

**AGRONOMIC PERFORMANCE AND MINI-TUBER  
PRODUCTION OF POTATO VARIETIES UNDER  
AEROPONIC SYSTEM**

A Thesis

Submitted in partial fulfillment of the requirements for the  
award of the degree of

**DOCTOR OF PHILOSOPHY**

in

**AGRONOMY**

By

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2020**



## **DECLARATION**

I hereby declare that the thesis entitled “**Agronomic performance and mini-tuber production of potato varieties under aeroponic system**” submitted for **Doctor of Philosophy in Agronomy** to the School of Agriculture, Lovely Professional University is entirely original work and all ideas and references are duly acknowledged. The research work has not been formed the basis for the award of any other degree.

Place: LPU, Phagwara

Date: 16/May/2020

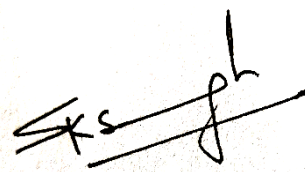
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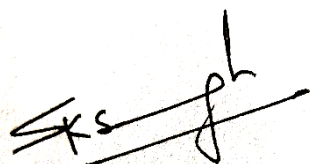


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**CERTIFICATE-II**

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**ABSTRACT**

Aeroponic is a technique of growing seedlings in an air mist environment without using soil. Aeroponic word is derived from the Latin language ‘aero’ (air) while ‘ponic’ meaning labour work. The basic principal of aeroponics is to grow plants in a closed environment by periodically spraying roots with a nutrient solution containing all the required elements for plant growth and tuberization. Aeroponic system is one important component of producing disease free seed of potato. Before this technology came into practice, potato mini-tubers from in-vitro plants were produced in soil or other media under net house conditions. Aeroponic techniques optimizes root aeration which is the major factor leading to a yield increase of many crops compared to classical hydroponic systems and consequently has the potential to drastically reduce the number of field generations for the production of potato seed. The current studies were planned on the above mentioned background with the standardization of basic components in aeroponics system for production of mini-tuber seed potato with following objectives: To standardize the planting and harvest date for mini-tuber production in different cultivars under Punjab condition; To standardize the planting densities for mini-tuber production in different cultivars under Punjab condition; To study the economics of potato

mini-tuber production through aeroponics. The experimental material used during the study was three well-known cultivars of Potato viz. Kufri Jyoti (V<sub>1</sub>), Kufri Pukhraj (V<sub>2</sub>) and Kufri Khyati (V<sub>3</sub>) which were released by Central Potato Research Institute, Shimla. The study was conducted with two factors of four planting dates that are 15th October, 25th October, 5th November and 15th November and three spacings viz., 7X7 cm, 14X14 cm and 21X21 cm.

For Kufri Jyoti variety the performance behavior is unique as Early sown Crop shows high foliage growth a smaller number of tubers, even though the root length is very high, harvesting index is low and does not give promising result in economic analysis. But the same variety performed well if sown on late in the crop season that is 5<sup>th</sup> and 15<sup>th</sup> of November. Kufri Khyati and Kufri Pukhraj performed well in early dates of sowing but their performance is also enhanced in late sowing as the number of tubers and weight of tubers both improved in crop sown on 5<sup>th</sup> and 15<sup>th</sup> of November in both the crop seasons. Harvesting index and economic analysis show that Kufri Khyati leads and Kufri Pukhraj is not far back but Kufri Jyoti lags in terms of harvesting index and economic analysis. In terms of spacing, three spacing's 7x7 cm, 14x14 cm, 21x21cm were studied and results have clearly shown that 14x14 cm spacing suits well to all the varieties in terms of space for foliage growth, space for flourishing root system and economic analysis in terms of per unit area yield.

## ACKNOWLEDGEMENT

All praises to almighty God, the cherisher and sustainer of the world, master of the “Day of Judgment”, who bestowed me the health and courage to undertake these studies

I gratefully acknowledge the enthusiastic cooperation, venerable gratitude extended by esteemed chairman of my advisory committee Dr. Shailesh Kumar Singh, Associate Professor, School of Agriculture, Faculty of Technology and Sciences, LPU, Jalandhar Punjab for his highly imaginative and unending inspiration, valuable guidance, sound counseling, meticulous suggestion sustained interest and above all his positive attitude towards my abilities which made the achievements of this goal a challenging, rewarding and stimulating experience.

It gives me immense pleasure to place on record my profound sense of reverence to my co- supervisor, Dr. J. S. Minhas, Principal Scientist, ICAR-CPRS, Jalandhar, Punjab.

My heartfelt gratitude is due to Dr. Ramesh Sadawarti, Head, School of Agriculture, LPU for boosting my morale and inspiring me always and scholarly suggestions, constructive criticism and affection throughout my course work and research programme. I am highly grateful to all the Faculty and staff members of School of Agriculture, Faculty of Technology and Science, LPU, for their constant encouragement, support and guidance during the study programme.

With profound sense of gratitude, I found myself lucky enough to reciprocate the help and sincere cooperation offered by my colleagues especially Dr. Madhu Sharma, Er. Sukhwinder Singh, Dr. Lal Bhadur, Dr. Damandeep Singh, Dr. Kapil Kumar Sharma, ACTO, CPRS, Kufri and all staff members of CEP, Dhogri.

I shall be failing in my duties if I do not acknowledge the assistance and cooperation provided to me during the study and research work by the staff of Central library, Lovely Professional University.

I am overwhelmed with rejoice to avail this opportunity to evince my profound sense of gratitude to my father Sh. Lal Chand Numberdar and mother Gurbakash Kaur and my in-laws Late Sh. Amar Chand Kenth and Smt. Bimla Devi Kenth. My brothers Dr. Kamaljit Singh and his better half Prof. Balwinder Kaur and Sh. Amarjit Singh and his better half Smt. Neelam and all my well-wishers for their measureless prayers, everlasting love and constant encouragement

I want to **dedicate** the success of my Ph.D. degree to my wife Dr. Bindu Kenth and my kids Karmanjit Singh and Onkarjit Kaur. They stand all the way in this long, tiresome journey and supported wholeheartedly throughout the period of my study.

At last, I want to thank all those who care for me may not have got a mention, but none shall ever be forgotten.

**Place: Jalandhar, Punjab**

**Date: 16/May/2020**

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## LIST OF ABBREVIATIONS

Abbreviated Form	Full Form
ha	Hectare
ha <sup>-1</sup>	Per hectare
MT	Million tonnes
<i>et al.</i>	et alii (and order)
ft.	Foot
mm	Milli meter
m	Meter
%	Per cent
g	Gram
cm	Centi meter
cm <sup>2</sup>	Centi meter square
mg	Mili gram
mg/g	Milli gram per gram
cv.	Cultivar
FYM	Farm Yard Manure
N: P: K	Nitrogen: Phosphorus: Potassium
ml	Milli liter
/	Per
°C	Degree celsius
°B	Degree Brix
hrs	Hours
Min.	Minute
nm	Nano Meter
A	Absorbance at specific wavelength
V	Volume
W	Weight
sq. cm	Square centimeter
DAP	Days after planting
LAI	Leaf area index
TSS	Total Soluble Solids
E-W	East-West
N-S	North-South
FAO	Food and Agriculture Organisation of the United Nation
FAOSTAT	FAO statistics
NHM	National Horticulture Mission
C P R I	Central Potato Research Institute, Shimla

# CHAPTER-I

## INTRODUCTION

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Agriculture and allied sectors ensures fundamental materials requirement for livelihood of nearly 58.4% of Indian population and one of the important pillar of the Indian economy and contributed nearly 17.3 and 15.4 percent of Gross Domestic Product (GDP of India) during 2016-17 and 2017-18, respectively (Anonymous, 2020). The major food crops *e.i.* cereals have reached a “yield plateau” and global rise in yield of cereals has shown a declining trend as in wheat it was reported 2.92% per year for the period from 1961 to 1979 while it was 1.78% for the period from 1980 to 1997 (Simanis & Hart, 2000). By 2050 the world’s population may achieve a value of 9.1 billion, 34 percent higher than today (FAO, 2009; Wise, 2013). The world cereal production may need to rise upto 3000 million tonnes by 2050, which needs to improve the productivity by 700 million tonnes by that time (FAO, 2009; Wise, 2013).

Potato can be one of the answers to this problem which is going to be faced by the world in the future. Potato has been considered as the future food by Food and Agriculture Organisation of the united nation (Pandey and Chakrabarti, 2008). Potato (*Solanum tuberosum* L.) belongs to the genus Solanum of family Solanaceae. Potato known for high level of dry matter production, major food content, minerals and vitamins. It is a staple food with low calories, high biological value of protein and can rescue the food scarcity of developing countries. The dry matter of potato ( $47.6 \text{ Kg ha}^{-1}\text{day}^{-1}$ ) is higher than that of wheat ( $18.1 \text{ Kg ha}^{-1}\text{day}^{-1}$ ) and rice ( $12.4 \text{ Kg ha}^{-1}\text{day}^{-1}$ ) while edible protien is significantly better ( $3 \text{ Kg ha}^{-1}\text{day}^{-1}$ ) than that of wheat ( $2.5 \text{ Kg ha}^{-1}\text{day}^{-1}$ ) and rice ( $1.0 \text{ Kg ha}^{-1}\text{day}^{-1}$ ) (Ezekiel and Pandey, 2008). Potato production in India was estimated to 52589 MT (in '000 MT) from area of 2184 ('000 ha) in 2018-19 as compared to 51310 million tonnes in the year 2017-18 in an area of 2142 million hectares (NHM, 2018-19 Ist Adv.). The global stand of India on potato production was evidenced from the FAOSTAT data that India has always remained in the top ten for the last twenty years and contributed 12.8% of the total global potato production. These potato producing countries are: China, India, Russian

Federation, Ukraine, United State, Germany, Bangladesh, Poland, Netherlands and France (FAOSTAT, 2019).

The major challenge in potato cultivation throughout the developing world is availability of inferior quality seed which has resulted in poor yield. The multiplication rate of potato tuber is relatively low (optimally 4-6 times) so a large area, time and inputs are required to produce a sufficient quantity of potato seed tubers. Further, at every time during harvesting a bulk of pathogens are also built-up and are transmitted to next cropping season. In India, low productivity of potato is the principal cause of poor-quality tuber seed and presently most of central and state potato seed-producing organizations are able to meet only 25–30% requisite of quality tubers (Kumar *et al.*, 2007). The concept of micro-tubers and mini-tubers has brought revolution in potato production, resultant in shortening the life cycle and assuring a good level of health of base materials (Wróbel, 2015). Micro-tubers are the 1<sup>st</sup> generation tiny, nuclear potato seeds with the weight varies from 24–273mg, diameter from 4–7mm with length being 10–12mm (Ranalli, 2007). Disease-free mini-tubers of potato seed tubers were produced through meristem tip culture (KARI, 2007). The *in-vitro* seedlings are produced and multiplied 4-5 times under laboratory conditions using cuttings. After multiplication, these are transferred into seedling trays holding sand substrate supplied with water and nutrient solution (1:1) and daily watering is practiced prior to transplantation of these plantlets into the aeroponic boxes (Muthoni *et al.*, 2011). Mini-tubers are easier to handle than plant and are mild delicate, hence require less aftercare. They can be characterised as the offspring tubers which are produced under *in vitro* conditions. The size of such tubers is lesser than the traditional seed tubers but bigger than the tubers produced under *in vitro* conditions in artificial media (Struik, 2006). Potato mini-tuber production can be done variously like NFT (Wheeler *et al.*, 1990; Medeiros *et al.*, 2002; Corrêa, *et al.*, 2008), hydroponically having regular circulation of nutrient solutions (Struik and Wiersema, 1999), raised bed in greenhouse (Tierno *et al.*, 2014) or in different containers containing suitable growing media (Struik and Wiersema, 1999). Similar finding was reported by (Chang *et al.*, 2011).

Aeroponic is a technique of growing seedlings in an air mist environment without using soil. Aeroponic word has been derived from Latin language ‘aero’ means air while ‘ponic’ meaning labour work (Farran and Mingo-Castel, 2006). It is an alternative approach of growing plants without soil, which was first recognized in the 1920s by scientists who

used aeroponics to study the structure of various plant parts; and was used as the primary accessing tool for study of root physiology (Lakhiar *et al.*, 2018). In the starting of the 1940s, this technique was used as a research tool rather than for the crop production process. The aeroponics system works on the principle of growing plants under closed environment by periodically spray of suitable nutrient solution, over roots, which contains all the required elements for plant growth and tuberization (Franke *et al.*, 2011). Aeroponic system is one of the important components of producing disease-free seed of potato. Before this technology came into practice, potato mini-tubers from in-vitro plants were produced in soil or other media under net house conditions. Farran and Mingo-Castel (2006) revealed that a yield of 800 mini-tubers m<sup>-2</sup> can be obtained from a number of 60 plants m<sup>-2</sup> over a period of five-month with 7-8 days harvesting interval. This interprets exponentiation rate of 1:13. Similar field performance was reported in tubers, produced aeroponically and from the pots. Yields of over 100 tuberlets plant<sup>-1</sup> were recorded at the International Potato Centre (CIP) in Peru (Otazu, 2010).

Aeroponic techniques ensure optimization of root aeration which is not possible through hydroponic system and lead to better tuber yield and reduction of field generations required for production of potato seed tubers. This also ensures regulated availability of nutrients and management of pH through recirculation of nutrient solution (Farran & Mingo-Castel, 2006). In aeroponics approach, other advantages are there like the anticipation of soil, informal inspection, prevention of tuber-borne diseases and restricted space requirement along with vertical growth make this technology more widespread. Further, several research works carried at International Potato Center (CIP) had resulted in high number of seed tubers (80 tubers plant<sup>-1</sup>) of potato through aeroponic system (Otazu, 2007). Aeroponic system also ensures repeated and convenient harvesting of good size potato tubers with high number of cycle (Ritter *et al.*, 2001). Lommen and Struik (1992a) had also emphasised the timing and number of non-destructive harvestings as the prime factors to maximize mini-tuber production. Removal of bigger size tubers provides opportunity for initiation of new tubers and divergence of nutrient to small growing tubers which can be harvested in subsequent cycles.

One of the major challenges of aeroponic system is diversion of nutrients from stolen and tubers to the vegetative part. Thus, optimization of nutrient solution and nutrient uptake in an aeroponics system is required to provide balanced vegetative growth for early



and better tuberization. Many factors like planting density or plant spacing, harvesting interval or frequency and optimum size of mini-tubers at the time of harvesting can possibly influence the vegetative growth of potato plants under aeroponic systems and so the tuber initiation and yield will also be affected for different cultivars under different growing seasons.

Aeroponic technology was standardized for potato seed production by C P R I, Shimla in 2009–10 (Singh *et al.*, 2010; Bag *et al.*, 2015). This technology was implemented in October 2012 at Shimla (Buckseth *et al.*, 2016). Various cultivars of potato are possible to cultivate by this system. The plant spacing of 15 × 15 cm has been used and an interval of 3 days harvesting is considered best (Buckseth *et al.*, 2016). They had also stated a lot of information on time of planting, sprouting, survival, yield performance and post handling practices of aeroponic mini-tuber in potato different varieties. Aeroponic system seems to have a lot of potential for improving seed production. Optimization of various factors in aeroponics technique for mini-tubers production needs to be accessed. In soilless culture, optimization of nutrient solution is the main input for production of good quality and sufficient potato seed.

Keeping in view the above-identified conditions, the current studies were planned with the standardization of basic components in aeroponics system for production of mini-tuber seed potato with following objectives:

1. To standardize the planting and harvest date for mini-tuber production in different cultivars under Punjab condition.
2. To standardize the planting densities for mini-tuber production in different cultivars under Punjab condition.
3. To study the economics of potato mini-tuber production through aeroponics.

## CHAPTER-II

# AIMS AND OBJECTIVES

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### Research Background

Potato (*Solanum tuberosum* L.), being propagated vegetatively through underground modified stem, is prone to accumulation of pathogenic microbial inoculum from soil during development of tubers and harvest which are further transmitted from one cropping season to subsequent one and from one place to other. Thus, availability of healthy planting materials in potato production chain is challenge.

Different multiplication techniques like clonal selection, seed plot techniques and tissue culture approach have been successfully used for multiplication of planting materials in potato; however, these systems have their own limitations as we cannot proceed field production with these techniques as either the plantlets produced are very delicate and survival rate is very low or the micro-tubers produced are very small and cannot be directly sown in the fields. Thus, there is need of techniques for rapid multiplication of plants with greater number of mini-tubers production under *in vitro* condition (Struik and Wiersema, 1999).

Micropropagation techniques is one of the techniques which ensures *in vitro* multiplication of high-quality potato seed (Struik and Wiersema, 1999; Pruski, 2007). The aeroponically produced potato mini-tubers are free from pathogen with high quality and can be directly sown in the fields with a little modification in agronomic practices used for conventional planting (Ritter *et al.*, 2001; Nichols, 2004). Thus, the present investigation has been carried out on the above-mentioned background and the objectives dealt below.

### Objectives

The main objective of the present study is to determine the suitability of potato cultivars for production of mini-tubers under aeroponic system. The observations recorded and the experimental findings have sufficient capability to facilitate the diffusion of aeroponic technology for quality potato seed tubers production and increase in accessibility with lower production costs. The objectives of the study are:

1. To standardize the planting and harvest date for mini-tuber production in different cultivars under Punjab condition.
2. To standardize the planting densities for mini-tuber production in different cultivars under Punjab condition.
3. To study the economics of potato mini-tuber production through aeroponics.

### **Hypothesis**

The present study entitled, “**Agronomic performance and mini-tuber production of potato varieties under aeroponic system**” has been carried out to validate the fruitfulness of following hypothesis:

H<sub>1</sub>: Aeroponics system will provide multiple number of planting cycle in a year.

H<sub>2</sub>: Each cultivar will have specific spacing under aeroponics for efficient mini-tuber production.

H<sub>3</sub>: Aeroponic is economically feasible practice for mini-tuber production in potato.

# REVIEW OF LITERATURE

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Quality of potato tuber seed is major concern in traditional potato production. Most of the farmers reproduce their tuber seeds for utilization in subsequent year. This has resulted in spread of tuber borne diseases at massive scale causing poor yield. However, the problem has been resolved upto greater extent by multiplication of seed tubers through tissue culture and aeroponics system which needs to be given serious concern and required to be promoted throughout the developing world (Buckseth *et al.*, 2016; Buckseth *et al.*, 2018). In this chapter, an effort has been made to review the relevant research work on standardization of basic components in aeroponics system for production of mini-tuber seed potato. The information from various sources have been collected and presented under following headings:

- 2.1. Influence of planting dates on growth and yield of potato cultivars
- 2.2. Growth and yield of different potato cultivars
- 2.3. Influence of plant spacing on growth and yield of potato cultivars

### **2.1. Influence of planting dates on growth and yield of potato**

Mendoza and Estrada (1979) had deciphered that temperature is major production constraint in potato cultivation and the variation temperature during various growth and development phase of plants and tubers results in reduced production of potato tubers. Thus, delayed planting in potato results in exposure to high temperature resulting poor tuberization. Similarly, Ronsen and Ekeberg (1979) had also established that sowing at the first two dates result into alike yield of potato tubers but at the same time late planting may lead to less yield.

Birhman *et al.* (1980) revealed that there is maximum difference in number of potato tubers and yield when planting dates were 5<sup>th</sup>, 15<sup>th</sup> and 25<sup>th</sup> October. Ahmad and Rashid (1980) recorded maximum tuber yields planted on 23 November but potato tuber size was increased with postponement in planting time. Emergence reduction was recorded

from 98.6-100 to 82.5 per cent by the later planting date. Number of stems per hill and stem height were not influenced.

Das (1981) established that deferring planting dates beyond 1<sup>st</sup> March to 15<sup>th</sup> April declined shoot emergence rate. Highest tuber yield of 23.05 t/ha was acquired by sowing on 1<sup>st</sup> March and deferred planting (beyond this date) expressively reduced the tuber yield. They have further concluded that this reduction might be associated with restricted vegetative growth which is required for formation of photosynthates.

Ewing (1981) recorded that tuber initiation was favoured by temperature but lower than 20°C. When conditions are comparatively hotter means temperature was more than 18-20°C, it stimulated haulm growth along with depression of tuber yield. Rioux *et al.* (1981) evaluated the influence of planting dates on growth and quality of potato under wet and cold soil conditions. They obtained higher yield after 90 days when planted during mid-June than at the end of May month. Nevertheless, higher yield was achieved with the earlier planting dates after 110 days of after planting. But yield after planting of 130 days was not meaningfully altered from yield at 110 days. Total yield after 90 days of planting was higher in plots sown in May than in sown in the end of May month, though after planting of 110 days there was no substantial alteration in yield.

Kondratowicz and Paprocki (1981) perceived that fresh yield of tubers was declined with deferment in planting date from 4<sup>th</sup> May to early June. It was noted that late planting on 1<sup>st</sup> June declined average tuber yield to 26.5 t/ha in comparison to 30.0-32.0 t/ha when planting time was on 4<sup>th</sup>, 20<sup>th</sup> April or 18<sup>th</sup> May.

Samul (1982) observed that tuber number per plant and potato tuber yield improved in the early planted crops. He also perceived that postponement in planting time, date declined the number of tubers per plant in various cultivars. Haulm gave least yields at flowering stage while greater with early planting date. Tuber number per plant was advanced in cultivar Prosna and Nysa than in cultivar Notec.

Jones and Allen (1983) described that delayed sowing time only improved yield in the early variety which had the smaller leaf surfaces. Simultaneously, in main crop time of planting had very little influence on final yield. White and Sanderson (1983) described that deferred planting (18<sup>th</sup> May) decreased the yield of potato cultivar Russet Burbank. Five

potato varieties viz., Bintje, Cardinal, Desiree, Spunta and Redosa were sown on date 20<sup>th</sup> February, 1<sup>st</sup> and 10<sup>th</sup> March and variance in tuber germination was detailed.

Bhatti *et al.* (1984) stated that potato planting on date 15<sup>th</sup> October gave the highest tuber weight and length. Caliskan and Incekara (1984) described that sowing in months of January, February and March resulted in higher yields, while moderate yields during July and August and in May and June low yields. Cardiz *et al.* (1985) established that potato tubers in month December planting were biological considerably smaller than those obtained from November month planting in two varieties of medium-late and medium-early. During experiment, no consistent influence upon tuber production was observed.

Sharma and Verma (1988) recorded that tuber got from 30<sup>th</sup> October confined more Ca Cu, Fe, Mg and P content in comparison to other dates of planting in cultivars viz. Kufri Chandramukhi and Kufri Sindhuri. The experiment was lasted two years under field conditions at Kanke, (Rachi) in rabi season.

Gupta (1990) recorded maximum plant population when planting was done on 22<sup>nd</sup> April under Ambikapur (M. P.) conditions while planting on 12<sup>nd</sup> May and 22<sup>nd</sup> May reduced plant population. Gupta *et al.* (1991) described that potato crop sown on 20<sup>th</sup> October resulted in the highest tuber production, trailed by the crop, planted on dated 10<sup>th</sup> October and 30<sup>th</sup> October. Deferral planting after 20<sup>th</sup> October declined the tuber yield significantly. These losses of yield increased with late planting and planting during 30<sup>th</sup> November resulted in the lowermost yield in variety Kufri Chandramukhi under Ambikapur conditions.

Kabir *et al.* (1991) stated that potato cultivar Patrones seems to be more reactive to early sowing, while cv. Kufri Sindhuri to late planting and cultivar Cardinal to middle November planting time. They concluded that Kufri Sindhuri yielded maximum production trailed by cultivar Patrones and Cardinal. From experiment they concluded that potato tuber yield inclined with the deferred planting date while late sowing gave the highest yield trailed by sowing on 1<sup>st</sup> November and 15<sup>th</sup> November. Krishnanappa *et al.* (1991) described that late planting after 30<sup>th</sup> November in Karnataka resulted in the lowest weight of tuber per plant.

Ezekiel and Bhargava (1992) stated that potatoes cultivar Kufri Bahar and cv. Kufri Badshah were planted on 21<sup>st</sup> October, 5<sup>th</sup> November or 20 November, 1988 and on 16

October, 1st November or 15 November, 1989 at New Delhi, India. Certain characters like plant height, leaf number, internodes length, and potato tuber yield, were declined with delayed planting, but number of tubers per plant was the maximum with the late planting. They perceived that low yield of potato tubers acquired in the early crop was primarily due to a lesser and small canopy, which leads to diminished interception of solar radiation while high temperature conditions during early crop season depressed tuber production through reduced subdividing of photosynthates to the tubers.

Lommen and Struik (1992b) had also confirmed the mini-tuber production as function of plant spacing and the high-density planting with continuous harvest under hydroponic system and deep-water culture with inert growing media is more suitable for mini-tuber production in potato.

Ewing and Struik (1992) discovered that vegetative growth in potato may be categorized into four developing stages from planting to emergence of shoots to initiation of tubers and from initiation (tuber) to the development of highest leaf area and from leaf area to harvest process. Further, early planting of cultivars increased water requirement while later planting reduced the tolerance of against surplus water.

The findings of Roy *et al.* (1994) and Van der Veen and Lommen (2009) were similar for lowest planting density for potato as 25 plants per m<sup>-2</sup>. However, a significant variation was reported between results of both experimentations. Roy and co-workers have reported relatively higher number of mini-tubers plant<sup>-1</sup> as 11.1, but Veen and Lommen have obtained only 5.4 mini-tubers. The number of mini-tubers, size of mini-tubers and yield of mini-tubers were greatly influenced by planting density with negative correlation for size and yield while positive with number of mini-tubers. It was reported that as planting density increased the yield and size of mini-tubers was decreased while the number of mini-tubers per plant was increased when observed after 10 weeks of planting.

Nooruddin *et al.* (1995) established that the early planting of tubers improved small grade tubers (21%) but simultaneously late planting yielded the maximum large grade tubers (28%). Early planting dates resulted in maximum yield. Both types of yield were decreased markedly, especially during low rainfall. Tuber yield in Stobrawa and Bobr and production of seed tuber in cultivar Atol were not reliant on planting time. Deferred planting caused the maximum decrease in tuber segments with a diameter of 4 cm or above,

seed tuber weight reduced and mean tuber weight, but improved the number of seed tubers/plant. Production of Seed tuber yield drop down more in late varieties.

Saini *et al.* (1996) described that Potato cultivar Kufri Jyoti when sown in row at a distance of 30, 45 or 60 cm on 25th April, 10th or 25th May or 6th June under conditions of H. P. potato tuber yield was decreased by postponing planting. Yield of large sized potato tubers (> 51g) were maximum when sowing was done on 25th April and at distance of 45 cm apart.

Karafyllidis *et al.* (1996) established that deferring the summer planting by 2-3 weeks from the normal date, consistent and better growth with advanced per cent age of lastly surviving plants and advanced marketable and total yield is predicted (Onder *et. al.*, 2005).

Nandekar and Sharma (1997) stated that plant stand was highest at 20<sup>th</sup> planting of November trailed by plantings of 10<sup>th</sup> November and 30<sup>th</sup> October. The yield was reported to be highest when planting was done on 20<sup>th</sup> October followed by 30<sup>th</sup> October and 10<sup>th</sup> November. The potato cultivar Kufri Badshah was reported to give higher yield with lower incidence of Potato Leaf Roll Virus (PLRV) even for late sowing potato in Satpura Plateau and Madhya Pradesh. Large size tubers along with higher yield were achieved from 3<sup>rd</sup> week of November planting trailed by 1st week of December and 3rd week of December.

Roy and Jaiswal (1998) had also reported high yield in October planting. It was established that planting date 25<sup>th</sup> October was verified economically superior to planting date of 15<sup>th</sup> October. Highest tuber yield of 13.59 t/ha was achieved from planting on 15<sup>th</sup> November while the lowest tuber yield of 8.68 t/ha from 15<sup>th</sup> December planting.

Patel *et al.* (2000) carried out a field experiment to assess the effect of planting time on the yield and quality of two potato varieties viz. Kufri Lauvakar and Kufri Badshah. In this experiment 3 planting times were accessed 3<sup>rd</sup> week of November (D1); 1<sup>st</sup> week of December (D2); and 3<sup>rd</sup> week of December (D3). The highest yield and large-sized (>100g) potato tubers were yielded in D1. Weight of small-sized (0-50g) tubers was lowermost in D1 while number of average sized (51-100g) tubers was higher in cv. Kufri Badshah than in cv. Kufri Lauvalkar. Based on yield and quality, D1 date was considered superior planting date for the middle Gujarat agro-climatic zone.



Yenagi *et al.* (2002) recorded higher tuber yield of 12.76 t/ha in cultivar Kufri Chandramukhi at early planting i.e. 18th June, but when delayed planting on was there i.e. 25th June and 10th July declined in tuber yield by 10.03 and 20.45 per cent, respectively was recorded. Higher tuber yield was obtained when planting done on June 18th due to increased yield constituents viz., tuber weight and number of tubers per plant.

Herceg *et al.* (2003) perceived that locations and planting dates had important effects on yield and quality of tubers in potato cultivation. Potato tubers sown on 23<sup>rd</sup> February resulted in higher yield than planted on later date i.e. second and third dates.

Yenagi *et al.* (2005) described improved yield by early planting of cultivar Kufri Chandramukhi could be accredited to more plant height, and led to increase production of total dry matter. All these factors were diminished with deferred planting date.

Kawakami *et al.* (2005) recorded the effect of planting date on the growth traits and yield of potato plants produced from traditional seed tubers (CT) and micro tubers (MT) of potato. Conventional Tubers of about 50 g and micro tubers of 1 to 3 g of early cultivar (Kitaakari) and late cultivar (Norin 1) were sown at Hokkaido University, Japan, on May 13<sup>th</sup>, June 4<sup>th</sup> and June 25<sup>th</sup>, and various parameters like, growth and yields etc. were studied. Linear increase in leaf area index happened later, but afterwards it was higher in micro tubers than in traditional seed tubers, regardless of planting date and cultivar. Formation of tuber was later in micro tubers plants than in traditional seed tubers plants of both varieties, but this variation was very small on the last planting time. Linear increase in dry weight happened later in micro tubers plants than in traditional seed tubers plants, but the rate of increase was analogous in micro tubers and traditional seed tubers plants of both varieties and on all planting times. When planting date was delayed reduction in tuber yield was recorded, primarily due to the restriction of growing period in micro tubers and traditional seed tubers plants. In spite of the climatic deviations among the planting times, micro tubers plants produced 71 to 90% of fresh weight (tuber) relative to traditional seed tubers plants, suggesting that micro tubers are a decent substitute as propagules for potato tuber cultivation in those countries where seed production is problematic.

Malunjkar and Solanke (2007) had also established that planting of tubers on early resulted in higher yields while yield was decreased at later stages. This might be associated with higher temperatures during tuberization.

Kumar *et al.* (2009) described the interaction effect of cultivars and planting dates and reported a significant variation for growing traits and yield parameters with exception of plant emergence at 26 and 30 days after planting. Kufri Badshah was reported with highest foliage weight for planting on 10<sup>th</sup> Novemebr; Kufri Pukhraj had meaningfully maximum value for stems count per hill when sown on 20<sup>th</sup> October; Kufri Pushkar gave maximum total yield (456.32 q/ha) when planted on 20<sup>th</sup> October, which was trailed by Kufri Bahar planted on 10<sup>th</sup> October, other varieties like K. Badshah and K. Pukhraj also gave improved tuber yield when planting on 20<sup>th</sup> October. Similarly, plant growth parameters like plant emergence (%) at 14 days after planting, number of leaves per stem, plant height at 45 days after planting along with leaf area index with planting date on 20<sup>th</sup> October.

Mobini *et al.* (2009) had reported a significant increase in LAI, root to shoot ratio, tuber yield, dry matter content of tubers and number of mini-tubers due to supplementary aeration in hydroponic system. The favourable concentration of oxygen near the root zone enabled better nutrient utilization so had resulted in efficient root growth, greater number of stolen per plants and more and large size tubers (Ritter *et al.*, 2001).

Singh *et al.* (2010) recorded maximum yield in potato crop planted on 29<sup>th</sup> October and 15<sup>th</sup> November, while minimum yields were acquired from 1<sup>st</sup> October. A steady increase in the yield was noted with delayed planting towards the optimal date i.e. end of October month, beginning or middle of November at Gwalior and Kota.

Khan *et al.* (2011) stated that delay in planting resulted in increased total number of stems. Per cent age of large sized tubers (>55 mm) and total number of tubers per unit area were maximum when planting was done earlier in September compared to later planting.

Abdullateef *et al.* (2012) had reported a greater number of mini-tubers per plant at closer spacing or low density (25 plants m<sup>-2</sup>) in comparison to wider spacing or low plant density (35 and 50 plants m<sup>-2</sup>).

Though, dry matter was obtained when delayed planting was done. At the same time more plant biomass was resulted by earlier planting. Sandhu *et al.* (2012) described the processing type cultivars like Kufri Chipsona-1 along with two exotic ones viz. Atlantic and Lady Rosetta including table variety Kufri Pukhraj. All these cultivars were assessed

in relation to various planting times and cuttings from haulm (70, 80 and 90 days after planting) at Punjab and highest yield was recorded with October plantings. Kufri Pukhraj was reported with high processing grade potato tubers; however, processing qualities were poor.

Rykaczewska (2016) had also reported 32.5-36.0 mini-tubers per plant and 1268-1396 m<sup>-2</sup> as per the type of cultivars at lower spacing plantation of potato under aeroponic system. The aeroponic production of mini-tubers was 2-3 times that of traditional methods. This method is essential for the production of seed potatoes (Brocic *et al.*, 2018). Further, tuber multiplication rate was very high in aeroponic system in comparison to conventional method.

Many of the authors have reported that planting time of tubers regulates the vegetative growth and late planting led to more vegetative growth resulting taller plant with additional number of leaves and shoots.

## **2.2. Growth and yield of different potato cultivars**

White and Sanderson (1983) assessed the effect of three planting durations on potato varieties Kennebec and Notted Gem. Planting during Middle-May resulted in the maximum mean total yields. Late and mid-June sowing reduced mean total yields of variety Notted Gem by 9 and 28%, correspondingly 5 and 13% for variety Kennebec. Taja *et al.*, (1984) accessed that highest tuber yield of 14 t/ha at early planting date i.e. 9<sup>th</sup> December. Reduction in yield was noted with late planting dates (4.6 t/ha) from 21 January planting date. Less marketable tuber yield was also recorded with later planting time. Matlob and Mahmood (1984) explained that potato cv. Radosa Cardinal, Spunta Desiree and Bintej planted on 20<sup>th</sup> February, 1<sup>th</sup> March and 10<sup>th</sup> March and potato cultivars viz. Sunta and Radosa resulted in the highest mean tuber yields of 7.63 and 6.86 t/donum [1 donum =0.25 ha]. Lesser yields were recorded with late planting date. At the same time the highest and early yields were obtained in potato (8.32 t/ha) crops planted on 20<sup>th</sup> April and harvested on 10<sup>th</sup> July.

Khurana and Pandita (1986) recorded decrease in tuber yield was resultant of late planting in Kufri Sindhuri and Kufri Chandramukhi. Higher Tuber weight was observed in case of Kufri chandramukhi than that of Kufri sindhuri during the early growth stages, but senescence was happened later in Kufri Sindhuri and noted higher yield. They also deliberated the impact of date of planting on leaf and tuber advancement in 2 potato

cultivars, planted on 18<sup>th</sup> and 22<sup>nd</sup> October. Markedly decreased the leaf weight was recorded in Kufri Chandramukhi throughout the growth period compared with planting on earlier periods. Planting during late times also decreased the leaf mass in potato cultivar Kufri Sindhuri during the early phases of growth period, but no significant was noted during later growth phases.

Moharam and Abdul (1987) recorded higher yield in cv. Spunta than Claustar but there was no variance in unmarketable potato yields between these two cultivars. Cultivar Spunta produced better marketable and total yields along with yield per plant and planting done on 1<sup>th</sup> and 15<sup>th</sup> August. Among these planting dates, Maximum and marketable yields, yield per plant was obtained when planting was done on 1<sup>st</sup> or 15 February.

Sharma and Verma (1988) stated that planting during 30<sup>th</sup> October resulted in higher yield than later or earlier planting of cultivar Kufri Sindhuri and Kufri Chandramukhi. Yield increased with postponement in harvesting. At the same time, Kufri Chandramukhi resulted in average yield of 12.3 q/ha but less than Kufri Sindhuri. They further established that potato tuber yield acquired from 30<sup>th</sup> October contained more Ca P, Mg, Ca and Fe content in comparison with other planting dates in potato cultivar Kufri sinduri and Kufri Chandramukhi in two consecutive years field study conducted at Kanke (Ranchi).

Gupta *et al.* (1991) proved that cultivar planted on 20<sup>th</sup> October resulted in the maximum tuber yield, trailed by planted on 10<sup>th</sup> October and 30<sup>th</sup> October. Late planting after 20<sup>th</sup> October decreased tuber yield evidently. Further decrease in yield losses were noted with late planting and 30<sup>th</sup> November planting resulted in lowest yield in potato cultivar Kufri Chandramukhi at Ambikapur. Sharma and Parsad (1999) also stated that late planting of potato cultivar Kufri Badshah resulted in reduced yield.

Gronowicz *et al.* (1992) revealed the planting date effect of (20<sup>st</sup> April, 5<sup>th</sup> May and 18<sup>th</sup> May) and cultivars (Bogna, Foka and Ceza) on potato and found that production from these cultivars were 41.3, 30.1 and 34.1 t/ha, correspondingly for the 20<sup>st</sup> April was slightly lower and fell to 31.6, 20.7 and 25.1 t/ha for latter planting dates. Nandekar *et al.* (1994) carried out an experiment on potato cultivars viz. Kufri Chandramukhi, Kufri Jyoti, Kufri Bahar, Kufri Lauvkar, Kufri Lalima, Kufri Deva, Kufri Badshah, Kufri Chamtkar and Kufri Sindhuri planted between months of November and February in 1987-89 and 1988-89, respectively. During first year Kufri Badshah gave maximum yield (374.22 q/ha) trailed by Kufri Bahar and Kufri Jyoti but in 1988-89, variety Kufri Bahar resulted into highest yield (349.86 q/ha), trailed by Kufri Badshah, Kufri Jyoti and Kufri Lalima.

Snieg and Ludko (1995) carried research trials (1985- 89) and recorded that average yield of 20 potato varieties was 39.6 t/ha when planting date was 18<sup>th</sup> April and declined by 5.1 and 24.5% when sowing was delayed until 16<sup>th</sup> May, correspondingly. delaying planting responded until 16 May and it was minimum in Ceza Dukat, Bogna, Mila and Jogoda (reduction 21.0%) and maximum in Fauna, Bzura, Bobn, Irga, Bronka and Marta (average 35.8%). Sharma and Parsad (1999) accessed under Delhi conditions in Kufri Badshah that mean yield (35.4 t/ha) was the highest and planting date was 30<sup>th</sup> October and yield was the lowest (20.2 t/ha) when sowing on 20<sup>th</sup> November.

Yilmaz & Tugay (1999) proved under Turkey conditions that when potato cultivars viz. Yaylakizi, Isola, Resy, Gronola and Sultan were sown on 9th and 17th July 1993 and on 13th and 20th July 1994 higher yields were obtained at the earlier sowing time like in cultivar Sultan yield was 2154.7 kg/da, Rosy (2068.7 kg/da) and Yaylakizi (2151.3 kg/da).

Patel *et al.*, (2000) conducted research work to study the effect of planting time on quality and yield of two potato varieties named, Kufri Lauvkar and Kufri Badshah. Three planting times were assessed i.e. 3<sup>rd</sup> week of November, 1<sup>st</sup> week of December and 3<sup>rd</sup> week of December. Maximum yield and highest number of potatoes were produced during 3<sup>rd</sup> week of November month planting while the number of small-sized (0-50 g) tubers was meaningfully lowest. Number of medium-sized potato (51-100 g) tubers was higher in cultivar Kufri Badshah than in cultivar Kufri Lauvkar. Based on tuber quality and yield, planting during 3<sup>rd</sup> week of November was considered superior under middle Gujarat agro-climatic conditions. Bak and Aminpour (2001) revealed the effects of planting during late October, early February and early March and at depth of 10 and 20 cm on yield of three potato cultivars (Cosima, Morene and Marfona). Marfona cultivar produced maximum overall yield (40.39 t/ha) while large-sized tuber yielded (27.84 t/ha) and these were meaningfully varied from those of the two other varieties.

Oraby *et al.* (2015) proposed that production of potato tubers in aeroponic systems by cooling down the nutrient solution to 18°C temperature can increase number of tubers under high summer. Rolot and Seutin (1999) and Farran and Mingo-Castel (2006) had also reported that the number of mini-tubers per sq. meter is function of cultivars as well as planting density.

Srivastava *et al.* (2016) standardized the geometry of potato crop under net house conditions with micro-plants of two popular cultivars viz. Kufri Girdhari and Kufri Himsona. These cultivars were planted at two spacing viz., 15 x 10cm and 20 x 10cm at C.

P. R. S., Shillong during 2013-14. Growth and yield were reported to be significantly influenced by varieties and spacing with high plant survival (> 80%). Closer planting (15 x 10cm) had resulted improvement in plant height and canopy. Kufri Himsona showed better stem height, stems per plant, number of leaves per plant, improved canopy cover, tuber weight and numbers of mini-tubers per plant and per unit area in comparison to Kufri Girdhari. Kufri Himsona produced more big size tubers as compared to cultivar Kufri Girdhari. The number of tubers per plant was recorded better at closer planting (15 x 10cm) while improved yield per plant was recorded in wider spacing (20 x 10cm) due to more competition for space, sunlight and nutrients, leads to increased number of tubers per plant but successive reduction in total tuber yield per plant at narrow spacing. At narrow spacing more little sized tubers were collected (<3g to 20g) while at wider spacing larger sized tubers were obtained (over 20g).

Thus, depending on the seed size prerequisite and accessibility of area under net house conditions, narrow as well as wide spacing can be adopted for production of mini-tubers from potato plants in N E Himalayan region.

### **2.3. Influence of plant spacing on growth and yield of potato**

Standardization approach of planting densities may cause to higher production of mini-tuber and will maximize the use of green house facility (per square meter) and reduction in cost tuber production.

Lommen and Struik (1992b) defined a substantial decline in tuber yield (1130 mini-tubers per m<sup>2</sup>) and tuber count per plant by increasing planting density (50 plants m<sup>-2</sup>). They had also stated a sharp decline in tuber yield and tubers number per plant by inclining planting density in media with harvesting again and again. Similar interpretations were defined by Struik and Lommen (1990). They acquired with harvesting (repeated again and again) up to 3500 tubers/m<sup>2</sup> of small size (>5 mm) using high planting densities up to 800 plants/m<sup>2</sup>. But, under agro-climatic conditions there is requirement of larger number of mini-tubers (>20 mm) to obtain a satisfactory yield.

Kim *et al.* (1997) revealed that maximum production of mini-tuber production was possible to obtain by aeroponics technique with harvesting intervals of 10 days. This experiment indicated that used planting density, along with irradiation, was too good to support such a small harvesting Interval.

Rolot and Seutin (1999) acquired up to 600 mini-tubers  $m^2$  in hydroponics at planting density of 59 plants  $m^{-2}$  but 802 tubers were obtained at plant density of 60 plants  $m^{-2}$  by Farran and Mingo-Castel (2006) under aeroponic approach.

Ritter *et al.* (2001) had reported postponement of tuberization and extension of crop cycle upto 7 months of cultivar Ngore under aeroponic system. Though the crop cycle duration was influenced by potato genotypes, the deviation in growing conditions and cropping seasons had ideal effect for tuber development and accordingly acceleration for shoot senescence.

Farran and Mingo-Castel (2006) improved production of mini-tuber through aeroponics technique by some horticultural management aspects. Potato cultivar, cv Zorba, was planted aeroponically at two various plant densities i.e. 60 and 100 plants/ $m^2$ . They have recorded extension of vegetative growth cycle after transplanting with increased stolons count at lower plant densities; accelerated tuber formation with lower N application; improved number (13.4 tubers with average weight of 8.1g) and production of mini-tubers (800 tubers  $m^{-2}$ ; 118.6 g  $plant^{-1}$ ) at plant density of 60 plantlets  $m^{-2}$  and decreased harvesting interval (every 7 days). Nevertheless, number of mini-tubers and yield were not influenced by harvesting intervals when planted at higher density (100 seedlings  $m^{-2}$ ).

A study was conducted by Mateus-Rodríguez *et al.* (2011) to evaluate performance of three potato cultivars under aeroponics system. The observation taken on number of days taken for tuberization, plant growth parameters and yield of tubers was reported to show significant variations between treatments with highest number of mini-tubers per plant (71.7, 56.2 and 30.6) in cultivars Chucmarina, Serranita and Yana Imilla, respectively. The range of average tuber yield and tuber weight was recorded as 197.6-860.2 g  $plant^{-1}$  and 6.3-12.1 g  $tuber^{-1}$  for all cultivars under study. Thus, the suitability and viability of aeroponic potato cultivation for these varieties for potato seed tuber production is justified.

Abdullateef *et al.* (2012) obtained the highest mini-tubers per plant at planting density of 25 plants per  $m^2$ . But planting density was not affected that yield per  $m^2$ . Average of 805 mini-tubers  $>20$  mm (when planting density was 25 plants per  $m^2$ ) could be harvested per  $m^2$  associated with 11.2 and 10.4 kg per  $m^2$  for 35 and 50 plants per  $m^2$ , respectively.

Tsoka (2012) used *in-vitro* plantlets and apical stem cuttings for the assessment of potato seed tuber production under aeroponics and confirmed the potential of *in-vitro* plantlets for potato seed tuber production. The *in-vitro* plantlets yielded significantly high number of seed potato tubers ( $24.3 \text{ plant}^{-1}$ ) while it was very lower in apical stem cuttings ( $3.4 \text{ plant}^{-1}$ ).

In a trial, Chiipanthenga *et al.* (2012) had also recognized that meristem culture has produced good number and quality of potato tubers seed which are free from pathogenic contamination. This system was found to have great potential of increase in income and reducing cost of production of quality seed, thereby, enable availability of quality potato tuber seed to the potato growers of developing world where quality and disease-free seeds are constraint. Thus, aeroponic system has potential for revolutionizing the potato seed production.

Pathania *et al.* (2014) has also confirmed the application of aeroponic technology for production of low cost mini-tubers in tropics. They have harvested a highest number of first-generation potato seed tuber in cultivar Nicolo ( $>900 \text{ mini-tubers m}^{-2}$ ) followed by Sebago ( $630 \text{ mini-tubers m}^{-2}$ ). They were able to take five crops in two years where tubers were free from soil borne disease. Similar findings had been reported by Mateus-Rodriguez *et al.* (2011) and Rykaczewska *et al.* (2016) who had recorded more than 900 mini-tubers and 1268-1396 mini-tubers per sq. m., respectively. Performance, physiology and post-harvest handling practices of producing mini-tubers by aeroponics have to be systematically explored under dissimilar climatic environments. The training system, bower, was effectively applied to enhance yield in the aeroponic system where vegetative advancement was maximum (Buckseth *et al.*, 2016).

Wang *et al.* (2017) conducted an experiment on influence of plant density on yield and composition of potato tubers. They stated that planting density had a very intense influence on both tuber weight and number produced per unit area and on a per plant basis. On a unit area base,  $63 \text{ plants m}^{-2}$  was the optimal for tuber weight production per unit area. However, the potato tuber production is reliant on taken cultivars (Rolot and Seutin, 1999) and rate of multiplication in aeroponics technique is much advanced (Struik and Wiersema, 1999). This might be associated with the frequent harvesting of the foremost larger potato tubers, which permits the commencement of formation of new tubers and the improvement in existing tubers.



Terentieva & Tkachenko (2018) had advocated for aeroponic production of potato mini-tubers. got much attention in agrobiotechnology and agriculture. Search for new, effective growth regulators that can provide stably stable yields, including under abiotic stress in aeroponic based potato mini-tubers production. Proper aeration to the hydroponic system provides sufficient oxygen to root systems for growth and development to ensure high production of mini-tubers as confirmed by Mobini *et al.* (2015) while Brocic *et al.* (2018) advocated for mini-tubers production in potato through aeroponic system.

Different potato cultivars require specific-nutrient solution for mini-tuber production under the aeroponics system. It is necessary to have sufficient information on requirements for formulation of optimal nutrient solution. Such an ideal solution will be able to supply necessary elements to the plants for production of maximum tubers and minimize the susceptibility to abiotic and biotic stresses. It needs timely adjustment based on the existing growing condition of a variety and the agro-ecology. It can be inferred that various nutrient solutions expressively affected the root length, tuber number, size and weight (Tolessa, 2018).

From the various literature cited, it has been reported that aeroponic system can be the potential way of providing seed tubers to the farmers which can be healthy and disease free. Since this technique is in the initial phase in India so the major research centres like CPRI (Central Potato Research Institute, Shimla) and CPRS (Central Potato Research Station, Jalandhar) have to play vital role in progress of this technology.

## CHAPTER-IV

### MATERIALS AND METHODS

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The present investigations on the “**Agronomic performance and mini-tuber production of potato varieties under aeroponic system**” were carried out during two consecutive Rabi season of year 2016-17 and 2017-18 at Centre of Excellence for Potato, Village– Dhogri, under the supervision of School of Agriculture, Lovely Professional University, Phagwara. The experimental details to describe materials used and methodology followed during the study are dealt as:

#### 3.1. Geographical location and climate of Experimental Site

Centre of Excellence for Potato, Department of Horticulture, Village– Dhogri, District Jalandhar is situated at an altitude of 748’ above mean sea level, between 31.40 North latitude and 75.63 East latitude. It has a subtropical climate with cool winters and long, hot summers. The land of the district is covered by the alluvial deposits of Indus-Ganga and lies in the central plain regions. The summers season lasts during April - June and winters during November - February. The maximum temperatures in the summer was around 48°C (118°F) while minimum was around 25°C (77°F). The winter temperature ranged from a high value of 19°C (66°F) to a minimum of –1°C (19°F). The region is characterized by dry climate, except advent of small south-west monsoon during July – August with an average annual rainfall of 70cm.

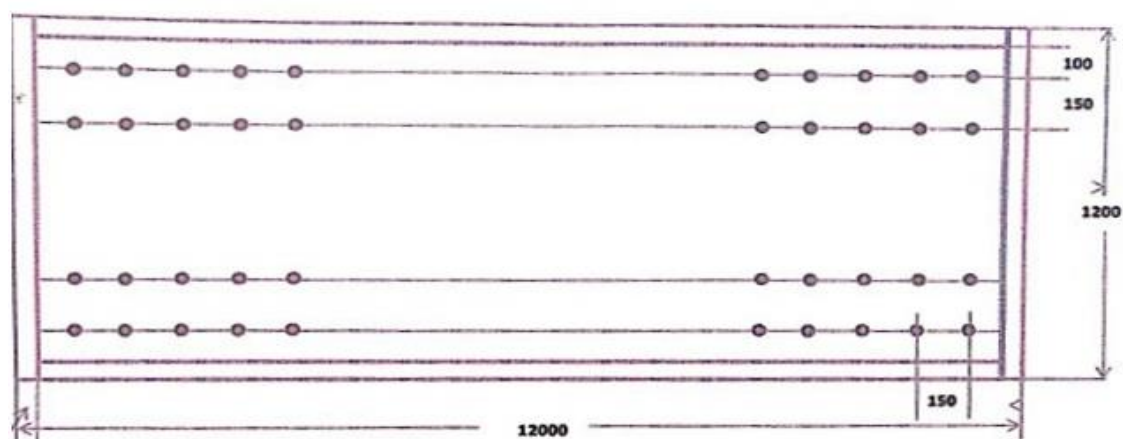
#### 3.2. Experimental Unit

The research work was carried out in the aeroponic system available at Centre of Excellence for Potato, Department of Horticulture, Village– Dhogri, District Jalandhar, Punjab, during the year 2016-17 and 2017-18.



### 3.2.1. Design of the aeroponic chamber for conducting study:

The power-dependent or pressurized aeroponic system (PAS) utilized electrical power in its operations. It utilized a high-pressure pump which was used to atomize the water through small orifice misters to create water droplets of 50 microns or less in diameter. Fertigation was automatically timed using irrigation timers.



All dimensions in mm

### 3.3. Experimental details

Experimental details for the proposed study on assessing the Standardization of fundamental components in aeroponics system for mini-tuber seed potato production.

#### 3.3.1. Factors:

Three factors were taken into account while undertaking this study. Details of these factors were elaborated below:

**(A) Varieties of potato:** The experimental material used during the study was three well-known cultivars of Potato viz. Kufri Jyoti ( $V_1$ ), Kufri Pukhraj ( $V_2$ ) and Kufri Khyati ( $V_3$ ) which were released by Central Potato Research Institute, Shimla. The characterization of the cultivars is given below:

- i) Kufri Jyoti [3069d (4) x 2814a (1)]: It was released in 1968 for commercial cultivation. The variety can be characterized by: compact canopy; green stems with red-brown pigmentation scattered throughout; ovate leaflet; white flowers; white-cream and ovoid tubers with shallow eyes and cream flesh; red-purple sprouts; recommended for growing under hilly regions, plains and plateau; 200-300 q ha<sup>-1</sup> yield; medium maturity period and good storability; moderately resistant to early and

late blight; immune to wart disease; susceptible to charcoal rot, viruses and cyst nematodes; easy to cook with waxy texture and mild flavor; good for processing and free from after- cooking discoloration.

- ii) Kufri Pukhraj [Craigs Defiance x JEX/B-687]: It was released in 1998 for commercial cultivation. The variety can be characterized by: semi-compact canopy; green stems with purple pigmentation scattered throughout; ovate-lanceolate leaflet; white flowers; yellow and ovoid tubers with shallow-medium eyes and yellow flesh; red-purple sprouts; recommended for growing under North Indian plains and plateau; 350-400 q ha<sup>-1</sup> yield; early to medium maturity period and medium storability; resistant to early blight and moderately resistant to late blight; immune to wart disease; easy to cook with waxy texture and mild flavor; good for processing and free from after- cooking discoloration.
- iii) Kufri Khyati [MS/82-638 x Kufri Pukhraj]: It was released in 2008 for commercial cultivation. The variety can be characterized by: semi-compact canopy; green stems with purple pigmentation scattered throughout; ovate-lanceolate leaflet; white flowers; white-cream and ovoid tubers with medium-deep eyes and yellow flesh; red-purple sprouts; recommended for growing under North Indian plains; 250-300 q ha<sup>-1</sup> yield; early maturity period and good storability; field resistant to early and late blight; easy to cook with waxy texture and mild flavor; good for processing and free from after- cooking discoloration.

The observation on various parameters was carried out over 540 plants of each cultivar. The tissue plantlets were further acclimatized with the existing atmosphere before they were transplanted in the aeroponic system. The varieties for this study were chosen from a point of view considering popular varieties in Punjab. The observations of potato plantation were recorded as per the standard procedures.

**(B) Dates of transplanting (sowing dates):** Four different dates of planting were used as listed below:

D <sub>1</sub>	15 October
D <sub>2</sub>	25 October
D <sub>3</sub>	5 November
D <sub>4</sub>	15 November

**(C) Plant spacing:** Three different plant spacings were used as listed below:

S <sub>1</sub>	7 X 7 cm
S <sub>2</sub>	14 X 14 cm
S <sub>3</sub>	21 X 21 cm

### 3.3.2. Layout of details of the experiment:

A total of 3X4X3= 36 treatment combination has been studied. Fifteen plants were taken per replication for observation. The details of the layout are given below:

Number of treatment combinations	36
Number of plants per treatments	15
Number of replications	3
Design for data analysis	Split plot design
Crop Cycle	One
Years of observation	2016-17 & 2017-18

### 3.4. Observations recorded

#### 3.4.1. Plant height:

The height of each tagged plant was measured successively at 45, 60, 75 DAP (days after planting) from the base to the tip of longest leaf by stretching. It is measured with the help of meter scale and the data were recorded in centimetre (cm). The mean plant height was obtained by summing up the length of five plants and dividing by five.

#### 3.4.2. Root length:

The root length measured from the suspended stem to the tip by using a hand measuring meter and average value was expressed in cm.

#### 3.4.3. Plant spread:

Plant spread is the maximum width of the plant as measured at its widest part from leaf tip to leaf tip at maturity.

#### 3.4.4. Root number:

Root number was counted from the rooting primordia. It is recommended the plant have to be removed from its growing medium in order to capture accurate data. One technique is

grid intersection technique in which we dye the roots using an acidic stain and later lay the roots on a grind pattern and count the number of times the roots intersect the grid.

#### **3.4.5. Initiation of tuber formation:**

After stolon formation, evaluation of tuber formation is continuously checked. Number of days taken for tuber initiation was counted from date of planting.

#### **3.4.6. Number of mini-tubers (2.5-3.0g) per stolon:**

Number of mini-tubers per stolon were manually counted and noted throughout the study.

#### **3.4.7. Number of mini-tubers (2.5-3.0g) per plant:**

Number of mini-tubers per plant was estimated by multiplying number of stolons with number of mini-tubers per stolon.

#### **3.4.8. Number of tubers under different tuber size (Large, medium, small):**

The mini-tubers were categorized into two grades i.e. normal weight = 2.5 to 3.0 g and underweight < 2.5 g while the tubers with weight more than 3.0g are large sized. The number of tubers under different grades were counted while the weight was taken by using digital weighing balance and was expressed as gm per plant.

#### **3.4.9. Number of days taken for first picking:**

The date at which tubers were harvested first time was noted and number of days were counted from date of planting.

#### **3.4.10. Total crop duration in days:**

Days from planting date to harvesting date was counted which was considered as duration of the potato crop under aeroponic.

#### **3.4.11. Tuber yield per plant:**

To calculate the cumulative tuber yield, the tubers were assorted into different weight grades. The sum of the weight within each grade divided by total fresh matter gives the proportion per grade. Mini-tubers of 2.5 to 3.0 gms are considered as suitable size. Weight of these mini-tubers after the harvest was noted for data analysis. For calculating yield per

plant, the average weight of the tubers multiplied by number of required size tubers per plant. Tubers were divided into three categories as below:

- i. Normal weight tubers = weight of tubers (2.5 to 3.00gm)/total yield
- ii. Underweight tubers = weight of tubers (<2.5gm)/total yield
- iii. Overweight tubers = weight of tubers (>3.0gm)/total yield

### 3.4.12. Harvest index:

The harvest index was calculated by dividing the economic yield by total biological yield and expressed as per cent. The biological yield is the biomass of potato plants measured as the fresh weight of vegetative parts above ground.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield above the ground}} \times 100$$

### 3.4.13. Economics of the treatments:

To work out the economic feasibility and cost of cultivation and benefit: cost ratios, the cost of production of potato crop was calculated based on different treatments. The cost of production was calculated based on current price of the inputs. Total expenditure was subtracted from total income to find out the net return and the benefit: cost ratio was calculated using gross returns and cost of production. The estimated data were tabulated as below:

Year	Input cost	Gross Income	Net Income	Benefit: cost ratio

### 3.5. Meteorological Observations

Meteorological observations for temperature ( $T_{\max}$  and  $T_{\min}$ ) in °C, relative humidity ( $R_H$ ) in percent, rainfall (RF) in mm and wind velocity in per meter recorded at the meteorological observatory of CPRS, Jalandhar. Thermohygrograph was used to record the mean temperature ( $T_{\max}$  and  $T_{\min}$ ) and relative humidity ( $R_H$  %) in aeroponic units.

### 3.6. Statistical analysis

Split plot design with three replications and 15 plants per replication with single factor in three varieties. Data was analyzed by using analysis software like Microsoft excel or SPSS.

# RESULTS AND DISCUSSION

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Aeroponic culture is one of the forms of soil less culture where the plants are provided with growth-controlled atmosphere and root system remains suspended in air and mist of nutrient solution. The aeroponic or hydroponic system has many advantages over the ground production which can be greater water and nutrient use efficiency ensuring an increased nutrient availability in recirculated systems and better cropping due to well managed nutrient availability and pH of growing media (Farran and Mingo-Caste, 2006; Mobini et al., 2009). Aeroponics ensures the proper exploitation of the vertical space of the green house with optimized root, tubers and foliage growth in potato plants; keep precise control over root zone nutrient and water regimes and environmental condition around the root system (Hayden et al., 2004). One of the foremost barriers in the achievement of optimum yield in potato is the lack of quality potato seed tuber with cost effectiveness. It is undoubtedly “AEROPONICS” technology is a master technology for disease-free mini-tuber production in the shortest interval in controlled conditions at conventional and non-conventional seed-producing areas leading to a ray of hope for the availability of disease-free mini-tubers for seed Potato. The present study on “Agronomic performance and mini-tuber production of potato varieties under aeroponic system” with three varieties viz., Kufri Jyoti, Kufri Pukhraj and Kufri Khyati of potato. The study was conducted with two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and three spacings viz., 7X7 cm, 14X14 cm and 21X21 cm. The results of study have been presented in this chapters with support of available literatures.

### 4.1. Plant height (cm):

The foliage is the fingerprint of the variety for its field identification. Vegetative growth and height of the plant plays an important role in increasing the rate of photosynthesis and the rate of assimilation of the photosynthates. The data recorded for plant height (Table-4.1), illustrated the variation in response of different potato cultivars under aeroponics system.



There was a significant effect of date of planting on vegetative growth potato plants grown under aeroponic conditions, the vegetative growth was maximum in the early part of crop season with Kufri Jyoti, showing maximum plant height (106.05 cm) followed by Kufri Pukhraj (71.88 cm) and Kufri Khyati (70.77 cm) for the crop sown on 15<sup>th</sup> October. A similar trend of plant height was reported for the plants sown on 25<sup>th</sup> October with maximum plant height in Kufri Jyoti (102.55 cm) followed by Kufri Pukhraj (68.95 cm) and Kufri Khyati (66.85 cm). However, a slightly different trend was reported when planting was done on 5<sup>th</sup> November with highest plant height in Kufri Jyoti (94.26 cm) followed by Kufri Khyati (62.12 cm) and Kufri Pukhraj (62.02 cm). Similarly, the highest plant height was observed in Kufri Jyoti (89.83 cm) followed by Kufri Khyati (60.10 cm) and Kufri Pukhraj (60.00 cm) when planting was done on 15<sup>th</sup> November. However, the mean plant height was maximum in Kufri Jyoti (98.17 cm) followed by Kufri Pukhraj (56.71 cm) and Kufri Khyati (64.96 cm) while the mean plant height was maximum in planting date of 15<sup>th</sup> October (82.90 cm) which was decreased till late planting and was 69.97 cm at the planting date of 15<sup>th</sup> November.

In response to spacing, the maximum plant height was observed in Kufri Jyoti (73.37 cm) followed by Kufri Pukhraj (51.23 cm) and Kufri Khyati (45.34 cm) when planted at spacing of 7X7 cm while a different trend with maximum plant height in Kufri Jyoti (108.75 cm and 112.40) followed by Kufri Khyati (71.85 cm and 77.70 cm) and Kufri Pukhraj (69.46 cm and 76.45 cm) when planted at spacing of 14X14 cm and 21X21 cm, respectively. Thus, it is evident from the observation that the plants with greater spacing were have significantly better vegetative growth with highest mean plant height at spacing of 21X21 cm (88.85 cm) followed by 14X14 cm (83.35 cm) and 7X7 cm (56.64 cm) for all varieties and all dates of planting.

It is evident from appendices (I - III) that the trend of plant height was similar for all factors under study. The average data for the crop season 2016-17 and 2017-18 studied for all the three factors viz. three varieties (Kufri Jyoti, Kufri Pukhraj and Kufri Khyati); four planting dates (15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November); and three plant spacing (7X7 cm, 14X14 cm and 21X21 cm) were analysed under split plot statistics and analysis of variance (ANOVA) for plant height has been presented. It confirms significant effect of cropping seasons, varieties, date of planting and plant spacing over plant height of potato. The interaction effect of variety x date of planting, year x

variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant while year x variety and year x date of planting interaction not significantly affected the plant height of potato.

**Table-4.1: Plant height (cm) of potato cultivars grown at different dates and spacing under aeroponic system**

Date of planting	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
D <sub>1</sub>	106.05	71.88	70.77	<b>82.90<sup>a</sup></b>
D <sub>2</sub>	102.55	68.95	66.85	<b>79.45<sup>b</sup></b>
D <sub>3</sub>	94.26	62.02	62.12	<b>72.80<sup>c</sup></b>
D <sub>4</sub>	89.83	60.00	60.10	<b>69.97<sup>d</sup></b>
<b>Mean (V)</b>	<b>98.17<sup>a</sup></b>	<b>65.71<sup>b</sup></b>	<b>64.96<sup>c</sup></b>	
<b>CD (P≤0.05)</b>				
<b>V</b>	<b>0.43</b>			
<b>D</b>	<b>0.75</b>			
<b>V X D</b>	<b>1.29</b>			
Plant spacing	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (S)
S <sub>1</sub>	73.37	51.23	45.34	<b>56.64<sup>c</sup></b>
S <sub>2</sub>	108.75	69.46	71.85	<b>83.35<sup>b</sup></b>
S <sub>3</sub>	112.40	76.45	77.70	<b>88.85<sup>a</sup></b>
<b>Mean (V)</b>	<b>98.17<sup>a</sup></b>	<b>65.71<sup>b</sup></b>	<b>64.96<sup>c</sup></b>	
<b>CD (P≤0.05)</b>				
<b>V</b>	<b>0.43</b>			
<b>S</b>	<b>0.03</b>			
<b>V X S</b>	<b>0.05</b>			
<b>S X D</b>	<b>0.06</b>			
<b>V X S X D</b>	<b>0.10</b>			

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November; Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm; V= Varieties]

The significant reduction in plant height due to delayed planting might be associated with availability of reduced time for vegetative growth in potato plants grown under aeroponic system. Further, wider spacing has resulted better utilization of nutrients and sufficient space availability to ensure better plant growth. The variation among varieties might be related to their differential response during interactions viz. V x S, V x D or V x S x D. The present finding is in conformity with the work carried out by Ezekiel and Bhargava (1992) who had confirmed the decline of certain characters like plant height, leaf

number and internode length with delayed planting. Similar finding was reported by Yenagi *et al.* (2005) who had advocated for more plant height in early planting of Kufri Chandramukhi cultivar of potato. While working on Kufri Girdhari and Kufri Himsona, Srivastava *et al.* (2016) have also reported significant effect of varieties and spacing for plant growth parameters.

#### **4.2. Root Length (cm):**

Root architecture is one of the most important factors in aeroponics and has to be studied from various angles as the growth of plant, rate of absorption of nutrients and stolon formation depends on these factors. The response of different varieties for spacing and planting dates was observed and presented in Table-4.2. All the three varieties Kufri Jyoti, Kufri Pukhraj and Kufri Khyati were studied under two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and plant spacing that are 7X7 cm, 14X14 cm and 21X21 cm.

It is obvious from the above table that root length is maximum in the early part of crop season with the trend in root length is Kufri Jyoti (106.76 cm) followed by Kufri Khyati (90.74 cm) and Kufri Pukhraj (86.96 cm) for the crop sown on 15<sup>th</sup> October. A similar trend was also noticed on other planting dates but the root length was showing decrease with the late season cropping. The root length trend for the crop sown on 25<sup>th</sup> October was Kufri Jyoti (132.57 cm) followed by Kufri Khyati (87.98 cm) and Kufri Pukhraj (84.67 cm). In the 5<sup>th</sup> November sown crop, the trend was Kufri Jyoti (100.57 cm) followed by Kufri Khyati (84.90 cm) and Kufri Pukhraj (80.16 cm). On 15<sup>th</sup> November sown crop, the trend was Kufri Jyoti (98.04 cm) followed by Kufri Khyati (82.70 cm) and Kufri Pukhraj (78.06 cm). So, it is inferred that mean root length in all the three varieties under study shows a general trend with Kufri Jyoti (102.24 cm) was leading followed by Kufri Khyati (86.58 cm) and Kufri Pukhraj (82.46 cm).

In 7X7 cm spacing, the root length for all the three varieties followed the trend that was Kufri Jyoti (75.62 cm) followed by Kufri Khyati (73.87 cm) and Kufri Pukhraj (70.97 cm). The root length trend for the crop sown on 14X14 cm spacing was Kufri Jyoti (113.15 cm) followed by Kufri Khyati (89.87 cm) and Kufri Pukhraj (86.06 cm). In 21X21 cm spacing sown crop, the trend was Kufri Jyoti (117.95 cm) followed by Kufri Khyati (96.01 cm) and Kufri Pukhraj (90.36 cm).

**Table-4.2: Root length (cm) of potato cultivars grown at different dates and spacing under aeroponic system**

Date of planting	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
D <sub>1</sub>	106.76	86.96	90.74	<b>94.82<sup>a</sup></b>
D <sub>2</sub>	103.57	84.67	87.98	<b>92.07<sup>b</sup></b>
D <sub>3</sub>	100.57	80.16	84.90	<b>88.54<sup>c</sup></b>
D <sub>4</sub>	98.04	78.06	82.70	<b>86.27<sup>d</sup></b>
Mean (V)	<b>102.24<sup>a</sup></b>	<b>82.46<sup>c</sup></b>	<b>86.58<sup>b</sup></b>	
<b>CD (P≤0.05)</b>				
V		<b>0.09</b>		
D		<b>0.02</b>		
V X D		<b>0.03</b>		
Plant spacing	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (S)
S <sub>1</sub>	75.62	70.97	73.87	<b>73.48<sup>c</sup></b>
S <sub>2</sub>	113.15	86.06	89.87	<b>96.36<sup>b</sup></b>
S <sub>3</sub>	117.95	90.36	96.01	<b>101.44<sup>a</sup></b>
Mean (V)	<b>102.24<sup>a</sup></b>	<b>82.46<sup>c</sup></b>	<b>86.58<sup>b</sup></b>	
<b>CD (P≤0.05)</b>				
V		<b>0.09</b>		
S		<b>0.02</b>		
V X S		<b>0.03</b>		
S X D		<b>0.04</b>		
V X S X D		<b>0.06</b>		

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November; Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm; V= Varieties]

It is evident from appendices (IV - VI) that the trend of root length was similar for all factors under study. The average data for the crop season 2016-17 and 2017-18 studied for all the three factors viz. three varieties (Kufri Jyoti, Kufri Pukhraj and Kufri Khyati); four planting dates (15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November); and three plant spacing (7X7 cm, 14X14 cm and 21X21 cm) were analysed under split plot statistics for root length and analysis of variance (ANOVA) has been presented. It confirms significant effect of cropping seasons, varieties, date of planting and plant spacing over root length of potato plants. The interaction effect of variety x date of planting, year x variety, year x date of planting, year x variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date

of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant for root length of potato plants.

The significant reduction in root length due to delayed planting might be associated with availability of reduced time for plant growth in potato plants grown under aeroponic system. Further, wider spacing has resulted better utilization of nutrients and sufficient space availability to ensure better rooting. The variation among varieties might be related to their differential response during interactions viz. V x S, V x D or V x S x D which can be confirmed by findings of Ezekiel and Bhargava (1992) who had confirmed the decline of certain plant growth characters with delayed planting. Similar finding was reported by Yenagi *et al.* (2005) who had advocated for more root growth and biomass production in early planting of Kufri Chandramukhi cultivar of potato. Kawakami *et al.* (2005) had also confirmed reduced root growth and yield with delayed planting. While working on Kufri Girdhari and Kufri Himsona, Srivastava *et al.* (2016) have also reported significant effect of varieties and spacing for root growth of potato plants.

#### **4.3. Plant spread (cm):**

Plant spread can be stated as a parameter to assess the rate of conversion of solar light into photosynthates. Higher the plant spread, more will be the rate of photosynthesis. The data pertaining to plant spread of potato cultivars grown under aeroponic conditions at different time of planting and spacing has been presented in Table-4.3 and appendices (VII-IX).

As obvious from the table that plant spread was maximum in the early part of crop season with the trend in plant spread as Kufri Jyoti (31.00 cm) followed by Kufri Khyati (28.58 cm) and Kufri Pukhraj (26.44 cm) with an average of 28.67 cm for the crop sown on 15<sup>th</sup> October. A similar trend was also noticed on other planting dates but the plant spread was decreased with the late season cropping. Plant spread trend for the crop sown on 25<sup>th</sup> October was Kufri Jyoti (29.98 cm) followed by Kufri Khyati (27.55 cm) and Kufri Pukhraj (25.53 cm) with an average of 27.69 cm. In the 5<sup>th</sup> November sown crop, the trend was Kufri Jyoti (27.44 cm) followed by Kufri Khyati (24.55 cm) and Kufri Pukhraj (22.54 cm) with an average of 24.84 cm. In 15<sup>th</sup> November sown crop, the trend was Kufri Jyoti (26.30 cm) followed by Kufri Khyati (23.39 cm) and Kufri Pukhraj (21.20 cm) with an

average of 23.63 cm. So, it was inferred that plant spread in all the three varieties under study reflected a general trend with highest in Kufri Jyoti (28.68 cm) followed by Kufri Khyati (26.02 cm) and Kufri Pukhraj (23.93 cm).

**Table-4.3: Plant spread (cm) of potato cultivars grown at different dates and spacing under aeroponic system**

Date of planting	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
D <sub>1</sub>	31.00	26.44	28.58	<b>28.67<sup>a</sup></b>
D <sub>2</sub>	29.98	25.53	27.55	<b>27.69<sup>b</sup></b>
D <sub>3</sub>	27.44	22.54	24.55	<b>24.84<sup>c</sup></b>
D <sub>4</sub>	26.30	21.20	23.39	<b>23.63<sup>d</sup></b>
<b>Mean (V)</b>	<b>28.68<sup>a</sup></b>	<b>23.93<sup>b</sup></b>	<b>26.02<sup>c</sup></b>	
<b>CD (P≤0.05)</b>				
<b>V</b>	<b>0.02</b>			
<b>D</b>	<b>0.02</b>			
<b>V X D</b>	<b>0.03</b>			
Plant spacing	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
S <sub>1</sub>	23.79	16.57	20.67	<b>20.34<sup>c</sup></b>
S <sub>2</sub>	30.60	26.90	28.24	<b>28.58<sup>b</sup></b>
S <sub>3</sub>	31.66	28.32	29.15	<b>29.71<sup>a</sup></b>
<b>Mean (V)</b>	<b>28.68<sup>a</sup></b>	<b>23.93<sup>b</sup></b>	<b>26.02<sup>c</sup></b>	
<b>CD (P≤0.05)</b>				
<b>V</b>	<b>0.02</b>			
<b>S</b>	<b>0.01</b>			
<b>V X S</b>	<b>0.01</b>			
<b>S X D</b>	<b>0.01</b>			
<b>V X S X D</b>	<b>0.02</b>			

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup>

November; Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm; V= Varieties]

The observations on plant spread of aeroponically grown potato plants were significantly influenced by plant spacing for all the varieties under study. In 7X7 cm spacing, the plant spread for all the three varieties followed the trend that was Kufri Jyoti (23.79 cm) followed by Kufri Khyati (20.67 cm) and Kufri Pukhraj (16.57 cm). The plant spread trend for the crop sown on 14X14 cm spacing was Kufri Jyoti (30.60 cm) followed by Kufri Khyati (28.24 cm) and Kufri Pukhraj (26.90 cm). In 21X21 cm spacing sown crop, the trend was Kufri Jyoti (31.66 cm) followed by Kufri Khyati (29.15 cm) and Kufri Pukhraj (28.32 cm). Thus, an increasing trend was noticed in plant spread due to increase

in plant spacing with highest (29.71 cm) at 14X14 cm spacing (S<sub>1</sub>) followed by 28.58 cm in S<sub>2</sub> (14X14 cm) and 20.34 cm in S<sub>3</sub> (7X7 cm).

It is evident from appendices (VII - IX) that the trend of root length was similar for all factors under study. The average data for the crop season 2016-17 and 2017-18 studied for all the three factors viz. three varieties (Kufri Jyoti, Kufri Pukhraj and Kufri Khyati); four planting dates (15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November); and three plant spacing (7X7 cm, 14X14 cm and 21X21 cm) were analysed under split plot statistics for root length and analysis of variance (ANOVA) has been presented. It confirms significant effect of cropping seasons, varieties, date of planting and plant spacing over plant spread of potato plants. The interaction effect of variety x date of planting, year x variety, year x date of planting, year x variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant for plant spread of potato plants.

The significant reduction decline of certain characters like plant height, leaf number and internode length with delayed planting might be associated with availability of reduced time for plant growth in potato plants grown under aeroponic system. Further, wider spacing has resulted better utilization of nutrients and sufficient space availability to ensure better spread of plants and biomass production. The variation among varieties might be related to their differential response during interactions viz. V x S, V x D or V x S x D which can be confirmed by findings of Ezekiel and Bhargava (1992) Similar finding was reported by Yenagi *et al.* (2005) who had advocated for more plant height in early planting of Kufri Chandramukhi cultivar of potato. While working on Kufri Girdhari and Kufri Himsona, Srivastava *et al.* (2016) have also reported significant effect of varieties and spacing for plant growth parameters like plant height and plant spread.

#### **4.4. Root Number:**

Root number is one of the most important factors relating to the rate of absorption in aeroponics and has to be studied from various angles as the growth of plant. The data pertaining to root count of potato cultivars grown under aeroponic conditions at different time of planting and spacing has been presented in Table-4.4 and appendices (X-XII). In

both the crop season, all the three varieties under study that are Kufri Jyoti, Kufri Pukhraj and Kufri Khyati were studied under two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and plant spacing that are 7X7 cm, 14X14 cm and 21X21 cm.

**Table-4.4: Root number of potato cultivars grown at different dates and spacing under aeroponic system**

Date of planting	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
D <sub>1</sub>	9.36	11.11	11.17	<b>10.54<sup>d</sup></b>
D <sub>2</sub>	8.80	11.83	11.75	<b>10.79<sup>c</sup></b>
D <sub>3</sub>	10.50	15.29	18.25	<b>14.68<sup>b</sup></b>
D <sub>4</sub>	13.86	14.89	16.99	<b>15.24<sup>a</sup></b>
<b>Mean (V)</b>	<b>10.63<sup>c</sup></b>	<b>13.28<sup>b</sup></b>	<b>14.54<sup>a</sup></b>	
<b>CD (P≤0.05)</b>				
<b>V</b>	<b>0.01</b>			
<b>D</b>	<b>0.01</b>			
<b>V X D</b>	<b>0.02</b>			
Plant spacing	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
S <sub>1</sub>	7.58	6.98	8.58	<b>7.71<sup>c</sup></b>
S <sub>2</sub>	11.12	14.66	16.75	<b>14.17<sup>b</sup></b>
S <sub>3</sub>	13.20	18.20	18.29	<b>16.56<sup>a</sup></b>
<b>Mean (V)</b>	<b>10.63<sup>c</sup></b>	<b>13.28<sup>b</sup></b>	<b>14.54<sup>a</sup></b>	
<b>CD (P≤0.05)</b>				
<b>V</b>	<b>0.01</b>			
<b>S</b>	<b>0.02</b>			
<b>V X S</b>	<b>0.03</b>			
<b>S X D</b>	<b>0.03</b>			
<b>V X S X D</b>	<b>0.04</b>			

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November; Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm; V= Varieties]

As obvious from the given table that highest root number was in Kufri Khyati (11.17) followed by Kufri Pukhraj (11.11) and Kufri Jyoti (9.36) for the crop sown on 15<sup>th</sup> October. A similar trend was also noticed on other planting dates but the root number was showing an increase with the late season cropping. The root number trend for the crop sown on 25<sup>th</sup> October was Kufri Khyati (11.75) followed by Kufri Pukhraj (11.83) and Kufri Jyoti (8.80). In the 5<sup>th</sup> November sown crop, the trend was Kufri Khyati (18.25) followed by Kufri Pukhraj (15.29) and Kufri Jyoti (10.50). In 15<sup>th</sup> November sown crop, the trend



was Kufri Khyati (16.99) followed by Kufri Pukhraj (14.89) and Kufri Jyoti (13.86). So, it is inferred that the mean root number in all the three varieties under study shows a general trend with Kufri Khyati (14.54) was leading followed by Kufri Pukhraj (13.28) and Kufri Jyoti (10.63).

The second factor under consideration was the spacing that are 7X7 cm, 14X14 cm, and 21X21 cm. In 7X7 cm spacing, the root number for all the three varieties followed the trend that is Kufri Khyati (8.58) followed by Jyoti (7.58) and Kufri Pukhraj (6.98). The root number trend for the crop sown on 14X14 cm spacing was Kufri Khyati (16.75) followed by Kufri Pukhraj (14.66) and Kufri Jyoti (11.12). In 21X21 cm spacing sown crop, the trend was Kufri Khyati (18.29) followed by Kufri Pukhraj (18.20) and Kufri Jyoti (13.20). Higher is the spacing more was the root number in potato plants grown under aeroponics as maximum root number (16.56) was reported in 21X21 cm (S<sub>3</sub>) spacing followed by 14.17 in 14X14 cm (S<sub>2</sub>) and 7.71 in the spacing of 7X7 cm (S<sub>1</sub>).

The observation confirms higher mean value of root numbers in Kufri Khyati (14.54) followed by Kufri Pukhraj (13.28) and Kufri Jyoti (10.63) under the influence of spacing and date of planting as well. The data confirms significant effect of cropping seasons, varieties, date of planting and plant spacing over root numbers of potato plants. The interaction effect of variety x date of planting, year x variety, year x date of planting, year x variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant for root numbers of potato plants.

The increasing trend of number of roots with delayed planting might be associated with reduced divergence of nutrients for vegetative growth and the root was becoming major sink of nutrients to achieve the minimum growth which can enable the plant for tuberization. Further, it was also noticed that in cultivars Kufri Khyati and Kufri Pukhraj the root numbers in D<sub>4</sub> (15<sup>th</sup> November) was lesser than D<sub>3</sub> (5<sup>th</sup> November) which might be associated with the fact that the rooting of these varieties have already been achieved to substantial level and tuberization was initiated early so the sink was shifted from rooting to tuberization. The response of potato cultivars for different dates of planting was also studied by Ezekiel and Bhargava (1992) and Yenagi *et al.* (2005). Kawakami *et al.* (2005) had also confirmed reduced root growth and yield with delayed planting. While working

on Kufri Girdhari and Kufri Himsona, Srivastava *et al.* (2016) have also reported significant effect of varieties and spacing for root growth of potato plants.

#### **4.5. Number of days taken for tuber initiation:**

The data pertaining to number of days taken for tuber initiation of potato cultivars grown under aeroponic conditions at different time of planting and spacing has been presented in Table-4.5 and appendices (XIII-XV). Number of days taken for initiation of tuber was studied in the both crop seasons or all the three varieties under study *viz.* Kufri Jyoti, Kufri Pukhraj and Kufri Khyati, under two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and plant spacing of 7X7 cm, 14X14 cm and 21X21 cm.

The number of days taken for initiation of tuber for crop planted on 15<sup>th</sup> October (D<sub>1</sub>) was largest (48.23 days after planting) followed by 44.22 days after planting on 25<sup>th</sup> October (D<sub>2</sub>), 33.01 days after planting on 5<sup>th</sup> November (D<sub>3</sub>) and the highest (29.89 days after planting) on 15<sup>th</sup> November (D<sub>4</sub>). Thus, a significant effect of days of planting was reported on number of days taken for tuberization. Similarly, the plant spacing had also significantly affected number of days taken for tuberization in potato under aeroponics and highest number of days taken for tuberization (39.55 days) was reported in 7X7 cm of spacing (S<sub>1</sub>) followed by 39.45 days in 14X14 cm of spacing (S<sub>2</sub>) and 37.56 days in 21X21 cm of spacing. Further, a significant variation among varieties was also reported and highest number of days taken for tuber initiation (57.97 days) was reported in Kufri Jyoti (V<sub>1</sub>) followed by 29.50 days in Kufri Khyati (V<sub>3</sub>) and 29.09 days in Kufri Pukhraj (V<sub>2</sub>).

The interaction effect at various level was also reported to be significantly influenced the number of days taken for tuber initiation with highest number of days taken for tuber initiation (71.62 days) in D<sub>1</sub>V<sub>1</sub> followed by 66.42 days in D<sub>2</sub>V<sub>1</sub>, 50.14 days in D<sub>3</sub>V<sub>1</sub> and 43.70 days in D<sub>4</sub>V<sub>1</sub> and 36.55 days in D<sub>1</sub>V<sub>2</sub> whereas the lowest number of days taken for tuber initiation (22.48 days) was in D<sub>4</sub>V<sub>2</sub> for V X D interaction while for V X S interaction the highest number of days taken for tuber initiation (60.00 days) in S<sub>1</sub>V<sub>1</sub> followed by 57.03 days in S<sub>3</sub>V<sub>1</sub> and 56.88 days in S<sub>2</sub>V<sub>1</sub> whereas the lowest number of days taken for tuber initiation (26.09 days) was in D<sub>4</sub>V<sub>2</sub> followed by 28.84 days in D<sub>1</sub>V<sub>3</sub>.

It is also evident that the minimum number of days taken for tuber initiation is a commercially desirable attribute. Thus, it is inferred that initiation of tuber formation in all

the three varieties under study shows a general trend of initiation of tuber formation with earliness in Kufri Pukhraj followed by Kufri Khyati and the last one is Kufri Jyoti at all level of interactions.

**Table-4.5: Number of days taken for tuber initiation in potato cultivars grown at different dates and spacing under aeroponic system**

Date of planting	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
D <sub>1</sub>	71.62	36.55	36.52	<b>48.23<sup>a</sup></b>
D <sub>2</sub>	66.42	33.18	33.07	<b>44.22<sup>b</sup></b>
D <sub>3</sub>	50.14	24.14	24.92	<b>33.07<sup>c</sup></b>
D <sub>4</sub>	43.70	22.48	23.49	<b>29.89<sup>d</sup></b>
Mean (V)	<b>57.97<sup>a</sup></b>	<b>29.09<sup>c</sup></b>	<b>29.50<sup>b</sup></b>	
<b>CD (P≤0.05)</b>				
V		<b>0.03</b>		
D		<b>0.03</b>		
V X D		<b>0.04</b>		
Plant spacing	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (S)
S <sub>1</sub>	60.00	29.80	28.84	<b>39.55<sup>a</sup></b>
S <sub>2</sub>	56.88	31.38	30.09	<b>39.45<sup>b</sup></b>
S <sub>3</sub>	57.03	26.09	29.56	<b>37.56<sup>c</sup></b>
Mean (V)	<b>57.97<sup>a</sup></b>	<b>29.09<sup>c</sup></b>	<b>29.50<sup>b</sup></b>	
<b>CD (P≤0.05)</b>				
V		<b>0.03</b>		
S		<b>0.03</b>		
V X S		<b>0.04</b>		
S X D		<b>0.05</b>		
V X S X D		<b>0.09</b>		

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup>

November; Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm; V= Varieties]

The data confirms significant effect of varieties, date of planting and plant spacing over number of days taken for tuber initiation; however, there was no significant effect of cropping seasons. The interaction effect of variety x date of planting, year x variety, year x date of planting, year x variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant for number of days taken for tuber initiation.

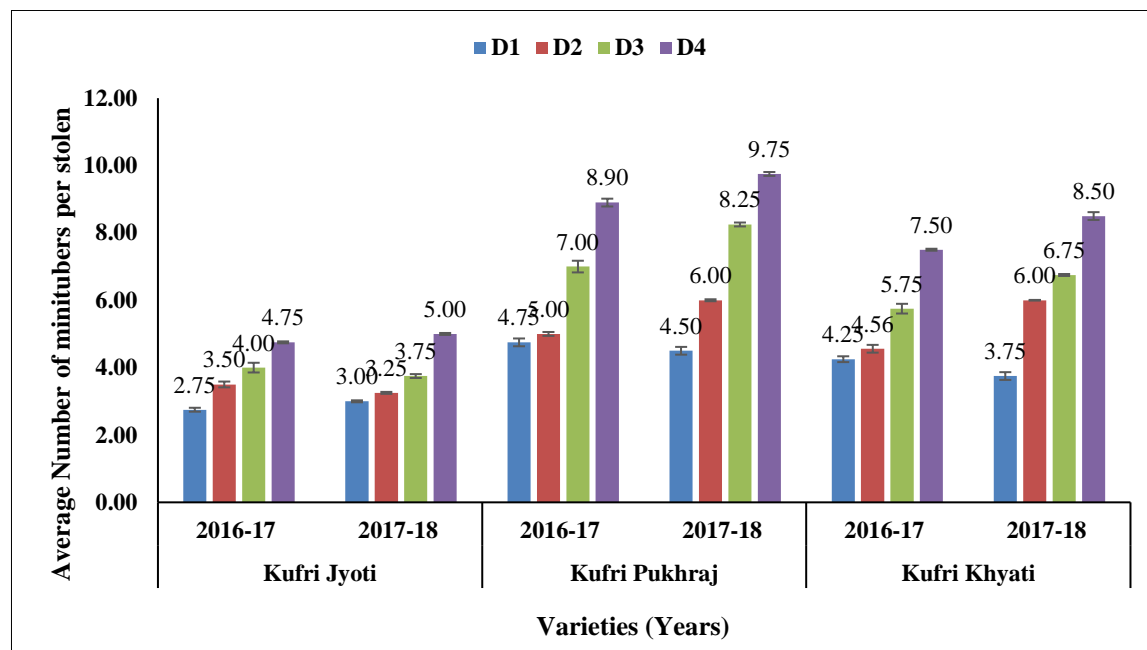
Tuberization was reported to be influenced by date of planting and plant spacing. The requirement of lesser number of days for tuberization in each cultivar for delayed planting might be associated with the availability of lesser time for growth of roots and stolon. Delayed planting has resulted in restricted growth and tuberization has started along with plants which were grown at early planting. Tuberization and vegetative growth in tomato is largely being governed by temperature. The optimum temperature for foliage growth and net photosynthesis is 20 and 25°C, respectively. Low mean temperatures (15-19°C) and short photoperiods (12h) are favourable for tuberization and early tuber growth (Vandam *et al.* 1996). Under such conditions a transmissible signal is activated that triggers cell division and elongation in the sub-apical region of the stolon to produce tuber initials (Xu *et al.*, 1998). Thus, in all the plants, planted late or early and at any spacing, tuberization was initiated at same time due for a given variety so the plants with late planting have taken lesser number of days for tuber initiation.

A difference of 13 to 18 days was reported for number of days taken for tuber initiation when a comparison between first planting (D<sub>1</sub>) and last planting (D<sub>4</sub>) was done. However, in spacing it was primarily the varietal variation and was dominant over the variation due to spacing. Thus, number of days taken for tuber initiation was more prominently affected by date of planting followed by cultivars and minimal by plant spacing, rather variety X date of planting interaction was more effective. Similar findings have also been reported by Saini *et al.* (1996), Raj *et al.* (1997) and Patel *et al.* (2000). Kawakami *et al.* (2005) had also confirmed restriction of growing period in roots and stolon due to late planting on potato. The plants of smaller spacing and high planting density had resulted in poor and restricted root growth and vegetative growth to induce early tuberization. Wider the spacing, more the space available for growth of stolon resulting delayed tuberization. Similar findings were reported by Angel (2006) and Srivastava *et al.* (2016).

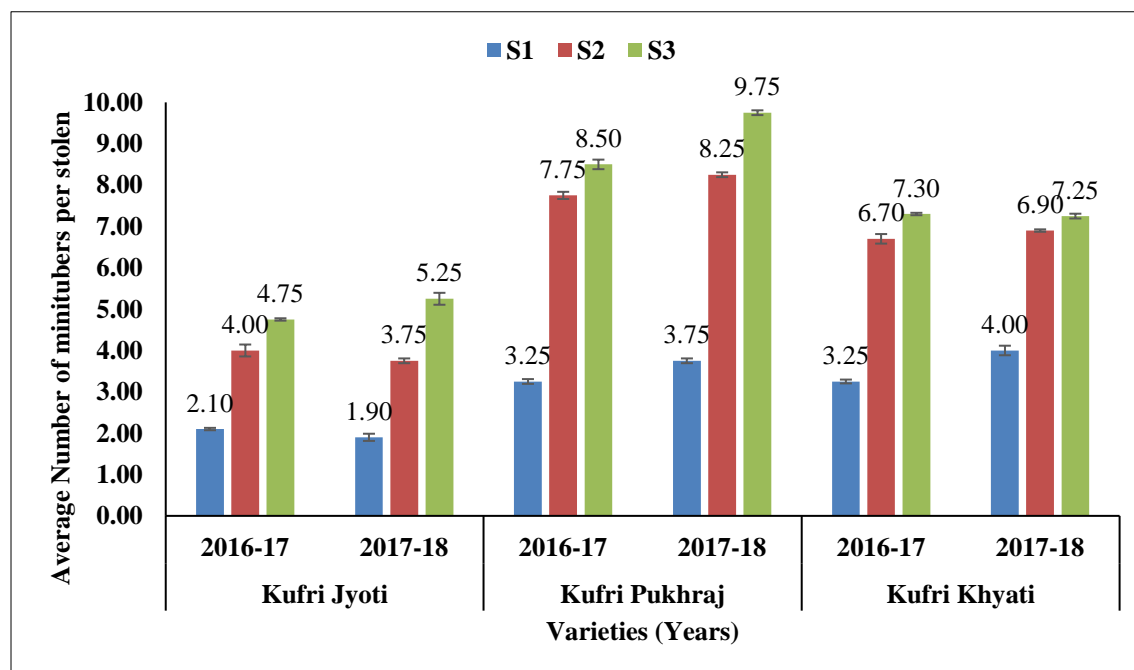
#### **4.6. Number of mini-tubers per stolon:**

Data analysis of the mean number of tubers per stolon (Figure-4.1) for year 2016-17 and 2017-18 revealed that in crop sown on 15<sup>th</sup> October has a smaller number of tubers per stolon in all the three varieties and can be correlated with more length of stolons with a smaller number of tuber initiations per stolon. The crop sown on 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November has shown increase in tuber initiations per stolon. Variety

wise analysis for number of tubers per stolon reflects highest value in Kufri Pukhraj (7 to 10 mini-tubers per stolon) followed by Kufri Khyati (5 to 8 mini-tubers per stolon) and Kufri Jyoti (3 to 5 mini-tubers per stolon).



**Figure-4.1A: Mean number of mini-tubers per stolon with respect to planting dates**  
(SeM± ranged from 0.00962 to 0.14434)



**Figure-4.1B: Mean number of mini-tubers per stolon with respect to plant spacing**  
(SeM± ranged from 0.02887 to 0.14434)

Analysis of the average data for the number of mini-tubers per stolon and effect of spacing confirms lesser numbers of mini-tubers per stolon in 7x7 cm spacing in all the three varieties and can be accounted to competition with root system and high plant density. At 14x14 cm spacing, the numbers of mini-tubers per stolon are better in all the three varieties with Kufri Pukhraj takes the lead among them under study. At 21x21 cm spacing, the number of mini-tubers per stolon was almost same but the size of mini-tubers improved with spacing.

Under field condition, it has been reported that late planting results in low tuber production and a greater economic loss to the farmers but under hydroponic or aeroponic system where mini-tubers are more important than large size tubers considering the significance of seed tuber production, the delayed planting has resulted reduction in production of large size tubers and most of the tubers have been developed in the range of mini-tubers (2.5-3.0g) (Krishnanappa *et al.*, 1991). The present finding is in conformity with the work carried Singh *et al.* (2001) and Yenagi *et al.* (2002).

Further, higher spacing might be responsible for better circulation and availability of air. When the oxygen in the root zone is in a favourable concentration, larger tubers will be produced, so potato plants will have more efficient and longer roots with a higher number of stolons and can produce more and larger tubers (Ritter *et al.*, 2001; Mobini *et al.*, 2009). However, it is being in contradiction with the findings of Abdullateef *et al.* (2012), Rykaczewska (2016) and Brocic *et al.* (2018) who had confirmed greater number of mini-tubers at lower spacing. Rolot and Seutin (1999) and Faran and Mingo-Castel (2006) had also reported that the number of mini-tubers per sq. meter is function of cultivars as well as planting density. Roy *et al.* (1994) and Veeken and Lommen (2009) also studied the plant density function of number of mini-tubers in potato and had reported a decrease in number of mini-tubers production with decrease in plant density or increase in spacing.

#### **4.7. Number of mini-tubers (2.5-3.0 g) per plant:**

The number of mini-tubers in aeroponics is the ultimate as the real output of all the efforts made for whole crop season. Data pertaining to number of mini-tubers per plant was recorded, analysed for testing the significance and has been presented in Table-4.6 and appendices-XVI to XVIII. In both the crop seasons, all the three varieties Kufri Jyoti, Kufri Pukhraj and Kufri Khyati were studied under two factors of four planting dates that are 15<sup>th</sup>

October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and plant spacing that are 7X7 cm, 14X14 cm and 21X21 cm. As obvious from the given table, the number of mini-tubers per plant was highest in Kufri Pukhraj (V<sub>2</sub>- 64.26 tubers) followed by Kufri Khyati (V<sub>3</sub>- 57.80 tubers) and was lowest in Kufri Jyoti (V<sub>1</sub>- 24.49 tubers) for all dates of planting. The delayed planting was reported with greater number of mini-tubers and the highest (79.62 tubers per plant) was reported in D<sub>4</sub> (planting on 15<sup>th</sup> November) followed by 65.60 tubers in D<sub>3</sub> (planting on 5<sup>th</sup> November) and 27.30 tubers in D<sub>2</sub> (planting on 25<sup>th</sup> October) while it was lowest (22.87 tubers) in D<sub>1</sub> (planting on 15<sup>th</sup> October). Spacing of planting was also reported to have significant influence over number of mini-tuber production with highest (65.75 tubers) in S<sub>3</sub> (21X21 cm) and 56.95 tubers per plant in S<sub>2</sub> (14X14 cm) while it was lowest (23.85 tubers) in S<sub>1</sub> (7X7 cm).

**Table-4.6: Number of mini-tubers (2.5-3.0 g) per plant in potato cultivars grown at different dates and spacing under aeroponic system**

Date of planting	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
D <sub>1</sub>	7.35	30.84	30.42	22.87 <sup>d</sup>
D <sub>2</sub>	10.20	35.76	35.95	27.30 <sup>c</sup>
D <sub>3</sub>	26.89	91.62	78.30	65.60 <sup>b</sup>
D <sub>4</sub>	53.53	98.81	86.52	79.62 <sup>a</sup>
Mean (V)	24.49 <sup>c</sup>	64.26 <sup>b</sup>	57.80 <sup>a</sup>	
<b>CD (P≤0.05)</b>				
V	0.16			
D	0.17			
V X D	0.29			
Plant spacing	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (S)
S <sub>1</sub>	10.59	29.66	31.29	23.85 <sup>c</sup>
S <sub>2</sub>	28.75	76.49	65.62	56.95 <sup>b</sup>
S <sub>3</sub>	34.13	86.63	76.49	65.75 <sup>a</sup>
Mean (V)	24.49 <sup>c</sup>	64.26 <sup>b</sup>	57.80 <sup>a</sup>	
<b>CD (P≤0.05)</b>				
V	0.16			
S	0.15			
V X S	0.27			
S X D	0.31			
V X S X D	0.54			

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November; Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm; V= Varieties]

The data confirms significant effect of varieties, date of planting and plant spacing over number of mini-tubers formation; however, there was no significant effect of cropping seasons. The interaction effect of variety x date of planting, year x variety, year x date of planting, year x variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant for number of mini-tubers per plant. The interaction study of VxD and VxS had also reflected significant impact over number of tubers per plant with highest (98.81 tubers per plant) in D<sub>4</sub>V<sub>2</sub> followed by D<sub>3</sub>V<sub>2</sub> (91.62 tubers), D<sub>4</sub>V<sub>3</sub> (86.52 tubers) and D<sub>3</sub>V<sub>3</sub> (78.30 tubers) while lowest was in D<sub>1</sub>V<sub>1</sub> (7.35 tubers) and D<sub>2</sub>V<sub>1</sub> (10.20 tubers) for VxD interaction. Similarly, the highest (86.63) number of tubers per plant was reported in S<sub>3</sub>V<sub>2</sub> followed by S<sub>2</sub>V<sub>2</sub> and S<sub>3</sub>V<sub>3</sub> (76.49 tubers each) while the lowest (10.59 tubers) was reported in S<sub>1</sub>V<sub>1</sub> (Kufri Jyoti variety planted at 7X7 cm spacing).

Under field condition, it has been reported that late planting results in low tuber production and a greater economic loss to the farmers but under hydroponic or aeroponic system where mini-tubers are more important than large size tubers considering the significance of seed tuber production, the delayed planting has resulted reduction in production of tubers with smaller (less than 2.5g) and over size (more than 3.0g) and most of the tubers have been developed in the range of mini-tubers (2.5-3.0g) (Krishnanappa *et al.*, 1991). The present finding is in conformity with the work carried Singh *et al.* (2001) and Yenagi *et al.* (2002).

Further, higher spacing might be responsible for better circulation and availability of air. When the oxygen in the root zone is in a favourable concentration, larger tubers will be produced, so potato plants will have more efficient and longer roots with a higher number of stolons and can produce more and larger tubers (Ritter *et al.*, 2001; Mobini *et al.*, 2009). However, it is being in contradiction with the findings of Abdullateef *et al.* (2012), Rykaczewska (2016) and Brocic *et al.* (2018) who had confirmed greater number of mini-tubers at lower spacing. Rolot and Seutin (1999) and Faran and Mingo-Castel (2006) had also reported that the number of mini-tubers per sq. meter is function of cultivars as well as planting density. Roy *et al.* (1994) and Veeken and Lommen (2009) also studied



the plant density function of number of mini-tubers in potato and had reported a decrease in number of mini-tubers production with decrease in plant density or increase in spacing.

#### 4.8. Number of tubers under different categories:

Analysis of the average data for crop season 2016-17 and 2017-18 in terms of mean number of tubers in terms of size in gram in potato varieties viz Kufri Jyoti, Kufri Pukhraj and Kufri Khyati on different planting dates (Table-4.7A and Figure-4.2A) revealed that in the crop sown on 15<sup>th</sup> October, Kufri Jyoti has produced 16.97 tubers per plant while Kufri Pukhraj and Kufri Khyati produced 51.58 and 47.50 tubers per plant, respectively. In the crop sown on 25<sup>th</sup> October, Kufri Jyoti has produced lowest number of tubers (25.18) while Kufri Pukhraj and Kufri Khyati produced 55.71 and 58.20 tubers per plant, respectively. In the crop sown on 5<sup>th</sup> November, Kufri Jyoti has produced 48.73 tubers while Kufri Pukhraj has produced 107.12 and Kufri Khyati as 100.55 tubers per plant.

**Table-4.7A: Number of tubers per plant of potato cultivars grown at different dates under aeroponic system (2016-17 & 2017-18)**

Dates of planting	Kufri Jyoti			Kufri Pukhraj			Kufri Khyati		
	>3.00 g	2.5-3.0 g	<2.5 g	>3.00 g	2.5-3.0 g	<2.5 g	>3.00 g	2.5-3.0 g	<2.5 g
<b>D1</b>	0.00	7.35	9.62	3.25	30.83	17.50	2.10	30.40	15.00
<b>D2</b>	1.90	10.18	13.10	5.20	35.76	14.75	2.75	35.95	19.50
<b>D3</b>	2.10	26.88	19.75	7.25	91.62	8.25	4.50	78.30	17.75
<b>D4</b>	3.20	53.52	9.25	10.20	98.81	6.50	7.75	86.52	14.00

**Table-4.7B: Number of tubers per plant of potato cultivars grown at different spacing under aeroponic system (2016-17 & 2017-18)**

Spacing	Kufri Jyoti			Kufri Pukhraj			Kufri Khyati		
	>3.00 g	2.5-3.0 g	<2.5 g	>3.00 g	2.5-3.0 g	<2.5 g	>3.00 g	2.5-3.0 g	<2.5 g
<b>S1</b>	0.00	10.59	12.00	1.25	29.65	13.00	1.75	31.29	6.25
<b>S2</b>	3.00	28.75	8.00	3.75	76.49	7.00	2.20	65.61	4.00
<b>S3</b>	6.00	34.13	5.00	7.00	86.62	2.00	7.25	76.48	1.10

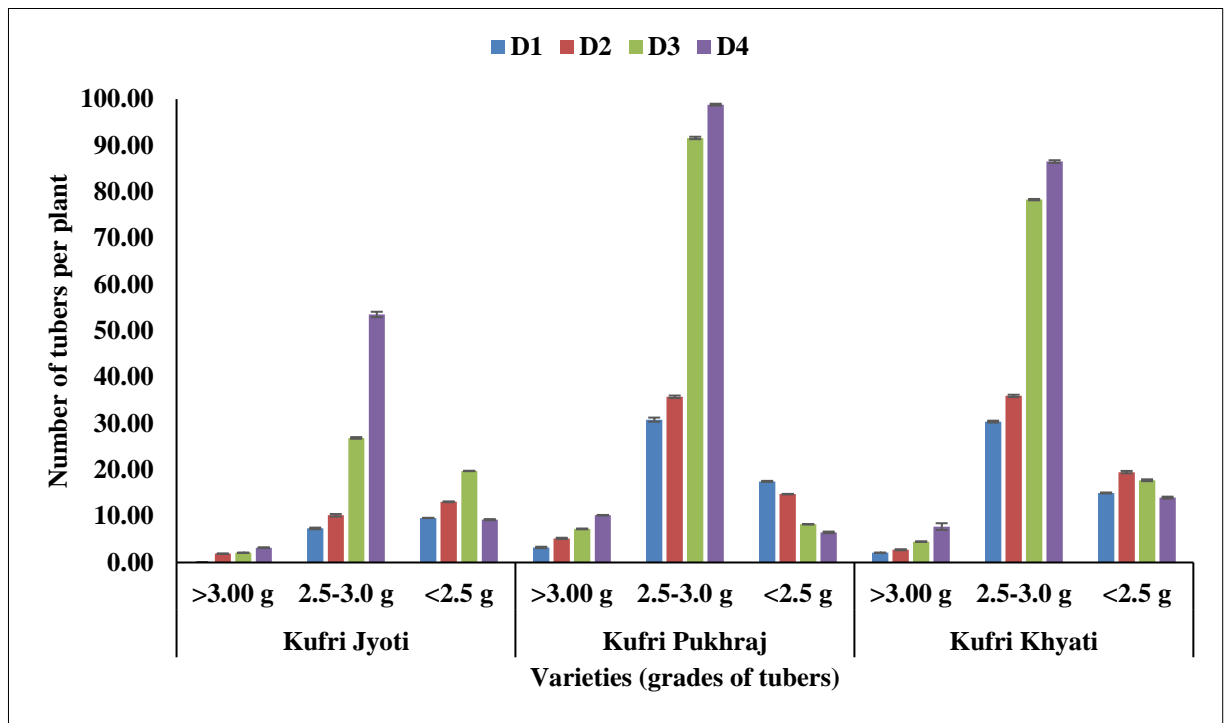


Figure-4.2A: Number of tubers per plant of potato cultivars grown at different dates under aeroponic system (SeM± ranged from 0.0 to 0.58882)

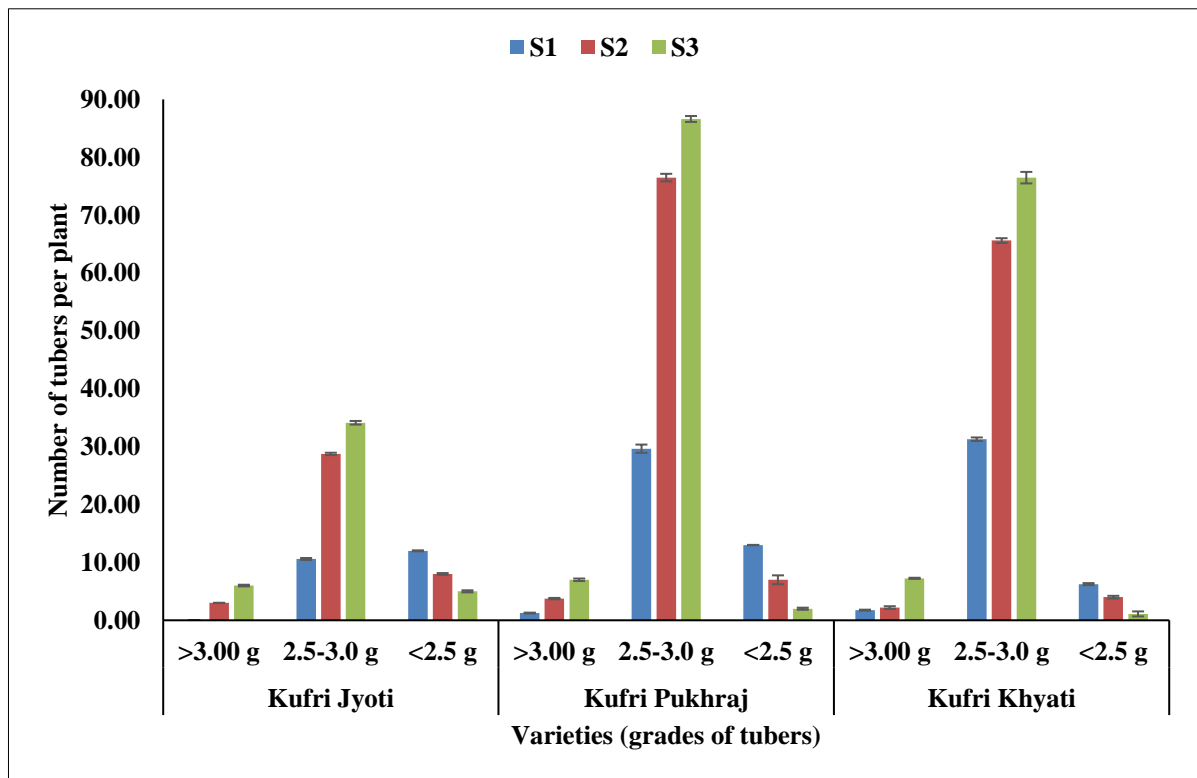


Figure-4.2B: Number of tubers per plant of potato cultivars grown at different spacing under aeroponic system (SeM± ranged from 0.0 to 0.99527)

In the crop sown on 15<sup>th</sup> November, Kufri Jyoti has produced 65.97 tubers while Kufri Pukhraj and Kufri Khyati produced 115.51 and 108.27 tubers per plant, respectively. Kufri Jyoti improves its performance in late planting season while Kufri Pukhraj and Kufri Khyati are good throughout the season but these varieties also improve the number of mini-tubers in late planting dates of 5<sup>th</sup> and 15<sup>th</sup> November.

Analysis of the average data for crop season 2016-17 and 2017-18 in terms of mean number of tubers in terms of size in gram in potato varieties viz. Kufri Jyoti, Kufri Pukhraj and Kufri Khyati on different spacing (Table-4.7B and Figure-4.2B) revealed that in the crop sown at 7x7 cm spacing, Kufri Jyoti has produced 22.59 tubers per plant while Kufri Pukhraj and Kufri Khyati produced 43.90 and 39.29 tubers per plant, respectively. In crop sown at 14x14cm spacing, Kufri Jyoti has produced 39.75 tubers while Kufri Pukhraj and Kufri Khyati 87.24 and 71.81 tubers per plant, respectively. In the crop sown at 21x21cm spacing, Kufri Jyoti has produced 45.13 tubers while Kufri Pukhraj and Kufri Khyati produced 95.62 and 84.83 tubers per plant, respectively. Spacing plays an important role in the formation of mini-tubers. The spacing of 21x21 cm is better in terms of the number of tubers per plant as compared to 14x14 cm which in turn is better than 7x7 cm spacing. But economic analysis of productivity revealed that 14x14 cm is the best spacing for planting potato varieties per unit area.

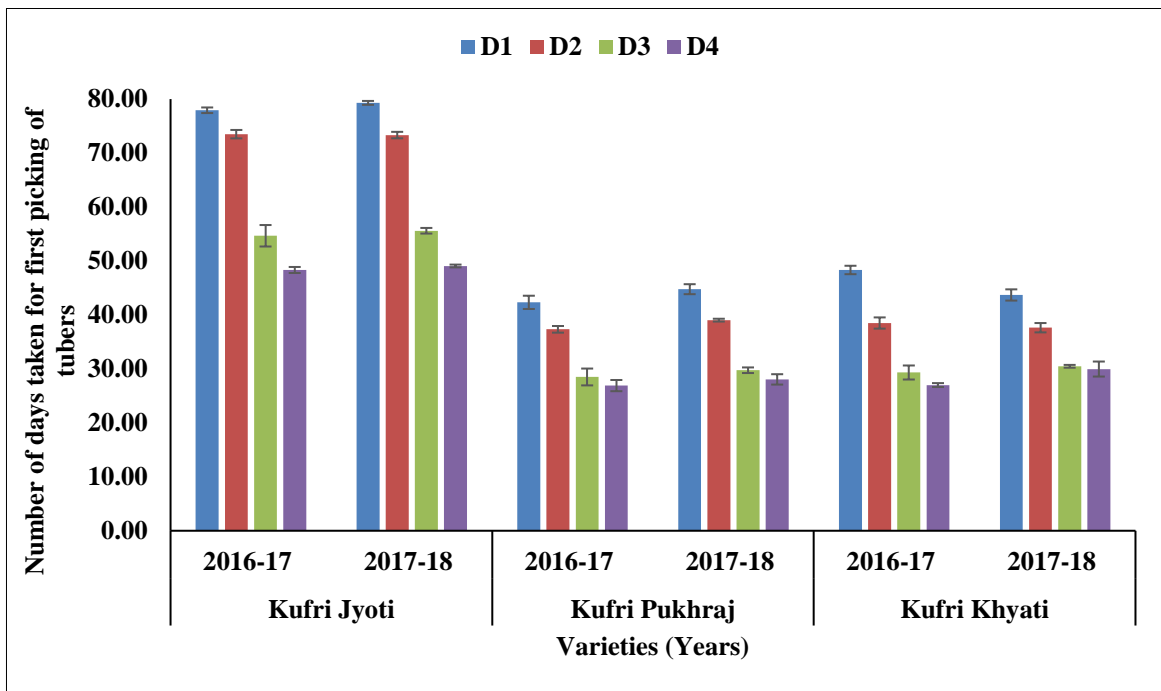
Thus, the observation confirms that the number of tubers with size more than equal to 2.5g were increased with delayed planting while smaller tubers (less than 2.5g) were produced in lesser number during late planting. The delayed planting has resulted reduction in production of tubers with smaller (less than 2.5g) and over size (more than 3.0g) and most of the tubers have been developed in the range of mini-tubers (2.5-3.0g) which might be balanced distribution of nutrients at later stage of growth and development due to senescence in vegetative growth (Krishnanappa *et al.*, 1991). Similar findings have been reported by Ahmed and Rashid (1980) and Yilmaz (1999). Further, the number of tubers with size more than equal to 2.5g were increased with increased plant spacing while smaller plant spacing has resulted in a greater number of undersized (less than 2.5g) tubers which might be due to greater compactness in low spacing planting and low aeration (Srivastava *et al.*, 2016).

#### 4.9. Number of days taken for first picking:

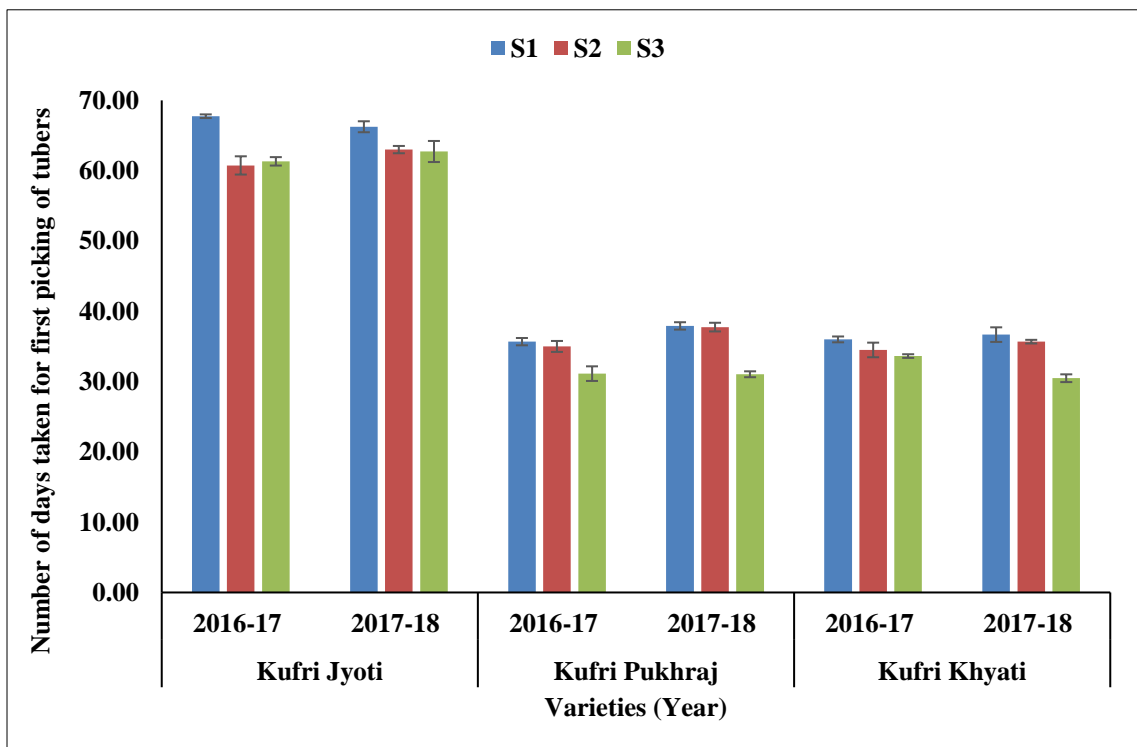
Data pertaining to number of days taken for first picking was analysed and presented through Figure-4.3. Data analysis of the average data for date of planting during the crop season 2016-17 and 2017-18 has revealed a trend that Kufri Jyoti sown on 15<sup>th</sup> and 25<sup>th</sup> October got its first mini-tubers picking at 7 days after initiation of tuberization and 5 days after initiation of tuberization in crop sown on 5<sup>th</sup> and 15<sup>th</sup> of November. In Kufri Khyati and Kufri Pukhraj, the crop sown on 15<sup>th</sup> October got its first mini-tubers picking at 7 days after initiation of tuberization. If these varieties are sown on 25<sup>th</sup> October, 5<sup>th</sup> and 15<sup>th</sup> of November, first picking was done at 5 days after onset of tuber initiation. It is inferred from the above data analysis that Kufri Khyati and Kufri Pukhraj are the varieties under study can be planted earlier in the crop season (15<sup>th</sup> and 25<sup>th</sup> October) while Kufri Jyoti is fit to be sown in late season that is 5<sup>th</sup> and 15<sup>th</sup> November.

Analysis of the average data for the crop season 2016-17 and 2017-18 has revealed that spacing show effect on initiation of tuberization and hence affects the time of first picking. In 7x7 cm spacing, first picking in all the three varieties was carried 7 days after tuber initiation. This observation shows that less spacing means more time for tuber initiation.

The finding was reported to be synchronised with initiation of tuberization as reflected in 4.5 which confirms that tuberization and hence number of days taken for picking of tubers was reported to be influenced by date of planting and plant spacing. The requirement of lesser number of days for tuberization in each cultivar for delayed planting might be associated with the availability of lesser time for growth of roots and stolon. Delayed planting has resulted in restricted growth and tuberization has started along with plants with early planting. Similar findings have also been reported by Saini *et al.* (1996), Raj *et al.* (1997) and Patel *et al.* (2000). Kawakami *et al.* (2005) had also confirmed restriction of growing period in roots and stolon due to late planting on potato. The plants of smaller spacing and high planting density had resulted in poor and restricted root growth and vegetative growth to induce early tuberization. Wider the spacing, more the space available for growth of stolon resulting delayed tuberization. Similar findings were reported by Angel (2006) and Srivastava *et al.* (2016).



**Figure-4.3A: Number of days taken for first picking of tubers of potato cultivars grown at different dates under aeroponic system (SeM $\pm$  was 0.25981 to 1.99038)**



**Figure-4.3B: Number of days taken for first picking of tubers of potato cultivars grown at different spacing under aeroponic system (SeM $\pm$  was 0.25981 to 1.49904)**

#### 4.10. Total crop duration (days):

Total Crop duration is one of the most important factors in aeroponics and has to be studied from various angles as the growth of plant, rate of absorption of nutrients and stolon formation depends on these factors (Table-4.8 and appendices-XIX to XXI). In both the crop seasons, all the three varieties Kufri Jyoti, Kufri Pukhraj and Kufri Khyati were studied under two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and spacing's that are 7X7 cm, 14X14 cm and 21X21 cm.

As obvious from the Table-4.8 that total crop duration was maximum in the early part of crop season with the trend as Kufri Jyoti (102.70 days) followed by Kufri Khyati (98.23 days) and Kufri Pukhraj (98.07 days) for the crop sown on 15<sup>th</sup> October. A similar trend was also noticed on other planting dates but the total crop duration was showing decrease with the late season cropping. The total crop duration in days for the crop sown on 25<sup>th</sup> October was Kufri Jyoti (111.69 days) followed by Kufri Khyati (109.37 days) and Kufri Pukhraj (109.19 days). In the 5<sup>th</sup> November sown crop, the trend was relatively different as Kufri Khyati (113.67 days) followed by Kufri Jyoti (112.68 days) and Kufri Pukhraj (109.36 days). On 15<sup>th</sup> November sown crop, the trend was Kufri Jyoti (118.50 days) followed by Kufri Khyati (116.38 days) and Kufri Pukhraj (114.84 days).

Further, the date of planting was also having significant effect on total crop duration with highest (116.56 days) in D<sub>4</sub> (15<sup>th</sup> November) followed by 111.89 days in D<sub>3</sub> (5<sup>th</sup> November) and 110.06 days in D<sub>2</sub> (25<sup>th</sup> October) while it was lowest (99.61 days) was in D<sub>1</sub> (15<sup>th</sup> October).

The plant spacing was having substantial impact on the total crop duration and the highest (121.25 days) was in S<sub>3</sub> (21X21 cm) and 107.53 days in S<sub>2</sub> (14X14 cm) while it was lowest (99.88 days) in S<sub>1</sub> (7X7 cm). It is also inferred that total crop duration was significantly affected by varieties under study and a general trend was reported with highest (111.39 days) in Kufri Jyoti (V<sub>1</sub>) followed by 109.37 days in Kufri Khyati (V<sub>3</sub>) and 107.91 in Kufri Pukhraj (V<sub>2</sub>).

**Table-4.8: Total crop duration in potato cultivars grown at different dates and spacing under aeroponic system**

Date of planting	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (D)
D <sub>1</sub>	102.70	98.07	98.23	<b>99.61<sup>d</sup></b>
D <sub>2</sub>	111.69	109.37	109.19	<b>110.06<sup>c</sup></b>
D <sub>3</sub>	112.68	109.36	113.67	<b>111.89<sup>b</sup></b>
D <sub>4</sub>	118.50	114.84	116.38	<b>116.56<sup>a</sup></b>
Mean (V)	<b>111.39<sup>a</sup></b>	<b>107.91<sup>c</sup></b>	<b>109.37<sup>b</sup></b>	
<b>CD (P≤0.05)</b>				
V				<b>0.04</b>
D				<b>0.05</b>
V X D				<b>0.08</b>
Plant spacing	Kufri Jyoti (V <sub>1</sub> )	Kufri Pukhraj (V <sub>2</sub> )	Kufri Khyati (V <sub>3</sub> )	Mean (S)
S <sub>1</sub>	99.88	96.63	103.15	<b>99.88<sup>c</sup></b>
S <sub>2</sub>	111.65	103.55	107.40	<b>107.53<sup>b</sup></b>
S <sub>3</sub>	122.65	123.55	117.55	<b>121.25<sup>a</sup></b>
Mean (V)	<b>111.39<sup>a</sup></b>	<b>107.91<sup>c</sup></b>	<b>109.37<sup>b</sup></b>	
<b>CD (P≤0.05)</b>				
V				<b>0.04</b>
S				<b>0.03</b>
V X S				<b>0.06</b>
S X D				<b>0.07</b>
V X S X D				<b>0.10</b>

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November; Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm; V= Varieties]

The data confirms significant effect of varieties, date of planting and plant spacing over total crop duration (days); however, there was no significant effect of cropping seasons. The interaction effect of variety x date of planting, year x variety, year x date of planting, year x variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant for total crop duration (days). Total crop duration of aeroponically grown potato was reported to be function of cultivars, plant spacing and date of planting. Delayed planting and wider plant spacing had increased the duration of harvest and so crop duration. However, there is no such kind of literature available regarding total crop duration of aeroponically grown potato crops.

#### 4.11. Tuber yield per plant:

The tuber yield per plant in aeroponics is the ultimate as the real output of all the efforts made for whole crop season. Data pertaining to tuber yield per plant was estimated, analysed for testing the significance and has been presented in Figure-4.4. In the crop season 2016-17, all the three varieties under study Kufri Jyoti, Kufri Pukhraj and Kufri Khyati were studied under two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and plant spacing that are 7X7 cm, 14X14 cm and 21X21 cm. As obvious from the given figure, the tuber yield per plant in Kufri Pukhraj (93.00g) followed by Kufri Khyati (90.99g) and Kufri Jyoti (22.50g) for the crop sown on 15<sup>th</sup> October. A similar trend was also noticed on other planting dates for the crop sown on 25<sup>th</sup> October is Kufri Pukhraj (108.00g) followed by Kufri Khyati (107.01g) and Kufri Jyoti (30.99g). In the 5<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (276.00g) followed by Kufri Khyati (234.99g) and Kufri Jyoti (80.49g). In 15<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (296.01g) followed by Kufri Khyati (258.99g) and Kufri Jyoti (158.01g). So, it is inferred that the Number of mini-tubers in all the three varieties under study shows a general trend with Kufri Pukhraj was leading followed by Kufri Khyati and Kufri Jyoti.

The second factor under consideration is spacing's that are 7X7 cm, 14X14 cm, and 21X21 cm. In 7X7 cm spacing the Number of mini-tubers for all the three varieties follow the trend that Kufri Pukhraj (103.87g) followed by Kufri Khyati (95.97g) and Kufri Jyoti (50.48g). The number of mini-tubers trend for the crop sown on 14X14 cm spacing was Kufri Pukhraj (216.47g) followed by Kufri Khyati (178.62g) and Kufri Jyoti (96.87g). In 21X21 cm spacing sown crop, the trend Kufri Pukhraj (241.55g) followed by Kufri Khyati (215.15g) and Kufri Jyoti (113.32g).

In the crop season 2017-18 all the three varieties under study Kufri Jyoti, Kufri Pukhraj and Kufri Khyati were studied under two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and spacing's that are 7X7 cm, 14X14 cm and 21X21 cm. As obvious from the given figure, the tuber yield per plant in Kufri Pukhraj (92.01g) followed by Kufri Khyati (91.50g) and Kufri Jyoti (21.60g) for the crop sown on 15<sup>th</sup> October. A different trend was noticed on other planting dates for the crop sown on 25<sup>th</sup> October is Kufri Khyati (108.69g) followed by Kufri Pukhraj (106.56g) and Kufri Jyoti (30.18g). In the 5<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (273.72g) followed by Kufri Khyati (234.81g) and Kufri Jyoti (80.82g). In 15<sup>th</sup> November

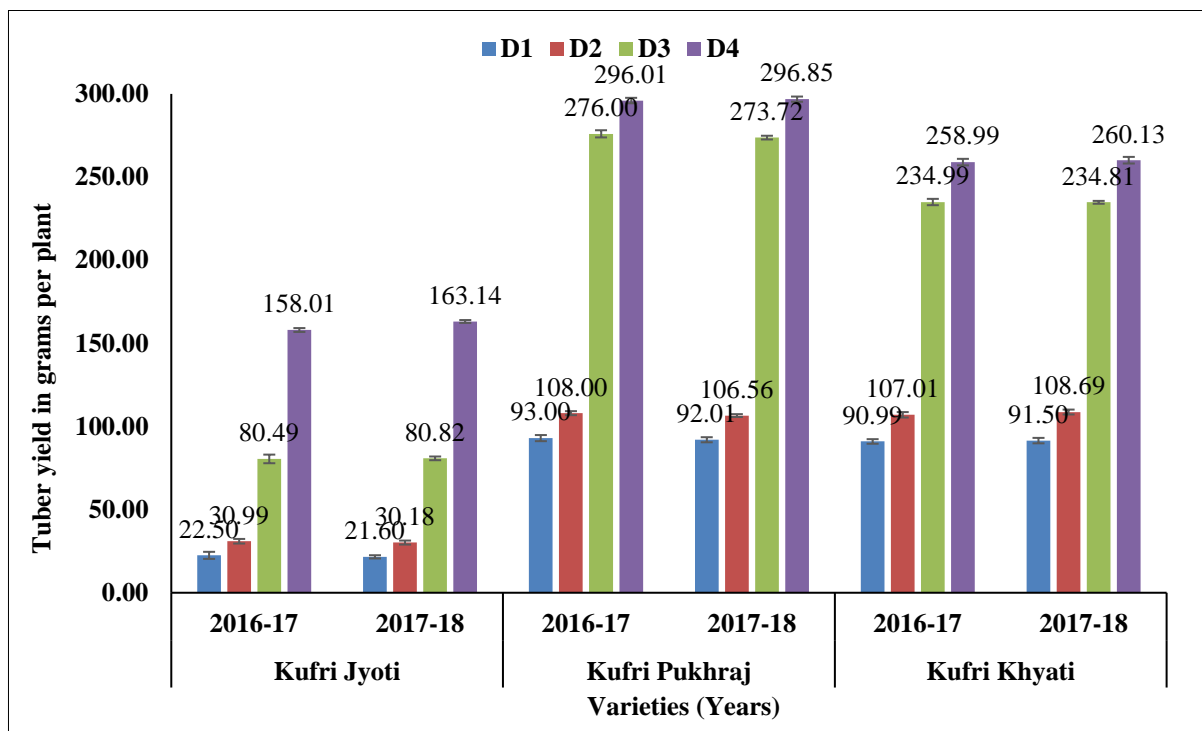


sown crop, the trend was Kufri Pukhraj (296.85g) followed by Kufri Khyati (260.13g) and Kufri Jyoti (163.14g). So, it is inferred that the Number of mini-tubers in all the three varieties under study shows a general trend with Kufri Pukhraj was leading followed by Kufri Khyati and Kufri Jyoti.

The second factor under consideration is spacing's that are 7X7 cm, 14X14 cm, and 21X21 cm. In 7X7 cm spacing the Number of mini-tubers for all the three varieties follow the trend that Kufri Pukhraj (102.87g) followed by Kufri Khyati (96.08g) and Kufri Jyoti (49.88g). The number of mini-tubers trend for the crop sown on 14X14 cm spacing was Kufri Pukhraj (215.36g) followed by Kufri Khyati (179.23g) and Kufri Jyoti (95.78g). In 21X21 cm spacing sown crop, the trend Kufri Pukhraj (240.58g) followed by Kufri Khyati (210.57g) and Kufri Jyoti (112.95g).

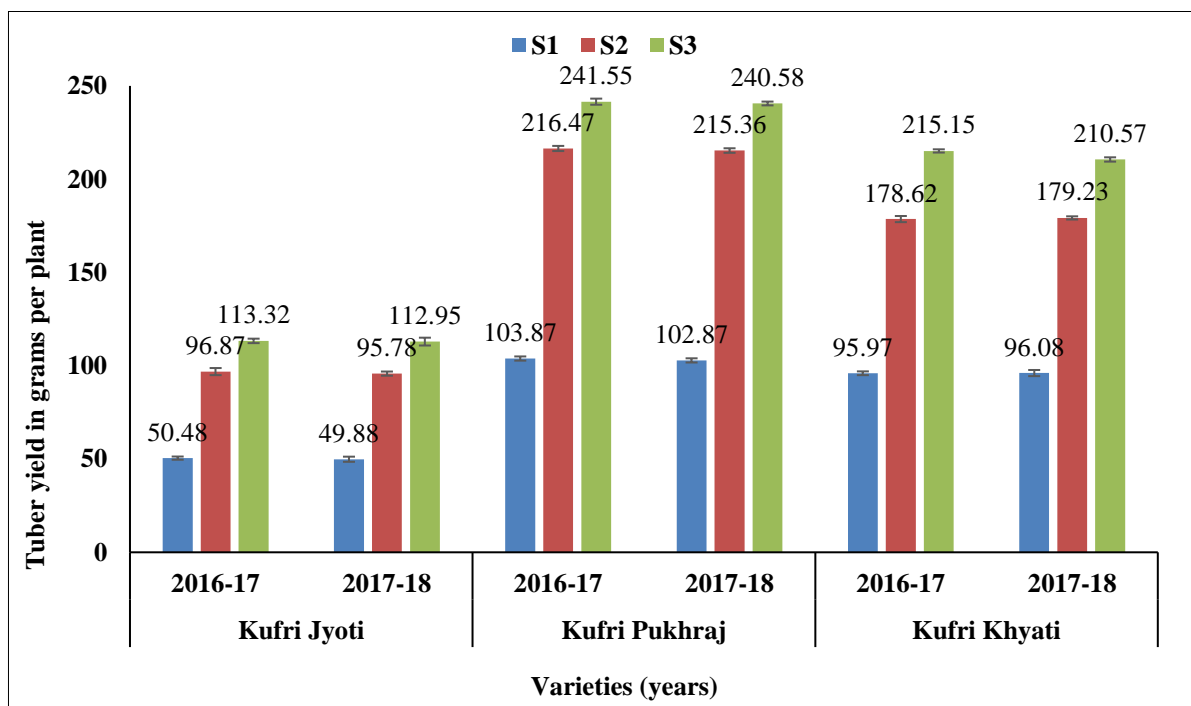
The data confirms significant effect of varieties, date of planting and plant spacing over number of mini-tubers formation; however, there was no significant effect of cropping seasons. The interaction effect of variety x date of planting, year x variety, year x date of planting, year x variety x date of planting, year x plant spacing, variety x plant spacing, year x variety x plant spacing, date of planting x plant spacing, year x date of planting x plant spacing, variety x date of planting x plant spacing and year x variety x date of planting x plant spacing was also reported to be significant for number of mini-tubers per plant.

Ezekiel and Bhargava (1992) perceived that low yield of potato tubers acquired in the early crop was primarily due to a lesser and small canopy, which leads to diminished interception of solar radiation, high temperature conditions during early crop season depressed tuber production through reduced subdividing of photosynthates to the tubers. Similar findings were reported by Singh et al. (2001). However, in contradiction, Kawakami *et al.* (2005) had observed reduction in tuber yield with delayed planting, primarily due to the restriction of growing period in micro tubers and traditional seed tubers plants. Further, spacing was also reported be directly correlated with tuber yield as confirmed by Farran and Mingo-Castel (2006) while Mateus-Rodriguez et al. (2012) had reported varietal variation in yield of aeroponically grown potato cultivars.



**Figure-4.4A: Tubers yield per plant of potato cultivars grown at different dates of planting under aeroponic system (SeM± ranged from 0.25981 to 1.49904)**

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November]



**Figure-4.4B: Tubers yield per plant of potato cultivars grown at different plant spacing under aeroponic system (SeM± ranged from 0.25981 to 1.49904)**

[Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

#### 4.12. Harvest index:

Harvest index of a crop is the measure to calculate the ratio of the product to the total biomass above the ground. Harvest index of all the three potato varieties under study was calculated on different dates of planting. In the crop season 2016-17, all the three varieties under study that are Kufri Jyoti, Kufri Pukhraj and Kufri Khyati were studied under two factors of four planting dates that are 15<sup>th</sup> October, 25<sup>th</sup> October, 5<sup>th</sup> November and 15<sup>th</sup> November and plant spacing that are 7X7 cm, 14X14 cm and 21X21 cm.

As obvious from the Table-4.9, the Harvest index is maximum in the late part of crop season with the trend as Kufri Pukhraj (0.516) followed by Kufri Khyati (0.492) and Kufri Jyoti (0.064) for the crop sown on 15<sup>th</sup> October. A similar trend was also noticed on other planting dates but the Harvest index was showing an increase with the late season cropping. Harvest index for the crop sown on 25<sup>th</sup> October was Kufri Pukhraj (0.617) followed by Kufri Khyati (0.509) and Kufri Jyoti (0.121). In the 5<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (1.104) followed by Kufri Khyati (1.044) and Kufri Jyoti (0.358). In 15<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (1.316) followed by Kufri Khyati (1.295) and Kufri Jyoti (0.752). So, it is inferred that Harvest index in all the three varieties under study shows a general trend with Kufri Khyati is leading followed by Kufri Pukhraj and Kufri Jyoti in the early crop season but in late crop season the trend had shown a twist with Kufri Pukhraj takes the lead followed by Kufri Khyati and last one is Kufri Jyoti.

Similarly, in the crop season 2017-18, the Harvest index was maximum in the late part of crop season with the trend as Kufri Pukhraj (0.525) followed by Kufri Khyati (0.436) and Kufri Jyoti (0.072) for the crop sown on 15<sup>th</sup> October. A similar trend was also noticed on other planting dates but the Harvest index was showing an increase with the late season cropping. Harvest index for the crop sown on 25<sup>th</sup> October was Kufri Pukhraj (0.592) followed by Kufri Khyati (0.435) and Kufri Jyoti (0.110). In the 5<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (1.370) followed by Kufri Khyati (1.170) and Kufri Jyoti (0.324). In 15<sup>th</sup> November sown crop, the Kufri Pukhraj (1.48) followed by Kufri Khyati (1.41) and Kufri Jyoti (0.816). So, it is inferred that the Harvest index in all the three varieties under study shows a general trend with Kufri Pukhraj is leading followed by Kufri Khyati and Kufri Jyoti in the crop season 2017-18.

Harvest index of the average data (Table-4.9) in all the three varieties under study that are Kufri Jyoti, Kufri Pukhraj and Kufri Khyati confirms that the Harvest index was maximum in the late part of crop season with the trend as Kufri Pukhraj (0.520) followed by Kufri Khyati (0.464) and Kufri Jyoti (0.068) for the crop sown on 15<sup>th</sup> October. Harvest index for the crop sown on 25<sup>th</sup> October was Kufri Pukhraj (0.604) followed by Kufri Khyati (0.472) and Kufri Jyoti (0.115). In the 5<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (1.237) followed by Kufri Khyati (1.107) and Kufri Jyoti (0.341). In 15<sup>th</sup> November sown crop, the trend was Kufri Pukhraj (1.398) followed by Kufri Khyati (1.352) and Kufri Jyoti (0.784). So, it is inferred that the Harvest index in all the three varieties under study shows a general trend with Kufri Pukhraj is leading followed by Kufri Khyati and Kufri Jyoti.

**Table-4.9: Harvest index of the average data in all the three varieties**

Date of Planting	Kufri Jyoti			Kufri Pukhraj			Kufri Khyati		
	Harvest index (2016-17)	Harvest index (2017-18)	Harvest index (Average data)	Harvest index (2016-17)	Harvest index (2017-18)	Harvest index (Average data)	Harvest index (2016-17)	Harvest index (2017-18)	Harvest index (Average data)
<b>D1</b>	0.064	0.072	0.068	0.516	0.525	0.520	0.492	0.436	0.464
<b>D2</b>	0.121	0.11	0.115	0.617	0.592	0.604	0.509	0.435	0.472
<b>D3</b>	0.358	0.324	0.341	1.104	1.37	1.237	1.044	1.17	1.107
<b>D4</b>	0.752	0.816	0.784	1.316	1.48	1.398	1.295	1.41	1.352

Relatively high value of Harvest index of cultivars Kufri Pukhraj and Kufri Khyati might be associated with high varietal attributes which confirms suitability of these cultivars for cultivation under aeroponic conditions. There are no any observations have been reported over Harvest index of aeroponically grown potato cultivars. The Harvest index of potato cultivars was reported to be increased with delayed planting which might be associated with increased mass of potato tubers with delayed planting and is associated with the high tuberization and dry matter content of tubers in comparison to dry matter

content of vegetative parts as described by Lallawmkima *et al.* (2018). Due to lack of availability of literatures for related observations the present findings cannot be further justified.

#### 4.13. Multiple regression analysis

The multiple regression equation for the number of mini-tubers per plant (Y) as dependent variable and seven independent variables (X<sub>1</sub> to X<sub>7</sub>) can be expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \dots + \beta_7 X_7 + \varepsilon$$

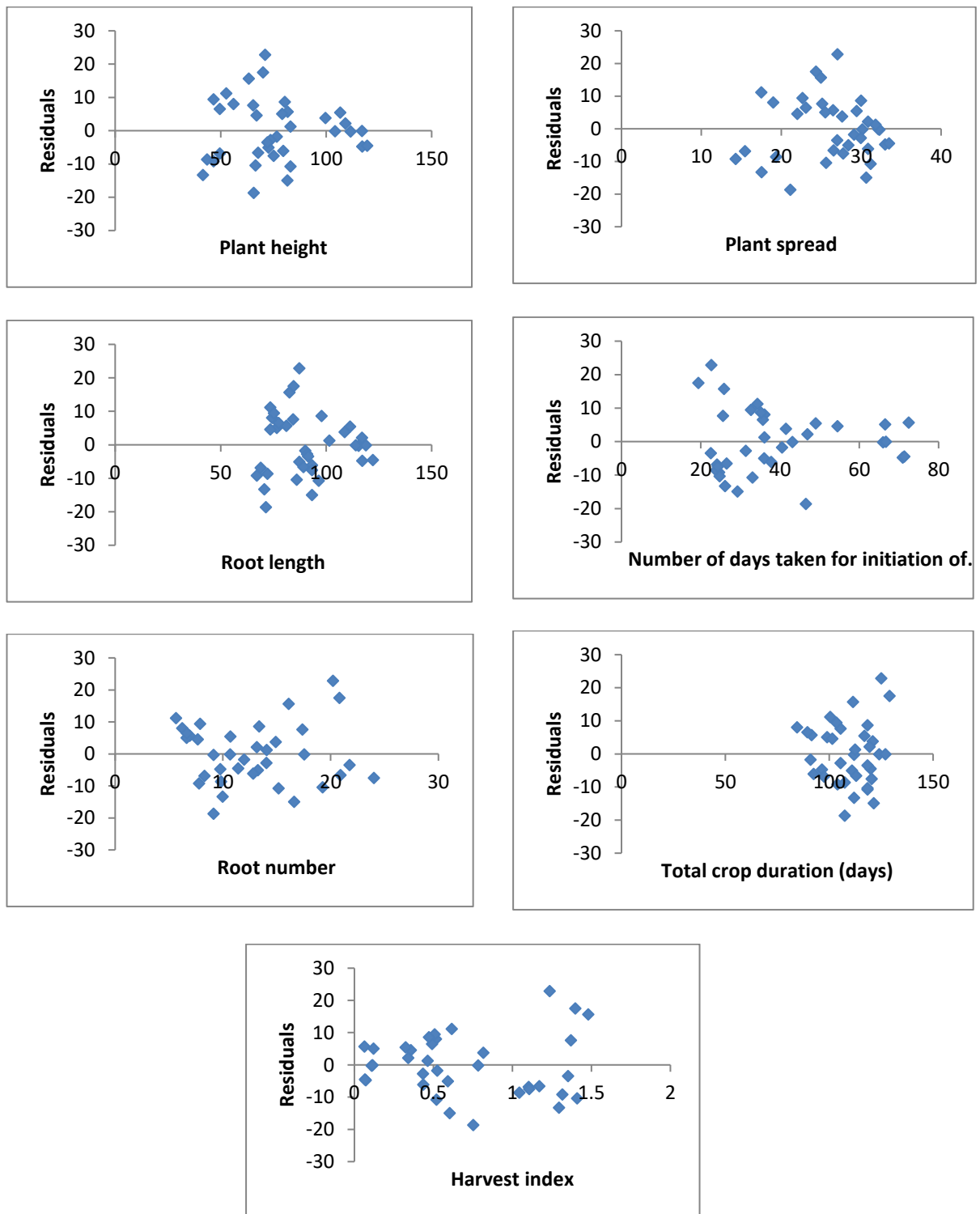
Where,  $\beta_0$  to  $\beta_7$  are the estimated coefficient for eight parameters under study.

**Table-4.10: Multiple regression analysis for number of mini-tuber production per plant (Y) as function of seven independent variables (X<sub>1</sub> to X<sub>7</sub>)**

<i>Regression Statistics</i>	
<b>Multiple R</b>	0.97
<b>R Square</b>	0.94
<b>Adjusted R Square</b>	0.92
<b>Standard Error</b>	10.46
<b>Observations</b>	36

<b>ANOVA</b>					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F value</i>	<i>P value</i>
<b>Regression</b>	7	47994.57	6856.37	62.66	2.008 x 10 <sup>-5</sup>
<b>Residual</b>	28	3063.76	109.42		
<b>Total</b>	35	51058.34			

	<i>Coefficients (β)</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>
<b>Intercept</b>	-56.65	35.51	-1.59	0.12	-129.38	16.08
<b>Plant height (X<sub>1</sub>)</b>	0.33	0.47	0.71	0.48	-0.63	1.29
<b>Root length (X<sub>2</sub>)</b>	-0.42	0.51	-0.82	0.42	-1.47	0.63
<b>Plant spread (X<sub>3</sub>)</b>	1.26	1.24	1.01	0.32	-1.29	3.80
<b>Root number (X<sub>4</sub>)</b>	<b>3.18</b>	1.21	2.62	<b>0.01</b>	0.69	5.66
<b>Number of days taken for initiation of tuber (X<sub>5</sub>)</b>	0.01	0.36	0.02	0.98	-0.73	0.74
<b>Total crop duration (days) (X<sub>6</sub>)</b>	0.01	0.25	0.06	0.95	-0.50	0.52
<b>Harvest index (X<sub>7</sub>)</b>	<b>60.53</b>	13.07	4.63	<b>7.62 x 10<sup>-5</sup></b>	33.75	87.32



**Figure-4.5: Residual plots for predicted Y-values under each independent variable**

ANOVA for multiple regressions between dependent variable (Y) and independent variables ( $X_1$  to  $X_7$ ) has been presented in Table-4.10. F-value or statistics is the test of significance for entire regression. At  $\alpha = 0.05$ , the  $P$ -value ( $2.008 \times 10^{-15}$ ) is less than 0.05

so the regression is statistically significant. At  $\alpha = 0.05$ , the t-value of root numbers and the Harvest index is statistically significant as their corresponding *P*-values ( $0.01$  and  $7.622 \times 10^{-5}$ , respectively) are less than  $0.05$ . Thus, out of seven independent variables only two variables root number ( $X_4$ ) and harvest index ( $X_7$ ) are individually useful in the prediction of number of mini-tubers per plants ( $Y$ ). Further, individual coefficients of these two variables are positive and high reflecting greater direct and positive impact of  $X_7$  ( $\beta_7$  is  $60.53$ ) and  $X_4$  ( $\beta_4$  is  $3.18$ ) on number of mini-tubers per plants ( $Y$ ). The regression coefficient ( $r^2$ ) is  $0.94$  means  $94\%$  of the total variation in the number of mini-tubers per plant ( $Y$ ) is explained by the regression. The measure of unexpected variation as standard error is  $10.46$ . the adjusted  $r^2$  is also high ( $92\%$ ) which confirms the existence of some other independent variables which can contribute to the  $Y$ . Further, the residual plot for predicted  $Y$ - values under each independent variable is being presented in Figure-4.5. This confirms independent distribution of each variable about the mean. Most of the distribution is localized while it is becoming wider for Harvest index so there is existence of unequal variance of the residual distribution for this trait.

#### **4.14. Economic analysis of the mini-tubers production through aeroponics:**

The economic analysis of mini-tuber production under aeroponics system was carried out for all cultivars and dates of planting under different plant spacing and has been presented in Table-4.11. The average of three varieties, four dates of planting and two years was worked out and estimation was done at three different spacing for determining the cost of each mini-tuber. The highest number of mini-tubers per season were produced in spacing of  $7X7$  cm ( $324702$ ) followed by  $14X14$  cm ( $230640$ ) and  $21X21$  cm ( $115302$ ) as the number of plants accommodated in the given area ( $90$  sq. m.) was highest in spacing of  $7X7$  cm ( $15462$ ) followed by  $14X14$  cm ( $3844$ ) and  $21X21$  cm ( $1747$ ). The total cost of production of mini-tubers under aeroponic was also aligned with same trend with highest in spacing of  $7X7$  cm (Rs.  $658266$ ) followed by  $14X14$  cm (Rs.  $449142$ ) and  $21X21$  cm (Rs.  $411396$ ). The sharp reduction in total cost of production on the basis of effective resource utilization was reported from spacing of  $7X7$  cm to  $14X14$  cm with significantly high production of mini-tubers which might be reason behind lowest cost of each tuber production in spacing of  $14X14$  cm (Rs.  $1.94$ ) followed by  $7X7$  cm (Rs.  $2.02$ ) and  $21X21$  cm (Rs.  $3.57$ ). Thus, it can be concluded from this estimation that planting of potato at

spacing of 14X14 cm is most viable practice for economic mini-tuber production under aeroponic system.

**Table-4.11: Economic analysis of the mini-tubers production through aerponics  
(Size of Aeroponic system: 90 sq. m.)**

<b>Spacings (cm)</b>	<b>7X7</b>	<b>14X14</b>	<b>21X21</b>
Seasons per year	1	1	1
Area of table (m <sup>2</sup> )	90	90	90
Effective planting area (m <sup>2</sup> )	87.36	87.36	87.36
Number of plants	15462	3844	1747
Multiplication rate (Number of mini-tubers per plant) average of mini-tubers in crop season 2016-17 and 2017-18	21	60	66
Mini-tubers /season	324702	230640	115302
<b>Costs</b>			
Total fixed costs (Rs)	250000	250000	250000
Cost of plants @ Rs 12/- per plant	185544	46128	20964
Cost of chemicals @ Rs 6/- per plant	92772	23064	10482
Labour @Rs 400/- per day	52000	52000	52000
Technical person @ Rs 100/- per day	13000	13000	13000
Storage@ Rs 200/ per 50 kg	800	800	800
Packing charges	500	500	500
Cost of electricity (15 units per day) @Rs 7/- unit	13650	13650	13650
<b>Subtotal-2</b>	<b>358266</b>	<b>149142</b>	<b>111396</b>
<b>Annual Maintenance</b>			
Maintenance (Equipments) @ 5% of the fixed cost	50000	50000	50000
<b>Total Cost of production</b>	<b>658266</b>	<b>449142</b>	<b>411396</b>
<b>Cost per tuber</b>	<b>Rs. 2.02</b>	<b>Rs. 1.94</b>	<b>Rs. 3.57</b>



## CHAPTER-VI

### SUMMARY AND CONCLUSION

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The aim of this study was to elucidate the cultivation aspects of producing quality potato seed tubers aeroponically under local conditions. An experiment was performed at Centre of Excellence for Potato, Department of Horticulture, Village-Dhogri, District-Jalandhar from 2016 to 2018 to investigate the study on “**Agronomic performance and mini-tuber production of potato varieties under aeroponic system**” with three varieties viz. Kufri Jyoti, Kufri Pukhraj and Kufri Khyati. The basic principle of aeroponics is to grow plants in a closed environment by periodically spraying roots with a nutrient solution containing all the required elements for plant growth and tuberization. The results of the experiment can be summarised and concluded as below:

**Mean plant height (cm) with respect to date of planting:** As per the average data, it is clear that the crop sown on 15 October in crop season 2016-17 and 2017-18 has shown maximum plant height as compared to planting on 25<sup>th</sup> October, 5<sup>th</sup> and 15<sup>th</sup> November. Within the varieties, Kufri Jyoti has shown maximum plant height on all the planting dates while Kufri Khyati and Kufri Pukhraj are almost at par with each other on all the planting dates in both the crop season.

**Mean plant height (cm) with respect to plant spacing:** Average data of mean plant height with respect to spacing that are 7x7 cm, 14x14cm, 21x21cm in crop seasons 2016-17 and 2017-18 for three Potato varieties viz Kufri Jyoti, Kufri Pukhraj, Kufri Khyati have shown a trend that 21x21 cm spacing have maximum height as compared to other two sets of spacing.

**Mean root length(cm) with respect to dates of planting:** The variety Kufri Jyoti has maximum root length as compared to Kufri Pukhraj and Kufri Khyati. Comparative analysis between Kufri Pukhraj and Kufri Khyati shows a very little difference. The crop sown on 15<sup>th</sup> and 25<sup>th</sup> October has longer root system as compared to late planting of 5<sup>th</sup> and 15<sup>th</sup> November, in all the three varieties in both the crop season.

**Mean root length (cm) with respect to plant spacing:** The plant spacing of 21x21 cm shows maximum root length for all the three varieties viz. Kufri Jyoti, Kufri Pukhraj, Kufri Khyati in all planting dates and replications.

**Plant Spread (cm) with respect to planting dates:** It is maximum in Kufri Jyoti followed by Kufri Khyati and then it is Kufri Pukhraj. Analysis of data with date of planting shows that the crop sown on 15<sup>th</sup> and 25<sup>th</sup> October has more plant spread as compared to the crop sown on the 5<sup>th</sup> and 15<sup>th</sup> of November in both crop seasons under study.

**Mean plant spread with respect to plant spacing:** The plant spacing of 21x21 cm shows maximum plant spread for all the three varieties viz. Kufri Jyoti, Kufri Pukhraj Kufri Khyati in all planting dates and replications.

**Mean root number with respect to planting dates:** The number of roots in Kufri Khyati is maximum followed by Kufri Pukhraj and the least root number among the three varieties under study accounts for Kufri Jyoti. Analyzing the data of root number with date of sowing also shows a trend that late sown crop that is on the 5<sup>th</sup> and 15<sup>th</sup> of November has a higher root number as compared to earlier sown crops that are on the 15<sup>th</sup> and 25<sup>th</sup> of October in crop season 2016-17 and 2017-18.

**Root number with respect to plant spacing:** The plant spacing of 21x21 cm shows maximum root length for all the three varieties viz. Kufri Jyoti, Kufri Pukhraj, Kufri Khyati in all planting dates and replications, It also shows a trend that late sown crop that is on 5<sup>th</sup> and 15<sup>th</sup> of November has higher root number as compared to earlier sown crops that is on 15<sup>th</sup> and 25<sup>th</sup> of October in crop season 2016-17 and 2017-18.

**Initiation of tuber formation (Days after planting) with respect to planting dates:** The crop sown late starts tuberisation earlier than the crop sown in the early season. Kufri Khyati and Kufri Pukhraj sown on 15<sup>th</sup> and 25<sup>th</sup> October started tuberisation after 30 to 40 days interval after planting while Kufri Jyoti onset tuber formation 60-70days after planting. Kufri Khyati and Kufri Pukhraj sown on 5<sup>th</sup> and 15<sup>th</sup> November start tuberisation within 20 to 30 days after planting while Kufri Jyoti starts tuber initiation in 40 to 50 days after planting. It is inferred from the above data analysis that Kufri Khyati and Kufri Pukhraj are the varieties under study can be planted earlier in the crop season (15<sup>th</sup> and 25<sup>th</sup> October) while Kufri Jyoti is fit to be sown in late season that is 5<sup>th</sup> and 15<sup>th</sup> November.

**Number of mini-tubers (2.5 to 3.0 gm) per plant with respect to planting dates:**

Analysis of data for the number of mini-tubers of 2.5 to 3.0 gm per plant on the three varieties under study has shown that Kufri Pukhraj leads the race followed by Kufri Khyati and then Kufri Jyoti. In crop sown on the 15<sup>th</sup> and 25<sup>th</sup> of October in both the crop seasons under study have shown that Kufri Pukhraj and Kufri Khyati give 30 to 40 mini-tubers of 2.5 gm to 3.0 gm while Kufri Jyoti ends at 7 to 10 tubers. In crop sown on 5<sup>th</sup> and 15<sup>th</sup> November of the crop seasons under study Kufri Pukhraj gives 90 to 100 mini-tubers of 2.5 to 3.0 gm followed by Kufri Khyati produces 70 to 90 mini-tubers of the above said weight. Kufri Jyoti has given mini-tubers of above said weight in the range of 50 to 60 mini-tubers in late sown crop

**Number of mini-tubers (2.5 to 3.0 gm) per plant with respect to plant spacing:** Number of mini-tubers is one of the most important parts of this study. Analysis of the average data for the crop season 2016-17 and 2017-18 has revealed spacing show a major effect on the number of mini-tubers. Maximum number of tubers of 2.5 to 3.0 gms harvested in both the crop seasons in all the three potato varieties viz Kufri Jyoti, Kufri Pukhraj and Kufri Khyati at 21x21 cm spacing but 14x14 cm is also utmost at par in the study.

**Yield of required size mini-tubers (gm) with respect to dates of planting:** Analysis of tuber weight in gms for average data for the crop season 2016-17 and 2017-18 shows that date of planting and weight of tuber formation has a clear-cut correlation. Crop sown on 15<sup>th</sup> and 25<sup>th</sup> October has shown low weight tubers ranging from 1.75 gms to 2.80 gms but in crop sown on 5<sup>th</sup> and 15<sup>th</sup> November has other stories to say, here tuber weight of Kufri Khyati ranged between 3.27 gms to 3.48 gms while in Kufri Pukhraj it ranged between 3.10 to 3.37 gms while in Kufri Jyoti the range of tuber weight lies between 2.48 to 2.89 gms. For both the crop season under study.

**Total crop duration (days) with respect to dates of planting:** Data analysis of the average data for both the crop season under study shows that Variety Kufri Jyoti in earlier sown crop that is 15<sup>th</sup> and 25<sup>th</sup> October shows highest crop duration of about 103 days while Kufri Pukhraj and Kufri Khyati gives up in about 98 days. In the case of the crop sown on the 5<sup>th</sup> and 15<sup>th</sup> of November in both the crop seasons under study crop duration for all the varieties ranged from 110 to 120 days showing long stand of the crop means more harvesting cycles.

**Total crop duration (days) with respect to plant spacing:** Analysis of the average data for both the crop season 2016-17 and 2017-18 has shown that total crop duration is affected by spacing in planting table as 7x7 cm spacing has shortest crop duration as compared to 14x14cm and 21x21cm.

**Harvest Index:** In terms of varieties, Kufri Pukhraj takes the lead with the highest harvest index followed by Kufri Khyati while Kufri Jyoti comes to the last.

**Regression study:** Out of seven independent variables only two variables root number ( $X_4$ ) and harvest index ( $X_7$ ) are individually useful in the prediction of number of mini-tubers per plants ( $Y$ ).

**Economic analysis:** The sharp reduction in total cost of production on the basis of effective resource utilization was reported from spacing of 7X7 cm to 14X14 cm with significantly high production of mini-tubers which might be reason behind lowest cost of each tuber production in spacing of 14X14 cm (Rs. 1.94) followed by 7X7 cm (Rs. 2.02) and 21X21 cm (Rs. 3.57).

### **Conclusions:**

For Kufri Jyoti variety the performance behavior is unique as early sown Crop shows high foliage growth a smaller number of tubers, even though the root length is very high, harvest index is low and does not give promising result in economic analysis. But the same variety performed well if sown on late in the crop season that is 5<sup>th</sup> and 15<sup>th</sup> of November. Kufri Khyati and Kufri Pukhraj performed well in early dates of sowing but their performance is also enhanced in late sowing as the number of tubers and weight of tubers both improved in crop sown on 5<sup>th</sup> and 15<sup>th</sup> of November in both the crop seasons. Harvest index and economic analysis show that Kufri Khyati leads and Kufri Pukhraj is not far back but Kufri Jyoti lags in terms of harvest index and economic analysis. In terms of spacing, three spacing's 7x7 cm, 14x14 cm, 21x21cm were studied and results have clearly shown that 14x14 cm spacing suits well to all the varieties in terms of space for foliage growth, space for flourishing root system and economic analysis in terms of per unit area yield. On the basis of economic analysis also spacing of 14x14 cm resulted lowest cost of each tuber production (Rs. 1.94).

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## APPENDICES

**Appendix-I: Plant height (cm) of potato cultivars grown at different dates and spacing under aeroponic system (2016-17)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean
<b>D<sub>1</sub></b>	80.10	118.00	120.00	<b>106.03</b>	55.00	75.00	82.00	<b>70.67</b>	48.00	78.00	84.00	<b>70.00</b>
<b>D<sub>2</sub></b>	78.10	112.20	118.10	<b>102.80</b>	53.00	71.00	80.00	<b>68.00</b>	45.00	72.00	81.00	<b>66.00</b>
<b>D<sub>3</sub></b>	66.20	108.00	110.00	<b>94.73</b>	48.00	64.00	70.10	<b>60.70</b>	42.00	66.00	76.00	<b>61.33</b>
<b>D<sub>4</sub></b>	65.10	100.20	105.10	<b>90.13</b>	45.00	62.00	68.00	<b>58.33</b>	40.00	65.00	73.00	<b>59.33</b>
<b>Mean</b>	<b>72.38</b>	<b>109.60</b>	<b>113.30</b>		<b>50.25</b>	<b>68.00</b>	<b>75.03</b>		<b>43.75</b>	<b>70.25</b>	<b>78.50</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-II: Plant height (cm) of potato cultivars grown at different dates and spacing under aeroponic system (2017-18)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	Mean
<b>D<sub>1</sub></b>	83.25	116.20	118.82	<b>106.10</b>	57.00	78.13	84.10	<b>73.08</b>	51.20	81.23	82.20	<b>71.54</b>
<b>D<sub>2</sub></b>	80.15	110.80	115.90	<b>102.30</b>	52.30	74.20	83.20	<b>69.90</b>	48.19	75.10	79.80	<b>67.70</b>
<b>D<sub>3</sub></b>	67.80	105.30	108.25	<b>93.78</b>	51.19	66.80	72.00	<b>63.33</b>	45.10	69.35	74.25	<b>62.90</b>
<b>D<sub>4</sub></b>	66.20	99.150	103.20	<b>89.52</b>	48.30	64.50	72.19	<b>61.66</b>	43.20	68.10	71.30	<b>60.87</b>
<b>Mean</b>	<b>74.35</b>	<b>107.90</b>	<b>111.50</b>		<b>52.20</b>	<b>70.91</b>	<b>77.87</b>		<b>46.92</b>	<b>73.45</b>	<b>76.89</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]



**Appendix-III: ANOVA Table for Average data on Plant height (cm) of potato cultivars grown at different dates and spacing under aeroponic system during 2016-17 and 2017-18**

Source	D.F.	M.S.S.	F-Ratio	CD (5%)	C.V.
Replication	2	114.01	51.46		
Year (A)	1	79.01	35.67	0.87	
Error A	2	2.22			1.95
Variety (B)	2	7632.29	6244.25	0.43	
Year (A) X Variety (B)	2	1.99	1.63	NS	
Error B	8	1.22			1.45
Date of Planting (C)	3	201.45	54.98	0.75	
Year (A) X Date of Planting (C)	3	0.33	0.09	NS	
Variety (B) X Date of Planting (C)	6	6975.35	1903.61	1.29	
Year (A) X Variety (B) X Date of Planting (C)	6	15.26	4.16	1.83	
Error C	36	3.66			2.51
Plant Spacing (D)	2	21373.62	2935027.00	0.03	
Year (A) X Plant Spacing (D)	2	30.21	4149.10	0.04	
Variety (B) X Plant Spacing (D)	4	39.37	5406.58	0.05	
Year (A) X Variety (B) X Plant Spacing (D)	4	2.06	282.55	0.07	
Date of Planting (C) X Plant Spacing (D)	6	19.09	2621.51	0.06	
Year (A) X Date of Planting (C) X Plant Spacing (D)	6	0.91	124.98	0.08	
Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	166.88	22915.42	0.10	
Year (A) X Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	8.15	1119.44	0.14	
Error D	96	0.01			0.11

**Appendix-IV: Root length (cm) of potato cultivars grown at different dates and spacing under aeroponic system (2016-17)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	80.00	116.00	120.10	<b>105.37</b>	73.50	89.00	95.00	<b>85.83</b>	75.80	92.80	99.80	<b>89.47</b>
<b>D2</b>	77.30	114.10	117.50	<b>102.97</b>	72.90	86.20	92.30	<b>83.80</b>	73.30	90.70	97.30	<b>87.10</b>
<b>D3</b>	72.90	110.20	115.00	<b>99.37</b>	68.50	83.50	86.40	<b>79.47</b>	70.20	88.70	92.40	<b>83.77</b>
<b>D4</b>	70.80	108.30	112.90	<b>97.33</b>	66.90	81.90	83.90	<b>77.57</b>	68.90	85.90	90.80	<b>81.87</b>
<b>Mean</b>	<b>75.25</b>	<b>112.15</b>	<b>116.38</b>		<b>70.45</b>	<b>85.15</b>	<b>89.40</b>		<b>72.05</b>	<b>89.53</b>	<b>95.08</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-V: Root length (cm) of potato cultivars grown at different dates and spacing under aeroponic system (2017-18)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	82.10	118.20	124.10	<b>108.13</b>	75.20	91.23	97.80	<b>88.08</b>	79.10	93.80	103.13	<b>92.01</b>
<b>D2</b>	75.8	116.53	120.1	<b>104.14</b>	74.12	88.31	94.20	<b>85.54</b>	77.20	91.13	98.25	<b>88.86</b>
<b>D3</b>	74.1	112.4	118.8	<b>101.77</b>	69.29	85.13	88.12	<b>80.85</b>	74.14	89.72	94.20	<b>86.02</b>
<b>D4</b>	71.9	109.14	115.1	<b>98.71</b>	67.32	83.21	85.13	<b>78.55</b>	72.32	86.15	92.13	<b>83.53</b>
<b>Mean</b>	<b>75.98</b>	<b>114.07</b>	<b>119.53</b>		<b>71.48</b>	<b>86.97</b>	<b>91.31</b>		<b>75.69</b>	<b>90.20</b>	<b>96.93</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-VI: ANOVA Table for Average data on Root length (cm) of potato cultivars grown at different dates and spacing under aeroponic system during 2016-17 and 2017-18**

<b>Source</b>	<b>D.F.</b>	<b>M.S.S.</b>	<b>F-Ratio</b>	<b>CD (5%)</b>	<b>C.V.</b>
Replication	2	174.47	43.72		
Year (A)	1	179.46	44.97	1.17	
Error A	2	3.99			2.21
Variety (B)	2	2324.14	40167.40	0.09	
Year (A) X Variety (B)	2	6.94	119.86	0.13	
Error B	8	0.06			0.27
Date of Planting (C)	3	124.31	0.00	0.02	
Year (A) X Date of Planting (C)	3	0.67	0.00	0.00	
Variety (B) X Date of Planting (C)	6	2065.29	0.00	0.03	
Year (A) X Variety (B) X Date of Planting (C)	6	2.07	0.00	0.00	
Error C	36	0.00			0.00
Plant Spacing (D)	2	16253.75	5124004.00	0.02	
Year (A) X Plant Spacing (D)	2	8.88	2799.39	0.03	
Variety (B) X Plant Spacing (D)	4	115.51	36415.75	0.03	
Year (A) X Variety (B) X Plant Spacing (D)	4	0.64	202.73	0.05	
Date of Planting (C) X Plant Spacing (D)	6	6.27	1976.06	0.04	
Year (A) X Date of Planting (C) X Plant Spacing (D)	6	0.42	133.20	0.05	
Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	408.70	128842.70	0.06	
Year (A) X Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	2.04	644.15	0.09	
Error D	96	0.00			0.06

**Appendix-VII: Plant Spread (cm) of potato cultivars grown at different dates and spacing under aeroponic system (2016-17)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	26.00	32.00	33.00	<b>30.33</b>	20.00	28.00	30.00	<b>26.00</b>	22.00	30.20	32.50	<b>28.23</b>
<b>D2</b>	25.00	31.50	31.50	<b>29.33</b>	18.50	27.50	29.50	<b>25.17</b>	21.50	29.50	30.20	<b>27.07</b>
<b>D3</b>	22.00	28.10	30.20	<b>26.77</b>	16.10	24.00	26.00	<b>22.03</b>	18.50	26.30	28.50	<b>24.43</b>
<b>D4</b>	21.50	26.50	29.50	<b>25.83</b>	15.20	23.50	23.50	<b>20.73</b>	16.90	25.20	27.90	<b>23.33</b>
<b>Mean</b>	<b>23.63</b>	<b>29.53</b>	<b>31.05</b>		<b>17.45</b>	<b>25.75</b>	<b>27.25</b>		<b>19.73</b>	<b>27.80</b>	<b>29.78</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-VIII: Plant Spread (cm) of potato cultivars grown at different dates and spacing under aeroponic system (2017-18)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	27.00	34.00	34.00	<b>31.67</b>	18.00	30.20	32.40	<b>26.87</b>	24.20	31.50	31.10	<b>28.93</b>
<b>D2</b>	26.00	33.10	32.80	<b>30.63</b>	16.52	29.31	31.80	<b>25.88</b>	23.80	30.42	29.81	<b>28.01</b>
<b>D3</b>	22.00	30.80	31.50	<b>28.10</b>	14.80	26.25	28.10	<b>23.05</b>	20.18	26.80	27.00	<b>24.66</b>
<b>D4</b>	20.80	28.73	30.78	<b>26.77</b>	13.40	26.40	25.20	<b>21.67</b>	18.20	26.00	26.12	<b>23.44</b>
<b>Mean</b>	<b>23.95</b>	<b>31.66</b>	<b>32.27</b>		<b>15.68</b>	<b>28.04</b>	<b>29.38</b>		<b>21.60</b>	<b>28.68</b>	<b>28.51</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-IX: ANOVA Table for Average data on Plant spread (cm) of potato cultivars grown at different dates and spacing under aeroponic system during 2016-17 and 2017-18**

Source	D.F.	M.S.S.	F-Ratio	CD (5%)	C.V.
Replication	2	50.88	102.71		
Year (A)	1	39.86	80.46	0.41	
Error A	2	0.50			2.69
Variety (B)	2	484.48	302388.80	0.02	
Year (A) X Variety (B)	2	1.45	907.33	0.02	
Error B	8	0.00			0.15
Date of Planting (C)	3	36.44	0.00	0.02	
Year (A) X Date of Planting (C)	3	0.11	0.00	0.00	
Variety (B) X Date of Planting (C)	6	107.99	0.00	0.03	
Year (A) X Variety (B) X Date of Planting (C)	6	0.72	0.00	0.00	
Error C	36	0.00			0.00
Plant Spacing (D)	2	1877.66	9344049.00	0.01	
Year (A) X Plant Spacing (D)	2	12.58	62597.24	0.01	
Variety (B) X Plant Spacing (D)	4	4.11	20441.83	0.01	
Year (A) X Variety (B) X Plant Spacing (D)	4	1.34	6681.01	0.01	
Date of Planting (C) X Plant Spacing (D)	6	0.84	4162.62	0.01	
Year (A) X Date of Planting (C) X Plant Spacing (D)	6	0.59	2937.55	0.01	
Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	12.86	64000.30	0.02	
Year (A) X Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	6.47	32211.55	0.02	
Error D	96	0.00			0.05

**Appendix-X: Root number of potato cultivars grown at different dates and spacing under aeroponic system (2016-17)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	6.30	9.20	10.30	<b>8.60</b>	5.10	12.10	14.20	<b>10.47</b>	6.20	12.50	14.30	<b>11.00</b>
<b>D2</b>	6.10	8.70	9.70	<b>8.17</b>	4.80	13.70	15.80	<b>11.43</b>	7.50	13.80	13.80	<b>11.70</b>
<b>D3</b>	7.20	10.10	12.00	<b>9.77</b>	7.20	17.90	19.20	<b>14.77</b>	8.90	20.30	24.20	<b>17.80</b>
<b>D4</b>	8.90	14.20	16.30	<b>13.13</b>	7.80	16.60	19.80	<b>14.73</b>	9.80	18.70	22.30	<b>16.93</b>
<b>Mean</b>	<b>7.13</b>	<b>10.55</b>	<b>12.08</b>		<b>6.23</b>	<b>15.08</b>	<b>17.25</b>		<b>8.10</b>	<b>16.33</b>	<b>18.65</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-XI: Root number of potato cultivars grown at different dates and spacing under aeroponic system (2017-18)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	7.54	10.30	12.50	<b>10.11</b>	7.32	11.80	16.10	<b>11.74</b>	7.10	13.10	13.80	<b>11.33</b>
<b>D2</b>	7.13	9.54	11.62	<b>9.43</b>	6.50	12.75	17.40	<b>12.22</b>	8.23	14.25	12.90	<b>11.79</b>
<b>D3</b>	8.10	11.26	14.30	<b>11.22</b>	9.35	16.85	21.23	<b>15.81</b>	10.75	21.50	23.80	<b>18.68</b>
<b>D4</b>	9.34	15.60	18.80	<b>14.58</b>	7.75	15.57	21.82	<b>15.05</b>	10.13	19.80	21.20	<b>17.04</b>
<b>Mean</b>	<b>8.03</b>	<b>11.68</b>	<b>14.31</b>		<b>7.73</b>	<b>14.24</b>	<b>19.14</b>		<b>9.05</b>	<b>17.16</b>	<b>17.93</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-XII: ANOVA Table for Average data on Root number of potato cultivars grown at different dates and spacing under aeroponic system during 2016-17 and 2017-18**

<b>Source</b>	<b>D.F.</b>	<b>M.S.S.</b>	<b>F-Ratio</b>	<b>CD (5%)</b>	<b>C.V.</b>
Replication	2	20.98	35.21		
Year (A)	1	38.83	65.14	0.45	
Error A	2	0.60			6.02
Variety (B)	2	645.76	4702276.00	0.01	
Year (A) X Variety (B)	2	1.09	7917.78	0.01	
Error B	8	0.00			0.09
Date of Planting (C)	3	29.67	0.00	0.01	
Year (A) X Date of Planting (C)	3	0.19	0.00	0.00	
Variety (B) X Date of Planting (C)	6	74.29	0.00	0.02	
Year (A) X Variety (B) X Date of Planting (C)	6	2.03	0.00	0.00	
Error C	36	0.00			0.00
Plant Spacing (D)	2	1493.30	0.00	0.02	
Year (A) X Plant Spacing (D)	2	3.05	2322618.00	0.00	
Variety (B) X Plant Spacing (D)	4	50.46	38484480.00	0.03	
Year (A) X Variety (B) X Plant Spacing (D)	4	1.23	941800.80	0.03	
Date of Planting (C) X Plant Spacing (D)	6	4.43	3376221.00	0.00	
Year (A) X Date of Planting (C) X Plant Spacing (D)	6	0.19	148604.10	0.00	
Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	19.05	14524310.00	0.04	
Year (A) X Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	2.84	2163247.00	0.00	
Error D	96	0.00			0.00

**Appendix-XIII: Number of days taken for initiation of tuber of potato cultivars grown at different dates and spacing under aeroponic system (2016-17)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	72	70	70.8	<b>70.93</b>	35	39	32	<b>35.33</b>	36.5	37.5	35	<b>36.33</b>
<b>D2</b>	68	65	66.5	<b>66.5</b>	33.5	35	28.5	<b>32.33</b>	33.5	32.8	34.5	<b>33.5</b>
<b>D3</b>	55	48	46	<b>49.67</b>	23	24	23.5	<b>23.5</b>	24.5	25	23.5	<b>24.33</b>
<b>D4</b>	48	40	42	<b>43.33</b>	23.2	27	20.5	<b>21.9</b>	27.5	23	21.5	<b>22</b>
<b>Mean</b>	<b>60.75</b>	<b>55.75</b>	<b>56.33</b>		<b>28.68</b>	<b>30</b>	<b>26.13</b>		<b>29</b>	<b>29.5</b>	<b>28.63</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-XIV: Number of days taken for initiation of tuber of potato cultivars grown at different dates and spacing under aeroponic system (2017-18)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	73	72	71.9	<b>72.3</b>	37.2	42	34.1	<b>37.77</b>	34.8	38.1	37.2	<b>36.7</b>
<b>D2</b>	65	67	67	<b>66.33</b>	35.1	37	30	<b>34.03</b>	31.9	30	36	<b>32.63</b>
<b>D3</b>	54	50	47.8	<b>50.6</b>	25.26	27.2	21.8	<b>24.75</b>	23.25	28.1	25.1	<b>25.48</b>
<b>D4</b>	45	43	44.22	<b>44.07</b>	26.1	24.78	18.27	<b>23.05</b>	24.78	26.5	23.63	<b>24.97</b>
<b>Mean</b>	<b>59.25</b>	<b>58</b>	<b>57.73</b>		<b>30.92</b>	<b>32.75</b>	<b>26.04</b>		<b>28.68</b>	<b>30.68</b>	<b>30.48</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]



**Appendix-XV: ANOVA Table for Average data on number of days taken for initiation of tuber of potato cultivars grown at different dates and spacing under aeroponic system during 2016-17 and 2017-18**

<b>Source</b>	<b>D.F.</b>	<b>M.S.S.</b>	<b>F-Ratio</b>	<b>CD (5%)</b>	<b>C.V.</b>
Replication	2	114.27	27.25		
Year (A)	1	32.89	7.85	NS	
Error A	2	4.19			5.25
Variety (B)	2	10909.96	1540938.00	0.03	
Year (A) X Variety (B)	2	1.00	140.97	0.05	
Error B	8	0.01			0.22
Date of Planting (C)	3	459.37	99613.37	0.03	
Year (A) X Date of Planting (C)	3	3.30	714.54	0.04	
Variety (B) X Date of Planting (C)	6	4902.34	1063058.00	0.05	
Year (A) X Variety (B) X Date of Planting (C)	6	5.78	1254.14	0.06	
Error C	36	0.00			0.17
Plant Spacing (D)	2	112.25	18597.76	0.03	
Year (A) X Plant Spacing (D)	2	18.89	3129.20	0.04	
Variety (B) X Plant Spacing (D)	4	10.94	1813.10	0.04	
Year (A) X Variety (B) X Plant Spacing (D)	4	1.97	326.39	0.06	
Date of Planting (C) X Plant Spacing (D)	6	11.60	1922.09	0.05	
Year (A) X Date of Planting (C) X Plant Spacing (D)	6	4.46	739.52	0.07	
Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	45.38	7518.52	0.09	
Year (A) X Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	9.07	1502.73	0.13	
Error D	96	0.01			0.20

**Appendix-XVI: Number of mini-tubers (2.5-3.0 g) per plant of potato cultivars grown at different dates and spacing under aeroponic system (2016-17)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	3.5	7	12	<b>7.5</b>	14	38	41	<b>31</b>	16	32	43	<b>30.33</b>
<b>D2</b>	5	10	16	<b>10.33</b>	19	42	47	<b>36</b>	22	38	47	<b>35.67</b>
<b>D3</b>	15.5	30	35	<b>26.83</b>	37	110	129	<b>92</b>	40	95	100	<b>78.33</b>
<b>D4</b>	18	68	72	<b>52.67</b>	44	120	132	<b>98.67</b>	49	100	110	<b>86.33</b>
<b>Mean</b>	<b>10.5</b>	<b>28.75</b>	<b>33.75</b>		<b>28.5</b>	<b>77.5</b>	<b>87.25</b>		<b>31.75</b>	<b>66.25</b>	<b>75</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-XVII: Number of mini-tubers (2.5-3.0 g) per plant of potato cultivars grown at different dates and spacing under aeroponic system (2017-18)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	2.80	7.00	11.80	<b>7.20</b>	16.10	36.10	39.80	<b>30.67</b>	14.50	31.80	45.20	<b>30.50</b>
<b>D2</b>	4.79	10.00	15.40	<b>10.06</b>	21.20	40.25	45.12	<b>35.52</b>	23.20	36.10	49.40	<b>36.23</b>
<b>D3</b>	14.13	30.00	36.70	<b>26.94</b>	39.15	107.30	127.27	<b>91.24</b>	38.50	93.20	103.10	<b>78.27</b>
<b>D4</b>	21.00	68.00	74.15	<b>54.38</b>	46.80	118.26	131.80	<b>98.95</b>	47.13	98.83	114.18	<b>86.71</b>
<b>Mean</b>	<b>10.68</b>	<b>28.75</b>	<b>34.51</b>		<b>30.81</b>	<b>75.48</b>	<b>86.00</b>		<b>30.83</b>	<b>64.98</b>	<b>77.97</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-XVIII: ANOVA Table for Average data on number of mini-tubers (2.5-3.0 g) per plant of potato cultivars grown at different dates and spacing under aeroponic system during 2016-17 and 2017-18**

Source	D.F.	M.S.S.	F-Ratio	CD (5%)	C.V.
Replication	2	5.24	3.54		
Year (A)	1	0.60	0.40	NS	
Error A	2	1.48			2.49
Variety (B)	2	64211.36	349747.00	0.16	
Year (A) X Variety (B)	2	4.54	24.70	0.23	
Error B	8	0.18			0.88
Date of Planting (C)	3	6358.41	34188.50	0.17	
Year (A) X Date of Planting (C)	3	1.39	7.49	0.24	
Variety (B) X Date of Planting (C)	6	9462.20	50877.29	0.29	
Year (A) X Variety (B) X Date of Planting (C)	6	2.10	11.29	0.41	
Error C	36	0.19			0.88
Plant Spacing (D)	2	35155.33	161303.50	0.15	
Year (A) X Plant Spacing (D)	2	17.17	78.79	0.22	
Variety (B) X Plant Spacing (D)	4	4402.23	20198.80	0.27	
Year (A) X Variety (B) X Plant Spacing (D)	4	5.91	27.13	0.38	
Date of Planting (C) X Plant Spacing (D)	6	511.24	2345.73	0.31	
Year (A) X Date of Planting (C) X Plant Spacing (D)	6	1.58	7.26	0.44	
Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	947.03	4345.26	0.54	
Year (A) X Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	7.63	34.99	0.76	
Error D	96	0.22			0.96

**Appendix-XIX: Total crop duration (days) of potato cultivars grown at different dates and spacing under aeroponic system (2016-17)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	90.00	95.00	122.00	<b>102.33</b>	85.00	90.00	118.00	<b>97.67</b>	90.00	92.00	113.00	<b>98.33</b>
<b>D2</b>	98.00	110.00	127.00	<b>111.67</b>	99.00	110.00	121.00	<b>106.67</b>	104.00	105.00	119.00	<b>109.33</b>
<b>D3</b>	100.00	115.00	122.00	<b>112.33</b>	97.00	105.00	124.00	<b>108.67</b>	108.00	112.00	121.00	<b>113.67</b>
<b>D4</b>	107.00	120.00	132.00	<b>119.67</b>	103.00	110.00	128.00	<b>113.67</b>	112.00	118.00	124.00	<b>118.00</b>
<b>Mean</b>	<b>10.5</b>	<b>28.75</b>	<b>33.75</b>		<b>28.5</b>	<b>77.5</b>	<b>87.25</b>		<b>31.75</b>	<b>66.25</b>	<b>75</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-XX: Total crop duration (days) of potato cultivars grown at different dates and spacing under aeroponic system (2017-18)**

Factors	Kufri Jyoti				Kufri Pukhraj				Kufri Khyati			
	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
<b>D1</b>	93.00	98.00	118.00	<b>103.00</b>	84.00	92.00	119.00	<b>98.33</b>	89.00	93.00	112.00	<b>98.00</b>
<b>D2</b>	100.00	114.00	121.00	<b>111.67</b>	102.00	112.00	122.00	<b>112.00</b>	103.00	106.00	118.00	<b>109.00</b>
<b>D3</b>	103.00	119.00	117.00	<b>113.00</b>	98.00	106.00	126.00	<b>110.00</b>	107.00	114.00	120.00	<b>113.67</b>
<b>D4</b>	108.00	122.00	122.00	<b>117.33</b>	105.00	113.00	130.00	<b>116.00</b>	112.00	119.00	113.00	<b>114.67</b>
<b>Mean</b>	<b>101.00</b>	<b>113.25</b>	<b>119.50</b>		<b>97.25</b>	<b>105.75</b>	<b>124.25</b>		<b>102.75</b>	<b>108.00</b>	<b>115.75</b>	

[Dates of planting: D<sub>1</sub>=15<sup>th</sup> October, D<sub>2</sub>=25<sup>th</sup> October, D<sub>3</sub>=5<sup>th</sup> November, D<sub>4</sub>=15<sup>th</sup> November

Spacings: S<sub>1</sub>=7X7 cm, S<sub>2</sub>=14X14 cm, S<sub>3</sub>=21X21 cm]

**Appendix-XXI: ANOVA Table for Average data on total crop duration (days) of potato cultivars grown at different dates and spacing under aeroponic system during 2016-17 and 2017-18**

Source	D.F.	M.S.S.	F-Ratio	CD (5%)	C.V.
Replication	2	326.54	60.23		
Year (A)	1	8.05	1.48	NS	
Error A	2	5.42			2.13
Variety (B)	2	3000.76	0.00	0.04	
Year (A) X Variety (B)	2	4.09	0.00	0.00	
Error B	8	0.00			0.00
Date of Planting (C)	3	137.40	8901.66	0.05	
Year (A) X Date of Planting (C)	3	7.39	478.91	0.07	
Variety (B) X Date of Planting (C)	6	364.97	23645.28	0.08	
Year (A) X Variety (B) X Date of Planting (C)	6	7.27	470.82	0.12	
Error C	36	0.02			0.11
Plant Spacing (D)	2	8015.21	0.00	0.03	
Year (A) X Plant Spacing (D)	2	78.87	0.00	0.00	
Variety (B) X Plant Spacing (D)	4	381.12	0.00	0.06	
Year (A) X Variety (B) X Plant Spacing (D)	4	2.01	0.00	0.00	
Date of Planting (C) X Plant Spacing (D)	6	41.00	0.00	0.07	
Year (A) X Date of Planting (C) X Plant Spacing (D)	6	0.45	0.00	0.00	
Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	176.86	0.00	0.10	
Year (A) X Variety (B) X Date of Planting (C) X Plant Spacing (D)	12	16.88	0.00	0.00	
Error D	96	0.00			0.00

**Appendix-XXII: Images of research activities at Center of Excellence, Dhogri,  
Punjab**















