cultivation, farming experience, organizational membership and land ownership status (Table 7).

The study revealed that majority of the respondents (42.22 per cent) fall under the age group of 41 to 50 years. It is evident from the table that 46.11 per cent of respondents were found having their education at plus two level, followed by SSLC and below with 28.33 per cent. It was also noted that 6.67 per cent of farmers were post-graduates. It could be observed from the table that majority (31.11 per cent) of sample farmers earned an income between ₹1 to 1.5 Lakh, followed by 26.11 per cent of growers earned an income between ₹50,000 to ₹1 Lakh. Hence, it is very clear that vegetable cultivation in the study area was highly remunerative.

Among the total, more than half (61.67 per cent) of the respondents were found to be dependent on farm income alone. Besides farming, 38.33 per cent of respondents were engaged with other income generating activities. It could also be observed that majority (45 per cent) of the farmers were grouped under the small size of holding 1 to 2 hectares of land. The classification was made with three categories of land holding size (cents) under vegetable cultivation. It is evident from the table that 53.33 per cent of bitter gourd famers fell under the group of holding one acre and above, whereas snake gourd fell under the group of holding 50 to 100 cents with 56.67 per cent.

Vegetable cultivation in the study area was found done in both owned as well as leased land and the respondents were categorized into three groups as given in the Table. Around 54.44 per cent of respondents were found cultivating in their own land and 33.33 per cent and 12.22 per cent of farmers were observed cultivating in owned plus leased-in land and leased-in land only respectively. The average lease amount paid was ₹1,00,000 $ha^{-1}yr^{-1}$. According to the experience (in years) in vegetable farming, sample respondents were grouped into four categories. As the highest, 43.89 per cent of farmers were found to have an experience between 11 to 20 years, followed by 28.89 per cent of farmers with 21 to 30 years of experience.

The sample respondents were classified based on their membership status in different organizations in which, about 70.56 per cent of the respondents were members in VFPCK and 23.89 per cent of farmers hold membership with other small farmers groups and associations. Around 31.67 per cent and 30 per cent of respondents depend on cooperative societies and commercial banks as their credit sources. Also, 17.22 per cent of farmers tend to source credits from their traders, to whom they market their produce.

Table 7 Socio-economic profile of the vegetable farmers

Age of the sample respondents			
Sl. No.	**Age (years)**	**No. of respondents**	**Percentage**
1	30-40	7	5.83
2	41-50	56	46.67
3	51-60	38	31.67
4	>61	19	15.83
Educational status of the sample respondents			
Sl. No.	**Educational status**	**No. of respondents**	**Percentage**
1	SSLC and below	31	25.83
2	Plus two	63	52.50
3	Degree/diploma	20	16.67
4	Post-graduate	6	5.00

Annual Income level of the sample respondents

Sl. No.	Annual Income (₹)	No. of respondents	Percentage
1	<50,000	8	6.67
2	50,000 - 1lakh	32	26.67
3	1 - 1.5lakh	51	42.5
4	1.5 - 2lakh	29	24.16

Income sources of the sample respondents

Sl. No.	Sources of Income	No. of respondents	Percentage
1	Farm income alone	74	61.67
2	Farm + non-farm income	46	38.33

Land holding pattern

Sl. No.	Size of holding (ha)	No. of respondents	Percentage
1	Marginal (<1)	18	15.00
2	Small (1 - 2)	61	50.83
3	Medium (2 - 4)	26	21.67
4	Large (>4)	15	12.5

Distribution of area under vegetable cultivation

Sl. No.	Size of holding (cents)	Bitter gourd		Snake gourd	
		No.	Per cent	No.	Per cent
1	<50	7	11.67	18	30.00
2	50 - 100	21	35.00	34	56.67
3	>100	32	53.33	8	13.33

Land ownership status under vegetable cultivation

Sl. No.	Land ownership status	No. of respondents	Percentage
1	Owned alone	65	54.17
2	Owned + leased-in	40 (33.33)	33.33
3	Leased-in only	15 (12.22)	12.50

Vegetable farming experience

Sl. No.	Farming experience category (years)	No. of respondents	Percentage
1	<10	21	17.00
2	11 – 20	53	44.00
3	21 – 30	35	29.00
4	>30	12	10.00

Distribution of respondents based on membership status

Sl. No.	Membership organization	No. of respondents	Percentage
1	VFPCK	84	70
2	Others	29	24.17
3	No membership	7	5.83

Credit sources of respondents

Sl. No.	Sources	No. of respondents	Percentage
1	Commercial banks	36	30.00
2	Co-operatives	38	31.67
3	Traders	21	17.50
4	Others	19	15.83
5	No credits	6	5.00

3.3 Nature and extent of losses

3.3.1 Post-harvest losses in bitter gourd

The nature and extent of post-harvest losses in vegetables were determined by classifying them into three major categories *viz*. physical loss, physiological loss and loss due to biotic factors as presented in the Table 8. In bitter gourd, the losses were found to be 3.68 (1.02 ton/ha), 2.1 (0.58 ton/ha) and 6.68 (1.85 ton/ha) percent to the total production (per hectare) in terms of physical damages, physiological deterioration and loss due to biotic factors respectively at farm level. Thus, the total loss observed in bitter gourd at farm level was about 12.46 percent (3.45 ton/ha). Table 9 depicts that at trader level, the physiological loss contributed to almost 45 percent of the total losses. Hence, the total loss in bitter gourd was observed to be 21.88 per cent (Table 10).

Table 8 Nature and extent of losses in bitter gourd at farm level

S. No.	Nature and stage of losses	Extent of losses	
		Losses (%)	**Losses (ton/ha)**
1	Physical losses	**3.68**	**1.020** (29.53)
	a. Harvesting	*1.75*	*0.485*
	b. Grading & packaging	*1.12*	*0.311*
	c. Transportation and marketing	*0.81*	*0.224*
2	Physiological losses	**2.1**	**0.582** (16.85)
	a. Harvesting	*1.4*	*0.388*
	b. Grading & packaging	*0.7*	*0.194*
3	Losses due to biotic factors	**6.68**	**1.851** (53.61)
	Total	**12.46**	**3.453** (100.0)

Note: Figures in parenthesis indicate percentage to total

Table 9 Nature and extent of losses in bitter gourd at trader level

S. No.	Nature of losses	Extent of losses	
		Losses (%)	**Per cent to total**
1	Physical losses	4.12	43.74
2	Physiological losses	4.2	44.58
3	Losses due to biotic factors	1.1	11.68
	Total	**9.42**	**100.0**

Table 10 Total post-harvest losses in bitter gourd

S. No.	Nature of losses	Extent of losses (%)			Per cent to total
		Farm level	**Trader level**	**Total**	
1	Physical losses	3.68	4.12	7.8	35.65

2	Physiological losses	2.1	4.2	6.3	28.79
3	Losses due to biotic factors	6.68	1.1	7.78	35.56
	Total	**12.46**	**9.42**	**21.88**	**100.0**

Post-harvest loss in bitter gourd was due to inability to sense the appropriate maturity indices for local and distant markets by the farmers (Zong *et al.,* 1995). Due to harvest at improper time, the post-harvest quality of the fruits was degraded. But, in the present study, the farmers were well-aware of maturity indices of bitter gourd as vegetable cultivation in the area is being under taken from times in memorial and it is the "**hub of vegetable cultivation in the state**".

3.3.2 Post-harvest losses in snake gourd

The total loss in snake gourd was found to be 9 per cent of the production, which in physical terms accounted for 26.10 qtl/ha. The pests and disease incidences which were prevalent in snake gourd accounted for 52.66 per cent of total losses (13.74 qtl/ha) (Table 11). Physiological losses were found to the extent of 6.96 qtl/ha, which was due to deformed tender fruits. The loss per cent which could be attributed to physical and physiological factors were 1.86 (5.39 qtl/ha) and 2.4 (6.96 qtl/ha) respectively.

The highest percentage of losses was found in quantity (2.2 per cent) terms due to improper handling, followed by physiological damages (1.99 per cent) (Table 12). The total loss observed was almost 4.89 per cent of the total produce handled by the traders. Besides in snake gourd, it was observed that losses at the trader level were relatively less compared to farm level, because of its semi-hardy nature. Losses due to biotic factors were found to be 0.7 per cent at trader level.

Table 11 Nature and extent of losses in snake gourd at farm level

S. No.	Nature and stage of losses	Extent of losses	
		Losses (%)	Losses (ton/ha)
1	Physical losses	**1.86**	**0.539** (20.67)
	a. Harvesting	*1.08*	*0.313*
	b. Grading & packaging	*0.56*	*0.162*
	c. Transportation and marketing	*0.22*	*0.064*
2	Physiological losses	**2.40**	**0.696** (26.67)
	a. Harvesting	*1.50*	*0.435*
	b. Grading & packaging	*0.90*	*0.261*
3	Losses due to biotic factors	**4.74**	**1.374** (52.66)
	Total	**9.00**	**2.610** (100.0)

Note: Figures in parenthesis indicate percentage to total

Table 12 Nature and extent of losses in snake gourd at trader level

S. No.	Nature of losses	Extent of losses	
		Losses (%)	Per cent to total
1	Physical losses	2.2	44.99

2	Physiological losses	1.99	40.69
3	Losses due to biotic factors	0.7	14.32
	Total	**4.89**	**100.0**

It is evident from the table that losses were found relatively higher in grower's field (9 per cent) when compared to trader level (4.89 per cent) (Table 13). The highest loss in snake gourd was due to losses by biotic factors especially due to the fruit rot at the tips (5.44 per cent), followed by physiological losses (4.39 per cent). Hence, the total computed losses in the study area for snake gourd accounted for 13.89 per cent of the total produce.

Table 13 Total post-harvest losses in snake gourd

S. No.	Nature of losses	Extent of losses (%)			Per cent to total
		Farm level	Trader level	Total	
1	Physical losses	1.86	2.2	4.06	29.23
2	Physiological losses	2.4	1.99	4.39	31.61
3	Losses due to biotic factors	4.74	0.7	5.44	39.16
	Total	**9.00**	**4.89**	**13.89**	**100.0**
3	Losses due to biotic factors	7.58	0.8	8.38	41.49
	Total	**11.53**	**8.67**	**20.2**	**100.0**

Aggregate post-harvest losses of 22.65 per cent occurred in potato at various levels, which was around 9.2, 8.45, 2, 1, 2 per cent at farm level, wholesale, retailer, cold storage and others respectively. The qualitative losses (physiological and diseases) were estimated to 21.85 per cent in Baragaon block and 23.45 per cent in Pindra block of Varanasi (Gautam, 2017).

Highest losses were observed in bitter gourd with 12.46 per cent, followed by snake gourd (9.0 per cent). Loss due to biotic factors was the highest among different factors in all the two study vegetables (Figure 5). It was also observed that both the vegetables were harvested based on the harvest indices and the consumers preferences. As these products were preferred in farm fresh quality, they were marketed and channelized to reach consumers at the earliest possible time. Also, the losses were found higher in farm level than the trader level.

Economical (post-harvest) losses of the fruits and vegetables in storage and transportation were caused mostly by the pathogenic fungal complex (Sommer, 1985). This has also been confirmed in the present study, since the losses due to biotic factors were observed to be relatively higher in the study vegetables.

3.4 Monetary losses

Economic loss is obtained by addition of post-harvest loss values and value of second grade produce. The monetary loss of vegetables at farm level were also estimated by taking into consideration the prevailed prices (during the study period) of ₹34 (bitter gourd) and ₹23 (snake gourd) (per kg). The vegetables were graded by the shape and size of the produce into standard and second grades, and it was observed that the second grade fetched only half the price of the standard grade.

3.4.1 Estimated loss values in study vegetables

The post-harvest monetary losses accounted for ₹1,17,402 ha^{-1} in bitter gourd. Farmers tend to lose the value of their produce for second grades (Table 14). Thus, the economic losses were estimated at ₹3,05,439 ha^{-1}. Similarly, the monetary loss for snake gourd was computed as ₹60,040 ha^{-1}, whereas the economic loss valued at ₹94,316 ha^{-1} (Table 15). Therefore, the monetary losses were observed to be highest in bitter gourd (32.41 percent to total value of production per hectare) followed by snake gourd (Figure 6).

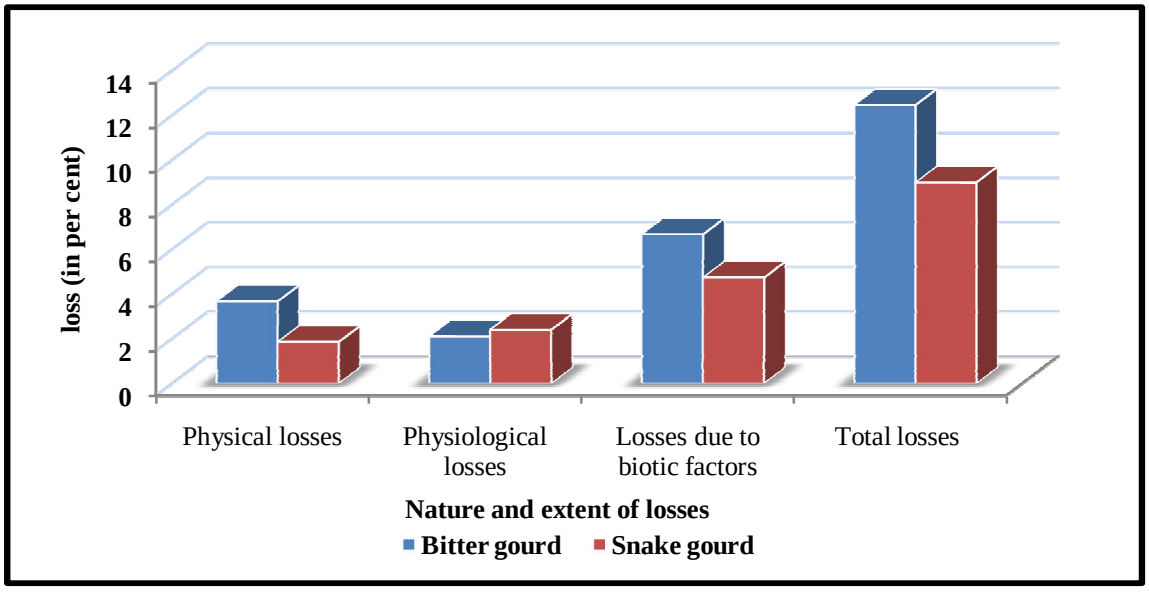


Figure 5 Total losses in study vegetables at farm level

3.4.2 Estimated loss values in study area

Using the values of the farm level losses, the monetary losses were extrapolated to block and district levels. The estimated loss values for Chittur block were ₹10.82 lakh and ₹4.43 lakh in bitter gourd and snake gourd respectively, taking the production data into consideration (Table 16). In Nenmara, the losses were estimated to ₹122.27 lakh for bitter gourd and ₹56.31 lakh for snake gourd. Similarly, for Palakkad district the estimated losses were ₹152.22 lakh and ₹59.49 lakh respectively (Table 17).

Table 14 Monetary loss values of bitter gourd at farm level (₹/ha)

Particulars	Gross production	First grade	Second grade	Wastage/loss
Quantity (Qtl/ha)	277.15 **(100)**	132 **(47.63)**	110.62 **(39.91)**	34.53 **(12.46)**
Values (₹/ha)	9,42,310	4,48,800	1,88,054	1,17,402

Note: Figures in parentheses indicate percentage to total

Nature of loss	Losses in monetary terms			
	Kg/qtl (%)	₹/qtl	Loss (Qtl/ha)	₹/ha
Physical loss	3.68	12,512	10.2	34,680

Physiological loss	2.1	7,140	5.8	19,720
Losses due to biotic factors	6.68	22,712	18.5	62,900
Total	**12.46**	**42,364**	**34.53**	**1,17,402**

Gross income (₹/ha)	Economic income (₹/ha)	Economic loss (₹/ha)
9,42,310 **(100)**	6,36,871 **(67.59)**	3,05,439 **(32.41)**

Note: Figures in parenthesis indicate percentage to gross income
Source: Computed from survey data

Table 15 Monetary loss values of snake gourd at farm level (₹/ha)

Particulars	Gross production	First grade	Second grade	Wastage/loss
Quantity (Qtl/ha)	290.05 **(100)**	236.53 **(81.55)**	27.41 **(9.45)**	26.11 **(9.0)**
Values (₹/ha)	7,25,125	5,91,325	34,262.5	60,040

Note: Figures in parenthesis indicate percentage to gross production

Nature of loss	Losses in monetary terms			
	Kg/qtl (%)	₹/qtl	Loss (Qtl/ha)	₹/ha
Physical loss	1.86	4,278	5.39	12,408
Physiological loss	2.4	5,520	6.96	16,011
Losses due to biotic factors	4.74	10,902	13.75	31,621
Total	**9**	**20,700**	**26.1045**	**60,040**

Gross income (₹/ha)	Economic income (₹/ha)	Economic loss (₹/ha)
7,25,125 **(100)**	6,25,587.5 **(86.4)**	94,315.5 **(13.6)**

Note: Figures in parenthesis indicate percentage to gross income
Source: Computed from survey data

Gross income = Yield x price
Economic income = Standard grade value + second grade value
Economic loss = Second grade value + wastage/loss value

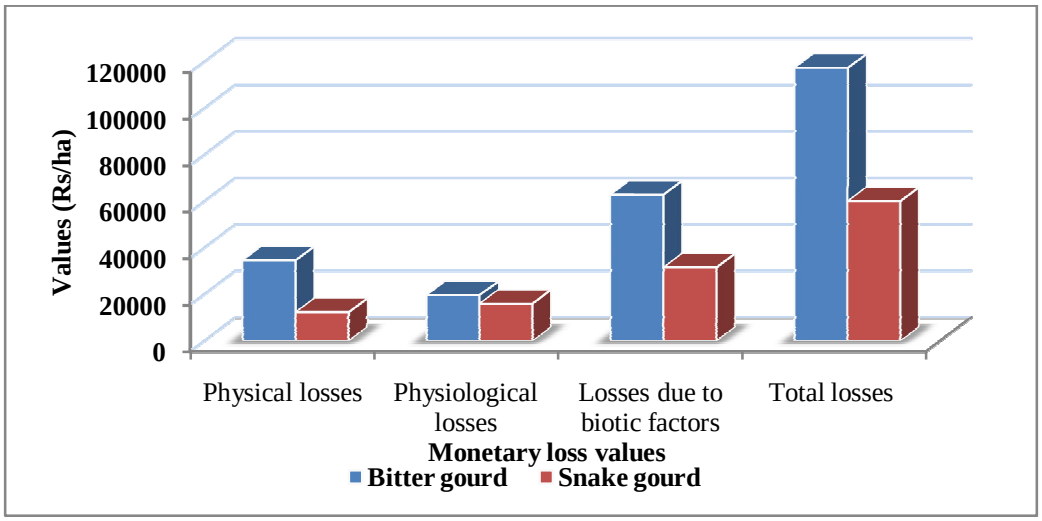


Figure 6 Estimated monetary loss values in study vegetables

Table 16 Monetary loss values of vegetables (farm level) in the study area (₹/ha)

CHITTUR BLOCK				
Vegetable	**Production (Qtl)**	**Average loss %**	**Total loss (Qtl)**	**Loss value (lakh ₹)**
Bitter gourd	2555.14	12.46	318.37	10.82
Snake gourd	2141	9.0	192.69	4.43
NENMARA BLOCK				
Bitter gourd	28861.84	12.46	3596.18	122.27
Snake gourd	27200	9.0	2448	56.31

Table 17 Monetary loss values of vegetables (farm level) in Palakkad district (₹/ha)

Vegetable	**Production (Qtl)**	**Average loss %**	**Total loss (Qtl)**	**Loss value (lakh ₹)**
Bitter gourd	35931.66	12.46	4477.085	152.22
Snake gourd	28740	9.0	2586.6	59.49

Source: Computed from primary and secondary data

3.5 Major determinants of post-harvest losses at farm level

Regression analyses were used to delineate the factors responsible for losses at farm level. In bitter gourd, area under cultivation, unfavourable weather conditions, pests and diseases and use of packing materials like jute sacks and wooden baskets were found as major determinants for losses. Area under cultivation, experience in farming and prevailing pests and diseases in snake gourd were found to affect the volume of post-harvest losses at farm level.

3.5.1 Factors responsible for losses in bitter gourd

Area under cultivation, unfavourable weather, usage of packing materials like, sacks, wooden baskets, *etc.* and incidence of pests and diseases were the factors found positively

significant (Table 18). Due to timely labour availability, labour power was found to be non-significant and subsequently helped in reducing the losses. Majority of the farmers were found following the post-harvest ma-nagement practices like pre-cooling, grading and sorting, *etc.* Hence, educating the farmers with cost-effective crop protection practices and crop-specific strategic plan to combat the poor weather conditions would help to solve the post-harvest loss problems to a marked extent.

Table 18 Factors responsible for losses in gourds at farm level

S. No.	Determinants	Bitter gourd		Snake gourd	
		Coefficients	Std. error	Coefficients	Std. error
1	Intercept	10.206	1.35	9.014	0.28
2	Age (years)	-0.040	0.03	0.001	0.004
3	Area under bitter gourd cultivation (ha)	2.663*	0.57	1.745**	0.533
4	Experience in bitter gourd farming (years)	0.067	0.03	-0.050**	0.008
5	Influence of bad weather	1.092*	0.41	0.032	0.127
6	Inadequate labour power	-0.445	0.40	-0.047	0.168
7	Packing materials used	1.008**	0.28	0.051	0.121
8	Incidence of pests and diseases	0.852*	0.40	0.386**	0.141
9	R-square	**71.75**	-	**74.30**	-
10	Adjusted R-square	**67.95**	-	**70.84**	-

*Level of significance $p<0.05$

**Level of significance $p<0.01$

Kumar *et al*. (2006) applied functional analysis to identify the factors that affect the post-harvest losses in onion and potato of Karnataka and pointed out that by promoting the adequate storage units and proper handling of produce during the harvest it is possible to minimize the losses to possible extent.

3.5.2 Factors responsible for losses in snake gourd

Area under cultivation and incidence of pests and diseases were the factors found positively significant, while farming experience was negatively significant. Due to timely labour availability, labour power was found to be non-significant and subsequently helped in reducing the losses (Table 18). Fortunately, majority of the farmers were found following the post-harvest management practices like pre-cooling, grading and sorting, *etc.* Hence, educating the farmers with cost-effective crop protection practices and crop- strategic plan to combat the poor weather conditions would definitely solve the post-harvest loss problems.

Moss (2002) stated that fungal group of pathogens mainspring the rots through mycotoxins in fruits and vegetables with lower pH and elevated moisture content.

3.6 Perception level of farmers regarding losses

It could be inferred from the table 19, that majority of the farmers in the study area had good knowledge regarding the post-harvest losses like practicing the post-harvest management practices. But, due to the external factors like climate, natural disasters, sometimes, hike in lead wage rate, *etc.* were stated as major issues regarding the reasons for losses. Only a few of the vegetable growers were found aware of existence of cold storage unit in the study area. So,

training and practicing of modernized use of cold structures for vegetable storage during the period of high production would also help in reducing the losses to maximum possible extent.

Table 19 Perception level of vegetable farmers regarding the post-harvest losses

Perception categories	Mean perception index	No. of respondents
Low level	Mean - SD	13 **(10.83)**
Medium level	Mean ±SD	90 **(75)**
High level	Mean + SD	17 **(14.17)**

According to Kwarteng *et al*. (2017), vegetable amaranth farmers in Ghana were aware of effects of pre-harvest operations on the post-harvest losses.

3. Conclusion and suggestions

The study aimed at analyzing the growth rates of total vegetable area, production and yield for India and Kerala and estimating the nature and extent along with monetary losses in the selected (bitter gourd and snake gourd) vegetables. The results shows that the area under vegetable cultivation, production as well as the productivity in India were found to have increasing trend at 2.94 per cent, 4.44 per cent and 1.48 per cent respectively and tested statistically and was positive and significant. In Kerala, the area under vegetable cultivation has shown a positive growth rate with 3.12 per cent. The losses were studied under three major categories based on their nature at both farm level and trader level. The results obtained showed that about 21.88 per cent of losses in bitter gourd, 13.89 per cent in snake gourd. Of the total loss, the farm level losses were observed to be higher than the trader level losses in both the selected vegetables. The losses associated with the physical damages were more in bitter gourd whereas the physiological deteriorations were found to be higher in snake gourd. The monetary losses estimated for the farm level losses has been found to be highest in bitter gourd with ₹1,17,402 ha^{-1}, followed by snake gourd with ₹60,040 ha^{-1}, as the economic loss per cent has been observed with the similar trend.

Using the regression analysis, the major determinants affecting the losses at farm level were delineated. In bitter gourd, the factors like area under cultivation, poor weather conditions, packing materials used and biotic factors contributed for the losses. In snake gourd, area under cultivation, experience and prevailing pest and diseases were the determinants responsible for causing the losses. Using five-point Likert type scale, the perception level of farmers regarding the losses have been recorded and the results revealed that the majority of the farmers in the study area were found to be categorized under medium-level perception. The constraints in vegetable cultivation and marketing faced by the farmers were analysed and the major constraints recorded were unfavourable climatic conditions, high input costs and incidence of pest and diseases in the study area.

Thus, it can be concluded that with improvement in the awareness level among farmers regarding the post-harvest losses and by training them in the area of post-harvest operations and handling (farm as well as in supply chains), the losses could be reduced to a remarkable extent in the area.

Suggestions

- By trainings the farmers with cost-effective post-harvest management practices, the losses could be reduced to a marked extent.
- Effective utilization of existing cold storage structures in the study area during the period of bumper production would help to reduce the losses due to glut in the market.
- Transportation losses could be minimized to some extent by providing better logistic supports to the farmers.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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