EFFECT OF SPACING ON GROWTH, YIELD AND QUALITY OF TIKHUR (*Curcuma angustifolia* Roxb.)

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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for the Degree of

MASTER OF SCIENCE
IN
HORTICULTURE
(VEGETABLE SCIENCE)

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Enrolment Number – LL/317 **2019**

DECLARATION OF STUDENT

I hereby declare that, the experimental work and its interpretation in the thesis entitled **" EFFECT OF SPACING ON GROWTH, YIELD AND QUALITY OF TIKHUR (*Curcuma angustifolia* Roxb.)"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Akola **(Ghyar Madhuri Pandurang)**

Date: / /2019 Enrolment No. LL/317

CERTIFICATE

This is to certify that, the thesis entitled **" EFFECT OF SPACING ON GROWTH, YIELD AND QUALITY OF TIKHUR (*Curcuma angustifolia* Roxb.)"** submitted in partial fulfillment of the requirement for the degree of **"Master of Science in Horticulture (Vegetable Science)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Ghyar Madhuri Pandurang** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

Place : Akola
Date : / /2019

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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA–VOCE)

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(D) Abbreviations

@	-	at the rate
%	-	per cent
/	-	Per
Anon.	-	Anonymous
B:C ratio	-	Benefit cost ratio
^0C	-	Degree Celsius
CC	-	Cost of cultivation
CD	-	Critical Difference
c.f.	-	Cited from
cm	-	Centimetre
Cv	-	Cultivar
cm^2	-	Centimeter square
DAP	-	Days after planting
day^{-1}	-	Per day
e. g.	-	Exampli gratia (for example)
et al.	-	et alia (and others)
etc	-	etcetera
Fig.	-	Figure
FYM	-	Farm Yard Manure
GMR	-	Gross monitory return
g	-	Gram
H_2SO_4	-	Sulphuric acid
ha.	-	Hectare
ha^{-1}.	-	Per hectare
hr	-	Hours
i.e.	-	Id est. (that is)
J	-	Journal
K	-	Potassium
K_2O	-	Potassium oxide
kg	-	Kilogram
LAI	-	Leaf Area Index
m	-	Meter

mm	-	Millimeter
N	-	Nitrogen
NMR	-	Net Monetary Return
No.	-	Number
NS	-	Non Signifiant
P_2O_5	-	Diphosphorus pentoxide
p^H	-	puissance de hydrogen
$plant^{-1}$	-	per plant
q	-	Quintal
RBD	-	Randomized Block Design
Res.	-	Research
RH	-	Relative humidity
Rs.	-	Rupees
SE(m)+	-	Standard error of mean
Sig	-	Significant
SSP	-	Single superphosphate
t	-	tone (s)
Treat.	-	Treatment
Viz.,	-	Vide licet (Namely)

(E) THESIS ABSTRACT

a)	**Title of the thesis**	:	**" EFFECT OF SPACING ON GROWTH, YIELD AND QUALITY OF TIKHUR (*Curcuma angustifolia* Roxb.)"**
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ABSTRACT

A field experiment entitled "Effect of spacing on growth, yield and quality of tikhur (*Curcuma angustifolia* Roxb.)" was conducted at Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* season of 2018 - 2019. With the objectives to study the effect of spacing on growth, yield and quality of tikhur and to find suitable spacing for better growth, yield and quality of tikhur.

The experiment was laid out in Randomized Block Design (RBD) with four replications and six treatments viz. T_1 (45 cm × 20 cm), T_2 (45 cm × 30 cm), T_3 (45 cm × 45 cm), T_4 (60 cm × 20 cm), T_5 (60 cm × 30 cm) and T_6 (60 cm × 45 cm). The various observations in respect of plant growth, yield and quality of tikhur were recorded periodically.

From the present findings, it was observed that the growth parameters in respect to plant height and leaf area index were found to be significantly maximum in treatment T_1 (45 cm × 20 cm). Whereas number of leaves per plant, leaf length and leaf breadth were found to be significantly maximum in treatment T_6 (60 cm × 45 cm).

As regards to the yield parameters, treatment T_6 (60 cm × 45 cm) was found superior in respect of weight, number and thickness of mother and primary rhizome per plant and rhizome yield per plant. While yield per plot and yield per hectare was found superior in treatment T_1 (45 cm × 20 cm). Whereas, days to maturity and dry matter percentage of rhizome per plant were non significantly influenced by plant spacing.

In respect of quality parameters, treatment T_1 (45 cm × 20 cm) gave maximum starch recovery per hectare. However starch recovery percentage and protein content were non significantly influenced by plant spacing.

Considering the cost economics, the highest gross and net monetary return were obtained with treatment T_1 (45 cm × 20 cm) and the highest B:C ratio was obtained in treatment T_4 (60 cm × 20 cm). Therefore, treatment T_4 (60 cm × 20 cm) was found to be most remunerative as per the B:C ratio.

CHAPTER I

INTRODUCTION

Tuber crops are the third important food crops in the world after cereals and grain legumes. These crops contribute a good share in the food basket of India.In India the area under cultivation of tuber crop was 25,06,000 hectares with 5,42,36,000 million tones of production. (Anon., 2017). These crops will play an important role in future also. The plant grows wild in many places. It is found in moist and cool situations at altitudes of about 450 m.

1.1 Background information

Tikhur (*Curcuma angustifolia* Roxb.) belonging to the family Zingiberaceae is a rhizomatous herb. It is important food (Starch plant) having chromosome number 2n = 42. It is also known as white turmeric, narrow leaved turmeric, East Indian arrowroot or Bombay arrowroot. Its common names in various regional languages are - Tavaksira in Sanskrit, Tavakeera or Tavakila in Marathi, Tikhur in Hindi, Koova in Malayalam, Yaipan in Manipuri, Keturi Halodhi in Bengali, Ararutkilangu or Ararut-kizhangu in Tamil, Koove - hittu in Kannad. Tikhur cultivated as medicinal crop in many parts of the state under moist deciduous mixed and salforest of Madhya Pradesh, Chhattisgarh and Jharkhand. It is generally propagated by rhizomes and good source of starch and fibre (Misra and Dixit, 1983).

It is a perennial flowering plant. It generally grows about height of 90-120 cm. The plant bears small spike inflorescences of three or four yellow, funnel shaped flowers within tufts of pink terminal bracts (Coma Bracts). Flowers are usually seen at the beginning of the rainy season from Jully to August, before the leaves have had the chance to fully develop and they continue to flower even after the leaves have fully developed. Leaves may grow to about 36-37 cm long and 8-10 cm in width. The leaves also smell and taste similar to turmeric.

The plant is most commonly found growing wild in India especially in the North East and Western coastal plains and hills. Such areas include the states of Maharashtra, Madhya Pradesh, Andhra Pradesh, Himachal Pradesh, Chhattisgarh, Bihar, Jharkhand, West Bengal, Tamil Nadu and Kerala. (Tiwari and Patel, 2013). This species is native to indian subcontinent. This species can also be found in Burma, Laos, Nepal and Pakistan (Ravindran *et al*., 2007). Its major availability is reported in moist deciduous Sal and mixed forest of Madhya Pradesh, Chhattisgarh and Jharkhand. The farmers of Chhattisgarh reside in vicinity to the forest, collect naturally grown tikhur rhizomes as a minor forest produce and some farmers grow commercially in their kitchen garden and *badi* farming system. Total area of tikhur crops in Chhattisgarh is 93.48 ha, total production is 2047.13 t and average productivity of tikhur crop is 18.04 t ha-1. The total collection of tikhur rhizome as a minor forest produce in Chhattisgarh is 190 tones. Bastar and Bilaspur divisions are the major potential area of the state for tikhur (Anon., 2005).

Farmers grow tikhur for rhizome production for starch extraction. Farmer's yield less starch due to lack of improved production technologies, high starch yielding genotypes and proper nutrient management practices. It is understood that there is a wide gap between potential yield and the yield obtained under actual field situations for tuber crops. It is found that over exploitation of the species that resulted in bringing it in valuable category of International Union for Conservation of Nature (IUCN). Thus, it has necessiated the cultivation of this species in the farmer's field.

The rhizome of tikhur is light bitter, demulcent, non irritating, nutritive and fragrant. The fresh rhizomes of tikhur are used for the preparation of starchy flour which has medicinal value and effective for many diseases. The tikhur rhizome are use as appetizer reducing burning sensations and stomach pains, removal of stone from kidney, useful for ulcer patient (Sharma, 2003) and rhizome pulp is used for treatment of headache as well as it gives cooling effect (Nag *et al*., 2006). The rhizomes of the tikhur can be used to heal peptic ulcers, used in treatments of diarrhoea and colitis and is often employed as an herbal tonic for patients suffering from tuberculosis. Rhizome pulp is used as a remedy for headache, joint pains, jaundice and leucoria (Hemadri and Rao, 1984), essential oil of tikhur rhizome is used against tape worm (Benerjee and Nigam, 1978).

The starch recovery from tikhur rhizome is about 15 - 25 % and is highly nutritious and easily digestible, therefore, it is recommended for infants, weak children and invalids. It is also used for the preparation of many sweet meals and herbal dishes like *halwa, barfi, jalebi etc*. It is used specially during fast (*vrata, upwas*) as it is rich source of energy. It is found as a primary ingredient in cakes, fruit preserves, biscuits and puddings. Farmers also prepare herbal drink "*sarbat"* using *tikhur* starch especially during summer seasons due to its cooling effect (Singh and Palta, 2004). In addition, scientists have compared the tikhur starch with corn starch. Its binding and disintegration properties make it viable and perhaps superior substitute for corn starch as an excipient in medicinal tablets.

1.2 Importance and need of study

As tikhur is a underexploited vegetable crop and it is mostly grown in forest areas. It is most important crop in terms of medicinal and nutritive value therefore systematic cultivation of tikhur is necessary. Similarly, it is essential to increase the production of tikhur considerably.

Suitable spacing is required to ensure proper utilization of inputs like nutrient, moisture and light resulting in better production performance of the plant. The sowing strategy involves inter and intra row spacing essential for obtaining maximum yield along with quality. The spacing depends on the optimum plant stand / population required for different regions. Among the other crop production factor, spacing contributes much to a proper crop stand establishment in field.

Tikhur starch is having nutritive and medicinal value. It gives good monitory returns to the farmer as well as processing industry. Its high price (Ranging from Rs. 300 – 500 per kg) in the market has prompted growers to include this crop in their traditional cropping system.

Therefore, the present study was, undertaken to find out suitable spacing for maximum yield and better quality.

1.3 Objectives

The present study entitled "Effect of spacing on growth, yield and quality of tikhur (*Curcuma angustifolia* Roxb.)" was conducted at Insructional Farm, Department of Vegetable Science, Faculty of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the *kharip* season with the following objectives.

1. To study the effect of spacing on growth, yield and quality of tikhur .
2. To find out suitable spacing for better growth, yield and quality of tikhur .

1.4 Hypothesis

To obtain optimum production, productivity and good quality of rhizome, it is essential to find out suitable spacing. Plant spacing is important character, which can be manipulated to attain the maximum production from per unit land area . The optimum plant spacing with proper geometry of planting is dependent on variety its growth habit and agro-climatic conditions.

Thus, spacing between plants is one of the most important factor which ultimately affects nutrients uptake, growth, yield and quality of plants. With increase in plant spacing, the total population per hectare decreases, but with more nutrition, the individual plant grow better and yields more and vice - versa. Thus the increase and decrease in plant spacing has definite pattern in relation to yield. In view of these facts the yield of tikhur can be increased by adopting improved production technologies like improved variety, proper planting methods, spacing and nutrient management. Plant spacing has a permanent importance for tikhur production as it influences the interplant competition.

1.5 Scope and limitation

This crop did not received much attention so far and therefore technological information about this crop is much scanty. Hence for its commercial cultivation in the region the improved technological practices are much needed.

A very little information is available regarding this crop is specially on aspect of spacing. As a result of this, farmers yielded less starch due to lack of improved practices also they are doing processing of rhizomes through the traditional method of starch extraction. As starch is valuable product of tikhur therefore it facilitate wider scope in processing industries and due to its nutritive value, its preparation are used for some medicinal purpose. Thus this kind of research work insure and enhance the production of tikhur plant, besides the economical up scaling of farmer and the augmentation of supply of raw material to pharmaceutical industries.

Due to lack of information in vidarbha region promising research on spacing aspect on tikhur is major limitation. However, on the other hand this will open new doors of wide scope to check the performance of tikhur crop in semi-arid climate and restructuring of different spacing for optimum economic yields of crop with sustainable soil health. The specific climatic requirement are major factor limiting in its cultivation.

CHAPTER II

REVIEW OF LITERATURE

The experiment entitled " Effect of spacing on growth, yield and quality of tikhur (*Curcuma angustifolia* Roxb.) " was carried out during *kharip* season of the year 2018-19 at Instructional Farm, Department of Vegetable Science, Faculty of Horticulture, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

The relevant literature on the effect of spacing on growth, yield and quality of tikhur is reviewed and presented in this chapter under appropriate sub-headings.

2.1 Effect of spacing on growth

Bahadur *et al.* (2000) studied the effect of different spacing (50 cm x 20 cm, 50 cm x 30 cm and 50 cm x 40 cm) on the growth, dry matter production and yield of turmeric and reported that close spacing produced the taller plants (87.89 cm) which was statistically at par to that recorded at medium spacing (50 cm x 30 cm). Wider spacing increased the leaves per plant of turmeric. Whereas, different spacings had non significant effect on days to maturity of turmeric.

Dayankatti and Sulikeri (2000) studied the effect of plant population levels on growth of ginger and reported that lower population level reported maximum number of leaves per shoot whereas the maximum leaf area index was recorded at medium population.

Singh *et al.* (2000) reported that plant spacing had non-significant effect on plant emergence and tillers per plant in turmeric. However, with closer spacing (50 cm x 20 cm), the plant height was maximum (69.2 cm) and significantly more than that recoded with wider spacing (50 cm x 40 cm).

Kaur (2001) carried out an experiment at Ludhiana on effect of spacing and farmyard manure levels on growth and yield of flat and ridge planted turmeric and reported non-significant effect of two spacing (60 cm x 10 cm and 60 cm x 15 cm) on growth characters of turmeric.

Gill *et al*. (2002) carried out an experiment at PAU, Ludhiana and reported that different plant spacings (60 cm x 10 and 60 x 15 cm) did not influence on the growth parameters in turmeric.

Islam *et al.* (2002) while studying the effect of different plant spacing (45 cm x 10 cm, 45 cm x 20 cm, 45 cm x 30 cm and 60 cm x 30 cm) on the production of turmeric at the farmer's field and reported that the higher number of leaves (10.4) and number of stems per hill (5.0) were produced when plants were planted at wider (60 cm x 30 cm) spacing closely followed by the 45 cm x 30 cm spacing and the lower was found in closer (45 cm x 10 cm) spacing.

Manjunathgaud *et al*. (2002) conducted an experiment in turmeric at Banglore, Karnataka. The main treatments comprised of 30 cm x 15 cm (S_1), 30 cm x 30 cm (S_2) and 30 cm x 45 cm (S_3) spacing S_2 gave the maximum plant height, S_3 gave the highest number of tillers and leaves per clump and leaf area.

Gill *et al*. (2004) observed that plant spacing of 60 x 10 cm produced significantly taller plants (54.4 cm) as compared to wider spacing of 60 x 15 cm (47.7 cm) in turmeric under Ludhiana (Punjab) conditions.

Hore *et al*. (2004) studied the effect of different spacing viz. 20 cm × 15 cm, 20 cm × 20 cm and 25 cm × 20 cm in turmeric and revealed that narrow spacing produce taller plants 90.13 cm while widest spacing recorded highest numbers of tillers 15.4 and leaves 221.18.

Hossain *et al.* (2005) while working on the effect of planting pattern and plant spacing on growth and yield of turmeric found that low plant spacing was insufficient for the proper growth of turmeric.

Gopichand *et al.* (2006) reported that the crop responded significantly to different plant spacing in wild turmeric. Plant height increased with reduction in plant spacing from 50 cm x 50 cm to 25 cm x 25 cm, whereas, the number of plantlets followed the reverse trend. Leaf length: breadth ratio and leaf area density showed an increasing trend with closer spacing.

Kandiannan and Chandragir (2006) observed that the closer spacing (30 × 15 cm) produced on an average 32.8 and 52.2 percent higher leaf area index than medium (45 × 15cm) and wider spacings (60 × 15 cm) at 180 after planting in turmeric.

Wakhare *et al.* (2007) studied the effect of spacing on growth of turmeric and reported that closer spacing in turmeric of 30 cm x 15 cm recorded the maximum plant height (130.50 cm). Wider spacing of 60 cm x 15 cm recorded significantly maximum number of leaves (8.72) per plant and produced significant number of tillers (2.04) per plant. Medium spacing 45 cm x 15 cm recorded highest leaf area (3839.33 cm^2) and dry weight of shoots (36.98 g / plant).

Kumar and Gill (2010) carried out an experiment to study the effect of planting method, plant density and planting material on growth, yield and quality of turmeric at Ludhiana. Closer plant spacing produce significantly taller plants than wider plant spacing and Leaf area index is maximum in closer plant spacing and it decreased significantly in wider plant spacing.

Pandey *et al.* (2011) worked with four spacing viz., 30 cm x 15 cm, 30 cm x 30 cm, 30 cm x 45 cm and 45 cm x 45 cm in turmeric. They concluded that closer spacing of 30 cm x 15 cm being on par with 30 cm x 30 cm produced taller plants than the wider spacing of 30 cm x 45 cm and 45 cm x 45 cm. However, more number of leaves were recorded with wider spacing of 45 cm x 45 cm.

Modupeola *et al.* (2013) studied that the plant height, number of leaves differed significantly with different plant spacing. Plant height was significantly improved in the wider spacing compared with closer spacing. The widest spacing (45 cm x 50 cm) produced the tallest plant (65.1 cm). The highest number of leaves was obtained when plants were spaced closer 25 cm x 50 cm.

Yadav *et al.* (2013) reported that the spacing level 25 cm × 15 cm showed greatest plant height at 120 DAP (50.35 cm) and 210 DAP (82.39 cm) in turmeric, which was significantly superior over the other treatments. The widest spacing of 25 cm × 35 cm significantly produced the longest and broadest leaf while the shortest and narrowest leaf was produced by closest spacing of 25 cm × 15 cm.

Mahender *et al*. (2015) studied the effect of rhizome size and plant spacing on growth, yield and quality of ginger (*Zingiber officinale* Rosc). The study comprised of five spacing viz.25 cm × 15 cm , 25 cm × 25 cm, 30 cm ×20 cm, 30 cm × 30 cm and 40 cm × 20 cm. Highest plant height, leaf area index (5.25) was recorded from closest plant spacing of 25 cm × 25 cm. Spacing of 30 cm × 30 cm took lowest number of days to first sprouting.

Modupeola and olaniyi (2015) reported that with the closest spacing of 25 cm x 20 cm recorded the tallest plant of 79.18 cm while turmeric plants grown in 25 cm x 30 cm spacing recorded the shortest plant of 69.68 cm. With the widest spacing of 25 cm x30cm produced the highest number of leaves (54.07) while the least number of leaves (46.97) were recorded at the closest spacing.

Fariyike *et al*. (2016) worked with four plant spacing viz. 45 cm x 10 cm, 45 cm x 20 cm, 45 cm x 30 cm and 45 cm x 40 cm in turmeric and concluded that wider spacing of 45 cm x 40 cm had significantly highest plant height and number of leaves than lowest spacing 45 cm x 10 cm.

Nautiyal *et al.* (2016) studied the effect of plant spacing on growth and yield of turmeric and stated that the closest (45 cm x 10 cm) spacing recorded maximum plant height. While the maximum number of leaves per plant were recorded with widest spacing of (45 cm x 40 cm).

Sidhu *et al*. (2016) observed maximum plant height 74.7 cm where inter row spacing of turmeric was 37.5 cm and mulch was applied and least plant height 61.7 cm was observed in 30 cm × 20 cm spaced turmeric where mulch was not applied.

Woelore *et al*. (2016) stated that 15 cm and 10 cm intra-row spacings in ginger scored significantly higher mean height (41.76 and 42.72 cm, respectively) and higher number of leaves per plant (9.6 and 9.82) than 5 cm intra-row spacing. The 5 cm intra row spacing scored significantly higher (1.94) mean leaf area index per plant followed by 10 cm intra-row spacing. Inter row spacing had high leaf area index at 20 cm spacing (1.57) than 30 cm and 40 cm spacing. Whereas, inter row and intra-row spacing had non significant effect on days to 90 % maturity of ginger.

Fadia and Ismail (2017) studied the effect of plant spacing on growth and yield of turmeric. The study comprised of two plant spacing (20 cm × 20 cm) and (40 cm × 40 cm) and reported that 20 cm x 20 cm spacing gives the highest plant height (63.56 cm) and more no of leaves (7.08 cm) while 40 cm x 40 cm spacing gives lowest plant height (62.17 cm) and minimum numbers of leaves (6.33).

Preetham *et al.* (2018) studied the effect of three population levels (1,48,148, 74,074 and 98,765 plants / ha) on turmeric and states that plant population densities did not differ significantly for plant height and number of leaves per plant during all growth stages.

2.2 Effect of spacing on yield

Bahadur *et al*. (2000) conducted an experiment to study the effect of different spacing (50 cm x 20 cm, 50 x 30 cm and 50 x 40 cm) on growth and yield of turmeric and stated that wider spacing increased the fingers/plant which in turn produced maximum fresh and dry yield of the plant. The highest yield (13.21 t/ha) was obtained when plants were spaced closer (50cm x 20 cm) followed by 50 cm x 30 cm 12.25 t/ha). At widest spacing (50 cm x 40 cm) yield was the lowest (10.35 t/ha).

Choudhury *et al.* (2000) in an experiment with three spacing viz., 50 cm x 15 cm, 50 cm x 20 cm and 50 cm x 25 cm reported that closer spacing of 50 cm x 15 cm produced higher yield of turmeric than all other wide spacing of 50 cm x 20 cm and 50 cm x 25 cm.

Singh *et al.* (2000) conducted an experiment in turmeric at Haryana (India) and reported that the highest yield was obtained at 50 cm x 20 cm and in plant from whole mother rhizome as compare to other.

Carvalho *et al.* (2001) evaluated the spacing of turmeric between furrows (40 cm, 60 cm, 75 cm and 100 cm) and within the planting line (20 cm, 30 cm, 40 cm and 50 cm) and they observed that yield of rhizome was influenced only by the between plant spacing, with the 20 cm spacing giving the highest yield (305.6 q ha-1).

Islam *et al.* (2002) revealed that the highest average turmeric yield (17.87 t/ha) was obtained from 45 cm x 10 cm plant spacing which was closely followed by (16.77 t/ha) by 45 cm x 20 cm plant spacing. The lowest average yield (13.42 t/ha) was recorded from 60 cm x 30 cm plant spacing.

Hore and Chattopadhyay (2003) studied with the different spacing and reported that the plant spacing of 15 cm x 15 cm recorded significantly higher yield than the 30 cm x 15 cm spacing.

Filho *et al.* (2004) studied the effect of plant density on turmeric production and reported that plant to plant spacing of 20 cm recorded significantly higher yield (246.8 q/ha) than the plant to plant spacing of 35 and 50 cm.

Gill *et al.* (2004) studied the effect of spacing on yield of turmeric and observed that different spacings *viz.* 60 cm x 10 cm and 60 cm x 15 cm had no significant influence on weight and number of mother, primary and secondary rhizomes per plant and fresh rhizome.

Silva *et al.* (2004) reported that fresh rhizome yield of turmeric decreased from 250 q/ha in the plant to plant spacing of 25 cm to 180 q/ha in the spacing of 40 cm due to less accommodation of plants per hectare.

Gopichand *et al.* (2006) studied the effect of different plant spacings viz., 25 cm x 25 cm, 50 cm x 25 cm and 50 cm x 50 cm and reported the higher yield of turmeric rhizome with wider plant spacing (50 cm x 50 cm).

Kandiannan and Chandragir (2006) studied with the three different spacings i.e. S_1 (30 cm x 15 cm), S_2 (45 cm x 15 cm) and S_3 (60 cm x 15 cm) concluded that (30 cm x 15 cm) spacing registered highest rhizome yield while the minimum turmeric yield was recorded in (60 cm x

15 cm). He further reported that the dry recovery percent of turmeric did not influenced by plant spacing.

Pratap Ram and Singh (2007) studied six spacings viz.(30 cm × 15 cm, 30 cm × 20 cm, 30 cm × 30 cm, 45 cm × 15 cm, 45 cm × 20 cm, 45 cm × 30 cm in turmeric and reported that the closest spacing of 30 cm × 15 cm produce the highest yield (335.02 q/ha).

Wakhare *et al.* (2007) studied with the different spacings in turmeric and reported that medium spacing of 45 cm x 15 cm recorded highest fresh yield (47.47 t/ha) in turmeric, highest number of primary fingers (8.87) and weight of fingers (200.03 g) per rhizome. Wider spacing of 60 cm x 15 cm recorded significantly highest number of mother rhizomes per plant (2.17) and highest dry weight of rhizomes (220.07 g kg-1).

Behera *et al.* (2008) conducted experiment at Research farm of AICRPDA, OUAT, Phulbani and reported that the sole turmeric gave maximum dry rhizome yield during experimentation years with mean of 22.21 q/ha over turmeric and pigeonpea intercropping system.

Dhatt *et al*. (2008) states that ridge planting of turmeric at 60 cm × 15 cm spacing produce number of mother rhizome and primary fingers / plant, average weight of mother and fingers rhizome and yield per plant were significantly more than 45 cm ×15 cm spacing.

Zaman *et al*. (2008) reported that the plant spacing 40 cm × 20 cm significantly gave the highest all yield attributing characteristics which resulted the highest yield (30.58 t/ha).

Pandey and Mishra (2009) worked on the effect of different plant spacing viz., 30 cm x 15 cm, 30 cm x 30 cm, 30 cm x 45 cm and 45 cm x 45 cm on turmeric and reported that closer plant spacing (30 cm x 15 cm) registered higher yield of 295.53 q/ha, while minimum yield of 138.52 q/ha as noted under 45 cm x 45 cm plant spacing.

Sharma *et al.* (2012) carried out an experiment in ginger with nine different plant spacing (15 cm × 15, 15 cm × 20 cm, 15 cm × 25 cm, 20 cm × 20 cm, 20 cm × 25 cm, 20 cm × 30 cm, 25 cm × 25, 25 cm × 30 cm and 30 cm × 30 cm). Maximum yield was obtained in wider spacing of

25 cm × 30 cm that was statistically at par with 30 cm × 30 cm plant spacing while minimum yield was obtained in closer spacing of 15 cm × 20 cm.

Kiran *et al*. (2013) carried out an experiment in five different plant spacing (30 cm ×10 cm, 30 cm × 20 cm, 30 cm × 30 cm, 30 cm × 40 cm, and 30 cm × 50 cm). Plant spacing 30 cm × 50 cm have evidenced significant findings for almost all the parameters as it took significantly least no of days to sprouting (82), stem per plant (5.66), number of finger per plant (15.67), finger length (5.367 cm), finger weight (76.10 gm), Diameter of finger (4.220 mm) and turmeric yield (2184 kg/ha). Thus it is concluded that wider spacing gives more yield.

Modupeola *et al.* (2013) studied the three different spacing viz. (25 cm x 50 cm, 35 cm x 50 cm and 45 cm x 50 cm) in ginger and reported that the highest yield (26.8 t/ha) were obtained when plants were spaced closer (25 cm x 50 cm). At widest spacing (45 cm x 50 cm) the yield was the lowest (12 t/ha).

Yadav *et al*. (2013) reported that the spacing of 25 cm x 35 cm produced the longest (22.66 cm) and the broadest rhizome (9.90 cm) and also recorded the highest rhizome weight per plant (292.93 g).The highest green and dry ginger yield per hectare was produce in 25 cm x 15 cm.

Mahender *et al*. (2015) reported that among the plant spacing, treatment 30 cm × 30 cm. spacing (D_4) produced highest rhizome yield per plant (203.02 gm). However, green ginger yield per hectare was significantly highest with a closer spacing of 25 cm X 15 cm (26.40 t), while the lowest green ginger yield per hectare (19.92 t) was recorded from 30 cm × 30 cm.

Modupeola and olaniyi (2015) reported that the longest rhizome of 6.38cm was obtained from the widest spacing of 25 cm x 30 cm in ginger while the shortest rhizome of 5.42 cm was obtained from the closest spacing. The highest rhizome yield (52.79 t/ha) was obtained from

25 cm x 25 cm spacing followed by the closest (25 cm x 20 cm) spacing which gave the rhizome yield of 44.7 t/ha, while the widest (30 cm x 25 cm) spacing recorded the least rhizome yield of 42.5 t/ha.

Singh and Chinna (2015) reported that the yield of turmeric in tones per hectare and number of fingers per hill was significantly higher in case of ridge sowing at spacing of 60 cm x 15 cm as compared to flat sowing at spacing of 30 cm x 20 cm.

Fariyike *et al*. (2016) studied effect of planting dates and spacing on the growth and yield of turmeric (*Curcuma longa* L.) and reported that close spacing at 40 cm x 10 cm gave the highest rhizome yield (42 t/ha) while at widest spacing at 45 cm x 40 cm gave the lowest rhizome yield (13.71 t/ha).

Weolero *et al*. (2016) states that increasing inter row spacing in ginger from 20 to 40 cm increases mean rhizome fresh yield per plant by 14 % and 18.5 % respectively. Similarly, increasing intra-row spacing from 5-10 cm and 5-15 cm increased the mean fresh rhizome yield per plant by 13.47 % and 18.08 % respectively.

Datta *et al*. (2017) used five different spacing 20 cm × 15 cm, 20 cm × 20 cm, 25 cm × 20 cm, 25 cm × 25 cm and 30 cm × 25 cm in ginger. The clump weight increased from 225.33 g to 321.66 g and 188.50 g to 267.50 g with the increase in spacing from 20 cm × 15 cm to 30 cm × 25 cm. So increasing trend in yield per plant, was observed with increase in spacing.

Temteme *et al*. (2017) studied the four levels of planting densities viz., (222,222 plants / ha, 166,667 plants/ ha, 111, 111 plants/ha and 83,333 plants/ha) in turmeric and reported that broader plant spacing (83,333 plants/ha) produced high rhizome weight (777.69 g/clump). Similarly, higher rhizome numbers (65.42/plant). In the other hand narrow plant spacing (222,222/plant) produced low rhizome weight and number. Increase of planting space increased the weight and number of rhizome per plant.

Preetham *et al.* (2018) carried out an experiment at Horticultural Research Station, Adilabad (Northern Telangana Zone) in turmeric and reported that maximum number of mother rhizomes (3.97), primary fingers (13.05), secondary fingers (16.94), clump weight / plant (1140 g), girth of mother rhizome (21.60 cm) and weight of mother rhizome (87.65 g) were recorded in 74,074 plant population treatment. Maximum fresh rhizome yield (20.14 t/ha) was recorded with plant population stand of 1,48,148 plants/ ha which was on par with plant population stand of 98,765 and 74,074 plants/ha.

2.3 Effect of spacing on quality

Shashidhar and Sulikeri (1996) studied the effect of plant density on curcumin content of turmeric rhizomes cv. Amalapuram and reported that plant spacing has non significant influence on curcumin content.

Valsala *et al*. (1998) in Kerala conducted an experiment and reported that curcumin and curing percentage were not significantly affected by different spacing

Kaur (2001) in his study concluded non-significant effect of different spacings on the curcumin content of turmeric rhizomes and further reported that the plant spacing of 60 cm x 10 cm and 60 cm x 15 cm has no effect on N, P and K content of leaves and rhizomes.

Manjunathgaud *et al.* (2002) study with different spacing treatments viz. of 30 cm x 15 cm (S_1), 30 cm x 30 cm (S_2) and 30 cm x 45 cm (S_3) spacing and found non-significant effect on curcumin content of turmeric with different plant population.

Gill *et al.* (2004) carried out an experiment at Ludhiana (Punjab) with two different spacings (60 cm x 10 cm and 60 cm x 15 cm) in turmeric and reported that plant spacing did not affect the contents of nitrogen, phosphorus and potassium in leaves as well as rhizomes.

Gopichand *et al*. (2006) studied the effect manure and plant spacing on crop growth, yield and oil quality of curcuma *aromatica* salisb. and reported that the oil content is maximum at 50 cm × 50 cm spacing (

213.5 kg / ha) as compared to closer spacing of 25 cm × 25 cm (191.6 kg/ha).

Kandiannan and Chandragir (2006) studied the effect of plant spacing on quality of turmeric and concluded that plant spacing did not influence the dry recovery and curcumin content of turmeric.

Kumar and Gill (2010) carried out an experiment to study the effect of planting method, plant density and planting material on growth, yield and quality of turmeric at Ludhiana and reported that the effect of different plant densities on oil content and curcumin content of turmeric was non-significant.

Moduopala *et al.* (2013) studied the effect of plant density on nutritional value of ginger and reported that for the spacing significant difference were observed in crude protein, calcium, total starch and moisture content.

Mohamed *et al*. (2014) studied the effect of spacing on chemical constituents of turmeric plants. and reported that the carbohydrate content increased by decreasing the plant distance and it was highest at 15 cm spacing between plants, but the minimum value was occured at the spacing of 35 cm. The highest value of total curcumin (2.63 kg/feddan) recorded at 15 cm spacing between plants and the minimum value (1.81 kg/feddan) was obtained at the spacing of 35 cm between plants.

Om Parkash (2014) studied the three levels of plant population viz. (1,33,334, 1,66,667 and 2,00,000 plants/ha) on quality of turmeric and reported that curcumin content and oil content were not significantly influenced by different plant population.

Mahender *et al.* (2015) reported that the essential oil content and starch content in ginger differed non - significantly among the spacing treatments. However, highest essential oil content (1.81 %) and starch content (30.33 %) were observed in 30 cm x 30 cm spacing.

Nautiyal *et al*. (2016) studied the effect of plant spacing on turmeric and observed that essential oil (%) was non significantly influenced by different plant spacing.

Temteme *et al.* (2017) studied the four levels of planting densities viz. (222,222 plants/ha, 166,667 plants/ ha, 111, 111 plants/ha and 83,333 plants/ha) and reported that plant density did not affect the oleoresin content of turmeric.

CHAPTER III

MATERIAL AND METHODS

A field experiment entitled "Effect of spacing on growth, yield and quality of tikhur (*Curcuma angustifolia Roxb.*)" was conducted during *kharip* season of 2018-2019 at Instructional Farm, Department of Vegetable Science, Faculty of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The details of the material used and methods adopted during the course of present investigation are presented in the chapter under appropriate headings.

3.1 Location of the experimental site

The field experiment was conducted at Instructional Farm, Department of Vegetable Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season 2018. It is located in subtropical zone at $22^0 42'$ N latitude and 72^0 26' longitude, with an altitude of 307.42 m above mean sea level (MSL).

3.2 Climate and weather conditions

The climate of Akola is semi- arid and characterized by three distinct seasons *viz*. hot and dry summer from March to May, warm and rainy monsoon from June to October and mild cold winter from November to February. The normal mean monthly maximum temperature is 42.5^0C during the hottest May, while, the normal mean monthly minimum temperature is 10.6^0C in the coldest December.

The mean daily evaporation reaches as high as 16.8 mm in the month of May and as low as 4.3 mm in the month of August. The mean wind velocity varies from 4.7 Km/hr during October to 17.6 Km / ha during June. Relative humidity attains the maximum value (74-87 %) during the South West monsoon season and minimum (30-40 %) during summer month. The meteorological data recorded at Meteorological Observatory, University Department of Agronomy. Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the experimental period of 2018-19.

3.3 Soil characteristics of the experimental site

The land used under the experimental layout was fairly uniform with gentle slope. The soil was medium black with uniform in texture, colour and having good drainage. Before laying out the experiment, initial soil samples were drawn at five randomly selected spots at a depth of 0 - 30 cm from the field and the composite samples were analysed for physical and chemical characteristics.as per the methods suggested against each parameter.

Table 1. Physical analysis of the experimental soil

Ingredient	Quantity (%)
Sand	16.2
Silt	22.9
Clay	61.8

Table 2. Chemical analysis of the experimental soil

Chemical ingredient	Quantity (Kg / ha)	Methods adopted
Available Nitrogen	210.00	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available Phosphorus	11.41	Olsen's method (Watanabe and Olsen, 1965)
Available Potassium	290.02	Flame photometric method (Jackson, 1973)

3.4 Experimental Details

1. Name of crop : Tikhur
2. Botanical name : *Curcuma angustifolia (* Roxb*.)*
3. Family : Zingiberaceae
4. Design : Randomized Block Design
5. Variety : IGSJT-10-2
6. Layout : Ridges and furrows
7. Number of treatment : 06
8. Number of replications : 04 (Four)
9. Number of plots : 24
10. Spacing : As per treatment
11. Plot size : 3.6 m × 1.8 m
12. Season : *Kharif* 2018 - 2019
13. Place of research work : Instructional Farm, Department of Vegetable Science, Faculty of Horticulture, Dr. P. D. K. V., Akola.

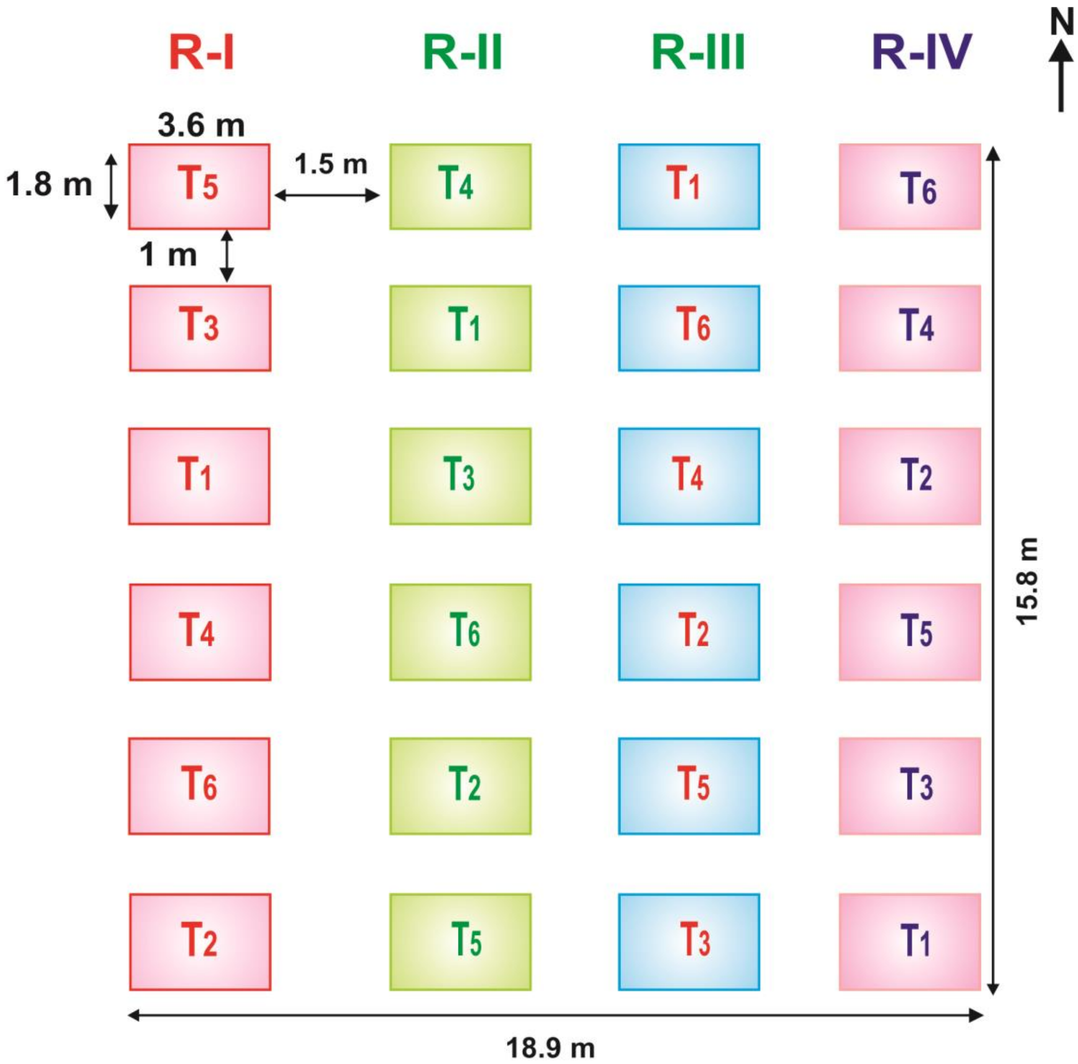
Treatment Details

Spacing :

Sr No.	Treatments
1	T_1 - 45 cm × 20 cm
2	T_2 - 45 cm × 30 cm
3	T_3 - 45 cm × 45 cm
4	T_4 - 60 cm × 20 cm
5	T_5 - 60 cm × 30 cm
6	T_6 - 60 cm × 45 cm

3.6 Design and layout

The experiment was laid out in Randomized Block Design (RBD) in four replication. The plan of layout of the experiment field is shown in Fig. 1.



Design	: Randomized block design (RBD)
Treatments	: (6)
Replication	: (4)

Fig. 1. Plan of layout

Plot Size

Gross plot - 3.6 m × 1.8 m

Net plot - As per treatment

3.7 Cultural practices

All the cultural practices were followed as per the recommended package of practices for tikhur cultivation.

3.7.1 Field preparation

The experimental area was ploughed 3-4 times and harrowed to bring the soil to a fine tilth. Well decomposed farm yard manure @ 20 tones per hectare was applied and mixed well in the soil before final harrowing. Experimental area was divided into plots according to plan.

3.7.2 Seeds and planting

Good quality planting material were collected from Indira Gandhi Krishi Vishwavidhyalay Raipur, Chhattisgarh. Planting was done according to the spacing mentioned above on 7 th July 2018.

3.7.3 Gap Filling

Gap filling was done 15 - 20 days after planting.

3.7.4 Fertilizer application

Half dose of N and full dose of P_2O_5 and K were applied in the form of urea, SSP and K_2O during field preparation and remaining half N was applied one months after planting according to the (RDF) i. e. recommended dose of fertilizer 60:40:60 kg NPK per hectare. These fertilizers were applied as broadcasting method.

3.7.5 After care

3.7.5.1 Weeding

Weeding was done manually after four weeks of planting.

3.7.5.2 Irrigation

Protective irrigations were given depending upon weather conditions to maintain the moisture content in the soil.

Plate 1(a) Field visit

Plate 1(b) General view of the experimental plot

3.7.5.3 Plant protection measures

Adequate plant protection measure was adopted to control the major disease- *Phytopthora infestance* during the crop growth. To control the infestation of Phytopthora disease spray of Macoban (Carbendazim 12% + Mancozeb 63 %) water was done at the time of vegetative stage.

3.7.6 Harvesting

A light irrigation was given 10 days before harvesting for easy and proper digging of rhizomes. The crop was harvested at maturity stage when all leaf are yellowish to fall down the ground. Digging of rhizomes was done manually with the help of spade. The crop was harvested on 9th January 2019 and the fresh rhizomes were collected.

3.8 Collection of experimental data

In the net plot area, treatment wise five plants were randomly selected and tagged for recording biometric as well as yield observations.

3.8.1 Growth parameters

3.8.1.1 Plant height (cm)

The plant height was measured from ground level to the tip of the new fully opened leaf. Observation were taken at 60, 90 and 120 DAP. The average value were expressed in centimeters**.**

3.8.1.2 Numbers of leaves per plant

The total number of leaves per plant was recorded at 60, 90 and 120 DAP which included all the leaves from the base of the randomly selected 5 five plants per plot.

3.8.1.3 Leaf length (cm)

Length of three leaves per plant was recorded from three positions, first from upper, second from middle & third from lower portions of leaf by the help of meter scale. It was recorded at 60, 90 and 120 DAP.

Plate 2(a) View during experimentation

Plate 2(b) Tikhur at flowering stage

Plate 2(c) Harvesting of tikhur rhizome

3.8.1.4 Leaf Breadth (cm)

Breadth of three leaves per plant was recorded from three positions, first from upper, second from middle & third from lower portions of leaf by the help of meter scale. It was recorded at 60, 90 and 120 DAP.

3.8.1.5 Leaf Area Index

Leaf area of three leaves per plant was calculated by using leaf area meter. For calculating leaf area index, leaf area was divided by plant spacing according to the treatments.

3.8.2 Yield parameters

3.8.2.1 Days to maturity

When all leaves of plant become dry, the C*urcuma angustifolia* plants has matured and calculated days to maturity for each treatment in each replication from date of planting.

3.8.2.2 Weight of mother rhizome per plant (g)

After harvesting of whole rhizomes, mother rhizomes of five randomly selected plants were weighed through physical balance and average was worked out in gram for weight of mother rhizome per plant.

3.8.2.3 Weight of primary (finger) rhizome per plant (g)

After harvesting of whole rhizomes, primary rhizomes (fingers) were separated from mother rhizomes of five randomly selected plants and weighed through physical balance and average was worked out in gram for weight of primary rhizome per plant.

3.8.2.4 Number of mother rhizome per plant

Number of mother rhizomes per plant were counted from five randomly selected plants for each plot at harvest and average was worked out**.**

3.8.2.5 Number of primary rhizome per plant

After harvesting of whole rhizomes, primary rhizomes (fingers) were separated from mother rhizomes of five randomly selected plants and number of primary rhizomes per plant were counted and average was worked out.

3.8.2.6 Thickness of mother rhizome per plant (cm)

After harvesting of whole rhizomes, thickness (diameter) of mother rhizome of five randomly selected plants was measured with the help of vernier calliper and average was worked out in centimeters.

3.8.2.7 Thickness of primary rhizome per plant (cm)

After harvesting of whole rhizomes, primary rhizomes (fingers) were separated from mother rhizomes of five randomly selected plants and thickness (diameter) of primary rhizome was measured with the help of vernier calliper and average was worked out in centimeters.

3.8.2.8 Dry matter % of rhizome per plant

The fresh weight of rhizomes from five randomly selected plants was recorded from each treatment. Thereafter these rhizomes were sun dried and furthure kept in hot air oven at temperature of 60^0 C for ten days for drying. Dry weight of plant was recorded by calculation. Dry matter per cent of rhizomes was calculated on the basis of following formula:

$$\textbf{Dry matter (\%)} \quad \frac{\text{Dry weight of rhizomes}}{\text{Fresh weight of rhizomes}} \times 100$$

3.8.2.9 Rhizome yield per plant (g)

Total rhizome obtained from five randomly selected plants of each treatment of each replication were weighed separately and their average was recorded in grams.

3.8.2.10 Rhizome yield per plot (kg)

Total rhizome obtained from five randomly selected plants of each treatment of each replication were weighed separately and their average was recorded then it was multiplied by total number of plant per plot thus rhizome yield per plot was worked out.

3.8.2.11 Total rhizome yield (t/ha)

Total five plants were selected for recording rhizome yield per plant. Total weight of rhizome obtained from five plants was averaged to compute rhizome yield then it was multiplied by total numbers of plants per plot. Thus, rhizome yield per plot was worked out. On the basis of rhizome yield per plot, rhizome yield per hectare was worked out.

3.8.3 Quality parameters

3.8.3.1 Starch recovery (%)

Fully mature rhizomes of tikhur weighing 250 g per plot of each replication were taken for starch extraction. Extracted starch was dried and weighted before estimation of recovery. The procedure of starch extraction is done manually. Starch recovery in percentage was calculated by using following formula.

$$\text{Starch Recovery (\%)} = \frac{\text{Wt of extracted starch}}{\text{Wt of rhizomes taken}} \times 100$$

3.8.3.2 Starch recovery (kg/ha)

Starch recovery was calculated by considering starch recovery percentage i.e. from 250 g rhizomes about (10.60-13.01%) starch could be obtained. Accordingly starch recovery of each treatment were worked out and average starch recovery was calculated in kilogram per hectare.

3.8.3.3 Protein content (%)

Protein of the *tikhur* powder was determined by Kjeldahl method (Jackson, 1958) by digesting 0.2 g of powder sample in 10 ml di-acid containing conc. H_2SO_4 and perchloric acid in 5:1 ratio and catalyst mixture of sodium sulphide and copper sulphate followed by distillation and titration. The obtained value of nitrogen was multiplied with the factor 6.25 to get powder protein percent.

3.8.4 Economics of the treatments (Benefit : Cost ratio)

3.8.4.1 Cost A

It is an actual paid cost for owner cultivars. This cost included the expenditure on the following items.

1) Hired human labour

2) Manure and fertilizers

3) Hired machine charges

4) Establishment cost

3.8.4.2 Cost B

Cost B was estimated as cost A plus rental value of the own land.

3.8.4.3 Cost C

Cost C was estimated as cost B plus imputed value of family labour. This is the total of all the costs, direct as well as imputed.

3.8.4.4 Gross monetary return (Rs/ha)

The total value of produce i.e. harvested rhizome was estimated treatment wise as per prevailing market rates and gross monetary returns was calculated.

3.8.4.5 Net monetary return (Rs/ha)

Net monetary return was calculated by subtracting the total cost from gross monetary returns treatment wise, since this represent the actual income of the farmer.

3.8.4.6 Benefit cost ratio

The benefit cost ratio was worked out by following formula

$$\text{B:C ratio} = \frac{\text{Gross monetary return}}{\text{Total cost}}$$

3.9 Statistical analysis

The data obtained on various characters were statistically analyzed by Randomized Block Design by Panse and Sukhatme (1985). Critical difference for examining treatment means for their significance was calculated at 5 % level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation entitled, **"Effect of Spacing on Growth, Yield and Quality of Tikhur (*Curcuma angustifolia* Roxb)"** was conducted at Instructional Farm, Department of Vegetable Science, Faculty of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) during *Kharip* season of 2018-19. The first objective of this investigation was to study the effect of spacing on growth, yield and quality of tikhur and second was to find out suitable spacing for better growth, yield and quality of tikhur.

In this chapter, careful explanations have been made relating to observations recorded on various aspects of investigation with suitable tables, graphs and photographs, as and wherever required.

4.1 Growth parameters

4.1.1 Plant height (cm) as influenced by spacing

The data regarding plant height as influenced by different spacing were recorded at 30, 60 and 90 DAP and presented in Table 3 and depicted in Fig.2.

The data presented in Table 3, clearly indicated that, the differences in plant height influenced by different spacing were found to be significant at all the stages of growth i. e. 60, 90 and 120 DAP.

At 60 DAP, significantly maximum plant height (32.15 cm) was recorded in the treatment T_1 (45 cm × 20 cm) which was followed (29.35 cm) by treatment T_4 (60 cm × 20 cm). Whereas, minimum plant height (23.75 cm) was recorded in treatment T_6 (60 cm × 45 cm).

At 90 DAP, significantly maximum plant height (41.93 cm) was recorded in the treatment T_1 (45 cm × 20 cm), which was followed (37.6 cm) by treatment T_4 (60 cm × 20 cm). Whereas, minimum plant height (30.85 cm) was recorded in treatment T_6 (60 cm × 45 cm).

Table 3. Plant height (cm) as influenced by spacing

Treatments	Plant height (cm)		
	60 DAP	**90 DAP**	**120 DAP**
T_1 - 45 cm × 20 cm	32.15	41.93	52.50
T_2 - 45 cm × 30 cm	28.10	35.80	44.05
T_3 - 45 cm × 45 cm	25.23	31.13	39.85
T_4 - 60 cm × 20 cm	29.35	37.60	47.15
T_5 - 60 cm × 30 cm	26.50	32.80	40.60
T_6 - 60 cm × 45 cm	23.75	30.85	37.55
'F' test	Sig.	Sig.	Sig.
SE(m)±	0.74	0.99	1.38
CD at 5 %	2.22	2.99	4.17

At 120 DAP, significantly maximum plant height (52.50 cm) was recorded in the treatment T_1 (45 cm × 20 cm), which was followed (47.15 cm) by treatment T_4 (60 cm × 20 cm). Whereas, minimum plant height (37.55 cm) was recorded in treatment T_6 (60 cm × 45 cm).

The data presented in table 3, indicated that higher plant density or closer plant spacing produced significantly taller plants than wider plant spacing and plant height decreased with increased in plant spacing. This is due to the fact that under closer spacing, plant might have adjusted its canopy in the vertical space by increasing inter nodal length as there was limited horizontal space. While in case of wider spacing, there was less interplant competition resulting in greater horizontal spread, less internode length and shorter plants.

The results of present investigation are in agreement with the findings of Kumar and Gill (2010), Pandey *et al*. (2011) in turmeric, Mahendar *et al.* (2015) in ginger and Nautiyal *et al*. (2016) in turmeric.

4.1.2 Number of leaves per plant as influenced by spacing

The data regarding number of leaves per plant as influenced by different spacing were recorded at 30, 60 and 90 DAP and presented in Table 4 and depicted in Fig. 3.

The data presented in Table 4, indicated that, the differences in number of leaves per plant influenced by different spacing were found to be significant at all the stages of growth i.e. 30, 60 and 90 DAP.

Table 4. Number of leaves per plant as influenced by spacing

Treatments	Number of leaves per plant		
	60 DAP	**90 DAP**	**120 DAP**
T_1 - 45 cm × 20 cm	3.25	5.10	6.45
T_2 - 45 cm × 30 cm	4.30	6.35	7.50
T_3 - 45 cm × 45 cm	4.55	6.70	7.85
T_4 - 60 cm × 20 cm	4.00	6.25	7.45
T_5 - 60 cm × 30 cm	4.35	6.40	7.70
T_6 - 60 cm × 45 cm	4.90	6.95	8.20
'F' test	Sig	Sig	Sig
SE(m)±	0.10	0.09	0.12
CD at 5 %	0.30	0.27	0.35

At 60 DAP, significantly maximum number of leaves per plant (4.90) were recorded in the treatment T_6 (60 cm × 45 cm) which was followed (4.55) by treatment T_3 (45 cm × 45 cm). Whereas minimum number of leaves per plant (3.25) were recorded in treatment T_1 (45 cm × 20 cm).

At 90 DAP, significantly the maximum number of leaves per plant (6.95) crop were recorded in the treatment T_6 (60 cm × 45 cm), which found statistically at par with (6.70) treatment T_3 (45 cm × 45 cm). Whereas, the minimum number of leaves (5.10) were recorded in treatment T_1 (45 cm × 20 cm).

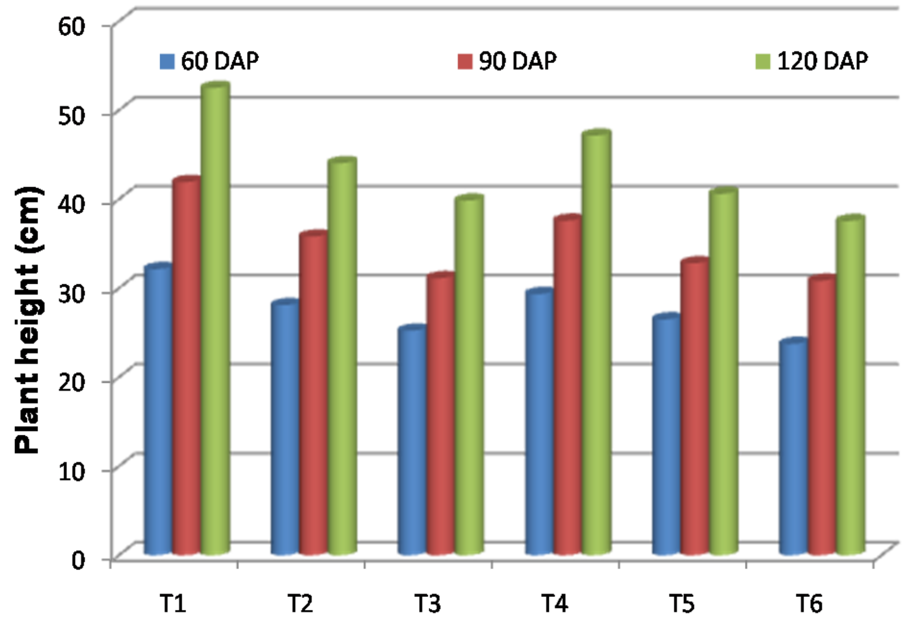


Fig. 2. Plant height (cm) as influenced by spacing

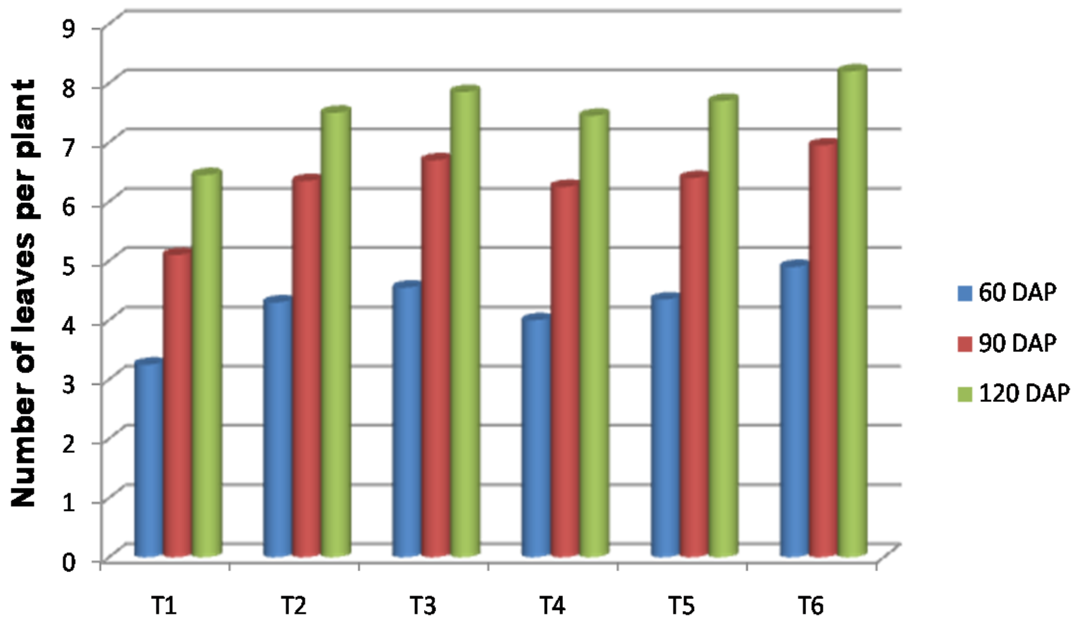


Fig.3 . Number of leaves per plant as influenced by spacing

At 120 DAP, the maximum number of leaves per plant (8.20) were recorded in the treatment T_6 (60 cm × 45 cm), which found statistically at par with (7.85) treatment T_3 (45 cm × 45 cm). Whereas, the minimum number of leaves per plant (6.45) were recorded in treatment T_1 (45 cm × 20 cm).

It is well evident from the above data that, wider plant spacing produced significantly more number of leaves per plant than closer plant spacing. This might be due to the fact that wider spacing gave an opportunity for more availability of nutrients, moisture and better interception of light for development of more number of leaves. Similar results were also reported by Wakhare *et al*. (2007), Pandey *et al*. (2011), Modupeola and olaniyi (2015) and Nautiyal *et al.* (2016) in turmeric.

4.1.3 Leaf length as influenced by spacing

The data regarding to the leaf length as influenced by different spacing was recorded at 60, 90 and 120 DAP and presented in Table 5 and depicted in Fig. 4.

The data presented in Table 5, indicated that, the differences in length of leaves influenced by spacing were found to be significant at all the stages of growth i. e. 60, 90 and 120 DAP.

Table 5. Leaf length (cm) as influenced by spacing

Treatments	**Leaf length (cm)**		
	60 DAP	**90 DAP**	**120 DAP**
T_1 - 45 cm × 20 cm	13.13	17.58	20.95
T_2 - 45 cm × 30 cm	14.49	20.25	23.80
T_3 - 45 cm × 45 cm	15.32	20.73	24.85
T_4 - 60 cm × 20 cm	13.29	18.60	22.95
T_5 - 60 cm × 30 cm	14.90	20.52	24.7
T_6 - 60 cm × 45 cm	16.15	21.67	26.79
‘F’ test	Sig.	Sig.	Sig.
SE(m)±	0.20	0.21	0.33
CD at 5 %	0.60	0.65	1.00

At 60 DAP, significantly maximum leaf length (16.15 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (15.32 cm) by treatment T_3 (45 cm × 45 cm). Whereas, minimum leaf length (13.13 cm) was recorded in treatment T_1 (45 cm × 20 cm).

At 90 DAP, significantly the maximum leaf length (21.67 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (20.73 cm) by treatment T_3 (45 cm × 45 cm). Whereas, minimum leaf length (17.58 cm) was recorded in treatment T_1 (45 cm × 20 cm).

At 120 DAP, significantly the maximum leaf length (26.79 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (24.85 cm) by treatment T_3 (45 cm × 45 cm). Whereas, minimum leaf length (20.95 cm) was recorded in treatment T_1 (45 cm × 20 cm).

It is observed from the data that wider plant spacing produced significantly longest leaf than closer plant spacing. Under wider spacing, there might be sufficient availability of nutrients, moisture, space and better interception of sunlight within the plant canopy than closer spacing which results into an increase in length of leaves. These results are in line with the findings of Raut *et al*. (2004) in turmeric, Yadav *et al*. (2013) in ginger.

4.1.4 Leaf breadth as influenced by spacing

The data regarding leaf breadth as influenced by different spacing was recorded at 30, 60 and 90 DAP and presented in Table 6 and depicted in Fig. 5.

The data presented in Table 6, clearly indicated that, the differences in breadth of leaves influenced by spacing were found to be significant at all the stages of growth i. e. 30, 60 and 90 DAP.

At 60 DAP, significantly the maximum leaf breadth (10.06 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (9.74 cm) by treatment T_3 (45 cm × 45 cm). Whereas, the minimum leaf breadth (8.63 cm) was recorded in treatment T_1 (spacing of 45 cm × 20 cm).

Table 6. Leaf breadth (cm) as influenced by spacing

Treatments	Leaf breadth (cm)		
	60 DAP	**90 DAP**	**120 DAP**
T_1 - 45 cm × 20 cm	8.63	10.04	11.57
T_2 - 45 cm × 30 cm	9.08	10.78	12.40
T_3 - 45 cm × 45 cm	9.74	11.36	13.16
T_4 - 60 cm × 20 cm	8.69	10.18	11.83
T_5 - 60 cm × 30 cm	9.69	10.90	12.78
T_6 - 60 cm × 45 cm	10.06	11.58	13.71
'F' test	Sig.	Sig.	Sig.
SE(m)±	0.08	0.12	0.12
CD at 5 %	0.24	0.36	0.37

At 90 DAP, the maximum leaf breadth (11.58 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which found statistically at par (11.36 cm) with treatment T_3 (45 cm × 45 cm). Whereas, minimum leaf breadth (10.04 cm) was recorded in treatment T_1 (45 cm × 20 cm).

At 120 DAP, significantly the maximum leaf breadth (13.71 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (13.16 cm) by treatment T_3 (45 cm × 45 cm). Whereas, minimum leaf breadth (11.57 cm) was recorded in treatment T_1 (45 cm × 20 cm).

The results revealed that, wider plant spacing produced significantly broadest leaf than closer plant spacing. Under wider spacing there might be sufficient availability of nutrients, moisture, space and better interception of sunlight within the plant canopy than closer spacing which results into an increase in breadth of leaves. Similar results have also been reported by Raut *et al*. (2004) in turmeric, Yadav *et al*. (2013) in ginger.

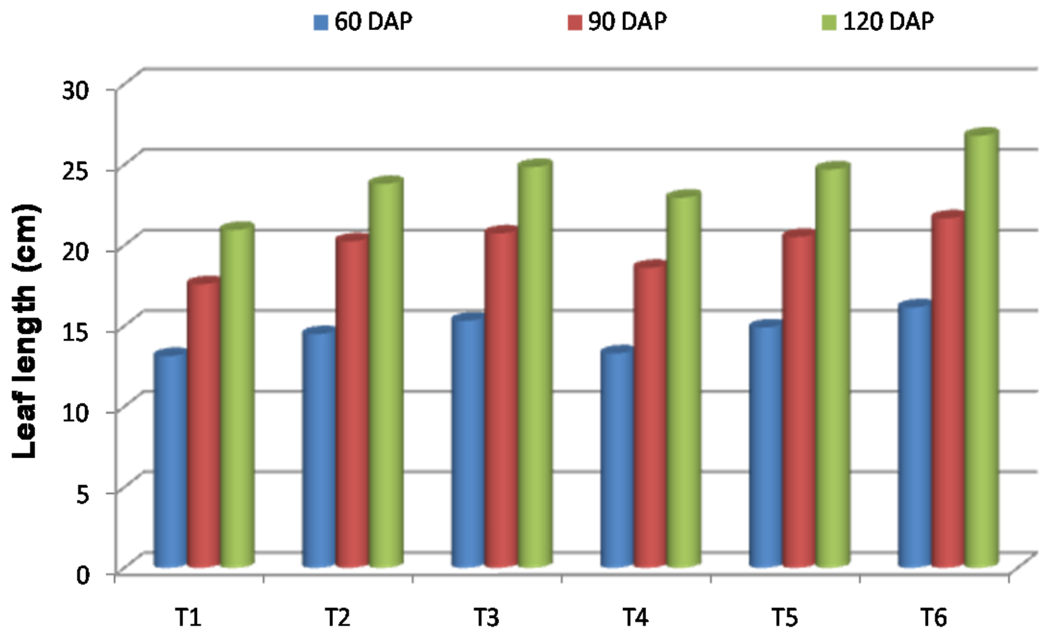


Fig. 4. Leaf length (cm) as influenced by spacing

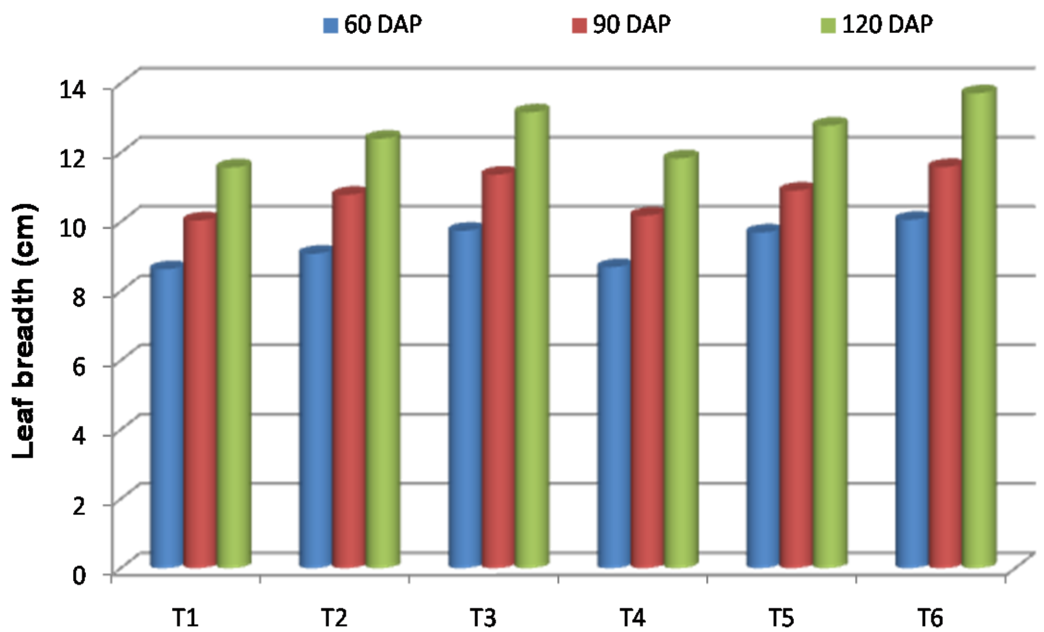


Fig. 5. Leaf breadth (cm) as influenced by spacing

4.1.5 Leaf area index as influenced by spacing

The data regarding to the leaf area index as influenced by spacing was recorded at 90 DAP and presented in Table 7 and depicted in Fig. 6.

The data presented in Table 7, clearly indicated that, the differences in leaf area index influenced by spacing was found to be significant at 90 DAP.

At 90 DAP, maximum leaf area index (1.73) was recorded in treatment T_1 (45 cm × 20 cm), which found statistically at par (1.66) with treatment T_4 (60 cm × 20 cm), whereas minimum leaf area index (1.11) was recorded in treatment T_6 (60 cm × 45 cm).

Table 7. Leaf area index as influenced by spacing

Treatments	Leaf area index (90 DAP)
T_1 - 45 cm × 20 cm	1.73
T_2 - 45 cm × 30 cm	1.63
T_3 - 45 cm × 45 cm	1.27
T_4 - 60 cm × 20 cm	1.66
T_5 - 60 cm × 30 cm	1.49
T_6 - 60 cm × 45 cm	1.11
‘F’ test	Sig.
SE (m)±	0.04
CD at 5 %	0.13

From the present data we understand that, closer plant spacing had significantly more leaf area index than widely spaced crop. Leaf area of crop planted at closer spacing was less as compared to crop planted at wider spacing but it was land area which had resulted in more leaf area index in case of closer spacing. Similar results also reported by

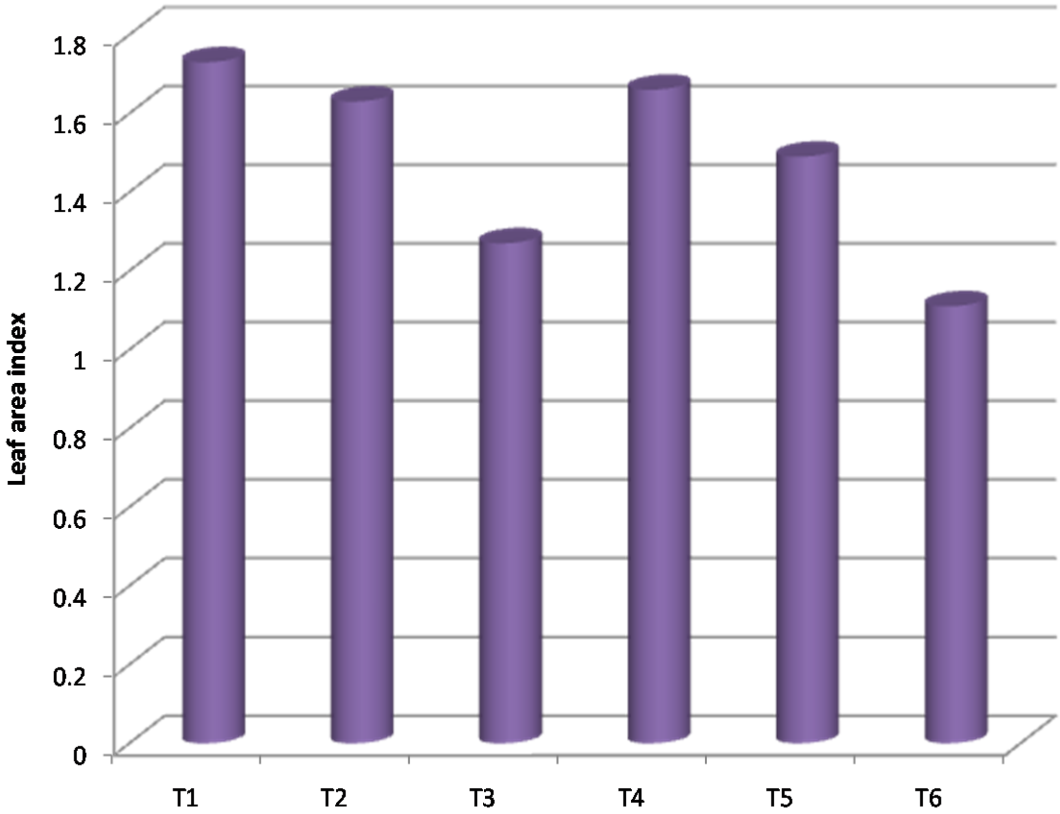


Fig. 6. Leaf area index as influenced by different spacing

Kandiannan and Chandragir (2006) and Kumar and Gill (2010) in turmeric, Mahender *et al*. (2015) in ginger.

4.2 Yield parameters of tikhur

4.2.1 Days to maturity as influenced by spacing

The data regarding days to maturity as influenced by spacing was recorded and presented in table 8. The data presented in Table 8, indicated that, effect of spacing on days to maturity was statistically found to be non-significant.

Table 8. Days to maturity as influenced by spacing

Treatments	Days to maturity
T_1 - 45 cm × 20 cm	154.25
T_2 - 45 cm × 30 cm	152.50
T_3 - 45 cm × 45 cm	149.25
T_4 - 60 cm × 20 cm	154.00
T_5 - 60 cm × 30 cm	149.50
T_6 - 60 cm × 45 cm	148.00
'F' test	NS
SE(m)±	2.11
CD at 5 %	NS

From the data presented in table 8, indicated that plant spacing showed non-significant effect on days to maturity. This results are in line with the findings of Bahadur *et al*. (2000) in turmeric, Woelore *et al*. (2016) in ginger.

4.2.2 Weight of mother rhizome per plant (g) as influenced by spacing

The data regarding weight of mother rhizome per plant as influenced by different spacing was recorded and presented in Table 9 and depicted in Fig. 7.

The data presented in Table 9, showed that, the differences in weight of mother rhizome per plant influenced by spacing was found to be significant.

Table 9. Weight of mother rhizome per plant (g) and weight of primary rhizome per plant (g) as influenced by spacing

Treatments	Weight of mother rhizome per plant (g)	Weight of primary rhizome per plant (g)
T_1 - 45 cm × 20 cm	42.35	87.25
T_2 - 45 cm × 30 cm	44.65	98.45
T_3 - 45 cm × 45 cm	46.50	106.85
T_4 - 60 cm × 20 cm	44.58	94.20
T_5 - 60 cm × 30 cm	46.00	103.60
T_6 - 60 cm × 45 cm	50.10	108.60
'F' test	Sig.	Sig.
SE(m)±	0.47	1.08
CD at 5 %	1.41	3.27

The data indicated that, significantly maximum (50.10 g) weight of mother rhizome was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (46.50 g) by treatment T_3 (45 cm × 45 cm) and minimum weight of mother rhizome per plant (42.35 g) was recorded in treatment T_1 (45 cm × 20 cm).

The data revealed that, wider plant spacing produced maximum weight of mother rhizome per plant than closer plant spacing. Highest weight in wider plant spacing may be due to better nourishment and availability of space and less competition between the plants. Present findings are supported with that of Kumar and Gill (2010), Pandey *et al*. (2011) and Preetham *et al.* (2018) in turmeric.

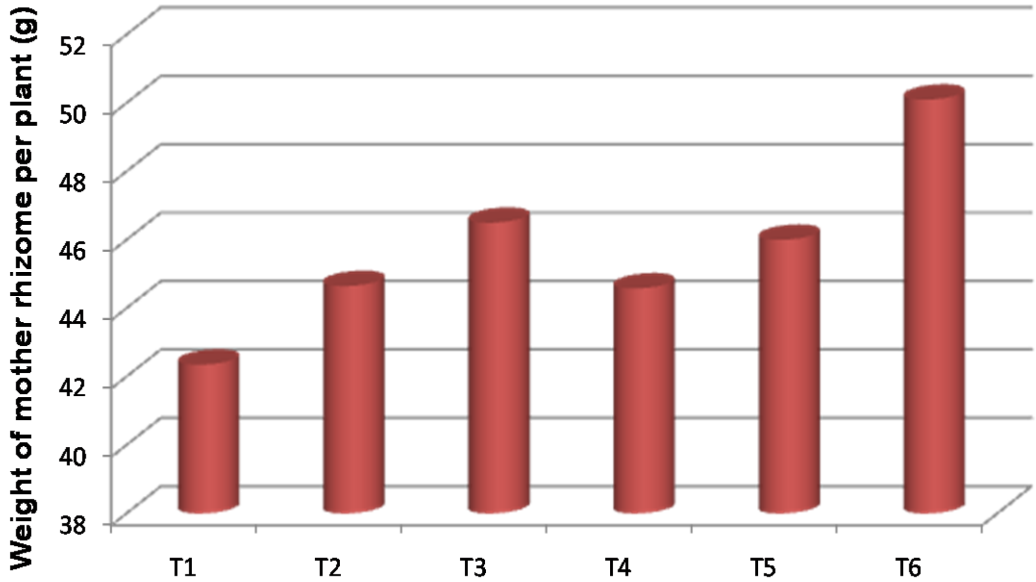


Fig. 7. Weigth of mother rhizome per plant (g) as influenced by spacing

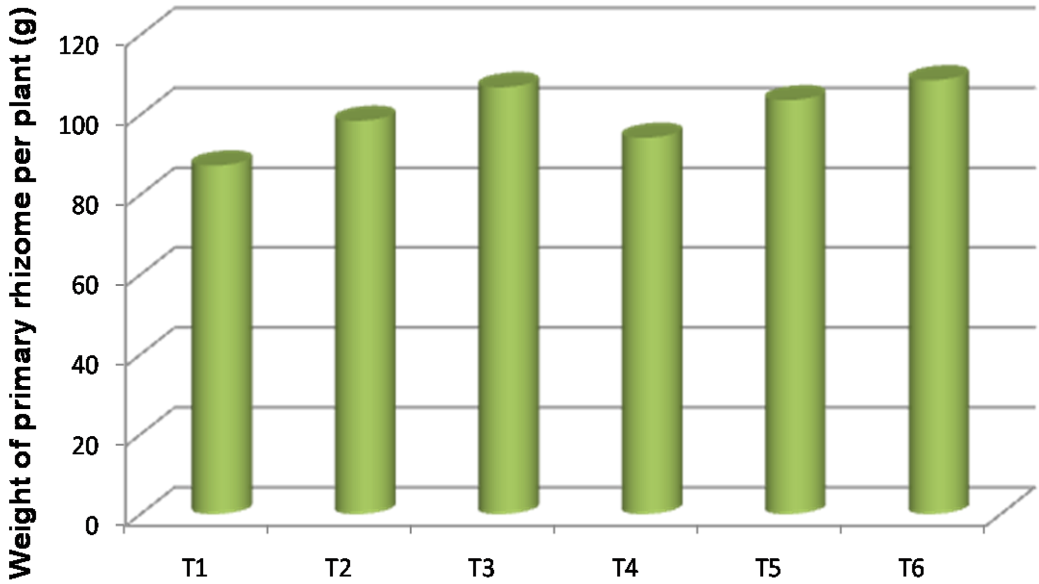


Fig.8. Weight of primary rhizome per plant (g) influenced by spacing

4.2.3 Weight of primary rhizome per plant (g) as influenced by spacing

The data on weight of primary rhizome per plant as influenced by spacing was recorded and presented in Table 9 and depicted in Fig. 8.

The data presented in Table 9, showed that, the differences in weight of primary rhizome per plant influenced by different spacing was found to be significant.

Maximum weight of primary rhizome per plant (108.60 g) was recorded in the treatment T_6 (60 cm × 45 cm), which found statistically at par (106.85 g) with treatment T_3 (45 cm × 45 cm). Whereas, minimum weight of mother rhizome per plant (87.25 g) was recorded in treatment T_1 (45 cm × 20 cm).

It is well evident from the present findings that, wider plant spacing produced maximum weight of primary rhizome per plant than closer plant spacing. Maximum weight in wider plant spacing may be due to better nourishment and availability of space and less competition between the plants. This is in confirmity with the results found by Pandey and Mishra (2009), Kumar and Gill (2010) and Kiran *et al*. (2013) in turmeric.

4.2.4 Number of mother rhizome per plant as influenced by spacing

The data regarding number of mother rhizome per plant as influenced by different spacing was recorded and presented in Table 10 and depicted in Fig. 9.

The data presented in Table 10, revealed that, the differences in number of mother rhizome per plant influenced by different spacing were found to be significant.

Significantly maximum number of mother rhizome per plant (1.70) was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (1.53) by treatment T_3 (45 cm × 45 cm). Whereas, the minimum number of mother rhizome per plant (1.23) was recorded in treatment T_1 (45 cm × 20 cm).

Table 10. Number of mother rhizomes per plant and Number of primary rhizomes per plant as influenced by spacing

Treatments	Number of mother rhizome per plant	Number of primary rhizome per plant
T_1 - 45 cm × 20 cm	1.23	4.60
T_2 - 45 cm × 30 cm	1.39	4.75
T_3 - 45 cm × 45 cm	1.53	5.55
T_4 - 60 cm × 20 cm	1.37	4.65
T_5 - 60 cm × 30 cm	1.42	5.25
T_6 - 60 cm × 45 cm	1.70	6.03
'F' test	Sig	Sig.
SE(m)±	0.03	0.17
CD at 5 %	0.10	0.51

The data presented in Table 10, indicated that, wider plant spacing produced maximum number of mother rhizome per plant than closer plant spacing. This may be due to Wider spacing might have given the plants an opportunity to utilize more space and resources for the production of more number of mother rhizomes per plant. Similar results were also obtained by Wakhare *et al*. (2007) and Preetham *et al.* (2018) in turmeric.

4.2.5 Number of primary rhizome per plant as influenced by spacing

The data on weight of primary rhizome per plant as influenced by spacing was recorded and presented in Table 10 and depicted in Fig. 10.

The data presented in Table 10, showed that, the differences in weight of primary rhizome per plant influenced by spacing were found to be significant.

The data depicted in Table 10, clearly indicated that, maximum number of primary rhizome per plant (6.03) was recorded in the

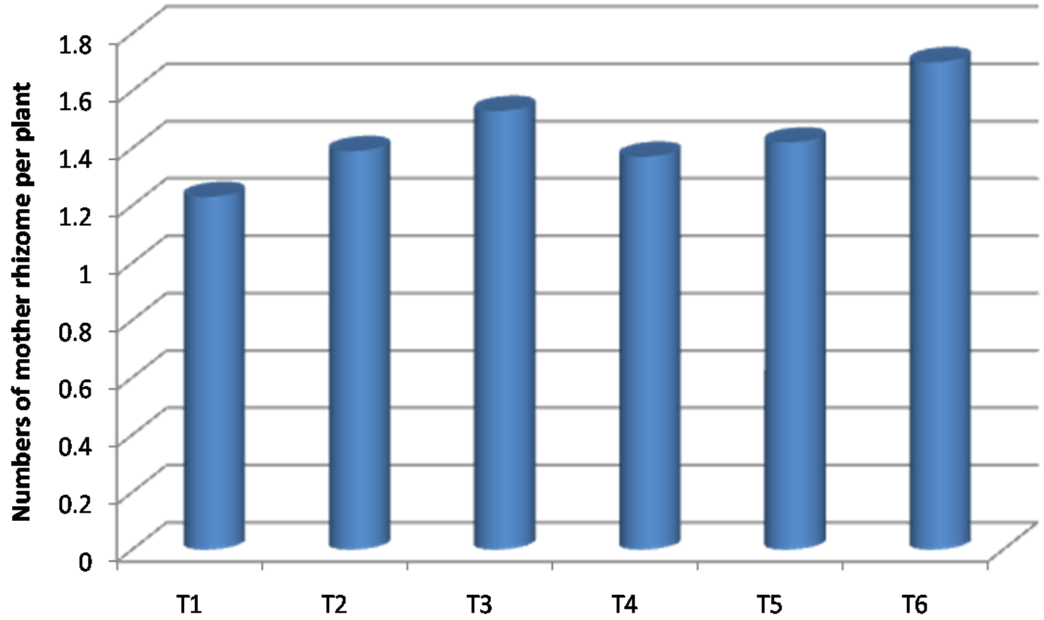


Fig.9. Number of mother rhizomes per plant as influenced by spacing

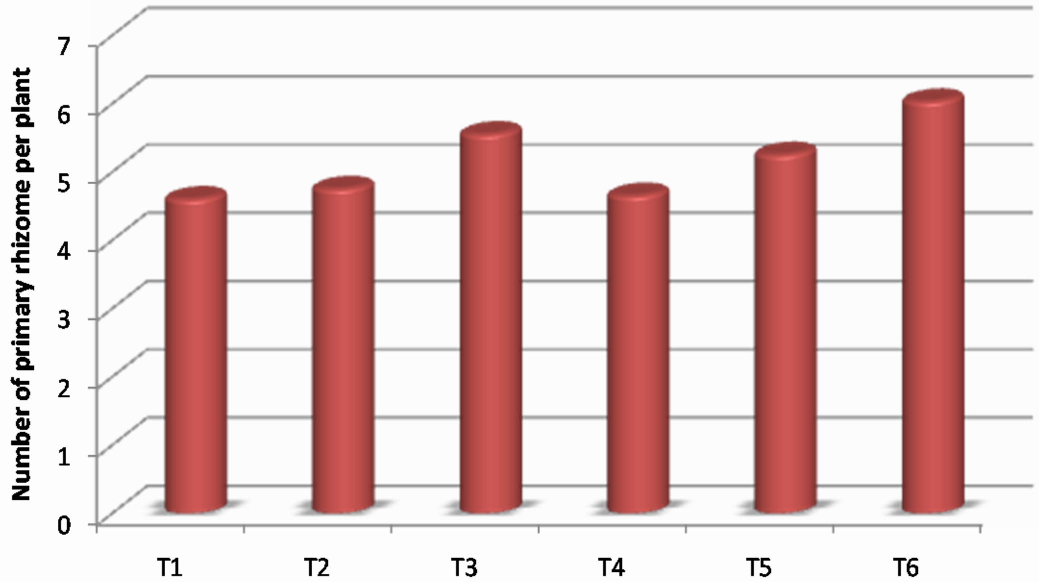


Fig.10. Number of primary rhizome per plant influenced by spacing

treatment T_6 (60 cm × 45 cm), which found statistically at par (5.55) with treatment T_3 (45 cm × 45 cm). Whereas, minimum number of primary rhizome per plant (4.6) was recorded in treatment T_1 (45 cm × 20 cm).

The results revealed that, wider plant spacing produced maximum number of primary rhizome per plant than closer plant spacing. This may be due to Wider spacing might have given the plants an opportunity to utilize more space and resources for the production of more number of primary rhizomes per plant. Present findings are supported with that of Kiran *et al*. (2013) in turmeric, Datta *et al*. (2017) in ginger and Preetham *et al.* (2018) in turmeric.

4.2.6 Thickness of mother rhizome per plant (cm) as influenced by spacing

The data regarding thickness of mother rhizome per plant as influenced by spacing was recorded and presented in Table 11 and depicted in Fig. 11.

Table 11. Thickness of mother rhizome per plant (cm) and thickness primary rhizome per plant (cm) as influenced by spacing

Treatments	Thickness of mother rhizome per plant (cm)	Thickness of primary rhizome per plant (cm)
T_1 - 45 cm × 20 cm	2.62	1.59
T_2 - 45 cm × 30 cm	2.72	1.70
T_3 - 45 cm × 45 cm	2.97	1.78
T_4 - 60 cm × 20 cm	2.68	1.65
T_5 - 60 cm × 30 cm	2.86	1.75
T_6 - 60 cm × 45 cm	3.06	1.92
'F' test	Sig.	Sig.
SE(m)±	0.04	0.04
CD at 5 %	0.13	0.12

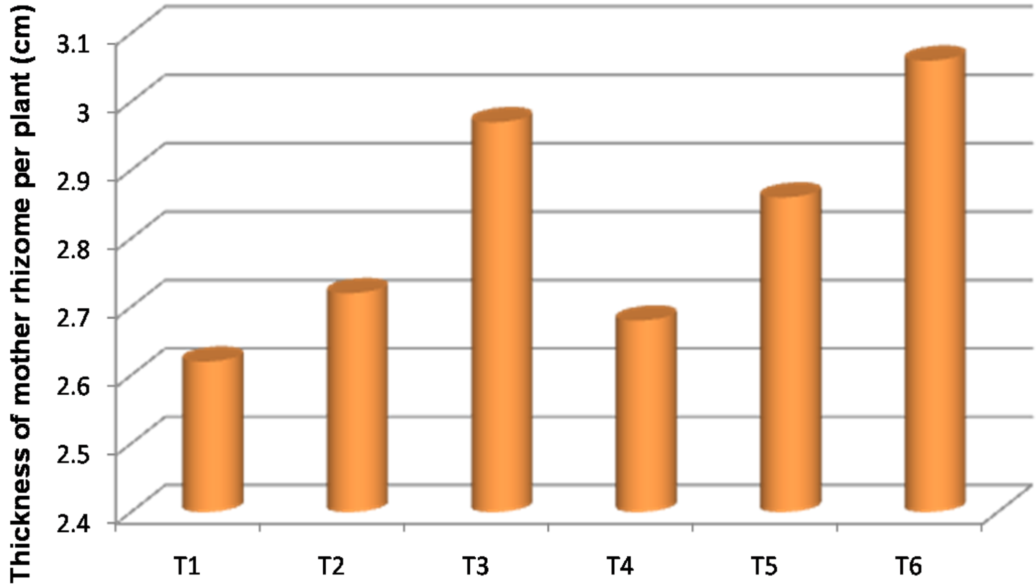


Fig. 11. Thickness of mother rhizome per plant (cm) as influenced by spacing

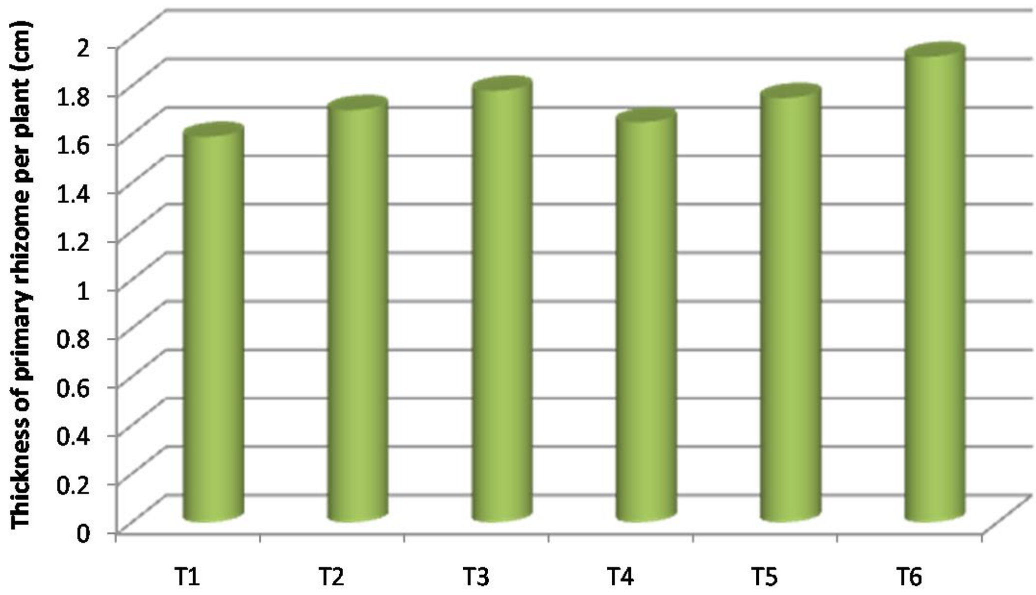


Fig. 12. Thickness of primary rhizome per plant (cm) as influenced by spacing

The data presented in Table 11, showed that, the differences in thickness of mother rhizome per plant influenced by spacing were found to be significant.

Data indicated the significant differences among the treatments. The maximum thickness of mother rhizome per plant (3.06 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which found statistically at par (2.97 cm) with treatment T_3 (45 cm × 45 cm). Whereas, minimum (2.62 cm) was recorded in treatment T_1 (45 cm × 20 cm).

The present findings suggests that, wider plant spacing produced more thickness of mother rhizome per plant than closer plant spacing. This might be due to better availability of plant nutrients, moisture and light in wider spaced plants. Under closer spacing rhizome could not expose properly, which ultimately resulted in smaller rhizome. This is in agreement with the findings of Preetham *et al*. (2018) in turmeric.

4.2.7 Thickness of primary rhizome per plant (cm) as influenced by spacing

The data regarding thickness of primary rhizome per plant as influenced by different spacing was recorded and presented in Table 11 and depicted in Fig.12.

The data presented in Table 11, showed that, the differences in thickness of primary rhizome per plant influenced by different spacing were found to be significant.

Significantly maximum thickness of primary rhizome per plant (1.92 cm) was recorded in the treatment T_6 (60 cm × 45 cm), which was followed (1.78 cm) by treatment T_3 (45 cm × 45 cm). Whereas, minimum thickness of primary rhizome per plant (1.59 cm) was recorded in treatment T_1 (45 cm × 20 cm).

The results revealed that, wider plant spacing produced more thickness of primary rhizome per plant than closer plant spacing. This might be due to better availability of plant nutrients, moisture and light in wider spaced plants. Under closer spacing rhizome could not expose properly, which ultimately resulted in smaller rhizome. This is in confirmation with the findings of Kiran *et al*. (2013) in turmeric and Datta *et al*. (2017) in ginger.

4.2.8 Dry matter (%) of rhizome per plant as influenced by spacing

The data regarding dry matter percent of rhizome per plant as influenced by spacing were recorded and presented in Table 12. The data clearly indicated that, effect of spacing on dry matter percent of rhizome per plant were statistically found non-significant. Kandiannan and Chandaragir also reported the non significant influence of plant spacing on dry recovery percent of turmeric.

Table 12. Dry matter (%) of rhizome per plant as influenced by spacing

Treatments	Dry matter (%) of rhizome per plant
T_1 - 45 cm × 20 cm	17.26 (4.27)
T_2 - 45 cm × 30 cm	17.87 (4.34)
T_3 - 45 cm × 45 cm	18.23 (4.39)
T_4 - 60 cm × 20 cm	17.59 (4.31)
T_5 - 60 cm × 30 cm	17.92 (4.35)
T_6 - 60 cm × 45 cm	18.48 (4.41)
'F' test	NS
SE(m)±	0.05
CD at 5 %	NS

(**Note** : Figures in parenthesis indicate squareroot transformed values.)

4.2.9 Rhizome yield per plant (g) as influenced by spacing

The data regarding rhizome yield per plant as influenced by different spacing were recorded and presented in Table 13 and depicted in Fig. 13.

The data presented in Table 13, showed that, the differences in rhizome yield per plant influenced by spacing was found to be significant.

Significantly the maximum rhizome yield per plant (158.7 g) was recorded in the treatment T_6 (60 cm × 45 cm) which was followed (53.35 g) by treatment T_3 (45 cm × 45 cm). Whereas, minimum rhizome yield per plant (129.6 g) was recorded in treatment T_1 (45 cm × 20 cm).

Table 13 Rhizome yield per plant (g) and rhizome yield per plot (kg) as influenced by spacing

Treatments	Rhizome yield per plant (g)	Rhizome yield per Plot (kg)
T_1 - 45 cm × 20 cm	129.60	9.33
T_2 - 45 cm × 30 cm	143.10	6.87
T_3 - 45 cm × 45 cm	153.35	4.91
T_4 - 60 cm × 20 cm	138.78	7.49
T_5 - 60 cm × 30 cm	149.60	5.39
T_6 - 60 cm × 45 cm	158.70	3.81
'F' test	Sig	Sig
SE(m)±	1.26	0.07
CD at 5 %	3.80	0.20

The data from Table 13, revealed that, wider plant spacing produced highest rhizome yield per plant than closer plant spacing. Increasing trend in yield per plant, was observed with increase in spacing, decrease in plant population level. This is may be due to better nourishment and availability of space in wider spaced plant. This is in confirmation with that of Bahadur *et al*. (2000) in turmeric, Mahender *et al*. (2015) and Datta *et al*. (2017) in ginger.

4.2.10 Rhizome yield per plot (kg) as influenced by spacing

The data regarding rhizome yield per plot as influenced by spacing was recorded and presented in Table 13 and depicted in Fig 14.

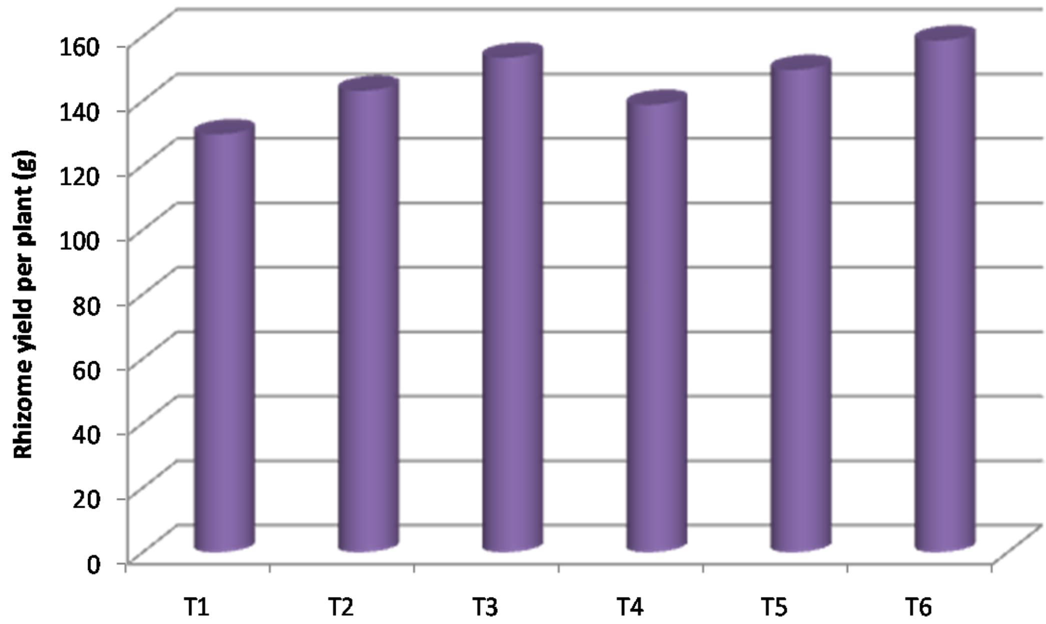


Fig. 13. Rhizome yield per plant (g) as influenced by spacing

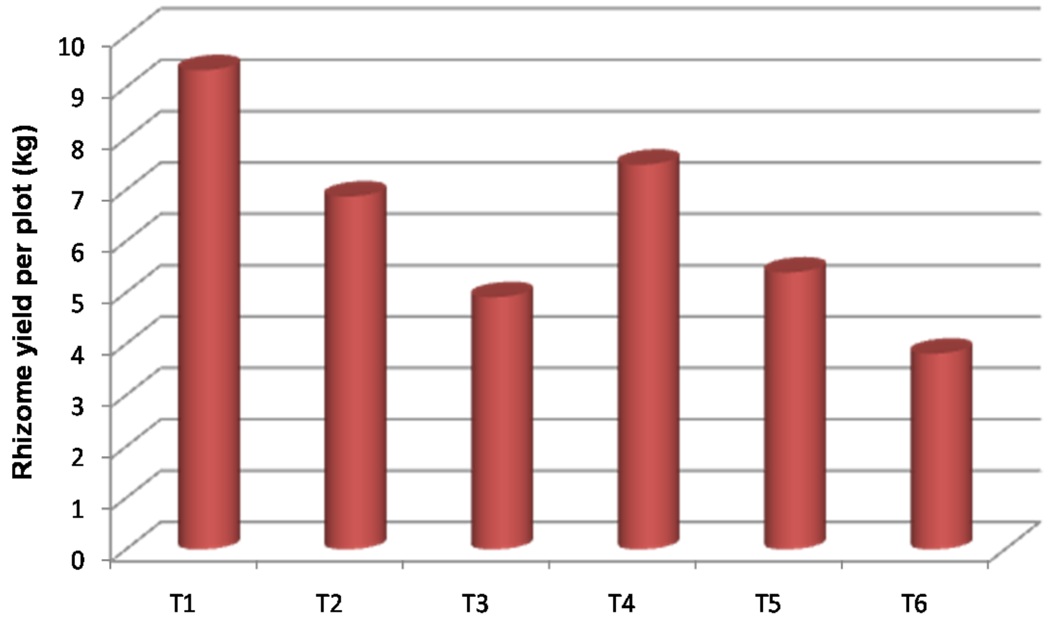


Fig. 14. Rhizome yield per plot (kg) as influenced by spacing

The data presented in Table 13, showed that, the differences in rhizome yield per plot influenced by different spacing were found to be significant.

Data indicated significant differences among the treatments. Significantly maximum (9.33 kg) rhizome yield per plot was recorded in the treatment T_1 (45 cm × 20 cm) which was followed (7.49 kg) by treatment T_4 (60 cm × 20 cm). Whereas, minimum rhizome yield per plot (3.81 kg) was recorded in treatment T_6 (60 cm × 45 cm).

It is well evident from the present findings that, closest plant spacing produced highest rhizome yield per hectare than wider plant spacing. Yield per plot is maximum in closer plant spacing. The possible reason for getting higher yields from closer spacing or higher plant population lies in the fact that larger number of plants were accommodated per unit area. Similar results were also reported by Silva *et al*. (2004) and Pandey and Mishra (2009) in turmeric.

4.2.11 Total rhizome yield (t/ha) as influenced by spacing

The data on total rhizome yield per hectare as influenced by different spacing was recorded and presented in Table 14 and depicted in Fig. 15.

Table 14. Total rhizome yield (t/ha) as influenced by spacing

Treatments	Total rhizome yield (t/ha)
T_1 - 45 cm × 20 cm	14.40
T_2 - 45 cm × 30 cm	10.59
T_3 - 45 cm × 45 cm	7.58
T_4 - 60 cm × 20 cm	11.56
T_5 - 60 cm × 30 cm	8.31
T_6 - 60 cm × 45 cm	5.87
'F' test	Sig
SE(m)±	0.10
CD at 5 %	0.31

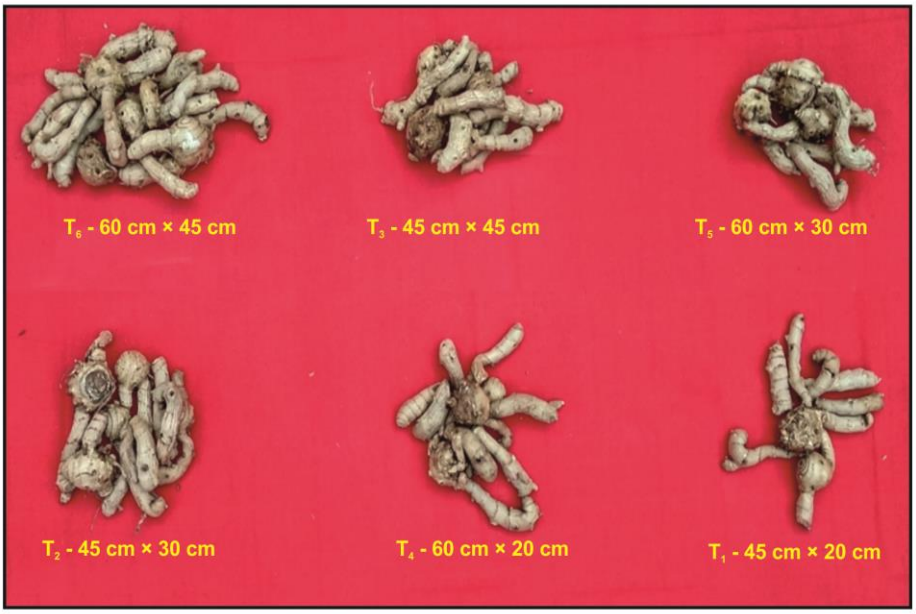


Plate 3(a) Mother and primary rhizomes of tikhur

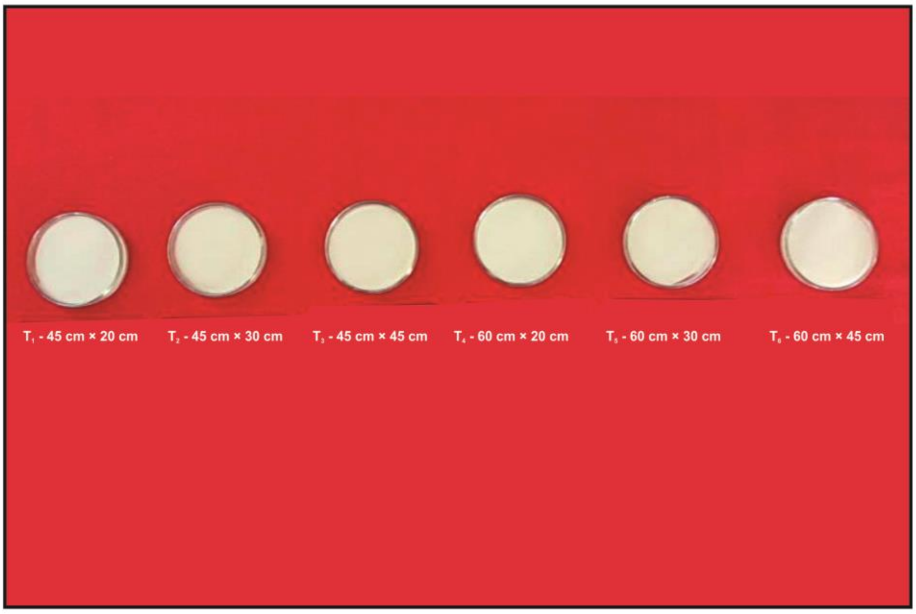


Plate 3(b) Starch recovery (%) according to spacing treatment

The data presented in Table 14, showed that, the differences in rhizome yield per hactare influenced by different spacing was found to be significant.

Data indicated significant differences among the treatments. Significantly the maximum rhizome yield per hectare (14.40 t) was recorded in the treatment T_1 (45 cm × 20 cm) which was followed (11.56 t) by treatment T_4 (60 cm × 20 cm). Whereas, minimum rhizome yield per hectare (5.87 t) was recorded in treatment T_6 (60 cm × 45 cm).

The present results reflected that, closest plant spacing produced highest rhizome yield per hectare than wider plant spacing. The possible reason for getting higher yields from closer spacing or higher plant population lies in the fact that larger number of plants was accommodated per hectare.

The results of present investigation are in accordance with findings of Islam *et al*. (2002), Pandey and Mishra (2009) and Kumar and Gill (2010) in turmeric, Modepeola *et al* .(2013), Yadav *et al*. (2013) and Mahender *et al*. (2015) in ginger.

4.3 Quality parameters of tikhur

4.3.1 Starch recovery (%) as influenced by spacing

The data regarding starch recovery as influenced by spacing was recorded and presented in table 15.

The data presented in table 15, indicated that, plant spacing showed non-significant difference on starch recovery percentage. Similar results also reported by Mahender *et al*. (2015) in ginger.

Table 15. Starch recovery (%) and starch recovery (kg/ha) as influenced by spacing

Treatments	Starch recovery (%)	Starch recovery (kg/ha)
T_1 - 45 cm × 20 cm	10.60 (3.40)	761.75
T_2 - 45 cm × 30 cm	12.23 (3.63)	646.27
T_3 - 45 cm × 45 cm	12.86 (3.72)	492.33
T_4 - 60 cm × 20 cm	11.84 (3.58)	692.84
T_5 - 60 cm × 30 cm	12.33 (3.65)	506.77
T_6 - 60 cm × 45 cm	13.01 (3.74)	381.48
'F' test	NS	Sig
SE(m)±	0.09	24.73
CD at 5 %	NS	74.52

(**Note** : Figures in parenthesis indicate squareroot transformed values.)

4.3.2 Starch recovery (kg/ha) as influenced by spacing.

The data regarding starch recovery as influenced by spacing was recorded and presented in Table 15 and depicted in Fig 16.

The data presented in Table 15, showed that, the differences in starch recovery per hectare as influenced by different spacing were found to be significant.

Data indicated significant differences among the treatments. Maximum starch recovery per hectare (761.75 kg) was recorded in the treatment T_1 (45 cm × 20 cm), which found statistically at par (692.84 kg) with treatment T_4 (60 cm × 20 cm). Whereas, minimum starch recovery per hectare (381.48 kg) was recorded in treatment T_6 (60 cm × 45 cm).

The present results revealed that, more starch recovery per hectare was obtained from closely spaced than widely spaced plant. The possible reason for getting higher starch recovery per hectare from closer spacing or higher plant density might be due to reason that larger number

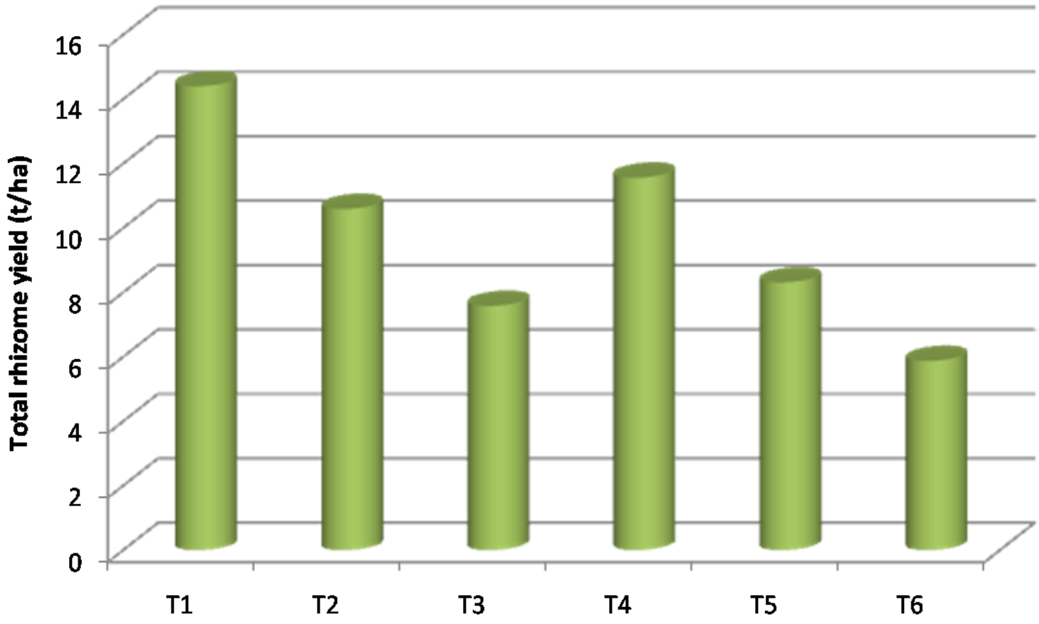


Fig. 15. Total rhizome yield (t/ha) as influenced by spacing

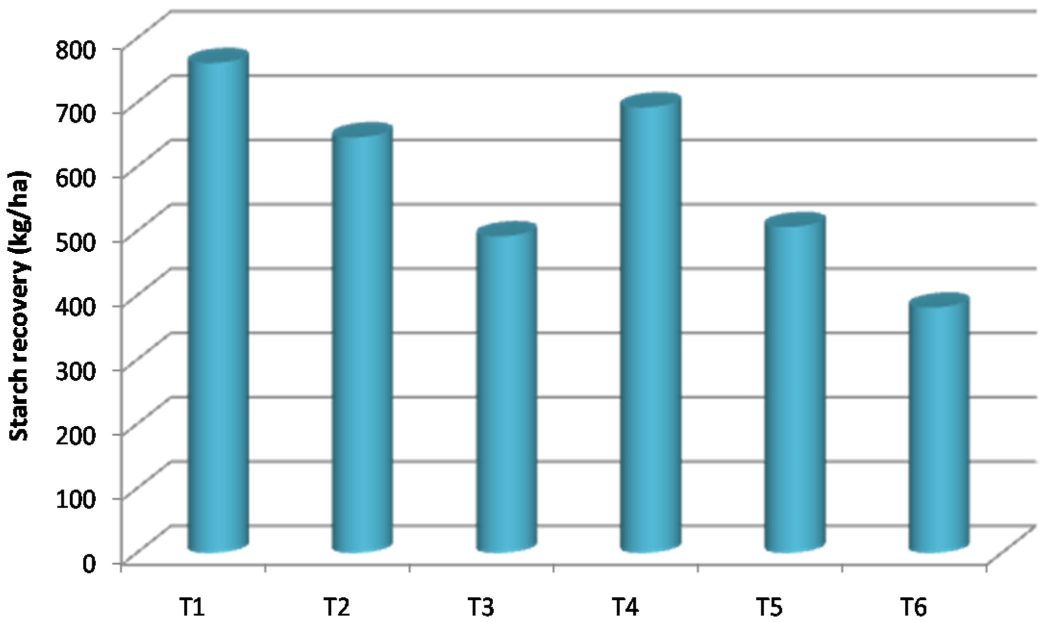


Fig. 16. Starch recovery (kg/ha) as influenced by spacing

of plants were accommodated per hectare than wider spacing resulting into more starch recovery per hectare.

4.3.3 Protein content (%) as influenced by spacing

The data regarding protein content as influenced by spacing was recorded and presented in table 16. The data presented in Table 16, indicated that, effect of spacing on protein content were statistically found non-significant.

Table 16. Protein content (%) as influenced by spacing

Treatments	Protein content (%)
T_1 - 45 cm × 20 cm	0.54 (1.24)
T_2 - 45 cm × 30 cm	0.56 (1.25)
T_3 - 45 cm × 45 cm	0.58 (1.26)
T_4 - 60 cm × 20 cm	0.55 (1.25)
T_5 - 60 cm × 30 cm	0.57 (1.25)
T_6 - 60 cm × 45 cm	0.59 (1.26)
‘F’ test	NS
SE(m)±	0.009
CD at 5 %	NS

(**Note** : Figures in parenthesis indicate squareroot transformed values.)

4.4 Effect of spacing on economics of cultivation

The data regarding economics of tikhur as influenced by spacing was recorded and presented in Table 17 and depicted in Fig 17.

The data presented in table 17, showed that, the highest gross monetary return (553526.00 Rs/ha), net monetary return (359571.25 Rs/ha) were obtained from treatment T_1 (45 cm × 20 cm) which was followed by gross return (470227.00 Rs/ha) and net return (314469.75 Rs/ha) treatment T_4 (60 cm × 20 cm). But the highest benefit cost ratio (3.02) was recorded in T_4 (60 cm × 20 cm) which found statistically at par with (2.98) treatment T_2 (45 cm × 30 cm). Whereas, the lowest gross monetary return (242864.00 Rs /ha), net monetary return (150769.25 Rs /ha) and benefit cost ratio (2.64) were obtained in treatment T_6 (60 cm × 45 cm).

Table 17. Economics of tikhur as influenced by spacing

Treatments	Gross return	Net return	B : C ratio
T_1 - 45 cm × 20 cm	553526.00	359571.25	2.85
T_2 - 45 cm × 30 cm	426620.00	283595.25	2.98
T_3 - 45 cm × 45 cm	309399.00	200262.70	2.83
T_4 - 60 cm × 20 cm	470227.00	314469.75	3.02
T_5 - 60 cm × 30 cm	334769.00	217099.25	2.84
T_6 - 60 cm × 45 cm	242864.00	150769.25	2.64
'F' test	Sig	Sig	Sig
SE(m)±	6507.44	6507.44	0.04
CD at 5 %	19611.40	19611.40	0.13

The highest benefit cost ratio was obtained in treatment T_4 (60 cm × 20 cm). This might be due to a sizable increase in yield and decrease in cost of planting material. The results of the present investigation are in agreement with that of Nautiyal *et al.* (2016) in turmeric crop.

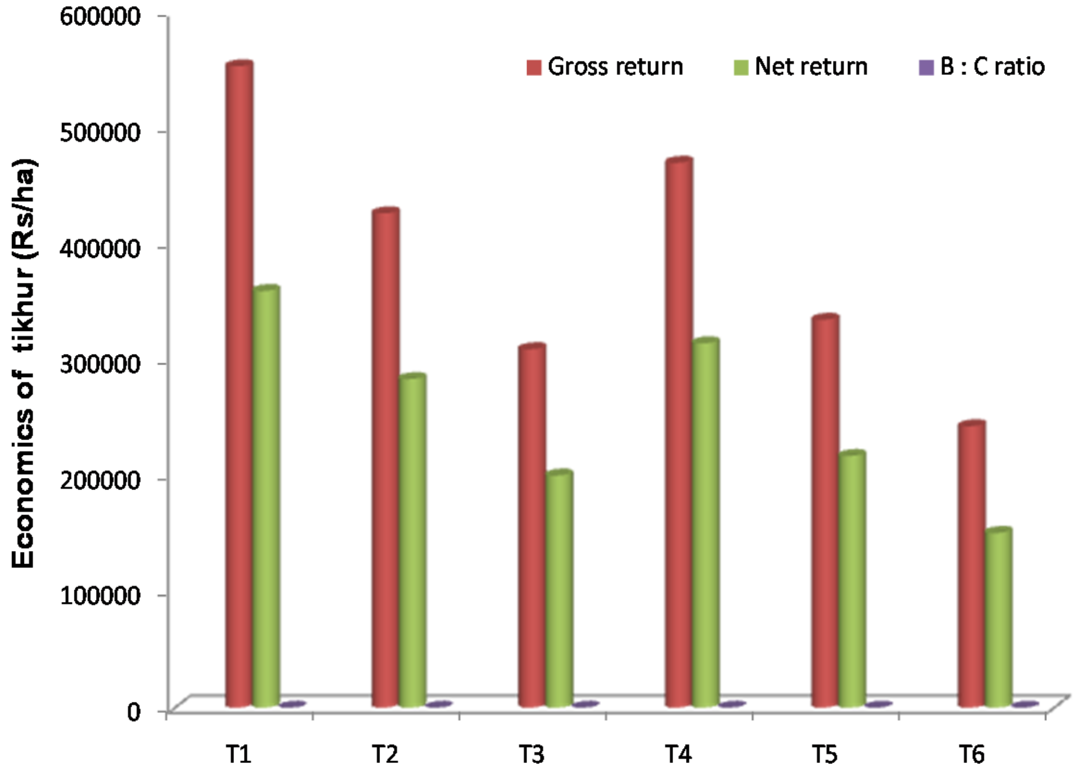


Fig. 17. Economics of tikhur (Rs/ha) as influenced by spacing

CHAPTER V

SUMMARY AND CONCLUSIONS

An experiment was undertaken at Instructional Farm, University Department of Vegetable Science, Faculty of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to study the "Effect of spacing on growth, yield and quality of tikhur (*Curcuma angustifolia Roxb.*)"

The experiment was laid out in Randomized Block Design with six treatments and four replication. The results of this experiment are briefly summarized and concluded below.

5.1. Growth parameters

1. The growth parameters like plant height was significantly maximum throughout the growth period (32.15 cm, 41.93 cm and 52.50 cm at 60, 90 and 120 DAP respectively) in treatment T_1 (45 × 20 cm). Whereas minimum plant height was recorded (23.75 cm, 30.85 cm and 37.55 cm) in T_6 (60 × 45 cm) at 60, 90 and 120 DAP respectively).
2. Significantly maximum number of leaves per plant, leaf length and leaf breadth was observed throughout the growth periods at 60, 90 and 120 DAP respectively. Maximum number of leaves per plant (4.90, 6.95 and 8.20), leaf length (16.15 cm, 21.67 cm and 26.79 cm) and leaf breadth (10.06 cm, 11.58 cm and 13.71 cm) were observed in T_6 (60 × 45 cm). Whereas minimum number of leaves per plant (3.25, 5.10 and 6.45), leaf length (13.13 cm, 17.58 cm and 20.95 cm) and leaf breadth (8.63 cm, 10.04 cm, 11.57 cm) were observed in T_1 (45 × 20 cm).
3. Significantly maximum leaf area index (1.73) was observed in T_1 (45 cm × 20 cm). Whereas the minimum leaf area index (1.11) was observed in T_6 (60 cm × 45 cm).

5.2. Yield parameters

1. Weight of mother rhizome per plant and weight of primary rhizome per plant influenced by spacing was found significant. Significantly maximum weight of mother rhizome per plant (50.10 g) and weight of primary rhizome per plant (108.60 g) were recorded in T_6 (60 cm × 45

cm). Whereas minimum weight of mother rhizome per plant (42.35 g) and weight of primary rhizome per plant (87.25 g) were recorded in T_1 (45 cm × 20 cm).

2. Number of mother rhizome and number of primary rhizome per plant significantly influenced by spacing. Significantly maximum number of mother rhizomes per plant (1.70) and number of primary rhizome per plant (6.03) were recorded in T_6 (60 cm × 45 cm). Whereas minimum number of mother rhizome per plant (1.23) and number of primary rhizome per plant (4.60) were recorded in T_1 (45 × 20 cm).
3. Thickness of mother rhizome per plant and thickness of primary rhizome per plant as influenced by spacing was found significant. Significantly more thickness of mother rhizome per plant (3.06 cm) and thickness of primary rhizome per plant (1.92 cm) were recorded in T_6 (60 cm × 45 cm). While T_1 (45 cm × 20 cm) recorded minimum thickness of mother rhizome per plant (2.62) and thickness of primary rhizome per plant (1.59 cm).
4. Rhizome yield per plant, rhizome yield per plot and rhizome yield tones per hectare as influenced by spacing was found significant. Significantly maximum rhizome yield per plant (158.70 g) was recorded in T_6 (60 cm × 45 cm). However minimum rhizome yield per plant (129.60 g) was recorded in T_1 (45 cm × 20 cm). Rhizome yield per plot (9.33 kg) and rhizome yield per hectare (14.40 t) were maximum in T_1 (45 cm × 20 cm). Whereas minimum rhizome yield per plot (3.81 kg) and rhizome yield per hectare (5.87 t) was recorded in T_6 (60 cm × 45 cm).
5. Days to maturity and dry matter percentage of rhizome per plant as influenced by spacing was found to be non significant.

5.3. Quality parameters

1. Significantly maximum starch recovery per hectare (761.75 kg) was obtained in T_1 (45 cm × 20 cm). Whereas the minimum starch recovery per hectare (381.48 kg) was obtained in T_6 (60 cm × 45 cm).
2. Starch recovery percentage and protein content as influenced by spacing were remained statistically non significant.

5.4. Cost of economics

As regards to economics of tikhur the highest gross monetary return (553526.00 Rs/ha) and net monetary return (359571.25 Rs/ha) were obtained from treatment T_1 (45 cm × 20 cm). But the highest benefit cost ratio (3.02) was recorded in T_4 (60 cm × 20 cm). Whereas, the lowest gross monetary return (242864.00 Rs /ha), net monetary return (150769.25 Rs /ha) and benefit cost ratio (2.64) were obtained in treatment T_6 (60 cm × 45 cm).

CONCLUSIONS

On the basis of present findings, it can be concluded that, effect of spacing has significantly influenced the growth, yield and quality parameters of tikhur.

Regarding the growth parameters, treatment T_1 (45 cm × 20 cm) was found significantly superior in respect of plant height and leaf area index. While for number of leaves per plant, leaf length and leaf breadth treatment T_6 (60 cm × 20 cm) was found significantly superior over all the treatments.

For yield parameters, weight, number and thickness of mother and primary rhizome per plant, rhizome yield per plant were found to be maximum in treatment T_6 (60 cm × 45 cm). While yield per plot and yield per hectare was found maximum in T_1 (45 cm × 20 cm). Whereas, days to maturity and dry matter percentage of rhizome per plant non significantly influenced by spacing.

With respect to the quality parameters, starch recovery per hectare was found to be maximum in treatment T_1 (45 cm × 20 cm). However starch recovery percentage and protein content was found to be non significant for all the treatments.

Considering the cost of economics, the highest net monetary return obtained with treatment T_1 (45 cm × 20 cm) and the highest B:C ratio obtained in treatment T_4 (60 × 20 cm).

From the overall assessment of results obtained, it may be concluded the treatment T_4 (60 cm × 20 cm) may prove economically better for producing higher yield of tikhur.

The present observations are based on the results of experiment conducted for the first time for only one season in black cotton soil under conditions of Akola, Maharashtra. Therefore, these results are suggestive and not conclusive. Besides the present findings, other good agronomic practices such as planting time, fertilizer management etc. needs to be studied to get high biological and economical yield.

CHAPTER VI

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Appendix I
Cost of Cultivation of tikhur

Particulars	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Land rent (Rs./ha)	3000	3000	3000	3000	3000	3000
Land preparation (Rs./ha)	4000	4000	4000	4000	4000	4000
Planting material cost (Rs./ha)	138888.89	92592.59	61728.4	104166.67	69444.44	46296.3
Plant protection measures (Rs./ha)	1500	1500	1500	1500	1500	1500
Electricity charges (Rs./ha)	700	700	700	700	700	700
Water charges (Rs./ha)	900	900	900	900	900	900
Fertilizer charges (Rs./ha)	4054.32	4054.32	4054.32	4054.32	4054.32	4054.32
Cost of cultivation (Rs./ha)	193954.75	143024.75	109136.30	155757.25	117669.75	92094.75

Note : Planting material cost - 25 Rs./kg, Labour - 130 Rs/day, Starch rate - 300 Rs./kg,

Fertilizer rate : Urea- 6 Rs./kg
SSP - 7 Rs./kg
MOP 16 Rs./kg

Appendix II- Weekly Weather data for the year 2018 recorded at Meteorological Observatory Department of Agronomy Dr. PDKV., Akola

		Actual				2018									Normal				1971-2000	
Weeks	Dates	T MAX (oC)		T MIN (oC)		BSH (hrs)		WS (km/hr)		RH I	(%)	RH II	(%)	Evap (mm)		RF (mm)		CRF (mm)	Rainy Days	
		N	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A		N	A
22	28-3 Jun	41.9	43.1	27.6	29.5	9.7	8.0	16.2	8.8	56	50	23	23	16.3	14.5	5.7	8.5	13.4	0.5	1.0
23	4-10	39.0	37.5	25.8	25.5	8.0	4.0	14.9	10.7	62	73	30	44	13.4	11.2	18.3	72.5	85.9	1.2	2.0
24	11-17	38.2	37.7	25.5	26.5	7.5	6.2	15.4	12.9	71	66	42	31	11.1	10.8	43.3	17.5	103.4	2.0	2.0
25	18-24	35.3	36.0	24.9	24.6	7.1	7.2	15.1	6.5	76	80	50	49	9.1	9.5	52.3	83.1	186.5	2.2	3.0
26	25-1Jul	34.1	32.3	24.2	23.7	5.3	3.9	13.4	5.8	80	86	55	56	7.3	6.4	38.2	111.0	297.5	2.3	5.0
27	2-8	33.5	32.7	24.4	24.3	5.2	3.8	12.9	5.9	81	83	58	61	6.8	6.3	34.7	54.8	352.3	2.4	5.0
28	9-15	32.3	28.4	23.7	23.6	3.8	1.0	12.0	8.2	84	93	62	80	5.5	4.2	52.2	140.3	492.6	2.8	6.0
29	16-22	32.0	29.9	23.9	24.1	3.3	0.6	11.2	7.3	84	88	65	71	5.6	3.2	58.6	35.1	527.7	2.6	3.0
30	23-29	31.7	28.0	23.3	23.5	4.3	0.7	11.9	4.4	85	90	64	74	5.3	3.2	44.2	30.7	558.4	2.6	4.0
31	30-5 Aug	31.1	32.2	23.1	24.2	3.6	5.8	11.7	8.1	88	81	66	56	4.6	6.0	49.3	3.2	561.6	2.5	1.0
32	6-12	30.2	30.8	22.9	24.3	3.5	1.4	11.6	9.4	87	84	69	65	4.2	5.2	59.9	4.8	566.4	2.9	1.0
33	13-19	30.5	29.4	22.8	24.0	4.4	1.2	11.7	8.5	86	89	66	74	4.5	4.1	40.6	97.8	664.2	2.2	3.0
34	20-26	30.5	27.6	22.6	22.6	4.3	1.8	11.0	9.2	88	91	66	77	4.3	4.0	46.7	106.4	770.6	2.0	3.0
35	27-2 Sep	30.4	28.5	22.7	23.4	4.4	0.1	10.6	6.6	86	88	64	70	4.2	2.9	47.1	1.0	771.6	2.4	0.0
36	3-9	31.1	29.8	22.5	21.9	5.7	3.8	9.1	8.1	85	84	61	56	4.7	4.5	28.5	1.0	772.6	1.5	0.0
37	10-16	32.2	32.6	22.4	24.0	7.1	8.6	9.0	2.6	85	81	56	48	5.1	5.6	18.9	0.0	772.6	1.1	0.0
38	17-23	33.4	33.3	22.3	23.1	7.2	4.4	8.5	3.3	83	85	53	52	5.3	4.9	24.6	62.4	835.0	1.4	2.0
39	24-30	33.7	33.6	21.9	22.7	7.6	8.5	5.4	0.6	83	85	50	49	4.9	4.5	24.4	0.0	835.0	1.5	0.0
40	1-7 Oct	33.9	35.1	20.2	21.3	8.1	8.6	7.5	0.6	81	78	45	38	5.5	4.9	21.8	0.0	835.0	1.1	0.0
41	8-14	34.1	35.4	18.7	18.6	4.2	8.6	4.1	0.8	76	77	40	29	5.3	5.1	16.0	0.0	835.0	0.9	0.0
42	15-21	33.9	34.8	18.1	19.3	8.4	8.5	4.4	0.5	74	72	36	30	5.5	5.1	3.1	0.0	835.0	0.4	0.0
43	22-28	33.1	35.3	18.5	17.1	8.4	8.9	4.1	0.4	73	68	36	22	5.3	5.2	10.0	0.0	835.0	0.6	0.0
44	29-4 Nov	33.0	33.4	15.8	18.1	8.7	8.9	4.7	1.3	72	68	31	32	5.3	5.9	2.3	0.0	835.0	0.3	0.0
45	5-11	32.4	33.6	14.8	16.5	8.6	7.0	4.5	0.5	70	76	30	28	5.2	4.2	3.7	0.0	835.0	0.3	0.0
46	12-18	31.7	33.3	13.7	14.0	8.6	8.9	4.6	0.4	70	66	30	20	4.9	5.0	1.1	0.0	835.0	0.2	0.0
47	19-25	31.0	32.8	13.1	17.2	8.6	7.8	4.4	0.6	71	78	30	34	4.6	4.8	10.1	4.5	839.5	0.3	1.0
48	26-2 Dec	30.3	31.0	12.4	12.3	8.8	8.0	4.6	0.5	71	74	31	27	4.3	4.3	6.8	0.0	839.5	0.3	0.0
49	3-9	29.8	29.8	11.2	15.9	8.7	5.2	4.7	0.9	70	76	29	41	4.3	4.0	1.3	0.0	839.5	0.2	0.0
50	10-16	29.4	28.9	10.3	12.3	8.8	6.6	4.5	1.1	70	83	27	31	4.2	4.1	1.3	0.0	839.5	0.2	0.0
51	17-23	29.5	26.5	10.6	10.2	8.7	7.5	4.7	1.1	69	116	29	34	4.3	4.2	0.9	0.0	839.5	0.1	0.0
52	24-31	29.2	27.5	10.7	9.6	8.6	8.4	4.8	1.5	70	59	31	23	4.3	5.0	2.6	0.0	839.5	0.2	0.0
										2019										
1	1-7 Jan	29.0	29.8	10.3	9.4	8.7	8.4	4.9	0.7	78	68	30	22	4.2	4.0	1.7	0.0	0.0	0.2	0.0
2	8-14	29.2	28.1	11.3	10.0	8.6	7.8	6.3	1.2	71	72	30	30	4.5	5.4	3.4	0.0	0.0	0.2	0.0
3	15-21	29.9	29.4	11.6	10.4	8.9	7.6	5.4	1.2	69	66	28	24	4.8	5.2	0.9	0.0	0.0	0.1	0.0
4	22-28	30.8	28.1	11.8	14.0	9.1	6.1	5.5	1.7	67	75	27	36	5.2	5.0	1.1	0.0	0.0	0.2	0.0
5	29-4 Feb	31.1	28.1	12.1	10.7	9.3	7.9	5.8	1.5	61	61	25	22	5.6	5.3	2.8	0.0	0.0	0.2	0.0