Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)

THESIS

Submitted To

Babasaheb Bhimrao Ambedkar University

(A Central University)

Lucknow

FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

in

Horticulture

Supervisor

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Enrollment No.-867/17

DEPARTMENT OF APPLIED PLANT SCIENCE (HORTICULTURE)

SCHOOL FOR BIOSCIENCES AND BIOTECHNOLOGY

BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY

(A CENTRAL UNIVERSITY)

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INDIA

2021

Dedicated To

My

Loving Parents

Bhag Chand Shivran

DECLARATION

I, **Bhag Chand Shivran**, Enrollment No. **867/17**, hereby declare that, I am a candidate for the degree of **Doctor of Philosophy in Horticulture**, Department of Applied Plant Science (Horticulture), School for Bio-sciences and Biotechnology, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Raebareli Road, Lucknow-226025 (U.P.), India and have carried out my research work entitled **"Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)".** This thesis has been submitted for the award of the degree of Doctor of Philosophy in Horticulture is my original research work.

I do also hereby undertake that the thesis is essentially free from any kinds of plagiarism.

Date:

Place: **(Bhag Chand Shivran)**

CERTIFICATE

This is to certify that the thesis titled **"Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)".** Submitted by **Mr. Bhag Chand Shivran**, Enrollment No. **867/17** is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other university.

The thesis submitted to Babasaheb Bhimrao Ambedkar University, Lucknow satisfies all the requirements as stipulated in the Master of Philosophy (M.Phil.)/Doctor of Philosophy (Ph.D.) regulations amended in 2017 and it is fit for submission and evaluation for the award of the degree of Doctor of Philosophy of the University.

Date:

Place: BBAU, Lucknow

Supervisor **Head of the Department**

ACKNOWLEDGEMENT

It is the contribution of all the persons of the University towards this works that makes this works a successful. It gives me immense pleasure in acknowledging all the help received during the period of research.

I would like to offer my heartfelt salutation at the fact almightily God for the unbroken health, vigor, bestowed, upon me all through the span of my studies in these resting days.

First and foremost, I express my deep sense of gratitude to my supervisor ***Dr. M.L. Meena,*** *Associate Professor, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow, who is not only a teacher and guide to me, but my mentor and well-wisher too. His persistent encouragement, perpetual motivation, everlasting patience, constructive criticism and valuable technical inputs in research have benefitted me to an extent which is beyond expression. She not only trained me in science but in all aspects of life.*

It is my deep sense to express my heartiest guidance to ***Prof. Sanjay Kumar, Prof. R.B. Ram, Prof. Deepa Hansraj Dwivedi, Dr. R.S. Verma, Dr. Sutanu Maji*** *and* ***Dr. Rubee Lata*** *Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow for her encouragement and help during the course of study.*

I am highly grateful to revered ***Prof. Sanjay Singh, Hon'ble Vice-Chancellor,*** *and* ***Prof. Sanjay Kumar, Head and Dean,*** *Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh for providing all the necessary facilities for the completion of the experiment.*

I have no words to express about the help, affection and moral support of my Parents, ***Mr. Ganesh Shivran*** *&* ***Mrs. Baraji Devi*** *for their indispensable encouragement, selfless sacrifice, sustained inspiration & invaluable assistance throughout my life.*

I express my heartiest affection to my brother ***Ramdhan Shivran***, ***Mahesh Kumar Shivran*** *&* ***my wife Suman Jat****, for their everlasting love and forgettable moral and emotional support throughout my life.*

I also wish to convey my thanks to ***Dr. U.S. Ola, Dr. D.R. Shivran, Dr. R.N. Shivran, Dr. R.K. Shivran, Dr. A.C. Shivran, Dr. Arjun Lal Ola, Hemraj Nehra, Dr. S.M. Choudhary*** *for their moral support, and constant encouragement during the course of this study.*

I wish to extend my sincere thanks to ***my batchmates,*** *Mr. Harvindra Pal, Mr. Som Prakash, Mr. Viplaw Kumar, Mr. Mata Prashad, Mr. Srikant Bharti, Mr. Lalit Kumar and My lovely* ***juniors*** *Mr. Rupesh Mondal, Mr. Rajmani Singh, Mr. Dharm Raj Meena, Mr. Rajesh Kumar Meena, Mr. Ramesh Chand Meena and Mr. Maya Ram. I wish to record my sincere thanks to my all juniors for making sweet souvenir with me during my degree programme, again a lot of thanks to all them for providing support to me.*

Who directly or indirectly, gave encouragement and humorous company at BBAU, Lucknow. I am also thankful to all departmental staff members, especially Mr. ***Vinay Kumar,*** *Office Assistant, Department of Applied Plant Science (Horticulture), BBAU, Mrs.* ***Anita Tiwari,*** *Mr.* ***Saheb sharan Verma*** *Laboratory Assistant, Mrs.* ***Munni Devi*** *and Mr.* ***Anilesh Kumar Singh.***

I thank every person of leading me all the ways towards successful completion of this work. I am also thankful to library section for the providing the facility of library during my research period and no plagiarism found in the thesis.

Is like drop in the ocean by me all regards to ***Lord Shiva*** *for providing me energy and patience without which it would have been none.*

Many more people helped me, if I do not listed them all, it is not of lack of gratitude but lack of space. To all of them I give my thanks.

Date:

Place: *BBAU, Lucknow* ***(Bhag Chand Shivran)***

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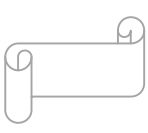
List of Abbreviations

Symbols	Abbreviation	Stands for
%	-	Percentage
&	-	And
/	-	Per
@	-	At the rate of
-	$^{\circ}C$	Degree Celsius
-	ANOVA	Analysis of variance
-	CD	Critical difference
-	Cm	Centimeter
	Cm^2	Centimeter square
	M	Meter
-	cv.	Cultivar
-	Df	Degree of freedom
-	*et al.*	Et alli (co-author)
-	etc.	etcetera (and therest)
-	Fig.	Figure
-	FRBD	Factorial Randomized Block Design
-	G	Gram
-	Ha	Hectare
	q/ha	Quintal per hectare
-	Kg	Kilogram
-	M.S.S.	Mean sum of square
-	Max.	Maximum
-	Min.	Minimum
-	Mg	Milligram
-	G	Gram

-	Kg	Kilogram
-	No.	Number
-	NS	Non-significant
-	ml	Milliliter
-	mm	Millimeter
-	R.H.	Relative humidity
-	S.Em±	Standard error of mean
-	e.g.,	Example gratia (for example)
-	Viz.	Namely
-	N	Normal solution
-	ug	Microgram
-	nm	Nanometer
-	rpm	Rotation per minute
-	Conc.	Concentrated
-	hr.	Hour
-	IU	International unit
-	$^{\circ}$B	Degree brix
-	fig	Figure
-	Vit-c	Ascorbic acid
-	Vis.,	Namely
-	i.e.	id est (that is)
-	Per se	As such with mean
-	VRS	Vegetable Research Station



Chapter-**1**

INTRODUCTION

Knol-khol (*Brassica oleracea* var. *gongylodes* L.) is popularly known as kohlrabi or mini cabbage in India and belongs to the family Brassicaceae. It is a winter season crop and is originated from the coastal countries of Northern Europe are considered to be the probable origin of this crop. **(Silatar *et al*., 2018).** In India, the cultivation of knol-khol is popular in Kashmir, West Bengal and also in some parts of Uttar Pradesh **(Thamburaj and Singh, 2010).** It is a herbaceous annual when grown for vegetable purpose both in plains and hills but it becomes a biennial for seed production. It has a chromosome 2n = 18. It is also known as German turnip, cabbage turnip, Navalkol and Ganth gobhi. Of late demand for knolkhol has gained momentum in National Capital Region of Delhi and adjoining states because of its wholesome utility as fresh vegetable and value addition products which support the food needs of the people. Knol-khol has a bulb-like swollen edible portion called knob, which is formed by stem tissue swelling above the cotyledons. The stem's fleshy turnip-like expansion matures completely above ground. The knob is picked for human use as a raw or cooked vegetable, while young leaves are also utilised in some areas **(Chadha, 2009).**

India is the second largest producer of vegetables followed by China. The total area under vegetables in India is 10.35 million hectares with the production of 191.77 MT and productivity of 19.01 tonnes/ hectare (NHB, 2019).

Cole crops a group of vegetables crops has originated from a common parent, the wild cabbage or ‘cole wart’; *Brassica oleracea* var. *sylvestris*. These are known as cole crops. This group comprises cabbage, cauliflower, brussels sprouts, broccoli, collards, knol-khol and kale. It is a group of highly differentiated plants.

In general, cole crops are used against gouts, diarrhea, colic trouble, stomach trouble, deafness and headache. The cabbage juice is said to be remedy against poisonous mushrooms and used as gargle to remove hoarseness of throat. The leaves are used to cover wounds, ulcers and also recommended against hangover. The studies conducted on these vegetables in Japan and the USA have revealed certain protective properties against bowl cancer. The Cole crops are a rich source of vitamin A and C. They also contain minerals phosphorus, potassium, calcium, sodium and iron. Kohl rabi tastes and feels like broccoli stems or cabbage, but it's gentler and sweeter. The knobs have a crunchy texture and a rich flavour. One 100 gram of

knol-khol includes 92.7 g of moisture, 1.1 g of protein, 0.2 g fat, 0.7 g of minerals, 1.5 g of fiber, 3.8 g of carbohydrates and 25 calories. Energy, 20 mg calcium, 18 mg magnesium, 10 mg oxalic acid, 35 mg phosphorus, 0.4 mg iron, 0.12 mg sodium, 37 mg potassium, 0.09 mg copper, 143 mg sulphur, 36 I.U. vitamin A, 0.12 mg riboflavin, 0.5 mg nicotinic acid, 0.05 mg Thiamin, and 85 mg Vitamin C (Bose, 2001). It contains sulforaphane, a cancer-fighting compound. All components of the knol-khol plant have been reported to have enormous therapeutic powers. Asthma, cancer, high cholesterol, heart disorders, indigestion, muscle and nerve functioning, prostate and colon cancer, skin problems, and weight loss are among the medicinal characteristics of the crop **(Chauhan *et al*., 2016).**

Knol-khol is mostly cultivated as a winter vegetable crop that thrives in cool, moist climates. Seeds germinate successfully at temperatures ranging from 15 to 30 ℃. The ideal temperature for its growth is between 15 and 25 ℃, depending on the cultivar. If exposed to low temperatures after germination, varieties that are susceptible to bolting lack a juvenile phase and become generative without producing knobs. The round and flat round varieties produce long oval-shaped knobs when the temperature is low during the knob formation stage. Low temperatures or frost can cause anthocyanin pigments to grow on knobs or plant components. If there is a deficiency of N and P in the soil, these pigments become more intense, degrading the quality of knobs, particularly green varieties. Knolkhol grows well in a wide range of soils. Knobs grow well in soil that is rich in manures and fertilizers. Sandy loam is best for an early crop, whereas clay or silt loam is best for a late crop with a larger yield. It struggles to thrive in acidic soil. The ideal pH range is 5.5–6.8 **(Choudhary, 2015)**.

A diverse range of tropical, sub-tropical and temperate vegetable crops can be found in India. However, there are some crops that are unknown or unusual to the majority of our growers and consumers. Our farmers can make a lot of money farming these rare or odd high-value crops near big cities and towns since they sell for a lot of money in cosmopolitan markets, star hotels and tourist attractions. Chinese cabbage, sprouting broccoli, red cabbage, knolkhol and brussels sprouts, among other vegetables, have provided new chances for diversification and off-season production for high market prices in metropolis for our country's vegetable growers.

Knol-khol is a heavy feeder that responds well to fertilizer treatment. However, it has been discovered that intensive use of inorganic compounds as fertilizers damages soil characteristics and restricts the free flow of nutrients in the soil. Excessive use of chemical

fertilizer has also been demonstrated to deplete soil fertility, preventing appropriate crop growth and yield. Kohlrabi yields are quite poor as compared to their potential yield. This large gap between actual and prospective production can be closed by using current farming methods such as planting methods, fungicide use, controlled irrigation and improved soil nutrition.

The exact timing of seed sowing in the nursey and transplanting into the field is critical for obtaining a high yield and quality of vegetables. Both the yield and size of the knob are affected by plant spacing. According to recent research, more extensive splitting leads to larger and heavier knob, while closer spacing increases output per hectare. Consequently, it is important to optimize proper plant spacing for acquiring higher yield with better quality. Access to selected high yielding varieties and optimum plant spacing may aid farmers in achieving higher returns per unit area, as well as more efficient fertilizers consumption and solar energy uptake **(Bhangre *et al.*, 2011).**

Crop plant growth, yield and quality are primarily influenced by two main elements: genetics and cultural or management factors. The first factor is concerned with diverse breeding procedures for crop variety improvement. The second component is horticultural techniques, such as plant population, planting date, fertilizer dose, irrigation, and weed management, among others. Growth, yield and quality mainly effected by two major factors viz. varieties and spacing. The existing varieties have emerged mostly through selection from wide variability available. The improvement in the crop is mainly achieved through selection and evaluation. For successful cultivation of any crop in any area, the identification of suitable varieties is most important. By utilizing new techniques such as the right combination of diverse organic, inorganic, and bio-fertilizers manure sources, there is significant potential for raising knol-khol yields to meet rising demand. Knol-khol improved growth and production are dependent on maintaining an appropriate plant population per unit area. Various researchers have investigated the effects of spacing on knol-khol growth, knob size, days to maturity and yield under various agro-climatic situations. Crop spacing can be adjusted based on climate, soil fertility and cultivar adaptability to a specific location. The plant was more robust in terms of leaf size with wider spacing than with closer spacing, which might be attributed to reduced competition for light, nutrients and moisture **(Rai *et al*., 2003).**

Availability of suitable high yielding variety and optimum plant spacing may help the farmers to achieve more returns per unit area and also for efficient absorption of nutrients and trapping of solar energy. The varieties show variable response to plant density because of

differences in morphology and phenology **(Prasad *et al*., 2010).** Different cultivars have different growth, yield and quality parameters varying with growing conditions **(Thapa *et al*., 2017).** In the growth and development of a crop, varieties are important. Only a few cultivars of knolkhol, such as Pusa Virat, White Vienna, Early White Vienna and Palam Tender Knob were developed for the cold winters of North India. For knolkhol to grow and produce more, an appropriate plant population per unit area must be maintained. Optimum spacing confirms judicious use of natural resources and makes the intercultural procedure easier as suggested by **(Hasan *et al*., 2017).** Crop spacing was determined by climatic conditions, soil fertility and cultivar adaptation to a specific location **(Bairwa *et al*., 2017)** reported that plant growth was more robust when the spacing was wider, possibly due to reduced competition for light, nutrients and moisture as compared to narrow spacing **(Kaur *et al*., 2020).**

One of the most significant elements is the number of plants per unit area. Crop growth and development are influenced by the number of plants per unit area. Proper plant spacing is one of the most important factors in increasing crop yield and quality. As a result, the current research attempted to promote high-value Knol-khol by identifying and standardized suitable plant spacing and varieties in order to improve knol-khol growth, yield and quality which is critical for Lucknow conditions. With this consideration, the present studies entitled **"Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)"** was under taken at Horticultural Research Farm -I, BBAU Campus, during 2018-19 and 2019-20 with the following objectives:

1. To find out the effect of different varieties on growth, yield and quality of knol-khol.
2. To assess the effect of spacing on growth, yield and quality of knol-khol.
3. To determine the interactive effect of varieties and spacing on growth, yield and quality of knol-khol.
4. To work out the economics of different treatments of knol-khol.

Chapter- **2**

REVIEW OF LITERATURE

This chapter presents an overview of the research done on the **"Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)"**. The importance of the literature in terms of knolkhol varieties and spacing has been managed, and important research findings on other horticultural crops have been selectively included in this review of the literature.

2.1 Effect of varieties

2.1.1 Effect of varieties on growth attributes

Kumar *et al.* (2021) revealed that the variety Pusa Broccoli KTS-1 showed the highest plant height (66.7 and 66.2 cm), stem diameter (3.5 and 3.5 cm), plant spreading (E-W and N-S) (61.3, 62.5 and 54.2, 55.3 cm), leaves per plant (23.7 and 23.9), length of leaves (51.1 and 51.1cm) and width of leaves (30.3 and 30.6 cm) in broccoli.

Giri (2020) studied that the highest height of plant, leaf length and canopy diameter were mostly produced by Titan, Snow mystique, and NS 106 while the lowest plant height, leaf length and canopy diameter were produced by Snowball 16 and Amazing in cauliflower.

Meena *et al.* (2017) investigated the effects of two cauliflower cultivars (Pusa Sharad and Pusa Paushja) and six nutrient levels (N-80:60:60 kg NPK/ha, N -80:80:60 NPK kg/ha, N -100:60:60 NPK kg/ha, N -100:80:60 NPK kg/ha, N -120:80:60 NPK kg/ha. Among the varieties Pusa Paushja had the longest leaves (51.32 cm), heaviest plant weight (147.56 g), highest curd yield (355.97 q ha^{-1}), highest T.S.S. (5.79 °Brix), highest vitamin C (44.82 mg/100 g) and best nutrient absorption. N also has a higher value in cauliflower for growth, yield, quality measures and nutrient recommendation in cauliflower.

Zaki *et al.* (2015) investigated the effect of various potassium fertilizer rates (20, 40, and 60 kg K_2O/fed.) on the growth, yield and quality of three broccoli cultivars in sandy loam under drip irrigation: Calabrese American, Calabrese France, and Southern Star Hybrid. The Southern Star Hybrid cultivar outperformed the others in terms of vegetative growth (number of leaves, fresh weight of spears and total plant), main spear yield and physical head quality (mean head weight and diameter); chemical head quality (vitamin C); N percent in leaves and stems; P percent in stems and spears; and K percent in stems and spears, with Calabrese France taking first place. Calabrese American had the tallest plants, heaviest leaves and stems fresh

weight, highest leaves and spears dry weight and best TSS, while Southern Star hybrid heads had the highest vitamin C content and Calabrese France cultivar had the most branches, stem dry weight and protein percentage.

Chaudhari *et al.* (2015) determined the effects of varied planting dates and cultivars on the growth of knol-khol. The experiment included three planting dates: November 1st, November 15th, and December 1st, with four varieties: White Vienna (V_1), Palam Tender Knob (V_2), Early White Vienna (V_3) and Purple Vienna (V_4). The 15th November planting date resulted in a considerable increase in plant height, East-West and North-South plant spread and leaf area. Purple Vienna outperformed the other kinds in terms of growth characteristics.

Yadav *et al.* (2013) studied the performance of 15 cauliflower hybrid variety viz., Aghani, Kinaya, Snow crown, Shalakha, Cashmere, Easley show, Kavita, Madhvi, NHB-Saritha, Sharad Safedhi 70, Shigra, NHB 1011, Poornima, GS 75 and Girija. Amongst all the cauliflower hybrid Poornima had the highest height of plant (24.64cm), number of leaves per plant (20.83), plant spread (65.79cm), curd diameter (18.92cm), weight of untrimmed curd (2.45 kg), weight of trimmed curd (1001.67g), curd yield (345.083 ha^{-1}), ascorbic acid (53.93 mg/100g), curd yield (345.083 ha^{-1}) and moisture – dry matter ratio (7.85). Poornima, a hybrid cultivar with high growth, yield and good quality, is suggested for commercial cultivation in Allahabad's agro-climatic conditions.

Mhaske *et al.* (2011) concluded a field experiment to see how organic and inorganic nitrogen sources, as well as biofertilizers, affect the growth and yield of cabbage cv. Golden Acre. There were twenty treatment combinations, each with four levels of nitrogen sources and five levels of biofertilizers. For growth characters, the fertilizer combination of 75 percent RDN through inorganic fertilizer + 25 percent N through FYM, as well as the biofertilizer combination Azotobacter + PSB + VAM, was found to be superior to other treatments (height of plant, number of leaves, diameter of stem, plant spread and yield of cabbage).

Ara *et al.* (2009) investigated the yield potentialities of cauliflowers using two different cauliflower lines, CL026 and CL0134, as well as four different planting dates in the summer season: 1st May, 1st June, 1st July and 1st August. Height of plant, leaves per plant, total weight of plant, marketable curd weight per plant, and yield t/ha were all higher in CL0134 lines. The height of the plant, the number of leaves per plant and the total weight of the plant are all factors to consider. Between planting dates, the weight of marketable curd per plant and the yield t/ha

both varied significantly. The weight of marketable curd per plant (419.61g) was obtained during the summer season from the 1st August planting in combination with the 1st August planting. Substantially maximum yield (17.56 t/ha) was found from the line CL0134 when combination with 1st August planting.

Hamid *et al.* (2005) examined cauliflower cultivars (Express, Reagent, Shehzadi and Indus Holland) for their performance. Reagent had the most leaves, stem diameter, root length, dry root weight and curd diameter, while Indus Holland had the most plant height, leaf length, fresh root weight, fresh weight of plant and curd weight per plant under the climatic circumstances of Rawalakot. Express had the smallest plant height, number of leaves, fresh root weight, stem diameter, curd weight and fresh plant weight when compared to the other cultivars, while Shehzadi had the smallest. When compared to Express, Reagent and Shehzadi, Indus Holland had 61.87, 52.55 and 27.35 percent greater curd weight, showing that this cultivar did well in terms of yield and is ideal for cultivation under Rawalakot environmental conditions.

Prasad (1992) conducted a study in Ranchi to assess the performance of various varieties from the early, medium and late maturation groups in order to select optimal variety for each group. Those who discovered that the cultivars 75-1C, 114-S and Pusa Snowball K1 were best for early, medium, and late maturity crops, respectively.

2.1.2 Effect of varieties on yield and yield attributing traits

Dolkar *et al.* (2018) determined the average performance of thirty genotypes of knol-khol (*Brassica oleracea* var. *gongylodes* L.) genotypes for numerous quantitative parameters in sub-tropical conditions in Jammu. The trial field was set up using a Randomized Block Design with three replications spaced 30 cm apart. Based on the average performance of genotypes in terms of several growth and yield contributing genotypes such as SJKK04, G-40 and Green Gold, yield was statistically comparable to Early Super White, Vienna, which had the highest yield among the genotypes investigated. SJKK-04 was also one among the top performers in terms of number of leaves per plant, net knob weight per plant and gross knob weight per plant. Genotype Early Super White Vienna had the largest marketable knob diameter and took the shortest time to reach commercial knob maturity, while Pusa Virat had the lowest stalk and petiole lengths.

Thakur *et al.* (2016) studied the performing of six broccoli cultivars (Palam Haritika, Palam Vichitra, Palam Kanchan, Palam Samridhi, MSB-12, and Ganesh) were evaluated in 2 different environments (open field and naturally ventilated polyhouse). Among the cultivars, Palam Kanchan had the highest plant dry weight at curd stage (161.92 g) and harvesting stage (277.33 g), SPAD value (66.10), and curd output (374.41q/ha), and Palam Vichitra had the largest plant spread (10852.40 cm2). Palam Haritika had the biggest stem diameter at the time of curd commencement (3.33cm) and harvesting (3.79cm).

Singh (2015) studied on effect of cabbage varieties Krishna (Hybrid), Kranti (Hybrid), Golden acre and Pride of India, the influence of a mixture of GA and NAA at four concentrations (0, 10, 15, and 20 ppm) on growth, yield parameters and yield. The most effective growth regulator was determined to be 15 ppm GA_3 + NAA in enhancing cabbage varieties growth, yield parameters, head yield (688.50 q ha^{-1}) and net returns (1,05,792 ha^{-1}). In comparison to the other varieties, Krishna (Hybrid) exhibited the highest growth, yield (625.35 q ha^{-1}), and net income (93893 ha^{-1}). In terms of growth, yield, and net returns, Pride of India came up short.

Dhar and Singh (2014) evaluated twenty-one cauliflower breeding lines/varieties from the early and mid-maturity groups were tested for marketable curd output and quality. The maturity of the curds ranged from 50 to 72 days after transplanting, with marketable curd weights ranging from 253 to 750 g. PN-1 produced good quality white and compact curd (238.33 q/ha) among the early genotypes and DCH 822 produced 375.00 q/ha among the mid maturity genotypes, followed by DC-76 (311.67 q/ha) among the late genotypes.

Singh *et al.* (2014) conducted an experiment on Palam Samridhi (green head), Palam Kanchan (yellowish green head), Palam Vichitra (purple head), and Palam Haritika (green head) were tested for their performance and market preference on four different broccoli cultivars with varying colour heads. Palam Vichitra (210.7 q/ha) and Palam Kanchan (206.9 q/ha) were the broccoli cultivars with the highest yields. Palam Kanchan had the heaviest terminal head, weighing 357.5 g, whereas Palam Samridhi produced the earliest head in Himachal Pradesh's low hill conditions. Only green head types were favoured in the local market, however green and purple-colored varieties were preferred in larger mandis such as New Delhi, Shimla and Chandigarh, among others. Broccoli varieties with a yellow colour are the least popular on the market.

Giri *et al.* (2013) tested the optimum rate of nitrogen (N) fertiliser for effective growth and yield of two types of broccoli in the southern plains of Nepal. The study used a three-replication two-factorial fully random 32 block design (RCBD) with two varieties of broccoli (Calabrese and Green Sprouting) and five N rates (0, 50, 100, 150 and 200 kg ha^{-1}). The effects of variety and N rate on total curd yield were substantial, but the interaction effect was not. Green Sprouting produced 11% more total curd than Calabrese. Curd production increased by 200 kg ha^{-1}, reaching a peak of 14.47 t ha^{-1}.

Karistsapol *et al.* (2013) studied the effects of planting dates and varieties on broccoli (*Brassica oleracea* L. var. *italica* Plenck) on growth and yield. Except for the special, seedling survival rates for the Top Green, Green Queen, and Yok Kheo were 76.53-100.00 percent from January to June. With yields of 12.31 and 10.65 t ha^{-1}, the Yok Kheo was the most productive. When it comes to planting, January and March are the best months. Yok Kheo is an intriguing novel hybrid variety that yielded slightly more than Green Queen but not considerably more than Top Green. It may be harvested 11.67 days earlier than Top Green and 9.38 days earlier than Yok Kheo, respectively.

Chabok and Amoli (2013) concluded that Memphis and space Star varieties of cauliflower had 130 and 120 days duration growth, and the highest yield 30 and 28 ton/ha. Arizona was the earliest variety with 100 day growing period and 22 ton/ha yields in this study. Cauliflower crops have been good potential for 3 to 5 months period.

Singh *et al.* (2010) examined the influences of distinct transplanting time on growth, yield and quality of several cabbage (*Brassica oleracea* var. *capitata* L.) varieties and hybrids viz, NS-160 (hybrid), KGMR-1 (hybrid, bred by IARI Regional Station Katrain, HP), Ryozeki (hybrid, bred by Nunhems India Ltd., Hyderabad, Andhra Pradesh), Golden Acre (variety, bred by IARI Regional Station Katrain, HP), and INDAM-1299(hybrid, bred by IARI Regional Station Katrain, HP (hybrid, bred by IAHS Co., Bengluru, Karnataka). INDAM-1299 had the most compact head, followed by Golden Acre, NS-160, KGMR-1 and Ryozeki had the least. The cultivars KGMR-1 and Golden Acre (both bred by IARI Regional Station, Katrain, Himachal Pradesh) yielded higher plant biomass, which may be utilised during the summer and rainy seasons, notably for leaf production.

Iqbal *et al.* (2010) examined the performance of different varieties and distinctive fertilizer management practices on growth and yield of Knol-khol (*Brassica oleracea* var.

gongylodes). There were five different varieties in the experiment: V_1: White Vienna; V_2: Quick Star; V_3: Sufala-14; V_4: UFO; V_5: Early 005, as well as four different fertilizer management strategies, viz. F_0: Organic Manure; F_1: Inorganic Fertilizer; F_2: Organic Fertilizer+ Inorganic Fertilizer; F_3: Organic Fertilizer+ Inorganic Fertilizer. V_1 had the largest marketable yield (29.4 t/ha) while V_5 produced the lowest (22.4 t/ha). In terms of fertilizer, F_3 had the highest marketable yield (31.8 t/ha) while F_0 had the lowest (19.0 t/ha). V_1F_3 had the highest marketable yield (37.5 t/ha) and V_5F_0 had the lowest (16.3 t/ha) for combined effect. Under the Madhupur tract of Bangladesh, farming the White Vienna of Knol-khol with both organic and inorganic fertilizers could result in a higher yield.

Adeniji *et al.* (2010) studied that Gloria F_1 and Victoria F_1 performed best for head yield during the long wet season, while fast Start and Rotan was quite during the short rainy season. Summer Summit F_1 was the best in terms of taste, head shape and firmness. Tropical Delight was chosen because of its large head size, sturdiness and lack of loose heads. Gloria F_1 was shown to be an early maturing cultivar with a strong head. Summer Summit, Summer Glory, and Bonus are tasty cabbage cultivars.

Jana and Mukhopadhyay (2006) studied the influence of sowing date (15th August, 31st August, and 15th September) on growth and curd yield of several cauliflower varieties in a field experiment (Early Kunwari, Improved Japanese, Kartika, First Crop and Aghani). They discovered that Aghani had the maximum curd output of 15.76 t/ha among the cultivars. The greatest marketable curd yield was achieved by Aghani, which was seeded on August 31st and yielded 16.65 t/ha. They also discovered that seeding on August 15 produced the maximum curd production (13.07 t/ha), which declined when sowing time was extended.

Arin *et al.* (2003) evaluated the feasibility of cultivating knolkhol (*Brassica oleracea* var. *gongylodes* L.) throughout the spring and fall growing seasons in Trakya (Turkey). In each phase, yield and quality characteristics of three knolkhol varieties (Express Forcer, Neckar and Lahn), 2 seedling ages (four or six weeks old) and 3 planting dates (at two-week intervals in April, May for spring and September, October for fall) were assessed. In both seasons, the cultivars Neckar and Express Forcer outperformed Lahn in terms of yield and quality. In the spring, seedlings that were six weeks old yielded more, whereas seedlings that were four weeks old yielded more in the fall.

Pun *et al.* (2003) evaluated the effect of eight different cauliflower varieties, Snow Crown, Snow Dome, Snow King, Snow Ball-16, Kibo Giant (Holland), Kibo Giant (Nepal), Kathmandu Local and Madhuri were evaluated for consecutive three years in dissimilar agro environmental areas western hills of Nepal during 1998 to 2001. The hybrid variety Snow King was observed as outstanding for early and off-season production, whereas Snow Crown, as a superior variety in term of high curd yield (24.7 t/ha). The lowest mean curd yield (16.86 t/ha) was recorded in Kathmandu Local. Snow Dome, Snow King and Snow Crown showed better performance for early production, whereas Kibo Giant (Holland) and Madhuri were appropriate for late season production in the altitude range of 800 to 1600 m. The good quality curd (marketable size, compactness and color) was found in Snow Dome and Snow King and these varieties were highly preferred by the farmers and consumers.

Nathoo (2003) tested four varieties (Cashmere, Hybrid Rami, White Contesa and Splender) in two agroclimatic conditions (Reduit and Wooton) with three planting dates (March, October and July) and found a significant interaction effect between planting date and site, as well as between planting date and variety. He also noted that changing the planting date in a certain region would improve yield. There was a substantial difference in curd compactness across the types examined, with Cashmere, Hybrid Rami and White Contessa having higher compactness than the local cultivar.

Chaubey *et al.* (2001) conducted an experiment with twenty three genotypes of cabbage over 4 fertility levels in two seasons. For all of the traits tested, analysis of variance revealed substantial variations between genotypes across all fertility levels in both seasons. The yields were between 105.61 and 590.82 q/h. Higher reproduction levels increased the SILt and net head weight, but not the head shape index. At higher levels of fecundity, the percentage of marketable heads and their durability both expanded.

Thakur and Veerpal (2001) carried out a field trial in Himachal Pradesh to evaluate the effect of cauliflower cultivars (RSK-1301, White Fox, RS-119, SWI-1 and PHJ as controls) transplanted during May, it was discovered that SWI-1 had the highest average yield of 38.72 t/ha, net curd weight, good curd quality, good size and the fewest outer leaves, as well as the fewest outer florets.

Bhardwaj *et al.* (1993) tested eight cabbage hybrids along with three check varieties (Golden Acre, Pride of India and Selection-8) in sub-tropical conditions of Himachal Pradesh and reported that Golden Acre takes 84 days to mature, while hybrid TKCBH30 takes 102 days. Number of non-wrapper leaves varied from 11.6 (Pride of India) to 18.0 (Sri Ganesh). The head of TKCBH 28 was the largest and weighted the most (1033 g) followed by Sri Ganesh (987 g) and TKCBH 27 (957 g). These 3 hybrids also gave the highest marketable yields (36.7, 34.9 and 38.8 t/ha, respectively). Under sub-tropical conditions these hybrids recorded, respectively, 69.7, 51.6 and 47.1 per cent higher yields than a check variety Golden Acre.

Muniz (1988) evaluated three cultivars and eight hybrids of cabbage for commercial yields, head weights, the number of leaves that aren't wrapped, head compactness and concluded that Sooshu, Gloria and Shutoku were the most promising hybrids giving 38.0, 37.9 and 32.8 t/ha yields, respectively. The cv. Chato de Brunswick was the lowest yielder (23.5 t/ha).

Rastogi and Korla (1988) in the mid hills of Himachal Pradesh, conducted trials with 5 hybrids, one synthetic variety and two check varieties and found that Pusa Synthetic (290.3 q/ha) and Sri Ganesh Gol (282.0 q/ha) gave the highest yields and were followed by ARU Glory followed by Pusa Synthetic. Improved Hybrid (Holland) recorded the highest weight per head followed by Improved Hybrid (Japanese). These two hybrids also had higher number of non-wrapper leaves.

Csizinszky and Jones (1983) carried out an experiment in West Central Florida to evaluate performance of 35 broccoli cultivars in the fall-winter and 34 cultivars in the winter spring season. They observed that the cultivar Green Top had the highest head weight, greatest proportion of marketable heads and highest yield in both fall winter and winter spring season. According to their finding cultivars Dandy Early, Early Emerald and Prominence also recorded high yields among the other cultivars.

Pillai *et al.* (1982) studied variation in marketable yield was discovered in an experiment with nine cabbage varieties. Autumn Early Giant produced the maximum commercial yield of 161.6 q/ha, after that Drum Head (153.4 q/ha) and Golden Acre (141.2 q/ha).

Thangaraj *et al.* (1980) studied the performance of cabbage cultivars namely, Golden Acre, Eclipse Drum Head, Early Wonder, Express, and Copenhagen Market were chosen for their yields and Early Wonder and Eclipse Drum Head were suggested for profitable production in the Sheveroys hills of South India.

Wijk (1980) while studying the performance of 19 white cabbage hybrids in summer reported that 3 hybrids viz., Julia, Hijula and Histona were the earliest to mature and the highest yields were recorded from Menza and No. 76120.

Williams (1979) evaluated the growth and yield of 33 cabbage varieties and selections in a low land tropical atmosphere and reported that Y.R. Cross 20 F_1 K.K. Cross F_1 and Spring light F_1 gave the highest head yields and largest head size, while Princess 39 F_1, Atlas 70 F_1, Pak Rite, Leo 80 F_1 and Harvester Queen gave high yields of small, compact heads. These small headed cultivars could be planted at close spacings.

Cuellar (1978) conducted a comparative trial on productivity and adaptation of vegetables to the tropics and reported that out of the 10 cabbage cultivars studied over two years Savoy King, Cross and Drum Head yielded on an average 26.52, 26.32 and 20.11 tones/ha, respectively. The lowest yielding cultivars Red Acre, Primavera and Golden Acre.

Bhagchandani *et al.* (1977) conducted studies on the selection of cabbage cultivars for summer cultivation in hills with 12 round headed cabbage varieties and reported variation for number of non-wrapper leaves (16.4-26.9). net weight of head (492-955 g), marketable heads (80.5-100%) and days to maturity (60.5-73.0).

2.1.3 Effect of varieties on quality parameters

Giri (2020) carried out an experiment to evaluate eleven late season cauliflower varieties at Rampur, Chitwan, Nepal during November 2017 to March, 2018. All the tested varieties were introduced from USA, Europe, and India viz. Amazing, Artica, Freedom, Ravella, Titan, Bishop, Casper, Indam 9803, and NS 106 while two varieties; Snow mystique and Snowball 16 were from Nepal. The experiment was set by using Randomized Complete Block Design (RCBD) with an arrangement of each treatment replicated for four times. The higher TSS of 5.4 ºBrix and Vitamin C content of 55 mg/100 g was produced by Snowball 16 and Bishop, respectively.

Thapa *et al.* (2017) studied that the four best performing varieties namely Early You, Princess, Fiesta and Nok Guk were evaluated with four different date of planting viz. 21 September, 15 October, 7 November and 30 November to find out the best performing variety and suitable sowing/planting dates. The experiment was laid down in Factorial Randomized Block Design and replicated th thrice. Among the varieties, highest amount of total chlorophyll content was recorded from Early You i.e., 6.19 mg/100 g. The maximum reducing sugar 1.26%, non-reducing sugar 0.35% and total sugars 1.61% were observed from the variety Fiesta. Among the cultivars, Early You variety contents maximum ascorbic acid of 107.49 mg/100g and maximum TSS 10.60 °Brix in broccoli.

Thapa and Rai (2012) conducted an experiment to evaluate the performance of twelve genotypes (*viz*. Fiesta, Nokguk, Early You, Princess, Sultan, KE-180, Priya, Puspa, Grandsino, Rapido, Prema and Packman) of broccoli at Mohanpur, West Bengal during rabi season. They discovered that Nokguk was superior to all other Broccoli varieties, yielding a larger yield (145.47 q/ha) and having the best head development. KE-180, on the other hand, was found to have the highest chlorophyll b, reducing sugar, total sugars and carotene content of entirely the genotypes studied in chemical analysis. They also stated that the success of this crop with several hybrid varieties shown that three is adequate space for cultivating broccoli.

Kumar *et al.* (2010) studied in early Indian cauliflower, there were considerable variances between genotypes. DC-98-10, DC-98-4 and DC-124 were superior to other genotypes in early cauliflower for yield and quality features, with yield being inversely connected with period of curd availability and days to 50% curd formation. Substantial variances were noted between genotypes, indicating that yield and quality traits have enough variation. They also discovered that genotypes DC-98-10 had the maximum ascorbic acid concentration (103.23 mg/100 g) and CC-12 had the lowest (17.68 mg/100 g).

2.2 Effect of spacing

2.2.1 Effect of spacing on growth attributes

Kaur *et al.* (2020) revealed that the highest height of plant (54.27 cm), plant spread (69.53 cm), leaves per plant (17.00), leaf length (46.60 cm), leaf width (25.03 cm), fresh weight of curd (833.33 g), dry matter of curd (0.89 g) was found from N_1S_3. However, maximum curd yield plot^{-1} (30.03 kg) and ha^{-1} (326.90 q) was obtained from N_3S_1. While, maximum net income (299443.45 Rs./ha) and B:C ratio (3.22) was observed with 100 % N ha^{-1} + 45×30 cm^2. Results demonstrated that treatment combination N_3S_3 (N100 % ha^{-1} at 60×45cm) obtained to

be finest in most growth and yield characteristics in cauliflower variety Golden-75 but the maximum yield ha^{-1} was recorded in N_3S_1(N100 % ha^{-1} at 45×30 cm).

Singh *et al.* (2019) determined the impact of spacing distance on growth and yield parameters of cauliflower (*Brassica oleracea* L.). The experiment consisted of three different spacing viz., S_1 :30, S_2 :45 and S_3 :60 cm and respectively with three different stages N_1 :40, N_2 :60 and N_3 :80 days denotes as respectively. The weight of plant, weight of fresh leaves, dry weight of leaves and height of plant were found to have been significant effect at spacing 30 and 60 cm of the plant, spacing of 45 and 60 cm were found to have substantial effect on plant fresh weight and leaves dry weight.

Rana *et al.* (2019) investigated the impact of boron, molybdenum and different spacing on growth and development of cabbage. Two spacing 60 x 60 (S_1) and 60 x 45 (S_2) and three levels of each Boron and Molybdenum i.e., B_1- (Boron @ 0%), B_2- (Boron @ 0.25%), B_3- (Boron @ 0.5%), and M_1- (Molybdenum @ 0%), M_2- (Molybdenum @ 0.25%), M_3- (Molybdenum @ 0.5%). Spacing S_1 recorded higher value for plant height 36.94 cm, plant spread 94.43 cm^2, leaf length 27.90 cm, leaf width 23.85 cm, no. of open leaves 16.11 and diameter of head 17.06 cm.

Tejaswini *et al.* (2018) studied the impact of various plant spacing on broccoli growth, yield and quality (*Brassica oleracea* var. *italica* L). S_1 (30 cm x 30 cm), S_2 (45 cm x 30 cm) and S_3 (45 cm x 45 cm) are the three plant spacings. The treatment S_1 (30 cm x 30 cm) had the highest plant height at transplanting (21.90 cm), 45 DAT (39.35 cm) and harvest (57.67 cm), as well as the earliest days for head initiation (61.48) and head harvest (81.37) and the highest yield per plot (5.73 kg) and yield per hectare (219.36 q). With the wider plant spacing treatment S_3 (45 cm x 45 cm), the highest plant spread E-W (50.36 cm) & N-S (49.91 cm) at 45 DAT & at harvest E-W (62.15 cm) & N-S (62.12 cm), highest head diameter (14.10 cm), fresh weight of head (275.53 g), total dry matter content of the head (19.81%), crude protein content (2.91%), potassium content (464.2 mg) and calcium content.

Bairwa *et al.* (2017) determined the performance of sulphur and spacing on growth and yield attributes of knol-khol (*Brassica oleracea* var. *gongylodes* L.) var. Early White Vienna. The study evaluated sixteen treatment combinations, including four levels of sulphur (0 kg, 20 kg, 40 kg and 60 kg sulphur ha^{-1}) and spacing, using a randomised block design with three replications (30x20 cm, 30x30 cm, 45x30 cm and 45x45 cm). The most superior treatment

combination in terms of knob diameter and volume was a combined application of 40 kilogramme sulphur ha^{-1} with 45x30 cm spacing, whereas the most superior treatment combination in terms of total knob yield was a combined application of 40 kg sulphur ha^{-1} with 30x30 cm spacing.

Elahi *et al.* (2015) evaluated the response of cauliflower cultivars to phosphorus levels viz., (0, 40, 60, 80 kg ha^{-1}) and cauliflower cultivars (Silver Star, Peshawar local, White Diamond, White King), which were repeated three times. Among cultivars, White King showed highest number of leaves $plant^{-1}$ (23), days to curd initiation (104), curd diameter (30 cm), weight of curd (793 g) and yield (19 tons ha^{-1}). In terms of the interaction between phosphorus levels and cauliflower cultivars, when cultivar White King was treated with 80 kg P_2O_5 ha^{-1}, most of the growth and flowering properties of cauliflower performed at their best. The treatment of phosphorus at 80 kg ha^{-1} and the cultivar White King yielded the best results and hence advocated for Peshawar growers.

Thirupal *et al.* (2014) evaluated the effect of planting dates and plant spacings with four planting dates viz., 20th November, 10th December, 31st December and 20th January and three spacings viz., 50 × 30cm, 45 × 45cm and 60 × 45cm. The uppermost values for plant spread, leaves per plant, vitamin C concentration, and chlorophyll content were found in the 60 x 45 cm plant geometries. Height of plant, yield/ha and fewer number of days to flower bud commencement were all maximum in the 50 x 30 cm geometry. The interaction of planting dates and geometries resulted in the highest plant height and yield/ha in December 10th planting with a spacing of 50 x 30 cm and the highest number of leaves per plant in December 10th planting with a spacing of 60 x 45 cm. The maximum chlorophyll content was measured on January 20th, with a spacing of 60 x 45 cm.

Bhuiyan *et al.* (2014) discovered that spacing 40x15 cm was substantially higher in height of plant, leaves per plant, plant spread, length of leaves and fresh weight of plant rest of other plant spacings in batishak.

Turbin *et al.* (2014) assessed the impact of plant population on Brussels sprouts' growth, development, and yield. The period between the beginning of head formation and maturity was shortened when the area per plant was increased. They discovered that increasing the distance between plants increased the leaf assimilation area, stalk diameter and number of heads per plant, but that the plants' height remained low.

Ullah *et al.* (2013) determined the impact of planting time and spacing on growth and yield of cabbage. The experiment was set up in a Randomized Complete Block Design (RCBD) with three replications and three distinct planting times: T_1 (7th November), T_2 (21st November) and T_3 (5th December) and three different spacing; S_1 (60 cm×40 cm), S_2 (60 cm×45 cm) and S_3 (60 cm×50 cm). The results of the study revealed significant differences in terms of plant height, leaves per plant, number of non-wrappers leaves per plant, plant weight, fresh weight of head per plant, head diameter, head thickness, dry matter of head per plant and moisture content percentage. The maximum fresh weight of head per plant (1.36 kg) was recorded from T_1 S_1 and the minimum fresh weight of head per plant (0.4 kg) from T_3 S_3. The spacing (60 cm×50 cm) and 21st November planting time were found appropriate for growth and yield of cabbage.

Ilakyanila *et al.* (2013) observed the impact of spacing and fertigation on yield and quality attributes of cauliflower. The trial consisted of 3 dissimilar spacings (60 x 60, 60 x 45 and 60 x 30 cm) and 9 fertigation treatments. In fertigation, four levels of straight fertilizers (125, 100, 75 and 50 per cent of 200:125:125 kg NPK ha^{-1}) and 4 levels of water-soluble fertilizers (125, 100, 75 and 50 per cent of 200:125:125 NPK kg ha^{-1}) and conventional method were compared. In a split plot design, the treatments were replicated three times. The results showed that the spacing of 60 x 45 cm with the application of 100 % RDF through water soluble fertilizer recorded better growth, yield and quality attributes in both the seasons. However maximum BC ratio was noted with the application of 75 per cent RDF through straight fertilizers at 60 x 60 cm spacing.

Dev (2012) evaluated that varying plant spacing boosted yield and its attributes except plant height, days to head initiation, maturity and harvest period in broccoli throughout first and second year. The yield plant^{-1}, weight of primary head, weight of secondary head and secondary heads plant^{-1} exhibited an increasing trend with increase in spacing and the maximum values were noted at the wider spacing of 60 x 60 cm. However, height of plant, days to head initiation, maturity and harvest time did not expression substantial comeback to spacing levels. The yield was significantly reduced by delayed planting, although days to head initiation, maturity and harvest duration were unaffected by planting time and spacing.

Solunke *et al.* (2011) determined the impact of various dates of planting and spacing on growth and yield parameters of broccoli (*Brassica oleracea* var. *italica*). Planting will take place on the 15th, 30th September and 15th of October, with 3 spacings of 60x30 cm, 60x45 cm

and 60x60 cm. They found that broccoli transplanted on September 15th produced much higher yield (122.14 q ha^{-1}) than broccoli planted on other dates and that spacing 60x60 cm resulted in significantly higher height, number of leaves, stem diameter and leaf area. In terms of curd yield per hectare, there was a substantial interaction between planting dates and spacing. The treatment combination of $D_1S_1$15th September and 60x30 cm spacing produced the highest curd yield/hectare (134.05 q ha^{-1}).

Prasad *et al.* (2010) reported that significantly highest height of plant (49.75 cm), leaf area (930.45 cm), stalk length (28.41 cm), diameter of stem (3.77 cm), diameter of curd (23.13 cm), weight of curd (413.29 g), number of sprout (5.36 cm) and weight of sprout (35.60 g) were obtained in spacing (75x60 cm) but highest curd yield per plot (4.49 kg), curd yield per ha (89.45 q) and sprout yield per plot (373.44 kg) was noted in spacing (45x45 cm) in sprouting broccoli which was pursued by spacing (60x60 cm).

Singhal *et al.* (2009) determined the impact of planting dates (15th October, 30th October and 14th November in the first year and 1st October and 29th November in the second year) and spacing (45x30, 45x45 and 45x60 cm) on broccoli execution. Planting on the 14th of November the first year resulted in the tallest plants followed by planting on the 1st, 15th and 30th of October the second year. Only the first year, when planting on November 14th was ideal, had the influence of planting date on stalk diameter appear substantial.

Sharma *et al. (*2009) observed that knolkhol seedlings transplanted in October ensued in 50% knob initiation in 22.3 days at a broader spacing of 3045 cm, whereas seedlings transplanted in December took 38 days for 50% knob commencement at the equal spacing.

Singh *et al.* (2004) concluded that significant encourage in height of plant in cabbage at thin spacing (45 x 30 cm) could be attributable to solar energy competition coupled with a shallow root system and higher plant height at closer spacing. The spacing had a substantial impact on the number of leaves per plant, the spread of the plant and the width of the stem, with values peaking at wider spacing.

Kumar and Rawat (2002) studied the impact of various nitrogen levels (0,50, 100, 150, and 200 kg N/ha) and spacings (30 x 60 cm, 45 x 60 cm, and 60 x 60 cm) on yield and quality parameters of cabbage. TSS (%), dry matter (%), chlorophyll content (mg/g), compactness of head, head diameter (cm), head weight (g) and yield (q/ha) were all affected by nitrogen. In 200 kg N/ha, the maximum TSS, dry matter per cent, chlorophyll content and

head diameter were measured. However, the application of 150 kg N/ha resulted in the maximum head weight (1127.22 g) and yield (312.42 q/ha). Cabbage yield and quality parameters were also affected by spacing. The quality improved when the spacing was increased. In 30 x 60 cm spacings, the highest output of 303.09 q/ha was reported.

2.2.2 Effect of spacing on yield and yield attributing traits

Rana *et al.* (2016) evaluated the effect of spacing and boron levels on yield and quality of cabbage. Two spacing 60 x 60 (S_1) and 60 x 45 (S_2) and three levels of Boron i.e., B_1- 0%, B_2-0.25%, B_3- 0.5% with three replications in FRBD. Boron foliar spraying was performed at 30 and 50 days after planting (DAP), and all other cultivation procedures were followed as directed. With a 60 x 45 cm planting distance and a foliar spray of 0.5 percent boric acid, a higher yield of 577 q/ha was achieved compared to 440 q/ha with a 60 × 60 cm planting distance and a foliar spray of 0.5 percent boric acid.

Haque *et al.* (2015) determined that nitrogen @ 250 kg ha^{-1} with 50 × 50 cm spacing provided the highest fresh weight of head (2.17 kg) and marketable head yield (86.93 t ha^{-1}) of cabbage. This treatment was likewise more gainful than the others, with N_0S_1 yielding the lowest profit.

Kołota and Chohura (2015) investigated that White cabbage cv. "Kalorama F1" was planted in rows 45 cm apart and 50, 40, 35, or 30 cm within rows in a field experiment, yielding 44000, 55000, 63000, and 74000 plants per hectare, respectively. In comparison to the treatment with 44,000 plants, the use of 300 kg N ha^{-1} with plant populations of 63,000 and 74,000 per hectare yielded considerably larger yields of heads.

Mehta *et al.* (2015) observed that the impact of head decapitation and plant population on growth, seed yield and quality parameters of sprouting broccoli (*Brassica oleracea* var. *italica* L.) using cultivar “Green Head”. They discovered that decapitating the primary head at appearance, extracting seeds from secondary heads and plant population (45x45 cm) were the factors that resulted in the maximum seed yield per plot and per hectare, both individually and in combination. The maximum seed output per plant was found at the largest spacing of 60x60 cm, whereas the highest seed yield per plot and per hectare was obtained at 45x45 cm. The rise in yield per ha over suggested spacing of 60 x 45 cm was 23.65 %.

Thirupal *et al.* (2014) found that broccoli with a crop geometry of 60 x 45 cm had the highest plant spread, leaves per plant, vitamin C concentration, and chlorophyll content. The crop geometry of 50 x 30 cm produced the maximum height of plant, yield ha^{-1} and earlier flower bud initiation.

Scuderi *et al.* (2013) discovered that plant population (7, 10 and 16 plants m^2) influenced head weight reduction, with Manoko (48.5 percent) showing the greatest reduction and that the yield of two cultivars (Bilko and Manoko) increased proportionally in Chinese cabbage.

Dev (2012) discovered that plant spacing has a substantial impact on broccoli yield and characteristics. In 2005-06 and 2006-07, the tightest spacing of 60 x 30 cm produced the best gross yields of 154.8 and 142.7 q/ha. It's possible that this is due to the higher plant density at this spacing. The best yield per plant at 60 x 60 cm spacing was insufficient to compensate for the lower per hectare output due to reduced plant density at this wider spacing.

El-Shabrawy *et al.* (2012) reported that the effect of plant population, chicken manures and N, P rates on cabbage cv. Brunswick growth, yield and quality using a combination of 3 spacings (45 x 75 cm, 35 x 75 cm, and 25 x 75 cm) to achieve 3 plant densities of 8500, 11000, and 16000 plants/fed. In both seasons, plant population had a significant impact on all of the attributes studied. Fresh weight of plant, outer leaf weight, diameter of head, weight of head and average time from transplantation to maturity all decreased as plant density increased (16 thousand plants/fed). They also discovered that as plant density was raised, total yield, dry matter % in inner leaves and vitamin C content increased.

Moniruzzaman (2011) studied that the largest head diameter was achieved with a spacing of 60 x 30 cm and the varieties “Southern Treasure” and “K-K Cross,” although a wider spacing of 60 x 45 cm with Southern Treasure generated the highest head weight exclusive of unfurled leaves in both years, trailed by KK Cross.

Khatun *et al.* (2011) conducted a study on broccoli growth and yield as increased by spacing. The experimentation comprised of 4 spacing *viz.* 60 cm x 50 cm, 60 cm x 40 cm, 50 cm x 50 cm and 50 cm x 40 cm and noticed the highest height of plant, leaves per plant, length and width of leaf, crown spread, weight of primary curd, diameter of primary curd and yield (381.06 g) per plant was found in broader spacing (60x50 cm) then the yield (9.64 kg) per plot

and yield (16.07 t ha^{-1}) were observed to be highest in nearest spacing (50 cm x 40 cm) whereas the lowest yield per plot (7.62 kg) and per hectare was noted in the broadest spacing.

Sharma *et al.* (2009) found that when seedlings were transplanted in October, they produced the highest yield (495 q/ha) at a maximum plant population of 30x15 cm, compared to January transplanting in knolkhol, however the knobs were larger at broader spacing and elongated at nearer spacing.

Tanjin (2007) observed that highest fresh weight (399.92 g/plant) of unfolded leaves, gross yield (91.00 t/ha), marketable yield (77.67 t ha^{-1}) were found from the combined effect of S_2M_2 (50 cm x 30 cm spacing + black polythene mulch) and those of lowest were recorded from S_1M_0 (50 cm x 20 cm spacing + no mulch) in Chinese cabbage. From the result it was confirmed that the treatment combination of S_2M_2 (50 cm x 30 cm spacing + black polythene mulch) achieved the maximum yield than other treatment combination but the treatment combination of S_2M_1 (50 cm x 30 cm + water hyacinth mulch) was more profitable because of availability of water hyacinth than those other mulch treatments. The highest benefit cost ratio (2.71) was observed from the treatment combination of S_2M_1 (50 cm x 30 cm spacing + water hyacinth mulch) and the lowest (1.17) was noticed from S_3M_0 (50 cm x 40 cm spacing + no mulch material).

Znidarcic *et al*. (2007) investigated a trial to examine the yield and quality attributes of early cabbage in response to spacing. The varieties -Vestri, Parel, Delphi, Destiny and Hermes were spaced at 20, 30 and 40 cm inside rows and 30 cm between rows, resulting in populations of 166,000, 108,000 and 82,000 plants ha^{-1}, respectively. Marketable yield, yield parameters (head diameter and volume) and quality attributes were all observed (core volume, head density, total soluble solids and dry matter). On the assessed variables, there was no relation impact between varieties and spacing. They discovered that as the within-row spacing enlarged, marketable yield per head, head diameter, volume and head density all increased. The yield possibility of cv. "Vestri" was greater than that of the other varieties.

Yoldas and Esiyok (2004) studied the impacts of seedling age (1, 2, and 3-months), spacing (70x30 and 70x40) and growth stages (vegetative and generative) on the yield and quality of broccoli cultivars Green Dome, KY110 and Marathon F_1 and found that plants grown from one-month-old seedlings produced the highest yield (4910 kg/ha). Marathon F_1 had the

highest initial yield (1855.2 kg/ha). Early yield increased as plant density increased, but fell as seedling age and sowing delay increased.

Singh *et al.* (2004) discovered that the close spacing (45 x 30 cm) led in a considerably better head yield than the wider spacing in cabbage.

Kumar and Rawat (2002) carried out a trial to investigate the impact of various levels of nitrogen (0, 50, 100, 150 and 200 kg N/ha) and spacings (30 x 60 cm, 45 x 60 cm and 60 x 60 cm) on quality parameters and yield attributes of cabbage (*Brassica oleracea* L. Var. *capitata*) cv. Pride of India. They obtained that highest yield of 303.09 q/ha were found in 30 x 60 cm spacing.

Khatiwada (2001) found that head yields were statistically greater at 45 x 30 cm and 45 x 20 cm spacing than at other spacing. There was a definite linear association between cabbage head yield and closer plant spacing. 45 x 30 cm spacing was determined to be more cost-effective. For rainy season cabbage production in steep hills, declining the spacing from 75 x 60 cm to 45 x 30 cm can maintain a plant population of up to 74,074 plants per hectare. In the rainfed conditions of the high hills, as much as 35 t ha^{-1} cabbage head can be grown using this spacing.

Das *et al.* (2000) tested the influence of different N:P:K fertilizer levels (80:60:50, 120:90:75, 160:120:100, and 200:150:125 kg/ha) and plant spacing(45 x 45 cm, 60 x 45 cm, and 60 x 60 cm) on curd production of cauliflower cv. Pusa Katki. The highest curd output per plant was achieved with a 60 x 60 cm spacing and a N:P:K rate of 160:120:100 kg/ha.

Pornsuriya *et al*. (1997) conducted a study in Thailand to discover various cultural strategies for increasing broccoli yield and quality. The optimal spacing was 40x60 cm, which yielded the most and had the finest quality.

Mallik and Biswajit (1996) carried out a trial to determine the influence of spacing on yield of cabbage cv. Pusa Drum Head. There were 2 spacings used: 60 x 45 cm and 60 x 60 cm. They got a greater yield with broader spacing than they did with nearer spacing.

Bjorn and Khan (1994) planted 13 cabbage varities at a regular spacing of 60x50 cm and 11 varieties at a near spacing of 50 x 30 cm in a trial. The results showed that the varieties was large enough to identify good cultivars that could be grown at conventional spacing.

Sorensen and Grevsen (1994) found that spacing of 40 cm x 50 cm, 30 cm x 50 cm, 20 cm x 50 cm, 10 cm x 50 cm and 20 cm x 25 cm had minimal effect on maturity standards in early planting. At increased plant population, a greatest variability in maturity index was seen in late planting.

Griffith and Carling (1991) discovered that single plant transplants produced the highest yield of individual heads of broccoli for the fresh market at a spacing of 45 x 30 cm. Green Valiant and Emperor yielded 18.3 and 15.0 t ha^{-1} correspondingly, at this spacing.

Khan *et al.* (1991) carried out an experiment at Bixby, Oklahome. Before and after (side dressing) planting, broccoli cv. Premium crop seedlings were planted at 15 or 30 cm apart and given 4 N rates in 10 split treatments. The force required to shear the stalk was unaffected by plant spacing and reducing spacing only reduced average stalk width by 3 mm. Despite higher head production, lower average marketable head weight, delayed maturity and a lower percentage of field planted transplants producing marketable heads stalk with the 15 cm spacing, the 30 cm spacing resulted in higher head production, lower average marketable head weight, delayed maturity and a lower percentage of field planted transplants producing marketable heads stalk with the 30 cm spacing.

Farooque and Islam (1989) discovered that spacings of 60x30 cm and 60x45 cm provided much larger yields and improved cabbage growth.

Nortze and Henrica (1989) advocated that the inter row spacing is mostly determined by water usage and performance of crop. The impacts of 3 inter-row spacings, namely 60x60 cm, 60x40 cm, and 60x30 cm, on water utilisation under various irrigation regimes were also studied. The nearest planting had a considerable reduction in head bulk.

Titze and Alpers (1987) carried out investigations on spacing of white cabbage cultivars Castello and Apex Seeds and conducted that average head weight decreased by half in Castello and by a quarter in Apex Seeds, when planting density increased from 27,000 to 40,000 plants/ha. Head weight decreased only a little at the highest density. With increasing planting density, particularly over 60,000 plants/ha, the proportion of attractive heads weighing 0.8-1.5 kg increased.

Khurana *et al.* (1987) observed that the efficacy of spacing on yield of cabbage. In their experiment, they employed spacings of 50x50 cm, 60x40 cm, and 70x30 cm and found

that spacing had a substantial impact on average head weight, with the 70x30 cm spacing yielding the maximum yield of cabbage.

2.2.3 Effect of spacing on quality attributes

Bairwa *et al.* (2017) studied the influence of sulphur and spacing on knolkhol (*Brassica oleracea* var. *gongylodes* L.) quality parameters and economics, with4 levels of sulphur (0 kg, 20 kg, 40 kg and 60 kg sulphur ha^{-1}) and spacing (30x20 cm, 30x30 cm, 45x30 cm and 45x45 cm). When compared to 30x20 cm spacing and 30x30 cm spacing, the level of spacing 45x45 cm greatly increased the sulphur content in knob, protein content and ascorbic acid content in knob (mg/100g), but statistically at par with 45x30 cm spacing. The net returns and B:C ratio were significantly higher at 30x30 cm spacing than at 45x45 cm or 30x20 cm spacing, which were statistically equivalent to 45x30 cm spacing.

Kołota and Chohura (2015) reported that the closer spacing 45x30 cm seemed to be helpful for dry matter, vitamin C and total sugar concentration and for reduction of nitrates accumulation in white cabbage.

Mehta *et al.* (2015) observed that the impact of head decapitation and plant population on growth, seed yield and quality parameters of sprouting broccoli (*Brassica oleracea* var. *italica* L.) cv. Green Head. They stated that when planting density increased, quality attributes decreased. The finest quality was obtained with the largest spacing of 60x60 cm, however this spacing yielded the minimum yield per hectare.

Thirupal *et al.* (2014) found that plant spread, leaves per plant, vitamin C and chlorophyll content were all highest at 60x45 cm. In broccoli, the 50x30 cm crop geometry produced the maximum plant height, yield/ha and a shorter number of days to flower bud initiation.

Grabowska *et al.* (2009) investigated the effect of spacing on the marketability and nutritional quality of 'Lord F1' broccoli heads, finding that the spacing (20, 30, 40 and 50 cm x 67.5 cm) had no discernible effect on the dry matter content of the heads.

Znidarcic *et al.* (2007) carried out a field trial to determine the yield and quality characters of early cabbage in response to spacing. The cultivars "Vestri," "Parel," "Delphi," "Destiny," and "Hermes" were spaced at 20, 30, and 40 cm inside rows and 30 cm between

rows, resulting in populations of 166,000, 108,000 and 82,000 plants per ha, respectively. They discovered that total soluble solids were not affected by spacing.

Singh *et al.* (2004) found that the usage of different plant spacings, such as S_1 (45x30 cm), S_2 (45x45 cm) and S_3 (60x45 cm), had no effect on the acidity and ascorbic acid content of cabbage heads.

Kumar and Rawat (2002) conducted a trial to see just how various nitrogen levels (0, 50, 100, 150, and 200 kg N/ha) and spacings (30 x 60 cm, 45 x 60 cm and 60 x 60 cm) affected the quality and production of cabbage (*Brassica oleracea* L. Var. *capitata*) cv. Pride of India. They discovered that as the spacing was increased, the quality improved. The quality metrics (TSS concentration, chlorophyll content and dry matter per cent) and yield of cabbage were impacted by spacing.

Pornsuriya *et al.* (1997) investigated an experiment in Thailand to discover various cultural strategies for increasing broccoli yield and quality. The optimal spacing was 40 x 60 cm, which yielded the most and had the finest quality.

2.3 Interactive effect of varieties and spacing

Kaur *et al.* (2021) revealed that the application of black polythene mulch with wider spacing (45 x 60 cm) proved to be most effective in increasing the vegetative growth and quality characters of sprouting broccoli while, narrow spacing (45x30 cm) with black mulch induces the higher production of sprouting broccoli under Punjab conditions in terms of growth, yield and biochemical characters.

Silatar *et al.* (2018) evaluated the performance of Knolkhol varieties with various spacing for quality and economics. Highest length (7.17 cm) and volume of knob (219.07 cc) were observed in plant grown with a spacing of 30×30 cm. Whereas, highest crude protein (3.54%) and organoleptic score (7.31) were obtained in spacing (25×25 cm). The maximum TSS (7.50°Brix) was noted with plant spacing 20×20 cm. Variety Purple Vienna noted highest volume of knob and crude protein (186.36 cc and 3.24%, respectively). Highest TSS content (7.50°Brix) and organoleptic score (7.10) was recorded with White Vienna variety. Highest B:C ratio (8.43:1) and net returns (Rs 6,37,279) found with 20×20 cm spacing and White Vienna variety.

Mehta *et al.* (2015) reported that the broader spacing (60x60 cm and 60x45 cm) resulted in earlier flowering, seed harvesting and a higher branches per plant, but that it had no influence on plant height. D_4S_2 (control with 60x45 cm spacing) had the most branches per plant, which was comparable to D_4S_1 and D_4S_3.

Bhangre *et al.* (2011) observed that the Ganesh outperformed it, days to 50% harvest (53.4 days), days to last harvest (68.4 days), diameter of curd (10.81 cm), average weight of curd (154.80 g) and yield ha^{-1} for Pusa KTS-1 (70.75 q). Except for days to 50% harvest (64.5 days), days to last harvest (79.33 days) and yield per hectare, 45x30 cm spacing yielded significantly lower values for all of the parameters studied (77.08 q) in broccoli.

Moniruzzaman (2011) concluded that the in comparison to closer spacing of 60x30 cm, a wider spacing of 60x45 cm resulted in a much higher number of folded leaves and head weight (without unfolded leaves). The cabbage variety "Green Coronet" had the maximum plant height, number of unfolded leaves, longest loose-leaf length, widest loose-leaf length, head height, and head weight (with unfolded leaves).

Dave and Bamhhaniya (1993) conducted an experiment by planting three cabbage varieties (Pride of India, Express and Golden Acre) each at five spacings (30x30, 45x30, 45x45 and 60x45 cm) and observed maximum gross weight/plant, head size and marketable yield/hectare in cultivar Pride of India. They further reported that the highest and the lowest marketable yields/hectare were obtained in the narrowest (30x30 cm) and widest spacings (60x45 cm), respectively. However, net weight of head was maximum in 60x45 cm spacing.

Lal *et al.* (1981) conducted a field experiment with six cabbage varieties spaced at 45x45 cm, 45x60 cm and 60x60 cm and concluded that Chaubattia Early out yielded the other cultivars in all spacings and was particularly suitable for growing at the close spacing.

*Chapter-***3**

MATERIALS AND METHODS

A field investigation entitled "Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)" was carried out at Horticultural Research Farm-I, Department of Applied Plant Science (Horticulture), School for Biosciences and Biotechnology, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya-Vihar, Raebareli Road, Lucknow, (U.P.), India during *Rabi* season 2018-19 and 2019-20. This chapter goes over the details of the crop-raising technique and the standards used to evaluate treatment effectiveness throughout the investigation.

3.1 Climatic conditions:

Geographically, Babasaheb Bhimrao Ambedkar University, (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow (U.P.), India situated at $80^0$55'East longitude and $26^0$46' North latitude and 111 meter above MSL. Lucknow's climate is classified as subtropical, with hot, dry summers and cool winters. This area received an average annual rainfall of 650-750 mm, which is distributed over a period of more than 100 days with peak period during January-June. It also received scattered showers during summer months. In general, the temperature ranges from 5.5^0 to 25^0. The average relative humidity is 60% in different seasons of the year. The monthly weather conditions prevailing during experimental period is specified in Table 3.1. The soil of experimental field was a saline-alkaline.

Table-3.1. Weekly meteorological data during crop season (*Rabi* 2018-19) at Lucknow (U.P.):

Standard meteorological Week	Period (2018-2019)	Temperature (^{0}C)		Relative humidity (%)	Annual Rainfall (mm)
		Max.	Min.		
43	**Oct, 25-31**	32.4	14.8	62.5	0.0
44	**Nov, 01-07**	32.0	14.3	67.0	0.0
45	**Nov, 08-14**	28.5	11.0	64.0	0.0
46	**Nov, 15-21**	29.1	12.7	63.0	0.0
47	**Nov, 22-28**	28.1	10.3	64.5	0.0
48	**Nov, 29-Dec, 05**	26.9	9.8	70.5	0.0
49	**Dec, 06-12**	25.1	6.7	69.5	0.0
50	**Dec, 13-19**	23.9	7.0	69.5	0.0
51	**Dec, 20-26**	23.5	3.4	64.5	0.0
52	**Dec, 27-Jan, 02**	21.8	2.5	62.0	0.0
1	**Jan, 03-09**	22.7	4.9	71.0	0.0
2	**Jan, 10-16**	22.6	5.8	65.0	0.0
3	**Jan, 17-23**	22.9	4.5	68.0	0.0
4	**Jan, 24-30**	21.8	10.3	77.5	0.0
5	**Jan, 31- Feb, 06**	22.3	7.0	69.5	0.0
6	**Feb, 07-13**	22.5	9.5	77.5	0.0
7	**Feb, 14-20**	23.6	10.4	73.5	0.0
8	**Feb, 21-27**	26.4	11.3	67.5	0.0
9	**Feb, 28- Mar, 06**	23.6	9.5	71.0	0.0
10	**Mar, 07-13**	27.5	10.9	63.0	0.0

Table-3.2. Weekly meteorological data during crop season (*Rabi* 2019-20) at Lucknow (U.P.)

Standard meteorological Week	Period (2019-2020)	Temperature (^{0}C)		Relative humidity (%)	Annual Rainfall (mm)
		Max.	Min.		
43	**Oct, 25-31**	30.0	11.6	73.2	0.0
44	**Nov, 01-07**	30.0	15.2	75.0	0.0
45	**Nov, 08-14**	29.5	14.9	67.5	0.0
46	**Nov, 15-21**	29.4	13.0	64.0	0.0
47	**Nov, 22-28**	27.7	11.9	69.0	0.0
48	**Nov, 29-Dec, 05**	26.5	12.5	76.0	0.0
49	**Dec, 06-12**	24.9	8.2	70.0	0.0
50	**Dec, 13-19**	22.2	10.4	79.5	0.0
51	**Dec, 20-26**	17.9	7.9	80.0	0.0
52	**Dec, 27-Jan, 02**	15.2	5.7	79.0	0.0
1	**Jan, 03-09**	20.4	8.3	75.3	0.0
2	**Jan, 10-16**	17.7	7.1	84.5	4.6
3	**Jan, 17-23**	17.7	10.2	93.1	12.2
4	**Jan, 24-30**	20.8	6.6	71.3	67.8
5	**Jan, 31- Feb, 06**	22.3	7.2	71.2	0.0
6	**Feb, 07-13**	22.9	5.3	65.2	0.0
7	**Feb, 14-20**	25.6	9.5	62.1	0.0
8	**Feb, 21-27**	26.5	12.1	75.5	9.2
9	**Feb, 28- Mar, 05**	26.7	12.7	73.6	0.2
10	**Mar, 06-12**	26.3	13.2	72.1	24.8

Source: Indian Institute of Sugarcane Research (ICAR-IISR), Lucknow, (UP).

3.2 Programme of Work

The materials used and procedures followed during the research work are described in details below

3.2.1 Location of experimental field:

The experimentation was laid out at the Horticultural Research Farm-I, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya-Vihar, Raebareli Road, Lucknow, (U.P.), India-226 025 during *Rabi* season 2018-19 and 2019-20.

3.3 Soil status of the experimental site

Before the experiment began, representative soil samples were randomly collected from the experimental field at a depth of 15 cm and transported to the laboratory for physical and chemical investigation. The field's soil was sandy loam in texture and slightly alkaline in reactivity.

Table 3.3 Physical property of soil

S.N.	Soil status	%	Method of determination
1.	Sandy	34.50	Hydrometer methods **(Black, 1965)**
2.	Silt	50.20	
3.	Clay	15.30	
4.	Texture class	Sandy loam	Pipette method, **(piper, 1950)**

Table 3.4 Chemical property of the soil

S.N.	Components	Amounts	Methods determination
1.	Available N_2 (kg/ha)	110.50	Kjeldahl's method **(A.O.A.C., 1980)**
2.	Available P_2O_5 (kg/ha)	40.50	Olsen's method **(Jackson, 1983)**
3.	Available K_2O (kg/ha)	190.40	Flame photometer **(Jackson, 1983)**
4.	Organic carbon (%)	0.12	Rapid titration method **(Jackson, 1983)**
5.	pH	8.2	Glass electrode, pH meter (**Jackson, 1983)**
6.	E.C. (1:1)	0.26	Conductivity meter **(Jackson, 1983)**
7.	E.S.P.	14.80	Conductivity meter **(Jackson, 1983)**

3.4 Experimental design and layout

The experiment was set up in factorial randomized block design (FRBD) with three replications. Randomization of the treatments was done with the help of random number table as suggested by **Panse and Sukhatme (1985)**. Figure 3.1 depicts the experiment layout plan. Table 3.5 shows the treatment with symbol in details.

Table 3.5: Details of experimental layout

Name of crop	Knol-khol (*Brassica oleracea* var. *gongylodes* L.)
Season and Year	*Rabi,* 2018-19 and 2019-20
Varieties	(i) Pusa Virat (ii) White Vienna (iii) Early White Vienna (iv) Palam Tender Knob
Number of treatments	16
Replication	3
Total plots	48
Number of spacing	4
Net plot size	1.8m x 1.8m
Spacing first (row to row x plant to plant)	30 cm x 30 cm
Number of plants per plot	36 Plants
Spacing second (row to row x plant to plant)	45cm x 30cm
Number of plants per plot	24 Plants
Spacing third (row to row x plant to plant)	45cm x 45cm
Number of plants per plot	16 Plants
Spacing fourth (row to row x plant to plant)	60 cm x 45cm
Number of plants per plot	12 Plants
Total plants are required for entire field	1056 Plants
Design	Factorial Randomized Block Design
Date of transplanting	1st November, 2018 and 4th November, 2019

FIG 3.1 LAYOUT OF EXPERIMENT

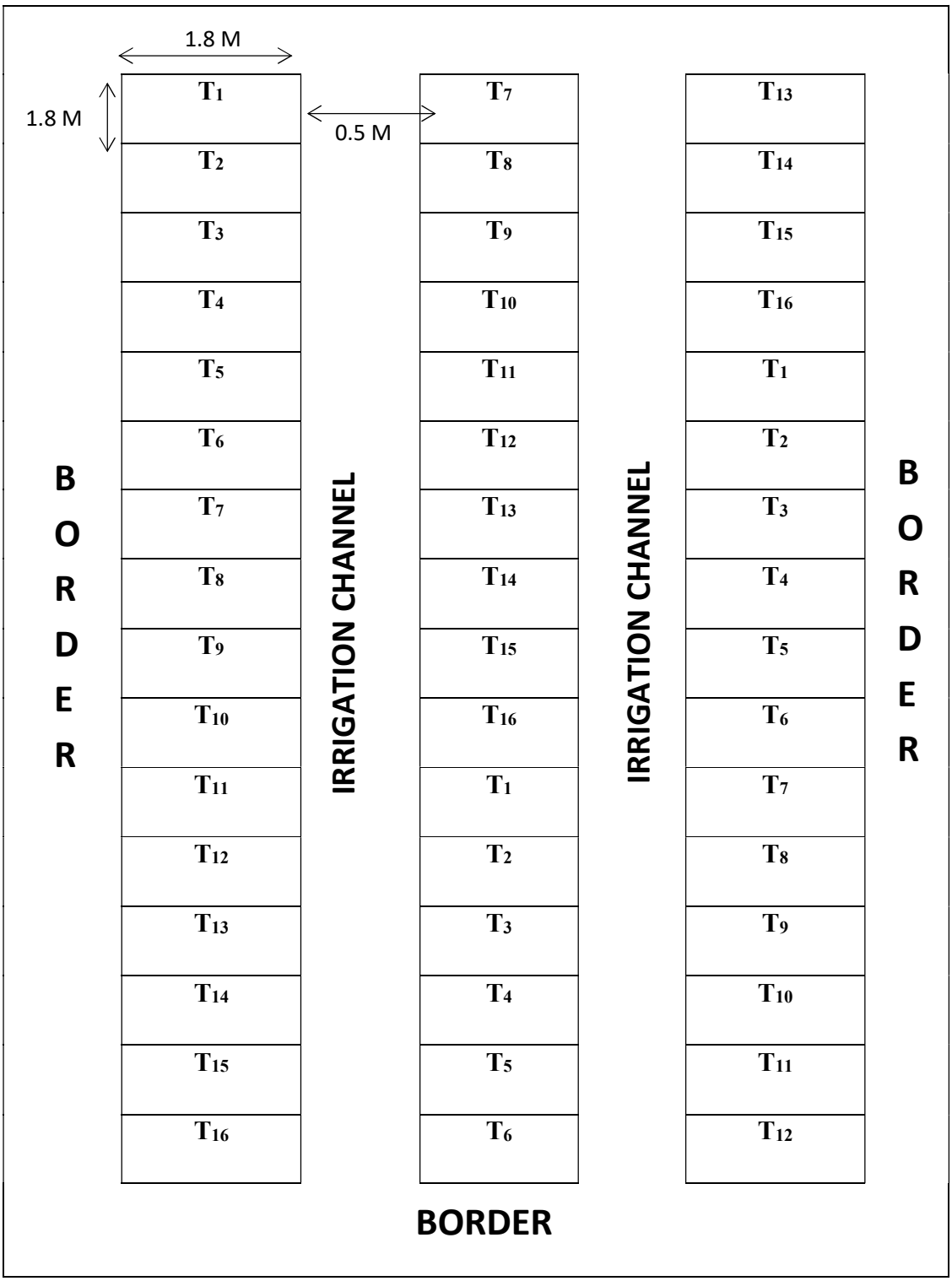


Table 3.6 Details of treatments with symbols

S.N.	Treatment	Symbols	
1.	Varieties	(i) Pusa Virat	(V_1)
		(ii) White Vienna	(V_2)
		(iii) Early White Vienna	(V_3)
		(iv) Palam Tender Knob	(V_4)
2.	Spacing	(i) 30 cm x 30 cm	(S_1)
		(ii) 45 cm x 30 cm	(S_2)
		(iii) 45 cm x 45 cm	(S_3)
		(iv) 60 cm x 45 cm	(S_4)

Table 3.7 Details of the treatments along with combinations.

Treatment	Combination	Treatment	Combination
T_1	V_1S_0	T_9	V_3S_1
T_2	V_1S_2	T_{10}	V_3S_2
T_3	V_1S_3	T_{11}	V_3S_3
T_4	V_1S_4	T_{12}	V_3S_4
T_5	V_2S_1	T_{13}	V_4S_1
T_6	V_2S_2	T_{14}	V_4S_2
T_7	V_2S_3	T_{15}	V_4S_3
T_8	V_2S_4	T_{16}	V_4S_4

3.5 Characteristics of varieties

Pusa Virat- The variety has dwarf plant type and semi spreading habit. Individual knob weights around 400 g and average yield is 23 tones/ha. Harvesting can be done from 50-60 days after transplanting. Both knobs and leaves are edible. It can withstand high frost and cold conditions. There is little or no fiber development at maturity.

White Vienna- It is an early maturing variety takes about 55–65 days to mature after transplanting. The plants are dwarf with medium green leaves and stem. The knobs are globular, light green, smooth and tender with delicate flavour. Its yielding potential is 175 q ha^{-1}.

Early White Vienna- It's a very early variety. Plants are dwarf, petite topped having medium green foliage. The knobs are globular to round. Flesh is tender and crisp. It takes about 50-55 days for knob formation after transplanting.

Palam Tender Knob- Early variety with light green knobs and gives average yield of 250-275 q/ha.

3.6. Raising of experimental crop

3.6.1 Preparation of nursery beds and rising of the seedling

Two raised nursery beds measuring 3 x 1 x 0.15 m were created by putting 5-6 kg of well rotting farm yard manure per square meter into the soil. To prevent damping off, seeds were given a treatment of 0.02 percent thiram. On November 1st, 2018 and November 4th, 2019, seeds were dropped at a depth of 1-2 cm in shallow furrows 5-6 cm apart. To cover the seed, a thin layer of powdered leaf mound was applied. Watering, hoeing, weeding and plant protection measures, among other things, were done on a regular basis. Within five to six weeks of sowing seeds in the nursery beds, the seedlings were ready for transplantation.

3.6.2 Field preparation

With a mould board plough, the trial field was tilled and cross-ploughed extensively, then cross-harrowing was completed with a tractor, followed by planking and levelling to get the desired tilth. The experiment's layout was followed in the construction of 1.8 x 1.2 m beds, as well as pathways and channels.

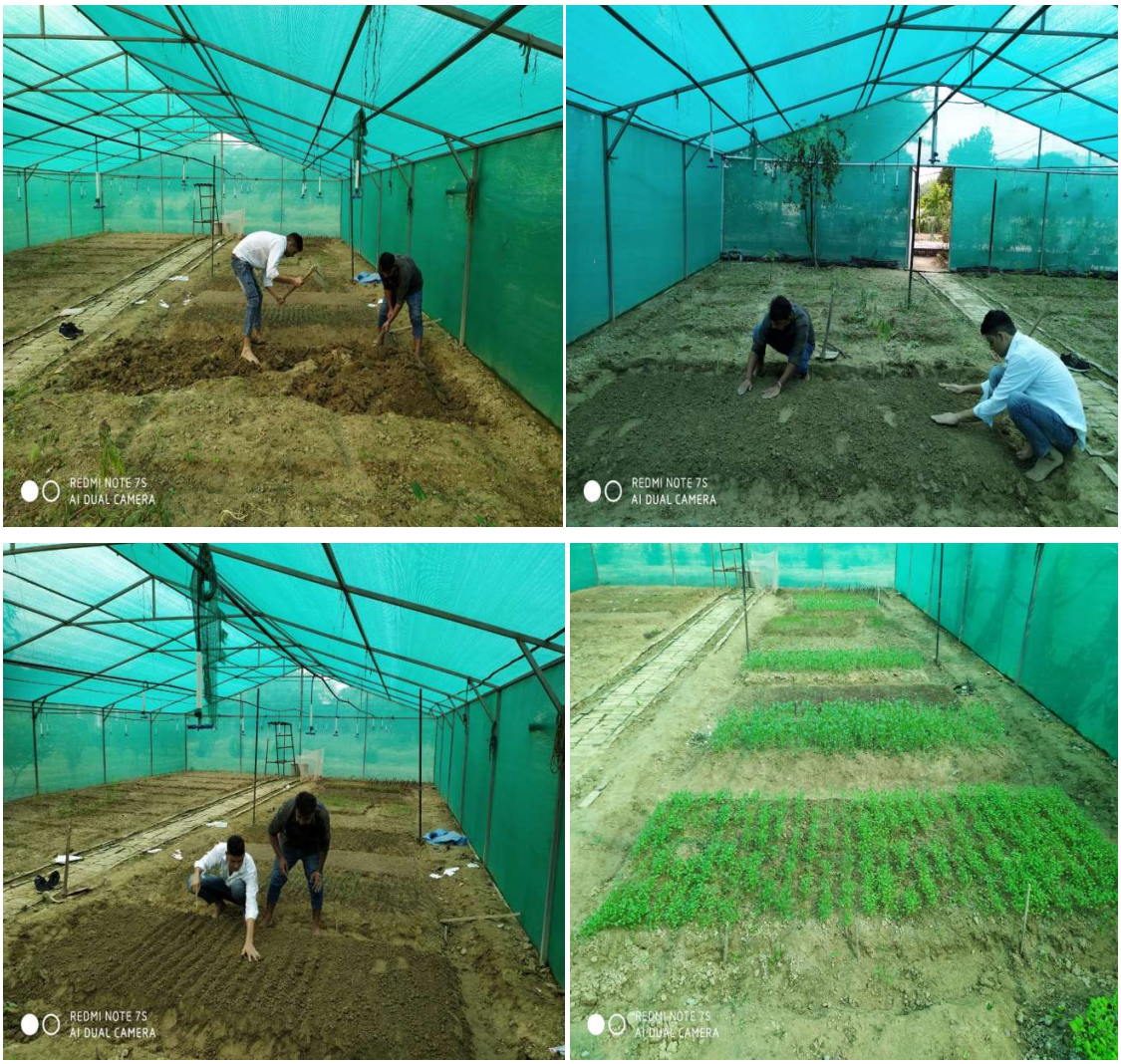


Fig.-1: A general view of preparation of nursery of knol-khol crop

Fig.-2: Preparation of experimental field of knol-khol

Fig.-3: A view of layout plan of experimental field

3.6.3 Application of fertilizers

The suggested dose of NPK urea, DAP, and MOP were used, respectively. The recommended dose of NPK for knol-khol crop was 180:120:100 kg ha^{-1}.

3.6.4 Transplanting

On November 1st, 2018 and November 4th, 2019, five-week-old seedlings were transplanted, with an average height of about 10-12 cm. 30 x 30 cm, 45 x 30 cm, 45 x 45 cm and 60 x 45 cm were used as the row to row and plant to plant distances. As a result, plants were arranged in each plot conferring to their spacing. After a light irrigation, the transplanting was completed in the evening.

3.6.5 Irrigation

Irrigation was started right after transplanting and continued every 2-3 days until plants were established. After then, the crop was watered every 9 to 10 day intervals.

3.6.6 Gap filling

In the early stages of the crop, gap filling was used to replace failed or dead seedlings in order to keep the plant population in each plot uniform.

3.6.7 Weeding and hoeing

To maintain the proper plant stand, the first and second weeding cum hoeing were done 25 and 40 days after transplanting.

3.6.8 Plant protection measures

Chlorpyriphos 20 EC @ 0.70 kg per ha was treated to the whole field shortly then transplantation with irrigation to prevent termite attack on plants. Prophylactic steps were performed to prevent cabbage butterfly, hopper and aphid attacks, with the knolkhol plants being sprayed with malathion 50 EC (0.05 percent) at 20-day intervals starting 45 days after transplant and ending a week earlier the crop's maturity.

3.6.9 Harvesting of knobs

Tender knob was collected by plucking the entire plant out of the ground. Following that, the root portion of the knob, as well as a portion of the stem around the base of the knob, were removed. Before being discarded for selling, the leaves were clipped and the knob was cleaned.

Fig.-4: A general view of experimental field of knol-khol

3.7 Characters studied and observation recorded

Five competitive plants from each net plot were selected randomly for recording observations for following different characters and averages were used in the statistical analysis.

3.8 Procedure for observations:

3.8.1 Growth characters

3.8.1.1 Plant height (cm)

At 30 DAT and harvest, plant height was measured. With the use of a meter scale, the height of five marked plants was computed from the base to the top of the longest leaf and the mean height was computed.

3.8.1.2 Number of leaves per plant

The average number of leaves per plant was estimated by counting the leaves of five tagged plants from each plot at 30 DAT and harvest.

3.8.1.3 Length of leaves (cm)

At 30 DAT and at maturity, length of five fully open leaves of each five plants was measured by meter scale. The average was computed to get the mean length of leaf per plant in centimeter.

3.8.1.4 Width of leaves (cm)

The leaf taken for measuring the length was also utilized to measure the width of leaf in the centimeter with the help of meter scale. The cumulative total of the width of three leaf from each of the three tagged plants were measured presented an average width of leaf in centimeter.

3.8.1.5 Plant spread (cm)

After transplanting, plant spreading of the five observational plant was measured by meter scale. The average was computed to get the mean plant spreading per plant.

3.8.1.6 Stem girth (cm)

The stem girth was measured from the bottom portion of knob of five plants selected randomly from each treatment per replication and an average was calculated.

3.8.1.7 Days to knob initiation

The average of the number of days from the day of transplanting to the first knob formation was calculated.

3.8.1.8 Days taken to knob harvest

The days taken to harvest was noted from the date to transplanting, when at least on edible mature knob was harvested from 50% of the plant population and average was worked out.

3.8.2 Yield and yield attributing traits

3.8.2.1 Weight of knob (g)

With the use of a digital electronic balance, the weight of five randomly chosen knobs from individually treatment per replication was weighted and a mean value was calculated.

3.8.2.2 Diameter of knob (cm)

The diameter of edible mature knobs was measured from the central portion of five plants selected randomly from each treatment per replication and an average was calculated.

3.8.2.3 Volume of knob (cc)

The volume of the knob was determined in cc by estimating the displaced water, which was attained by dropping the knob in a measuring cylinder.

3.8.2.4 Yield (kg/plot)

The total edible mature knob yield of all the plants in each treatment was recorded in gram and mean was worked out in kilogram.

3.8.2.5 Yield (q/ha)

Knob yield per hectare was calculated using per plot yield. The area of one hectare was divided by the total plot area and multiplied by the yield per plot.

3.8.3 Quality parameters:

3.8.3.1 Vitamin-C (mg/100 g)

The amount of ascorbic acid in knobs was measured using the 2, 6 – dichlorophenol indophenol visual titration method (A.O.A.C., 1995) and expressed in mg/100 g of fresh sample. With 100 ml of 3 percent metaphosphoric acid solution, the crushed knobs are diluted. Titrate 10 ml of aliquot against 2, 6 – dichlorophenol indophenols dye solution for 10 seconds or until light pink colour appears. The following formula is used to express this in mg/100g:

$$\text{Dye Factor} = \frac{0.5}{\text{Titrate volume of standard ascorbic acid}}$$

$$\textbf{Ascorbic acid} = \frac{\textbf{titrate X Dye factor X Volume made up}}{\textbf{Aliquot of axtract taken for estimation X Wt.of volume of sample taken for estimation}} \boldsymbol{x\ 100}$$

3.8.3.2 Total soluble solid (TSS) (^{0} Brix):

A digital refractometer was used to determine the total soluble solid in knol-khol. A composite sample (10 g) was collected from five randomly chosen knobs from each treatment. At room temperature, the knob juice was extracted by crushing the sample with a mortar pestle. Little drops of extract were disposed on the refractometer's optical prism, the analysis was taken and the mean was calculated and given in °Brix.

3.8.3.3 Total sugars (%)

The total sugars percentage was determined by the method of Dubois *et al*., (1956) using Phenol reagent. The sugar extract 0.1 ml was taken in test tube and volume made up to 1 ml with distilled water. Then 0.1 ml 80 per cent phenol reagent was added and 4 ml conc. H_2SO_4 was added by the side of test tube and cooled at room temperature. The intensity of colour was recorded at 480 nm on spectronic-20. The calculating was done with the help of standard curve and results were expressed in per cent on the basis of 100g fruit sample.

3.8.3.4 Reducing sugar (%)

Reducing sugar (%) in fruit was determined by the method of Miller (1959). One ml sugar extract was mixed with 3 ml of dinitro Salicylic acid (DNS) reagent and kept on boiling water both for 10 minutes. The test tube was cooled at room temperature and the

intensity of colour was measured as 575 nm on spectronic 20. The calculation was done with the help of standard curve and results were expressed in per cent of reducing sugar.

Non-reducing sugar (%)

Non-reducing sugar was obtained by subtraction of reducing sugar from total sugar.

Non-reducing sugar = (Total sugar – reducing sugar) x 0.95

3.8.3.5 Total chlorophyll content in leaves (mg/g)

Total chlorophyll content in leaves was determined at 45 days after transplanting by using the method of Hiscox and Israelstom (1979) with slight modification. 50 mg fresh leaf material from randomly selected leaf was used for chlorophyll estimation. The material was taken in test tubes to which 5.0 ml DMSO was added. These tubes were tightly capped and placed in an oven at 60°C for 6 hrs. Finally the tubes were thoroughly shaken and extracted solvent was decantated to read at 645 and 663 nm by spectrophotometer (Systronics, India). The amount of total chlorophyll in leaves (mg/g) was calculated as advocated by Arnon (1949).

$$\text{Total chlorophyll (mg/g)} = \frac{A_{(652)} \times 29 \times \text{Total volume (ml)}}{\alpha \times 1000 \times \text{Weight of sample (g)}}$$

Where,

A= Absorbance specific wave lengths

α is the path length = 1 cm

3.8.4 Economics of the treatments

The cost of production per hectare for each treatment was evaluated by adding up the costs of various operations used to cultivate the crop separately for respectively treatment. The net income for each treatment was assessed by subtracting the cost of production from the total income per hectare. By dividing gross income by the cost of cultivation, the cost-benefit ratio was computed.

3.8.4.1 Cost of cultivation

Cost of cultivation = Total variable cost + Total fixed cost

3.8.4.2 Price/quintal

Price per quintal was estimate according to market average price. Average market price 1000 Rs/quintal.

3.8.4.3 Gross returns

Gross returns = Yield (q/ha)

3.8.4.4 Net returns

Net return = Total income – total cost of cultivation

3.8.4.5 Benefit cost ratio

Benefit cost ratio = Cost of total benefit/ Cost of production

Fig.-5: A general view of estimation of total soluble solids of knol-khol

Fig.-6: A view of estimation of vitamin-C content in knob of knol-khol

3.9 Statistical analysis

As advised by Panse and Sukhatme (1985), the data collected on numerous studies for each treatment were subjected to "Analysis of Variance". The following is the skeleton of an ANOVA as designed:

Table 3.8: Skeleton of analysis of variance (ANOVA)

ANOVA					
Source of variation (S.V.)	Degree of freedom (df)	Sum of square (SS)	Mean sum of squares (MSS)	"F" value (Calculated) (F cal)	"F" value (Table) at 5% level of significance (F tab)
Replication	(r-1) = 2	SSR	MSR	MSR/MSE	
Variety(V)	(v-1) = 3	SSW	MSV	MSV/MSE	
Spacing (S)	(s-1) = 3	SSV	MSS	MSS/MSE	
Interaction (V x S)	(v-1) x (s-1) = 9	SSVW	MSVS	MSVS/MSE	
Error	{total DF-(r+v+rs)} = 30	SSE	MSE		
Total	(vsr-1) = 47	SST			

Where,

r=Number of replications

t=Number of treatments

MSR = Mean square due to replications

MSV = Mean square due to variety

MSS = Mean square due to spacing

MSE = Mean square due to error

The mean square due to replications and treatments were tested against corresponding error mean square and the calculated 'F' value was compared with table value of 'F' at P=0.005 and P=0.001.

The mean, standard error, critical difference and coefficients of variation were calculated as follows:

3.9.1.1 Mean:

The mean value of each character was worked out by dividing the totals by corresponding number of observations.

$$m = \frac{\sum X_{ij}}{N}$$

Where,

X_{ij} = Any observation in i^{th} varieties, spacing and j^{th} replication,

N= Total number of observations.

3.9.1.2 Standard Error (S.E.):

The standard errors (SEm ±) for genotypes were calculated with the help of mean square due to error from the analysis of variance table by the following formula:

$$\mathbf{S.E.\ m\pm} = \sqrt{\frac{MSE}{r}}$$

Where,

MSE = mean of squares due to error

r = number of replication

3.9.1.3 Critical difference:

Critical difference was calculated to find out the superiority of one variety over the other by following formula.

$$C.D. = \sqrt{\frac{2MSE}{r}} \text{ X t value at 5\% and 1\% error d.f}$$

Where,

$$SE(d) = \sqrt{\frac{2 \text{ X variance due to error}}{\text{no. of replication}}}$$

t = Table value of 't' distribution at error degree of freedom on P<0.05 and 0.01.

Chapter – 4

EXPERIMENTAL FINDINGS

Results of the field experiment entitled "Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)**"** was carried out at Horticultural Research Farm-I, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya-Vihar, Rae Bareli Road, Lucknow, (U.P.), India during *Rabi* season 2018-19 and 2019-20 have been presented in this chapter and data pertaining to various criteria used for evaluation of the treatments were statistically analyzed and analysis of variance has been furnished in Appendices. Interpretation of data had been made on pooled basis, highlighting the significant of treatments. The chapter as affected by different treatments has been categorized in following sub heads: -

4.1 Growth characters

4.2 Yield and yield attributing traits

4.3 Quality parameters

4.4 Economics of treatments

4.1 Growth characters

4.1.1 Plant height (cm)

Effect of varieties:

Data regarding the effect of varieties of knol-khol on the plant height has been presented in (Table 4.1 and Fig. 4.1). The plant height was significantly influenced by different varieties. During the first year (2018-19) the maximum plant height (17.59 cm) at 30 DAT and (29.60 cm) at harvest was recorded with V_2 (White Vienna) followed by V_3 (Early White Vienna) (17.14 cm) at 30 DAT and (29.06 cm) at harvest. This treatment was significantly superior over rest of the treatments. However, the minimum plant height (15.67 cm) at 30 DAT and (27.66 cm) at harvest was recorded in V_1 (Pusa Virat).

During the second year (2019-20) the plant height was significantly influenced by different varieties. The maximum plant height (17.22 cm) at 30 DAT and (29.95 cm) at harvest was recorded with V_2 (White Vienna) followed by V_3 (Early White Vienna) (16.54 cm) at 30 DAT and (29.60 cm) at harvest while, the minimum plant

height (16.19 cm) at 30 DAT and (27.06 cm) at harvest was recorded in V_1 (Pusa Virat).

The mean value of both years clearly revealed that the maximum plant height was recorded in V_2 (White Vienna) (17.40 cm) at 30 DAT and (29.77 cm) at harvest followed by V_3 (Early White Vienna) (16.91 cm) at 30 DAT and (29.33 cm) at harvest while, the minimum plant height (15.93 cm) at 30 DAT and (27.36 cm) at harvest was recorded in V_1 (Pusa Virat) in knol-khol.

Effect of spacing:

It is also evident from the data (Table 4.1 and Fig 4.2) that plant height was significantly influenced by different spacing. During the first year (2018-19) the maximum plant height (18.07 cm) at 30 DAT and (31.14 cm) at harvest was recorded with S_4 (60 x 45 cm). This treatment was significantly superior over rest of the treatments. However, the minimum plant height (15.40 cm) at 30 DAT and (27.04 cm) at harvest was recorded in S_1 (30 x 30 cm).

During the second year (2019-20) the plant height was significantly influenced by different spacing. The maximum plant height (17.93 cm) at 30 DAT and (31.31 cm) at harvest was recorded with S_4 (60 x 45 cm) while, the minimum plant height (15.60 cm) at 30 DAT and (27.42 cm) at harvest was recorded in S_1 (30 x 30 cm).The mean value of both years clearly revealed that the maximum plant height (18.00 cm) at 30 DAT and (31.22 cm) at harvest was recorded in S_4 (60 x 45 cm) while, the minimum plant height (15.50 cm) at 30 DAT and (27.23 cm) at harvest was recorded in S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on plant height during both years. The data on pooled mean basis (Table 4.1 & Fig. 4.3) revealed that the maximum plant height (18.63 cm and 31.92 cm) at 30 DAT and at harvest was recorded under treatment V_2S_4 (White Vienna with spacing 60 x45 cm). It was found statistically at par with V_3S_4 and V_4S_4 treatment combination but significantly superior to other treatment combinations. The minimum plant height (14.02 cm and 25.65 cm) at 30 DAT and at harvest was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x30 cm) during 2018-19 and 2019-20, respectively.

Table 4.1: Effect of varieties, spacing and their interaction on plant height (cm) of knol-khol

Treatments	Plant height (cm)					
	30 DAT			At harvest		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	15.67	16.19	15.93	27.66	27.06	27.36
V_2	17.59	17.22	17.40	29.60	29.95	29.77
V_3	17.14	16.82	16.98	29.06	29.59	29.33
V_4	16.81	16.54	16.67	28.57	29.01	28.79
SEm ±	0.34	0.14	0.18	0.24	0.27	0.18
CD (P=0.05)	0.99	0.41	0.52	0.69	0.79	0.51
Spacing (S)						
S_1	15.40	15.60	15.50	27.04	27.42	27.23
S_2	17.28	17.04	17.16	28.38	27.88	28.13
S_3	16.45	16.20	16.32	28.32	29.02	28.67
S_4	18.07	17.93	18.00	31.14	31.31	31.22
SEm ±	0.34	0.14	0.18	0.24	0.27	0.18
CD (P=0.05)	0.99	0.41	0.52	0.69	0.79	0.51
Interaction (V x S)						
V_1S_1	13.32	14.72	14.02	25.17	24.60	24.88
V_1S_2	16.21	18.06	17.14	28.11	27.34	27.73
V_1S_3	15.44	14.97	15.21	26.71	26.25	26.48
V_1S_4	17.69	17.01	17.35	30.63	30.05	30.34
V_2S_1	16.88	15.78	16.33	29.29	28.56	28.93
V_2S_2	16.44	17.24	16.84	30.25	28.98	29.62
V_2S_3	17.96	17.07	17.52	27.18	30.09	28.64
V_2S_4	18.47	18.79	18.63	31.66	32.17	31.92
V_3S_1	16.48	15.81	16.15	27.44	28.93	28.19
V_3S_2	17.03	16.19	16.61	28.56	28.35	28.46
V_3S_3	17.56	16.05	16.81	29.17	29.89	29.53
V_3S_4	18.07	18.11	18.09	31.08	31.22	31.15
V_4S_1	14.92	16.08	15.50	26.24	27.57	26.91
V_4S_2	16.88	16.67	16.77	26.61	26.86	26.73
V_4S_3	17.40	16.69	17.05	30.21	29.84	30.03
V_4S_4	18.03	17.83	17.93	31.20	31.78	31.49
SEm ±	0.68	0.28	0.36	0.47	0.54	0.36
CD (P=0.05)	1.98	0.81	1.04	1.38	1.58	1.02

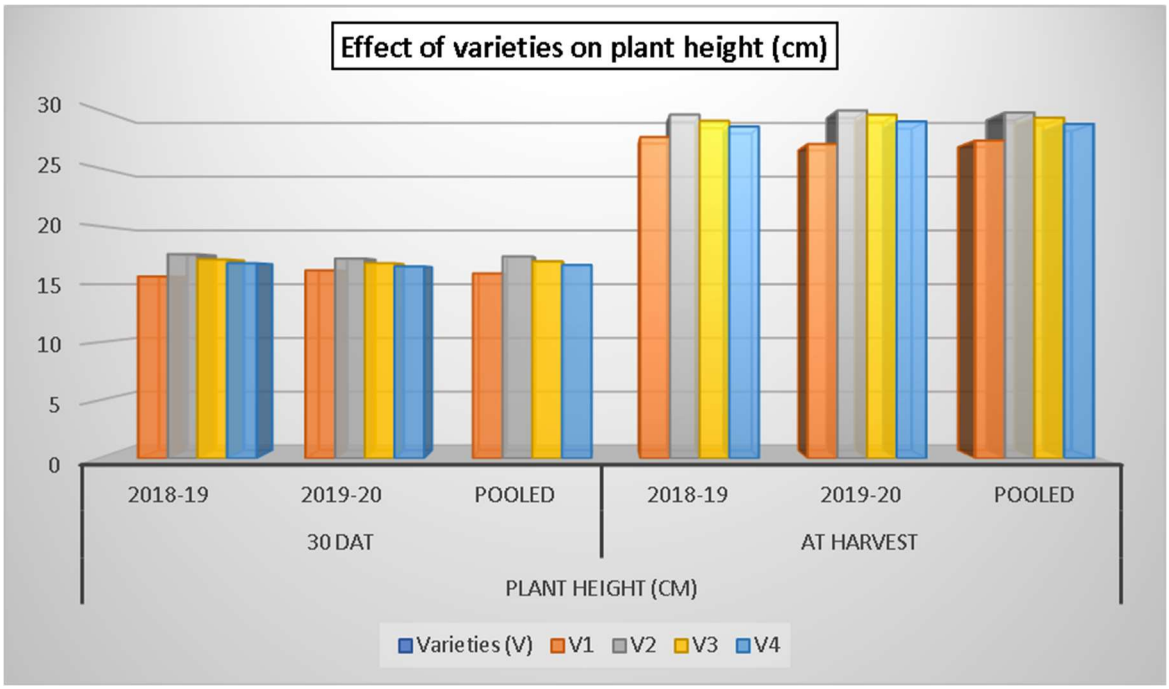


Fig. 4.1: Effect of varieties on plant height (cm) of knol-khol

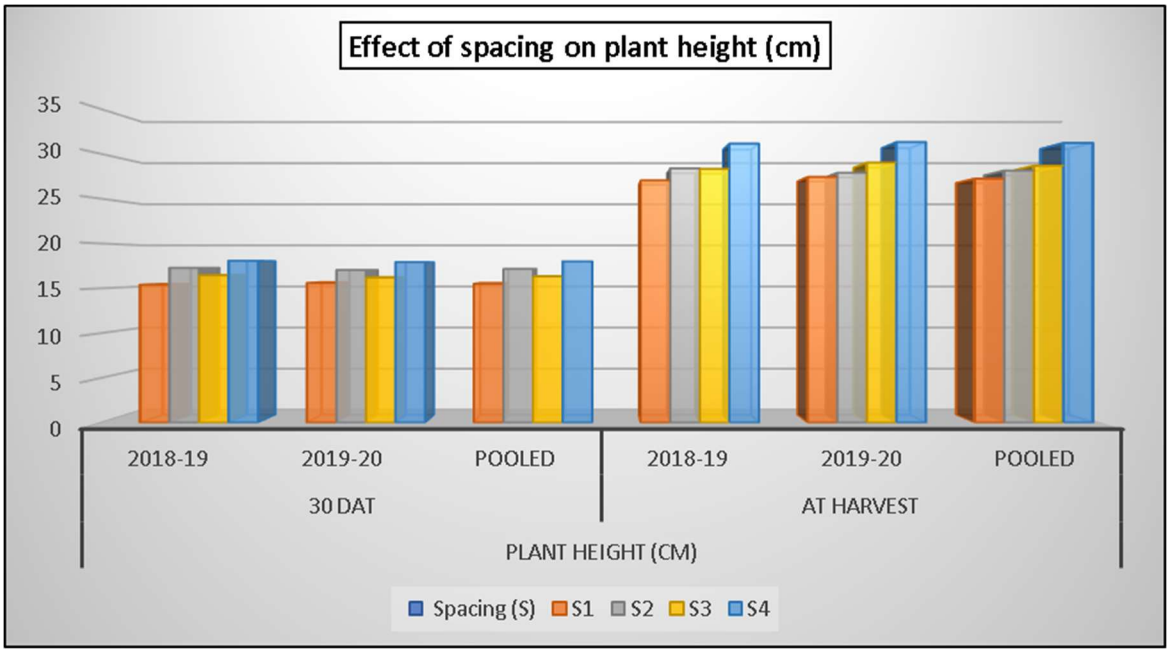


Fig. 4.2: Effect of spacing on plant height (cm) of knol-khol

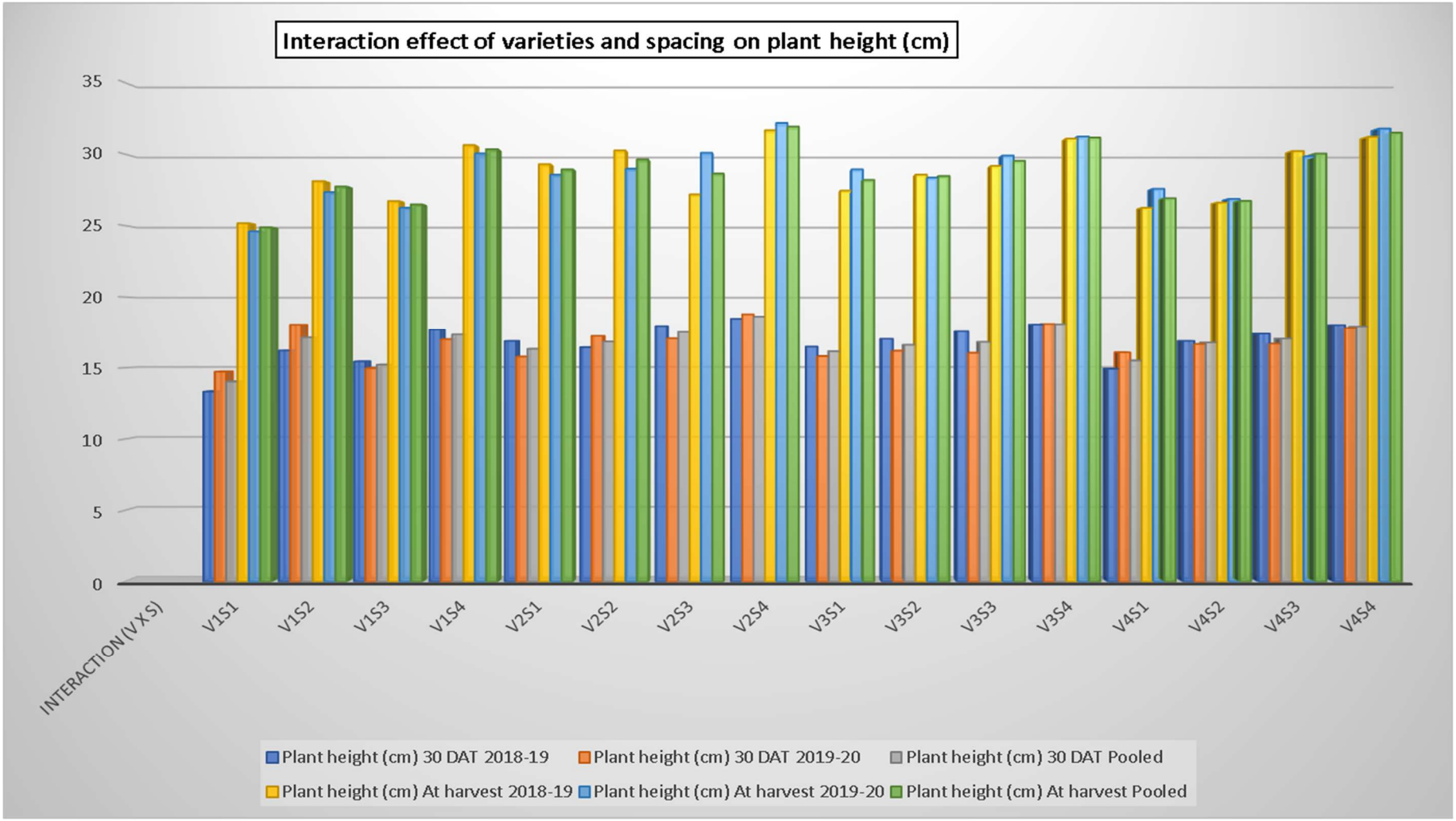


Fig. 4.3: Interaction effect of varieties and spacing on plant height (cm) of knol-khol

4.1.2 Number of leaves per plant

Effect of varieties

It is amply from the data (Table 4.2 and Fig 4.4) that number of leaves per plant increased significantly with different varieties. The maximum number of leaves per plant (11.50 and 10.89) at 30 DAT and (19.00 and 18.78) at harvest was recorded with V_2 (White Vienna) followed by V_4 (Palam Tender Knob) (11.04 and 10.80) at 30 DAT and (17.78 and 18.47) at harvest. This treatment was significantly superior over rest of the treatments. However, the minimum number of leaves per plant (9.59 and 9.82) at 30 DAT and (16.59 and 17.61) at harvest were recorded in V_1 – Pusa Virat during 2018-19 and 2019-20, respectively.

During both the years, mean number of leaves per plant was noticed to be maximum in V_2 -White Vienna (11.20) at 30 DAT and (18.89) at harvest followed by V_4 -Palam Tender Knob (10.92) at 30 DAT and at harvest (18.12) while, the minimum number of leaves at (9.71) 30 DAT and (17.10) at harvest were recorded in V_1 – Pusa Virat.

Effect of spacing

Data in (Table 4.2 and Fig 4.5) also indicated that application of different spacing significantly enhanced the number of leaves during both the years. The maximum number of leaves as (11.66 and 11.70) at 30 DAT and (18.12 and 19.54) at harvest stage, were recorded under treatment S_4 (60 x 45 cm). While, it was found minimum as (9.90 and 9.64) at 30 DAT and (16.89 and 17.35) at harvest stage, under S_1 (30 x 30 cm) respectively, during both years.

The mean number of leaves per plant over two years, irrespective of treatments were obtained maximum (11.68) at 30 DAT and (18.83) at harvest under the treatment S_4 (60 x 45 cm) while, minimum number of leaves (9.77) at 30 DAT and (17.12) at harvest stage under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on number of leaves per plant during both years. The data on pooled mean basis (Table 4.2 & Fig. 4.6) revealed that the maximum number of leaves per plant (11.96 and 19.94) at 30 DAT and at harvest was recorded under treatment V_2S_4 (White Vienna with spacing 60 x45 cm). The minimum number of leaves (8.54 and

16.25) at 30 DAT and at harvest was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x30 cm) during 2018-19 and 2019-20, respectively.

Table 4.2: Effect of varieties, spacing and their interaction on number of leaves per plant of knol-khol

Treatments	Number of leaves per plant					
	30 DAT			At harvest		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	9.59	9.82	9.71	16.59	17.61	17.10
V_2	11.50	10.89	11.20	19.00	18.78	18.89
V_3	10.67	10.74	10.71	16.80	18.32	17.56
V_4	11.04	10.80	10.92	17.78	18.47	18.12
SEm ±	0.22	0.21	0.15	0.24	0.21	0.16
CD (P=0.05)	0.64	0.60	0.43	0.68	0.61	0.45
Spacing (S)						
S_1	9.90	9.64	9.77	16.89	17.35	17.12
S_2	10.37	9.98	10.17	17.32	17.79	17.55
S_3	10.88	10.94	10.91	17.84	18.50	18.17
S_4	11.66	11.70	11.68	18.12	19.54	18.83
SEm ±	0.22	0.21	0.15	0.24	0.21	0.16
CD (P=0.05)	0.64	0.60	0.43	0.68	0.61	0.45
Interaction (V x S)						
V_1S_1	8.11	8.97	8.54	15.34	16.89	16.11
V_1S_2	9.34	9.65	9.50	15.61	17.34	16.47
V_1S_3	9.88	9.33	9.61	17.04	17.23	17.13
V_1S_4	11.04	11.34	11.19	18.38	18.98	18.68
V_2S_1	10.74	9.76	10.56	18.72	18.12	18.42
V_2S_2	11.46	9.98	9.92	17.86	17.48	17.67
V_2S_3	11.33	12.39	11.86	19.62	19.45	19.54
V_2S_4	12.48	11.45	11.96	19.81	20.08	19.94
V_3S_1	9.86	9.37	10.61	15.87	17.60	16.73
V_3S_2	10.41	10.06	10.24	16.87	17.39	17.13
V_3S_3	10.94	11.47	11.21	17.11	18.45	17.78
V_3S_4	11.48	12.06	11.77	17.34	19.83	18.59
V_4S_1	10.88	10.45	10.60	17.38	16.79	17.08
V_4S_2	10.27	10.23	9.82	19.21	18.94	19.08
V_4S_3	11.36	10.58	10.97	17.58	18.87	18.23
V_4S_4	11.66	11.95	11.81	16.94	19.27	18.11
SEm ±	0.44	0.42	0.30	0.48	0.42	0.32
CD (P=0.05)	1.28	1.20	0.86	1.36	1.22	0.90

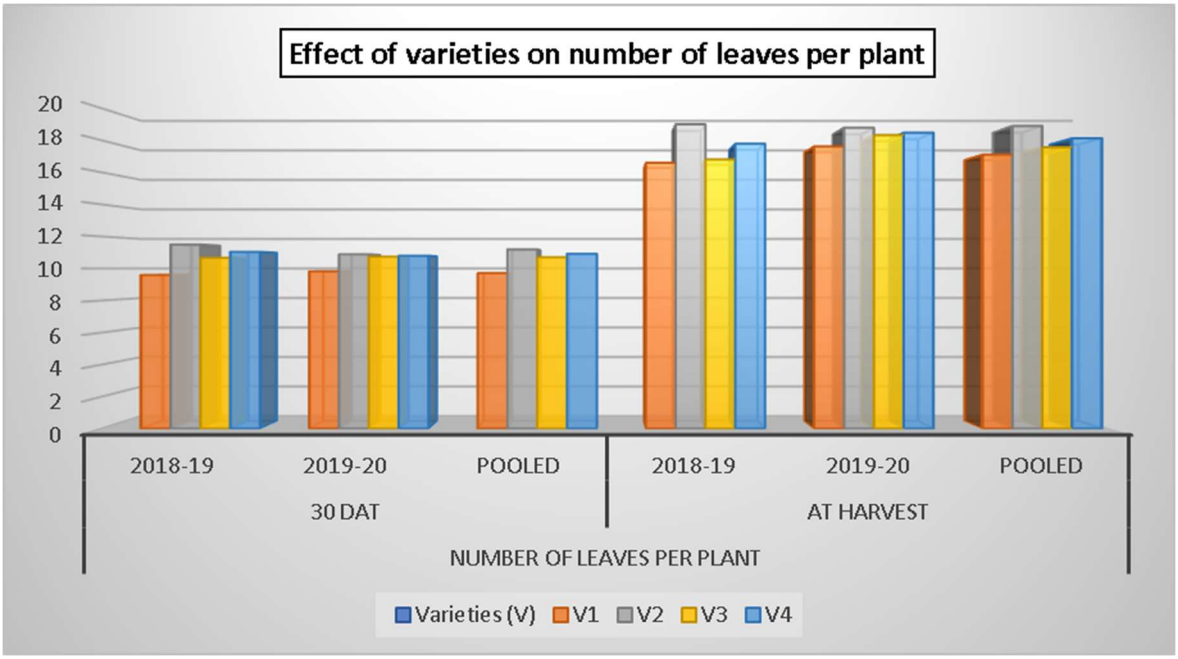


Fig. 4.4: Effect of varieties on number of leaves per plant of knol-khol

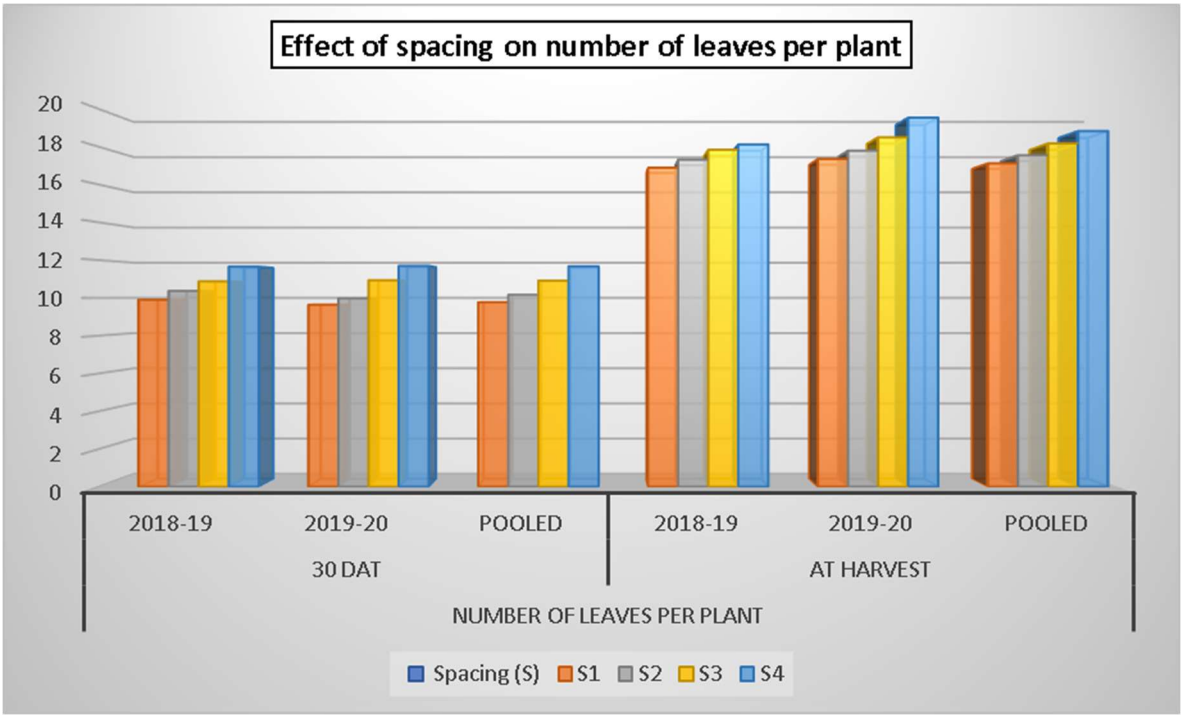


Fig. 4.5: Effect of spacing on number of leaves per plant of knol-khol

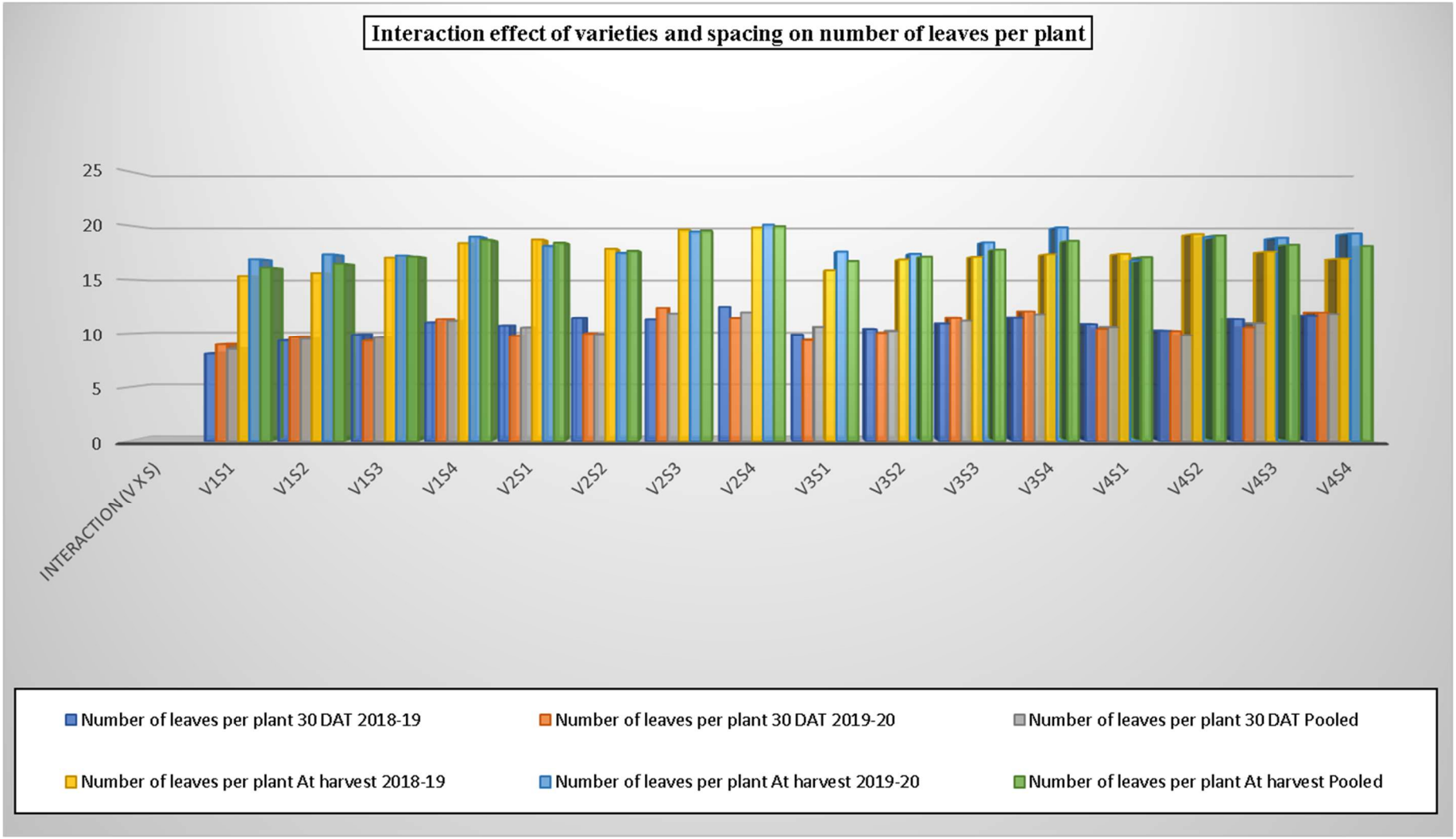


Fig. 4.6: Interaction effect of varieties and spacing on number of leaves per plant of knol-khol

4.1.3 Length of leaf (cm)

Effect of varieties:

It is apparent from the data (Table 4.3 and Fig 4.7) that there was a significant effect of different varieties individual at all the stage in both years. The maximum length of leaf (11.50 cm and 10.89 cm) at 30 DAT and (24.43 and 24.69 cm) at harvest was recorded in V_2 -White Vienna followed by V_4 -Palam Tender Knob (11.04 cm and 10.80 cm) at 30 DAT and (23.89 cm and 24.35 cm) at harvest. While minimum length of leaf was noted in V_1 – Pusa Virat (9.59 cm and 9.82 cm) at 30 DAT and (22.18 cm and 21.34 cm) at harvest, respectively during both years.

During both the years, mean length of leaf was noticed to be maximum in V_2 White Vienna (11.20 cm) at 30 DAT and at harvest (24.56 cm) followed by V_4 Palam Tender Knob (10.80 cm) at 30 DAT and at harvest (24.12 cm) while, the minimum length of leaf at 30 DAT (9.71 cm) and (21.76 cm) at harvest was recorded in V_1 – Pusa Virat.

Effect of spacing

The length of leaf was also affected significantly by different spacing at all the stage in both the year (Table 4.3 & Fig. 4.8). The maximum length of leaf (11.66 cm and 11.70 cm) was found at 30 DAT and (24.93 cm and 25.47 cm) at harvest in treatment S_4 (60 x 45 cm) followed by S_3 (45 x45 cm) (10.88 cm and 10.94 cm) at 30 DAT and (23.27 cm and 23.45 cm) at harvest while, the minimum length of leaf (9.90 cm and 9.64 cm) at 30 DAT and (22.84 cm and 22.47 cm) at harvest was recorded in S_1 (30 x 30 cm) respectively, during 2018-19 and 2019-20.

The mean length of leaf over two years was obtained maximum (11.68 cm) at 30 DAT and (25.20 cm) at harvest under the treatment S_4 (60 x 45 cm) while, minimum length of leaf (9.77 cm) at 30 DAT and (22.65 cm) at harvest stage, under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on length of leaf during both years. The data on pooled mean basis (Table 4.3 & Fig. 4.9) revealed that the maximum length of leaf (13.64 cm and 25.75 cm) at 30 DAT and at harvest was recorded under treatment V_2S_4 (White Vienna with spacing 60 x45 cm). It was found statistically at par with V_3S_4 and V_4S_4 treatment combination but significantly superior to other treatment combinations The minimum

length of leaf (9.57 cm and 19.83 cm) at 30 DAT and at harvest was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x30 cm) during 2018-19 and 2019-20, respectively.

Table 4.3: Effect of varieties, spacing and their interaction on length of leaf (cm) of knol-khol

Treatments	Length of leaf (cm)					
	30 DAT			At harvest		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	11.11	10.58	10.85	22.18	21.34	21.76
V_2	12.50	12.34	12.42	24.43	24.69	24.56
V_3	11.73	11.68	11.70	23.62	24.24	23.93
V_4	12.00	12.18	12.09	23.89	24.35	24.12
SEm ±	0.17	0.12	0.11	0.22	0.31	0.19
CD (P=0.05)	0.50	0.35	0.30	0.65	0.90	0.54
Spacing (S)						
S_1	10.75	10.62	10.68	22.84	22.47	22.65
S_2	11.72	11.31	11.51	23.10	23.25	23.17
S_3	11.86	11.72	11.79	23.27	23.45	23.36
S_4	13.01	13.14	13.07	24.93	25.47	25.20
SEm ±	0.17	0.12	0.11	0.22	0.31	0.19
CD (P=0.05)	0.50	0.35	0.30	0.65	0.90	0.54
Interaction (V x S)						
V_1S_1	9.37	9.78	9.57	20.38	18.79	19.56
V_1S_2	11.08	10.29	10.68	22.84	21.34	22.09
V_1S_3	11.34	9.99	10.66	20.86	20.51	20.69
V_1S_4	12.67	12.27	12.47	24.65	24.73	24.69
V_2S_1	11.37	11.26	11.32	23.79	23.54	23.66
V_2S_2	12.86	12.02	12.44	24.01	24.23	24.12
V_2S_3	12.16	12.41	12.29	24.53	24.88	24.71
V_2S_4	13.59	13.68	13.64	25.39	26.11	25.75
V_3S_1	11.18	10.25	10.72	23.74	24.06	23.90
V_3S_2	10.99	11.09	11.04	22.14	23.12	22.63
V_3S_3	11.81	12.13	11.97	23.86	24.43	24.15
V_3S_4	12.93	13.24	13.08	24.76	25.35	25.06
V_4S_1	11.08	11.18	11.13	22.96	23.47	23.21
V_4S_2	11.96	11.82	11.89	23.39	24.30	23.85
V_4S_3	12.11	12.35	12.23	24.30	23.97	24.13
V_4S_4	12.85	13.36	13.11	24.91	25.68	25.30
SEm ±	0.44	0.42	0.30	0.44	0.62	0.38
CD (P=0.05)	1.28	1.20	0.86	1.30	1.80	1.08

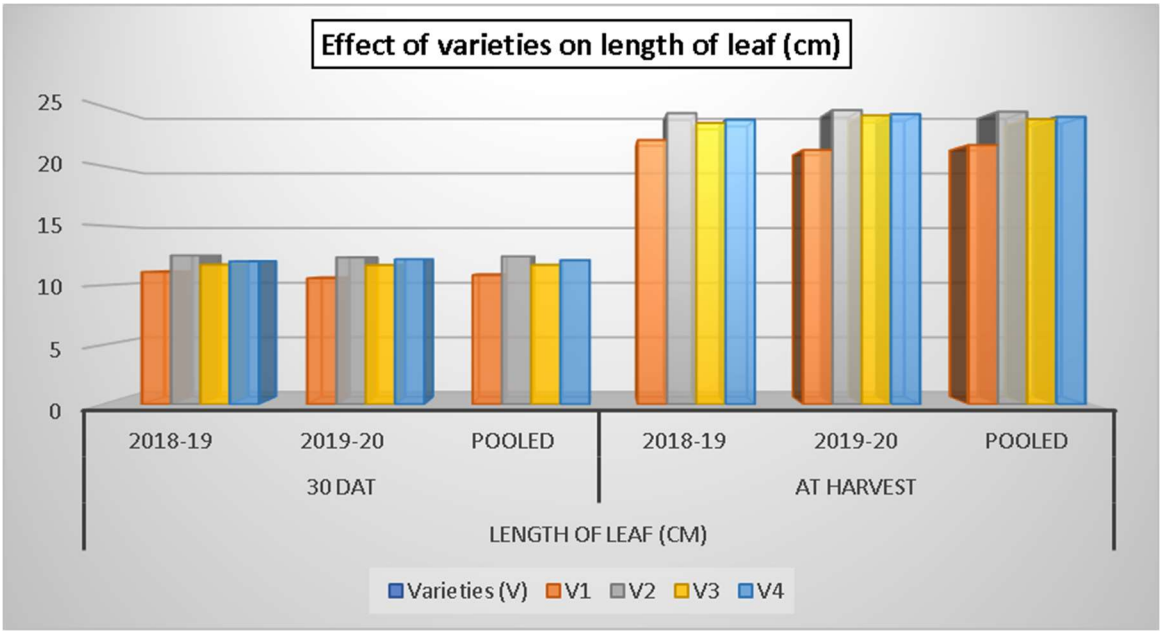


Fig. 4.7: Effect of varieties on length of leaf (cm) of knol-khol

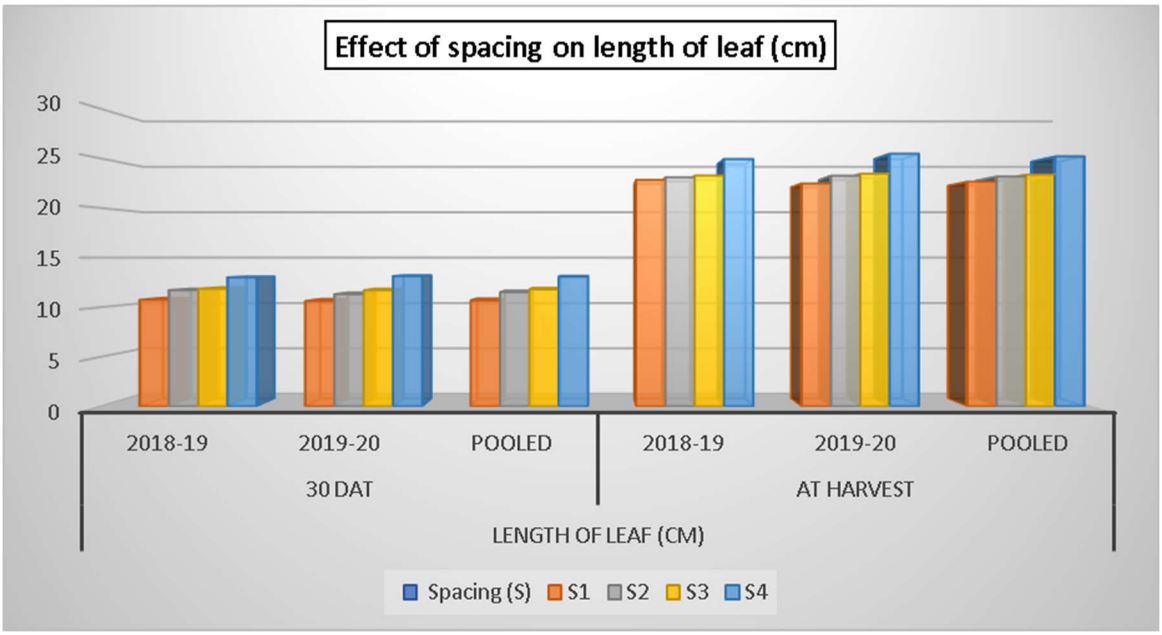


Fig. 4.8: Effect of spacing on length of leaf (cm) of knol-khol

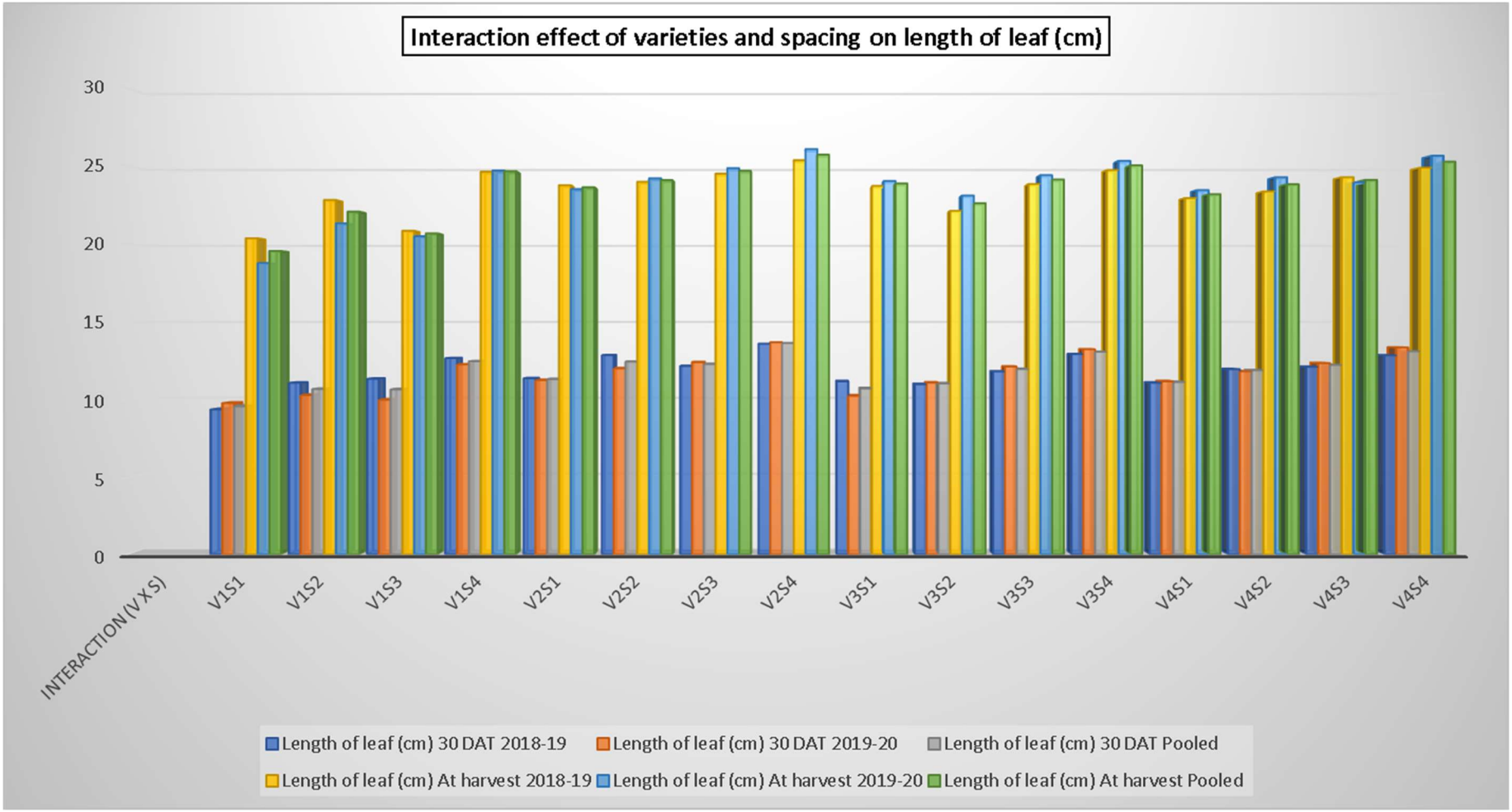


Fig. 4.9: Interaction effect of varieties and spacing on length of leaf (cm) of knol-khol

4.1.4 Width of leaf (cm)

Effect of varieties:

It is apparent from the data (Table 4.4 and Fig 4.10) that there was a significant effect of different varieties in both years. The maximum width of leaf (10.32 cm and 10.25 cm) at 30 DAT and (26.61 cm and 26.21 cm) at harvest was recorded in V_2 -White Vienna followed by V_4 -Palam Tender Knob (10.11 cm and 9.74 cm) at 30 DAT and (26.32 cm and 26.12 cm) at harvest. While minimum width of leaf was noted in V_1 – Pusa Virat (8.01 cm and 9.30 cm) at 30 DAT and (23.09 cm and 22.80 cm) at harvest, respectively during both years.

During both the years, mean width of leaf was noticed to be maximum in V_2 - White Vienna (10.29 cm) at 30 DAT and (26.41 cm) at harvest followed by V_4 -Palam Tender Knob (9.92 cm) at 30 DAT and (26.22 cm) at harvest while, the minimum width of leaf (8.65 cm) at 30 DAT and (22.94 cm) at harvest was recorded in V_1 – Pusa Virat.

Effect of spacing

The width of leaf was also affected significantly by different spacing at all the stage in both the year (Table 4.4 & Fig. 4.11). The maximum width of leaf (10.39 cm and 11.13 cm) was found at 30 DAT and (26.79 cm and 26.08 cm) at harvest in treatment S_4 (60 x 45 cm) followed by S_3 (45 x45 cm) (9.48 cm and 9.96 cm) at 30 DAT and (25.58 cm and 25.55 cm) at harvest while, the minimum width of leaf (8.42 cm and 8.62 cm) at 30 DAT and (24.56 cm and 24.36 cm) at harvest was recorded in S_1 (30 x 30 cm) respectively, during 2018-19 and 2019-20.

The mean width of leaf over two years was obtained maximum (10.76 cm) at 30 DAT and (26.44 cm) at harvest under the treatment S_4 (60 x 45 cm) while, minimum width of leaf (8.52 cm) at 30 DAT and (24.46 cm) at harvest stage under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on width of leaf during both years. The data on pooled mean basis (Table 4.4 & Fig. 4.12) revealed that the maximum width of leaf (11.20 cm and 27.63 cm) at 30 DAT and at harvest was recorded under treatment V_2S_4 (White Vienna with spacing 60 x45 cm). The minimum width of leaf (7.78 cm and 21.95 cm) at 30 DAT

and at harvest was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x30 cm) during 2018-19 and 2019-20, respectively.

Table 4.4: Effect of varieties, spacing and their interaction on width of leaf (cm) of knol-khol

Treatments	Width of leaf (cm)					
	30 DAT			At harvest		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	8.01	9.30	8.65	23.09	22.80	22.94
V_2	10.32	10.25	10.29	26.70	26.21	26.41
V_3	8.73	9.45	9.09	25.92	24.95	25.48
V_4	10.11	9.74	9.92	26.32	26.12	26.22
SEm ±	0.18	0.11	0.11	0.46	0.18	0.25
CD (P=0.05)	0.53	0.31	0.30	1.32	0.53	0.70
Spacing (S)						
S_1	8.42	8.62	8.52	24.56	24.36	24.46
S_2	8.88	9.03	8.95	25.09	24.10	24.60
S_3	9.48	9.96	9.72	25.58	25.55	25.56
S_4	10.39	11.13	10.76	26.79	26.08	26.44
SEm ±	0.18	0.11	0.11	0.46	0.18	0.25
CD (P=0.05)	0.53	0.31	0.30	1.32	0.53	0.70
Interaction (V x S)						
V_1S_1	7.21	8.34	7.78	21.88	22.01	21.95
V_1S_2	7.44	8.91	8.18	22.04	23.43	22.74
V_1S_3	7.58	9.11	8.35	23.61	22.75	23.18
V_1S_4	9.79	10.86	10.32	24.82	23.02	23.92
V_2S_1	9.14	9.48	9.31	26.14	26.80	26.47
V_2S_2	10.51	9.58	10.05	26.18	24.11	25.15
V_2S_3	10.91	10.27	10.59	26.54	26.58	26.56
V_2S_4	10.73	11.67	11.20	27.92	27.34	27.63
V_3S_1	7.22	8.21	7.72	24.01	23.67	23.84
V_3S_2	8.31	8.39	8.35	25.63	23.07	24.35
V_3S_3	8.94	10.21	9.58	26.49	26.13	26.31
V_3S_4	10.43	10.98	10.70	27.56	26.94	27.25
V_4S_1	10.11	8.46	9.29	26.21	24.96	25.58
V_4S_2	9.24	9.24	9.24	26.52	25.78	26.15
V_4S_3	10.47	10.23	10.35	25.67	26.73	26.20
V_4S_4	10.63	11.01	10.82	26.88	27.01	26.94
SEm ±	0.36	0.22	0.22	0.92	0.36	0.50
CD (P=0.05)	1.05	0.62	0.60	2.64	1.06	1.40

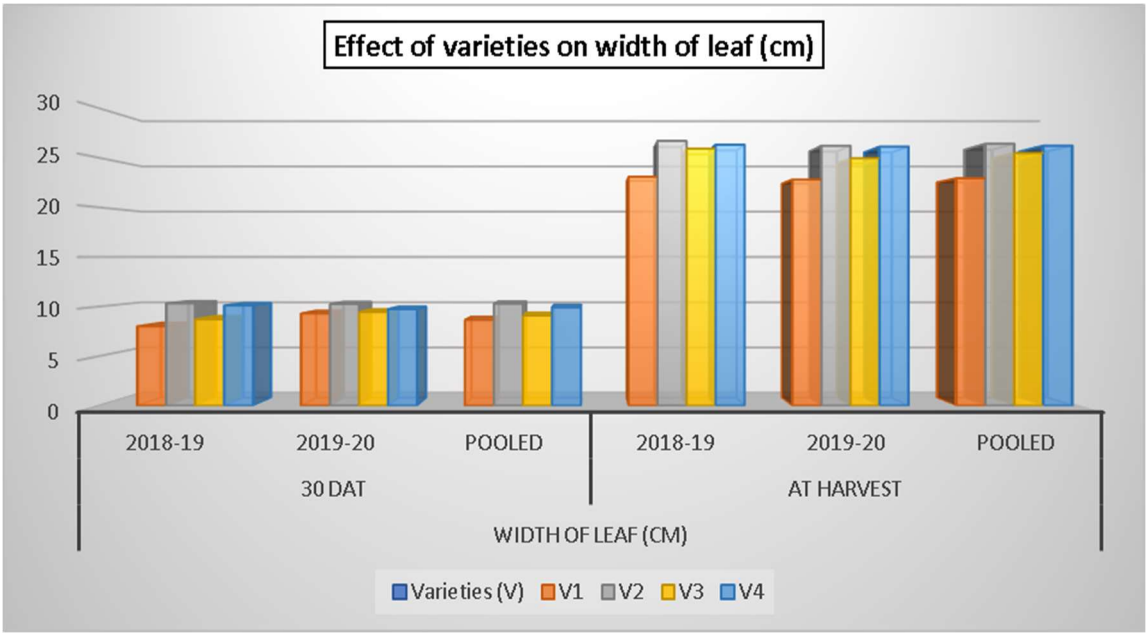


Fig. 4.10: Effect of varieties on width of leaf (cm) of knol-khol

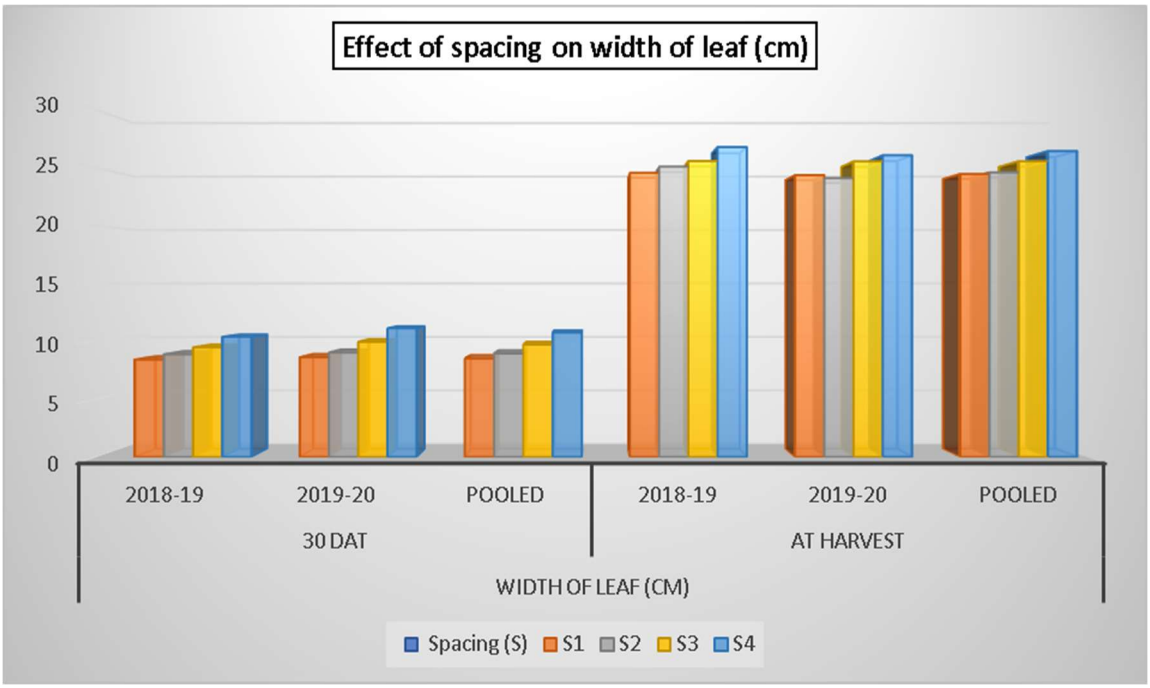


Fig. 4.11: Effect of spacing on width of leaf (cm) of knol-khol

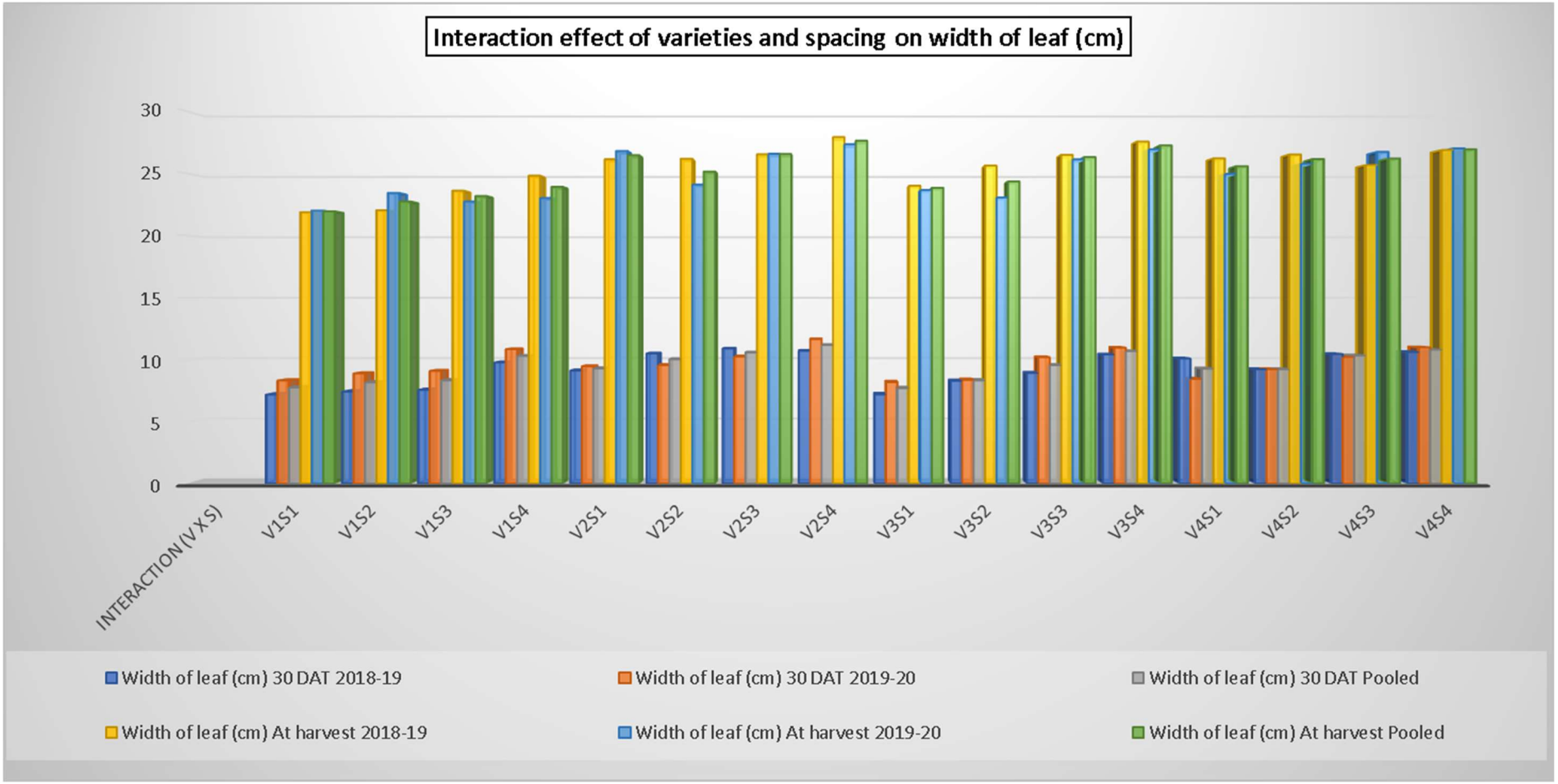


Fig. 4.12: Interaction effect of varieties and spacing on width of leaf (cm) of knol-khol

4.1.5 Plant spread (cm)

Effect of varieties:

Data recorded towards plant spreads due to significant influence of different varieties have been displayed in (Table 4.5 and fig 4.13). The maximum plant spreads (29.80 cm and 30.04 cm) at harvest were recorded in V_4 -Palam Tender Knob followed by V_3 -Early White Vienna (29.52 cm and 29.97 cm at harvest, while minimum plant spread was noted in V_1 – Pusa Virat (28.23 cm and 28.56 cm) at harvest, respectively during both years.

The mean of plant spread over two years, irrespective of treatment was obtained maximum (29.92 cm) at harvest under the treatment V_4 -Palam Tender Knob while, minimum spread of plant (28.40 cm) at harvest under V_1 – Pusa Virat.

Effect of spacing

The plant spreads were also affected significantly by different spacing at all the stage in both the year (Table 4.5 & Fig. 4.13). The maximum plant spreads (30.84 cm and 31.07 cm) were found at harvest in treatment S_4 (60 x 45 cm) followed by S_3 (45 x45 cm) (29.85 cm and 29.84 cm) at harvest while, the minimum plant spreads (28.04 cm and 27.93 cm) were recorded in S_1 (30 x 30 cm) respectively, during 2018-19 and 2019-20.

The mean plant spreads over two years were obtained maximum (30.96 cm) at harvest under the treatment S_4 (60 x 45 cm) while, minimum plant spreads (27.98 cm) at harvest stage under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on plant spread during both years. The data on pooled mean basis (Table 4.5 & Fig. 4.14) revealed that the maximum plant spread (31.94 cm) at harvest was recorded under treatment V_2S_4 (White Vienna with spacing 60 x45 cm). The minimum plant spread (26.77 cm) at harvest was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x30 cm) during 2018-19 and 2019-20, respectively.

4.1.6 Stem girth (cm)

Effect of varieties:

Data presented in (Table 4.5 and Fig. 4.15) showed non-significantly effect on stem girth due to different varieties during both the years. The maximum stem girth at harvest (1.15 cm and 1.13 cm) were recorded in V_4 -Palam Tender Knob followed by V_1-Pusa Virat (1.10 cm and 1.13 cm at harvest, while minimum stem girth was noted in V_2 – White Vienna (1.08 cm and 1.10 cm) at harvest, respectively during both years.

Pooled data showed that the maximum stem girth (1.14 cm) at harvest under the treatment V_4 -Palam Tender Knob while, minimum stem girth (1.09 cm) under V_2 – White Vienna.

Effect of spacing

It is evident from the data indicated in same table that different spacing non-significantly affected on stem girth in knol-khol (Table 4.5 and Fig. 4.15). The maximum stem girth (1.13 cm and 1.14 cm) was found in treatment S_4 (60 x 45 cm) followed by S_3 (45 x45 cm) at harvest (1.11 cm and 1.12 cm) while, the minimum stem girth (1.09 cm and 1.08 cm) was recorded in S_1 (30 x 30 cm) respectively, during 2018-19 and 2019-20.

The mean stem girth over two years was noted maximum under the treatment S_4 (60 x 45 cm) (1.14 cm) while, minimum stem girth (1.08 cm) under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on stem girth during both years. The data on pooled mean basis (Table 4.5 and Fig. 4.16) revealed that the maximum stem girth (1.17 cm) at harvest was recorded under treatment V_4S_4 (Palam Tender Knob with spacing 60 x45 cm). The minimum stem girth (1.03 cm) at harvest was recorded in treatment combination V_2S_1 (White Vienna with spacing 30 x 30 cm) during 2018-19 and 2019-20, respectively.

Table 4.5: Effect of varieties, spacing and their interaction on plant spread (cm) and stem girth (cm) of knol-khol

Treatments	Plant spread (cm)			Stem girth (cm)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	28.23	28.56	28.40	1.10	1.13	1.12
V_2	29.28	30.04	29.66	1.08	1.10	1.09
V_3	29.52	29.77	29.64	1.10	1.11	1.11
V_4	29.80	29.00	29.40	1.15	1.13	1.14
SEm ±	0.21	0.31	0.19	0.02	0.02	0.01
CD (P=0.05)	0.60	0.90	0.53	NS	NS	NS
Spacing (S)						
S_1	28.04	27.93	27.98	1.09	1.08	1.08
S_2	28.11	28.72	28.42	1.10	1.11	1.10
S_3	29.85	29.84	29.84	1.11	1.12	1.11
S_4	30.84	31.07	30.96	1.13	1.14	1.14
SEm ±	0.21	0.31	0.19	0.02	0.02	0.01
CD (P=0.05)	0.60	0.90	0.53	NS	NS	NS
Interaction (V x S)						
V_1S_1	26.11	26.02	26.06	1.06	1.15	1.10
V_1S_2	27.52	28.23	27.87	1.14	1.13	1.13
V_1S_3	29.08	29.87	29.47	1.07	1.12	1.09
V_1S_4	30.21	30.14	30.17	1.15	1.14	1.14
V_2S_1	26.51	27.06	26.79	1.02	1.05	1.03
V_2S_2	28.79	28.51	28.65	1.09	1.08	1.08
V_2S_3	30.14	28.24	29.19	1.10	1.09	1.10
V_2S_4	31.69	32.18	31.94	1.12	1.17	1.15
V_3S_1	29.08	29.88	29.48	1.11	1.12	1.12
V_3S_2	28.81	29.02	28.92	1.13	1.10	1.12
V_3S_3	29.97	30.08	30.02	1.09	1.11	1.10
V_3S_4	30.22	30.89	30.55	1.08	1.10	1.09
V_4S_1	29.06	28.74	28.90	1.17	1.12	1.15
V_4S_2	28.72	29.13	28.93	1.10	1.11	1.11
V_4S_3	30.19	31.19	30.69	1.15	1.13	1.14
V_4S_4	31.23	31.09	31.16	1.18	1.16	1.17
SEm ±	0.42	0.62	0.38	0.04	0.04	0.02
CD (P=0.05)	1.20	1.80	1.06	NS	NS	NS

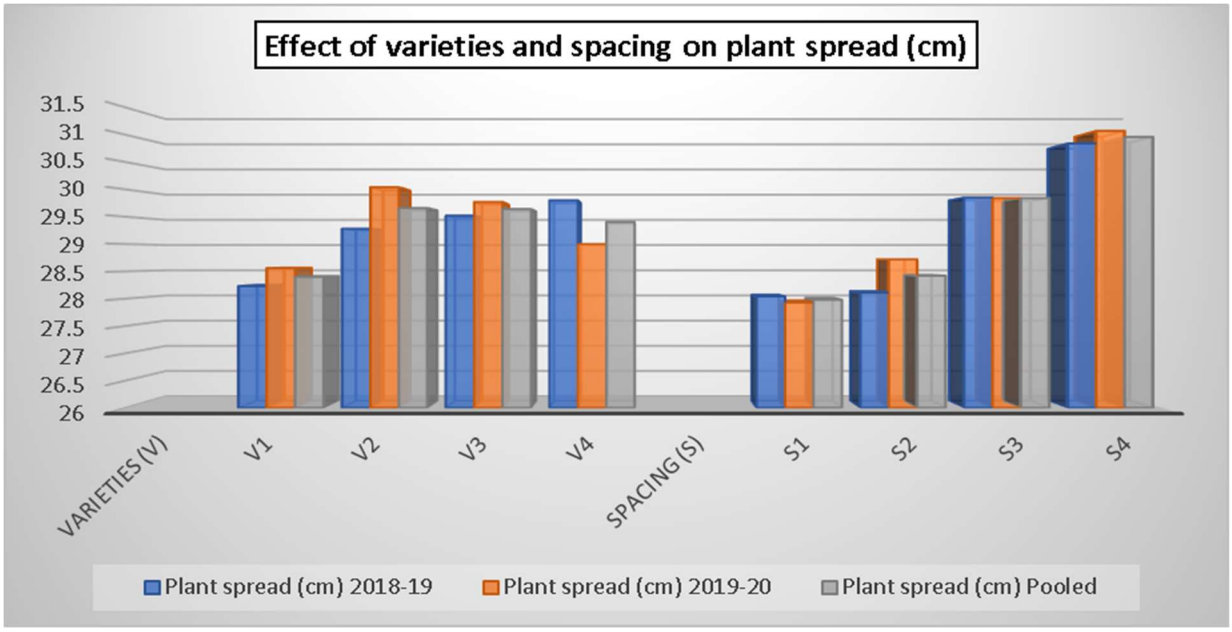


Fig. 4.13: Effect of varieties and spacing on plant spread (cm) of knol-khol

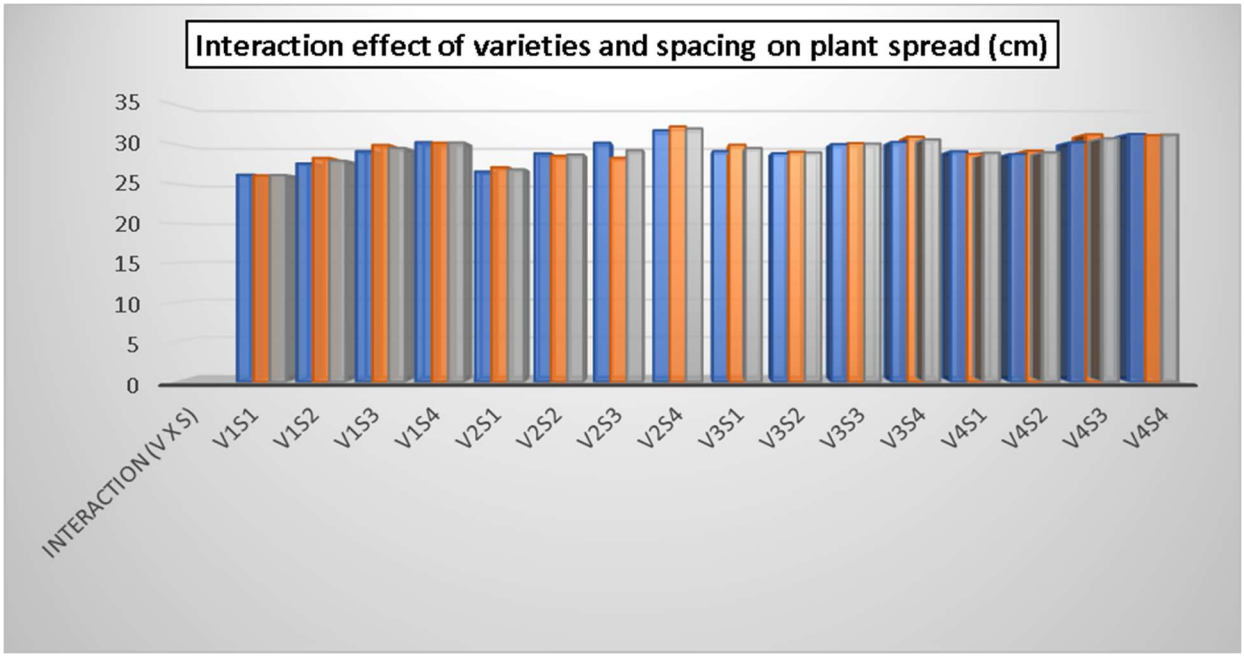


Fig. 4.14: Interaction effect of varieties and spacing on plant spread (cm) of knol-khol

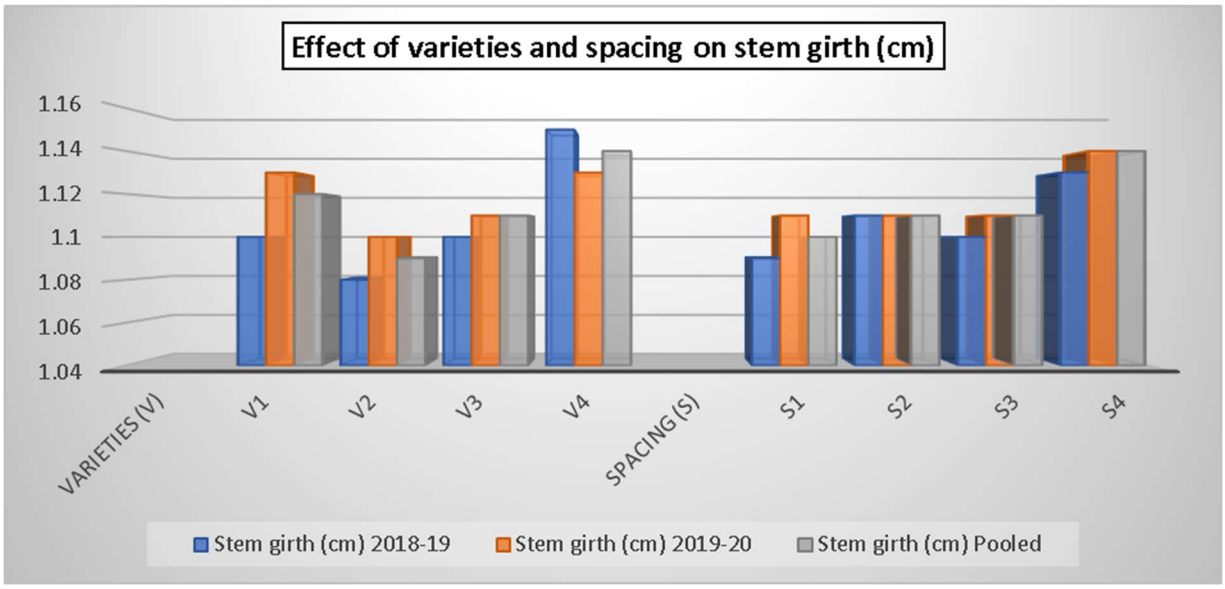


Fig. 4.15: Effect of varieties and spacing on stem girth (cm) of knol-khol

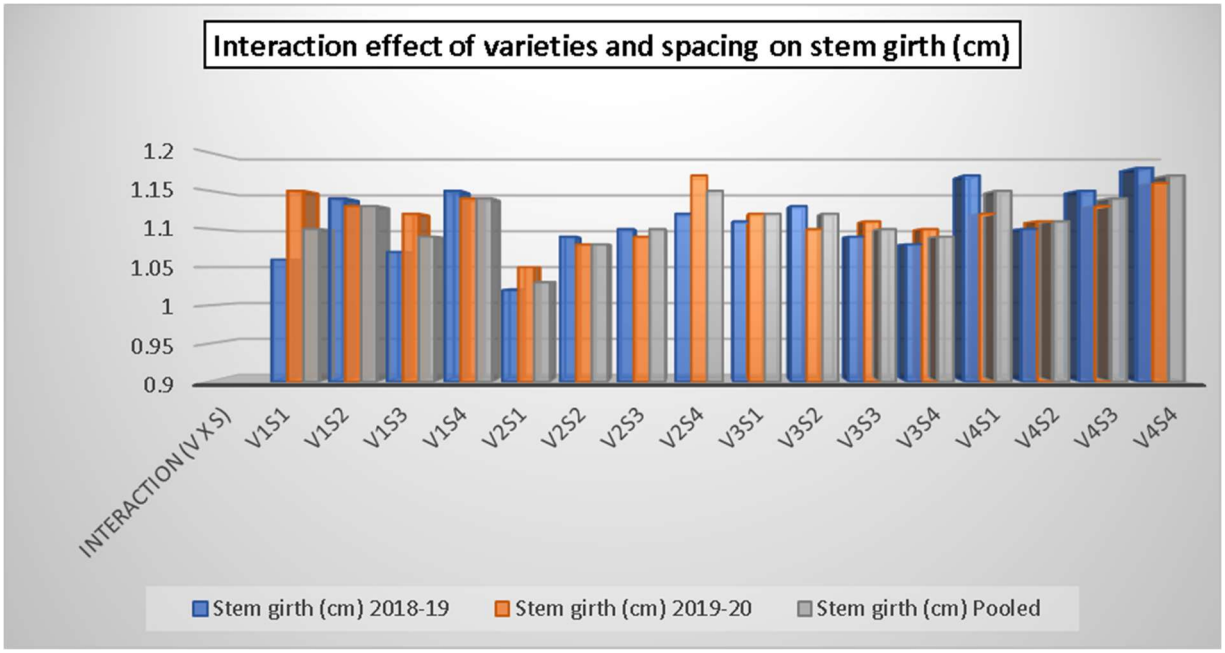


Fig. 4.16: Interaction effect of varieties and spacing on stem girth (cm) of knol-khol

4.1.7 Days taken to knob initiation

Effect of varieties

Data pertaining (Table 4.6 and Fig.4.17) to the effect of different varieties on days taken to knob initiation indicated that all the treatments were noted to non-significantly reduce the days taken to knob initiation during both the years of investigation. The minimum days to knob initiation (34.71 and 34.95) were recorded under treatment V_2 (White Vienna). The maximum days to knob initiation (37.55 and 37.86) were noticed under treatment V_4 (Palam Tender Knob). The pooled mean days to knob initiation over two years, irrespective of treatments was obtained minimum (34.83) under the treatment V_2 (White Vienna) while, maximum (37.71) mean days to knob initiation was obtained under the treatment V_4 (Palam Tender Knob).

Effect of spacing

Perusal of data further (Table 4.6 and Fig. 4.18) showed that days taken to knob initiation non-significantly affected due to different spacing. The minimum (35.22 and 33.05) days to knob initiation was recorded under treatment S_2 (45 x 30 cm). The maximum (36.96 and 39.12) days to knob initiation was noticed under treatment S_4 (60 x 45 cm). The pooled mean days to knob initiation over two years, irrespective of treatments was obtained minimum (34.13) under the treatment S_2 (45 x 30 cm) while, maximum (38.04) mean days to knob initiation was obtained under the treatment S_4 (60 x 45 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had non-significant influence on days taken to knob initiation during both years. The data on pooled mean basis (Table 4.6 and Fig. 4.19) revealed that the minimum (34.14) days to knob initiation was recorded under treatment combination V_2S_2 (White Vienna with spacing 45 x 30 cm) followed by V_3S_1 (Early White Vienna with spacing 30 x30 cm). The maximum (38.36) days to knob initiation was recorded in treatment combination V_4S_4 (Palam Tender Knob with spacing 60 x 45 cm).

4.1.8 Days taken to knob harvest

Effect of varieties

Data pertaining (Table 4.6 and Fig.4.17) to the effect of different varieties on days taken to knob harvesting indicated that all the treatments were noted to non-significantly reduce the days taken to knob harvesting during both the years of investigation. The minimum days to knob harvest (63.15 and 63.01) days were recorded under treatment V_2

(White Vienna). The maximum days to knob harvest (64.62 and 64.35) were noticed under treatment V_2 (White Vienna). The pooled mean days to knob harvesting over two years, irrespective of treatments was obtained minimum (63.08) under the treatment V_2 (White Vienna) while, maximum (64.48) mean days to knob harvest was obtained under the treatment V_1 (Pusa Virat).

Effect of spacing

Perusal of data further showed that days taken to knob harvest non-significantly affected due to different spacing. The minimum (61.84 and 62.70) days to knob harvest was recorded under treatment S_2 (45 x 30 cm). The maximum (65.12 and 64.75) days to knob harvest was noticed under treatment S_4 (60 x 45 cm). The pooled mean days to knob harvest over two years, irrespective of treatments was obtained minimum (62.27) under the treatment S_2 (45 x 30 cm) while, maximum (64.94) mean days to knob harvest was obtained under the treatment S_4 (60 x 45 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on days taken to knob harvest during both years. The data on pooled mean basis (Table 4.6 & Fig. 4.19) revealed that the minimum (61.61) days to knob harvest was recorded under treatment combination V_4S_2 (Palam Tender Knob with spacing 45 x 30 cm) followed by V_3S_2 (Early White Vienna with spacing 45 x 30 cm). The maximum (66.07) days to knob harvest was recorded in treatment combination V_4S_4 (Palam Tender Knob with spacing 60 x 45 cm).

Table 4.6: Effect of varieties, spacing and their interaction on days taken to knob initiation and knob harvest of knol-khol

Treatments	Days taken to knob initiation			Days taken to knob harvest		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	36.61	36.92	36.76	64.62	64.35	64.48
V_2	34.71	34.95	34.83	63.15	63.01	63.08
V_3	35.12	37.53	36.33	63.54	63.98	63.76
V_4	37.55	37.86	37.71	63.51	63.75	63.63
SEm ±	0.78	1.64	0.91	0.79	1.33	0.77
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Spacing (S)						
S_1	35.74	37.05	36.40	63.67	63.28	63.47
S_2	35.22	33.05	34.13	61.84	62.70	62.27
S_3	36.08	38.03	37.05	64.19	64.36	64.28
S_4	36.96	39.12	38.04	65.12	64.75	64.94
SEm ±	0.78	1.64	0.91	0.79	1.33	0.77
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Interaction (V x S)						
V_1S_1	37.11	36.12	36.62	64.65	65.28	64.97
V_1S_2	36.49	35.28	35.89	62.29	63.74	63.02
V_1S_3	35.24	39.12	37.18	67.49	64.47	65.98
V_1S_4	37.61	37.14	37.38	64.04	63.91	63.98
V_2S_1	34.91	36.67	35.79	63.26	63.01	63.14
V_2S_2	32.06	36.22	34.14	62.92	61.94	62.43
V_2S_3	36.08	38.25	37.17	61.25	62.88	62.06
V_2S_4	35.78	40.71	38.25	65.19	64.21	64.70
V_3S_1	33.18	37.89	35.54	63.83	62.04	62.94
V_3S_2	35.46	36.98	36.22	60.19	63.88	62.04
V_3S_3	34.97	37.05	36.01	64.94	65.22	65.08
V_3S_4	36.86	39.51	38.19	65.21	64.79	65.00
V_4S_1	37.75	37.53	37.64	62.93	62.78	62.86
V_4S_2	36.86	35.78	36.32	61.97	61.24	61.61
V_4S_3	38.01	37.69	37.85	63.08	64.88	63.98
V_4S_4	37.59	39.13	38.36	66.05	66.09	66.07
SEm ±	1.56	3.28	1.82	1.58	2.66	1.54
CD (P=0.05)	4.50	9.47	5.14	4.54	7.70	4.38

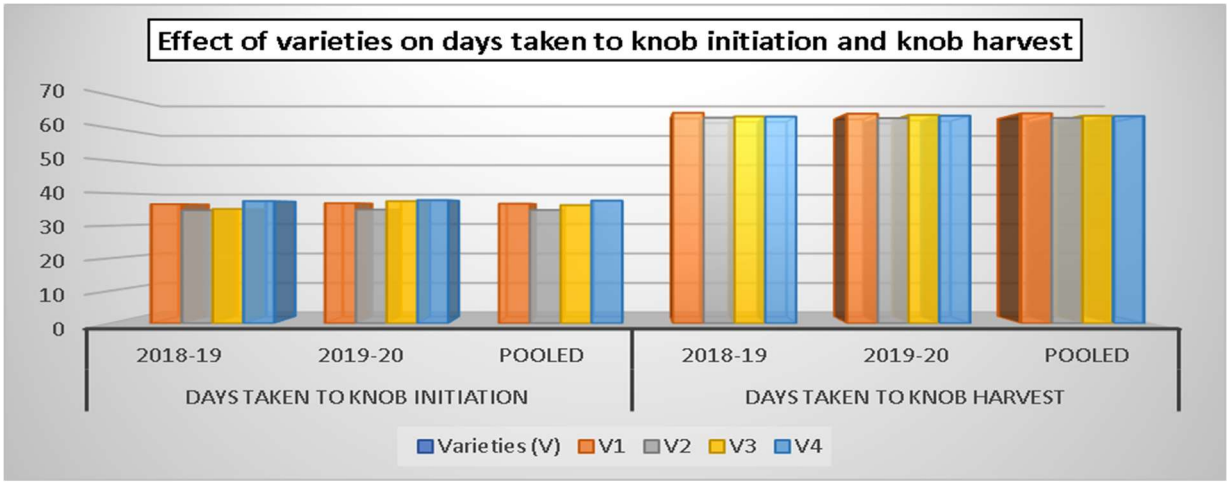


Fig. 4.17: Effect of varieties on days taken to knob initiation and knob harvest

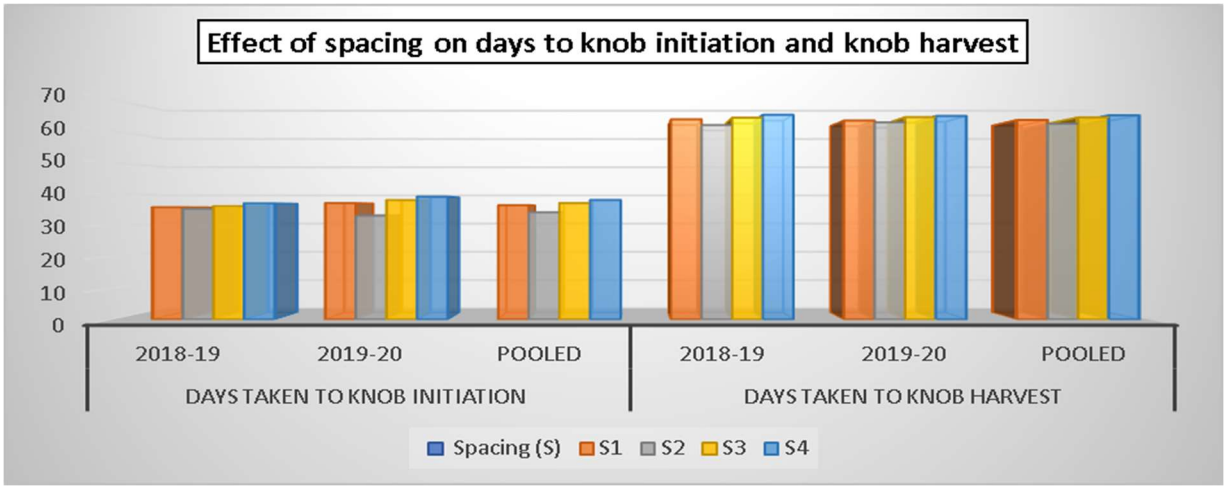


Fig. 4.18: Effect of spacing on days taken to knob initiation and knob harvest

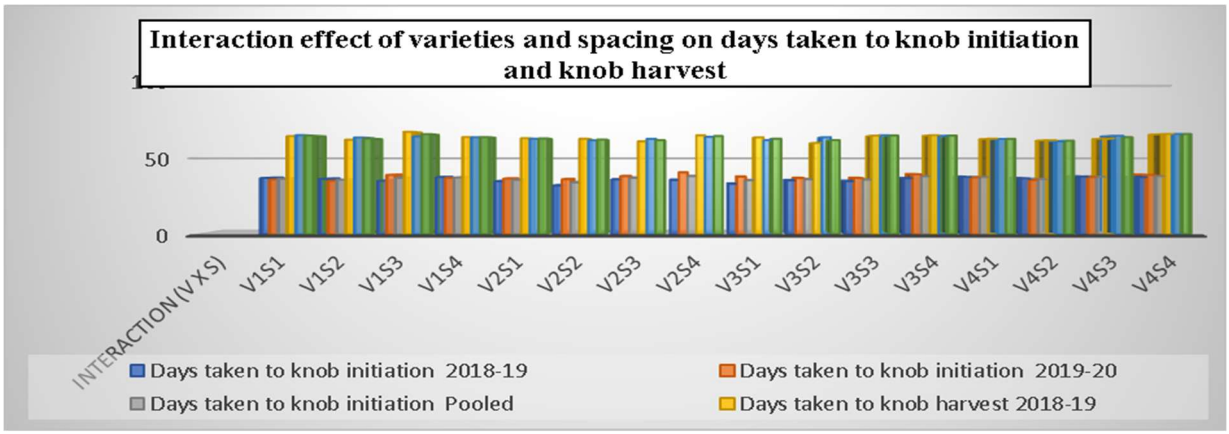


Fig. 4.19: Interaction effect of varieties and spacing on days to knob initiation and knob harvest of knol-khol

4.2 Yield and yield attributing traits

4.2.1 Weight of knob (g)

Effect of varieties

A critical examination of the data presented in (Table 4.7 and Fig. 4.20) indicated that different varieties showed significant improvement in weight of knob of knol-khol during both the years. The data presented in above table clearly indicated that the maximum knob weight (222.22 g and 220.06 g) was recorded under treatment V_2 -White Vienna followed by V_3 -Early White Vienna (212.79 g and 212.74 g), while minimum knob weight was noted in V_1 – Pusa Virat (196.84 g and 187.60 g) at harvest, respectively during 2018-19 and 2019-20.

A perusal of data over two years reveal that mean knob weight was maximum (221.14 g) in treatment V_2 -White Vienna followed by V_3 -Early White Vienna (212.76 g) at harvest. While minimum knob weight (192.22 g) was noted in V_1 – Pusa Virat.

Effect of spacing

It is evident from the data (Table 4.7 and Fig. 4.20) that different spacing also had significant influence on the weight of knob. The maximum knob weight (231.59 g and 228.23 g) was found in treatment S_4 (60 x 45 cm) followed by S_3 (45 x45 cm) at harvest (212.69 g and 213.23 g) while, the minimum knob weight (190.60 g and 192.92 g) was recorded in S_1 (30 x 30 cm) respectively, during both years.

The mean weight of knob over two years was obtained maximum (229.91 g) under the treatment S_4 (60 x 45 cm) while, minimum knob weight (191.76 g), under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on knob weight during both years. The data on pooled mean basis (Table 4.7 and Fig. 4.21) revealed that the maximum knob weight (238.25 g/plant) was recorded under treatment V_2S_4 (White Vienna with spacing 60 x45 cm). It was found statistically at par with V_4S_4 treatment combination but significantly superior to other treatment combinations. The minimum knob weight (172.96 g) per plant was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x30 cm).

4.2.2 Diameter of knob (cm)

Effect of varieties

Data pertaining to the effect of different varieties on diameter of knob in knol-khol had significant influenced during both individual years (Table 4.7 and Fig 4.22). The maximum diameter of knob (5.45 cm and 5.65 cm) was recorded under V_2 – White Vienna followed by V_4 – Palam Tender Knob (5.14 cm and 5.26 cm), while minimum diameter of knob was noted in V_1 – Pusa Virat (4.35 cm and 4.61 cm) at harvest, respectively during 2018-19 and 2019-20.

A perusal of data for mean over two years reveal that mean diameter of knob was maximum (5.55 cm) in V_2 – White Vienna followed by V_4 – Palam Tender Knob (5.20 cm), while minimum diameter of knob (4.48 cm) was noted in V_1 – Pusa Virat.

Effect of spacing

Perusal of data further showed that diameter of knob significantly affected due to different spacing. The maximum diameter of knob (5.63 cm and 5.99 cm) was recorded under the treatment S_4 (60 x 45 cm) followed by S_3 (45 x 45 cm) (5.17 cm and 5.44 cm) respectively in both years. Data further indicated that different spacing significantly affected the diameter of knob over rest of the treatment. The minimum diameter of knob (4.52 cm and 4.41 cm) was recorded in S_1 (30 x 30 cm). During both the years, pooled mean diameter of knob was noticed to be maximum (5.81 cm) in the treatment S_4 (60 x 45 cm) followed by S_3 (45 x 45 cm) (5.30 cm) and minimum (4.46 cm) was reported in S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on diameter of knob during both years. The data on pooled mean basis (Table 4.7 and Fig. 4.23) revealed that the maximum diameter of knob (6.36 cm) was recorded under treatment V_2S_4 (White Vienna with spacing 60 x45 cm). It was found statistically at par with V_4S_4 treatment combination but significantly superior to other treatment combinations. The minimum diameter of knob (3.91 cm) was recorded in treatment combination V_1S_1 (Early White Vienna with spacing 30 x30 cm).

Table 4.7: Effect of varieties, spacing and their interaction on weight of knob (g) and diameter of knob (cm) of knol-khol

Treatments	Weight of knob (g)			Diameter of knob (cm)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	196.84	187.60	192.22	4.35	4.61	4.48
V_2	223.67	220.94	222.31	5.45	5.65	5.55
V_3	208.61	212.74	210.68	5.07	5.17	5.12
V_4	212.65	208.62	210.63	5.14	5.26	5.20
SEm ±	4.78	4.90	3.42	0.09	0.11	0.07
CD (P=0.05)	13.82	14.15	9.68	0.26	0.31	0.20
Spacing (S)						
S_1	190.60	192.92	191.76	4.52	4.41	4.46
S_2	206.89	195.53	201.21	4.69	4.86	4.77
S_3	212.69	213.23	212.96	5.17	5.44	5.30
S_4	231.59	228.23	229.91	5.63	5.99	5.81
SEm ±	4.78	4.90	3.42	0.09	0.11	0.07
CD (P=0.05)	13.82	14.15	9.68	0.26	0.31	0.20
Interaction (V x S)						
V_1S_1	171.86	174.06	172.96	4.04	3.78	3.91
V_1S_2	192.58	169.11	180.85	4.08	4.06	4.07
V_1S_3	201.67	189.29	195.48	4.97	5.24	5.11
V_1S_4	221.24	217.94	219.59	5.13	5.36	5.24
V_2S_1	197.21	213.37	205.29	4.31	4.85	4.58
V_2S_2	226.34	216.45	221.40	4.67	5.29	4.98
V_2S_3	229.21	219.38	224.30	5.01	5.97	5.49
V_2S_4	241.93	234.57	238.25	6.23	6.48	6.36
V_3S_1	194.56	190.23	192.40	4.37	4.28	4.33
V_3S_2	211.24	208.21	209.73	4.71	5.11	4.91
V_3S_3	201.59	223.18	212.39	5.29	5.29	5.29
V_3S_4	227.06	229.34	228.20	6.04	6.01	6.03
V_4S_1	198.78	194.02	196.40	4.38	4.71	4.55
V_4S_2	197.39	188.34	192.87	4.86	4.98	4.92
V_4S_3	218.29	221.05	219.67	5.92	5.24	5.58
V_4S_4	236.12	231.05	233.59	5.97	6.11	6.04
SEm ±	9.56	9.80	6.84	0.18	0.22	0.14
CD (P=0.05)	27.63	28.30	19.36	0.52	0.62	0.40

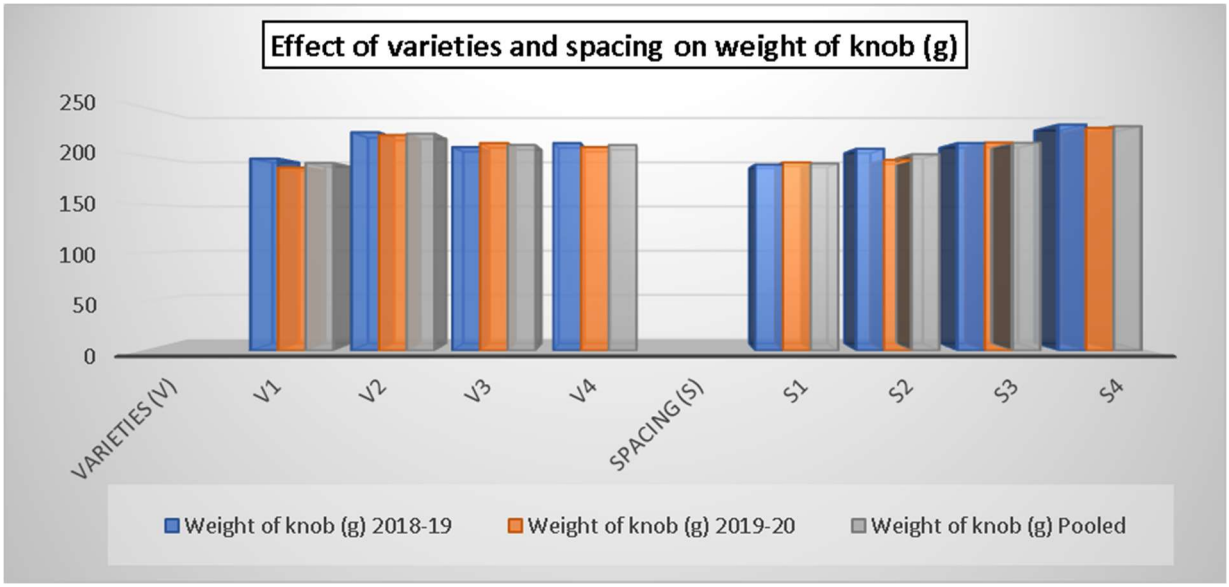


Fig. 4.20: Effect of varieties and spacing on weight of knob (g) of knol-khol

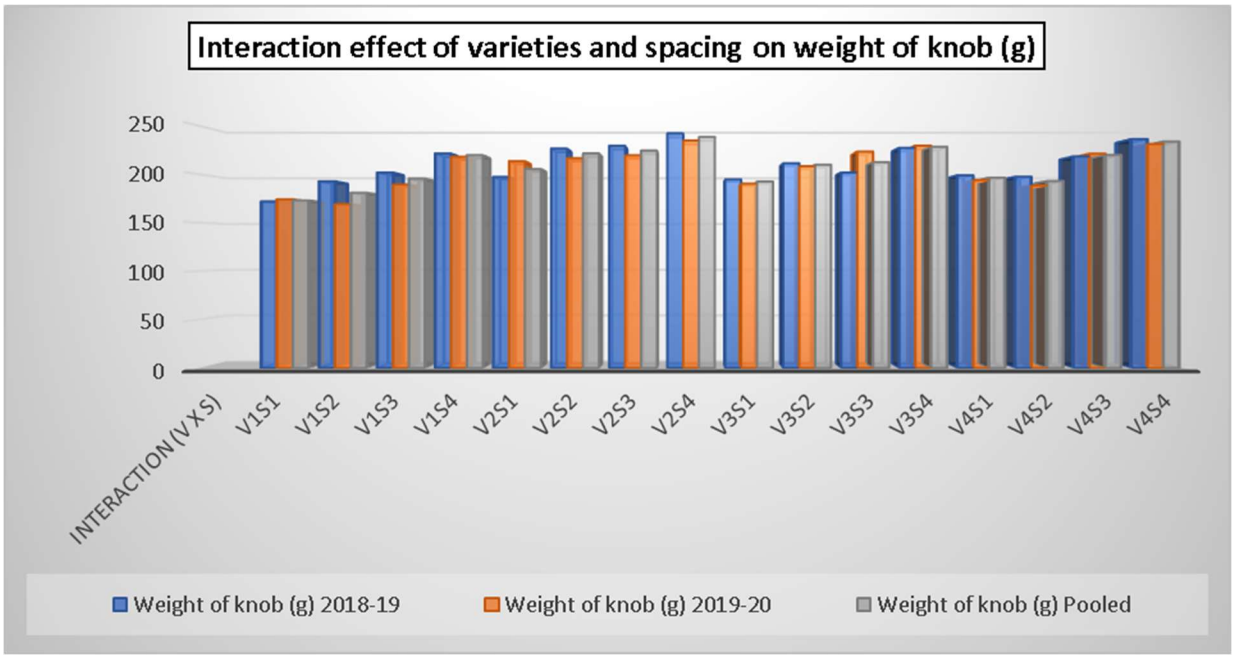


Fig. 4.21: Interaction effect of varieties and spacing on weight of knob (g) of knol-khol

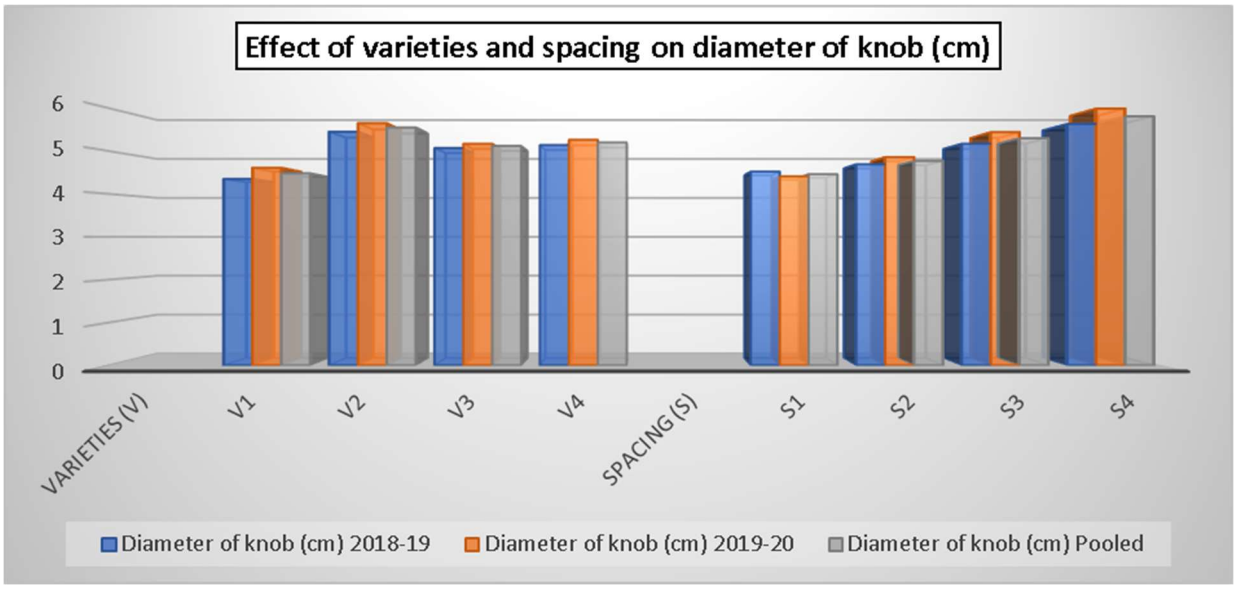


Fig. 4.22: Effect of varieties and spacing on diameter of knob (cm) of knol-khol

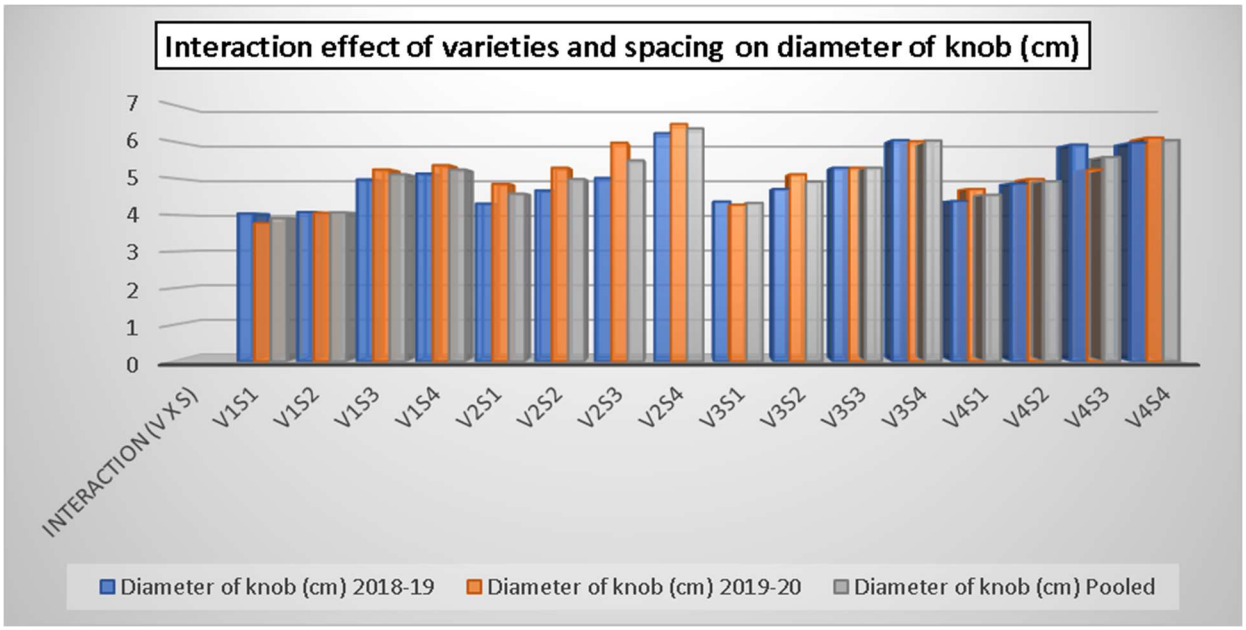


Fig. 4.23: Interaction effect of varieties and spacing on diameter of knob (cm) of knol-khol

4.2.3 Volume of knob (cc)

Effect of varieties

The data accumulated on volume of knob due to influence of different varieties have been displayed in Table 4.8 and graphically represented in figure 4.24. The analysis of variance of data on this parameter mentioned in Appendix XI. The maximum volume of knob (112.98 cc and 114.38 cc) was recorded in V_4 – Palam Tender Knob, which was found to be significantly higher as compared to other treatments but statistically at par with V_3 -Early White Vienna during both years. The minimum (99.82 cc and 105.10 cc) volume of knob was found under the treatment V_1- Pusa Virat.

The pooled mean volume of knob over two years, irrespective of treatments, was obtained maximum (113.68 cc) in V_4 – Palam Tender Knob, which was found to be significantly higher as compared to other treatments but statistically at par with V_3 -Early White Vienna while, minimum (102.46 cc) volume of knob was obtained under the treatment V_1- Pusa Virat.

Effect of spacing

The data in Table 4.8 revealed that different spacing had a significant effect on volume of knob. The maximum volume of knob (113.61 cc and 115.07 cc) was found under S_4 treatment (60 x45 cm). However, treatment S_3 was found statistically at par with treatment S_4. The minimum volume of knob (102.62 cc and 104.84 cc) was recorded in S_1 (30 x 30 cm). The pooled mean over two years revealed that mean volume of knob was maximum (114.34 cc) in treatment S_4 (60 x 45 cm) while, minimum volume of knob (103.73 cc) was found under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on volume of knob during both years. The data on pooled mean basis (Table 4.8 & 4.25) revealed that the maximum volume of knob (119.33 cc) was recorded under treatment combination V_4S_3 (Palam Tender Knob with spacing 45 x45 cm) followed by V_2S_4 (White Vienna with spacing 60 x45 cm). The minimum volume of knob (99.62 cc) was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x30 cm).

Table 4.8: Effect of varieties, spacing and their interaction on volume of knob (cc) of knol-khol

Treatments	Volume of knob (cc)		
	2018-19	2019-20	Pooled
Varieties (V)			
V_1	99.82	104.16	101.99
V_2	107.75	111.20	109.48
V_3	108.50	112.02	110.26
V_4	112.98	113.01	112.99
SEm ±	2.09	1.82	1.39
CD (P=0.05)	6.04	5.25	3.92
Spacing (S)			
S_1	102.62	104.84	103.73
S_2	103.37	108.43	105.90
S_3	109.45	110.69	110.07
S_4	113.61	116.44	115.02
SEm ±	2.09	1.82	1.39
CD (P=0.05)	6.04	5.25	3.92
Interaction (V x S)			
V_1S_1	96.04	99.44	97.74
V_1S_2	98.91	101.04	99.98
V_1S_3	99.21	104.38	101.80
V_1S_4	105.12	111.78	108.45
V_2S_1	101.09	103.20	102.14
V_2S_2	99.75	112.07	105.91
V_2S_3	111.82	108.83	110.33
V_2S_4	118.35	120.70	119.52
V_3S_1	105.14	110.23	107.69
V_3S_2	103.45	107.24	105.35
V_3S_3	108.79	114.32	111.56
V_3S_4	116.63	116.29	116.46
V_4S_1	108.21	106.47	107.34
V_4S_2	111.39	113.36	112.38
V_4S_3	117.96	115.24	116.60
V_4S_4	114.34	116.98	115.66
SEm ±	4.18	3.64	2.78
CD (P=0.05)	12.08	10.50	7.84

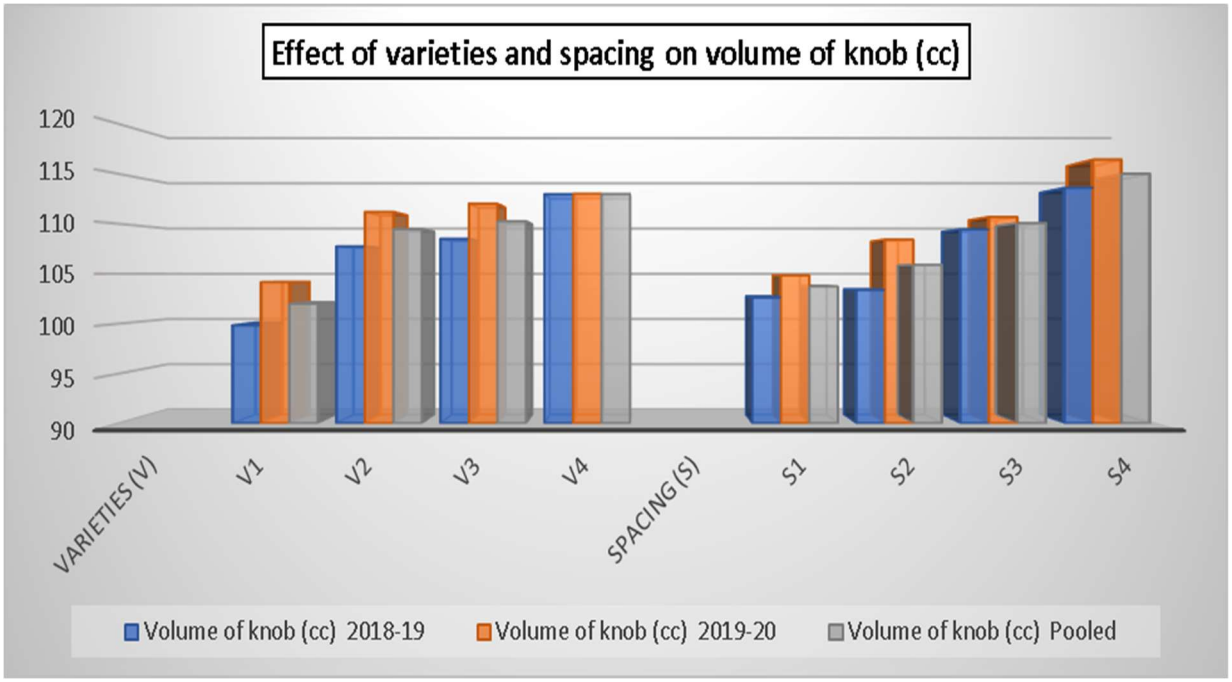


Fig. 4.24: Effect of varieties and spacing on volume of knob (cc) of knol-khol

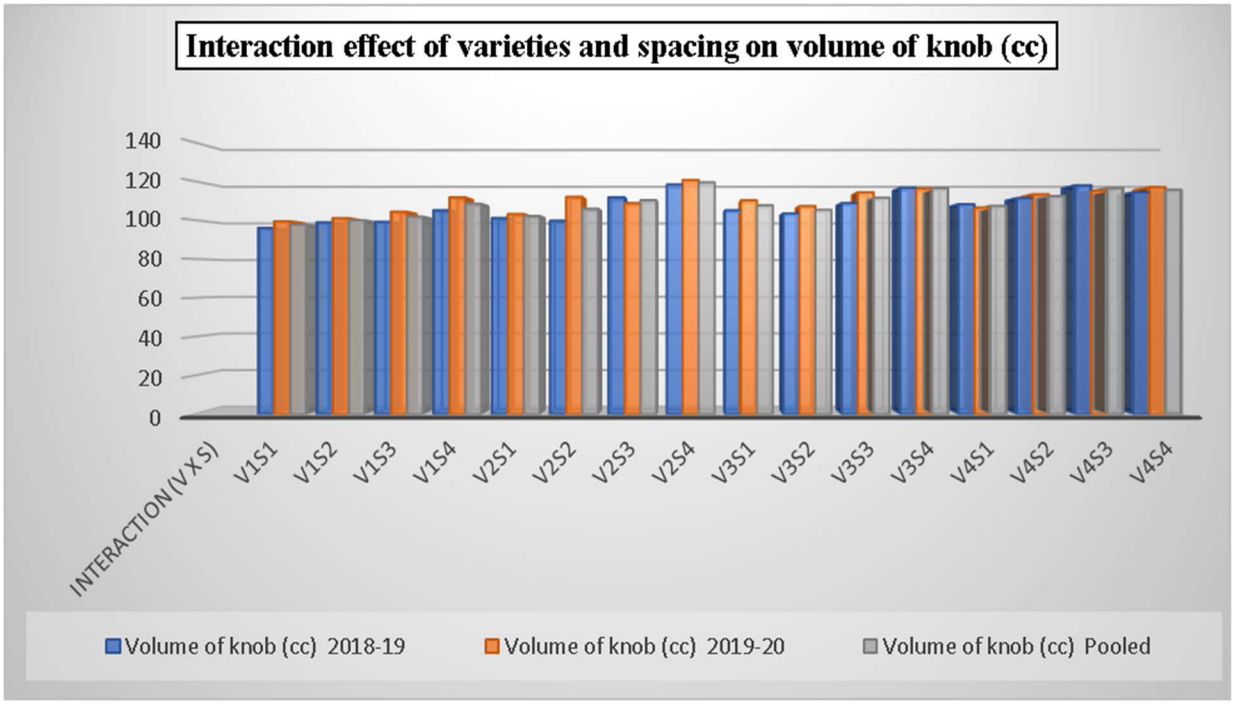


Fig. 4.25: Interaction effect of varieties and spacing on volume of knob (cc) of knol-khol

4.2.6 Yield (kg/plot)

Effect of varieties

A critical examination of the data presented in (Table 4.9 and Fig. 4.26) indicated that different varieties showed significant improvement in yield (kg/plot) of knol-khol during both the years. The data presented in above table clearly indicated that the maximum yield/plot (4.77 kg and 4.58 kg) was recorded under treatment V_2 -White Vienna followed by V_3 -Early White Vienna (4.58 kg and 4.57 kg) at harvest, while minimum yield per plot (4.20 kg and 3.99 kg) was noted in V_1 – Pusa Virat, respectively during 2018-19 and 2019-20. A perusal of data over two years reveal that mean yield per plot was maximum (4.68 kg) in treatment V_2 - White Vienna followed by V_3 -Early White Vienna (4.57 kg). While minimum yield per plot (4.10 kg) was noted in V_1 – Pusa Virat.

Effect of spacing

It is evident from the data (Table 4.9 and Fig. 4.26) that different spacing also had significant influence on the yield per plot. The maximum yield/plot (6.86 kg and 6.72 kg) was found in treatment S_1 (30 x 30 cm) followed by S_2 (45 x30 cm) at harvest (4.96 kg and 4.84 kg) while, the minimum yield/plot (2.78 kg and 2.74 kg) was recorded in S_1 (60 x 45 cm) respectively, during both years. The mean yield/plot over two years was obtained maximum (6.79 kg) under the treatment S_1 (30 x 30 cm) while, minimum yield/plot (2.76 kg), respectively under the treatment S_4 (60 x 45 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on yield per plot during both years. The data on pooled mean basis (Table 4.9 and Fig. 4.27) revealed that the maximum yield/plot (7.07 kg) was recorded under treatment V_2S_1 (White Vienna with spacing 30 x 30 cm). It was found statistically at par with V_3S_1 and V_4S_1 treatments combination but significantly superior to V_1S_1. The minimum yield/plot (2.63 kg) was recorded in treatment combination V_1S_4 (Pusa Virat with spacing 60 x45 cm).

4.2.7 Yield (q/ha.)

Effect of varieties

A critical examination of the data presented in (Table 4.9 and Fig. 4.28) indicated that different varieties showed significant improvement in yield (q/ha) of knol-khol during both the years. The data presented in above table clearly indicated that the maximum knob yield (147.22 q/ha and 142.90 q/ha) was recorded under treatment V_2 -White Vienna at par with V_3

-Early White Vienna (140.97 q/ha and 140.13 q/ha) and V_4 – Palam Tender Knob (137.46 q/ha and 139.27 q/ha), while minimum knob yield was noted in V_1 – Pusa Virat (129.77 q/ha and 123.15 q/ha), respectively during 2018-19 and 2019-20.

A perusal of data over two years reveal that pooled mean knob yield was maximum (145.06 q/ha) in treatment V_2 -White Vienna followed by V_3 -Early White Vienna (140.55 q/ha) at harvest. While minimum knob yield (126.46 q/ha) was noted in V_1 – Pusa Virat.

Effect of spacing

It is evident from the data (Table 4.9 and Fig. 4.28) that different spacing also had significant influence on knob yield per hectare of knol-khol. The maximum knob yield (211.72 q/ha and 207.25 q/ha) was found in treatment S_1 (30 x 30 cm) while, the minimum knob yield (85.65 q/ha and 84.41 q/ha) was recorded in S_4 (60 x 45 cm) respectively, during both years. The mean knob yield over two years was obtained maximum (209.49 q/ha) under the treatment S_1 (30 x 30 cm) while, minimum knob yield (85.03 q/ha) under the treatment S_4 (60 x 45 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on yield per hectare during both years. The data on pooled mean basis (Table 4.9 and Fig. 4.29) revealed that the maximum knob yield (218.06 q/ha) was recorded under treatment V_2S_1 (White Vienna with spacing 30 x 30 cm). It was found statistically at par with V_3S_1 and V_4S_1 treatments combination but significantly superior to V_1S_1. The minimum knob yield (81.17 q/ha) was recorded in treatment combination V_1S_4 (Pusa Virat with spacing 60 x45 cm).

Table 4.9: Effect of varieties, spacing and their interaction on yield per plot (kg) and yield per ha (q) of knol-khol

Treatments	Yield (kg/plot)			Yield (q/ha.)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	4.20	3.99	4.10	129.77	123.15	126.46
V_2	4.77	4.58	4.68	147.22	142.90	145.06
V_3	4.58	4.57	4.57	140.97	140.13	140.55
V_4	4.45	4.56	4.51	137.46	139.27	138.37
SEm ±	0.11	0.11	0.08	3.33	3.46	2.40
CD (P=0.05)	0.31	0.33	0.22	9.61	10.01	6.79
Spacing (S)						
S_1	6.86	6.72	6.79	211.72	207.25	209.49
S_2	4.96	4.84	4.90	153.16	149.38	151.27
S_3	3.40	3.41	3.41	104.89	104.41	104.65
S_4	2.78	2.74	2.76	85.65	84.41	85.03
SEm ±	0.11	0.11	0.08	3.33	3.46	2.40
CD (P=0.05)	0.31	0.33	0.22	9.61	10.01	6.79
Interaction (V x S)						
V_1S_1	6.33	6.26	6.30	195.49	193.21	194.35
V_1S_2	4.62	4.06	4.34	142.59	125.31	133.95
V_1S_3	3.21	3.03	3.12	99.20	93.52	96.36
V_1S_4	2.65	2.61	2.63	81.79	80.56	81.17
V_2S_1	7.15	6.98	7.07	220.68	215.43	218.06
V_2S_2	5.43	4.99	5.21	167.59	160.19	163.89
V_2S_3	3.67	3.54	3.61	113.27	109.26	111.27
V_2S_4	2.83	2.81	2.82	87.35	86.73	87.04
V_3S_1	7.00	6.84	6.92	216.05	211.11	213.58
V_3S_2	5.06	5.12	5.09	156.17	158.02	157.10
V_3S_3	3.49	3.57	3.53	107.72	110.19	108.95
V_3S_4	2.72	2.75	2.74	83.95	84.88	84.41
V_4S_1	6.95	6.78	6.87	214.66	209.26	211.96
V_4S_2	4.74	5.19	4.97	146.30	154.01	150.15
V_4S_3	3.22	3.51	3.37	99.38	108.33	103.86
V_4S_4	2.90	2.77	2.84	89.51	85.49	87.50
SEm ±	0.22	0.22	0.16	6.66	6.92	4.80
CD (P=0.05)	0.62	0.66	0.44	19.22	20.02	13.58

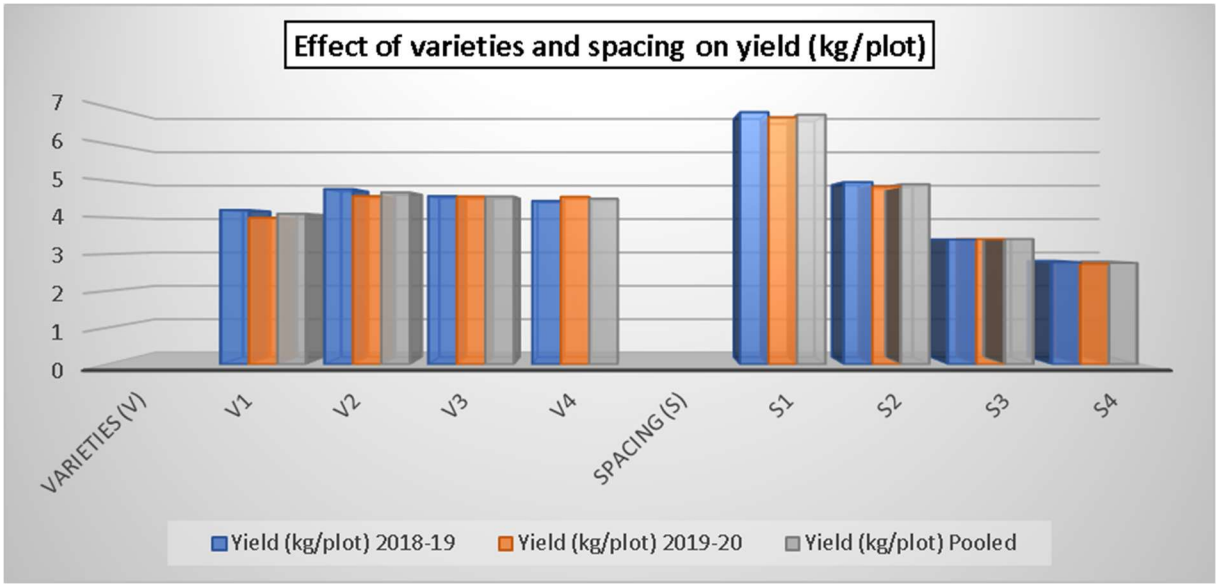


Fig. 4.26: Effect of varieties and spacing on yield per plot (kg) of knol-khol

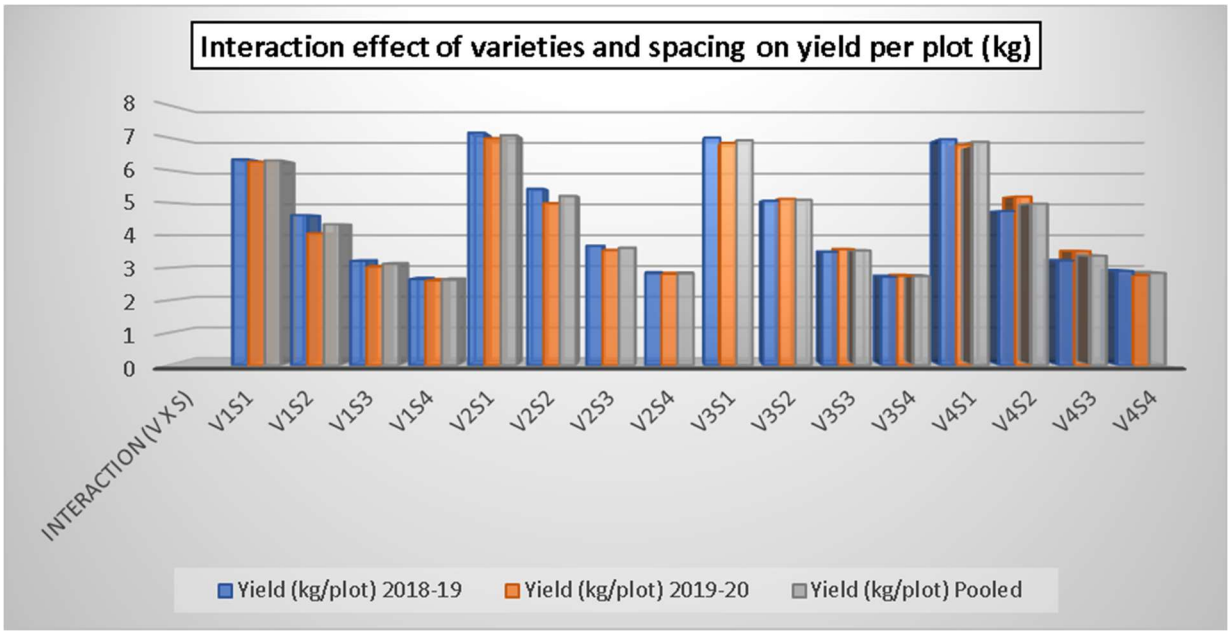


Fig. 4.27: Interaction effect of varieties and spacing on yield per plot (kg) of knol-khol

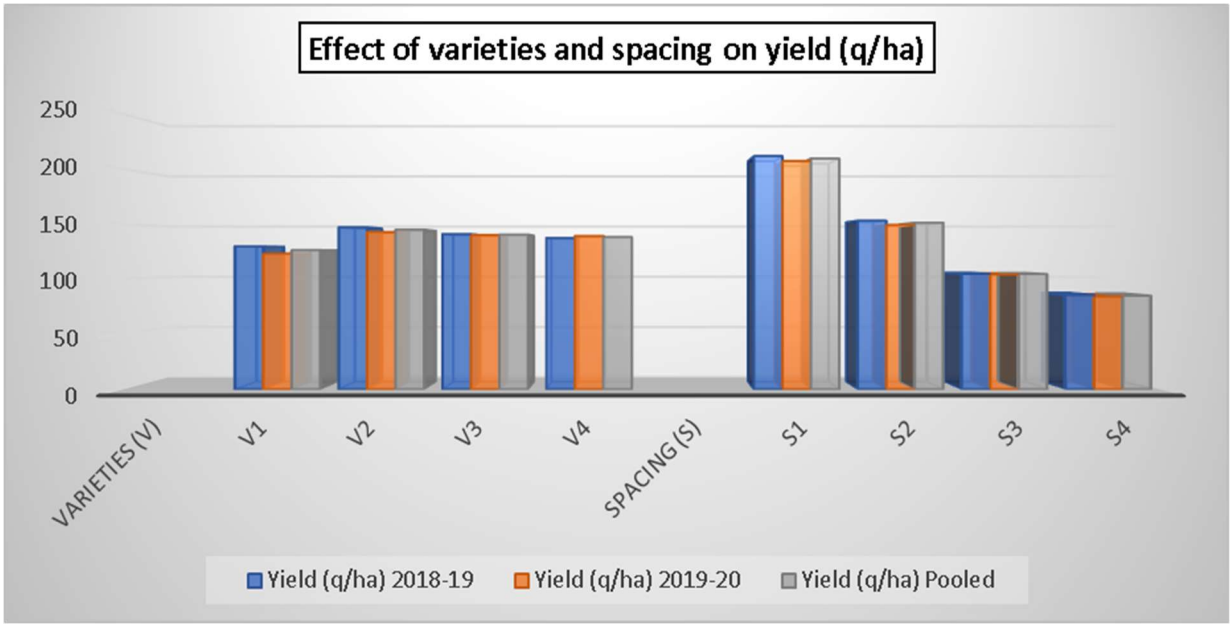


Fig. 4.28: Effect of varieties and spacing on yield per ha (q) of knol-khol

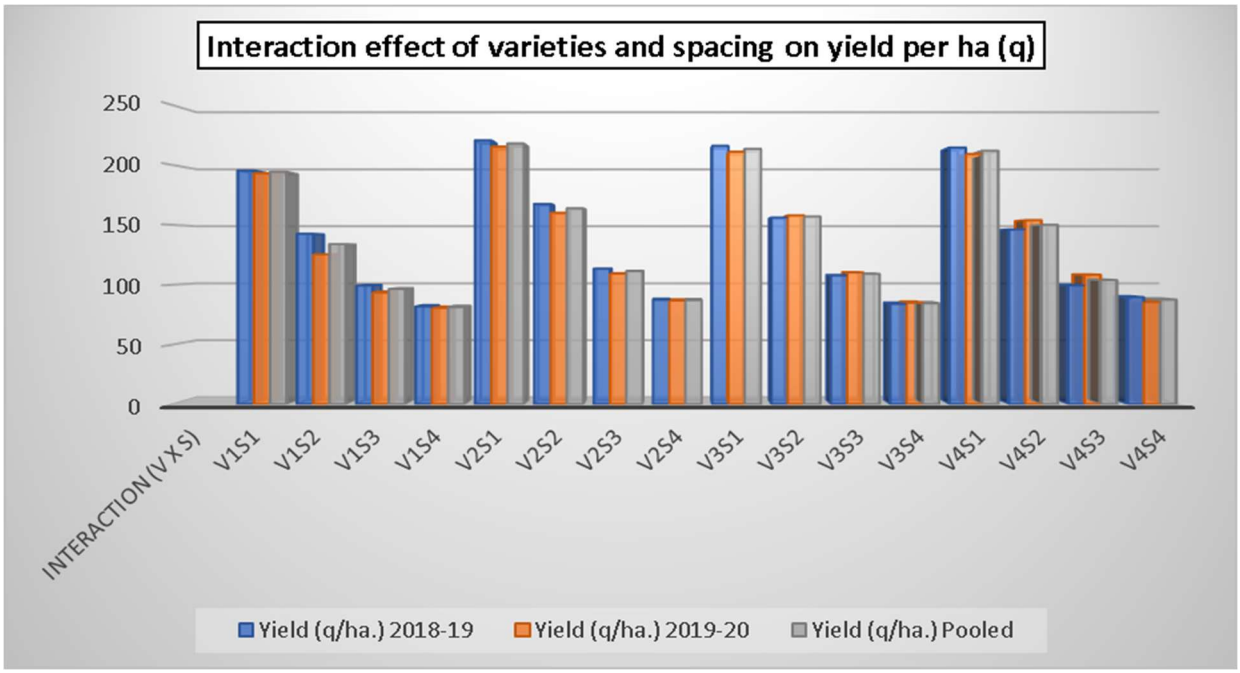


Fig. 4.29: Interaction effect of varieties and spacing on yield per ha (q) of knol-khol

4.3 QUALITY PARAMETERS

4.3.1 Total soluble solids (^{0}Brix)

Effect of varieties

A critical examination of the data presented in (Table 4.10 and Fig. 4.30) indicated that different varieties showed significant effect on total soluble solids content in knob of knol-khol during both the years. The data presented in above table clearly indicated that the maximum TSS content in knob (3.44 ^{0}Brix and 3.62 ^{0}Brix) was recorded under treatment V_4 (Palam Tender Knob) at par with V_3 (Early White Vienna) (3.24 ^{0}Brix and 3.18 ^{0}Brix) and V_2 (White Vienna) (3.28 ^{0}Brix and 2.96 ^{0}Brix), while minimum TSS content in knob was noted in V_1 (Pusa Virat) (2.56 ^{0}Brix and 3.09 ^{0}Brix), respectively during 2018-19 and 2019-20. A perusal of data over two years reveal that pooled mean TSS content in knob was maximum (3.53 ^{0}Brix) in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (3.21 ^{0}Brix) at harvest. While minimum TSS content in knob (2.83 ^{0}Brix) was noted in V_1 – Pusa Virat.

Effect of spacing

Perusal of data further showed that TSS content in knob significantly affected due to different spacing. The maximum TSS content in knob (3.44 ^{0}Brix and 3.62 ^{0}Brix) was recorded under treatment S_3 (45 x 30 cm). The minimum TSS content in knob (2.96 ^{0}Brix and 3.25 ^{0}Brix) was noticed under treatment S_1 (30 x 30 cm). The pooled mean TSS content in knob over two years, irrespective of treatments was obtained maximum (3.30 ^{0}Brix) under the treatment S_3 (45 x 30 cm) while, minimum (3.10 ^{0}Brix) mean TSS content in knob was obtained under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on TSS content in knob during both years. The data on pooled mean basis (Table 4.10 and Fig. 4.31) revealed that the maximum TSS content in knob (3.90 ^{0}Brix) was recorded under treatment V_3S_3 (Early White Vienna with spacing 45 x 45 cm) followed by V_4S_2 (Palam Tender Knob with spacing 45 x 30 cm) (3.73 ^{0}Brix). The minimum TSS content in knob (2.47 ^{0}Brix) was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x 30 cm).

4.3.2 Vitamin C (mg/100g)

Effect of varieties

The findings of the present experiment (Table 4.10 and Fig. 4.32) denoted significant effect of varieties on ascorbic acid content in knob during both years at harvest stage. Among the varieties, maximum vitamin C content of (37.42 mg/100g and 37.10 mg/100g) respectively, during both years was determined with V_4 (Palam Tender Knob), while minimum ascorbic acid content of (33.81 mg/100g and 34.12 mg/100g) was noted in case of variety V_1 (Pusa Virat). A perusal of data over two years reveal that pooled mean ascorbic content was maximum (37.26 mg/100g) in treatment V_2 (White Vienna). While minimum ascorbic acid content of (33.96 mg/100g) was noted in V_1 – Pusa Virat.

Effect of spacing

It is evident from the data (Table 4.10 and Fig. 4.32) that different spacing also had significant influence on ascorbic acid content of knol-khol. The maximum ascorbic content in knob (36.69 mg/100g and 36.74 mg/100g) was found in treatment S_2 (45 x 30 cm) while, the minimum ascorbic acid content in knob (35.27 mg/100g and 35.50 mg/100g) was recorded in S_1 (30 x 30 cm) respectively, during both years. The mean ascorbic content in knob over two years was obtained maximum (36.72 mg/100g) under the treatment S_2 (45 x 30 cm) while, minimum ascorbic acid content in knob (35.38 mg/100g) under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on ascorbic acid content in knob during both years. The data on pooled mean basis (Table 4.10 and Fig. 4.33) revealed that the maximum ascorbic content in knob (38.79 mg/100g) was recorded under treatment V_3S_2 (Early White Vienna with spacing 45 x 30 cm). It was found statistically at par with V_2S_2, V_3S_1 and V_4S_3 treatments combination but significantly superior to rest of the treatments. The minimum ascorbic acid content in knob (32.91 mg/100g) was recorded in treatment combination V_1S_2 (Pusa Virat with spacing 45 x 30 cm).

Table 4.10: Effect of varieties, spacing and their interaction on total soluble solids (°Brix) and vitamin C (mg/100g) of knol-khol

Treatments	Total soluble solids (°Brix)			Vitamin-C (mg/100g)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)						
V_1	2.88	3.09	2.99	33.81	34.12	33.96
V_2	2.96	2.95	2.95	37.42	37.10	37.26
V_3	3.24	3.18	3.21	36.30	36.46	36.38
V_4	3.45	3.62	3.54	36.49	36.97	36.73
SEm ±	0.12	0.09	0.07	0.28	0.19	0.17
CD (P=0.05)	0.34	0.26	0.21	0.81	0.56	0.48
Spacing (S)						
S_1	3.29	3.25	3.27	35.27	35.50	35.38
S_2	3.17	3.14	3.16	36.69	36.74	36.72
S_3	3.02	3.24	3.13	36.15	35.96	36.06
S_4	3.04	3.22	3.13	35.91	36.45	35.86
SEm ±	0.12	0.09	0.07	0.28	0.19	0.17
CD (P=0.05)	NS	NS	NS	0.81	0.56	0.48
Interaction (V x S)						
V_1S_1	3.26	2.98	3.12	32.67	32.81	32.74
V_1S_2	2.63	3.02	2.82	33.01	33.51	33.26
V_1S_3	2.84	3.14	2.99	35.33	34.33	34.83
V_1S_4	2.79	3.23	3.01	34.21	35.81	35.01
V_2S_1	3.30	3.28	3.29	36.83	34.82	35.82
V_2S_2	3.15	3.07	3.11	38.41	38.49	38.45
V_2S_3	1.97	2.48	2.22	37.76	37.06	37.41
V_2S_4	3.43	2.96	3.19	36.69	37.51	37.10
V_3S_1	3.12	3.21	3.17	39.12	39.04	39.08
V_3S_2	3.25	2.67	2.96	38.04	38.45	38.24
V_3S_3	3.94	3.86	3.90	34.65	33.79	34.22
V_3S_4	2.65	2.97	2.81	33.41	34.56	33.98
V_4S_1	3.48	3.53	3.51	35.02	35.32	35.17
V_4S_2	3.68	3.79	3.73	37.29	36.53	36.91
V_4S_3	3.34	3.48	3.41	36.87	38.65	37.76
V_4S_4	3.29	3.70	3.49	36.78	37.92	37.35
SEm ±	0.24	0.18	0.14	0.56	0.38	0.34
CD (P=0.05)	0.68	0.52	0.42	1.62	1.12	0.96

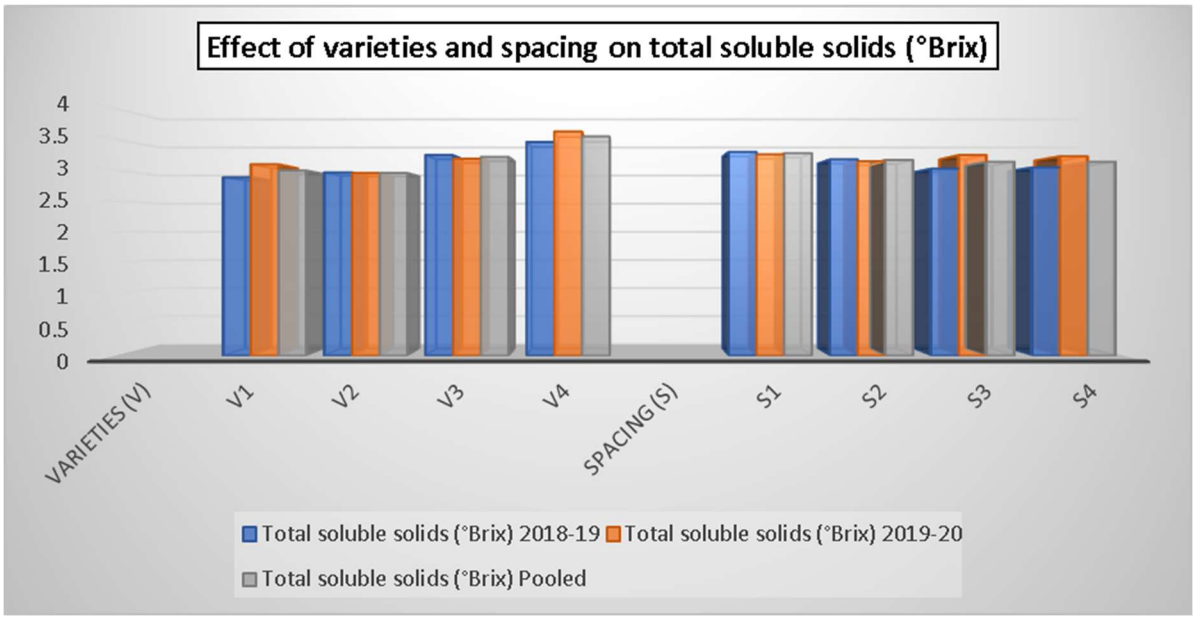


Fig. 4.30: Effect of varieties and spacing on total soluble solids (°Brix)

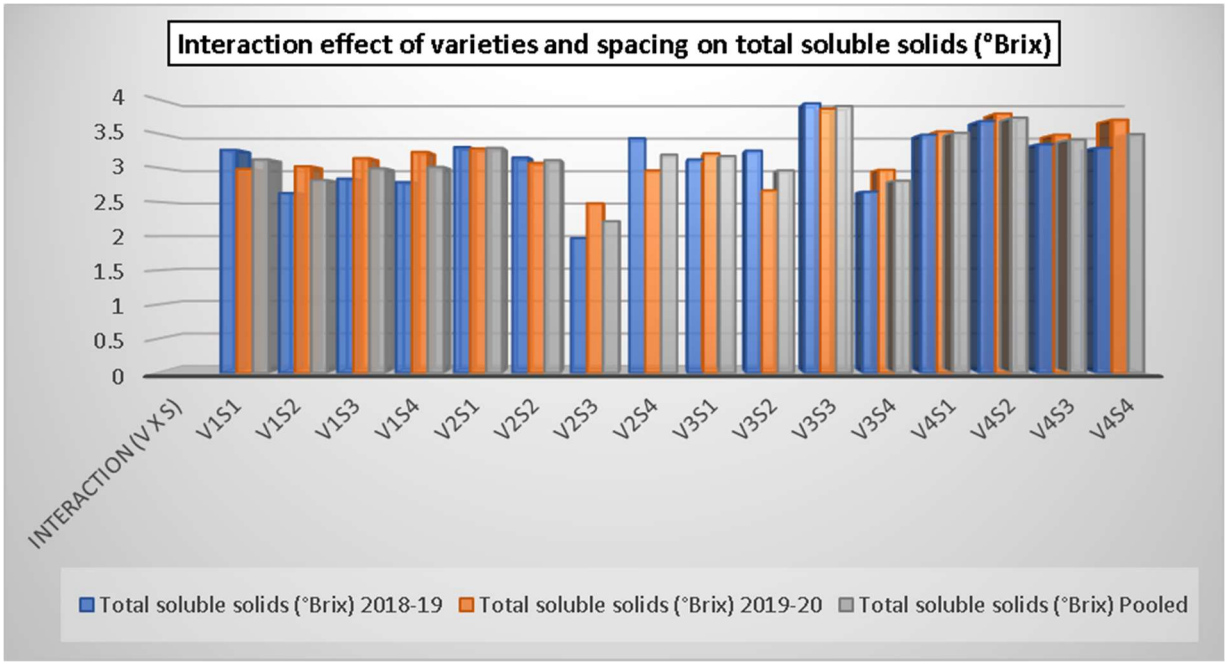


Fig. 4.31: Interaction effect of varieties and spacing on total soluble solids (°Brix)

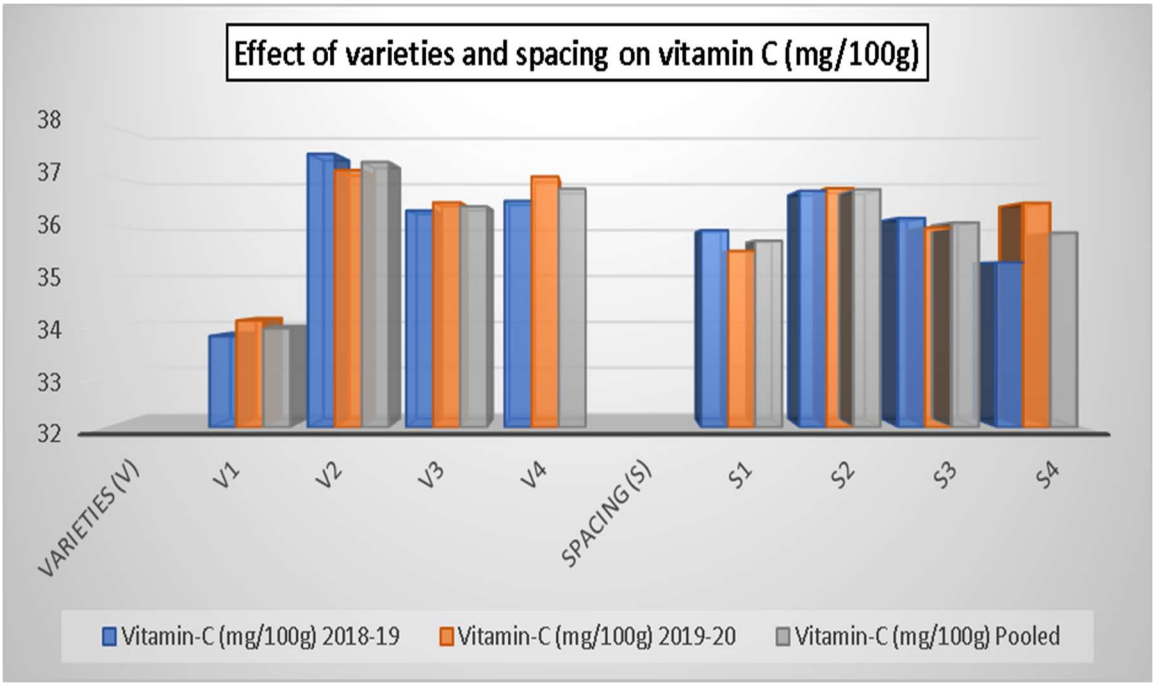


Fig. 4.32: Effect of varieties and spacing on vitamin C (mg/100g) of knol-khol

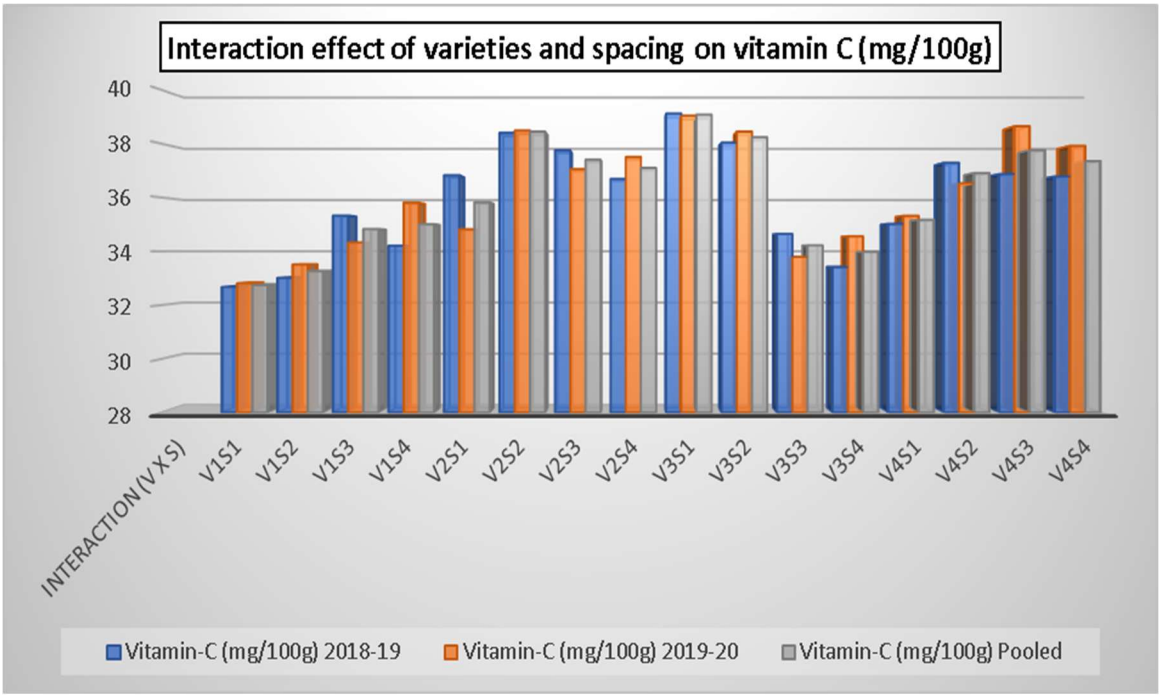


Fig. 4.33: Interaction effect of varieties and spacing on vitamin C (mg/100g) of knol-khol

4.3.3 Reducing sugar (%)

Effect of varieties

Data collected in connection with reducing sugar content in knob of knol-khol due to significantly influence by different varieties have been summarized in Table 4.11, graphically represented in figure 4.34 and analysis of variance computed for data depicted in Appendix XVI. The data presented in above table clearly indicated that maximum reducing sugar was noticed under V_3 (Early White Vienna) *i.e.,* 1.79 % and 1.75 % during 2018-19 and 2019-20, respectively. It was found statistically at par with V_4 (Palam Tender Knob) but significantly superior to rest of the treatments, while the minimum reducing sugar content in knob (1.45 % and 1.35 %) was recorded in V_1 (Pusa Virat). A perusal of data over two years reveal that pooled mean reducing sugar content in knob was maximum (1.77 %) in treatment V_3 (Early White Vienna) followed by V_4 (Palam Tender Knob) (1.70 %) at harvest. While minimum reducing sugar content in knob (1.40 %) was noted in V_1 (Pusa Virat).

Effect of spacing

It is evident from the data (Table 4.11 and Fig. 4.35) that different spacing also had significant influence on reducing sugar content in knob of knol-khol. The maximum reducing sugar content in knob (1.83 % and 1.71 %) was found in treatment S_3 (45 x 45 cm) while, the minimum reducing sugar content in knob (1.46 % and 1.44 %) was recorded in S_1 (30 x 30 cm) respectively, during both years. The mean reducing sugar content in knob over two years was obtained maximum (1.77 %) under the treatment S_3 (45 x 45 cm) while, minimum reducing sugar content in knob (1.45 %), under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on reducing sugar content in knob during both years. The data on pooled mean basis (Table 4.11 and Fig. 4.36) revealed that the maximum reducing sugar content in knob (1.99 %) was recorded under treatment V_3S_3 (Early White Vienna with spacing 45 x 45 cm) followed by V_2S_3 (White Vienna with spacing 45 x 45 cm) (1.87 %). The minimum reducing sugar content in knob (1.12 %) was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x 30 cm).

4.3.4 Non-reducing sugar (%)

Effect of varieties

Data recorded towards in connection with non-reducing sugar content in knob of knol-khol due to significantly influence by different varieties have been summarized in Table 4.11, graphically represented in figure 4.34 and analysis of variance computed for data depicted in Appendix XVII. The data clearly indicated that maximum non-reducing sugar was noticed under V_4 (Palam Tender Knob) *i.e.,* 0.70 % and 0.68% during 2018-19 and 2019-20, respectively while, the minimum non-reducing sugar content in knob (0.59 % and 0.49 %) was recorded in V_1 (Pusa Virat). A perusal of data over two years reveal that pooled mean non-reducing sugar content in knob was maximum (0.69 %) in treatment V_4 (Palam Tender Knob) followed by V_2 (White Vienna) (0.67 %). While minimum non-reducing sugar content in knob (0.54 %) was noted in V_1 – Pusa Virat.

Effect of spacing

It is evident from the data (Table 4.11 and Fig. 4.35) that different spacing also had significant influence on non-reducing sugar content in knob of knol-khol. The maximum non-reducing sugar content in knob (0.67 % and 0.66 %) was found in treatment S_1 (30 x 30 cm) while, the minimum non-reducing sugar content in knob (0.61 % and 0.55 %) was recorded in S_3 (45 x 45 cm) respectively, during both years. The mean non-reducing sugar content in knob over two years was obtained maximum (0.66 %) under the treatment S_1 (30 x 30 cm) while, minimum non-reducing sugar content in knob (0.58 %), respectively under the treatment S_3 (45 x 45 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on non-reducing sugar content in knob during both years. The data on pooled mean basis (Table 4.11 and Fig. 4.36) revealed that the maximum non-reducing sugar content in knob (0.74 %) was recorded under treatment V_4S_3 (Palam Tender Knob with spacing 45 x 45 cm) followed by V_4S_1 (Palam Tender Knob with spacing 30 x 30 cm) (0.73 %) at harvest. The minimum non-reducing sugar content in knob (0.48 %) was recorded in treatment combination V_1S_3 (Pusa Virat with spacing 30 x 30 cm).

4.3.5 Total sugars (%)

Effect of varieties

Data recorded towards in connection with total sugars content in knob of knol-khol due to significantly influence by different varieties have been summarized in Table 4.11, graphically represented in figure 4.34 and analysis of variance computed for data depicted in Appendix XVIII. The data clearly indicated that maximum total sugars was noticed under V_4 (Palam Tender Knob) *i.e.,* 2.43 % and 2.45 % during 2018-19 and 2019-20, respectively. It was found statistically at par with V_3 (Early White Vienna) but significantly superior to rest of the treatments, while the minimum total sugars content in knob (2.04 % and 1.84 %) was recorded in V_1 (Pusa Virat). A perusal of data over two years reveal that pooled mean total sugars content in knob was maximum (2.44 %) in treatment V_4 (Palam Tender Knob) followed by V_3 (Early White Vienna) (2.36 %). While minimum total sugars content in knob (1.94 %) was noted in V_1 – Pusa Virat.

Effect of spacing

It is evident from the data (Table 4.11 and Fig. 4.35) that different spacing also had significant influence on total sugars content in knob of knol-khol. The maximum total sugars content in knob (2.42 % and 2.29 %) was found in treatment S_4 (60 x 45 cm) while, the minimum total sugars content in knob (2.14 % and 2.09 %) was recorded in S_1 (30 x 30 cm) respectively, during both years. The pooled mean total sugar content in knob over two years was obtained maximum (2.35 %) under the treatment S_4 (60 x 45 cm) while, minimum total sugar content in knob (2.12 %) under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on total sugars content in knob during both years. The data on pooled mean basis (Table 4.11 and Fig. 4.36) revealed that the maximum total sugars content in knob (2.52 %) was recorded under treatment V_3S_3 (Early White Vienna with spacing 45 x 45 cm) followed by V_4S_3 (Palam Tender knob with spacing 60 x 45 cm) (2.46 %). The minimum total sugars content in knob (1.67 %) was recorded in treatment combination V_1S_1 (Pusa Virat with spacing 30 x 30 cm).

Table 4.11: Effect of varieties, spacing and their interaction on reducing sugar (%), non-reducing sugar (%) and total sugars (%) content in knob of knol-khol

Treatments	Reducing sugar (%)			Non-reducing sugar (%)			Total sugars (%)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)									
V_1	1.45	1.35	1.40	0.59	0.49	0.54	2.04	1.84	1.94
V_2	1.73	1.64	1.68	0.68	0.65	0.67	2.42	2.29	2.35
V_3	1.79	1.75	1.77	0.60	0.64	0.62	2.39	2.32	2.36
V_4	1.72	1.68	1.70	0.70	0.68	0.69	2.43	2.45	2.44
SEm ±	0.04	0.04	0.03	0.02	0.02	0.01	0.06	0.04	0.04
CD (P=0.05)	0.12	0.11	0.08	0.05	0.07	0.04	0.17	0.13	0.10
Spacing (S)									
S_1	1.46	1.44	1.45	0.67	0.66	0.66	2.14	2.09	2.12
S_2	1.65	1.60	1.62	0.65	0.65	0.65	2.30	2.24	2.27
S_3	1.83	1.71	1.77	0.61	0.55	0.58	2.41	2.26	2.34
S_4	1.78	1.63	1.71	0.62	0.63	0.62	2.42	2.29	2.35
SEm ±	0.04	0.04	0.03	0.02	0.02	0.01	0.06	0.04	0.04
CD (P=0.05)	0.12	0.11	0.08	0.05	0.07	0.04	0.17	0.13	0.10
Interaction (V x S)									
V_1S_1	1.18	1.06	1.12	0.56	0.53	0.55	1.74	1.59	1.67
V_1S_2	1.31	1.18	1.25	0.57	0.56	0.57	1.88	1.74	1.81
V_1S_3	1.47	1.53	1.50	0.64	0.33	0.48	2.11	1.86	1.98
V_1S_4	1.83	1.64	1.74	0.58	0.54	0.56	2.41	2.18	2.30
V_2S_1	1.58	1.56	1.57	0.73	0.65	0.69	2.31	2.21	2.26
V_2S_2	1.77	1.69	1.73	0.71	0.69	0.70	2.48	2.38	2.43
V_2S_3	1.91	1.83	1.87	0.65	0.64	0.65	2.56	2.47	2.52
V_2S_4	1.68	1.46	1.57	0.63	0.63	0.63	2.31	2.09	2.20
V_3S_1	1.48	1.44	1.46	0.68	0.70	0.69	2.16	2.14	2.15
V_3S_2	1.72	1.76	1.74	0.64	0.72	0.68	2.37	2.48	2.43
V_3S_3	2.13	1.84	1.99	0.51	0.47	0.49	2.64	2.41	2.52
V_3S_4	1.84	1.69	1.76	0.54	0.67	0.61	2.38	2.36	2.37
V_4S_1	1.62	1.71	1.67	0.72	0.73	0.73	2.34	2.44	2.39
V_4S_2	1.79	1.76	1.78	0.67	0.61	0.64	2.46	2.37	2.41
V_4S_3	1.66	1.79	1.73	0.73	0.75	0.74	2.39	2.53	2.46
V_4S_4	1.89	1.73	1.81	0.63	0.66	0.65	2.52	2.31	2.41
SEm ±	0.08	0.08	0.06	0.04	0.04	0.02	0.12	0.08	0.08
CD (P=0.05)	0.24	0.22	0.16	0.10	0.10	0.06	0.34	0.26	0.20

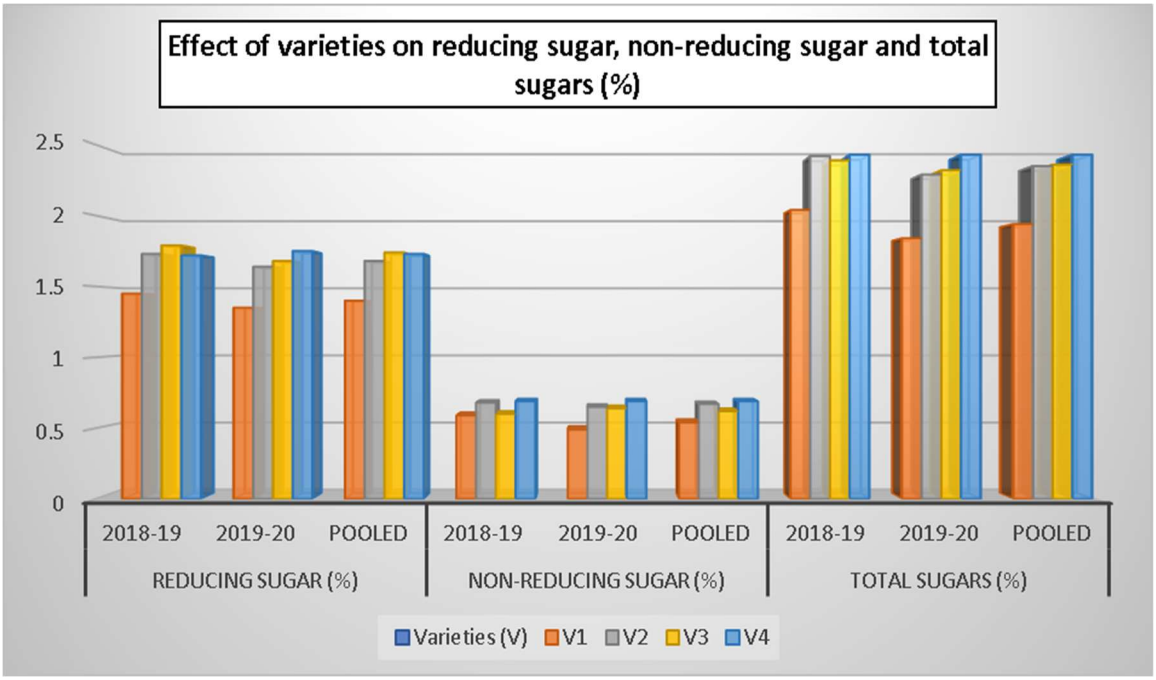


Fig. 4.34: Effect of varieties on reducing sugar (%), non-reducing sugar (%) and total sugars (%)

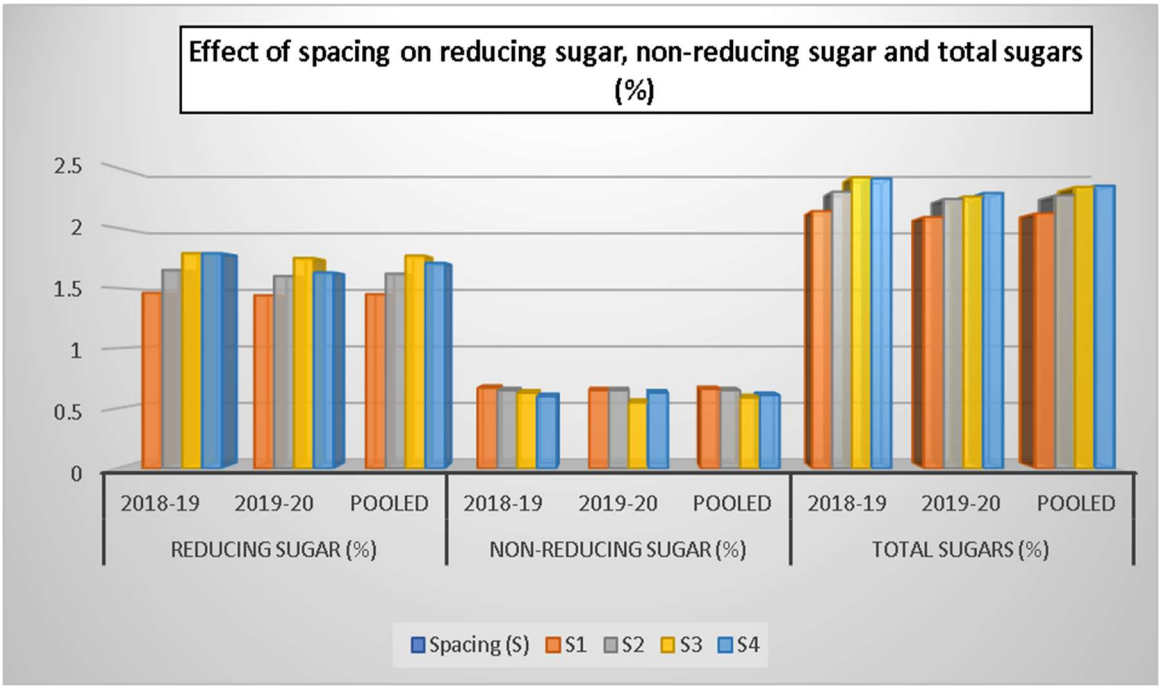


Fig. 4.35: Effect of spacing on reducing sugar (%), non-reducing sugar (%) and total sugars (%)

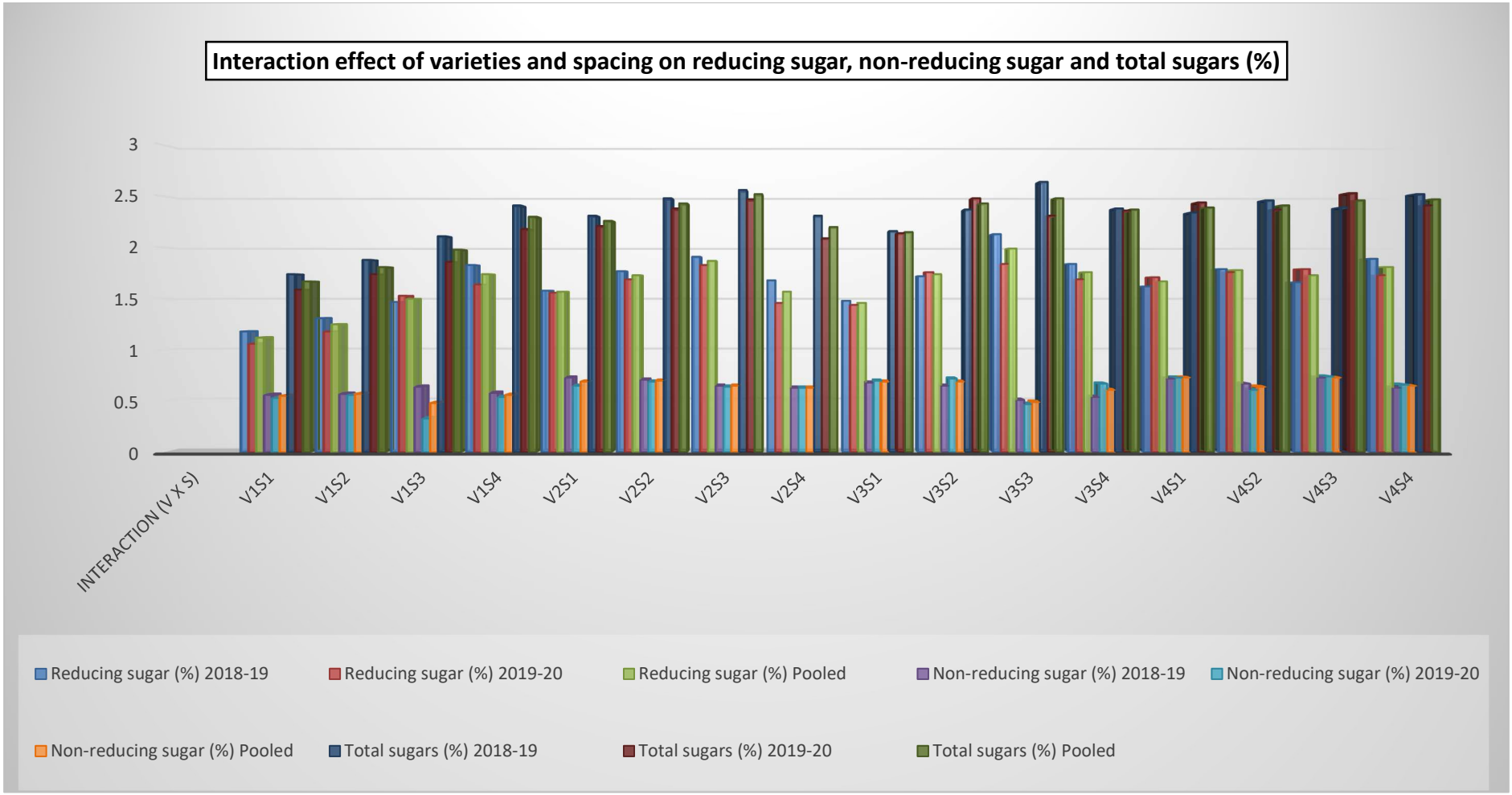


Fig. 4.36: Interaction effect of varieties and spacing reducing sugar (%), non-reducing sugar (%) and total sugars (%)

4.3.6 Total chlorophyll content in leaves (mg/g)

Effect of varieties

Data recorded towards in connection with chlorophyll content in plant leaves of knol-khol due to significantly influence by different varieties have been summarized in Table 4.12, graphically represented in figure 4.37 and analysis of variance computed for data depicted in Appendix XIX. The maximum chlorophyll content in plant leaves (0.70 mg/g and 0.73 mg/g) was noticed under treatment V_3 (Early White Vienna) while, the minimum chlorophyll content in plant leaves (0.59 mg/g and 0.61 mg/g) was recorded in V_1 (Pusa Virat) at 45 DAT respectively, during both years. A perusal of data over two years reveal that pooled mean chlorophyll content in plant leaves was maximum (0.71 mg/g) in treatment V_3 (Early White Vienna) followed by V_4 (Palam Tender Knob) (0.70 mg/g) at 45 DAT. While minimum chlorophyll content in plant leaves (0.60 mg/g) was noted in V_1 – Pusa Virat.

Effect of spacing

Perusal of data further showed that chlorophyll content in plant leaves at 45 DAT significantly affected due to different spacing. The maximum chlorophyll content in plant leaves (0.68 mg/g and 0.69 mg/g) was recorded under treatment S_4 (60 x 45 cm). The minimum chlorophyll content in plant leaves (0.65 mg/g and 0.67 mg/g) was noticed under treatment S_1 (30 x 30 cm). The pooled mean chlorophyll content in plant leaves at 45 DAT over two years, irrespective of treatments was obtained maximum (0.68 mg/g) under the treatment S_4 (60 x 45 cm) while, minimum (0.66 mg/g) mean chlorophyll content in plant leaves was obtained under the treatment S_1 (30 x 30 cm).

Interaction effect of varieties and spacing

The interactive effect of different varieties and spacing had significant influence on chlorophyll content in plant leaves at 45 DAT during both years. The data on pooled mean basis (Table 4.12 and Fig. 4.38) revealed that the maximum chlorophyll content in plant leaves (0.77 mg/g) was recorded under treatment V_3S_4 (Early White Vienna with spacing 60 x 45 cm). The minimum chlorophyll content in plant leaves (0.57 mg/g) was recorded in treatment combination V_1S_3 (Pusa Virat with spacing 45 x 45 cm).

Table 4.12: Effect of varieties, spacing and their interaction on chlorophyll content in leaves (mg/g) of knol-khol

Treatments	Chlorophyll content in leaves (mg/g)		
	2018-19	2019-20	Pooled
Varieties (V)			
V_1	0.59	0.61	0.60
V_2	0.67	0.66	0.67
V_3	0.70	0.73	0.71
V_4	0.70	0.69	0.70
SEm ±	0.02	0.01	0.01
CD (P=0.05)	0.04	0.03	0.03
Spacing (S)			
S_1	0.65	0.67	0.66
S_2	0.68	0.68	0.68
S_3	0.66	0.66	0.66
S_4	0.68	0.69	0.68
SEm ±	0.02	0.01	0.01
CD (P=0.05)	NS	NS	NS
Interaction (V x S)			
V_1S_1	0.59	0.58	0.59
V_1S_2	0.61	0.69	0.65
V_1S_3	0.55	0.57	0.57
V_1S_4	0.60	0.59	0.60
V_2S_1	0.63	0.67	0.65
V_2S_2	0.67	0.66	0.67
V_2S_3	0.68	0.63	0.66
V_2S_4	0.71	0.68	0.70
V_3S_1	0.64	0.69	0.67
V_3S_2	0.69	0.71	0.70
V_3S_3	0.72	0.73	0.73
V_3S_4	0.76	0.77	0.77
V_4S_1	0.73	0.72	0.73
V_4S_2	0.74	0.65	0.70
V_4S_3	0.68	0.69	0.69
V_4S_4	0.66	0.70	0.68
SEm ±	0.04	0.02	0.02
CD (P=0.05)	0.08	0.06	0.06

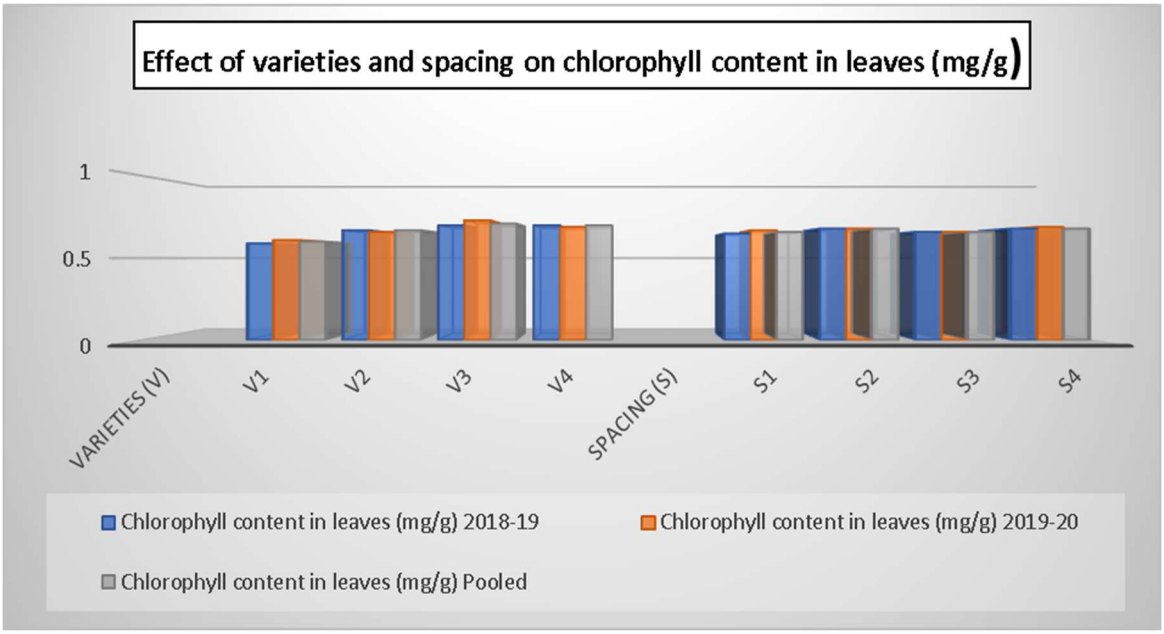


Fig. 4.37: Effect of varieties and spacing on chlorophyll content in leaves (mg/g) of knol-khol

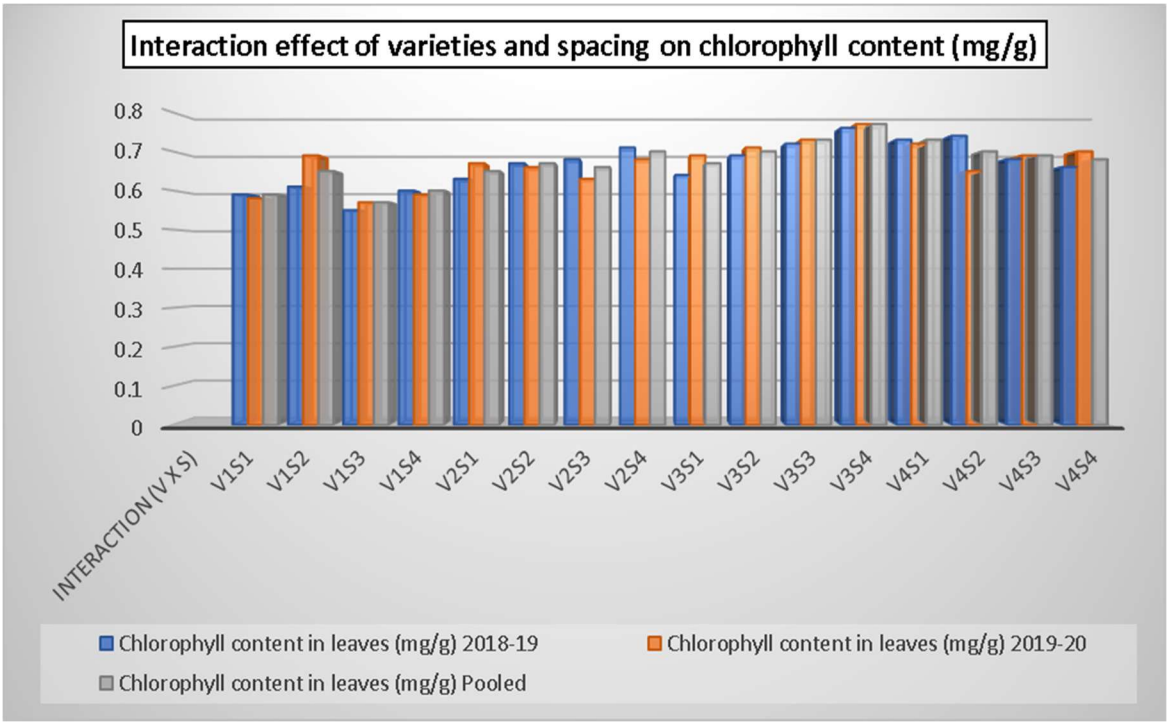


Fig. 4.38: Interaction effect of varieties and spacing on chlorophyll content in leaves (mg/g) of knol-khol

4.4 Economics of treatments

A perusal of data depicted in (Table 4.13) indicated that the cost of cultivation of knol-khol was Rs 54,850 per hectare including variables (labour charges, tractor charges and material inputs) and fixed cost. The production of knol-khol under different treatments have been given in (Appendix XXIII). The sale of knob of knol-khol were calculated at an average price of Rs 1000 per quintal and presented in same Table. The net profit from cultivation under different treatment was worked out after subtracting cost of cultivation from gross returns. The detail of cost of cultivation of knol-khol and the value of the produce have been worked out on the basis of prevailing market rates during the first year of experimentation (Appendix XXIII and XXIV).

4.4.1 Gross returns (Rs ha^{-1})

Effect of varieties

Data represented in (Table 4.13 and Fig. 4.39) revealed that different varieties significantly increased the gross returns during both the year of experimentation. The maximum gross returns (1,47,223 Rs/ha and 1,41,357 Rs/ha) was obtained under treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (1,40,973 Rs/ha and 1,41,049 Rs/ha) respectively, during 2018-19 and 2019-20, while minimum gross returns (1,28,703 Rs/ha and 1,23,149 Rs/ha) was recorded under treatment V_1 (Pusa Virat). A perusal of data over two years reveal that pooled mean gross returns was maximum (1,44,290 Rs/ha) in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (1,41,011 Rs/ha). While minimum gross returns (1,25,926 Rs/ha) was noted in V_1 – Pusa Virat.

Effect of spacing

Data represented in same Table and Appendix exhibited that gross returns of knol-khol was significantly influenced by different spacing during both the years of experimentation. The maximum gross returns (2,11,574 Rs/ha and 2,07,252 Rs/ha) were recorded under treatment S_1 (30 x 30 cm). The minimum gross returns (85,648 Rs/ha and 84,376 Rs/ha) was noticed under treatment S_4 (60 x 45 cm). The pooled mean gross returns over two years, irrespective of treatments was obtained maximum (2,09,413 Rs/ha) under the treatment S_1 (30 x 30 cm) while, minimum gross returns (85,012 Rs/ha) were obtained under the treatment S_4 (60 x 45 cm).

Interaction effect of varieties and spacing

Data in (Table 4.13 and Fig 4.41) showed that the combined effect of different varieties and spacings on gross returns of knol-khol was found to be significant. The data on pooled mean basis revealed that the maximum gross returns (2,18,055 Rs/ha) was recorded under treatment V_2S_1 (White Vienna with spacing 30 x 30 cm). The minimum gross returns (81,173 Rs/ha) were recorded in treatment combination V_1S_4 (Pusa Virat with spacing 60 x 45 cm).

4.4.2 Net returns (Rs ha^{-1})

Effect of varieties

Data represented in (Table 4.13, Fig. 4.39 and Appendix XXI) revealed that different varieties significantly increased the net returns during both the year of experimentation. The maximum net return (90,423 Rs/ha and 88,790 Rs/ha) was obtained under treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (84,397 Rs/ha and 84,249 Rs/ha) respectively, during 2018-19 and 2019-20, while minimum net returns (71,900 Rs/ha and 66,349 Rs/ha) were recorded under treatment V_1 (Pusa Virat). A perusal of data over two years reveal that pooled mean net returns was maximum (89,606 Rs/ha) in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (84,323 Rs/ha). While minimum net returns (69,125 Rs/ha) were noted in V_1 – Pusa Virat.

Effect of spacing

Data represented in same Table and Appendix exhibited that net returns of knol-khol was significantly influenced by different spacing during both the year of experiment. The maximum net returns (1,53,948 Rs/ha and 1,49,402 Rs/ha) were recorded under treatment S_1 (30 x 30 cm). The minimum net returns (29,598 Rs/ha and 28,363 Rs/ha) were noticed under treatment S_4 (60 x 45 cm). The pooled mean net returns over two years, irrespective of treatments was obtained maximum (1,51,675 Rs/ha) under the treatment S_1 (30 x 30 cm) while, minimum net returns (28,980 Rs/ha) were obtained under the treatment S_4 (60 x 45 cm).

Interaction effect of varieties and spacing

Data in (Table 4.13 and Fig 4.41) showed that the combined effect of different varieties and spacings on net returns of knol-khol was found to be significant. The data on pooled mean basis revealed that the maximum net returns (1,60,205 Rs/ha) was recorded under treatment V_2S_1 (White Vienna with spacing 30 x 30 cm). The

minimum net returns (25,123 Rs/ha) were recorded in treatment combination V_1S_4 (Pusa Virat with spacing 60 x 45 cm).

4.4.3 B:C ratio

Effect of varieties

Data represented in (Table 4.13, Fig. 4.42 and Appendix XXII) revealed that different varieties significantly increased the B:C ratio of knol-khol during both the years of experimentation. The maximum B:C ratio (1.58 and 1.55) was obtained under treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (1.49 and 1.46) respectively, during 2018-19 and 2019-20, while minimum B:C ratio (1.26 and 1.16) was recorded under treatment V_1 (Pusa Virat). A perusal of data over two years reveal that pooled mean B:C ratio was maximum (1.57) in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (1.48). While minimum B:C ratio (1.21) was noted in V_1 – Pusa Virat.

Effect of spacing

Data represented in same Table and Appendix exhibited that B:C ratio of knol-khol was significantly influenced by different spacing during both the year of experiment. The maximum B:C ratio (2.66 and 2.58) was recorded under treatment S_1 (30 x 30 cm). The minimum B:C ratio (0.53 and 0.51) was noticed under treatment S_4 (60 x 45 cm). The pooled mean B:C ratio over two years, irrespective of treatments was obtained maximum (2.62) under the treatment S_1 (30 x 30 cm) while, minimum B:C ratio (0.52) was obtained under the treatment S_4 (60 x 45 cm).

Interaction effect of varieties and spacing

Data in (Table 4.13 and Fig 4.43) showed that the combined effect of different varieties and spacings on B:C ratio of knol-khol was found to be significant. The data on pooled mean basis revealed that the maximum B:C ratio (2.77) was recorded under treatment V_2S_1 (White Vienna with spacing 30 x 30 cm) followed by V_3S_1 (Early White Vienna with spacing 30 x 30 cm) (2.70). The minimum B:C ratio (0.45) was recorded in treatment combination V_1S_4 (Pusa Virat with spacing 60 x 45 cm).

Table 4.13: Effect of varieties, spacing and their interaction on gross returns (Rs/ha), net returns (Rs/ha) and B:C ratio of knol-khol

Treatments	Gross returns (₹/ha)			Net returns (₹/ha)			B:C ratio		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Varieties (V)									
V_1	128703	123149	125926	71900	66349	69125	1.26	1.16	1.21
V_2	147223	141357	144290	90423	88790	89606	1.58	1.55	1.57
V_3	140973	141049	141011	84397	84249	84323	1.49	1.46	1.48
V_4	138503	140780	139641	81703	84018	82860	1.43	1.47	1.45
SEm ±	3522	3481	2476	3534	3839	2609	0.06	0.07	0.05
CD (P=0.05)	10173	10053	7004	10207	11087	7380	0.18	0.19	0.13
Spacing (S)									
S_1	211574	207252	209413	153948	149402	151675	2.66	2.58	2.62
S_2	153163	149383	151273	96313	92533	94423	1.69	1.63	1.66
S_3	105016	105325	105170	48563	53108	50835	0.86	0.94	0.90
S_4	85648	84376	85012	29598	28363	28980	0.53	0.51	0.52
SEm ±	3522	3480	2476	3534	3839	2609	0.06	0.07	0.05
CD (P=0.05)	10172	10053	7004	10207	11087	7380	0.18	0.19	0.13
Interaction (V x S)									
V_1S_1	190740	193210	191975	132890	135360	134125	2.30	2.34	2.32
V_1S_2	142593	125310	133952	85743	68460	77102	1.51	1.20	1.36
V_1S_3	99690	93520	96605	43227	37070	40148	0.77	0.65	0.71
V_1S_4	81790	80557	81173	25740	24507	25123	0.46	0.44	0.45
V_2S_1	220680	215430	218055	162830	157580	160205	2.82	2.72	2.77
V_2S_2	146297	154010	150153	89447	97160	93303	1.57	1.71	1.64
V_2S_3	99383	109260	104322	42933	69743	56338	0.76	1.23	1.00
V_2S_4	89503	86727	88115	33453	30677	32065	0.60	0.55	0.57
V_3S_1	216050	211110	213580	159097	153260	156178	2.75	2.65	2.70
V_3S_2	156173	158027	157100	99323	101177	100250	1.75	1.78	1.76
V_3S_3	107717	110183	108950	51267	53733	52500	0.91	0.95	0.93
V_3S_4	83950	84877	84413	27900	28827	28363	0.50	0.51	0.51
V_4S_1	218827	209257	214042	160977	151407	156192	2.77	2.62	2.69
V_4S_2	167590	160183	163887	110740	103333	107037	1.95	1.84	1.89
V_4S_3	113273	108337	110805	56823	51887	54355	1.01	0.92	0.96
V_4S_4	87347	85343	86345	31297	29443	30370	0.56	0.53	0.54
SEm ±	7044	6960	7415.4	7068	7678	5218	0.12	0.14	0.10
CD (P=0.05)	20344	20106	20977.2	20414	22174	14760	0.36	0.38	0.26

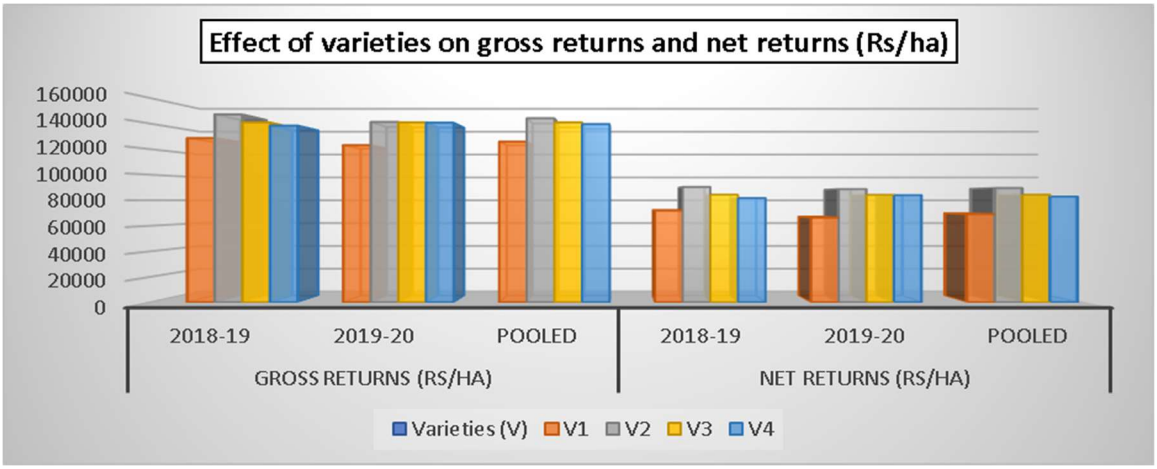


Fig. 4.39: Effect of varieties on gross returns and net returns (Rs/ha) of knol-khol

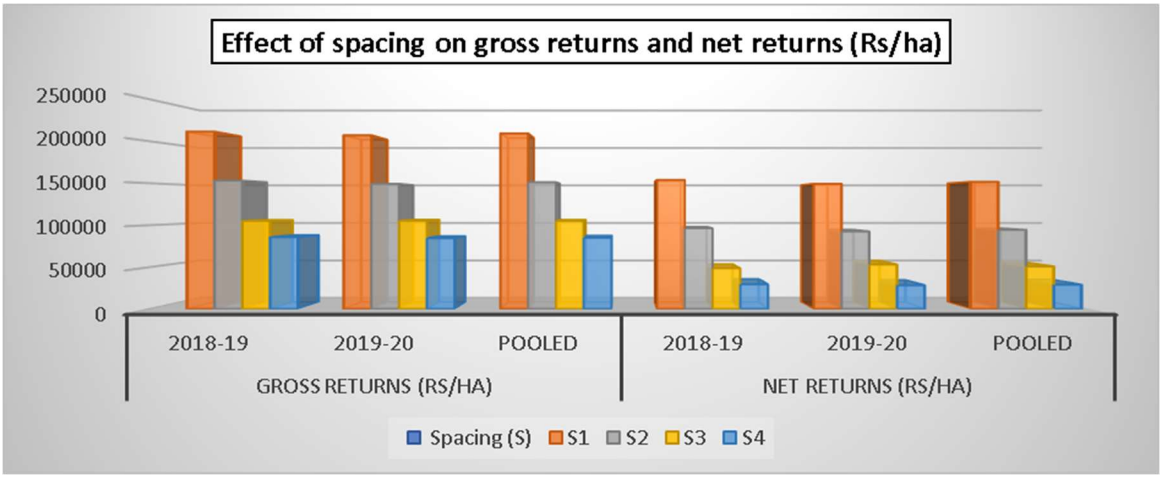


Fig. 4.40: Effect of spacing on gross returns and net returns (Rs/ha) of knol-khol

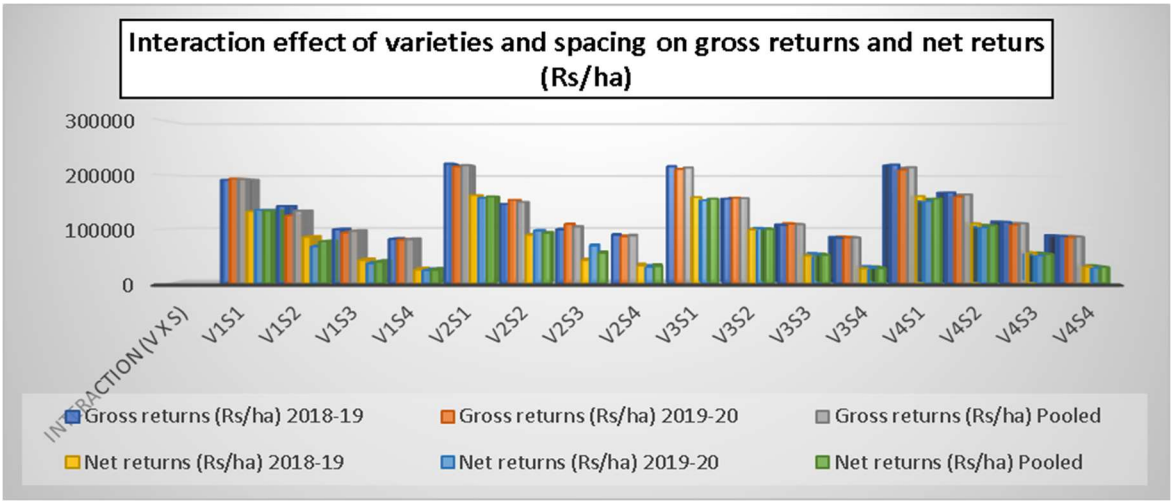


Fig. 4.41: Interaction effect of varieties and spacing on gross returns and net returns (Rs/ha) of knol-khol

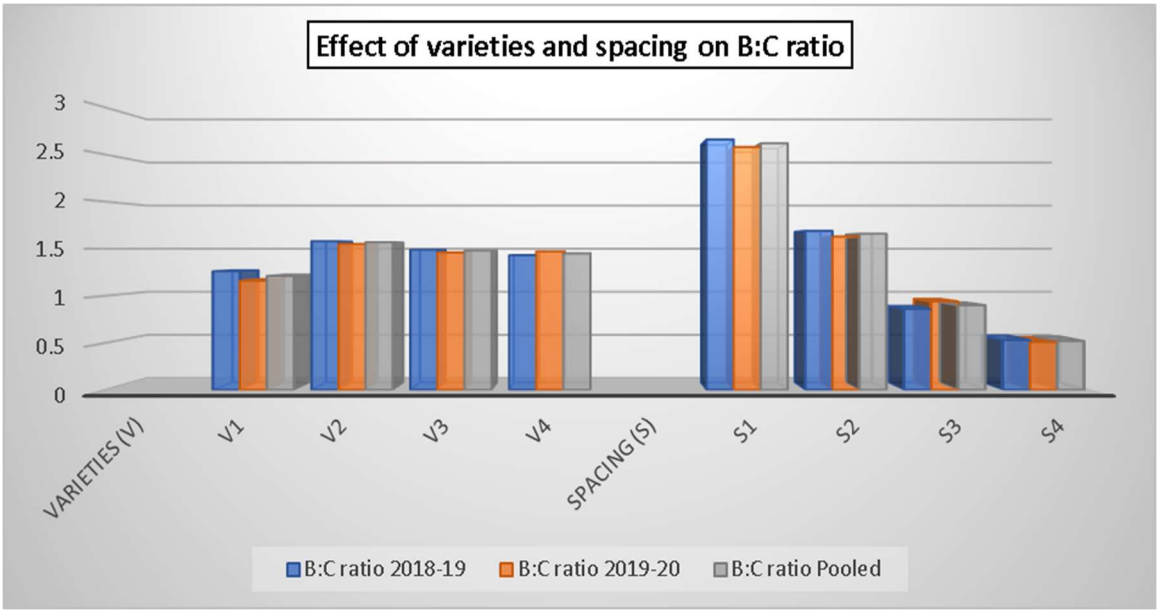


Fig. 4.42: Effect of varieties and spacing on B:C ratio of knol-khol

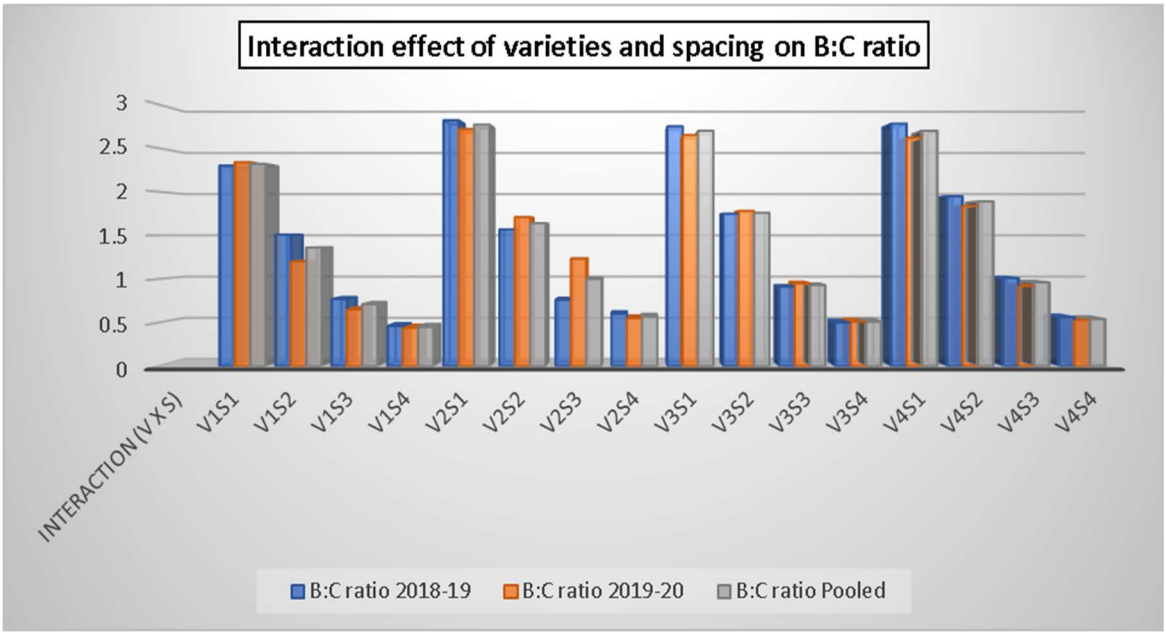


Fig. 4.43: Interaction effect of varieties and spacing on B:C ratio of knol-khol

DISCUSSION

The present findings of the experiment trial entitled **"Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)"** was carried out at the Horticultural Research Farm-I, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, (A Central University), Lucknow. The experimental findings presented in the previous chapter provided a detailed account of response of different varieties and spacing in term of growth, yield and quality of knol-khol between years of present investigation was also observed. In present section, an attempt has been made to highlight the salient experimental findings and the possible explanation and evidence with a view to determine the cause and effect relationship with regard to different characters and shorting information of practical the results pertaining to the field experiments are discussed under here:-

5.1 Effect of varieties

5.1.1 Growth characters

Growth characters of knol-khol *viz*., height of the plant (cm), leaves per plant, leaf length (cm), leaf width (cm), plant spread (cm), stem girth (cm), days to knob initiation and knob harvest were noted at different growth stages (Table 4.1 to 4.6). The results exhibited considerable influence of varieties on all the growth characters except stem girth, days to initiation of knob and harvest of knob.

As the growth period progressed, the plant's height increased. The rise in height between knob beginnings was fast in comparison to the knob maturation. At 30 DAT and harvest stage, V_2 (White Vienna) had the highest plant height compared to V_1, V_3 and V_4. It was discovered to be rapidly growing. These results might be due to favourable environmental conditions prevailed during initial growth of crop. The genotype of each cultivar is largely responsible for the observed variances in plant height between cultivars. Similar results have been discovered by Giri *et al*., (2013), Zaki *et al*., (2015) in broccoli, EI- Bassiony *et al.*, (2014) and Chaudhari *et al*., (2015) in kohlrabi.

The number of leaves differed slightly amongst knol-khol varieties. At 30 DAT and at harvest stage, variety V_2 (White Vienna) observed highest leaves per plant. The difference

between all varieties was substantial at both stages. This may be because of number of leaves per plant generally governed by genetic behaviour of the variety. These findings are similar with Arin *et al.*, (2003) and EI- Bassiony *et al.*, (2014) in kohlrabi, Giri *et al*., (2013), Zaki *et al.*, (2015) in broccoli, Yadav *et al.*, (2013) in cauliflower, Boroujerdnia *et al.*, (2007) in Romaine lettuce and Silatar *et al*., (2018) in knol-khol.

Leaf length and leaf width has a significant effect of different varieties individual at all the stage. Variety V_2 (White Vienna) recorded maximum length and width of leaf as compared to V_1, V_3 and V_4 at 30 DAT and harvesting stage. This might be due to genetic characteristics of the cultivars. These results are remarkably comparable to those of Bhangre *et al.*, (2011) in broccoli and Giri (2020) in cauliflower.

Plant spread and stem girth recoded with White Vienna (V_2) performance is better as compare to other varieties. The increase in number of plants spread and stem girth due to favourable environmental conditions prevailed during initial growth of crop. Present results are in close accordance to the finding Ozbakir *et al.,* (2009) and Chaudhari *et al.,* (2015) in knol-khol.

Days to knob commencement was observed non-significant difference between among varieties. Variety (White Vienna) had found initial knob commencement in comparison to V_1 (Pusa Virat), V_3 (Early White Vienna) and V_4 (Palam Tender Knob). In terms of days to knob harvesting, there was no significant difference between varieties. Variety V_1 (Pusa Virat) had recorded earliest harvesting as compared to other varieties. Variety V_2 (White Vienna) had the longest days to knob harvest. As a result of the delay in knob commencement, harvesting was delayed, which might be related to the genetic makeup of the cultivars. These findings are comparable to those of Idczak and Trautwein (2007) in cauliflower, Hossain *et al.*, (2011) in

5.1.2 Yield and yield attributing traits

Yield attributes *viz.,* weight of knob (g), knob diameter (cm), knob volume (cc), yield of knob (kg/plot) and knob yield (q ha^{-1}) showed significant influence of different varieties.

The data accessible in (Table 4.7) obviously indicated that maximum knob weight was recorded under treatment V_2 (White Vienna) followed by V_3 (Early White Vienna), while minimum knob weight was noted in V_1 (Pusa Virat) at harvest. The genetic architecture of

different cultivars may be responsible for differences in weight of knob. These finding are in consistent with those reported by Arin *et al.*, (2003), EI- Bassiony *et al.*, (2014) in knol-khol and Zaki *et al.*, (2015) in broccoli. The highest diameter of knob was recorded under V_2 (White Vienna) followed by V_4 (Palam Tender Knob), while minimum diameter of knob was noted in V_1 (Pusa Virat) at harvest (Table 4.7). These results are consistent with Arin *et al.*, (2003), Giri *et al.*, (2013), EI-Bassiony *et al.*, (2014), Zaki *et al.*, (2015) in broccoli and Dolkar *et al.*, (2018) in knol-khol.

The data accumulated on volume of knob due to influence of different varieties have been displayed in (Table 4.8). The highest volume of knob was noticed in V_2 (White Vienna) which was found to be significantly higher as associated to other treatments but statistically at parity with V_3 (Early White Vienna). Similar results have been reported by Silatar *et al.*, (2018) in knol-khol.

The findings accumulated in (Table 4.9) clearly indicated that the maximum yield (kg/plot) and yield of knob (q/ha) were recorded under treatment V_2 (White Vienna) followed by V_3 (Early White Vienna), while lowest yield plot^{-1} and yield hectare $^{-1}$ was noted in V_1 (Pusa Virat) at harvest. Under V_2, the maximum growth and yield parameters resulted in a highest knob yield. The significant yield different among the varieties may be due to genetical parameter. Each individual variety has its own specific characteristics which are inheritant. Accordingly, variation in yield parameters may be attributed to the genetic difference of varieties leads to better yield., as it is also influenced by the environmental factors. Similar results were reported by Arin *et al.*, (2003), EI-Bassiony *et al.*, (2014), Iqbal *et al.*, (2010) in knol-khol, Singh *et al.*, (2014) in broccoli, Silatar, *et al*., (2018) in knol-khol and Giri (2020) in cauliflower.

5.1.3 Quality parameters

To investigate the effect of variety, quality criteria such as ascorbic acid, total soluble solids, total sugars, reducing sugars, non-reducing sugars and chlorophyll contents were evaluated.

The results of this study revealed that variations had a significant impact on ascorbic acid concentration in knobs (Table 4.10). Amongst the varieties, highest vitamin C was noted with V_2. Lowest vitamin C content was found in variety V_1. It's possible that the genetic makeup of these varieties has something to do with it. These results have parity with

Zaki *et al*., (2015) in Broccoli. The data accessible in (Table 4.10) clearly indicated that the highest TSS content in knob (^{0} Brix) was recorded under treatment V_4 (Palam Tender Knob) followed by V_3 (Early White Vienna), while lowest TSS was noted in V_1 (Pusa Virat). The data accumulated in (Table 4.11) clearly indicated that the maximum reducing sugar, non-reducing sugar and total sugars present in knob were noticed under treatment V_4 (Palam Tender Knob), while minimum reducing sugar, non-reducing sugar and total sugar present in knob were noted in V_1 (Pusa Virat). This might be due to genetic characteristics of the cultivars. Each individual variety has its own specific characteristics. These finding are in close conformity with Singhal *et al.*, (2009) in broccoli) and Zaki *et al.*, (2015) in Broccoli.

The findings presented in (Table 4.12) exhibited that different varieties showed substantial influence in chlorophyll contented in leaves of knol-khol. The maximum chlorophyll contented in plant leaves (0.70 mg/g and 0.73 mg/g) was noticed under treatment V_3 (Early White Vienna) while, the minimum chlorophyll content in plant leaves (0.58 mg/g and 0.61 mg/g) was recorded in V_1 (Pusa Virat) at 45 DAT. The current findings are in close accordance with the results of Wojciechowska *et al*., (2016) in cauliflower and broccoli.

5.1.4 Economics of the various treatments for knol-khol cultivation

The findings (Table 4.13) shows that different varieties of knol-khol had a considerable impact on gross returns, net returns, and the B:C ratio. Treatment V_2 (White Vienna) had the higher gross returns, net returns and B:C ratio, after by V_3 (Early White Vienna), whereas treatment V_1 (Pusa Virat) had the minimum gross returns, net returns and B:C ratio. This could be due to highest gross return and net return. The current findings are in close agreement with those of Singh (2015) in cabbage and Meena *et al*., (2017) in cauliflower.

5.2 Effect of spacing

5.2.1 Growth characters

Substantial increases in height of plant (cm), leaves per plant, leaf length (cm), leaf width (cm), plant spreading (cm) and stem girth (cm) were found due to greater spacing in the current study using S_4 (60 x 45 cm) followed by S_2 (45 x 30 cm) at 30 DAT and harvest. (Table 4.1 and 4.4) This treatment outperformed the others by a significant margin. Wider plant spacing leads to good growth and development, less competition for the uptake of nutrients, water and sunlight, which leads to more lateral growth of plant which may have

improved height of plant, number of leaf and chlorophyll contents. The current findings are in line with those of Patil *et al.*, (2003), Singh *et al.*, (2004), Prasad *et al.*, (2010), Khatun *et al*., (2011), Moniruzzaman (2011), Solunke *et al*., (2011), Dev (2012), Thirupal *et al.*, (2011), Mehta *et al.*, (2015), Tejaswini *et al*., (2018) in broccoli.

Days to knob commencement and harvesting decreased non-significantly under 60x45 cm spacing as opposed to 30x30 cm and 45x30 cm spacing, which were statistically comparable to spacing 45x45 cm (Table 4.6). The spacing is an imperative factor to understand the variance of a crop's performing metrics. Appropriate spacing in knol-khol reduces the number of days required for knob start and maturity, as well as the percentage of it. Nearer spacing takes less period to initiate knob initiation than broader spacing as it reduces crop maturation by limiting the amount of sunshine, fertilisation space and tissue activity in a particular area. In the closest spacing, the right time maturity was observed. Because there is more room, sunlight and fertilisation available with wider spacing, plants must take longer to accomplish their physical and biological functions. When the time it takes to initiate a knob is shortened, the time it takes to reach marketable maturity is likewise shortened, resulting in tighter spacing. These findings are very similar to the results of Patil *et al.*, (2003) in knol-khol, Khan *et al*., (1991), Bhangre *et al.*, (2011), Dev (2012) and Thirupal *et al.*, (2014) in broccoli who claimed that adjacent spacing shortened the time it took for knob commencement, head commencement, flower bud commencement.

5.2.2 Yield and yield attributing traits

Yield parameters viz., weight of knob (g), knob diameter (cm), knob volume (cc), yield of knob (kg/plot) and knob yield (q/ha) showed significant influence of different spacing.

It is deceptive from the data (Table 4.7) that different spacing had significant influence on the weight of knob. The maximum knob weight was found in treatment S_4 (60 x 45 cm) followed by S_3 (45 x45 cm) at harvest while, the minimum knob weight was recorded in S_1 (30 x 30 cm). The findings exhibited that the knob weight per plant grew greatly as the distance was extended (wider spacing) and decreased as the distance was reduced (closer spacing). Plants that were spaced further apart generated a higher knob than those that were spaced closer together. Wider spacing resulted in increased knob weight. These findings are very consistent with the results of Khurana *et al.*, (1987), Titze and Alpers (1987), Islam *et*

al., (1989), Tanjin (2007), El-Shabrawy *et al*., (2012), Haque *et al.*, (2015) in cabbage and Khatun *et al.*, (2011) in broccoli.

The data accumulated on knob diameter and knob volume due to influence of different spacing have been displayed in table 4.7 and 4.8. The highest diameter of knob and volume of knob were recorded under the treatment S_4 (60 x 45 cm) followed by S_3 (45 x 45 cm). The lowest diameter and volume of knob were recorded in S_1 (30 x 30 cm). According to the findings the diameter and volume of the knob grew dramatically with increasing degrees of distance (broader spacing) and reduced with closest spacing. This could be due to a greater plant population in a given area, resulting in intense struggle for nutrition and sunshine, lowering diet assimilatory competence and as a result, a lower reserve of food in knobs, reducing knob weight and size. The data support Nieuwhof's (1969) hypothesis that larger spacing increases the weight of the knol-khol knob. Sande and Jaurissen (1986) similarly found that when the density increased, the size and weight of the knob reduced. Lawande *et al*., (1986) found that when cabbage plants were spaced closer together, their size decreased. These findings are in line with the rest of the study's results of Znidarcic *et al.*, (2007), El-Shabrawy *et al.*, (2012) in cabbage and Khatun *et al.*, (2011) in broccoli.

The data existing in (Table 4.9) showed that different varieties showed substantial improvement in yield of knob/plot and yield of knob/ha of knol-khol. The maximum yield of knob/plot and yield of knob/ha were found in treatment S_4 (60 x 45 cm) followed by S_3 (45 x45 cm) while, the minimum yield of knob/plot and yield of knob/ha were recorded in S_1 (30 x 30 cm). The overall yield of knol-khol reduced dramatically as the spacing was increased. It could be because the quantity of knobs gathered in a certain area decreased by way of the spacing grew. In other words, increased knol-khol yields with closer spacing were attributed to a larger plant population being accommodated in a given space. Wider spacing resulted in lower yields due to a lower plant populace in area, but quality of knob enhanced as the fruit size became larger and the unit knob weight increased. These findings are very similar to the findings of Patil *et al.*, (2003), Rai *et al.*, (2003) in knol-khol, Kumar and Rawat (2002), Singh *et al.*, (2004), Haque *et al*., (2015) in cabbage, Prasad *et al.*, (2010), Khatun *et al.*, (2011), Dev (2012) and Thirupal *et al*., (2014) in broccoli.

5.2.3 Quality parameters

Quality parameters *viz*., vitamin C, total soluble solids, total sugars, reducing sugars, non-reducing sugars and chlorophyll were determined to evaluate the impact of various spacing.

The current study discovered that varied spacing has a substantial impact on the ascorbic acid concentration of knol-khol knobs (Table 4.10). The highest ascorbic acid concentration in the knob was identified in treatment S_2 (45 x 30 cm), whereas the lowest ascorbic acid level in the knob was observed in treatment S_1 (30 x 30 cm). The increased in plant foliage might be reduced in light intensity and accumulation of ascorbic acid. These results are accordance with Lee and Kadar (2000) and Giri (2020) in cauliflower.

The findings of this study demonstrate that increasing the spacing raises the TSS content of knol-khol. The total soluble solids content in knob of knol-khol significantly influenced by different spacing (Table 4.10). The maximum TSS content in knob was recorded under treatment S_3 (45 x 30 cm). The minimum TSS content in knob was noticed under treatment S_1 (30 x 30 cm). These results might be due to increasing fertility and spacing level increases in TSS content. These findings are very similar to the results of Mehta *et al.*, (2015) in sprouting broccoli, Pornsuriya *et al.*, (1997), Kumar and Rawat (2002), Znidarcic *et al.*, (2007) in cabbage and Grabowska *et al.*, (2009) in broccoli.

The findings of current investigation show that different spacing significantly increase the total sugars, reducing sugar and non-reducing sugar content in knob of knol-khol. The maximum total sugars, reducing sugar and non-reducing sugar content in knob were noted in treatment S_4 (60 x 45 cm) while, the minimum total sugars, reducing sugar and non-reducing sugar content in knob of knol-khol were recorded in S_1 (30 x 30 cm). These quality attributes concentration significantly affected by closer plant spacing and some condition may be due to wider spacing plant get more better light, better availability of space, aeration and soil moisture as well as better nutrient for growth. These findings are quite consistent with the results of Suthar *et al.*, (2017) and Bairwa *et al*., (2017) in knol-khol.

The data exhibited in (Table 4.12) indicated that different spacing showed considerable influence in chlorophyll contents in leaves of knol-khol. The maximum chlorophyll content was recorded under treatment S_4 (60 x 45 cm). The minimum chlorophyll content in plant leaves was noticed under treatment S_1 (30 x 30 cm). It might be due to wider spacing plant received more sunlight and more nutrients due to less number of plants which could increase the chlorophyll content in leaves. The current findings are very similar to the results of Patil *et al*., (2003) in knol-khol, Singh *et al*., (2004), Prasad *et al*., (2010) in broccoli, Khatun *et al*., (2011) in broccoli, Thirupal *et al*., (2014) in broccoli.

5.2.4 Economics of treatments

Different spacing had a substantial impact on gross returns, net returns and the B:C ratio of knol-khol, as evidenced by data (Table 4.13). Treatment S_1 (30 x 30 cm) yielded the highest gross returns, net returns, and B:C ratio. Under treatment S_4 (60 x 45 cm), the lower gross returns, net returns and B:C ratio were observed. The low management cost in relation to extra output resulted in a higher net return under this treatment. The current findings are in full conformity with those of Bairwa *et al*., (2017) in knol-khol and Kaur *et al*., (2020) in cauliflower.

Chapter - 6

SUMMARY AND CONCLUSION

The current findings of the experiment entitled **"Effect of varieties and spacing on growth, yield and quality of knol-khol (*Brassica oleracea* var. *gongylodes* L.)"** conducted at Horticultural Research Farm-I, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya-Vihar, Rae Bareli Road, Lucknow, (U.P.), India during *Rabi* season 2018-19 and 2019-20, respectively. The studies on vegetative growth, yield and quality. The most important aspects of the study reported and mentioned in the preceding chapters are described below.

Effect of varieties:

1. The maximum plant height (17.40 cm) at 30 DAT and (29.77 cm) at harvest was obtained under the treatment V_2 (White Vienna) followed by V_3 (Early White Vienna). While, the minimum plant height (15.93 cm) at 30 DAT and (27.36 cm) at harvest was noticed in V_1 (Pusa Virat).
2. The maximum number of leaves per plant was noticed in V_2 (White Vienna) (11.20) at 30 DAT and (18.89) at harvest followed by V_4 (Palam Tender Knob) while, the minimum leaves at 30 DAT (9.71) and at harvest (17.10) were recorded in V_1 (Pusa Virat).
3. The maximum length of leaf was noticed in V_2 (White Vienna) (11.20 cm) at 30 DAT and (24.56 cm) at harvest followed by V_4 (Palam Tender Knob) while, the minimum length of leaf (9.71 cm) at 30 DAT and (21.76 cm) at harvest was recorded in V_1 (Pusa Virat).
4. The maximum width of leaf was obtained in V_2 (White Vienna) (10.29 cm) at 30 DAT and (26.41 cm) at harvest followed by V_4 (Palam Tender Knob) while, the minimum width of leaf (8.65 cm) at 30 DAT and at harvest (22.94 cm) was obtained in V_1 (Pusa Virat).
5. The maximum spread of plant (29.92 cm) at harvest was noted in treatment V_4 (Palam Tender Knob) while, minimum spread of plant (28.40 cm) at harvest was found in V_1 (Pusa Virat).
6. The maximum stem girth (11.37 cm) at harvest was obtained in V_1 (Pusa Virat) while, minimum stem girth (10.97 cm) at harvest was noted in V_2 (White Vienna). It was found statistically non-significant to all varieties.
7. The minimum days to knob initiation was obtained (34.83) under the treatment V_2 (White Vienna) while, maximum (37.54) days to knob initiation was obtained under the treatment V_4 (Palam Tender Knob). It was found statistically non-significant to all varieties.

8. The minimum days to knob harvest obtained (63.08) under the treatment V_1 (Pusa Virat) while, maximum (64.30) days to knob harvest was obtained under the treatment V_2 (White Vienna). It was found statistically non-significant to all varieties.
9. The maximum knob weight (221.14 g) was observed in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna). While minimum knob weight (192.22 g) was noted in V_1 (Pusa Virat).
10. The highest knob diameter (5.55 cm) was recorded in V_2 (White Vienna) followed by V_4 (Palam Tender Knob), while lowest values (4.48 cm) was noted in V_1 (Pusa Virat).
11. The highest knob volume (113.68 cc) was obtained in V_4 (Palam Tender Knob), which was noted to be considerably greater as compared to rest of treatments but statistically similar with V_3 (Early White Vienna) while, minimum volume of knob (102.46 cc) was found under the treatment V_1 (Pusa Virat).
12. The maximum yield per plot (4.68 kg) was noticed in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna). Whereas highest yield per plot (4.10 kg) was noted in V_1 (Pusa Virat).
13. The highest knob yield per ha (145.06 q) was recorded in variety V_2 (White Vienna) followed by V_3 (Early White Vienna) while minimum knob yield per ha (126.46 q) was noted in V_1 (Pusa Virat).
14. The maximum TSS content in knob (3.53 ^{0}Brix) was noted in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna). While minimum TSS content in knob (2.83 ^{0}Brix) was recorded in V_1 (Pusa Virat).
15. The maximum vitamin C (37.26 mg/100g) was observed in treatment V_2 (White Vienna). While minimum vitamin C content (33.96 mg/100g) was obtained in V_1 (Pusa Virat).
16. The maximum reducing sugar content in knob (1.77 %) was noticed in treatment V_3 (Early White Vienna) followed by V_4 (Palam Tender Knob). While minimum reducing sugar content in knob (1.40 %) was noted in V_1 (Pusa Virat).
17. The maximum non-reducing sugar content in knob (0.69 %) was found in treatment V_4 (Palam Tender Knob) followed by V_2 (White Vienna). While minimum non-reducing sugar content in knob (0.54 %) was noted in V_1 (Pusa Virat).
18. The maximum total sugars content in knob (2.44 %) was recorded in treatment V_4 (Palam Tender Knob) followed by V_3 (Early White Vienna). While minimum total sugars content in knob (1.94 %) was noted in V_1 (Pusa Virat).

19. The maximum chlorophyll contents in plant leaves (0.71 mg/g) was recorded in treatment V_3 (Early White Vienna) followed by V_4 (Palam Tender Knob) at 45 DAT. However lowest chlorophyll contents in plant leaves (0.60 mg/g) was noted in V_1 (Pusa Virat).
20. The maximum gross returns (1.44290 Rs/ha) was noted in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (1.41.011 Rs/ha). While minimum gross returns (1,25,926 Rs/ha) was noted in V_1 (Pusa Virat).
21. The maximum net returns (89,606 Rs/ha) was noted in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (84,323 Rs/ha). While minimum net returns (69,125 Rs/ha) was noted in V_1 (Pusa Virat).
22. The maximum B:C ratio (1.57) was obtained in treatment V_2 (White Vienna) followed by V_3 (Early White Vienna) (1.48). While lowest B:C ratio (1.21) was noted in V_1 (Pusa Virat).

Effect of spacing:

1. The maximum plant height (18.00 cm) at 30 DAT and (31.22 cm) at harvest was found in S_4 (60 x 45 cm) while, the minimum plant height (15.50 cm) at 30 DAT and (27.23 cm) at harvest was noticed in S_1 (30 x 30 cm).
2. The maximum leaves per plant (11.68) at 30 DAT and (18.83) at harvest was obtained maximum under the treatment S_4 (60 x 45 cm) while, minimum number of leaves (9.77) at 30 DAT and (17.12) at harvest was recorded under the treatment S_1 (30 x 30 cm).
3. The maximum length of leaf (11.68 cm) at 30 DAT and (25.20 cm) at harvest was obtained under the treatment S_4 (60 x 45 cm) while, minimum length of leaf (9.77 cm) at 30 DAT and (22.65 cm) at harvest was found under the treatment S_1 (30 x 30 cm).
4. The maximum width of (10.76 cm) at 30 DAT and (26.44 cm) at harvest was obtained under the treatment S_4 (60 x 45 cm) while, minimum width of leaf (8.52 cm) at 30 DAT and (24.46 cm) at harvest was noted under the treatment S_1 (30 x 30 cm).
5. The maximum plant spread (30.96 cm) at harvest was found under the treatment S_4 (60 x 45 cm) while, minimum plant spread (27.98 cm) was recorded under the treatment S_1 (30 x 30 cm).
6. The maximum stem girth (11.35 cm) at harvest was recorded under the treatment S_4 (60 x 45 cm) while, minimum stem girth (11.04 cm) was found under the treatment S_1 (30 x 30 cm).
7. The minimum days to knob initiation (34.13) was obtained minimum under the treatment S_2 (45 x 30 cm) while, maximum (38.04) days to knob initiation was obtained under the treatment S_4 (60 x 45 cm). It was found statistically non-significant to all spacing.

8. The minimum days to knob harvest (62.98) was obtained under the treatment S_1 (30 x 30 cm) while, maximum (64.94) days to knob harvest was obtained under the treatment S_4 (60 x 45 cm). It was found statistically non-significant to all spacing.
9. The maximum weight of knob (229.91 g) was obtained maximum under the treatment S_4 (60 x 45 cm) while, minimum knob weight (191.76 g) was noted under the treatment S_1 (30 x 30 cm).
10. The highest knob diameter (5.81 cm) was noticed in the treatment S_4 (60 x 45 cm) followed by S_3 (45 x 45 cm) while the minimum diameter of knob (4.46 cm) was reported in S_1 (30 x 30 cm).
11. The highest knob volume (114.34 cc) was obtained in treatment S_4 (60 x 45 cm) while, minimum volume of knob (103.73 cc) was found under the treatment S_1 (30 x 30 cm).
12. The highest yield/plot (6.79 kg) was obtained in treatment S_1 (30 x 30 cm) while, minimum yield/plot (2.76 kg) was observed in treatment S_4 (60 x 45 cm).
13. The maximum knob yield (209.49 q/ha) was obtained maximum under the treatment S_1 (30 x 30 cm) while, minimum knob yield (85.03 q/ha) was found under the treatment S_4 (60 x 45 cm).
14. The maximum TSS content in knob (3.30 ^{0}Brix) was obtained maximum under the treatment S_3 (45 x 30 cm) while, minimum TSS content in knob (3.10 ^{0}Brix) was recorded under the treatment S_1 (30 x 30 cm).
15. The maximum ascorbic content in knob (36.76 mg/100g) was obtained maximum under the treatment S_2 (45 x 30 cm) while, minimum ascorbic acid content in knob (35.66 mg/100g) was noted under the treatment S_1 (30 x 30 cm).
16. The maximum reducing sugar content in knob (1.77 %) was obtained maximum under the treatment S_3 (45 x 45 cm) while, minimum reducing sugar content in knob (1.45 %) was observed under the treatment S_1 (30 x 30 cm).
17. The maximum non-reducing sugar content in knob (0.66 %) was obtained maximum under the treatment S_1 (30 x 30 cm) while, minimum non-reducing sugar content in knob (0.58 %) was recorded under the treatment S_3 (45 x 45 cm).
18. The maximum total sugars content in knob (2.35 %) was obtained maximum under the treatment S_4 (60 x 45 cm) while, minimum total sugars content in knob (2.12 %) was found under the treatment S_1 (30 x 30 cm).
19. The maximum chlorophyll concentration in plant leaves (0.68 mg/g) at 45 DAT was obtained in treatment S_4 (60 x 45 cm) whereas, lower chlorophyll concentration in plant leaves (0.66 mg/g) was obtained in the treatment S_1 (30 x 30 cm).

20. The maximum gross returns (2,09,413 Rs/ha) was obtained under the treatment S_1 (30 x 30 cm) while, minimum gross returns (85,012 Rs/ha) was observed under the treatment S_4 (60 x 45 cm).
21. The maximum net returns (1,51,675 Rs/ha) was obtained maximum under the treatment S_1 (30 x 30 cm) while, minimum net returns (28,980 Rs/ha) was recorded under the treatment S_4 (60 x 45 cm).
22. The maximum B:C ratio (2.62) was noted maximum in the treatment S_1 (30 x 30 cm) however, lowest B:C ratio (0.52) was observed in the treatment S_4 (60 x 45 cm).

CONCLUSION

On the basis of results obtained in present investigation, it can be concluded that the effect of varieties and spacing on the growth, yield and quality of knol-khol was significantly. The White Vienna with spacing of 60 x 45 cm proved to be most effective in increasing the plant height, number of leaves, length of leaf, width of leaf, plant spread, weight of knob and volume of knob of knol-khol. While maximum yield, net returns and B:C ratio were obtained in White Vienna with spacing 30 x30 cm. In quality traits like total soluble solids, non-reducing sugar and total sugars were found maximum in Palam Tender Knob except reducing sugar and chlorophyll content. Hence, the variety White Vienna with 30 x 30 cm spacing may be suggested for higher crop production and can be recommended to farmers for successful cultivation of knol-khol (*Brassica oleracea* var. *gongylodes* L.) under Lucknow conditions.

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APPENDICES

Appendix-i Analysis of variance for plant height at 30 DAT in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	2.52	2.60	1.26	1.30	0.898	5.486
Treatment	15	81.30	58.87	5.42	3.92	3.871	16.577
Variety	3	23.09	6.83	7.70	2.28	5.498	9.614
Spacing	3	44.01	37.31	14.67	12.44	10.477	52.535
Interaction V x S	9	14.20	14.73	1.58	1.64	1.127	6.912
Error	30	42.00	7.10	1.40	0.24		
Total	47	125.82	68.57				

Significant at 5 % level of significance

Analysis of variance for plant height at harvest in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	2.52	2.60	1.26	1.30	0.898	5.486
Treatment	15	81.30	58.87	5.42	3.92	3.871	16.577
Variety	3	23.09	6.83	7.70	2.28	5.498	9.614
Spacing	3	44.01	37.31	14.67	12.44	10.477	52.535
Interaction V x S	9	14.20	14.73	1.58	1.64	1.127	6.912
Error	30	42.00	7.10	1.40	0.24		
Total	47	125.82	68.57				

Significant at 5 % level of significance

Appendix-ii Analysis of variance for number of leaves at 30 DAT in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.87	2.98	0.43	1.49	0.72	2.84
Treatment	15	49.54	52.16	3.30	3.48	5.52	6.63
Variety	3	23.86	8.96	7.95	2.99	13.30	5.69
Spacing	3	20.56	31.58	6.85	10.53	11.46	20.07
Interaction V x S	9	5.12	11.62	0.57	1.29	0.95	2.46
Error	30	17.94	15.74	0.60	0.52		
Total	47	68.34	70.88				

Significant at 5 % level of significance

Analysis of variance for number of leaves at harvest in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	1.94	2.75	0.97	1.38	1.46	2.60
Treatment	15	81.35	52.08	5.42	3.47	8.17	6.57
Variety	3	43.73	8.84	14.58	2.95	21.97	5.58
Spacing	3	10.64	32.92	3.55	10.97	5.34	20.78
Interaction V x S	9	26.98	10.32	3.00	1.15	4.52	2.17
Error	30	19.90	15.85	0.66	0.53		
Total	47	103.20	70.68				

Significant at 5 % level of significance

Appendix-iii Analysis of variance for length of leaf at 30 DAT in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	1.20	0.42	0.60	0.21	1.70	1.19
Treatment	15	48.26	66.44	3.22	4.43	9.10	25.03
Variety	3	11.93	22.70	3.98	7.57	11.25	42.76
Spacing	3	30.85	40.74	10.28	13.58	29.09	76.76
Interaction V x S	9	5.47	3.00	0.61	0.33	1.72	1.88
Error	30	10.61	5.31	0.35	0.18		
Total	47	60.07	72.17				

Significant at 5 % level of significance

Analysis of variance for length of leaf at harvest in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.93	0.45	0.47	0.23	0.77	0.20
Treatment	15	90.04	169.38	6.00	11.29	9.91	9.75
Variety	3	33.23	86.97	11.08	28.99	18.29	25.03
Spacing	3	32.27	58.82	10.76	19.61	17.76	16.93
Interaction V x S	9	24.54	23.60	2.73	2.62	4.50	2.26
Error	30	18.17	34.74	0.61	1.16		
Total	47	109.14	204.57				

Significant at 5 % level of significance

Appendix-iv Analysis of variance for width of leaf at 30 DAT in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.63	3.11	0.32	1.56	0.80	10.93
Treatment	15	82.98	53.99	5.53	3.60	13.90	25.25
Variety	3	44.55	6.29	14.85	2.10	37.31	14.70
Spacing	3	26.18	44.56	8.73	14.85	21.92	104.23
Interaction V x S	9	12.25	3.14	1.36	0.35	3.42	2.45
Error	30	11.94	4.28	0.40	0.14		
Total	47	95.55	61.38				

Significant at 5 % level of significance

Analysis of variance for width of leaf at harvest in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	1.99	4.45	0.99	2.22	0.40	5.51
Treatment	15	143.61	151.70	9.57	10.11	3.84	25.06
Variety	3	97.26	90.52	32.42	30.17	12.99	74.76
Spacing	3	32.77	32.23	10.92	10.74	4.38	26.62
Interaction V x S	9	13.58	28.95	1.51	3.22	0.60	7.97
Error	30	74.89	12.11	2.50	0.40		
Total	47	220.48	168.26				

Significant at 5 % level of significance

Appendix-v Analysis of variance for plant spread in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	1.80	0.47	0.90	0.24	1.72	0.20
Treatment	15	105.18	115.54	7.01	7.70	13.37	6.55
Variety	3	16.96	19.04	5.65	6.35	10.78	5.40
Spacing	3	67.58	67.60	22.53	22.53	42.94	19.17
Interaction V x S	9	20.64	28.90	2.29	3.21	4.37	2.73
Error	30	15.74	35.27	0.52	1.18		
Total	47	122.72	151.28				

Significant at 5 % level of significance

Appendix -vi Analysis of variance for stem girth in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.00	0.01	0.00	0.00	0.22	1.03
Treatment	15	0.08	0.04	0.01	0.00	1.06	0.62
Variety	3	0.03	0.01	0.01	0.00	1.92	0.77
Spacing	3	0.01	0.01	0.00	0.00	0.65	0.69
Interaction V x S	9	0.04	0.02	0.00	0.00	0.91	0.55
Error	30	0.16	0.14	0.01	0.00		
Total	47	0.24	0.19				

Significant at 5 % level of significance

Appendix -vii Analysis of variance for days to knob initiation in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	44.15	141.75	22.08	70.88	3.04	2.20
Treatment	15	125.47	606.51	8.36	40.43	1.15	1.25
Variety	3	62.82	61.30	20.94	20.43	2.88	0.63
Spacing	3	19.30	252.60	6.43	84.20	0.89	2.61
Interaction V x S	9	43.35	292.61	4.82	32.51	0.66	1.01
Error	30	218.06	967.36	7.27	32.25		
Total	47	387.68	1715.62				

Significant at 5 % level of significance

Appendix -viii Analysis of variance for days to knob harvesting in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	118.01	17.17	59.01	8.58	7.97	0.40
Treatment	15	156.09	83.55	10.41	5.57	1.41	0.26
Variety	3	14.42	11.52	4.81	3.84	0.65	0.18
Spacing	3	68.60	32.39	22.87	10.80	3.09	0.51
Interaction V x S	9	73.07	39.64	8.12	4.40	1.10	0.21
Error	30	222.05	640.47	7.40	21.35		
Total	47	496.15	741.19				

Significant at 5 % level of significance

Appendix -ix Analysis of variance for weight of knob in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	154.63	252.15	77.31	126.07	0.28	0.44
Treatment	15	16222.29	18989.15	1081.49	1265.94	3.94	4.40
Variety	3	4419.95	7264.91	1473.32	2421.64	5.37	8.41
Spacing	3	10301.11	9818.59	3433.70	3272.86	12.51	11.37
Interaction V x S	9	1501.23	1905.66	166.80	211.74	0.61	0.74
Error	30	8237.53	8637.73	274.58	287.92		
Total	47	24614.44	27879.03				

Significant at 5 % level of significance

Appendix -x Analysis of variance for diameter of knob in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.99	0.42	0.49	0.21	4.93	1.57
Treatment	15	23.35	24.99	1.56	1.67	15.54	12.43
Variety	3	7.83	6.60	2.61	2.20	26.08	16.42
Spacing	3	8.93	17.07	2.98	5.69	29.73	42.47
Interaction V x S	9	6.58	1.32	0.73	0.15	7.30	1.09
Error	30	3.00	4.02	0.10	0.13		
Total	47	27.34	29.43				

Significant at 5 % level of significance

Appendix -xi Analysis of variance for volume of knob in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	349.84	278.40	174.92	139.20	3.33	3.51
Treatment	15	2385.26	1675.45	159.02	111.70	3.03	2.82
Variety	3	1077.77	583.80	359.26	194.60	6.85	4.91
Spacing	3	980.90	852.22	326.97	284.07	6.23	7.17
Interaction V x S	9	326.59	239.44	36.29	26.60	0.69	0.67
Error	30	1574.14	1188.96	52.47	39.63		
Total	47	4309.24	3142.81				

Significant at 5 % level of significance

Appendix -xii Analysis of variance for yield per plot in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.01	0.04	0.00	0.02	0.03	0.12
Treatment	15	122.67	115.62	8.18	7.71	58.79	50.51
Variety	3	2.02	3.04	0.67	1.01	4.83	6.64
Spacing	3	119.74	111.57	39.91	37.19	286.91	243.72
Interaction V x S	9	0.91	1.01	0.10	0.11	0.73	0.73
Error	30	4.17	4.58	0.14	0.15		
Total	47	126.85	120.23				

Significant at 5 % level of significance

Appendix -xiii Analysis of variance for yield per ha in knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	12.55	48.26	6.27	24.13	0.05	0.17
Treatment	15	116751.10	110755.00	7783.41	7383.67	58.58	51.27
Variety	3	1908.16	2880.81	636.05	960.27	4.79	6.67
Spacing	3	113979.89	106978.05	37993.30	35659.35	285.96	247.62
Interaction V x S	9	863.05	896.15	95.89	99.57	0.72	0.69
Error	30	3985.89	4320.22	132.86	144.01		
Total	47	120749.54	115123.48				

Significant at 5 % level of significance

Appendix -xiv Analysis of variance for total soluble solids content in knob of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.95	0.67	0.48	0.34	2.92	3.40
Treatment	15	10.02	6.68	0.67	0.45	4.09	4.50
Variety	3	2.44	3.06	0.81	1.02	4.99	10.31
Spacing	3	0.57	0.10	0.19	0.03	1.17	0.32
Interaction V x S	9	7.00	3.53	0.78	0.39	4.77	3.96
Error	30	4.89	2.97	0.16	0.10		
Total	47	15.86	10.33				

Significant at 5 % level of significance

Appendix -xv Analysis of variance for vitamin C content in knob of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.04	3.27	0.02	1.63	0.02	3.68
Treatment	15	180.50	190.32	12.03	12.69	12.68	28.57
Variety	3	86.06	69.81	28.69	23.27	30.24	52.40
Spacing	3	12.40	10.88	4.13	3.63	4.36	8.17
Interaction V x S	9	82.03	109.62	9.11	12.18	9.61	27.43
Error	30	28.46	13.32	0.95	0.44		
Total	47	209.00	206.91				

Significant at 5 % level of significance

Appendix -xvi Analysis of variance for reducing sugar content in knob of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.02	0.03	0.01	0.01	0.47	0.67
Treatment	15	2.49	2.29	0.17	0.15	8.35	8.07
Variety	3	0.86	1.09	0.29	0.36	14.38	19.18
Spacing	3	0.86	0.57	0.29	0.19	14.50	10.02
Interaction V x S	9	0.77	0.63	0.09	0.07	4.29	3.72
Error	30	0.60	0.57	0.02	0.02		
Total	47	3.10	2.88				

Significant at 5 % level of significance

Appendix -xvii Analysis of variance for non-reducing sugar content in knob of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.00	0.00	0.00	0.00	0.39	0.06
Treatment	15	0.22	0.53	0.01	0.04	3.77	5.60
Variety	3	0.10	0.27	0.03	0.09	8.87	14.14
Spacing	3	0.04	0.09	0.01	0.03	3.38	4.67
Interaction V x S	9	0.08	0.17	0.01	0.02	2.20	3.06
Error	30	0.11	0.19	0.00	0.01		
Total	47	0.33	0.72				

Significant at 5 % level of significance

Appendix -xviii Analysis of variance for total sugar content in knob of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.05	0.03	0.03	0.01	0.65	0.60
Treatment	15	2.58	3.47	0.17	0.23	4.17	9.87
Variety	3	1.27	2.41	0.42	0.80	10.26	34.32
Spacing	3	0.62	0.27	0.21	0.09	5.00	3.91
Interaction V x S	9	0.69	0.78	0.08	0.09	1.87	3.71
Error	30	1.24	0.70	0.04	0.02		
Total	47	3.87	4.20				

Significant at 5 % level of significance

Appendix -xix Analysis of variance for chlorophyll content in leaves of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.02	0.02	0.01	0.01	3.13	4.16
Treatment	15	0.16	0.14	0.01	0.01	3.71	4.62
Variety	3	0.10	0.09	0.03	0.03	12.37	14.99
Spacing	3	0.01	0.01	0.00	0.00	1.18	1.10
Interaction V x S	9	0.04	0.04	0.00	0.00	1.67	2.34
Error	30	0.08	0.06	0.00	0.00		
Total	47	0.26	0.21				

Significant at 5 % level of significance

Appendix -xx Analysis of variance for gross returns of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	33105154	34372887	16552577	17186443	0.11	0.12
Treatment	15	117037479697	110178623725	7802498646	7345241581	52.41	50.52
Variety	3	2132152356	2889806675	710717452	963268891	4.77	6.63
Spacing	3	113627193222	106326461541	37875731074	35442153847	254.44	243.76
Interaction V x S	9	1278134118	962355508	142014902	106928389	0.95	0.74
Error	30	4465836245	4361878912	148861208	145395963		
Total	47	121536421097	114574875525				

Significant at 5 % level of significance

Appendix -xxi Analysis of variance for net returns of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	31036017	66233304	15518008	33116652	0.10	0.19
Treatment	15	114382339658	105221184131	7625489311	7014745609	50.88	39.67
Variety	3	2144838875	3538861790	714946292	1179620597	4.77	6.67
Spacing	3	110945737708	100323144573	36981912569	33441048191	246.77	189.11
Interaction V x S	9	1291763075	1359177769	143529231	151019752	0.96	0.85
Error	30	4495932117	5304903163	149864404	176830105		
Total	47	118909307792	110592320598				

Significant at 5 % level of significance

Appendix -xxii Analysis of variance for B:C ratio of knolkhol

Source of variation	D.F.	Sum of Squares		Mean Squares		F-Calculated	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Replication	2	0.01	0.02	0.00	0.01	0.10	0.18
Treatment	15	33.73	31.05	2.25	2.07	49.63	38.96
Variety	3	0.66	1.10	0.22	0.37	4.84	6.88
Spacing	3	32.68	29.52	10.89	9.84	240.42	185.18
Interaction V x S	9	0.39	0.44	0.04	0.05	0.96	0.92
Error	30	1.36	1.59	0.05	0.05		
Total	47	35.10	32.67				

Significant at 5 % level of significance

Appendix -xxiii General cost cultivation of Knol-khol crop (Rs ha^{-1}) (Including the cost of treatment inputs)

S.N.	Particulars	Unit	Cost/ Unit (Rs.)	Cost/ha (Rs)
I.	**Variables**			
A.	Service charges for land preparation by tractor (4 ploughing and one planking)	8 hrs	400 per hour	3200
	Sub total			**3200.00**
B	**Labour charges**			
(i)	Nursery seed bed preparation	4 man days	300	1200
(ii)	Sowing of seed and seed treatment	2 man days	300	600
(iii)	Weeding of nursery bed	8 man days	300	2400
(iv)	Layout of experimental field	6 man days	300	1800
(v)	Transplanting of seedlings	8 man days	300	2400
(vi)	Gap filling	2 man days	300	600
(vii)	Irrigation labour	12 man days	300	3600
(viii)	Weeding and hoeing	18 man days	300	2400
(ix)	Spraying of insecticide	4 man days	300	1200
(x)	Harvesting and selling	25 man days	300	7500
(xi)	Miscellaneous	5 man days	300	1500
	Sub total			**25200.00**
C.	**Material inputs**			
(i)	Fungicide for seed treatment	2 g	5000 kg^{-1}	10
(ii)	Farm yard manure (FYM)	15000 kg	0.5 kg^{-1}	7500
(iii)	Irrigation cost (in terms of electricity and other cost)	18 man days	300	5400
(iv)	Malathion 50 EC	1.5 lit/ha	320	480
(v)	Urea	310 kg	6.66 kg^{-1}	2064
(vi)	DAP	254 kg	24	6096

(vii)	MOP	160 kg	17.50	2800
	Sub total			**24350**
ll.	**Fixed cost**			
(i)	Rental value of land	-	-	1000
(ii)	Interest on working capital	-	-	500
(iii)	Depreciation	-	-	600
	Sub total			**2100**
	Total			**54850**

General cost of cultivation = I (A) + I (B) + I (C) + II

= 3200 + 25200 + 24350 + 2100 = **54850**

Cost of specific treatments of vegetable knol-khol given to different plots as per the experimental schedule

S.N.	Particulars	Seed rate/ha	Cost/ Unit (Rs.)
i.	S_1 (30 x 30 cm)	1.5 kg	3000
ii.	S_2 (45 x 30 cm)	1 kg	2000
iii.	S_3 (45 x 45 cm)	800 g	1600
iv.	S_4 (60 x 45 cm)	600 g	1200

Appendix -xxiv Economics of mean various treatments estimated on the basis of yield per hectare 2018-19 and 2019-20.

Treatment combination	Common cost (₹/ha)	Treatment cost (₹/ha)	Total cost (₹/ha)	Yield (q/ha)	Gross returns (₹ha)	Net returns (₹/ha)	B:C ratio
V_1S_1	54850	3000	57850	194.35	191975	134125	2.32
V_1S_2	54850	2000	56850	133.95	133952	77102	1.36
V_1S_3	54850	1600	56450	96.36	96605	40148	0.71
V_1S_4	54850	1200	56050	81.17	81173	25123	0.45
V_2S_1	54850	3000	57850	218.06	218055	160205	2.77
V_2S_2	54850	2000	56850	163.89	150153	93303	1.64
V_2S_3	54850	1600	56450	111.27	104322	56338	1.00
V_2S_4	54850	1200	56050	87.04	88115	32065	0.57
V_3S_1	54850	3000	57850	213.58	213580	156178	2.70
V_3S_2	54850	2000	56850	157.10	157100	100250	1.76
V_3S_3	54850	1600	56450	108.95	108950	52500	0.93
V_3S_4	54850	1200	56050	84.41	84413	28363	0.51
V_4S_1	54850	3000	57850	211.96	214042	156192	2.70
V_4S_2	54850	2000	56850	150.15	163887	107037	1.89
V_4S_3	54850	1600	56450	103.86	110805	54355	0.96
V_4S_4	54850	1200	56050	87.50	86345	30370	0.54

Sale price of knob = ₹ 10/kg

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