# EFFECT OF DIFFERENT TECHNOLOGICAL INTERVENTIONS ON YIELD AND QUALITY OF LITCHI GROWN IN NAGALAND

# DECLARATION

I, KURUBA AJAY KUMAR, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Horticulture (Fruit Science).

Date:

Place: SASRD: Medziphema (**KURUBA AJAY KUMAR)**

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Supervisor

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# CERTIFICATE – I

This is to certify that the thesis entitled **"Effect of Different Technological Interventions on Yield and Quality of Litchi Grown in Nagaland"** submitted to Nagaland University in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Fruit Science) is the record of research work carried out by Mr. KURUBA AJAY KUMAR Registration No. Ph D/HOR/00346 under my personal supervision and guidance.

The results of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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# CERTIFICATE – II

## VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN HORTICULTURE (FRUIT SCIENCE)

This is to certify that the thesis entitled **"Effect of Different Technological Interventions on Yield and Quality of Litchi Grown in Nagaland"** submitted by Kuruba Ajay Kumar Admission No. Ph-300/19 & Registration No. Ph D/HOR/00346 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Horticulture (Fruit Science) has been examined by the Advisory Board and External examiner on………………..............

The performance of the student has been found **Satisfactory/Unsatisfactory.**

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# LIST OF ABBREVIATIONS/ SYMBOLS

| | | |
|---|---|---|
| ANOVA | : | Analysis of Variance |
| @ | : | At the rate |
| % | : | Per cent |
| cv | : | cultivar |
| CD | : | Critical Difference |
| cm | : | centimeter |
| C/N ratio | : | Carbon/Nitrogen ratio |
| Df | : | Degree of freedom |
| °C | : | Degree Celsius |
| DAFS | : | Days after fruit set |
| E | : | East |
| *et al.* | : | and others |
| *viz.* | : | namely |
| m | : | Meter |
| Max. | : | Maximum |
| Min. | : | Minimum |
| kg | : | Kilogram |
| g | : | Gram |
| ha | : | Hectare |
| *i.e.* | : | That is |

| | | |
|---|---|---|
| No. | : | Number |
| SASRD | : | School of Agricultural science and Rural Development |
| NU | : | Nagaland University |
| PGRs | : | Plant Growth Regulators |
| PB | : | Primary Branch |
| PPW | : | Polypropylene White |
| PPP | : | Polypropylene Pink |
| BPB | : | Brown paper Bag |

# CONTENTS

**ABSTRACT**

Field trials entitled "Effect of different technological interventions on yield and quality of litchi grown in Nagaland" was conducted during September 2020 to June 2022 at Horticultural Research farm, Dept. of Horticulture, School of Agricultural Sciences and Rural Development, Medziphema campus, Nagaland University, under the following objectives: to study the effect of different levels & widths of girdling on bearing potential of litchi, to study the effect of bagging on quality of litchi fruits, to study the effect of plant bio regulators and chemicals on flowering and fruiting of litchi and to study the effect of various mulch materials on fruiting and quality of litchi fruits. Experiments under the first objective was laid out in Factorial Randomized Block Design and the other three objectives were laid out in Randomized Block Design with three replications each, to assess the effect of girdling, bagging, spray of PGRs and chemicals and mulch materials on yield and quality attributes of litchi. The findings of the different experiments are elucidated as follows:

To study the effect of different levels & widths of girdling on bearing potential of litchi cv. China:

Total ten treatments with three different levels (25, 50 & 75%) and widths (2, 4 & 6mm) of girdling was performed on primary branches during the month of September and it was observed that, among all the treatments, 50% PB & 4mm girdle treatment ($T_5$) showed best results with respect to flowering and fruiting attributes *viz*., higher flowering percentage (90.04%), fruit set number at clove stage (103.26), fruit retention per panicle (19.83), fruit length (4.00 cm), breadth (3.54 cm), weight (17.22g) and yield (17.72 kg/tree). 6mm girdle in 75% PB ($T_9$) in respect to C/N ratio of leaf after girdling showed high significant variance (4.32%) as compared to control (2.65%). However, minimal significant effect was observed on the bio-chemical parameters under girdling experiment. Thus, among the different treatments 4mm girdling on 50% primary branches was found to enhanced yield of litchi fruits.

To study the effect of bagging on quality of litchi fruits cv. Shahi:

Three different bagging materials *i.e.*, Non-woven Polypropylene White (PPW), Polypropylene Pink (PPP), Brown paper Bag (BPB) and control (no bagging) were used to bagged the fruit bunches at three different days after fruit set *viz*.,15 DAFS, 25 DAFS and 30 DAFS. Results indicated that PPP bags gave the best result with higher total sugar (15.21%), TSS (21.30 ºB), TSS: acid ratio (50.34) and low incidence of Sunburn (3.59%), fruit cracking (1.71%) in comparison to control, whereby, higher values of anthocyanin content (26.11 mg/100g) and fruit weight (23.12 g) were recorded in BPB. Highest titratable acidity (0.6%) content recorded fruits under control. PPP & BPB bagging materials were found to be the best of the treatments to create mean microclimate inside bag to improve fruit colour and other quality parameters with highest growing degree days *i.e*., 2115.50º days and 1990.17º days respectively. In the case of time of bagging, 15 DAFS was found to give higher performance as compared to 25 DAFS and 30 DAFS with maximum individual TSS content (21.30 ºB), TSS- acid ratio (50.34) and low Sunburn (3.59%) and cracking percentage (1.71%). As such, bagging with PPP at 15 DAFS was found to give the best treatment.

To study the effect of plant bio regulators and chemicals on flowering and fruiting of litchi cv. Shahi

The trees were sprayed with different chemical & PGRs alone and in combination included $T_1$ ($KNO_3$ 1%), $T_2$ ($K_2HPO_4$ 1%), $T_3$ (Ethrel 400ppm), $T_4$ ($GA_3$ 100ppm), $T_5$ ($KNO_3$ 1% +$K_2HPO_4$ 1%), $T_6$ ($KNO_3$ 1% + Ethrel 400ppm), $T_7$ ($KNO_3$ 1% + $GA_3$ 100ppm), $T_8$ ($K_2HPO_4$ 1% + Ethrel 400ppm), $T_9$ ($K_2HPO_4$ 1% + $GA_3$ 100ppm) and $T_{10}$ (No- spray) at one month interval from September to December (in both the year 2020 and 2021). Among the various treatment combination, it was recorded that $T_3$ (Ethrel 400ppm) took lesser time for panicle initiation (28.01.22), flower induction (-9 days), time taken to fruit set (22.50 days), days to mature (50.50 days) and days to harvest (59.50) and highest number of days was recorded in $T_4$ (26.02.22, +2, 34.50, 61.00 & 70 days respectively). Treatment $T_2$ ($K_2HPO_4$ 1%) significantly influenced on number of flowers/ panicles (881.03) however treatment $T_4$ ($GA_3$ 100ppm) on high sex ratio (6.66%). And quality parameters like total sugar (22.25%), TSS (20.30º B), TSS: acid ratio (46.99) and lower levels of acidity (0.43) was recorded. Results indicate that

$T_4$ ($GA_3$ 100ppm) was observed to perform better in case of fruit quality attributes and trees treated with $T_3$ (Ethrel 400ppm) was found to be more precocious in terms of flowering and fruiting.

To study the effect of various mulch materials on fruiting and quality of litchi fruits cv. China:

Treatments consisted of different organic and inorganic mulching materials *viz.*, $T_1$ (Black polythene), $T_2$ (White polythene), $T_3$ (dry grass), $T_4$ (Paddy straw), $T_5$ (Dry Banana leaves), $T_6$ (Banana pseudostem mat), $T_7$ (Leguminous cover crop- Soyabean) and $T_8$ (No mulch) were applied to soil surrounding the plant stem, in the month of September. Experimental findings revealed that different mulch materials significantly affected on the soil moisture content (%), soil available nutrients (kg/ha), fruit retention, number of fruits/panicle and physico-chemical qualities of fruits. Among different mulches, black polythene (27.56 & 30.07 N, 4.19 & 5.70 P and 14.87 & 11.67 K kg/ha) followed by white polythene mulch (22.39 & 24.25 N, 4.18 & 6.24 P and 18.78 & 16.68 K kg/ha) treatments were found to improve soil available nutrients after mulching in 2021 & 2022 while, black polythene mulch showed high per cent of soil moisture in 2021(14.80 %) and 2022 (15.50 %) surrounding the tree. Flowering (74.44%), fruit set (36.78%), fruit retention/panicle (13.53), average fruit weight (18.23g) and yield/ tree (18.00 kg/tree) was recorded highest in trees under black polythene mulch, which is on par with banana pseudostem mat (72.34%, 36.06%, 13.10, 18.28g & 17.10 kg/tree) followed by soyabean cover crop (72.11%, 35.17%, 12.86, 15.47g & 12.46 kg/tree) mulching. Highest fruit cracking (16.70%) compared to other treatments was recorded under control. Among all the mulching treatments, black polythene, banana pseudostem and soyabean mulching gave better results in conserving moisture, available nutrients and improving yield and yield attributing parameters.

From the above-mentioned fact of data, it may be concluded that the different experiments on technological interventions of litchi grown in Nagaland were found to provide effective results in terms of yield and quality on old and senile trees. Girdling with 4mm width on 50% PB (primary branches) was found to give best results in improving yield of litchi fruits. Also, bagging with Non-woven PPP at 15 DAFS and

PGR sprays of $GA_3$ 100ppm and Ethrel 400ppm was observed to perform better in respect to flowering, fruiting and quality attributes. In the case of mulching, polythene mulch, paddy straw mulch and banana pseudostem mat mulching were found to give best results in retaining moisture, available nutrients content and fruit yield.

**Keywords:** Litchi, primary branches, girdling, bagging, PGRs, mulching, yield and quality.

# INTRODUCTION

Litchi (*Litchi chinensis* Sonn.), the queen of sub-tropical fruit, is one of the important fruit crops of India. Though it is native to the Guangdong and Fujian provinces of south-eastern China, where cultivation is documented from the 11$^{th}$ century (Mortan, 1987).

It is a sub-tropical evergreen fruit tree, needs highly specific climatic requirements for improving the fruit yield and quality. Due to this reason, its cultivation is restricted to few subtropical countries in the world, where it is grown commercially. The main litchi growing countries are China, Israel, Australia, Thailand, Taiwan, India, Vietnam, parts of Africa and at higher elevations in Mexico and Central and South America. World production of litchi is estimated to be around 2.11 million tons, with more than 95% of the area and production share from Asia. It is believed to have been introduced in India at a very early date as it was mentioned by Bruton in the 17$^{th}$ century (Liang, 1981). Litchis are extensively grown in southern China, Taiwan, Vietnam and the rest of tropical Southeast Asia, the Indian subcontinent and in tropical regions of many other countries (Mitra, 2000). India and China account for 91 per cent of the world litchi production but it is mainly marketed locally. India enjoys a prominent position in the litchi map of the world both, in terms of production and productivity. Over the years, India has recorded significant growth in production and productivity of litchi.

India ranks second in the world next to China in litchi production a (Sahni *et al.* 2020). In India, 686.4 thousand metric tonnes of litchi fruits are produced annually from 92.3 thousand hectares area with productivity of 7.4 MT/ha (NHB, 2018). National average productivity of litchi is 6.1 t/ha. The production of litchi is mainly confined to Bihar (40 %), West Bengal (16 %), Jharkhand (10 %), Assam (8.2 %), Chhattisgarh (6.4 %), Uttarakhand (5.2 %) and to a smaller extent in Punjab, Odisha and Tripura. Punjab recorded the highest productivity with 16.14 MT/ ha (Anonymous, 2015). In Nagaland, North Eastern state of India with over 3.94 thousand MT production of litchi (NHB, 2018).

In Nagaland, China, Shahi, and Tezpur litchi varieties are grown and var. Shahi being predominant in the state. Nagaland has a good potentiality of producing litchi especially in the foothills of 4-12°C temperature for a month or more. The foothills and midhills of Dimapur, Mokokchung, Wokha, Peren, Kohima and Zunhebeto districts are also congenial for litchi cultivation. Fruit maturity in this state is quite late which comes in the market up to the last week of June. At Molungyimsen village of Mokokchung district, a 12.79m tall 138 years old litchi tree planted by Dr. Clark in June 1878, is probably the oldest litchi tree known to still bear fruits in north east of our country (Marboh *et al.* 2019).

Litchi belongs to family Sapindaceae which includes longan (*Dimocarpus longan*) and Rambutan (*Nephelium lappaceum*). Litchi trees is shallow rooted and may grow up to 40 ft (12 m) in height and have a beautiful, dense, rounded, symmetrical canopy extending nearly to the ground. Trees are very attractive with dark green foliage and reddish-coloured fruit. Typically, major limbs of nontrained trees begin within 3 ft (0.9 m) of the ground. Leaves are compound with 2 to 8 leaflets. Leaves have a reddish/silvery white colour when young, becoming shiny and bright green when mature. Flowers are small, greenish, and are borne on a large thyrse (a many-flowered inflorescence) that emerges at the ends of branches anytime from late December to April (more commonly February and March). Three types of flowers are commonly found in an inflorescence i.e., male, hermaphrodite (functional as female) and pseudo hermaphrodite (Functional as male). Flowers of different sexes are on the panicle, do not open simultaneously (Pandey and Sharma, 1984). Botanically the fruit is called as nut and fruits are borne in loose clusters numbering from 3 to 50 fruits and are round to oval and 1.0 to 1.5 inches (25 to 38 mm) in diameter. The skin (pericarp) ranges from yellow to pinkish or red and is leathery, with small, short, conical or rounded protuberances. The edible portion of the fruit (pulp) is called an aril that is succulent, whitish, translucent, with excellent flavour. Fruits contain one shiny, dark brown seed, usually relatively large, but it may be small and shrivelled (called chicken tongues) in some varieties.

Litchi is a delicious fruit having aromatic pulp with sweet and acid taste. Litchi is largely preferred as Table fruit. It is also used for canning, which has made its impact in international trade. 'Litchi Nut' a dried product of whole litchi fruit is also potential product worldwide. High quality flavoured squashes can be prepared from litchi. Litchi is a non-climacteric fruit hence; it is not expected to increase in soluble solids once it has been picked. Ripe fruits should be harvested for best quality and flavour depending upon variety and climate, the fruits contain 60% juice, 8% rag, 19% seed, and 13% skin.

Ripen litchi fruit is very rich nutritional values having good amount of sugar, T.S.S. (15.90- 20.10 ºBrix) and ascorbic acid (27.8 mg/100 g) content which can fulfil recommended daily allowance (RDA) of these nutrients by eating 14-17 fruits (Nath *et al.* 2018). The fruits are also offering source of minerals such as calcium (8.00-10.00 mg), phosphorus (30.00-42.00 mg), Iron (0.40 mg), sodium (3.00mg), and potassium (170.00 mg). The moisture and acid content of the fruits varies in between 77-83% and 0.2 % to 0. 64%. Litchi is not a significant dietary source of protein (only 0.8-0.9 per cent) and poor source of fat (0.30-0.50 per cent). The consumption of a litchi fruit would meet 2-4% of the dietary reference intakes (DRI) for P, K, Mg, Fe, Zn and Mn and provide 22% of the DRI for Cu. Most of the energy in a litchi is in the form of carbohydrate (sugar). Litchis are high in heart-healthy polyphenols, containing 15% more than grapes, a fruit commonly referenced as high in polyphenols. A new pharmaceutical composition and processes have been prepared for treating and preventing diabetes. The pharmaceutical composition of litchi is composed of three ingredients *i.e.*, Oleanolic acid, Saponins and Kuguasu which is nontoxic. It appears that the high ascorbic acid and sugar content are the chief nutritional constituents of litchi. Litchi is said to relieve coughing and to have a beneficial effect on gastralgia, tumours, hypoglycaemic, antibacterial, anti-hyperlipidaemic, anti-platelet, antipyretic, haemostatic, diuretic, antiviral activities, flatulence, stomach ulcers, neuralgic pains and enlargements of the glands (Ibrahim and Mohamed, 2015). In India, the seeds are powdered and administered in intestinal troubles. Decoctions of the root, bark and flowers are gargled to alleviate ailments of the throat. Litchi roots have shown activity against one type of tumor in experimental animals in the United States Department of Agriculture/National Cancer Institute Cancer Chemotherapy Screening Program. It have moderate amounts of polyphenols, including flavan-3-ol monomers and dimers as major compounds representing about 87% of total polyphenols, which declined in content during storage or browning. Litchi naturally produce butylated hydroxytoluene (BHT). Cyanidin-3-glucoside represented 92% of total anthocyanins (Dongling *et al.* 2000).

Usually, litchi plants have longer gestation period (> 15 years) to reach at consistent and regular bearing stage. In the juvenile stage of plant growths (7-14 years tree age), trees showed erratic and irregular behaviour of bearing due to continuous growth flushes after harvest and changing environment conditions and thus farmers suffer for a long period in order to get regular fruiting (Kumar *et al.* 2015). The litchi tree requires low temperature to induce flowering and subsequently fruiting (Menzel and Simpson, 1995). According to Garcia-Perez and Martins (2006), the litchi requires seasonal temperature variations for best flowering and fruiting. Most varieties need a cold period of 100 to 200 hours between 0° and 7° C, preferably with low rainfall. There is evidence that lower night temperature below 15° C during autumn months favour floral induction, and high day temperature at the same period reduce low night temperature effectiveness (Menzel and Simpson 1995). Litchi production in hot and subtropical climates is hampered by low flowering. Worldwide irregular production in litchi is associated with sparse flowering and low fruit fixation. Value of fruit crops not only depends upon the yield; quality production is one of the most important factors that determine market demand. (Sarkar *et al*. 2017).

Now-a-days, many farmers in India wish to invest on litchi including North Eastern states as this crop has ready market, high yield and demand in local as well as export market and can be easily grown in suitable climate. In some areas, it is the livelihood for many people as it provides both on-farm and off-farm employment. Small and marginal farmers get additional income from litchi plants in their homesteads. Thus, litchi cultivation is the livelihood security for a large population, especially in the state of Bihar. Commercial litchi plantation creates a source of job opportunity for the people associated with growing and managing orchards, harvesting and post-harvest handling, packing, transportation, export and value addition. Commercial litchi production is attaining the status of an industry in certain pockets with forward and backward linkages.

The major reason for slow spread of litchi cultivation are many external and internal factors. The major problems responsible for low economic potential of litchi cultivation in Nagaland in particular and India are poor fruit set and inferior fruit quality as well as other factors like irregular flowering, heavy fruit drop, poor fruit retention, alternate bearing, fruit cracking, small fruit size, low and erratic yields are reported wherever litchi is grown, hampering its development as a major commercial crop. The affected litchi fruits gain poor price in the market and such fruits are also rejected for processing. It causes serious economic loss to litchi growers. On the production side, the main complications are poor plant establishment, less fruiting span, low and irregular yields due to poor flowering and fruit set. Likewise, fruit cracking, browning and rotting of fruits, fruit borer and mite, poor shelf life, recalcitrant seeds and lack of suitable varieties with early and late maturity and good quality fruits are some of the factors hindering the growth of litchi industry at commercial scale in India and Nagaland in particular. Temperature, moisture, photoperiod, nutrition, bio regulators and some cultural practices are responsible for transformation of vegetative bud to a reproductive bud. Inspite of its greater economic value farmers are reluctant to establish the new orchards as flower and fruit drop is the major constraint. After planting of seedlings, it takes about 6 to 7 years for commencement of flowering. Many times, this period is extended up to 10 years. Furthermore, litchi requires dry and cold weather in winter to induce flowering and hot and humid weather during rest of the year. Alternate bearing is a characteristic of some litchi varieties, which is more pronounced when grown in warm climates. Worldwide irregular production in litchi is associated with sparse flowering and low fruit setting. Production alternation characteristics in different cultivars and climate order restriction are the main reasons related to flowering problems in litchi (Ghosh, 2001).

The main objective of a litchi grower is to harvest maximum quantity of marketable fruits at the lowest cost. This is possible only by maintaining a balance between vegetative growths immediately after harvest, which on maturity becomes the fruiting wood. The production of flowers may be governed not only by the amount of extension growth made, but also by the number of new shoots produced (Naik and Rao, 1942). Considering the importance of this fruit crop in the country, efforts have been made to improve the preventive practices that can be adopted to avoid the losses and curative options that can mitigate the problems through this research experiments. There are technologies which has shown as promise to induce flowering, amongst direct plant manipulations leading to the desired yield consist of two kinds of horticultural techniques. Removal of certain tree organs (training, pruning, fruit thinning) and interference with translocation between major tree organs (girdling, ringing, scoring, branch bending, which modifies auxin distribution, may be included in this second category). Fruit trees might be viewed as a system of sinks and sources (leaves, reproductive organs and roots) interconnected via vascular organs (trunk, branches and scaffold roots).

Girdling is basically an intervention in the phloem transport. The technique involves making an incision from 1.6 to 4.0 mm width on trunks or primary branches in September inhibits the downward movement of photosynthates and promotes accumulation in the upper canopy, it leads to promote flowering in unproductive litchi trees. It is a known practice to promote flowering, fruit set, retention, size, colour, and sugar content (Smit *et al.* 2005). In this operation, a portion of bark (phloem) is removed from the wood by a technique known as girdling. Since the woody xylem part remains intact, water and nutrients reach the leaves. After the preparation of photosynthate, it is not transported to other parts below the girdle and accumulation of photosynthate just above the girdle region takes place which in turn improves C:N ratio and there by flowering. In some studies, girdling used as an effective method for improving the yield by proper source-sink utilization in perennial woody plants (Kumar *et al.* 2015). The girdling treatment reduced about 15.9% of male flowers and increased 17.7% of hermaphrodite functioning as male flowers. However, girdling of the trunks also increased 31.2% of panicle formation. Wide varieties of fruit species are girdled to induce flowering and improving fruit set, are grape, mango, litchi, orange, peach, olive, avocado, apple etc. have responded in these areas.

Fruit bagging is an innovative technology and was first described in litchi by National Research Centre on Litchi, Muzaffarpur, Bihar and popularized by G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The technique saves the fruits from the insect and pest attacks including Litchi fruit borer, fruit sucking moth and fruit nut borer and also affecting various physiological disorders such as fruit cracking and sun burn. In this technique, fruits bunch is bagged on the tree for a specific period to get desired results. It is a physical protection technique, which not only improves fruit visual quality by promoting fruit coloration but can also alter the micro environment for fruit. Bagging is commonly applied to many fruits and a simple protection technique for improving fruit size, skin colour, taste, decreases cracking, protecting from pests [stone borers (*Platypepla sp*. and *Conogethes sp*.) cause dropping of immature fruits, while stalk-end borer (*Conopomorpha cramerella*) reduces the marketability of harvested fruits.], extreme environmental conditions, and pesticide residues, thus increasing commercial value (Xu *et al.* 2010 and Sharma *et al.*, 2014). Due to its many beneficial effects, fruit bagging has become an integral part of pomegranate, litchi, peach, apple, pear, grape and loquat cultivation in India, Japan, Australia, China and the USA.

Fruit weight, size, fruit colour, taste, and firmness are important quality attributes that play a major role in consumer acceptance and that determine the marketability of litchi at international markets. Pericarp browning, desiccation, loss of quality, post-harvest decays and micro cracking are major constraints affecting commercial quality during storage and transportation (Sivakumar *et al.* 2010 and Kumar *et al.* 2013). Litchi undergoes deteriorative changes immediately after harvest which makes it otherwise highly potential commercial crop and thus lose its marketability especially in the global context. Rapid desiccation of fruits leads to browning of pericarp which brings about a decline in the consumer's appeal and acceptability although the nutritive quality and taste is still retained. Pre-harvest application of various chemicals have been reported to enhance the shelf life of fruits by reducing physiological loss in weight, decay losses during storage (Gupta and Metha, 1988 and Kumar *et al.* 2017) and fruit cracking (Rathore *et al.* 2009). Applying various plant growth regulators and chemicals can help litchi growers to manage their orchard in such a way that it will have better quality production. Foliar application of calcium on the fruit is essential to strengthen the cell wall, cell membrane integrity, and thereby, reducing the physiological disorders (Fallahi *et al.* 1997) and improving fruit quality (Malakouti *et al.* 1999). Exogenous application of plant growth regulators for improving fruit quality and shelf life of litchi has been reviewed by Guangwen *et al.* (2010). Higher fruit quality attributes were recorded with $GA_3$ @ 40 ppm followed by $GA_3$ @ 20 ppm over other treatments. Reduced fruit cracking was also observed in trees which were sprayed with $GA_3$ and BA (Mishra *et al.* 2012). Mandal *et al.* (2014) observed that the ethrel (2 mL/L) was most effective for flower induction and fruit quality in litchi cultivar 'Bombai'. Pre-harvest sprays of potassium and growth regulators are the most important practices of the new strategies applied in the integrated fruit production systems, improving fruit quality (Misra and Pal, 2012). Application of ethrel @ 1,000 ppm, which could not only remove winter flushes but also dropped mature leaves, thereby affecting plant growth and development and sometimes bring flowering in coming season. Many investigations reported the use of potassium salts ($K_2HPO_4$ or $KNO_3$) as a chemical agent for induction of plant resistance and induction of flowering. Ethrel treatment increased the yield of litchi fruits by 57.1%. Therefore, plant growth regulators have been used for many years to alter the fruit plant behaviour for the economic benefits such as to control the vegetative growth, increase in flowering and fruit set, stimulation of maturity and ripening and improving fruit quality.

According to Cronje and Mostert (2010), soil moisture plays a key role in litchi production with high yield and quality. Moisture deficiency during flowering severely affects the fruit set and retention per cent (Carr and Menzel, 2014). Soil moisture fluctuations during fruit growth cause serious reductions in individual fruit weight and in severe cases may lead to fruit cracking. This reduces the fruit quality, ultimately crop productivity and marketing. Conservation of soil moisture reserves the key interventions for bearing behaviour and quality production in litchi. Mulches have a significant impact on improving the yield and quality of fruit. It enhances the physical and chemical qualities of the soil and availability of nutrient pool and biological qualities by increasing beneficial soil microorganisms. Mulches impart miscellaneous beneficial effects, like maintains the soil temperature, reduced water loss through evaporation, resulting enhanced soil moisture, which is utilized by the crop plants especially in the dry season (Shirgure *et al.* 2003), suppression of weed growth (Kaur and Kaundal, 2009; Sharma and Kathiravan, 2009), improvement in growth and yield (Pande *et al.* 2005). The practice of applying a layer of organic or inorganic mulch, to the soil surface has been prevalent for a very long time in many parts of the world. The mulching materials of organic origin are known to provide plant nutrient elements to the plant. Various materials of plant origin like straw, leaves and crop residues increases the aggregate stability and structure of soil add nutrients and humus to the soil as they decompose, improving its tilth and moisture holding capacity. Physiological disorders such as poor fruit set, fruit drop, fruit cracking and sunburn can be minimized with proper water management. Moisture conservation through mulching using dried leaves, plant parts or polythene sheet mulches has been found useful. Frequency of irrigation is reduced by adopting mulching. Thus, the present investigation was carried out to observe the effect of mulching using different mulches on nutritional content of litchi soil, yield and quality of fruits under rainfed condition of Nagaland.

The problems and low adaptation rate for area expansion of litchi responsible for low economic yield are poor fruit set, inferior fruit qualities as well as other factors such as irregular flowering, heavy fruit drop, poor fruit retention, fruit cracking, fruit borer infestation reported from the litchi growers of Nagaland which hamper to tap potentiality of this crop. Considering all these genuine issues and scattered information related with litchi production, an experiment was designed with the following objectives to mitigate and find out the solutions.

**Objectives:**

1. To study the effect of different levels & widths of girdling on bearing potential of litchi cv. China

2. To study the effect of bagging on quality of litchi fruits cv. Shahi

3. To study the effect of plant bio regulators and chemicals on flowering and fruiting of litchi cv. Shahi

4. To study the effect of various mulch materials on fruiting and quality of litchi fruits cv. China

# REVIEW OF LITERATURE

An attempt has been made to collect and review the relevant literatures available on various aspects of work done so far on girdling, bagging of panicles, use of PGRs & chemicals and effect of different organic and inorganic mulches for prolific flowering, yield and quality. As the relevant literature on some of these aspects is scarce in litchi, efforts were made to include review of other related fruit crops, wherever its essential. The review of literature on the subject is done under the following heads for proper understanding of the subject.

2.1 Girdling effect on bearing potential

2.2 Effect of panicle bagging on fruit quality

2.3 Foliar application of PGR & chemical on flowering and fruiting

2.4 Effect of mulching on yield and quality

## 2.1 Girdling effect on bearing potential

Effect of Girdling on flowering, fruiting, yield and fruit quality in litchi and many other fruits has been reviewed in brief hereunder:

Young (1977) reported that the effect of branch girdling on yield of severely pruned litchi trees cv. Brewster in early February and noticed unsuccessful to flower after pruning either on girdled branches or on ungirdled branches. Adjoining unpruned trees of same size blossomed fairly well and set a good crop on girdled branches, while ungirdled branches produced fewer flowers comparable to girdled ones. The results showed that the practice of girdling enhanced flowering on both pruned and unpruned trees. Light intensity was also favourable for blossoming on approximately as much bearing surface of pruned as unpruned trees but the pruned trees tended to remain vegetative.

Dabas *et al.* (1980) studied the effect of girdling on berry set, berry drop and quality of ‘Thompson Seedless’ grapes (*Vitis vinifera* L.) and found that all girdling treatments reduced berry drop as compared to the control. The best girdling treatment was cane girdling in which minimum berry drop was recorded followed by arm girdling trunk girdling treatments.

Ramburn (1995) conducted a study on effects of girdling and growth retardants on flowering and fruiting of Litchi in Mauritius. Results showed that girdling of primary branches 3-4 cm in diameter with foliar application of paclobutrazol (0.5g) + ethephon (0.4g) per litre improved the flowering percentage of litchi in un-productive trees.

Effect of girdling treatments on flowering and production of Mango trees cv. Tommy Atkins has been studied by Reboucas (1996). Work results showed that girdling Mango trees 60 and 75 days before potassium nitrate application gives higher flowering percentage and harvest advancement of 23days as compared to control. All girdled treatments showed lower vegetative flush in relation to control.

Ramburn (2001) observed the effect of girdling and growth retardants (0.5 g paclobutrazol+ 0.4 g of ethephon) on flowering and fruiting of litchi cv. Tai So in Mauritius. The girdling of branches 3-4 cm in diameter with hardened flush in may encourage flowering in unproductive litchi trees of cv. Tai So. Fruiting was regular on girdled branches and flowering can be produced every year.

The effect of scaffold branch girdling on flowering time, intensity and variance were studied by Oosthuyse (2004). The main scaffold branches of litchi trees were either girdled or ungirdled. The winter conditions were powerfully inducive, this evidently masking any treatment improvement of stimulating bud-development and increasing flowering intensity. Girdling or winter pruning or delayed bud advance, increased flowering intensity and enhanced flowering stage variance. These effects were outstanding in the following winter pruning.

Urban *et al.* (2004) suggested that girdling improved earliness in mango. Eighteen branches were selected for experiment which were homogeneous in terms of initial stem diameter and light exposure. From the 18 branches, 7 branches were girdled and 11 were ungirdled. The treated branches showed 15 days earlier flowering than the ungirdled branches.

Charoensri *et al.* (2005) evaluated on effects of potassium chlorate and girdling on flowering of "PhetSakhon" longan. Effect of trunk girdling and potassium chlorate ($KClO_3$) on flowering and total non-structural carbohydrate (TNC) in leaves and shoots of longan trees and they observed that girdling practices was effective than $KClO_3$ for flowering induction and no influence of girdling and $KClO_3$ on TNC was noted.

Garcia and Martins (2006) studied on flowering and fruiting lychee trees due to the girdling branches. Effect of girdling on main branches and subsidiary branches with thickness of 2, 4 and 6 mm on flowering and fruiting in 'Bengal' litchi cultivar. The girdling of main branches induced higher flowering and fruiting thus ultimately rising the total yield of the cultivar.

Sousa *et al.* (2008) examined on influence of trunk girdling on growth and fruit production of 'Rocha' and reported that TSS content was highest in fruits of girdled trees at full white and petal drop stage, however the fruits of the two opposing half circle cuts girdled trees had higher TSS at harvest and a significantly lower starch index compared with ungirdled tree. Singh et al. (2014) examined the response of Patharnakh pear to girdling on 18 -year-old vigorous trees growing under uniform cultural practices. The fruits with best quality characteristics in terms of juice content (58.5%), total soluble solids (11.8°Brix), TSS: acid ratio (42.8) and total sugars (8.86%) with low juice acid

(0.27%) contents were observed under sub-limb girdling performed on 15 days after flower initiation as compared to control.

Raffo *et al.* (2011) studied on effects of trunk girdling on fruit production, fruit size and tree vigour on 'Bartlett' pears and reported girdling of trunk enhanced yield in pear cv. Bartlett. A trial was conducted during two seasons in which trunk girdling was performed. Results showed that higher yield was obtained in girdled trees than in control, in both seasons. Singh *et al.* (2014) suggested girdling increased yield in pear cv. Patharnakh. Girdling was performed on 18-year-old vigorous trees growing under uniform cultural practices. Sub-limb girdling performed on 15 days after flower initiation was the best in enhancing fruit yield (162.0 kg/tree) compared to control (135.3 kg/tree) in Patharnakh pear under sub-tropics of north India. Girdling treatments also advanced the fruit maturity over control.

An experiment on induction of flowering by use of chemicals and cinturing in 'Bombai' litchi was conducted by Mandal *et al.* (2014) and revealed that the flower emergence was advanced by six to seven days by girdling and girdling was proved to be the most effective for flowering as well as fruit initiation in litchi cultivar Bombai.

Haldankar *et al.* (2014) studied on induction of flowering by girdling in Jamun cv. Konkan Bahadoli. Results revealed that girdling was beneficial in jamun for induction of flowering, greater flowering intensity, a greater number of flowers and fruits per branchlet, reduced period from flowering to harvesting and higher yield as compared to control plants. Girdling with deep cut without removal of bark was more beneficial than the removal of bark.

Khalkho *et al.* (2015) revealed that the treatment of girdling with no leaf removal of 40 DAFS influenced on physical fruit parameters *i.e.*, the maximum fruit weight (25.03g), bunch weight (351.02g) and lowest seed-pulp ratio (0.14).

The size of the fruit (3.18cm) was also good with treatment of girdling and no leaf removal of Litchi plant.

Kumar *et al.* (2015) an experiment was conducted to induce the flowering by use of chemicals and cincturing in cv. Shahi. Results showed that cincturing of branches showed highest (60.50 %) shoot converted into flowering panicles, as compared to control (37.50 %). And chemicals also showed 8-12 days early panicle emergence than control.

Kumar *et al.* (2016) conducted an experiment on the effect of varied extent of girdling for induction of flowering in litchi (*Litchi chinensis* sonn.) under Bihar condition. They concluded that girdling level of 2mm on 50% primary branches produced more flowering panicle, fruit yield, fruit size, TSS, and TSS/acid ratio in Shahi litchi trees compared to ungirdle (control) trees. study also revealed that the wound healing period of girdled portion increases with increasing the level of girdling notch. The average yields from all girdled treatments were about three to five times higher than control. Gradual decrease in fruit weight was noticed with increase of girdling size in both 25% PB and 50% PB.

Ghadage *et al.* (2016) conducted an experiment on effect of time and widths of girdling on economics of mango (*Mangifera indica* L.) cv. Alphonso. Results of the investigation revealed that girdling during 15th July with 1.50 cm width was gave maximum net realization and B: C ratio. In control vs rest of the treatment analysis, treated treatments gave significantly higher net realization and B: C ratio as compared to control (un-girdled).

Ibrahim *et al.* (2016) conducted an experiment on effect of some girdling treatments on fruiting behaviour and physio-chemical properties of Washington navel orange trees and examined the effects of girdled branches (GB) and girdled limbs (GL) on flowering of the cultivar. On girdling branches, the number of flowers increased by 34.2- 41.26% and on girdling limbs the number of flowers increased by 19.37-23.41%. These results showed that there is more accumulation of carbohydrates in girdled branches and girdling limbs as compared to ungirdled branches and limbs.

Ghadage *et al.* (2017) studied on effect of time and width of girdling on flowering and yield of Mango (*Mangifera indica* L.) cv. Alphonso. They concluded as girdling treatment during 15th July with girdled width of 1.50 cm was significantly influenced maximum percentage of fruit set at harvest stage, fruit weight (g), number of fruits per shoot and fruit yield (kg/plant) compared to other treatments.

Kabeel *et al.* (2017) investigated on effect of girdling and potassium fertilization on yield efficiency and fruit quality of Apricot cv. Amal. Investigated data showed that fruit set percentage, yield, fruit weight, volume, firmness, height, diameter and fruit shape index as well as fruit chemical properties (TSS %, acidity % and TSS/acid ratio) were significantly improved as a result of the highest with soil application level of K and girdled trees as compared with the control trees. The treatment of K at 1500 gm/tree x girdling gave the best and the most effective combination treatment for increasing fruiting parameters and improving both the most physical and chemical properties and leaf nutrient contents of Amal apricot.

Gawankar *et al*. (2019) reviewed the effect of girdling on induction of flowering and quality of fruits in horticultural crops. The growth and fruitfulness of a plant is influenced by the relative proportions of carbohydrates and nitrogen ratio. The C:N ratio of plants can be altered through special horticultural practices like girdling. It is a disruption in the phloem transport of photosynthates, mineral nutrients and plant bio-regulates between canopy and roots.

Agarwal *et al*. (2021) conducted an experiment on assessment of girdling on fruiting and yield attributes of Litchi cv. Late Bedana at Pantnagar. The results revealed that all the litchi trees which were subjected to different severity and width of girdling have more fruit set (%) and fruit retention (%), yield (kg/tree) and girdling also reduce fruit drop as compared to control. However, the treatment girdling of 50% of primary branches + 4 mm wide had significantly effect on improving fruit yield (57.02 kg/tree).

### 2.2 Effect of Pre harvest panicle bagging on fruit quality

Hu *et al.* (2000) conducted an experiment on effect of pre-harvest bagging on the fruit quality of ‘’Feizixia’’ litchi cultivar and reported that the bag made of sulphuric acid paper increased fruit colour, ascorbic acid and soluble solids content, however, acidity of the fruit was reduced.

Guibing *et al.* (2001) studied on effects of bagging on fruit coloration and phenylalanine ammonia lyase and polyphenol oxidase in ‘Feizixiao’ Litchi. Concluded that Cellophane or fabric bags advanced coloration by 10 days compared with the de-bagged fruit. It is recommended that fruit should be bagged 15 days after full bloom until harvest. The effect of bagging on coloration is associated to the metabolism of phenols and flavonoids, and the activities of phenylalanine ammonia lyase (PAL) and polyphenol oxidase (PPO) as well.

The effect of bagging on cracking and fruit quality was studied by Ding *et al.* (2004). They showed that, cracking rate of bagged fruit decreases remarkably, the bagging greatly improves the appearance of nectarine fruit, and the nectarine fruit looks bright and clean after bagging and takes up colour quickly. The soluble solid, soluble carbohydrate, soluble protein, acid and vitamin C all decrease in bagging fruit, but the intensity of fruits increases remarkably.

Jiang *et al.* (2005) reported that preharvest bagging of litchi fruits influenced storage potential. Results showed that, the best inhibition of the browning and disease development of litchi fruit was observed when the fruit was bagged 3 days before normal harvest. Thus, bagging fruit before normal harvest had the potential to reduce rots, maintain physical quality and extend storage life of harvested litchi fruits.

Study on response of bagging on maturity, ripening and storage behaviour of winter-Guava was done by Singh *et al.* (2007). Bagging induced early ripening characterized by high yellowness index, soft texture with excellent quality in terms of high TSS (11.5° B) and low acidity (0.31%) than other treated fruits. But these fruits have short shelf life of 6 days as compared to control, which had maximum shelf life of 9 days. These bagged fruits exhibited high rate of respiration along with ethylene evolution than other treatments. It is inferred from the present study that ripening and improvement in quality of winter guava can be achieved successfully by simple newspaper bagging one month before harvest.

Debnath and Mitra (2008) reported that quality of Litchi fruit was significantly improved under cellophane paper bags, with respect to colour development and TSS/acid ratio compared with the unbagged (control) fruits (24.10 vs. 8.20 mg anthocyanin/100 g of peel and TSS/acid ratio of 51.00 vs. 46.41).

Sarker *et al*. (2009) evaluated different bagging materials for the control of mango fruit fly attacking “Langra” and “Kirshapat” variety of mango and reported that all bagging materials gave 100 per cent protection of mango fruits against the fruit fly infestation. Bagging of fruits with brown paper bag was found to be the best in protecting mango fruits and provides more total soluble solids (TSS) and physical fruit quality (expressed by per cent black spots) in bagged fruits when compared with the un-bagged fruits of the control treatment.

The effects of different bagging material on fruit appearance, skin pigments, skin colour and fruit internal quality of mango cv. Zill was studied by Wu *et al.* (2009). They noticed that the fruit skin bagged with single white bags displayed significantly lower contents of chlorophyll and carotenoids. Single white layer bagging produce fruit with best internal quality, which had highest contents of vitamin C, titratable acidity, soluble solids, sucrose, glucose and fructose. When fruits bagged with yellow/black double-layer bags, the skin contained significantly lower levels of chlorophyll, carotenoids, anthocyanins and flavonoids.

While conducting an experiment on litchi fruit cv. Hong Huay, Senanan *et al.* (2011) bagged the fruits with newsprint paper, kraft paper, soon fong bag, re may bag, transparent plastic bag, unclear plastic bag, whereas non bagging fruits were used as control. They found that bagging materials made from kraft and newsprint papers enhanced the peel colour of litchi fruits. However, the bagging materials did not affect the fruit weight and size, peel, pulp and seed, total soluble solids, titratable acidity, TSS-acid ratio and vitamin C content of litchi fruits.

Awad and Al-Qurashi (2012) reported that bunch bagging increased bunch and fruit weight in 'Barhee' date palm cultivar but was lower than $GA_3$ treatments. So, $GA_3$ and bunch bagging worked synergistically to increase bunch weight and vitamin C. Fruit length significantly increased by $GA_3$ spray at 100 and 150 ppm and by bunch bagging alone or with $GA_3$ at 50 ppm compared to the control. $GA_3$ and bunch bagging increased flesh/seed ratio, length and T.S.S of fruit. Thus, both $GA_3$ spray and bunch bagging have promotive effects on bunch and fruit weight and improve quality of 'Barhee' dates under hot arid conditions.

Sharma *et al.* (2013) observed that the effect of pre-harvest fruit bagging influenced fruit colour and quality of Apple cv. Delicious. Observations was showed that bagged fruits have better colour development (Hunter “a” = 52) than non-bagged fruits at harvest (Hunter “a” = 38. Similarly, at harvest, bagged fruits contained high amounts of Ca (5.38 mg/100g) and total phenolics (9.3 mg

GAE/100g pulp) exhibited and had better ascorbic acid contents than non-bagged fruits, and there was a decline in all recorded parameters during storage.

Sharma *et al.* (2014) concluded that bagging operation which not only improves the visual attraction of fruits by promoting skin colouration and reducing blemishes, but can also alternates the micro-environment for fruit development, which can have several beneficial effects on internal fruit quality. Pre-harvest bagging of fruits can also reduce the incidence of disease, insect pest and/or mechanical damage, sunburn of the skin, fruit cracking on the fruits, and bird damage. Due to its many beneficial effects, fruit bagging has become an interculture operation of peach, apple, pear, grape, and loquat cultivation in Japan, Australia, China and the USA.

Sharma *et al.* (2014) concluded that fruit bagging is the modern and convenient technique of putting different colour bags over fruit to protect them from attack of pests, disease, sunburn of fruit and cracking of fruit etc. Among several good agricultural practices fruit bagging is becoming most popular in several parts of the world.

An experiment was conducted by Abbasi *et al.* (2014) on guava fruits. They covered guava fruits by various bagging materials and results showed that lowest weight loss (2.72 per cent), maximum fruit firmness (84.1N) and maximum storage period with newspaper bagged, While the highest Benefit cost (B:C) ratio, maximum reducing sugars (3.45 per cent), non-reducing sugars (3.03 per cent) and total sugars (7.34 per cent) were observed in fruit covered with polyethylene bags as compared to control.

Haldankar *et al.* (2015) found that pre-harvest bagging with newspaper bag, brown paper bag and brown paper bag with polythene coating in mango improved physical parameters viz, weight of fruit, length of fruit, diameter of fruit and pulp weight over unbagged control fruits. Pre-harvest bagging at 30 days after fruit set with various types of bags modified fruit retention, period required for harvesting, physicochemical composition, shelf life, occurrence of spongy tissue and pest incidence in mango cv. Alphonso.

Shinde *et al.* (2015) noticed that pre-harvest bagging with different types of bags improved fruit retention, fruit weight, fruit diameter, pulp weight, TSS, reducing sugars and total sugars of mature fruits of mango cv. Kesar. The sensory qualities were also maintained by bagging treatments. The disease incidence and pests were significantly reduced by pre-harvest bagging. Among the different types of bags newspaper and scurting bags were found to be the best.

Purbey and Kumar (2015) studied on effect of pre-harvest bagging on quality and yield of Litchi (*Litchi chinensis* sonn.) fruits. The results showed that minimum fruit borer infestation (6.12 %), brown/ black spotted fruits (3.43%), cracked fruits (1.85%) were observed with white butter paper bagging at 40 days after anthesis whereas highest fruit weight (25.12g) with WBPB and firmness (1.61 Kg $cm^{-2}$) was recorded with brown paper bagging at 40 days after anthesis. The highest ascorbic acid content (64.93 mg/ 100pulp) of fruit were found with WBPB at 40 days after anthesis.

Tran *et al.* (2015) conducted an experiment on effects of bagging on fruit characteristics and physical fruit protection in red Pitaya (*Hylocereus spp*.). Experiment showed important role of fruit bagging was to effectively protect fruits from physiological factors such as cracking, bird damage and blemish, which led to the significant decrease of the total damaged and defective fruits (13.7– 33.3%), as compared with non-bagged control (66.7– 72.6%).

The effect of bagging on fruit characteristics and its role in physical fruit protection were investigated in three pitaya cultivars by Tran *et al.* (2015) and reported that fruit bagging effectively protected fruits from physiological causes such as cracking, bird damage and blemish, which led to the significant reduction in total damaged and defective fruits (13.7–33.3 per cent), as compared with non-bagged control (66.7–72.6 per cent).

Devalla *et al.* (2016) carried out an experiment on effect of bagging on chemical properties of mango cv. Alphanso. Result showed that total sugars in fruits of muslin cloth and scurting bags were improved at ripe stage over control. It was concluded that different types of bags influenced chemical properties of mango fruit.

Prabha *et al.* (2018) analysed the effect of different bagging materials on fruit yield and quality of pineapple cv. Mauritius. They found that the fruit covering of paper bag and plastic bag improved the fruit length, weight, total sugar and total soluble solids (TSS) as compared to unbagged fruits.

Shah *et al.* (2019) studied on effect of pre harvest fruit bagging on the physicochemical properties of litchi (*Litchi chinensis* Sonn.) cv. rose scented. Results revealed that white polypropylene bag with 5% perforation had most significantly improved the physical and the chemical parameters of litchi fruits *viz*. fruit retention, fruit weight, fruit volume, pulp weight, pulp to seed ratio, TSS, total sugars, reducing sugars, non-reducing sugars, ascorbic acid and fruit peel anthocyanin content and less fruit cracking. However, higher fruit width and TSS: Acidity ratio with lower sun burn were obtained in fruits bagged with white polypropylene bags without any perforation. On the other hand, fruits bagged 30 days before harvest gave significant results for all the parameters.

Shah (2019) recommended that bagging of litchi fruits 30 days before the normal harvest with white polypropylene bags to enhance the physical as well as chemical parameters of litchi to obtain good quality litchi fruit for profitable litchi cultivation.

Chand *et al.* (2020) studied on 15 years old Litchi plants in Pantnagar, on impact of pre-harvest fruit bagging technology on growth and quality traits in litchi cv. Rose Scented and the data showed that bagging of litchi fruits with white polypropylene bags 15 days after fruit set resulted in lesser cracking and sunburn incidence. For other attributes, polypropylene pink bagged 30 days after fruit set was found promising in Fruit breadth (mm), Yield (Kg/tree), Anthocyanin (mg/100g), Fruit colour (visual). In Litchi under Indian condition, the novel technique of fruit bagging significantly enhance the fruit appearance and quality.

### 2.3 Foliar application of PGRs & chemicals on flowering and fruiting

The field experiment on use of growth regulators for early ripening of litchi (*Litchi chinensis* Sonn.) was studied by Sharma *et al.* (1986). Results indicated that Ethrel (400 ppm) significantly increased the fruit weight, total soluble solids of the fruits and advance the ripening by 8 days; NAA (25 ppm) was also effective and advanced maturity by 5 days.

Supitchpong *et al*. (1994) conducted an experiment to study the effect of $KNO_3$ and thiourea on mango cv. Nam Dok Mai. Foliar spray of thiourea and $KNO_3$, 80 days after being soil drenched with 1200 ppm of paclabutrazol resulted in greater number of panicle than those treated with distilled water. Number of panicles was lower with the $KNO_3$ treated tree compared to those treated with thiourea.

Stern *et al*. (1995) in an experiment on Mauritius litchi evaluated the rate of fruit development and abscission after treatment with the Auxin 2,4,5-TP. Results revealed that Tipimon (a commercial product containing the triethanolamine salt of the synthetic auxin 2,4,5-TP) consistently and significantly increased marketable fruit yield when applied between the two abscission periods. Chemical name used: 2,4,5 -trichlorophenoxy propionic acid (2,4,5 -TP).

Nguyen and Tran (2004) reported higher number of panicles, number of fruits per panicle and yield per tree, when thiourea (0.5%) was sprayed in November. An experiment was conducted to determine the effect of thiourea

(0.1%) and ferrous sulphate (0.5%) on fruit yield and quality of Ber cv. Gola. The highest fruit length (2.84 cm), fruit breath (2.97 cm), fruit weight (12.14 g), total soluble content (19.10%) and yield (34.47 kg/tree) were obtained with thiourea + ferrous sulphate. Dhua *et al.* (2005) observed that among various treatments, pre-harvest application of ethrel (0.25 ml/L) advanced the fruit ripening and anthocyanin content of harvested fruits as compared to control in litchi cv. Bombai. Although fruit ripening was advanced by about four days with ethrel, the fruit weight was lesser when compared to control. Ethrel application also caused early improvement of fruit colour associated with early increase in the TSS -acid ratio compared to control.

An experiment was conducted to study the effect of ortho-phosphoric acid ($H_3PO_4$), potassium di-hydrogen phosphate ($KH_2PO_4$), dipotassium hydrogen phosphate ($K_2HPO_4$), calcium nitrate {Ca ($NO_3$)$_2$} and salicylic acid (SA) on mango cv. Baneshan. The percentage of new laterals which flowered was highest with $K_2HPO_4$ at 1.0 per cent spray. The percentage of hermaphrodite flowers was highest with $K_2HPO_4$ at 1.0 per cent spray (Kumar and Reddy, 2008).

Cronje *et al.* (2009) conducted pre-harvest studies of effect of different preharvest treatment regimes on fruit quality of Litchi cv. Maritius. Concluded that Calcium chloride increased the fruit calcium (Ca), firmness, and skin colour. Some of the positive correlations were leaf potassium (K) and fruit K; fruit K and soluble solid concentrations (SSC); skin Ca and colour value “a”. Potassium nitrate and $CaCl_2$ affected the K/Ca ratio in the fruit.

An investigation was carried out on effect of plant growth regulators on fruit quality and leaf mineral composition of Litchi cv. Bombai grown in new alluvial zone of West Bengal by Dutta *et al.* (2011). The data revealed that NAA 50mg/L showing maximum fruit weight (24.22g), edible to non-edible ratio (2.25) and anthocyanin content of peel. While $GA_3$ 100mg/L showing highest

TSS (19.8 $^0$B), total sugar (14.30%), sugar: acid ratio (23.8) and ascorbic acid (32.25mg/100g pulp) content. Both NAA (50mg/L) and $GA_3$ (100mg/L) are same effective in enhancing the fruit quality and leaf mineral composition of Litchi.

Farag *et al.* (2012) conducted a study on ‘Canino’ apricot cultivar (*Prunus armeniaca* L.) grafted on Balady apricot rootstock. Treatments included water as the control, Ethephon at 200 ppm alone or in a combination with either $CaCl_2$ or oleic acid, in addition to oleic acid at 400 ppm, $CaCl_2$ (2 % w/v). Ethephon-treated fruits resulted in decreased fruit size, stone weight, while no consistent influence on fruit weight and flesh weight.

Sarkar and Rahim (2013) conducted the experiment to study the effect of $KNO_3$ on time of panicle emergence by spraying 4%, 6% and 8% $KNO_3$ on trees of mango cv. Amrapali and comparing these treatments with the control. They observed early emergence of panicles *i.e.*, 17 days earlier than control in the trees which were treated with 4% $KNO_3$. Trees treated with 4% $KNO_3$ exhibited significantly superior results towards length of panicle, breadth of panicle, secondary branches per panicle and number of panicles per plant as compared to control.

Sarkar and Ghosh (2014) studied the effect of chemicals *viz.*, paclobutrazol (2 and 3 ml a.i./$m^2$ of canopy surface area); ethrel (1.0 and 2.0 ml/l) and $KNO_3$ (1 and 2%) and cincturing (during September and October) on flower induction of litchi cultivar ‘Bombai’. The result showed that plants treated with ethrel (2 ml/l) had the highest C/N ratio both in leaves and shoots before flowering. Number of flowering panicles (71.58%), number of fruits per panicle at initial stage (63.92) and also at harvest (23.09) was found to be the highest under this treatment. However, the highest sex ratio (3.26) of flowers was found in untreated control plants and maximum percentage of fertile pollen was observed in plants treated with $KNO_3$ (2%). Application of paclobutrazol (3 ml *a.i.*/$m^2$ canopy surface area) advanced the flower emergence by six to seven days. Thus, among the treatments, ethrel (2 ml/l) proved to be the most effective for flowering and fruit induction.

Kacha *et al.* (2014) investigated on performance of various plant growth regulators on yield and quality of Phalsa (*Grewia asiatica* L.). Results indicated that an application of NAA 150 ppm significantly increased number of flowers per shoot (151.21), number of fruits per shoot (60.74), 100 fruits weight (49.80 g), juice percentage (57.78 per cent) and the maximum yield of fruits (1.71kg/plant and 5800 kg/ha) followed by NAA 200 ppm. The quality of fruits in terms of TSS (25.23 per cent), reducing sugar (2.01 per cent) and total sugar (5.74 per cent) were significantly higher in treatment with Ethrel 1000 ppm followed by Ethrel 750 ppm. Further, Ethrel 1000 ppm also significantly reduced the period of harvesting (9.76 days) and number of pickings (3.57) followed by Ethrel 750 ppm. An application of $GA_3$ 150 ppm significantly reduced acidity (2.55 %) and increased ascorbic acid content (39.50 %).

A field experiment was conducted to study foliar application of nutrients and thiourea to determine their effect on yield and economics of mango fruits cv. Kesar. Foliar application of 1.0% $KNO_3$ in mid-October followed by 0.5% Thiourea in mid-November induced early flowering and early maturity of fruits which fetches higher price in market. It also increased the yield of Kesar mango (Patel *et al.* 2016).

Sultana *et al.* (2016) conducted an experiment to evaluate various plant growth regulators in flower and fruit setting of litchi. It was found from the experiment that the highest fruit weight was about 23.26 g by NAA at 20 ppm application in the month of October and December. And aslo highest yield of 121.0 q/ha and B/C ratio was 1.83 by NAA at 20ppm.

A field trial was conducted by Kumar *et al.* (2016) on effect of micronutrients and plant growth regulators on yield and quality of Litchi (*Litchi* *chinensis* Sonn.) fruits. The Maximum number of fruits per tree (5422), average weight of fruit (20.91 g) and fruit yield per tree (111.05 kg) was obtained with the application of borax (0.4 per cent). Combination treatment *i.e.*, Borax 0.4% + $GA_3$ 20 ppm given highest fruit yield per plant of 123.10 kg. whereas micronutrient and PGR combination of $GA_3$ (20 ppm) and $ZnSO_4$ (0.4 per cent) were found most effective treatments to increase the content of reducing sugar and total sugar.

Pal *et al.* (2016) carried out an trail to extend the harvesting period, by effect of chemicals and physical means on harvesting span, yield and quality of Litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. Results showed that, application of $KNO_3$ @ 4% resulted in significantly higher fruits set per panicle (64.93). Treatment of $GA_3$ (40 ppm) being at par with BA @ 20 and 40 ppm exhibited significantly more TSS, total sugars and non-reducing sugars. Application of $KNO_3$ @ 4% exhibited significantly highest reducing sugars and significantly lower titratable acidity.

Kumar *et al.* (2017) conducted a field experiment on effect of foliar spray of chemicals on flowering and fruiting in Litchi in Bihar. The results indicated that, 1% mono-potassium phosphate and 400 ppm ethrel spray increased flowering percentage. Ethrel (400 ppm) spray showed advanced flowering, harvesting by 6-7 days and also maximum yield (70.48 kg per tree) due to highest number of female flower per panicle and improved the fruit quality in terms of total soluble solids (20.47 $^{o}$B) and TSS/Acid ratio. Combination of 1% mono-potassium phosphate and 1 % potassium nitrate revealed highest fruit weight, pulp recovery, female flower per panicle and sex ratio (1.03). Spray of 1 % potassium nitrate led to largest fruit and seed weight and most of the fruits were more than 21 g in weight which is most desirable characters to fetch premium price in market.

Experiment on effect of micronutrients and plant growth regulators on fruit set, fruit retention, yield and quality attributes in litchi cultivar Dehradun was carried out by Kaur, (2017) and recorded that the maximum fruit set (78.15%), fruit retention (60.17%), fruit length (5.6cm), breadth (5.0cm), fruit weight (25.90gm), fruit yield (158.73kg/tree), pulp weight (22.19gm), pulp stone ratio (9.44), TSS (22.96°Brix) and sugars (18.52%) with minimum fruit cracking (2%), stone weight (2.35gm), peel weight (1.36gm) and acidity (0.4%) were recorded with 0.4% borax application followed by 50ppm $GA_3$ application.

Mishra *et al*. (2017) conducted an experiment on effect of plant bio-regulators on quality and yield of Litchi (*Litchi chinensis* sonn.) cv. Rose Scented. Results exposed that application of three sprays of $GA_3$ @ 50 ppm was proved to be most effective in minimizing fruit drop and fruit cracking and improving the physico-chemical properties and yield of litchi.

Mandal *et al*. (2017) experiment was conducted with an objective to measure the effect of certain chemicals *viz*. Paclobutrazol (25% w/v) @ 2 ml and 3 ml a.i. $m^{-2}$ of canopy spread, Ethrel (40%) @1.0 ml and 2.0 ml $l^{-1}$, KNO3 1.0% and 2.0% along with cincturing (during September and October) against untreated plant on quality fruit production. The plants treated with ethrel @ 2 ml $l^{-1}$ produced maximum fruit weight (21.94 g), pulp weight (16.17 g) and juice content (62.79ml per100g pulp). The Total Soluble Solids (TSS) and TSS: acid ratio was also found highest 20.15 $^{o}$ Brix and 40.95 under this treatment. However, cincturing during September also enhanced the fruit weight (21.39 g) compared with control (19.57 g).

Prasad *et al.* (2018) conducted a trail on effect of foliar application of PGR and different potassium forms on sex expression, fruit setting, yield and fruit quality in litchi Mandraji. Results showed that 5.33 days of advancement in flowering with maximum flowering intensity (73.33%) was observed in foliar spray of Ethrel at 400 ppm. However, highest sex ratio (0.96), maximum fruits retention per panicle (22.00) with highest yield (98.66 kg $tree^{-1}$), maximum fruit weight (21.92 g) and TSS (19.97 °B), and harvest advancement (6.67 days) was observed in the treatment of $K_2HPO_4$ (1%) + $KNO_3$ (1%).

An experiment was conducted by Kumar *et al.* (2018) on response of growth regulators on flower induction, fruit yield and quality of litchi cv. Shahi. The data revealed that Plants treated with Ethrel at 100 and 150 ppm in the month of October, expressed significantly higher number of pure panicle emergence (86.67% and 91.67%) and fruit yield (53.33 and 52.50 kg $plant^{-1}$) than other treatments. PGRs treated plants expressed more fruit weight, pulp recovery and highest TSS than control.

Priyadarshi *et al.* (2018) conducted a field experiment on effect of growth regulators and micronutrients spray on chemical parameters of litchi (*Litchi chinensis* Sonn.) cv. Calcuttia. Results showed that $ZnSO_4$ treated plants highest TSS (20.40 $^{0}$B) and non-reducing sugars (2.98%). Foliar application of boric acid + $ZnSO_4$ has showed highest total sugar content (13.79%) and decreased the titratable acidity.

**2.4 Effect of mulching on yield and quality**

Garg *et al.* (2007) reported that highest fruit yield was obtained in case of banana leaf mulched plants (11.80 kg/plant) followed by black polyethylene mulch (10.00 kg/plant) compared to control. Banana leaf mulch seems to be the best mulch since the fungal and bacterial counts were also highest in guava.

Ganga *et al.* (2011) conducted an experiment on effect of drip fertigation and mulching on water requirement, yield and economics of high-density litchi and reported that least fruit drop and fruit cracking was recorded in treatment $Mid_3F_2$ (Black polyethylene mulch + drip irrigation at 100% of estimated irrigation water requirement +100% RDF) and the maximum in control (Conventional irrigation + no-fertilizer) in both the years. The highest yield (40.4kg/plant) was recorded in treatment $Mid_3F_2$ (Black polyethylene mulch +

drip irrigation at 100% of estimated irrigation water requirement +100% RDF) with highest BC ratio of 6.52.

Joshi *et al.* (2012) reported that highest fruit yield (14.80 kg /tree) was recorded in treatment (black polythene mulch + drip irrigation at 100% of estimated irrigation water requirement + 125% RDF). In the subsequent year, treatment (black polythene mulch + drip irrigation at 100% of estimated irrigation water requirement +75% RDF) gave the highest fruit yield (40.40 kg/tree) in Litchi cv. Rose scented.

Sureshkumar *et al.* (2012) noted that fruits harvested from strawberry plants which were mulched with black polythene recorded better TSS (8.18° Brix), lower acidity (0.93 %), higher ascorbic acid content (52.50 mg/100 g pulp), reducing sugar (2.81 %) and anthocyanin (25.33 mg/100 g) than fruit obtained from plants mulched with other materials.

Banyal *et al.* (2013) studied on effect of different chemicals and mulch materials on fruit quality and productivity of litchi cv. Dehradun. And results the study indicated that fruit trees sprayed with 1.0 per cent zinc sulphate in first week may at pit hardening stage registered maximum fruit weight (15.67g), percent aril (58.5), fruit set (98.7 fruits/panicle), yield (76.4 q/ha) and minimum fruit cracking (19.6%) in litchi cv. Dehradun.

Su *et al.* (2014) conducted an experiment on the effect of ground mulching on flowering and fruit development of Litchi, at China and results of the study indicated that ground mulching effectively increased soil temperature and soil moisture. In ‘Feizixiao’, flower panicle primordia in mulched trees developed 2-4 days earlier compared to control. There was a significant difference in the percentage of flowering terminal shoots and the fruit size between mulching and the control.

Manoj *et al.* (2015) reported that maximum TSS (8.33° Brix) , minimum acidity (0.77 %), maximum retention of ascorbic acid (41.66 mg/100g) was recorded in paddy straw mulch. The maximum juice content (54.58 %) was recorded in black polythene 200µ mulch in Kinnow.

Iqbal *et al.* (2015) studied the effect of different organic and inorganic mulching materials on Aonla cv. NA-7. Black polythene mulch significantly increased fruit weight (41.32 g), fruit length (3.73 cm), fruit diameter (4.42 cm), fruit volume (39.80 $cm^3$), fresh weight of pulp (39.57 g), dry weight of pulp (6.03 g) and pulp: stone ratio (20.94). It was also found to be superior in terms of chemical characteristics of fruits such as T.S.S. ($10.73^0$B), total sugar (5.71 %), reducing sugar (3.41 %), non-reducing sugar (2.30 %), vitamin-C (495.03 mg/100g fruit), chlorophyll content (36.90 %) and TSS: acid ratio (6.54). TitraTable acidity (1.92 %) and specific gravity (1.27) was found maximum in control (un-mulched) and minimum in black polythene mulch. From this study, it can be concluded that black polythene was much superior in terms of fruit quality as compared to un-mulched.

Ghosh and Bera (2015) reported that highest fruit yield of 9.90 kg was obtained from the plant mulched with saw dust followed by white polyethylene (8.80 kg/plant) and rice husk (8.00 kg/plant) in pomegranate cv. Ruby. The lowest yield was recorded from the control plants (6.10 kg/plant). Fruit weight was highest (178 g) in the plants mulched with rice straw (chopped) followed by black polyethylene (172 g) and saw dust (170 g) while in control it was the lowest (142 g).

Wang *et al.* (2015) revealed that straw mulch (SM) and plastic film mulch (PFM) in peach markedly increased soil water content particularly during bloom and fruit expansion. Whereas, the yield increased by 29.00% and 27.90% for Straw mulch and black plastic film mulching, respectively compared to control.

Pandey *et al.* (2015) reported that, larger fruit length (54.0 mm), fruit width (42.59 mm), fresh fruit weight (36.74 g), dry fruit weight (2.88 g), number of fruits (33.55 fruits/plant) and higher fruit yield (536.66 g/plant) under black polythene mulch compared to white polythene, rice husk and control in strawberry cv. Winter dawn.

Iqbal *et al.* (2016) studied on efficacy of organic and inorganic mulching materials on weed count, growth, and yield of Aonla (*Emblica officinalis*) cv. NA-7. Results showed that s floral characteristics, plant with black polythene mulch were the first to flower (11 April 2013), with maximum duration of flowering (23 days) and male: female flower ratio (22:1). Black polythene mulch was superior to all other mulching treatments in terms of yield attributes as it registered maximum fruit set (56.15%), minimum fruit drop (55.87%) and higher yield/tree (72.77 kg/tree).

Das *et al.* (2016) conducted, a field experiment on effect of organic mulches on yield, physico-chemical qualities and leaf mineral composition of litchi cv. Bombai in Indo-Gangetic plain of West Bengal. They found that, among different mulches, paddy straw mulch showed maximum (22.80%) soil moisture content and fruit retention (18.42 no. panicle$^{-1}$) with highest (94.42 kg plant$^{-1}$) yield followed by mulches with mango leaves. This treatment also showed maximum TSS (20.20 °Brix), total sugar (14.80%) with minimum (0.60%) acidity of fruit. Leaf mineral composition was also increased with the application of different mulches.

An experiment was conducted by Bhandari *et al.* (2017) on effect of mulching and irrigation interval on fruit quality and yield of litchi cv. Dehradun. Results of the showed that the trees supplied with irrigation at 6 days interval and mulching with black polythene ($T_8$) showed lowest fruit cracking (10.15%) and highest fruit yield (59.33 kg/tree). Fruit weight (18.27 g), fruit length (3.28 cm), fruit diameter (2.92 cm), pulp weight (10.45 g) and fruit firmness (2.51 kg/cm$^2$) were also found to be highest in trees mulching with black polythene and irrigated at 6 days interval with highest benefit: cost ratio (2.77:1).

Das and Dutta (2018) studied on effects of mulching on soil properties and post-harvest quality of Mango cv. Himsagar grown in new alluvial zone of West Bengal. Results showed that mulching with different materials displayed uniform growth and vigour, significantly increased the soil moisture content, available soil N, P and K, along with increase soil microbial population. Among the different mulching treatments, black polythene showed maximum soil moisture retention with improved soil properties. This treatment also exhibited maximum physico-chemical qualities of fruits followed by paddy straw and paddy husk.

Kumari and Khare (2019) studied on effect of mulching: a best practice of soil management in the litchi orchard at Bihar. Results of the study has showed soil moisture content improved from 11.9% to 20.67% (inorganic mulch). Soil nutrients, Nitrogen (252kg $ha^{-1}$), phosphate (53kg $ha^{-1}$) was found maximum in inorganic mulch as compared to control. Organic carbon (0.95%) and rhizobacterial diversity (2.5 X $10^{-8}$) was maximum in organic mulch. Fruit parameters also enhanced in mulched trees. Fruit yield/ tree was highest in inorganic mulch (97.56 kg), followed by organic mulch (85.64kg) and lowest was recorded in control (74.82 kg). Both organic and inorganic mulching treatment are good in maintaining the soil health and litchi production. Thus, it can be effectively used as a good cultural practice in modern agriculture system.

The experiment to evaluate the effect of different drip irrigation levels in combination with mulching on fruiting, yield and quality attributes of litchi (cv. Rose Scented) under high density by Tyagi (2021). During the study, litchi plants were subjected to three levels of drip irrigation *i.e.*, 100 %, 75 % and 50 % of estimated irrigation water requirement, with and without mulching. With respect to all treatments, the treatment $MDI_3$ *i.e.*, application of drip irrigation at 100 % level in tandem with mulching was showed significant difference over other treatments as well as control.

# MATERIALS AND METHODS

The present investigation entitled "Effect of different technological interventions on yield and quality of litchi grown in Nagaland" has been conducted in the research experimental block of Horticulture Department, School of Agriculture Sciences and Rural Development, Nagaland University, Medziphema campus, Nagaland. The details of the materials and methods used and fallowed during the experiment for recording various observations and analysis is presented below.

## 3.1 Geographical situation

The research experimental block of Horticulture Department, School of Agriculture Sciences and Rural Development, Nagaland University, Medziphema campus, Nagaland situated at 25º 45' 53" N latitude and 93º 53' 04" E longitudes at an elevation of 310 m above sea level, bringing sub-tropical climate.

## 3.2 Climatic condition and weather

The prevailing climatic condition of Medziphema Campus is humid and falls under sub-tropical region with an average annual rainfall ranging from 2000-2500 mm, with predominantly high humidity of 70-90%. The mean temperature ranges from 21º to 32º C during summer and during winter from 10º to 15º C, rarely goes below 8º C in winter. The meteorological data during the period of study have been collected from ICAR Regional Research Centre Jharnapani, Nagaland, it has shown in the table 3.1.

**Table 3.1 Meteorological data recorded during the period of crop investigation (September to June) for both years 2020-21 and 2021- 22**

| Month | Temperature (ºC) | | | | Relative Humidity (%) | | | | Rainfall (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | | Min. | | Max. | | Min. | | | |
| | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 | 2020-21 | 2021-22 |
| **September** | 34.00 | 33.10 | 23.50 | 23.80 | 93.00 | 94.00 | 68.00 | 68.00 | 98.70 | 116.20 |
| **October** | 33.80 | 32.10 | 23.00 | 22.10 | 95.00 | 95.00 | 67.00 | 68.00 | 114.30 | 130.00 |
| **November** | 30.00 | 28.50 | 15.00 | 14.80 | 95.00 | 96.00 | 51.00 | 51.00 | 00.00 | 00.00 |
| **December** | 26.50 | 25.10 | 12.50 | 11.30 | 94.00 | 95.00 | 50.50 | 51.00 | 02.50 | 16.40 |
| **January** | 24.00 | 22.70 | 08.90 | 10.10 | 96.00 | 96.00 | 50.00 | 56.00 | 03.40 | 34.60 |
| **February** | 27.10 | 23.20 | 09.70 | 09.60 | 95.00 | 95.00 | 40.00 | 48.00 | 02.30 | 56.30 |
| **March** | 31.10 | 32.20 | 14.90 | 15.50 | 93.00 | 90.00 | 41.00 | 40.00 | 43.50 | 02.30 |
| **April** | 33.10 | 30.90 | 17.90 | 19.90 | 87.00 | 90.00 | 34.00 | 68.00 | 59.60 | 175.70 |
| **May** | 32.80 | 30.50 | 21.90 | 21.90 | 90.00 | 92.00 | 58.00 | 71.00 | 85.40 | 224.70 |
| **June** | 33.10 | 32.00 | 24.30 | 23.90 | 93.00 | 95.00 | 69.00 | 72.00 | 117.40 | 160.80 |

### 3.3 Soil status of the experimental site

The soil of the experimental site was sandy loam, acidic in nature with mean pH of 4.4.

**Table 3.2 Soil fertility status of the experimental farm site**

| Parameters | Value | Status |
|---|---|---|
| $P^H$ | 4.4 | Acidic |
| Organic Carbon | 0.433 | Low |
| Available N (kg $ha^{-1}$) | 344.50 | Medium |
| Available $P_2O_5$ (kg $ha^{-1}$) | 46.13 | High |
| Available $K_2O$ (kg $ha^{-1}$) | 143.22 | Medium |

### 3.4 Experimental Details:

The present investigation has consisted of different technology using to enhance the yield and quality attributes of litchi. In these girdling, bagging, spray of PGR & chemicals and use of organic and inorganic materials was used to laid down the experiments.

#### 3.4.1 To study the effect of different levels & widths of girdling on bearing potential of litchi cv. China

**Layout and Experimental Design:**

The experiment was laid out in Factorial Randomized Block Design with different levels of girdling on primary branches with different sizes of girdling (removal of bark 2mm, 4mm and 6mm. The girdling operation was doing in the fourth week of September.

**Factor-1: Levels of girdling (G)** **Factor-2: Widths of girdling (L)**

$G_1$=Girdling 25% of the primary branches $L_1$=2mm

$G_2$=Girdling 50% of the primary branches $L_2$=4mm

$G_3$= Girdling 75% of the primary branches $L_3$=6mm

**$T_1$**= $G_1$ $L_1$ **$T_6$**= $G_2$ $L_3$

**$T_2$**= $G_1$ $L_2$ **$T_7$**= $G_3$ $L_1$

**$T_3$**= $G_1$ $L_3$ **$T_8$**= $G_3$ $L_2$

**$T_4$**= $G_2$ $L_1$ **$T_9$**= $G_3$ $L_3$

**$T_5$**= $G_2$ $L_2$ **$T_{10}$**= Control (un-girdle)

| | |
|---|---|
| Treatment combination | 9+1=10 |
| Replications | 3 (One plant/replication) |
| Spacing | 5*5m |
| Age of the Tree | 22 years |
| Variety | China |
| Experimental Design | Factorial Randomized Block Design |

**Observations recorded**

Observations on quantitative traits were recorded on five randomly selected plant parts in each treatment from all the three replications and averaged.

**3.4.1.1 Trunk girth(cm)**

The girth of trunk was measured 25 cm above the ground level with the help of measuring tape and expressed in centimetres (cm).

**3.4.1.2 Wound healing period(days)**

The trees were regularly observed for healing of girdled portions and when the phloem tissue was completely covered the girdled ring, it was considered as completion of healing. It has been recorded, as days taken to healing of wound from on the day of incision.

**3.4.1.3 Appearance of girdle portion (smooth/less swell/more swell)** Appearance of girdling portion was recorded and classified into three groups as Smooth, less swell and more swell.

**3.4.1.4 Days to flowering after girdle (Days)**

The period of time taken to induction of flowering has measured by number of days after girdling operation.

**3.4.1.5 Flowering per cent (%)**

Five randomly selected flower panicles were collected from each replication and the average value was worked out and expressed in percentage.

**3.4.1.6 Fruit set (number)- at clove stage**

Fruit set was studied by tagging panicles at the time of appearance of fruitlets on panicles. Five randomly selected fruit clusters were collected from each replication and the average value was worked out by counting the number fruit set at early (clove) stage.

**3.4.1.7 Fruit drop (%) at clove and harvest stage**

Data was recorded on every plant under treatment for studying the percentage of fruit drop. To calculate fruit drop percentage, total number of fruits dropped from initial fruit set to maturity was calculated by fallowing formula:

$$\text{Fruit drop @ clove stage (\%)} = \frac{\text{Number of fruits droped}}{\text{Number of female flowers per panicle}} \times 100$$

$$\text{Fruit drop @ harvest (\%)} = \frac{\text{Number of fruits droped}}{\text{Number of fruits set clove stage}} \times 100$$

**3.4.1.8 Fruit retention per panicle (number)**

Total number of fruits retained at harvesting in five randomly selected fruit clusters were collected from each replication and the average value was worked out.

**3.4.1.9 Fruit length (cm)**

The distance between the base and the apex of randomly selected fruits were measured and the average was expressed in centimetres (cm) with the help of digital vernier caliper.

**3.4.1.10 Fruit breadth (cm)**

The width of randomly selected fruits was measured around the midpoint of the fruit and the average was expressed in centimetre (cm) with the help of digital vernier caliper.

**3.4.1.11 Fruit weight(g)**

Weight of ten fruits from each treatment per replication were randomly selected and recorded by weight on top pan balance and average weight of fruit was expressed in grams (g).

**3.4.1.12 Pulp weight(g)**

Random sample of five fruits from each replication of different treatments were taken, Peel and seed were removed and weight of aril/pulp was recorded by using electronic balance and expressed in gram (g).

### 3.4.1.13 Pulp percentage (%)

Random sample of five fruits from each replication of different treatments were taken, Peel and seed were removed and weight of aril/pulp was recorded by using electronic balance. Average pulp percentage was obtained by dividing the total weight of pulp with the weight of fruits.

$$\text{Pulp percentage } (\%) = \frac{\text{Weight of pulp (g)}}{\text{Weight of fruits (g)}} \times 100$$

### 3.4.1.14 Seed weight(g)

It was calculated by taking the weight of each seed on electronic weighing balance after extracting it from the fruit which was collected randomly from each replication and was expressed in grams (g).

### 3.4.1.15 Yield(kg/tree)

The fruits were harvested from each replication and all the fruits from the individual trees were picked manually and collected under the trees. The total weight of the marketable fruits per tree was recorded using a pan balance of 5kg capacity and the data were expressed in kg per tree.

### 3.4.1.16 Total sugar (%)

Total sugar content of fruit juice was determined as per Lane and Eynon method (Ranganna, 1986). 50ml filtered juice was mixed with 100ml distilled water and neutralized with 0.1N NaOH solution using phenolphthalein as indicator and the solution was allowed to stand for ten minutes. Then 8ml of potassium oxalate solution was added and total volume was made up to 250 ml by adding distilled water. 5ml of the extract was taken in burette and titrated again 10ml mixed Fehling’s (5ml Fehling’s solution A+5ml Fehling’s solution B) solution using methyl blue as indicator. The end point is indicated by appearance of deep brick red colour precipitation. Calculation of total sugar is done with the fallowing formula:

$$\text{Total sugar (\%)} = \frac{\text{Factor of Fehling's solution} \times \text{Dilution factor}}{\text{Titre value} \times \text{wt of sample taken}} \times 100$$

Where, factor for Fehling's solution denotes the gram of invert sugar

$$\text{Factor} = (\text{Titre value} \times 2.5)/100$$

### 3.4.1.17 TSS (°Brix)

Total Soluble Solids, in the juice of representative sample were determined by using Digital refractometer (range of 0-32$^0$ Brix) and expressed in degree brix ($^0$B). The fruit juice was extracted from the mature fruits and the total soluble solids (TSS) were measured using a handheld refractometer, after prior calibration using distilled water. After each test, the prism plate was cleaned with distilled water and wiped with a soft tissue. The value was recorded and TSS was expressed in °Brix.

### 3.4.1.18 Titratable acidity (%)

Pulp (20 g) from 15 fruit without symptoms of disease was homogenized in a grinder and the supernatant phase was collected to analyze TA. Five ml aliquot was mixed with one to two drops of phenolphthalein and was titrated against 0.1N NaOH. The appearance of light pink colour marked as end point as per method described in the manual of analysing of fruits and vegetables product by Ranganna (1991). The acidity was expressed in percentage by following formula:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{Equivalent weight of acid}}{\text{Volume of sample taken} \times 1000} \times 100$$

### 3.4.1.19 TSS: Acid ratio

It was calculated by dividing the TSS (%) by titratable acidity (%) in each treatment.

### 3.4.1.20 C/N ratio of leaves before and after girdling

**Total carbohydrate**

Carbohydrate content could be measured by Anthrone method, hydrolysing the polysaccharides into simple sugars by acid hydrolysis and estimating the resultant monosaccharides at 630nm by using Spectro photometer.

**Nitrogen**

Available nitrogen in leaves will be estimated by Kjeldahl's method as described by Jackson (1973).

**C/N ratio:** The carbohydrate: nitrogen ratio in leaves will be estimated by dividing the total carbohydrate content by the total nitrogen content.

**3.4.1.21 Statistical analysis and interpretation of data:**

The data collected during the investigation was subjected to statistical analysis using Factorial Randomized Block Design (F-RBD). The mean values of different treatments were analyzed with the statistical software along with corresponding standard error of mean (S.E.±). The critical difference at 5 per cent level of significance was computed.

**3.4.2 To study the effect of bagging on quality of Litchi fruits cv. Shahi**

**Layout and Experimental Design:**

The experiment was laid out in Randomized Block Design. Bagging experiment, has conducted in early stage of fruit lets at clove size (March- April) with different colour bags of white, pink polypropylene bags and brown paper bags has used to create microclimate inside the bag to enhance the quality of fruits by increasing colour, TSS and reducing the cracking and sunburn.

**$T_1$**= Polypropylene white at 15 days after fruit set

**$T_2$**= Polypropylene white at 25 days after fruit set

**$T_3$**= Polypropylene white at 30 days after fruit set

**$T_4$**= Polypropylene pink at 15 days after fruit set

**$T_5$**= Polypropylene pink at 25 days after fruit set

**$T_6$**= Polypropylene pink at 30 days after fruit set

**$T_7$**= Brown paper bag at 15 days after fruit set

**$T_8$**= Brown paper bag at 25 days after fruit set

**$T_9$**= Brown paper bag at 30 days after fruit set

**$T_{10}$**= Control (No bagging)

| | |
|---|---|
| Treatments | 10 |
| Replications | 3 |
| Spacing | 5*5m |
| Variety | Shahi |
| Design | Randomized Block Design |

**Observation recorded**

### 3.4.2.1 Fruit colour

Colour of fruit estimated based on DUS guidelines and with the help of RHS (Royal Horticultural Society) colour chart categorized into purple red and deep red.

### 3.4.2.2 Fruit weight (g)

Weight of ten fruits from all the treatments including the three replications of each treatment were recorded by weighing the sample on pan balance (1/2 kg capacity). Average weight of fruit was taken in grams (g).

### 3.4.2.3 Sunburn (%)

Number of fruits having brown coloured patch on the skin due to sun burn or sun scald was counted by visual observation out of total number of fruits retained in the tagged panicles and expressed in terms of percentage.

$$\text{Sunburn (\%)}=\frac{\text{No. of sunburn showing fruits per panicle at harvesting stage}}{\text{No. of fruits retained per panicle at harvesting stage}}\times 100$$

### 3.4.2.4 Cracking (%)

Observations on fruit cracking were recorded from first May, at an interval of 7 days. For recording the data on fruit cracking one panicle was tagged in each of the four directions (east, west, north and south) of tree. Percentage fruit cracking was calculated on the basis of observations recorded on four panicles. The percentage fruit cracking in a particular treatment was worked out by using the following formula:

$$\text{Fruit cracking (\%)}=\frac{\text{No. of fruits cracked per panicle at harvesting stage}}{\text{No. of fruits retained per panicle at harvesting stage}}\times 100$$

### 3.4.2.5 Borer infestation (%)

The percentage of fruit borer infestation was calculated after harvesting fruits by removing the peel of individual fruit and it's recorded on each replication of different treatments. It was calculated by using fallowing formula:

$$\text{Borer infestation (\%)}=\frac{\text{No. of fruits infested per panicle at harvesting stage}}{\text{No. of fruits retained per panicle at harvesting stage}}\times 100$$

### 3.4.2.6 Pericarp anthocyanin content(mg/100g)

Sample of 2-5g was homogenized with AM (Acidic Methanol) and incubated for 72h. The mixture was squeezed and re-extracted the residue 2-3 times to extract all anthocyanin. Pooled extract was made up to volume with AM to 25ml. The intensity of colour was read at 540 nm adjusting 100% transmission against AM. Amount of anthocyanin in unknown sample was calculated using cyanidin hydrochloride as standard and expressed as mg/100g fresh weight.

$$\text{Anthocyanins (mg/100g)}=\frac{\text{OD}\times\text{Std value}\times 50\text{ml}\times 100}{\text{Weight of the sample (g)}\times 1000}$$

### 3.4.2.7 Mean temp of microclimate inside bags (˚C)

The Average temperature of inside bag was measured with the help of Thermometer and expressed in ˚C.

### 3.4.2.8 Mean RH of microclimate inside bags (%)

The Average humidity of inside bag was measured with the help of hygrometer and expressed in %.

### 3.4.2.9 Light intensity of microclimate inside bags (100 lux)

The Average intensity of light penetration inside bag was measured with the help of lux meter and expressed in lux.

### 3.4.2.10 Growing Degree Days for maturity (˚C)

The growing days values were measured using daily maximum and minimum temperatures considering a base line temperature of 10 ˚C.

### 3.4.2.11 Total sugar (%)

Total sugar content of fruit juice was determined as per Lane and Eynon method (Ranganna, 1986). 50ml filtered juice was mixed with 100ml distilled water and neutralized with 0.1N NaOH solution using phenolphthalein as indicator and the solution was allowed to stand for ten minutes. Then 8ml of potassium oxalate solution was added and total volume was made up to 250 ml by adding distilled water. 5ml of the extract was taken in burette and titrated again 10ml mixed Fehling’s (5ml Fehling’s solution A+5ml Fehling’s solution B) solution using methyl blue as indicator. The end point is indicated by appearance of deep brick red colour precipitation. Calculation of total sugar is done with the fallowing formula:

$$\text{Total sugar (\%)} = \frac{\text{Factor of Fehling's solution} \times \text{Dilution factor}}{\text{Titre value} \times \text{wt of sample taken}} \times 100$$

Where, factor for Fehling’s solution denotes the gram of invert sugar

$$\text{Factor} = (\text{Titre value} \times 2.5)/100$$

### 3.4.2.12 TSS ($^0$B)

Total Soluble Solids, in the juice of representative sample were determined by using Digital refractometer (range of 0-32$^0$ Brix) and expressed in degree brix ($^0$B). The fruit juice was extracted from the mature fruits and the total soluble solids (TSS) were measured using a handheld refractometer, after prior calibration using distilled water. After each test, the prism plate was cleaned with distilled water and wiped with a soft tissue. The value was recorded and TSS was expressed in $^o$Brix.

### 3.4.2.13 Titratable acidity (%)

Pulp (20 g) from 15 fruit without symptoms of disease was homogenized in a grinder and the supernatant phase was collected to analyze TA. Five ml aliquot was mixed with one to two drops of phenolphthalein and was titrated against 0.1N NaOH. The appearance of light pink colour marked as end point as per method described in the manual of analysing of fruits and vegetables product by Ranganna (1991). The acidity was expressed in percentage by following formula:

$$\text{Titratable acidity (\%)}=\frac{\text{Titre value}\times\text{Normality of alkali}\times\text{Equivalent weight of acid}}{\text{Volume of sample taken}\times 1000}\times 100$$

### 3.4.2.14 TSS: Acid ratio

It was calculated by dividing the TSS (%) by titratable acidity (%) in each treatment.

### 3.4.3 To study the effect of plant bio regulators and chemicals on flowering and fruiting of litchi cv. Shahi

**Layout and Experimental Design**

The experiment was laid out in Randomized Block Design. Plant bio-regulators & chemicals (potassium nitrate, Dipotassium phosphate, Gibberellins and Ethrel) spray has conducted before flowering once in a month (from Sept to Dec) four times with different combinations of plant bio-regulators and potassium forms to observed on flowering and fruiting induction behaviours.

**$T_1$**= $KNO_3$ (1%)

**$T_2$**=$K_2HPO_4$ (1%)

**$T_3$**=Ethrel (400ppm)

**$T_4$**=$GA_3$ (100ppm)

**$T_5$**=$KNO_3$ (1%) +$K_2HPO_4$ (1%)

**$T_6$**= $KNO_3$ (1%) + Ethrel (400ppm)

**$T_7$**= $KNO_3$ (1%) + $GA_3$ (100ppm)

**$T_8$**= $K_2HPO_4$ (1%) + Ethrel (400ppm)

**$T_9$**= $K_2HPO_4$ (1%) + $GA_3$ (100ppm)

**$T_{10}$**= Control

| | |
|---|---|
| Treatments | 10 |
| Replications | 03 |
| Variety | Shahi |
| Age of the Tree | 22 years |
| Design | Randomized Block Design |

**Observation recorded:**

### 3.4.3.1 Date of panicle initiation (DD/MM/YY)

When the scales enclosing the rudimentary panicles opened out so as to make the panicle visible, the stage was treated as initiation of panicle emergence. The date on which bud burst was visible was recorded as first emergence of panicle after spraying.

### 3.4.3.2 Advancement of flowering (%)

The period of early induction of flowering has been measured by comparing the date of flowering in all replication of different treatments with the date of flowering in control.

#### 3.4.3.3 Flowers/panicle (total)

Five randomly selected flower panicles were collected from each replication and the average value was worked out by counting the total number of flowers per panicle.

#### 3.4.3.4 Sex ratio (f/m)-%

Five randomly selected flower panicles was collected from each replication and the number of female to male flower counting was worked out by morphological differentiations of flowers.

#### 3.4.3.5 Time taken to fruit set

The period of time taken to set fruit was recorded when tagged panicles of each treatment started fruit setting. The date of fruit set was recorded by visual observation regularly from full bloom. It has expressed by number of days.

#### 3.4.3.6 Days taken to maturity

Fruits attained the maturity stage when they develop a bright red blush with flattened tubercles. Days taken to fruit maturity were determined by counting the number of days from the day of panicle initiation to the fruit maturity stage. And it has measured by number of days after fruit set.

#### 3.4.3.7 Days to harvest

Date of fruit harvest was recorded when fruits were harvested, it should be done as soon as it attains a good size and colour. Subsequently, days taken from fruit set to harvest were calculated by subtracting date of fruit set from date of harvest.

#### 3.4.3.8 Total sugar (%)

Total sugar content of fruit juice was determined as per Lane and Eynon method (Ranganna, 1986). 50ml filtered juice was mixed with 100ml distilled water and neutralized with 0.1N NaOH solution using phenolphthalein as indicator and the solution was allowed to stand for ten minutes. Then 8ml of potassium oxalate solution was added and total volume was made up to 250 ml by adding distilled water. 5ml of the extract was taken in burette and titrated again 10ml mixed Fehling's (5ml Fehling's solution A+5ml Fehling's solution B) solution using methyl blue as indicator. The end point is indicated by appearance of deep brick red colour precipitation. Calculation of total sugar is done with the fallowing formula:

$$\text{Total sugar (\%)} = \frac{\text{Factor of Fehling's solution} \times \text{Dilution factor}}{\text{Titre value} \times \text{wt of sample taken}} \times 100$$

Where, factor for Fehling's solution denotes the gram of invert sugar

$$\text{Factor} = (\text{Titre value} \times 2.5)/100$$

### 3.4.3.9 TSS ($^0$B)

Total Soluble Solids, in the juice of representative sample were determined by using Digital refractometer (range of 0-32$^0$ Brix) and expressed in degree brix ($^0$B). The fruit juice was extracted from the mature fruits and the total soluble solids (TSS) were measured using a handheld refractometer, after prior calibration using distilled water. After each test, the prism plate was cleaned with distilled water and wiped with a soft tissue. The value was recorded and TSS was expressed in $^o$Brix.

### 3.4.3.10 Titratable acidity (%)

Pulp (20 g) from 15 fruit without symptoms of disease was homogenized in a grinder and the supernatant phase was collected to analyze TA. Five ml aliquot was mixed with one to two drops of phenolphthalein and was titrated against 0.1N NaOH. The appearance of light pink colour marked as end point as per method described in the manual of analysing of fruits and vegetables product by Ranganna (1991). The acidity was expressed in percentage by following formula:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{Equivalent weight of acid}}{\text{Volume of sample taken} \times 1000} \times 100$$

**3.4.3.11 TSS: Acid ratio:** It was calculated by dividing the TSS (%) by titratable acidity (%) in each treatment.

### 3.4.4 To study the effect of various mulch materials on fruiting and quality of litchi fruits cv. China

**Layout and Experimental Design:**

The experiment was laid out in Randomized Block Design. Different organic (dry grass, paddy straw, dry Banana leaves and Banana pseudo stem mat) and inorganic (white polythene and black polythene) mulches are applied to soil surrounding the trees in the month of September in each year to observe the effect on flowering and fruiting attributes.

**$T_1$**= Black polythene

**$T_2$**=White polythene

**$T_3$**=dry grass

**$T_4$**=Paddy straw

**$T_5$**=Dry Banana leaves

**$T_6$**= Banana pseudo stem mat

**$T_7$**=Leguminous cover crop (Soyabean)

**$T_8$**= Control (No mulch)

| | |
|---|---|
| Treatments | 7+1=8 |
| Replications | 3 |
| Variety | China |
| Age of the tree | 22 years |
| Design | Randomized Block Design |

**Observation recorded**

### 3.4.4.1 Soil moisture content-before and after mulching (%)

Moisture content of all the treatments soil samples at a depth of 10-30 cm was measured by gravimetric method.

### 3.4.4.2 NPK status of soil

**Collection and preparation of soil samples:**

Soil samples were collected before sowing and after harvest in each treatment and a composite sample was prepared, thoroughly mixed analysed to determine the nutrient status of the soil.

The processing of soil samples for analysis was done as detailed below.

**Drying**

The soil samples were spread evenly and big soil clods were crushed.

**Grinding**

After drying, pounding was done with wooden pestle and mortar to break the soil aggregates.

**Sieving**

The crushed samples were passed through 2 mm (8 mesh) sieve.

**i)Available nitrogen- before and after (kg/ha)**

Available nitrogen was estimated by Kjeldahl's method as described by Jackson (1973).

**ii)Available phosphate- before and after (kg/ha)**

It was determined by Olsen's method, using spectrophotometer as described by Jackson (1973).

**iii) Available potash- before and after (kg/ha)**

It was extracted and estimated by neutral normal ammonium acetate method using flame photometer (Jackson, 1973).

### 3.4.4.3 Flowering panicles (%)

Five randomly selected flower panicles were collected from each replication and the average value was worked out and expressed in percentage.

### 3.4.4.4 Fruit set (%)

The total number of flowers at full bloom and the initial number of fruits at the end of blooming stage on the labelled panicles in all treatments were counted and recorded then the percentage of fruit set was calculated as the following equation

$$\text{Fruit set (\%)} = \frac{\text{No. of fruit lets set}}{\text{Total number of female flowers}} \times 100$$

### 3.4.4.5 Fruit drop (%)

Number of fruits present on the randomly selected branches of each replication of each treatment trees at the time of fruit set were recorded and number of fruits retained on these branches till maturity was recorded. The recorded data was expressed as per cent fruit drop.

$$\text{Fruit drop (\%)} = \frac{\text{Final fruit retention}}{\text{Initial fruit set}} \times 100$$

### 3.4.4.6 Fruit retention (number)

Total number of fruits retained at harvesting in five randomly selected fruit clusters were collected from each replication and the average value was worked out.

### 3.4.4.7 Fruit weight (g)

Weight of ten fruits from each treatment per replication were randomly selected and recorded by weight on top pan balance and average weight of fruit was expressed in grams (g).

### 3.4.4.8 Fruit length (cm)

The distance between the base and the apex of randomly selected fruits were measured and the average was expressed in centimetres (cm) with the help of digital vernier caliper.

**3.4.4.9 Fruit width (cm)**

The width of randomly selected fruits was measured around the midpoint of the fruit and the average was expressed in centimetre (cm) with the help of digital vernier caliper.

**3.4.4.10 Fruit cracking (%)**

Observations on fruit cracking were recorded from first May, at an interval of 7 days. For recording the data on fruit cracking one panicle was tagged in each of the four directions (east, west, north and south) of tree. Percentage fruit cracking was calculated on the basis of observations recorded on four panicles. The percentage fruit cracking in a particular treatment was worked out by using the following formula

$$\text{Fruit cracking (\%)} = \frac{\text{No. of fruits cracked per panicle at harvesting stage}}{\text{No. of fruits retained per panicle at harvesting stage}} \times 100$$

**3.4.4.11 Yield (kg/tree)**

The fruits were harvested from each replication and all the fruits from the individual trees were picked manually and collected under the trees. The total weight of the marketable fruits per tree was recorded using a pan balance of 5kg capacity and the data were expressed in kg per tree.

**3.4.4.12 TSS ($^{o}$Brix)**

Total Soluble Solids, in the juice of representative sample were determined by using Digital refractometer (range of 0-32$^{0}$ Brix) and expressed in degree brix ($^{0}$B). The fruit juice was extracted from the mature fruits and the total soluble solids (TSS) were measured using a handheld refractometer, after prior calibration using distilled water.

After each test, the prism plate was cleaned with distilled water and wiped with a soft tissue. The value was recorded and TSS was expressed in $^{o}$Brix.

### 3.4.4.13 Total Sugar (%)

Total sugar content of fruit juice was determined as per Lane and Eynon method (Ranganna, 1986). 50ml filtered juice was mixed with 100ml distilled water and neutralized with 0.1N NaOH solution using phenolphthalein as indicator and the solution was allowed to stand for ten minutes. Then 8ml of potassium oxalate solution was added and total volume was made up to 250 ml by adding distilled water. 5ml of the extract was taken in burette and titrated again 10ml mixed Fehling's (5ml Fehling's solution A+5ml Fehling's solution B) solution using methyl blue as indicator. The end point is indicated by appearance of deep brick red colour precipitation. Calculation of total sugar is done with the fallowing formula:

$$\text{Total sugar (\%)} = \frac{\text{Factor of Fehling's solution} \times \text{Dilution factor}}{\text{Titre value} \times \text{wt of sample taken}} \times 100$$

Where, factor for Fehling's solution denotes the gram of invert sugar

$$\text{Factor} = (\text{Titre value} \times 2.5)/100$$

### 3.4.4.14 Titratable acidity (%)

Pulp (20 g) from 15 fruit without symptoms of disease was homogenized in a grinder and the supernatant phase was collected to analyze TA. Five ml aliquot was mixed with one to two drops of phenolphthalein and was titrated against 0.1N NaOH. The appearance of light pink colour marked as end point as per method described in the manual of analysing of fruits and vegetables product by Ranganna (1991). The acidity was expressed in percentage by following formula:

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{Equivalent weight of acid}}{\text{Volume of sample taken} \times 1000} \times 100$$

### 3.5. Statistical analysis and interpretation of data

The data collected during the investigation were subjected using Randomized Block Design (RBD) by the standard method of statistical analysis (Gomez and Gomez, 2010). The mean values of different treatments were analyzed with the statistical software along with corresponding standard error of mean (S.E.m±). The critical difference at 5 per cent level of significance will be computed.

# RESULTS AND DISCUSSION

The results and discussion of the present investigation entitled, "Effect of different technological interventions on yield and quality of litchi grown in Nagaland" are presented objective wise in this chapter. In order to make the findings more comprehensive, the results obtained from the present studies have been duly supported by respective tables and figures.

## 4.1 To study the effect of different levels & widths of girdling on bearing potential of litchi cv. China

Performance of growth & flowering, yield and biochemical attributes under this experiment has shown below by using results tables and graphs.

### 4.1.1 Trunk girth

Trunk girth of trees were recorded by using measuring tape during girdling operation and the results as shown in the table 4.1 and 4.2.

From the pooled data on trunk girth revealed that there was no significant influenced of levels & widths of girdling on trunk girth. It was recorded that rate of growth of trunk girth was slow increasing trend in two consecutive years.

The interaction of different levels & widths of girdling on trunk girth showed non-significant effect however the measurement values in respect to trunk girth showed moderately significant in both the study year.

### 4.1.2 Wound healing period (Days)

The data on wound healing period as influenced by different levels and widths of girdling was recorded and presented in table 4.1. The effect of wound healing period was found non-significant to different levels of girdling during 2021 and significantly varied during 2022. From the pooled data observed that the minimum days taken for wound healing (150.78 days) in trees under the treatment of $G_1$ (25% PB) and the maximum (162.18 days) days taken in trees of $G_3$ (75% PB) treated plants.

Whereas in different sizes/widths of girdling shown the wound healing period significant. The minimum days (110.53 days) was recorded in $L_1$ (2 mm) followed by 162.26 days (4mm) and the maximum days (202.87 days) taken in trees of girdled with 6 mm. Similar results were reported by Kumar *et al.* (2016) that early healing of wound was observed in 2 mm size (108.87 days) and branch above as well as below the girdled portion become uniform. While, girdling with 6 mm size took maximum duration (195.67 days) followed by 4mm size (165.50 days).

The interaction effect of different levels and widths of girdling in wound healing period (table 4.2 and fig 4.1) was computed and found to be significant among the various treatment combinations. Maximum healing days was recorded with $G_3L_3$ (75% PB with 6mm) followed by $G_2L_3$ (50%PB with 6mm) and the minimum days was recorded in $G_1L_1$ (25%PB with 2mm). Same trend was recorded in both year of observations. This result is in accordance with the findings of Agarwal *et al*. (2021) and reported that time taken for healing of the girdled portion was delayed with the increase in thickness of girdling portion. Plants girdled with 50% of primary branches with 6mm thickness took maximum 210.10 days to heal the girdled portion and girdled 25%PB with 2mm thickness attained this within 125.3 days.

### 4.1.3 Appearance of girdle portion

Physical observation of appearance on girdle portion as not influenced by different levels of girdling (table 4.1 and 4.2) but showed difference looks with the thickness of girdling from smooth bark surface to less swell to more swell in linear increasing trend with increasing the size of girdling. The treatments size of girdling shown $L_1$ (2 mm): smooth, $L_2$ (4 mm): less swell and $L_3$ (6 mm): more swell. Similar observations were reported by Kumar *et al.* 2016.

2 mm　　　4 mm　　　6 mm

**PLATE 4.1. Different thickness(widths) of girdling on primary branches**

2 mm　　　4 mm　　　6 mm

**PLATE 4.2. Appearance of girdle portion after healing**

### 4.1.4 Days to flower after girdling (Days)

The pooled data in table 4.1 represented that the effect of different levels of girdling of primary branches on the number of days taken to flowering was found to be non- significant but initial year *i.e.*, 2021 recorded significant. The data shown minimum number of days taken in $G_2$ (50% PB) *i.e.*, 170.25 days and the maximum (175.75 days) days were taken to flowering plants under $G_1$ (25%PB).

However, the effect of thickness (widths) of girdling (table 4.1) on the number of days taken to flowers was found to be significant in both the observations. It's depicted from the pooled data that the minimum number of days taken for inflorescence emergence (165.75 days) was recorded in $L_1$ (2mm) while maximum number of days taken for inflorescence emergence was recorded in $L_3$ (6mm) *i.e.*, 180.41 days. Kumar *et al.* (2016) reported that girdled branches showed delay to bloom during both the years and panicles remains shorter than control branches.

The results in this study on the interaction effects presented in table 4.2 and fig 4.2 showed that number of days to flower was significantly differed on ungirdled trees (control). The minimum number of days taken to flower was recorded in trees under control (un- girdle) *i.e.*, 158.50 days and the maximum number of days taken for emergence of flowers was recorded in $G_1L_3$ (25% PB with 6mm width girdle) *i.e.*, 185.50 days. It may be due to bigger size of girdling and long healing period which suppressed vegetative flush as well as reproductive flushes. It is believed that litchi needs a period of vegetative dormancy to initiate floral buds (Das *et al* 2004). According to Singh *et al.* (2012) flowers are produced in late winter or early spring and there are three types of flowers which open in succession on the same panicle. Low flowering was also reported by Singh (2015) and Malhotra (2016) who reported that the management of litchi orchard includes girdling, growth regulators and pruning which greatly influence tree growth, yield and profitability but physiology of growth, flowering and cropping needs to be described as the lack of flowering is not only due to the weather or the timing of shoot growth but it is also related to shoot maturity, physiology, biochemical, nutritional and hormonal status of shoot buds during flower initiation/and vegetative phase, a critical period of production cycle.

**4.1.5 Flowering percentage (%)**

Perusal of the data in table 4.1 showed that there was significant difference on the flowering on girdled branches in both the years. The pooled data on percentage of flowering were shown maximum (76.59 %) in $G_3$ (75 %PB) and the minimum (74.13) in $G_1$ (25 %PB).

Whereas effect of different widths/sizes of girdling was recorded highest (86.66% in 2021; 87.52 in 2022 and pooled value 87.09 %) with $L_2$ (4mm thickness) treated branches and the lowest in $L_3$ (6mm thickness) *i.e*., 66.23%; 68.10% and 66.61% respected years. Similar findings were also reported by Kumar *et al.* (2016) and recorded highest flowering (84.83%) in branches girdled with 4 mm on 50% PB followed by girdled branches with 4 mm on 25% PB i.e., 82.89% and minimum in un-girdled branches (35.67%).

The interaction effect of different levels and widths of girdling (table 4.2 and fig 4.3) was found to be significantly induced the flowering in the litchi during both the years as compared to control. Highest percentage (90.04%) of flowering was found in $G_2L_2$ (girdled on 50%PB with 4mm thickness) and the lowest (44.07%) in control (un-girdle). Agarwal *et al*. (2021) also reported similar results that maximum flowering intensity (57.70%) was observed in the treatment T4 (girdling of 50% of primary branches + 4 mm wide). The reason behind that the girdling blocks the downward flow of photo-assimilates (carbohydrates) and auxin from the source to sink (Lomax *et al*. 1995), which can restrict root growth, vegetative growth and increase flowering percentage.

The inhibition of root growth may depress the production of cytokines in the root tips therefore, flowering percentage were increased in litchi (Chen *et al*. 1998). Menzal and Simpson (1987) who reported that girdling in litchi trees increased flowering by 40-80% in spring season.

**25% PB & 2mm wide**

**25% PB& 4mm wide**

**25% PB & 6mm wide**

**50%PB & 2mm wide**

**50% PB & 4mm wide**

**50% PB & 6mm wide**

**75% PB & 2mm wide**

**75% PB & 4mm wide**

**75% PB & 6mm wide**

**Control (Un-girdle)**

**PLATE 4.3. Intensity of flowering in different thickness & levels of girdled Primary Branches**

25% PB & 2mm wide

25% PB& 4mm wide

25% PB & 6mm wide

25% PB & 6mm wide

50% PB & 4mm wide

50% PB & 6mm wide

75% PB & 2mm wide

75% PB & 4mm wide

75% PB & 6mm wide

Control (Un- girdle)

**PLATE 4.4. Fruit set performance in different branches of girdled & non girdled trees**

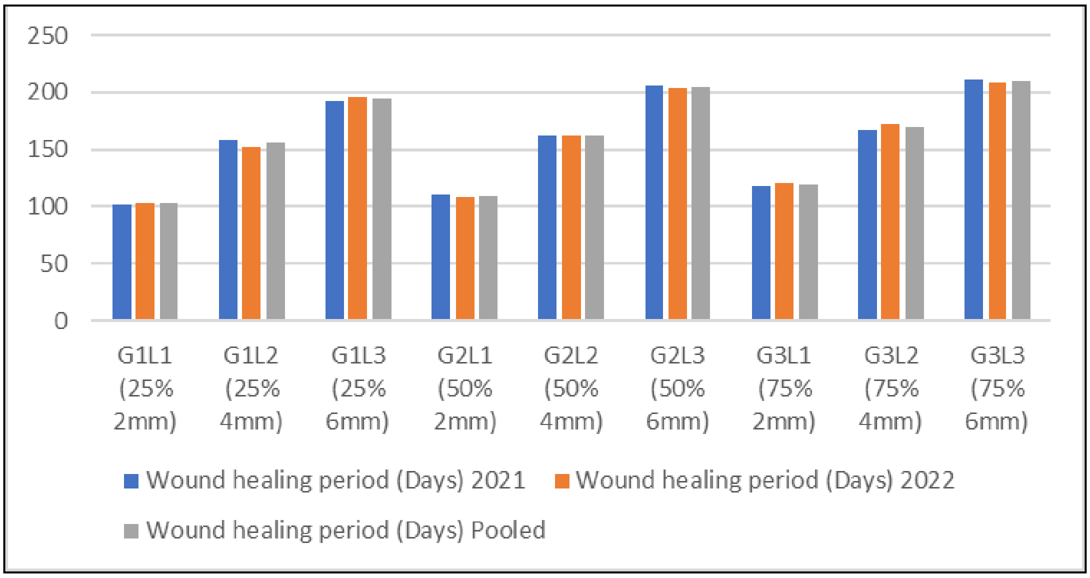



**Fig 4.1 Wound healing period (Days) of different girdled treatments**

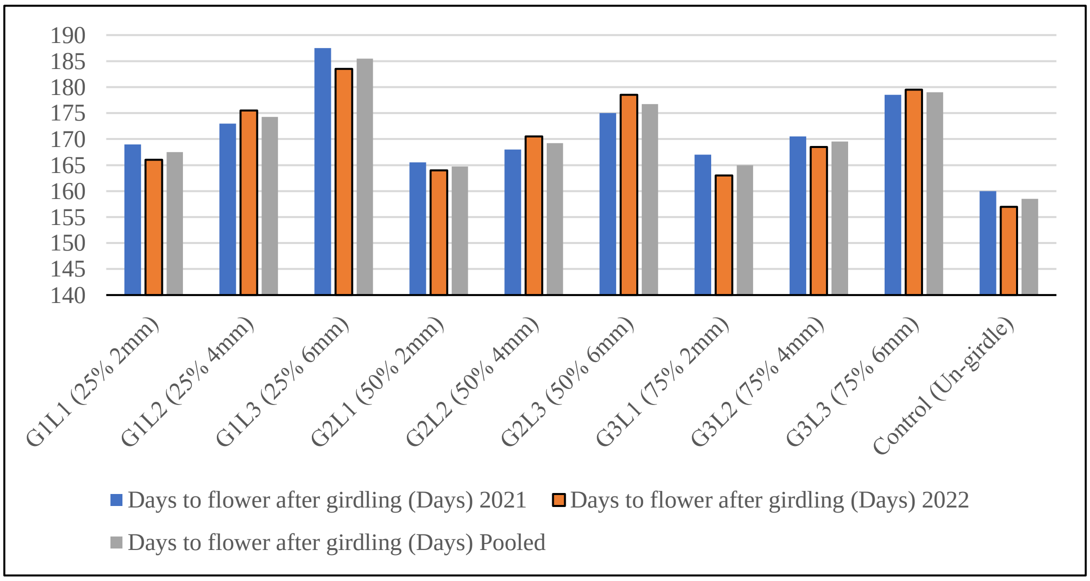



**Fig 4.2 Days taken to flowering after girdling in litchi**

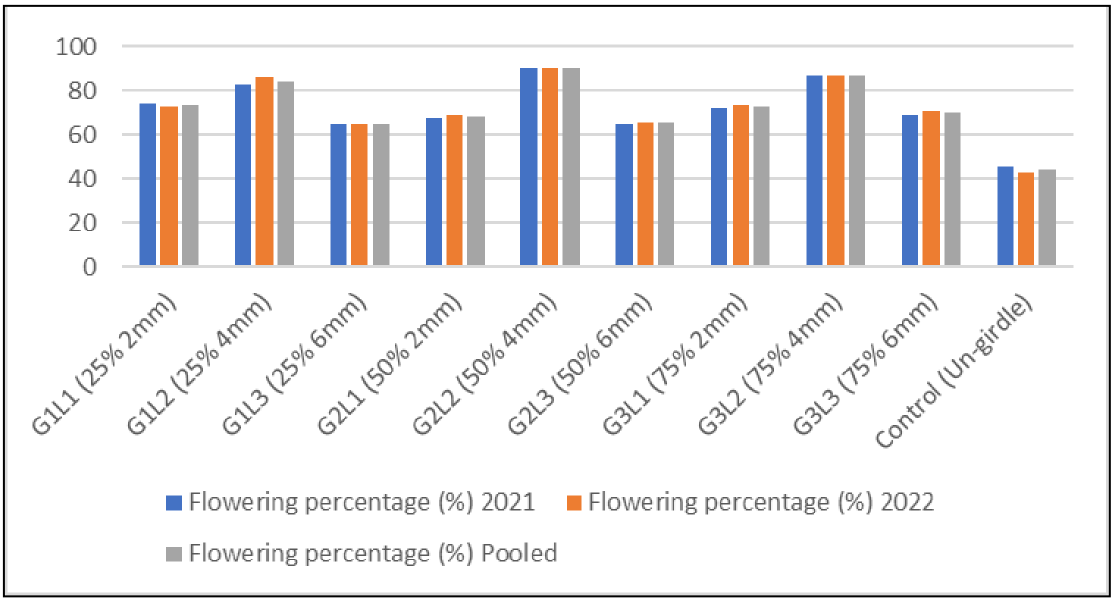



**Fig 4.3 Flowering percentage of litchi girdled branches**


**Fig 4.4 Fruit set at clove stage in different girdled branches**

The inhibition of root growth may depress the production of cytokines in the root tips therefore, flowering percentage were increased in litchi (Chen *et al*. 1998). Menzal and Simpson (1987) who reported that girdling in litchi trees increased flowering by 40-80% in spring season.

### 4.1.6 Fruit set in number at clove stage

Data in table 4.1 showed that the number of fruits counted at clove stage was found highly significant to influenced by different levels of girdling. The effect of different levels of girdling on fruit set were recorded highest number per panicle (84.97) in trees under $G_2$ (50%PB) compared with $G_1$ (25%PB) *i.e*., 66.38 per panicle.

Data on the number of fruits at clove stage was shown significant variation as influenced by different width of girdling. The maximum (85.97) fruit set recorded in panicle found the branches girdled with 4mm thickness ($L_2$) and the minimum (70.94) fruit set per panicle recorded in $L_3$ (6mm) girdled branches.

The data pertaining to the interaction effect on different levels and widths of girdling on fruit set per panicle at clove stage are presented in table 4.2 & fig 4.4 and results indicated that maximum fruit set per panicle (103.26) was counted in $G_2L_2$ (50%PB & 4mm thickness) and minimum was recorded in trees under control (un-girdle) *i.e*., 56.83 fruits per panicle. According to Agarwal *et al*., (2021) minimum percent (32.19%) of fruit set was observed in ungirdled trees and maximum (38.44%) of fruit set was recorded in treatment girdling of 50% of primary branches with 4 mm wide. It might be due to girdling block the downward movement of photo-assimilates thus this assimilates accumulates above the girdled portion so there are significantly increased levels of carbohydrates can be found throughout the canopy. Experiment conducted by Mataa *et al*. (1998) in citrus also demonstrated that carbohydrate content was the highest in girdled trees canopy, which resulted in significantly more fruit set.

Findings were observed by Chandra (2008) in litchi and Rivas *et al*. (2006) in citrus and opined that girdling has been a tool for improving fruit set in different fruit crops.

#### 4.1.7 Fruit drop percentage at clove stage

Data in table 4.3 showed that the percentage of fruit drop at clove stage was influenced by different levels and widths of girdling in litchi. Individual effect of different level of girdling on fruit drop at clove stage were showed similar trend in both the years. Pooled data showed nonsignificant effect on fruit drop percent at clove stage and recorded higher dropping percentage (84.38%) in branches of $G_3$ followed by $G_1$(81.17%) and lowest was recorded (80.91%) in $G_2$.

Data on the percent of fruit drop at clove stage as influenced significantly by different width of girdling. The maximum (87.18%) drops percentage recorded trees under $L_3$ (6mm) and the minimum (77.04%) recorded in $L_2$ (4mm). Similar trend was noticed in both 2021 and 2022.

The data pertaining to the interaction effect on different levels and widths of girdling on fruit drop percentage at clove stage are presented in table 4.4 & fig 4.5 and results indicated that high significant variation among the treatments during the present investigation. The highest percentage of fruit drop were recorded under control (un-girdle) *i.e.,* 93.03% and the lowest (74.59%) values were recorded under $G_2L_2$ (50%PB with 4mm). According to Khalkho *et al*. (2015) girdling with no leaf removal was recorded low fruit drop percentage. It may be due to the fruit retention capacity in a panicle is a function of the strength of source tissue to support the carbohydrate demand of the growing sink (fruits). Rivas *et al*. (2006) also suggested that girdling increased carbohydrate contents in developing fruitlets of mandarin and as a result of that reduced fruit drop and thereby diminished abscission.

**Table. 4.1 Effect of different widths & levels of girdling on growth and flowering attributes**

| Treatments | Trunk girth (m) | | | Wound healing period (Days) | | | Appearance of girdle portion | Days to flower after girdling (Days) | | | Flowering percentage (%) | | | Fruit set number @ clove stage (number) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| **$G_1$: 25%PB** | 1.36 | 1.37 | 1.36 | 150.94 | 150.34 | 150.78 | - | 177.08 | 175.00 | 175.75 | 73.72 | 74.49 | 74.13 | 66.94 | 64.55 | 66.38 |
| **$G_2$: 50%PB** | 1.27 | 1.27 | 1.26 | 159.64 | 158.14 | 158.71 | - | 169.91 | 171.00 | 170.25 | 74.28 | 74.72 | 74.47 | 79.53 | 90.00 | 84.97 |
| **$G_3$: 75%PB** | 1.11 | 1.12 | 1.11 | 162.23 | 162.88 | 162.18 | - | 172.50 | 170.33 | 171.16 | 76.19 | 77.14 | 76.59 | 79.61 | 81.00 | 80.77 |
| **SEm±** | **0.007** | **0.03** | **0.004** | **0.40** | **0.50** | **1.00** | **-** | **0.24** | **0.14** | **0.85** | **0.13** | **0.06** | **0.40** | **0.30** | **2.41** | **1.96** |
| **CD@5%** | **0.023** | **0.10** | **NS** | **NS** | **1.67** | **NS** | **-** | **0.71** | **NS** | **NS** | **0.46** | **0.22** | **1.33** | **1.02** | **7.29** | **6.52** |
| **$L_1$: 2mm wide** | 1.29 | 1.30 | 1.29 | 111.03 | 110.67 | 110.53 | Smooth | 167.75 | 164.33 | 165.75 | 71.29 | 70.73 | 71.49 | 73.66 | 75.77 | 75.22 |
| **$L_2$: 4mm wide** | 1.34 | 1.35 | 1.34 | 162.63 | 161.92 | 162.26 | Less swell | 170.91 | 171.50 | 171.00 | 86.66 | 87.52 | 87.09 | 82.41 | 87.55 | 85.97 |
| **$L_3$: 6mm wide** | 1.11 | 1.11 | 1.11 | 203.15 | 202.77 | 202.87 | More swell | 180.83 | 180.50 | 180.41 | 66.23 | 68.10 | 66.61 | 70.00 | 72.22 | 70.94 |
| **SEm±** | **0.002** | **0.009** | **0.003** | **0.92** | **1.00** | **1.21** | **-** | **0.36** | **0.27** | **1.12** | **0.17** | **0.10** | **0.63** | **0.49** | **2.11** | **1.78** |
| **CD@5%** | **NS** | **0.031** | **NS** | **2.80** | **3.46** | **3.36** | **-** | **1.09** | **0.81** | **3.39** | **0.54** | **0.30** | **1.89** | **1.48** | **6.33** | **5.35** |

**Table. 4.2. Interaction effect of girdling widths and levels on growth & flowering attributes**

| Treatments | Trunk girth (m) | | | Wound healing period (Days) | | | Appearance of girdle portion | Days to flower after girdling (Days) | | | Flowering percentage (%) | | | Fruit set number@ clove stage (number) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| **$G_1L_1$ (25%PB 2mm)** | 1.55 | 1.55 | 1.55 | 102.25 | 103.53 | 102.89 | Smooth | 169.00 | 166.00 | 167.50 | 73.94 | 72.82 | 73.38 | 70.00 | 67.00 | 68.50 |
| **$G_1L_2$ (25% 4mm)** | 1.25 | 1.27 | 1.26 | 158.75 | 151.66 | 155.20 | Less swell | 173.00 | 175.50 | 174.25 | 82.69 | 85.99 | 84.34 | 68.66 | 69.00 | 68.83 |
| **$G_1L_3$ (25% 6mm)** | 1.29 | 1.30 | 1.29 | 192.66 | 195.83 | 194.24 | More swell | 187.50 | 183.50 | 185.50 | 64.72 | 64.66 | 64.69 | 63.00 | 60.66 | 61.83 |
| **$G_2L_1$ (50% 2mm)** | 1.15 | 1.17 | 1.16 | 110.52 | 108.25 | 109.38 | Smooth | 165.50 | 164.00 | 164.75 | 67.52 | 68.72 | 68.12 | 74.00 | 79.33 | 76.66 |
| **$G_2L_2$ (50% 4mm)** | 1.56 | 1.58 | 1.57 | 161.83 | 162.43 | 162.13 | Less swell | 168.00 | 170.50 | 169.25 | 90.33 | 89.75 | 90.04 | 93.86 | 112.66 | 103.26 |
| **$G_2L_3$ (50% 6mm)** | 1.07 | 1.08 | 1.07 | 205.53 | 203.75 | 204.64 | More swell | 175.00 | 178.50 | 176.75 | 64.84 | 65.71 | 65.27 | 73.00 | 77.00 | 75.00 |
| **$G_3L_1$ (75% 2mm)** | 1.17 | 1.18 | 1.17 | 118.43 | 120.25 | 119.34 | Smooth | 167.00 | 163.00 | 165.00 | 72.33 | 73.66 | 72.99 | 79.00 | 82.00 | 80.50 |
| **$G_3L_2$ (75% 4mm)** | 1.20 | 1.21 | 1.20 | 167.25 | 171.66 | 169.45 | Less swell | 170.50 | 168.50 | 169.50 | 86.99 | 86.83 | 86.91 | 87.66 | 84.00 | 85.83 |
| **$G_3L_3$ (75% 6mm)** | 0.96 | 0.96 | 0.96 | 210.75 | 208.75 | 209.75 | More swell | 178.50 | 179.50 | 179.00 | 68.84 | 70.94 | 69.89 | 75.00 | 77.00 | 76.00 |
| **Control (Un-girdle)** | 1.14 | 1.15 | 1.14 | - | - | - | - | 160.00 | 157.00 | 158.50 | 45.23 | 42.91 | 44.07 | 58.00 | 55.66 | 56.83 |
| **SEm±** | **0.01** | **0.06** | **0.004** | **0.69** | **0.87** | **1.74** | **-** | **0.25** | **0.41** | **1.48** | **0.24** | **0.12** | **0.69** | **0.53** | **4.18** | **3.41** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CD@5%** | **0.03** | **0.18** | **NS** | **2.31** | **2.90** | **5.22** | **-** | **0.82** | **1.38** | **4.44** | **0.80** | **0.39** | **2.31** | **1.77** | **12.63** | **11.29** |

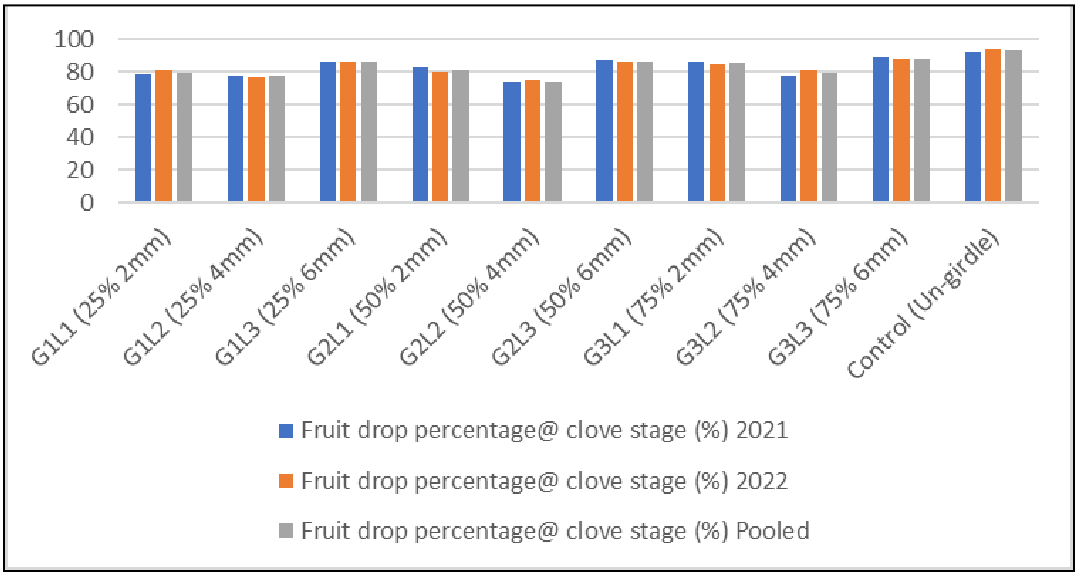



**Fig 4.5 Fruit drop percentage of litchi @ clove stage in girdled branches**

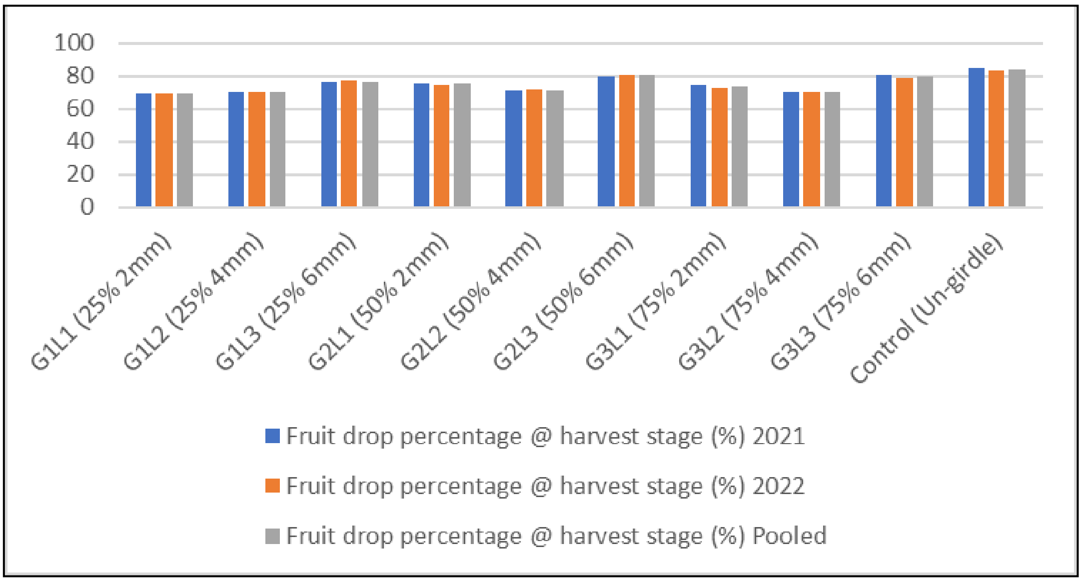



**Fig 4.6 Fruit drop percentage of litchi @ harvest stage in girdled branches**

### 4.1.8 Fruit drop percentage at harvest stage

Data in table 4.3 showed that the percentage of fruit drop at harvest stage was influenced by different levels and widths of girdling in litchi.

Individual effect of different levels of girdling on fruit drop at harvest stage were showed non- significant. The higher fruit drop (75.46%) recorded in $G_3$ (75%PB) and lower (71.87%) in $G_1$ (25%PB). Data on the per cent of fruit drop at harvest stage as influenced by width of girdling computed significant variation among thickness. The maximum (78.87%) fruit drop recorded trees under $L_3$ (6mm) and the minimum (70.52%) recorded in $L_2$ (4mm).

The data pertaining to the interaction effect on different levels and widths of girdling on fruit drop at harvest stage are presented in table 4.4 & fig 4.6 and results indicated that high significant variation noticed among the treatments during the investigation. The highest percentage were recorded under the un-girdled trees *i.e.*,84.17% and the lowest (70.19%) values were recorded under $G_1L_2$ (25% PB with 4mm girdling). The present data on fruit drop was supported by Khalkho *et al*. (2015) who revealed that there is positive effect of girdling on fruit drop of litchi. The fruit drop in litchi at harvest stage might be due to various factors such as cracking of fruits, infestation of nut borer and anthracnose, poor nutritional availability, moisture stress during ripening, competition between vegetative phase and reproductive phase etc. Besides all these factors soil and environmental conditions has been also suggested by Hayes (1985), Kanwar *et al*. (1989) and Kumar (2000).

### 4.1.9 Fruits retention/panicle (number)

Table 4.3 depicted that effect of different levels and widths of girdling on fruit retention/panicle. Study observed that individual effect of different levels of girdling on primary branches was shown non-significant impact on fruit retention. Maximum fruits/panicle (16.66) retained in $G_2$ (50%PB) and the lowest (13.69) in $G_1$ (25%PB) girdled branches.

Whereas, width of girdling on fruit retention/panicle were shown significant and recorded the highest (17.97) under $L_2$ (4mm) and lowest number (13.44) was under $L_3$ (6mm).

The data on table 4.4 & fig 4.7 represented the interaction effect of different levels and widths of girdling in respect to fruit retention/panicle and was found to be significant among the treatments. Highest number (19.83) was recorded in $G_2L_2$ (50%PB with 4mm wide) and the lowest number (7.66) in trees under control (un-girdle). Agarwal *et al*. (2021) reported that maximum number of fruits retained per panicle at harvest was observed in treatment T4 (Girdling of 50% of primary branches +4 mm wide) and minimum fruit retention was recorded in control (T7). The reason behind that in girdled trees there was higher level of gibberellins and low level of ABA as well as higher level of carbohydrates. Similar results were observed in finding of Rani and Brahamachari (2002) who examined that girdling of trees was significantly increased fruit retention percentage in litchi.

### 4.1.10 Fruit length (cm)

Data in table 4.3 showed that fruit length was influenced by different levels and widths of girdling. Individual effect of different levels of girdling on fruit length were showed less significant. The highest fruit length (3.87 cm) was recorded in $G_2$ (50 %PB) and lowest (3.73 cm) in $G_1$ (25 % PB).

Data on fruit length less significant variation as influenced by different width of girdling. The maximum fruit length (3.96 cm) was recorded in $L_2$ (4mm wide) and the minimum length (3.63 cm) recorded in $L_3$ (6mm wide).

The data pertaining to the interaction effect on different levels and widths of girdling on fruit length of litchi are presented in table 4.4 & fig 4.9 and results indicated that maximum length of fruit (4.00 cm) under the treatment of $G_2L_2$ (50%PB with 4mm wide) and minimum (3.56 cm) under $G_3L_3$ (75%PB & 6mm wide) which was at par with $G_3L_2$ (75% PB with 4mm wide) and $G_1L_2$ (25%PB with 4mm wide) and the value were 3.94 cm and 3.93 cm respectively. Furthermore, an increment of fruit size due to girdling is associated with the more availability of carbohydrates in the aerial portion and their translocation to the developing fruits (Villiers 1990).

### 4.1.11 Fruit breadth (cm)

Data in table 4.3 showed that fruit breadth was influenced by different levels and widths of girdling. Individual effect of different levels of girdling on fruit breadth were showed less significant. The highest fruit breadth (3.02 cm) was recorded in $G_2$ (50 % PB) and lowest (2.77 cm) in $G_1$ (25 % PB).

Data on fruit breadth less significant variation as influenced by different widths of girdling. The maximum fruit breadth (3.22 cm) was recorded in $L_2$ (4mm wide) and the minimum length (2.61 cm) recorded in $L_3$ (6mm wide thickness).

The data pertaining to the interaction effect on different levels and widths of girdling on fruit breadth of litchi are presented in table 4.4 & fig 4.9 and results indicated that maximum breadth of fruit (3.54 cm) under the treatment of $G_2L_2$ (50%PB with 4mm wide) and minimum (2.54 cm) under $G_1L_3$ (25%PB 6mm wide). These results were corroborated with the findings of Sousa *et al*. (2008) who reported that girdling of branches with thickness of 3mm applied at petal fall stage significantly improved fruit size in ‘Rocha’ pears.

**25% PB & 2mm wide**

**25% PB & 4mm wide**

**25% PB & 6mm wide**

**50% PB & 2mm wide**

**50% PB & 4mm wide**

**50% PB & 6mm wide**

**75% PB & 2mm wide**

**75% PB & 4mm wide**

**75% PB& 6mm wide**

**Control (Un- girdle)**

**PLATE 4.5. Fruit retention (%) in different girdled branches**

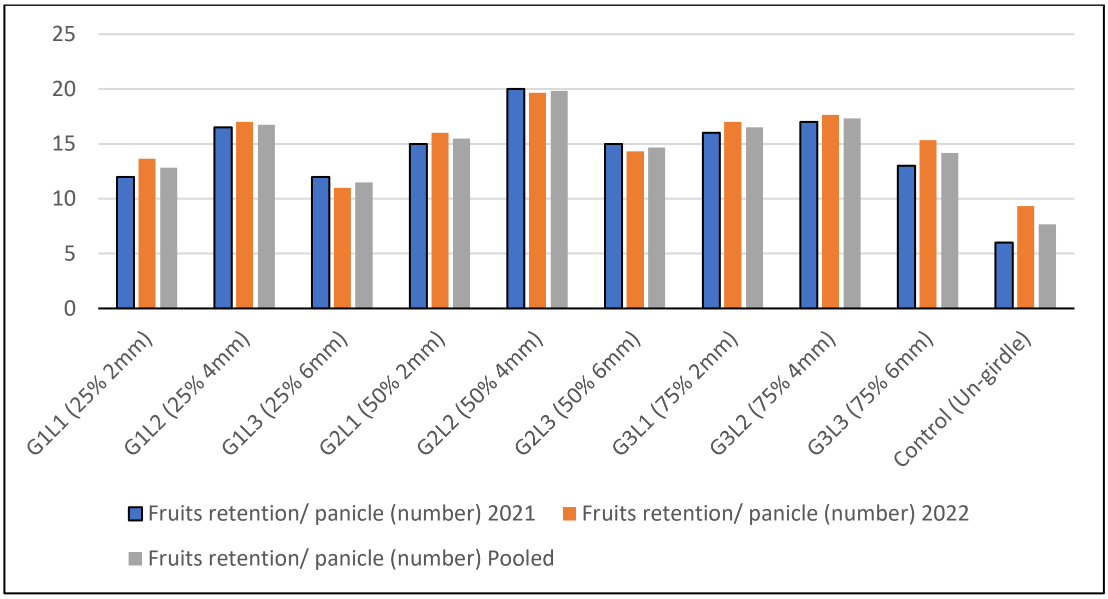



**Fig 4.7 Fruit retention per panicle in different girdled branches**

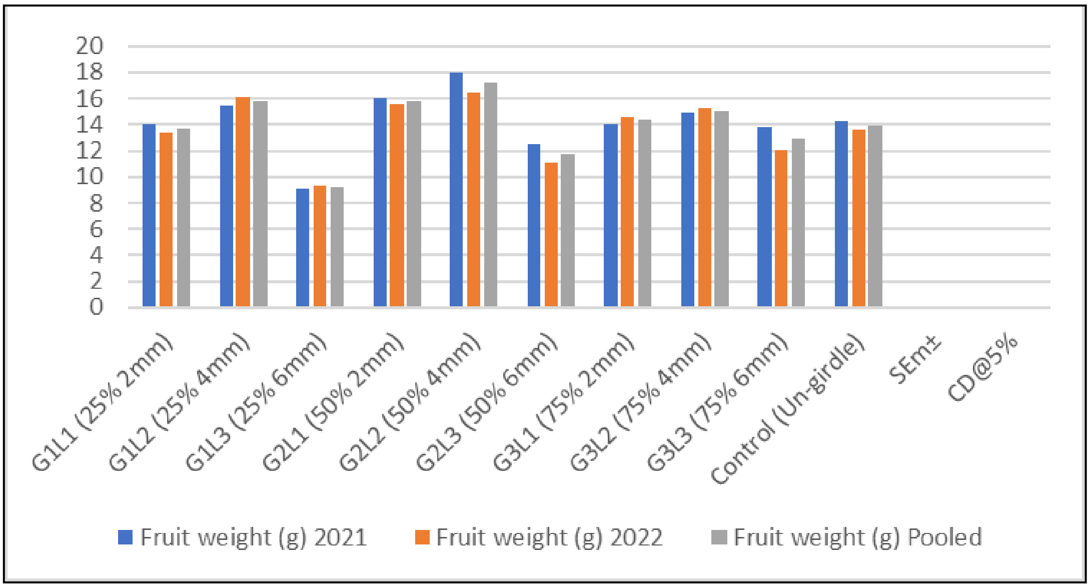



**Fig 4.8 Fruit weight variations on girdled branches**

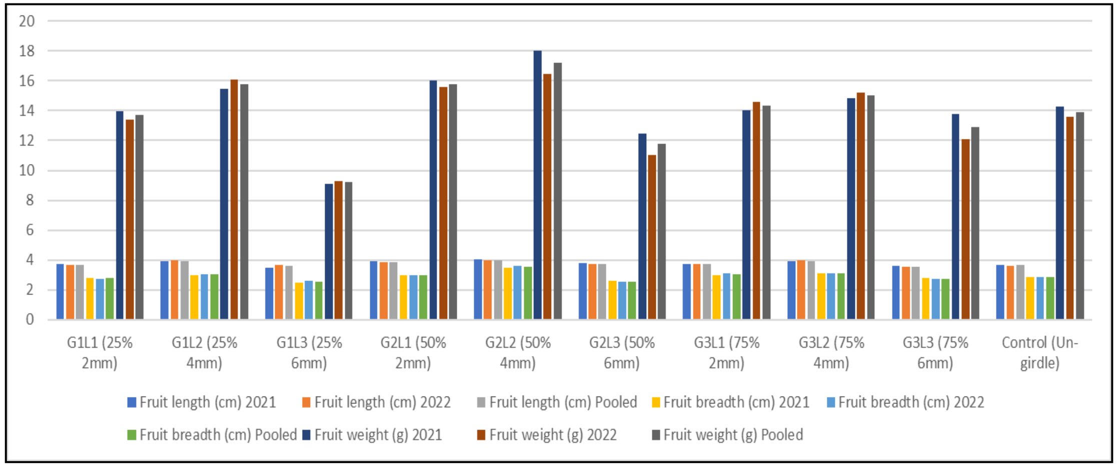



**Fig 4.9 Yield attributing characters (fruit length, width & weight) of girdled branches**

**Table. 4.3. Effect of different levels & widths of girdling on yield attributes**

| Treatments | Fruit drop at clove stage (%) | | | Fruit drop at harvest stage (%) | | | Fruits retention/ panicle (number) | | | Fruit length (cm) | | | Fruit breadth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| $G_1$: 25% PB | 81.17 | 81.34 | 81.17 | 72.23 | 71.96 | 71.87 | 13.25 | 13.88 | 13.69 | 3.56 | 3.77 | 3.73 | 2.70 | 2.79 | 2.77 |
| $G_2$: 50% PB | 81.75 | 80.32 | 80.91 | 75.35 | 74.04 | 74.54 | 16.16 | 16.66 | 16.66 | 3.76 | 3.85 | 3.87 | 2.91 | 3.02 | 3.02 |
| $G_3$: 75% PB | 84.67 | 84.41 | 84.38 | 75.45 | 75.68 | 75.46 | 14.83 | 16.24 | 15.99 | 3.65 | 3.75 | 3.74 | 2.92 | 2.97 | 2.96 |
| SEm± | **0.08** | **0.27** | **0.59** | **0.10** | **0.33** | **0.30** | **0.29** | **0.20** | **0.31** | **0.02** | **0.01** | **0.02** | **0.03** | **0.09** | **0.01** |
| CD@5% | **NS** | **0.90** | **NS** | **NS** | **1.12** | **NS** | **0.90** | **NS** | **NS** | **0.08** | **0.04** | **0.07** | **0.09** | **0.29** | **0.06** |
| $L_1$: 2mm wide | 82.81 | 81.86 | 82.23 | 73.22 | 72.17 | 72.47 | 14.16 | 15.55 | 14.94 | 3.68 | 3.75 | 3.76 | 2.87 | 2.93 | 2.92 |
| $L_2$: 4mm wide | 76.77 | 77.54 | 77.04 | 70.67 | 70.69 | 70.52 | 17.25 | 18.11 | 17.97 | 3.81 | 3.98 | 3.96 | 3.13 | 3.25 | 3.22 |
| $L_3$: 6mm wide | 88.01 | 86.67 | 87.18 | 79.13 | 78.81 | 78.87 | 12.83 | 13.55 | 13.44 | 3.48 | 3.64 | 3.63 | 2.53 | 2.61 | 2.61 |
| SEm± | **0.12** | **0.28** | **0.84** | **0.17** | **0.62** | **0.58** | **0.31** | **0.29** | **0.45** | **0.05** | **0.07** | **0.06** | **0.04** | **0.07** | **0.03** |
| CD@5% | **0.36** | **0.85** | **2.58** | **0.52** | **1.85** | **1.79** | **0.94** | **0.87** | **1.35** | **0.17** | **0.25** | **0.18** | **0.13** | **0.22** | **0.10** |

**Table. 4.4 Interaction effect of girdling widths and levels of primary branches on yield attributes**

| Treatments | Fruit drop at clove stage (%) | | | Fruit drop at harvest stage (%) | | | Fruits retention/ panicle (number) | | | Fruit length (cm) | | | Fruit breadth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| $G_1L_1$(25% 2mm) | 78.54 | 80.99 | 79.76 | 69.00 | 68.93 | 68.96 | 12.00 | 13.66 | 12.83 | 3.70 | 3.69 | 3.69 | 2.77 | 2.75 | 2.76 |
| $G_1L_2$(25% 4mm) | 77.80 | 76.83 | 77.31 | 70.33 | 70.06 | 70.19 | 16.50 | 17.00 | 16.75 | 3.90 | 3.97 | 3.93 | 3.00 | 3.04 | 3.02 |
| $G_1L_3$ (25% 6mm) | 86.70 | 86.19 | 86.44 | 76.06 | 76.88 | 76.47 | 12.00 | 11.00 | 11.50 | 3.50 | 3.67 | 3.58 | 2.50 | 2.59 | 2.54 |
| $G_2L_1$ (50% 2mm) | 82.99 | 80.12 | 81.55 | 75.29 | 74.70 | 74.99 | 15.00 | 16.00 | 15.50 | 3.91 | 3.84 | 3.87 | 2.97 | 2.96 | 2.96 |
| $G_2L_2$ (50% 4mm) | 74.38 | 74.80 | 74.59 | 70.62 | 71.54 | 71.08 | 20.00 | 19.66 | 19.83 | 4.01 | 4.00 | 4.00 | 3.50 | 3.59 | 3.54 |
| $G_2L_3$ (50% 6mm) | 87.14 | 86.06 | 86.60 | 79.83 | 80.80 | 80.31 | 15.00 | 14.33 | 14.66 | 3.80 | 3.71 | 3.75 | 2.60 | 2.52 | 2.56 |
| $G_3L_1$ (75% 2mm) | 86.33 | 84.46 | 85.39 | 74.06 | 72.89 | 73.47 | 16.00 | 17.00 | 16.50 | 3.70 | 3.72 | 3.71 | 3.00 | 3.09 | 3.04 |
| $G_3L_2$ (75% 4mm) | 77.49 | 80.99 | 79.24 | 70.12 | 70.48 | 70.30 | 17.00 | 17.66 | 17.33 | 3.92 | 3.97 | 3.94 | 3.10 | 3.11 | 3.10 |
| $G_3L_3$ (75% 6mm) | 89.24 | 87.77 | 88.50 | 80.93 | 78.76 | 79.84 | 13.00 | 15.33 | 14.16 | 3.58 | 3.55 | 3.56 | 2.78 | 2.71 | 2.74 |
| Control (Un-girdle) | 92.12 | 93.94 | 93.03 | 85.29 | 83.06 | 84.17 | 6.00 | 9.33 | 7.66 | 3.67 | 3.61 | 3.64 | 2.87 | 2.85 | 2.86 |
| SEm± | **0.13** | **0.47** | **1.03** | **0.17** | **1.94** | **0.52** | **0.35** | **1.56** | **0.54** | **0.04** | **0.02** | **0.03** | **0.05** | **0.01** | **0.03** |
| CD@5% | **0.45** | **1.57** | **3.10** | **0.59** | **0.58** | **1.75** | **1.17** | **0.51** | **1.62** | **0.13** | **0.07** | **0.10** | **0.17** | **0.05** | **0.11** |

### 4.1.12 Fruit weight (g)

The data on fruit weight to different levels and widths of girdling was found to be significant. The highest fruit weight (14.92 g) was recorded in $G_2$ (50% PB) and the lowest (12.89 g) in $G_1$ (25% PB) of cv China.

Whereas width of girdling has influenced on fruit weight significantly. Highest fruit weight (16.01 g) was found in $L_2$ (4mm wide) and the lowest (11.29 g) in $L_3$ (6mm wide) of cv. China.

The data presented in table 4.6 and fig 4.8 revealed that interaction effect of different levels and widths of girdling was found to be significant and influenced in fruit weight in both the years. Highest fruit weight (17.22 g) was found in girdled branches $G_2L_2$ (50%PB with 4mm wide) and the lowest in $G_1L_3$ (25% PB with 6mm wide) *i.e.*, 9.19 g. Which was at par with $G_2L_1$ (50%PB with 2mm wide) and $G_1L_2$ (25%PB with 4mm wide) and the value were 15.78 g and 15.78 g respectively. According to Kumar *et al*. (2016) significantly higher fruit weight and fruit size were observed in girdled tree than control during both the years. It appears that the girdled branches supplied more carbohydrate reserve and necessary hormones which were essential to increase the fruit weight. Gradual decrease in fruit weight was noticed with increase of girdling size in both 25% PB and 50% PB. Girdling of 2mm size produced extra class fruit (fruit length > 33 mm) with fruit weight (20.75g in 25% PB and 19.75g in 50% PB) and fruit size (34.72 mm and 34.25 mm) than other girdling treatments. Lower fruit weight in ungirdled tree might be due to less accumulation of carbohydrate reserves for developing fruit which might have diverted to other plant parts like shoots, roots and non-fruiting terminals that subsequently lead to new flushing during the active phase of fruit growth. Gradual decrease in fruit weight with increase in girdling size might be associated with delay in wound healing resulting into improper establishment of sap flow which hampered the proper regulation of carbohydrate and nitrogen reserve during fruit growth (Khalkho *et al*. 2015). Girdling of grape vine when berries were 4–5 mm in diameter reduced the incidence of berry shatter and improved berry size and weight (Wolf *et al.* 1991) in citrus and Agusti *et al*. (2015) in peach also found same result as compare to present investigation.

**4.1.13 Pulp (Aril) weight (g)**

Data in table 4.5 showed that weight of pulp was influenced by different levels and widths of girdling. Individual effect of different levels of girdling on pulp weight were showed non-significant. The maximum pulp weight (7.61 g) was recorded in $G_2$ (50 %) and lowest (6.98 g) in $G_1$ (25 %).

Data on pulp weight significant variation as influenced by different width of girdling. The maximum pulp weight (8.59 g) was recorded in $L_2$ (4mm) and the minimum weight (5.54 g) recorded in $L_3$ (6mm).

The data pertaining to the interaction effect on different levels and widths of girdling on pulp weight of litchi fruits were presented in table 4.6 & fig 4.10 and results indicated that maximum pulp weight (10.49 g) under the treatment of $G_2L_2$ (50% & 4 mm) and minimum (5.24 g) under $G_2L_3$ (50% & 6mm). The difference between maximum aril weight and minimum aril weight was 5.25 grams. Present experiment was supported by the Rani and Brahamachari (2002) who reported that girdling increase pulp weight in litchi. Girdling increase accumulation of photosynthates above the girdle portion which resulted in additional supply of carbohydrates from leaves to fruits therefore, the fruit and pulp weight of litchi increased. Similar results were also found by Proietti (2003) in olive who reported that girdling increased edible portion.

**4.1.14 Pulp percentage (%)**

Data in table 4.5 showed that the percentage of pulp was influenced by different levels and widths of girdling in litchi. Individual effect of different levels of girdling on pulp percentage were showed non- significant with second season of fruiting. The higher pulp percentage (54.73%) recorded in $G_1$ (25%) and lower (50.16%) in $G_2$ (50%).

Data on the per cent of pulp significant variation as influenced by different widths of girdling. The maximum (53.44%) pulp percentage recorded trees under $L_1$ (2mm) and the minimum (49.69%) recorded in $L_3$ (6mm).

The data pertaining to the interaction effect on different levels and widths of girdling on pulp percentage are presented in table 4.6 & fig 4.11 and results indicated that high significant variation among the treatments during the present investigation. The highest percentage were recorded under the treatment $G_2L_2$ (50% & 4mm) 60.87% and the lowest (44.38%) values were recorded under $G_2L_3$ (50% & 6mm). Which was at par with $G_3L_1$ (75% & 2mm) and $G_1L_1$ (25% & 2mm) and the value were 58.92 % and 56.41 % respectively. Rani and Brahamachari (2002) found significant results with girdling approach and reported more aril recovery percentage in litchi trees. Girdling increased average pulp weight, hence the aril percentage was also higher in fruits.

**4.1.15 Seed weight (g)**

Data in table 4.5 showed that the seed weight was influenced by different levels and widths of girdling in litchi. Individual effect of different levels of girdling on seed weight were showed non- significant. The high seed weight (3.55 g) recorded in $G_1$ (25%) and lower (3.12 g) in $G_2$ (50%).

Whereas width of girdling has influenced on seed weight significantly. Highest seed weight (4.20 g) was found in $L_1$ (2mm) and the lowest (2.79 g) in $L_3$ (6mm).

The data presented in table 4.6 & 4.12 revealed that interaction effect of different levels and widths of girdling was found to be significant and influenced in seed weight. Highest seed weight (4.97 g) was found in control (un-girdle) and the lowest in $G_3L_3$ (75% & 6mm) *i.e.*, 2.24 g. Which was at par with $G_3L_1$ (75% & 2mm) and $G_1L_1$ (25% & 2mm) and the value were 4.70 g and 4.31 g respectively. The results obtained are in accordance with the reporting's of Chandra *et al.* (2008) who observed that girdling treatments had significant effect on peel and stone weight. Similarly, maximum average stone weight was recorded in 2mm & 25% (2.93g).

**4.1.16 Yield (kg/tree)**

Data in table 4.5 and 4.6 showed that the yield was influenced by different levels and widths of girdling in litchi. From the table 4.5 it can be depicted that individual effect of different levels of girdling on yield was significant. Maximum yield (16.47 kg/tree) was recorded in $G_2$ (50 %) and the lowest (12.91 kg/tree) in $G_1$ (25 %).

Whereas in different widths, yield was recorded highest (15.71 kg/tree) in $G_2$ (50 %) and the lowest (13.89 kg/tree) in $L_3$ (6mm).

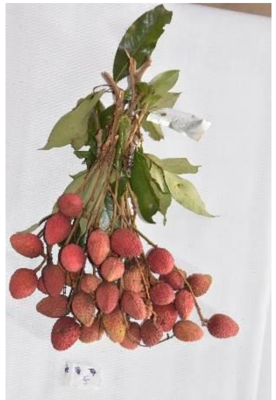
The data on interaction effect of different levels and widths of girdling in respect to litchi yield (table 4.6 and fig 4.13) was found to be significant due to variant combinations of treatments. The average yield during both the year from all girdled treatments was about 1.5 times higher than that from control. Highest yield (17.72 kg/tree) was recorded in $G_2L_2$ (50% & 4mm) and the lowest (11.82 kg/tree) in trees under control (un-girdle). Kumar *et al*. (2016) gave similar results of high fruit yield was noticed in $G_1L_2$ (25% & 4mm) 33.68 kg/plant followed by $G_2L_2$ (50% & 4mm) 30.41 kg. Similarly, Agarwal *et al*. (2021) reported that maximum fruit yield (57.02 kg/tree) was obtained in treatment $T_4$ (Girdling of 50% of primary branches + 4 mm wide) and minimum fruit yield (39.03 kg/tree) was obtained in $T_7$ (control). The girdling was found to increase fruit yield in wax apple (Minch and Chung 2012), apple (Samad 1998) and litchi (Li and Xiao 2001). It might be due to girdled branches supplied more carbohydrate reserve and necessary hormones which were essential to increase the fruit weight and yield.

25% & 2mm

25% & 4mm

25% & 6mm

50% & 2mm



50% & 4mm

50% & 6mm

75% & 2mm

75% & 4mm

75% & 6mm

Control (Un- girdle)

**PLATE 4.6. Fruit size differentiation in harvested girdled treatments**

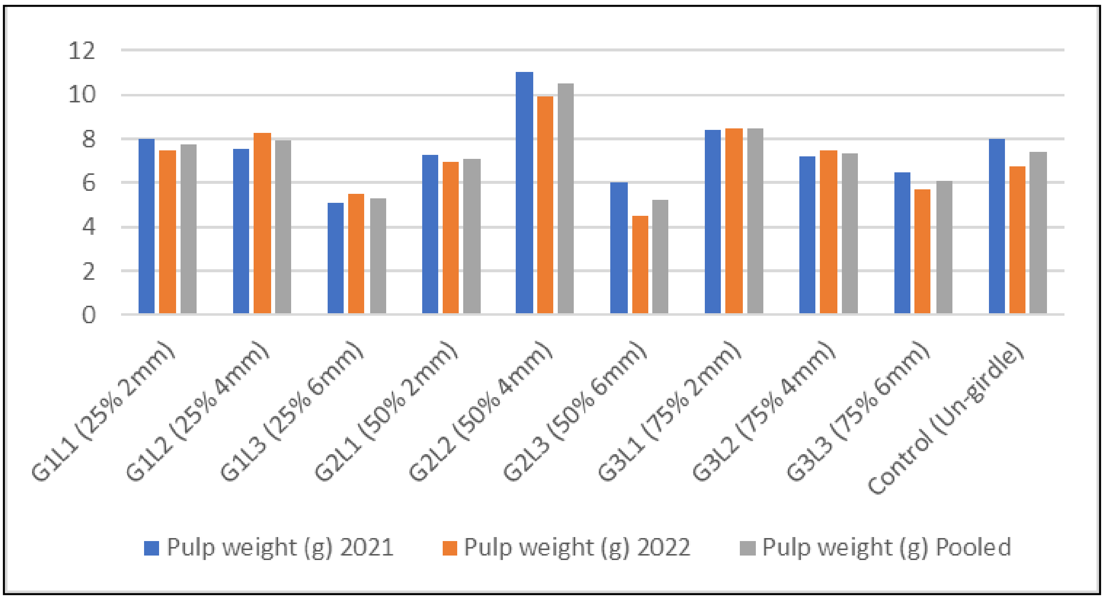



**Fig 4.10 Effect of girdling on influence of pulp weight**

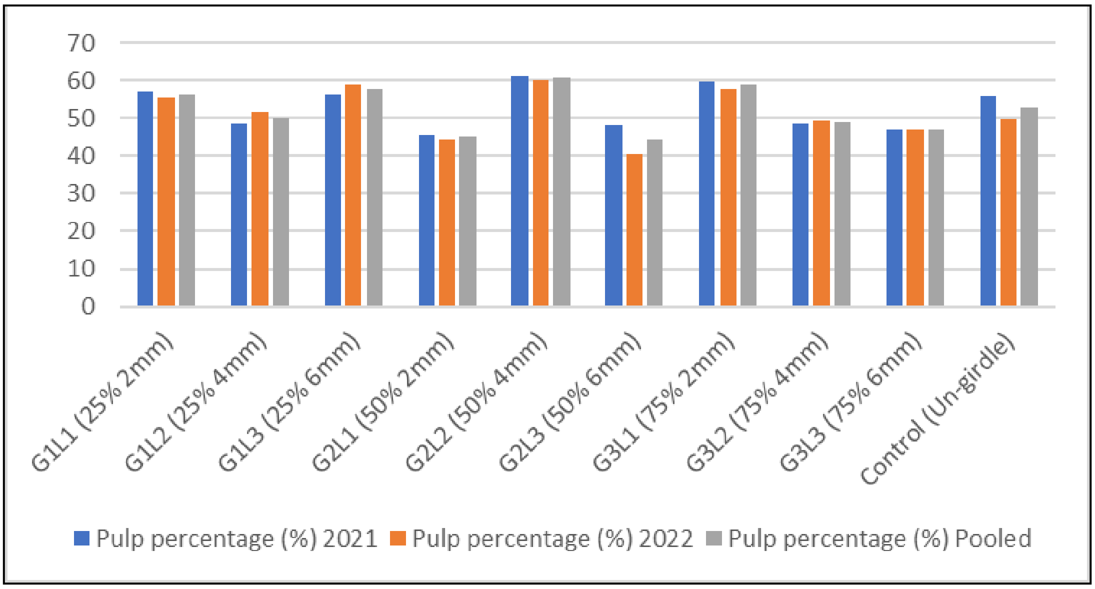



**Fig 4.11 Effect of girdling on influence of pulp percentage**

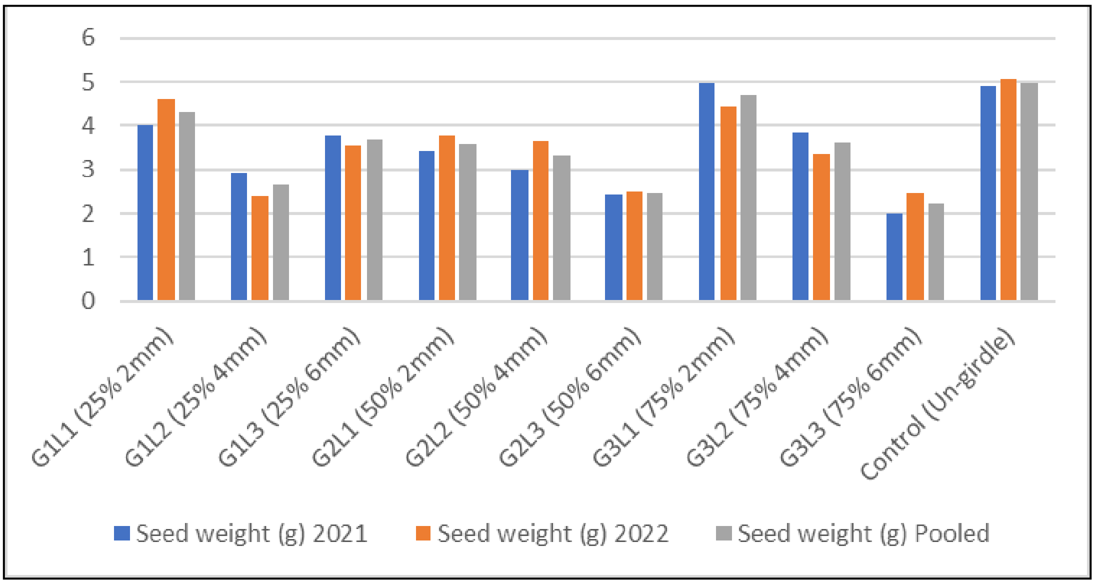



**Fig 4.12 Effect of girdling on seed weight of litchi cv. China**

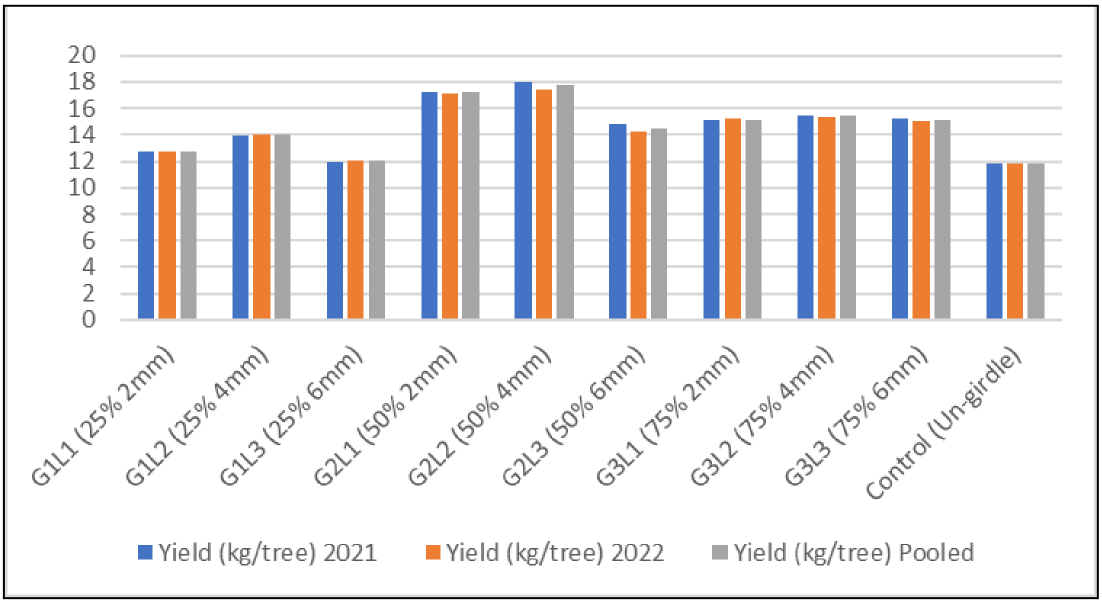



**Fig 4.13 Effect of girdling on yield of litchi tree cv. China**

**Table. 4.5. Effect of different levels & widths of girdling on yield and yield attributes**

| Treatments | Fruit weight (g) | | | Pulp weight (g) | | | Pulp percentage (%) | | | Seed weight (g) | | | Yield (kg/tree) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** |
| **$G_1$: 25% PB** | 12.93 | 13.10 | 12.89 | 6.88 | 7.08 | 6.98 | 53.84 | 54.04 | 54.73 | 3.54 | 3.52 | 3.55 | 12.80 | 12.93 | 12.91 |
| **$G_2$: 50% PB** | 15.44 | 14.89 | 14.92 | 8.13 | 7.10 | 7.61 | 52.64 | 47.68 | 50.16 | 2.85 | 3.31 | 3.12 | 16.58 | 16.28 | 16.47 |
| **$G_3$: 75% PB** | 13.93 | 13.97 | 14.09 | 7.20 | 7.22 | 7.29 | 51.61 | 51.68 | 51.65 | 3.52 | 3.42 | 3.51 | 15.21 | 15.18 | 15.24 |
| **SEm±** | **0.21** | **0.21** | **0.27** | **0.04** | **0.15** | **0.21** | **0.08** | **0.28** | **0.90** | **0.03** | **0.08** | **0.14** | **0.03** | **0.12** | **0.06** |
| **CD@5%** | **0.70** | **0.70** | **0.89** | **0.14** | **NS** | **NS** | **0.28** | **NS** | **2.99** | **0.12** | **NS** | **NS** | **0.11** | **0.40** | **0.22** |
| **$L_1$: 2mm wide** | 14.61 | 14.70 | 14.60 | 7.82 | 7.62 | 7.57 | 53.95 | 51.83 | 53.44 | 4.04 | 4.28 | 4.20 | 14.93 | 15.01 | 15.02 |
| **$L_2$: 4mm wide** | 15.69 | 16.47 | 16.01 | 8.06 | 8.57 | 8.59 | 52.63 | 52.03 | 53.32 | 3.20 | 3.13 | 3.19 | 15.71 | 15.60 | 15.71 |
| **$L_3$: 6mm wide** | 11.99 | 10.79 | 11.29 | 5.88 | 5.21 | 5.54 | 50.39 | 48.28 | 49.69 | 2.65 | 2.84 | 2.79 | 13.94 | 13.78 | 13.89 |
| **SEm±** | **0.24** | **0.29** | **0.36** | **0.12** | **0.16** | **0.27** | **0.10** | **0.41** | **0.97** | **0.05** | **0.11** | **0.19** | **0.48** | **0.75** | **0.62** |
| **CD@5%** | **0.71** | **0.89** | **1.10** | **0.36** | **0.49** | **0.84** | **0.31** | **1.24** | **2.92** | **0.17** | **0.35** | **0.59** | **1.45** | **2.28** | **1.89** |

**Table. 4.6. Interaction effect of girdling on yield and yield attributes**

| Treatments | Fruit weight (g) | | | Pulp weight (g) | | | Pulp percentage (%) | | | Seed weight (g) | | | Yield (kg/tree) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| $G_1L_1$ (25% 2mm) | 13.99 | 13.42 | 13.70 | 8.01 | 7.46 | 7.73 | 57.25 | 55.58 | 56.41 | 4.02 | 4.61 | 4.31 | 12.76 | 12.72 | 12.74 |
| $G_1L_2$ (25% 4mm) | 15.48 | 16.08 | 15.78 | 7.54 | 8.29 | 7.91 | 48.70 | 51.55 | 50.12 | 2.93 | 2.40 | 2.66 | 13.94 | 14.05 | 13.99 |
| $G_1L_3$ (25% 6mm) | 9.12 | 9.26 | 9.19 | 5.12 | 5.48 | 5.30 | 56.14 | 59.17 | 57.65 | 3.79 | 3.55 | 3.67 | 12.00 | 12.03 | 12.01 |
| $G_2L_1$ (50% 2mm) | 16.00 | 15.57 | 15.78 | 7.29 | 6.92 | 7.10 | 45.56 | 44.44 | 45.00 | 3.41 | 3.78 | 3.59 | 17.25 | 17.11 | 17.18 |
| $G_2L_2$ (50% 4mm) | 18.00 | 16.45 | 17.22 | 11.06 | 9.92 | 10.49 | 61.44 | 60.30 | 60.87 | 2.98 | 3.65 | 3.31 | 18.01 | 17.44 | 17.72 |
| $G_2L_3$ (50% 6mm) | 12.48 | 11.03 | 11.75 | 6.01 | 4.48 | 5.24 | 48.15 | 40.61 | 44.38 | 2.43 | 2.50 | 2.46 | 14.75 | 14.30 | 14.52 |
| $G_3L_1$ (75% 2mm) | 14.00 | 14.62 | 14.31 | 8.39 | 8.47 | 8.43 | 59.92 | 57.93 | 58.92 | 4.96 | 4.45 | 4.70 | 15.13 | 15.19 | 15.16 |
| $G_3L_2$ (75% 4mm) | 14.87 | 15.21 | 15.04 | 7.24 | 7.50 | 7.37 | 48.68 | 49.30 | 48.99 | 3.85 | 3.35 | 3.60 | 15.50 | 15.33 | 15.41 |
| $G_3L_3$ (75% 6mm) | 13.78 | 12.09 | 12.93 | 6.49 | 5.68 | 6.08 | 47.09 | 46.98 | 47.03 | 2.01 | 2.47 | 2.24 | 15.29 | 15.02 | 15.15 |
| Control (Un-girdle) | 14.29 | 13.58 | 13.93 | 7.99 | 6.78 | 7.38 | 55.91 | 49.92 | 52.91 | 4.89 | 5.05 | 4.97 | 11.85 | 11.79 | 11.82 |
| SEm± | **0.36** | **0.36** | **0.46** | **0.07** | **0.26** | **0.37** | **0.14** | **0.50** | **1.56** | **0.06** | **0.15** | **0.24** | **0.06** | **0.21** | **0.11** |
| CD@5% | **1.22** | **1.21** | **1.54** | **0.25** | **0.86** | **1.24** | **0.49** | **1.65** | **5.18** | **0.21** | **0.50** | **0.82** | **0.20** | **0.70** | **0.38** |

**4.1.17 Total sugar (%)**

Data in table 4.7 and 4.8 showed less significant difference within the treatments of different bio chemical parameters and was not much influenced by different levels and widths of girdling in litchi.

Analytical data on total sugar content presented in table 4.7 shown less significant difference among the treatments. Highest total sugar (14.06 %) was found in $G_2$ (50 %) and the lowest (12.37 %) was recorded in $G_3$ (75 %).

Whereas different width of girdling also shown less significant difference on the total sugar content. Highest sugar content (14.72 %) was found in $L_2$ (4mm) and the lowest (12.04 %) in $L_3$ (6 mm).

The interaction effect of different levels and widths of girdling presented in the table 4.8 and fig 4.14 showed significant difference in total sugar content. Highest sugar content (16.03 %) was recorded in $G_2L_2$ (50 % & 4 mm) and the lowest (11.54 %) in $G_2L_3$ (50 % & 6 mm). Which was at par with $G_2L_1$ (50% & 2mm) and $G_3L_2$ (75% & 4mm) and the value were 14.63 % and 14.18 % respectively. The results of present experiment were supported with Huang *et al.* (2012) who recorded that spiral girdling increase total sugar percentage in litchi fruits. Rather *et al.*, (2011) also observed that girdling increase reducing sugar percentage and total sugar percentage in grapevine. Li and Xiao (2001) in litchi and Singh *et al*. (2015) in pear observed similar results. The increase in sugars might be due to more accumulation and availability of carbohydrates to the fruits above the girdled portion. Sucrose concentrations during ripening increased with girdling, which may represent a concentration effect and import from the rest of the vine (Hunter and Ruffner 2001).

**4.1.18 Total Soluble Solids (ºB)**

Effect of different levels and width of girdling on TSS was found to be significant (table 4.7 and 4.8). Individual effect of different levels shown high TSS (15.70 º Brix) was recorded in $G_2$ (50 %) and the lowest (13.50 º Brix) in

$G_3$ (75 %). Effect of Width of girdling showed high TSS (16.26 º Brix) was recorded in $L_2$ (4 mm) and the lowest (12.42 º Brix) in $L_3$ (6 mm).

The interaction effect of different levels and widths of girdling was found to be significantly effective on the TSS (table 4.8 and fig 4.15). Highest TSS was observed in $G_2L_2$ (50 % & 4 mm) and the lowest in $G_1L_3$ (25 % & 6 mm) *i.e.*, 18.01 º Brix and 11.65 º Brix. Which was at par with $G_1L_2$ (25 % & 4 mm) 17.81 º Brix. Agarwal *et al*. (2021) reported that highest TSS content (19.29 $^0$Brix) was acquire in treatment $T_4$ (Girdling of 50% of primary branches + 4 mm wide). The improvement in fruit quality is due to blockage of transportation of carbohydrates (sugar) from leaves to roots, thus the level of sugar will increase in leaves and this additional sugar was transferred to fruits, therefore, the TSS content of litchi fruits will increase as compared to ungirdled trees. TSS and TSS/ acid ratio showed decreasing trend while acidity and ascorbic acid content of the fruit showed increasing trend with increased level of girdling width reported by Kumar *et al*. 2016. Similar results were also obtained by Ibrahim *et al.* (2016) in citrus. Ongusu *et al*. (2004) observed that partial girdling improved the fruit quality and increased the TSS content of litchi fruit as compared to control.

### 4.1.19 Titratable acidity (%)

Data presented in the table 4.7 and 4.8 revealed that there was not much significant difference in the acidity influenced by different levels and widths of girdling. The highest acidity (0.71 %) was recorded in $G_3$ (75 %) and the lowest acidity (0.58 %) in 50 % ($G_2$). Whereas in different width highest acidity (0.71 %) was observed in $L_3$ (6 mm) and the lowest acidity (0.60 %) in $L_2$ (4 mm).

The interaction effect of different levels and widths of girdling was found to be non-significant (table 4.8 and fig 4.16). Within the treatments no significant differences were observed. Highest acidity (0.83 %) was recorded in control (un-girdle) and the lowest acidity (0.53 %) in $G_2L_2$ (50 % & 4 mm). Experimental results are similar with Chandra et al. (2008) who observed that girdling decrease acidity percentage in litchi fruits. Kumar *et al.* (2016) reported that acidity content of the fruits showed increasing trend with increased level of girdling width. In contrast, Arakawa *et al.* (1997) reported that TSS and acidity content was enhanced with girdling in apples.

**4.1.20 TSS: Acid ratio**

TSS: acid ratio content shows significant variation to different levels and widths of girdling (table 4.7 and 4.8). Highest TSS: acid ratio content was observed in $G_2$ (50 %) and the lowest in $G_3$ (75 %) *i.e.*, 27.20 and 19.13. Whereas different width of girdling also shown significant difference. Highest TSS: acid ratio content (27.15) was recorded in $L_2$ (4mm) and the lowest (17.82) was recorded in $L_3$ (6 mm).

The variation in the TSS: acid ratio content on the interaction of different levels and widths of girdling was found to be significant (table 4.8 and fig 4.17). Highest TSS: acid ratio content was observed in $G_2L_2$ (50 % & 4 mm) and the lowest was recorded in control (un-girdle) *i.e.*, 33.81 and 14.52 respectively. Similar findings of Agarwal *et al*. (2021) reported that TSS/acid ratio was significantly enhanced with different girdling treatments being maximum of (33.46) in plants girdled with 50% of primary branches at 4 mm thickness ($T_4$) and minimum (26.86) in $T_7$ (control). Girdling restricts the movement of sugars from leaves to roots thus the level of sugar in fruits will increase and opposite the level of acidity will be reduced, therefore, resulted in high TSS: acidity ratio in litchi fruits. The data obtained on TSS: acidity ratio was significant with Chandra *et al*. (2008) who observed that girdling of main trunk + 50% of primary branches in which 3 mm deep and 3 mm wide ring of bark is removed resulted in higher TSS: acidity ratio in litchi.

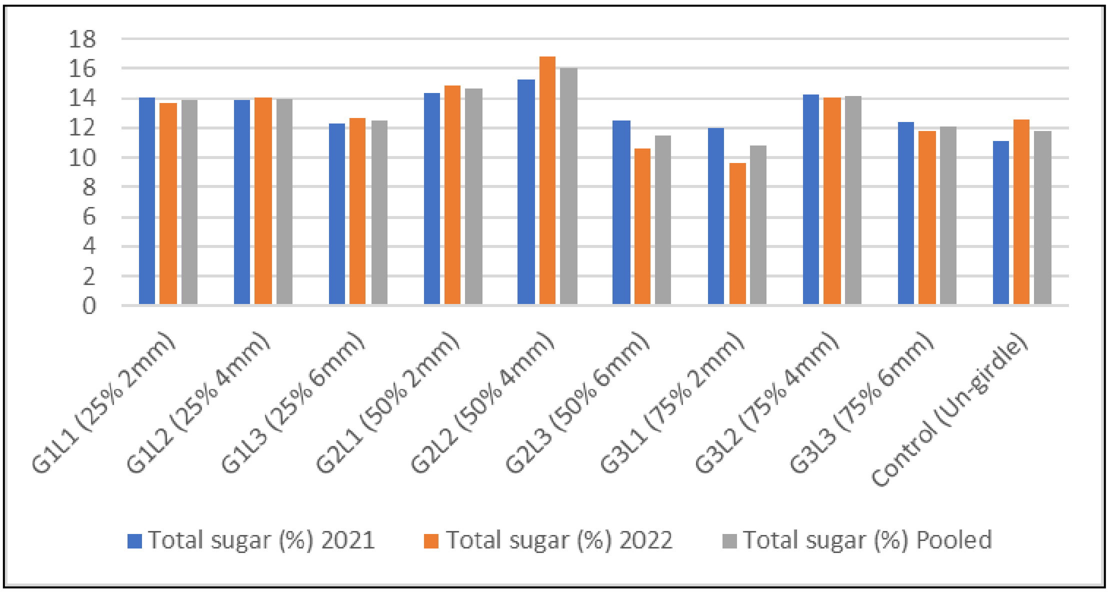



**Fig 4.14 Effect of different girdling on fruit total sugar content**

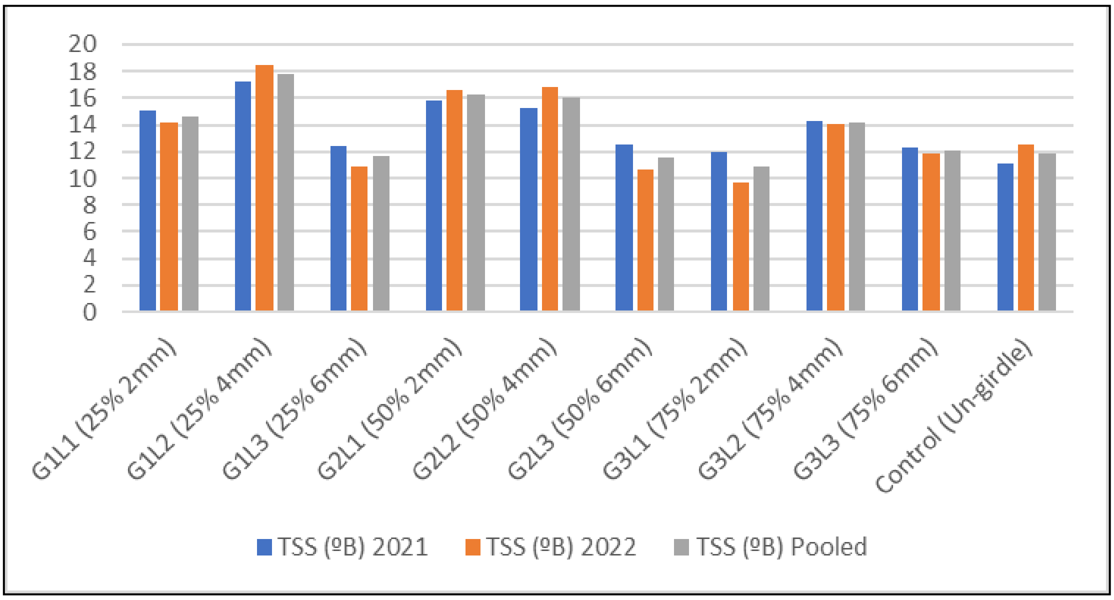



**Fig 4.15 Effect of different girdling treatments on fruit TSS content**

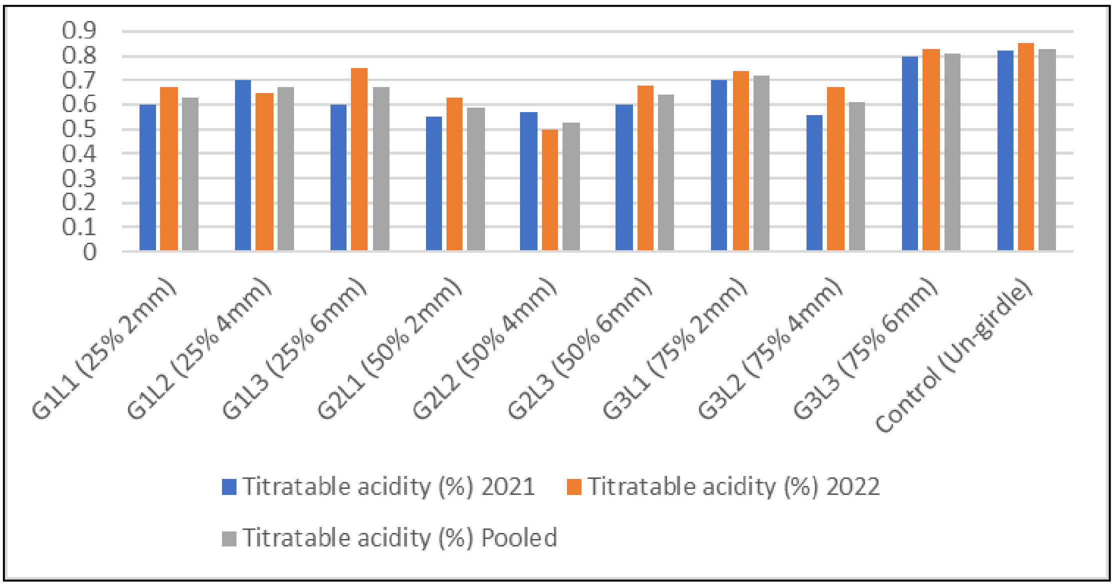



**Fig 4.16 Effect of different girdling treatments on fruit titratable acidity content**

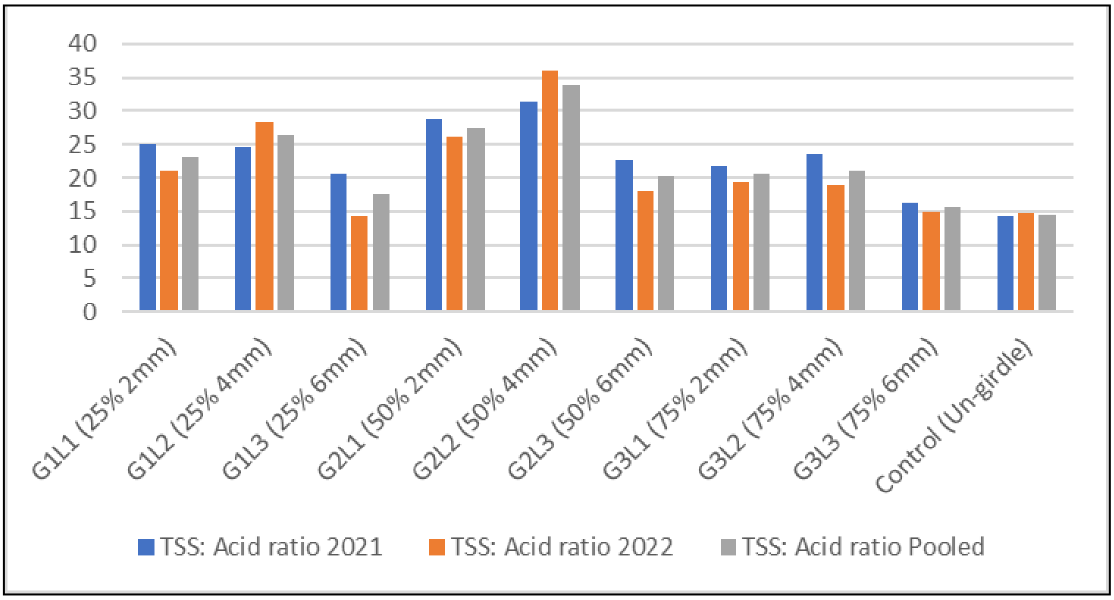



**Fig 4.17 Effect of different girdling treatments on fruit TSS: acid ratio**

### 4.1.21 C/N ratio of leaves: Before and after girdling (%)

Different levels and widths of girdling shows significant variation on C/N ratio content of leaves at before and after girdling operation (table 4.7 and 4.8). Before girdling showed highest C/N ratio content of leaves was observed in $G_3$ (75 %) and the lowest in $G_1$ (25 %) *i.e.*, 1.72 % and 1.31 %. Whereas after girdling highest was recorded in $G_2$ (50 %) and lowest in $G_1$ (25 %) *i.e.*, 3.41 % and 3.29 %.

Before girdling showed highest C/N ratio content of leaves was observed in $L_3$ (6 mm) and the lowest in $L_1$ (2 mm) *i.e.*, 1.68 % and 1.47 %. Whereas after girdling highest was recorded in $L_3$ (6 mm) and lowest in $L_1$ (2 mm) *i.e.*, 4.22 % and 2.83 %.

The variation in the C/N ratio content of leaves on the interaction of different levels and widths of girdling was found to be significant (table 4.8 and fig 4.18 & 4.19). Before girdling highest C/N ratio content was observed in control (un-girdle) and the lowest was recorded in $G_1L_2$ (25 % & 4 mm) *i.e.*, 2.66 % and 1.27 % respectively. Whereas after girdling highest was recorded in $G_3L_3$ (75 % & 6 mm) and lowest in control (un-girdle) *i.e.*, 4.32 % and 2.65 %. Which was at par with $G_2L_3$ (50 % & 6 mm) and $G_1L_3$ (25% & 6 mm) and the value were 4.22 % and 4.14 % respectively. Similar findings by Kumar *et al.* (2016) reported that the C/N ratio was found highest in $T_6$ (75 % & 6 mm) 4.15 % and $T_3$ (25 % & 6 mm) 4.12 % compare with 2.56 % in ungirdled trees. It may be due to girdling stops the basipetal movement of assimilates through phloem which resulted in accumulation of carbohydrates and plant growth hormones above the girdle (Urban and Alphonsout, 2006).

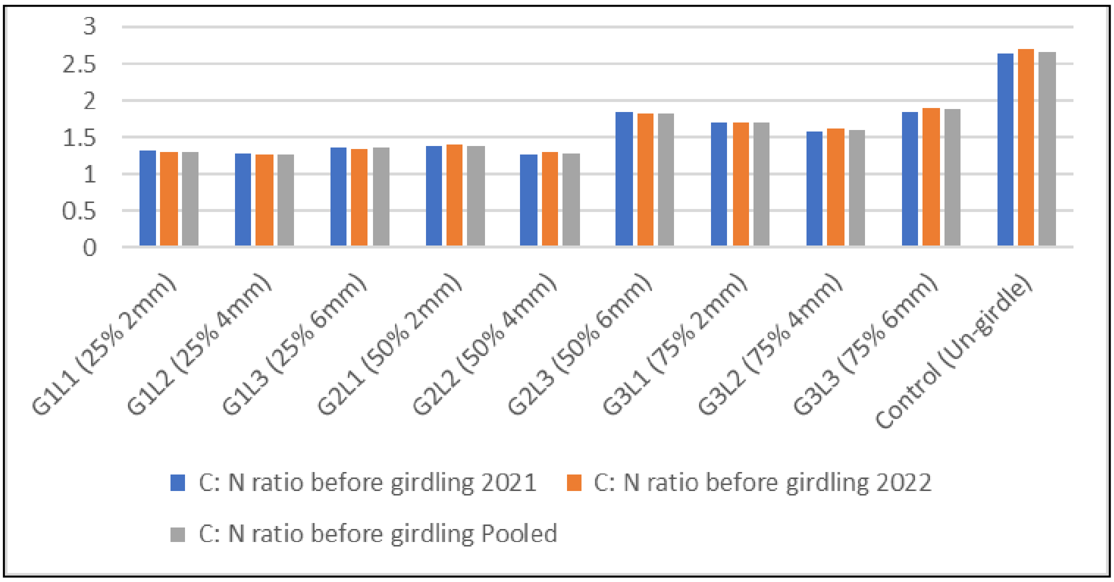



**Fig 4.18 Leaf C:N ratio before girdling**

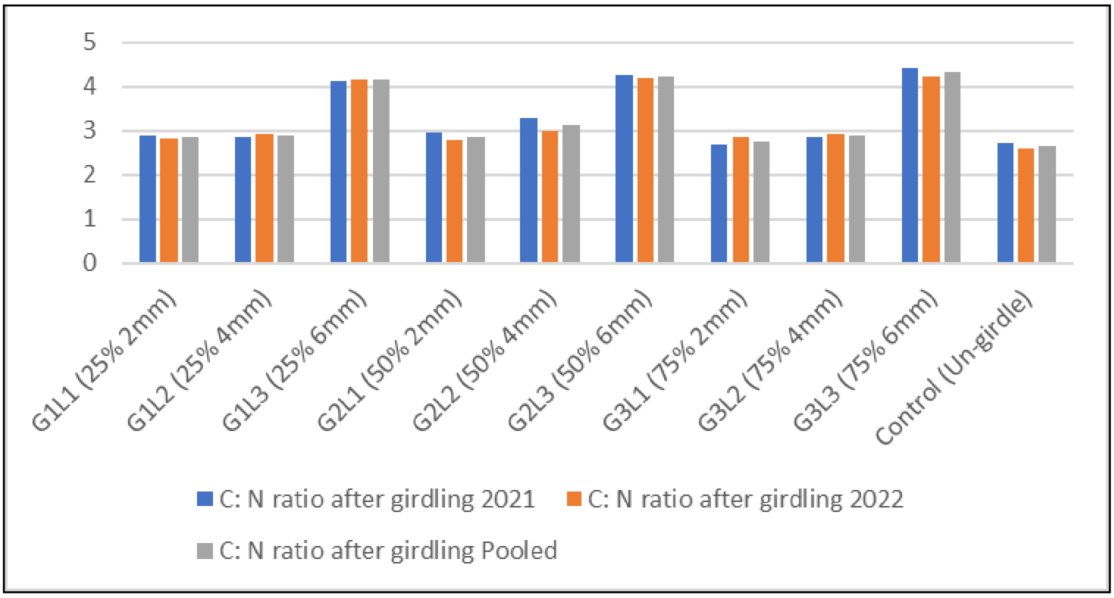



**Fig 4.19 Leaf C:N ratio after girdling**

**Table. 4.7. Effect of different levels & widths of girdling on bio chemical attributes of litchi**

| Treatments | Total sugar (%) | | | TSS (ºB) | | | Titratable acidity (%) | | | TSS: Acid ratio | | | C: N ratio in leaves (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | Before girdling | | | After girdling | | |
| | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** |
| **$G_1$: 25% PB** | 13.31 | 13.48 | 13.44 | 14.90 | 14.48 | 14.69 | 0.61 | 0.69 | 0.66 | 23.36 | 21.28 | 22.37 | 1.29 | 1.39 | 1.31 | 3.28 | 3.29 | 3.29 |
| **$G_2$: 50% PB** | 13.97 | 14.11 | 14.06 | 15.58 | 15.60 | 15.70 | 0.60 | 0.56 | 0.58 | 27.49 | 26.75 | 27.20 | 1.46 | 1.47 | 1.48 | 3.46 | 3.32 | 3.41 |
| **$G_3$: 75% PB** | 12.85 | 11.86 | 12.37 | 13.77 | 13.20 | 13.50 | 0.68 | 0.75 | 0.71 | 20.47 | 17.76 | 19.13 | 1.68 | 1.74 | 1.72 | 3.31 | 3.33 | 3.32 |
| **SEm±** | **0.03** | **0.33** | **0.35** | **0.06** | **0.41** | **0.26** | **0.01** | **0.009** | **0.02** | **0.07** | **0.51** | **1.08** | **0.009** | **0.04** | **0.01** | **0.01** | **0.005** | **0.04** |
| **CD@5%** | **0.10** | **1.11** | **1.16** | **0.21** | **1.38** | **0.87** | **0.05** | **0.031** | **0.06** | **0.24** | **1.69** | **3.58** | **0.031** | **0.13** | **0.03** | **0.04** | **0.016** | **0.13** |
| **$L_1$: 2mm wide** | 13.45 | 12.75 | 13.11 | 15.31 | 15.03 | 15.21 | 0.60 | 0.68 | 0.64 | 25.03 | 22.24 | 23.73 | 1.45 | 1.38 | 1.47 | 2.84 | 2.82 | 2.83 |
| **$L_2$: 4mm wide** | 14.37 | 14.99 | 14.72 | 15.97 | 16.41 | 16.26 | 0.60 | 0.59 | 0.60 | 26.47 | 27.79 | 27.15 | 1.44 | 1.53 | 1.48 | 2.97 | 2.94 | 2.97 |
| **$L_3$: 6mm wide** | 12.31 | 11.71 | 12.04 | 12.96 | 11.83 | 12.42 | 0.67 | 0.75 | 0.71 | 19.82 | 15.77 | 17.82 | 1.65 | 1.68 | 1.68 | 4.25 | 4.18 | 4.22 |
| **SEm±** | **0.07** | **0.56** | **0.48** | **0.12** | **0.55** | **0.39** | **0.06** | **0.04** | **0.05** | **0.11** | **0.51** | **1.51** | **0.10** | **0.15** | **0.14** | **0.18** | **0.11** | **0.19** |
| **CD@5%** | **0.22** | **1.68** | **1.45** | **0.36** | **1.66** | **1.21** | **0.20** | **0.17** | **0.15** | **0.37** | **1.57** | **4.58** | **0.30** | **0.48** | **0.45** | **0.56** | **0.39** | **0.57** |

## Table. 4.8. Interaction effect of girdling on bio chemical attributes of litchi

| Treatments | Total sugar (%) | | | TSS (ºB) | | | Titratable acidity (%) | | | TSS: acid ratio | | | C: N ratio in leaves (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | Before girdling | | | After girdling | | |
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| **$G_1L_1$ (25% 2mm)** | 14.05 | 13.71 | 13.88 | 15.00 | 14.20 | 14.60 | 0.60 | 0.67 | 0.63 | 25.00 | 21.16 | 23.08 | 1.32 | 1.30 | 1.31 | 2.90 | 2.81 | 2.85 |
| **$G_1L_2$ (25% 4mm)** | 13.85 | 14.06 | 13.95 | 17.23 | 18.40 | 17.81 | 0.70 | 0.65 | 0.67 | 24.61 | 28.30 | 26.45 | 1.28 | 1.27 | 1.27 | 2.87 | 2.93 | 2.90 |
| **$G_1L_3$ (25% 6mm)** | 12.29 | 12.68 | 12.48 | 12.46 | 10.85 | 11.65 | 0.60 | 0.75 | 0.67 | 20.76 | 14.39 | 17.57 | 1.37 | 1.35 | 1.36 | 4.13 | 4.15 | 4.14 |
| **$G_2L_1$ (50% 2mm)** | 14.36 | 14.90 | 14.63 | 15.87 | 16.55 | 16.21 | 0.55 | 0.63 | 0.59 | 28.85 | 26.23 | 27.54 | 1.39 | 1.40 | 1.39 | 2.95 | 2.80 | 2.87 |
| **$G_2L_2$ (50% 4mm)** | 15.23 | 16.84 | 16.03 | 17.97 | 18.05 | 18.01 | 0.57 | 0.50 | 0.53 | 31.52 | 36.10 | 33.81 | 1.27 | 1.31 | 1.29 | 3.28 | 2.99 | 3.13 |
| **$G_2L_3$ (50% 6mm)** | 12.47 | 10.61 | 11.54 | 13.56 | 12.20 | 12.88 | 0.60 | 0.68 | 0.64 | 22.60 | 17.94 | 20.27 | 1.84 | 1.81 | 1.82 | 4.26 | 4.18 | 4.22 |
| **$G_3L_1$ (75% 2mm)** | 12.01 | 9.65 | 10.83 | 15.29 | 14.35 | 14.82 | 0.70 | 0.74 | 0.72 | 21.84 | 19.32 | 20.58 | 1.70 | 1.71 | 1.70 | 2.70 | 2.85 | 2.77 |
| **$G_3L_2$ (75% 4mm)** | 14.28 | 14.09 | 14.18 | 13.12 | 12.80 | 12.96 | 0.56 | 0.67 | 0.61 | 23.42 | 18.98 | 21.20 | 1.59 | 1.62 | 1.60 | 2.87 | 2.91 | 2.89 |
| **$G_3L_3$ (75% 6mm)** | 12.35 | 11.84 | 12.09 | 13.01 | 12.45 | 12.73 | 0.80 | 0.83 | 0.81 | 16.26 | 14.99 | 15.62 | 1.84 | 1.90 | 1.87 | 4.41 | 4.23 | 4.32 |
| **Control (Un-girdle)** | 11.06 | 12.57 | 11.81 | 11.74 | 12.60 | 12.17 | 0.82 | 0.85 | 0.83 | 14.31 | 14.73 | 14.52 | 2.63 | 2.69 | 2.66 | 2.73 | 2.58 | 2.65 |
| **SEm±** | **0.05** | **0.58** | **0.60** | **0.11** | **0.72** | **0.45** | **0.02** | **0.01** | **0.03** | **0.13** | **0.88** | **1.87** | **0.01** | **0.07** | **0.01** | **0.01** | **0.008** | **0.06** |
| **CD@5%** | **0.18** | **1.93** | **2.01** | **0.36** | **2.40** | **1.51** | **0.08** | **NS** | **NS** | **0.43** | **2.92** | **5.62** | **0.05** | **0.23** | **0.05** | **0.05** | **0.028** | **0.20** |

### 4.2 To study the effect of bagging on quality of litchi fruits cv. Shahi

The data pertaining to the effect of bagging time and materials on quality improvement properties of litchi fruits were statistically analysed and the results are presented in the Tables, justified with proper scientific reasons and supported by available literature and discussed under the following appropriate headings:

#### 4.2.1 Fruit colour

The data displayed in table 4.9 shows that the fruit colour was influenced by different bagging time and bagging materials. Fruit colour of different treatments showed moderate purple red to deep purple red B. The good colour was noticed when fruits were bagged 30 days after fruit set *i.e*., deep purple red colour as compared to the unbagged fruits with moderate purple red colour. The litchi fruits, which were bagged with brown paper bag 30 days after fruit set and pink polypropylene bags 30 days after fruit set resulted in development of attractive deep purple red colour.

Similarly, Chand *et al*. (2020) reported that polypropylene bagged fruits showed the dark pinkish colour compared with un-bagged fruits shown light pinkish and un even ripening.  It might be due to increased relative humidity and temperature inside bags will create a better microclimate than outside un bagged fruits. These results are in conformity with the results of Shinde *et al*. (2015) in mango.

#### 4.2.2 Fruit weight (g)

The perusal of data given in table 4.9 and fig 4.20 shows the increase in fruit weight as affected by different bagging materials and time of bagging. The increase in fruit weight ranged from 9.68 g to 23.12 g in various treatments.

Brown paper bags in combination with bagging time 30 days after fruit set exhibited maximum fruit weight (23.12 g) followed by pink polypropylene bags (22.75 g) in treatment combination with 15 days after fruit set, while minimum fruit weight (9.68 g) was recorded in unbagged fruits. Purbey and Kumar (2015) reported maximum fruit weight was recorded with Brown Paper Bag (24.67 g). According to Dutta and Majumdar (2012), pre-harvest fruit bagging improved the fruit weight and size through the conducive effects such as increased relative humidity and a consequently reduced fruit water loss.

**4.2.3 Sunburn percentage (%)**

The data pertaining to effect of different bagging materials on percentage of sunburn was presented in table 4.9 and fig 4.21. The pericarp sunburn of litchi fruit varied from 3.59 to 28.87 per cent. The maximum pericarp sunburn 28.87 per cent was recorded in unbagged fruits, whereas minimum sunburn percentage (3.59 %) was recorded in pink polypropylene bagged at 15 days after fruit set.

In the present study, a considerable variation was observed in pericarp sun-burn which was appreciably influenced by both factors, namely bagging time and bagging materials. The reduction in fruit sun-burn might be due to protection of fruits from direct sun light inside bags (Hong and ZhengMing, 2001) as they observed bagging protected the navel orange cv. Robertson fruits from sunburn. Asrey *et al*. (2009) also resulted significant reduction in sun burn by using polypropylene bags.

**4.2.4 Cracking percentage (%)**

Data given in table 4.9 and fig 4.22 indicates that there was significant effect of different bagging material on fruit cracking. Minimum fruit cracking (1.71 %) was observed in pink polypropylene bags in combination with 15 days after fruit set followed by pink polypropylene bags (1.89 %) 30 days after fruit set which was significant over all treatments and maximum was observed in control (un bagged) fruits 10.77 per cent.

In this regard, Chand *et al*. (2020) registered that fruit cracking was found least (2.67 %) in WPP at 30 DAFS and PPP at 30 DAFS (2.54 %) and maximum cracking was observed in un bagged fruits 12.07 percent. Tran *et al*. (2015) reported that the most important role of fruit bagging was to effectively protect fruits from physiological factors such as cracking, bird damage and blemish, which led to the significant decrease of the total damaged and defective fruits (13.7-33.3%), as compared with non-bagged control (66.7-72.6%).

**4.2.5 Borer infestation (%)**

The perusal of data given in table 4.9 and fig 4.23 shows the decreasing in fruit borer infestation as affected by different bagging materials and time of bagging. The decreasing in fruit borer infestation ranged from 0.03 % to 87.16 % in various treatments.

Brown paper bags in combination with bagging time 15 days after fruit set exhibited minimum borer infestation (0.03 %) followed by brown paper bags (0.07 %) in treatment combination with 25 days after fruit set, while maximum infestation (87.16 %) was recorded in unbagged fruits. Similar findings found that 10.66% borer incidence was found in control while other treatments were unaffected with borer incidence. It may be because that bagging reduced the incidence of fruit borer in litchi (Debnath and Mitra, 2008). The results indicated that bagging served as a physical barrier and successfully protected the fruits against borer infestation. Bagging of litchi fruits with paper or polythene bags might have prevented the contact of female moth and other pest with the fruits, thereby protecting the fruits from borer and disease infestation.

**4.2.6 Pericarp anthocyanin (mg/100g)**

It is evident from the table 4.10 and fig 4.24 shows that anthocyanin content of fruit pericarp was significantly influenced by different bagging time and bagging materials. The maximum anthocyanin content 26.11 mg/100g was recorded in brown paper bag at 30 DAFS, whereas minimum (15.25 mg/100g) was recorded in un-bagged fruits. Which was at par with PPP 15 DAFS and BPB 15 DAFS and the value were 25.39 mg/100g and 24.75 mg/100g respectively.

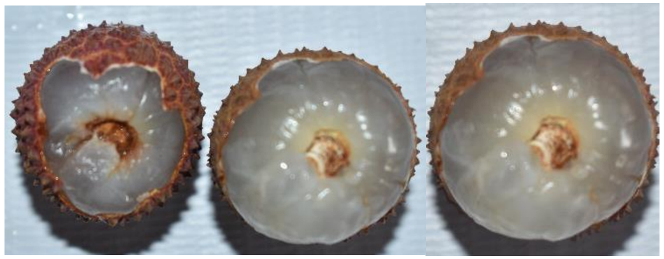
In present investigation, it was observed that anthocyanin content had been higher in bagged fruits as compared to the unbagged ones. The reason might be that due to increase temperature inside the bags the anthocyanin synthesis might have got hastened and at maturity during harvesting, bagged treatments accumulated higher anthocyanin content than the unbagged ones.

Islam *et al*. (2017) the fruits developed inside the bags were superior in quality with no blemishes on peel brown paper bag improved fruit colour, texture, appearance and sweetness. The above findings are in conformity with the findings of Debnath and Mitra (2008) in litchi, Tyasa *et al.* (1998) in litchi, Ding *et al*. (2004) bagging greatly improves the appearance of nectarine fruit, and the nectarine fruit looks bright and clean after bagging and takes up colour quickly.

*Conopomorpha sp*

**Anar butter fly**

**Un- bagged damaged fruits & seeds**



**Bagged fruits**

**PLATE 4.7. Fruit quality affected by pest infestation in litchi**

**PPW** **BPB**

**PPP** **Control (No- bagging)**

**PLATE 4.8. Different bagging materials used for improving quality of fruits**

**PPW**

**PPP**

**BPB**

**Control (Un-bagged)**

**PLATE 4.9. Physical appearance of bagged and un-bagged litchi fruits**

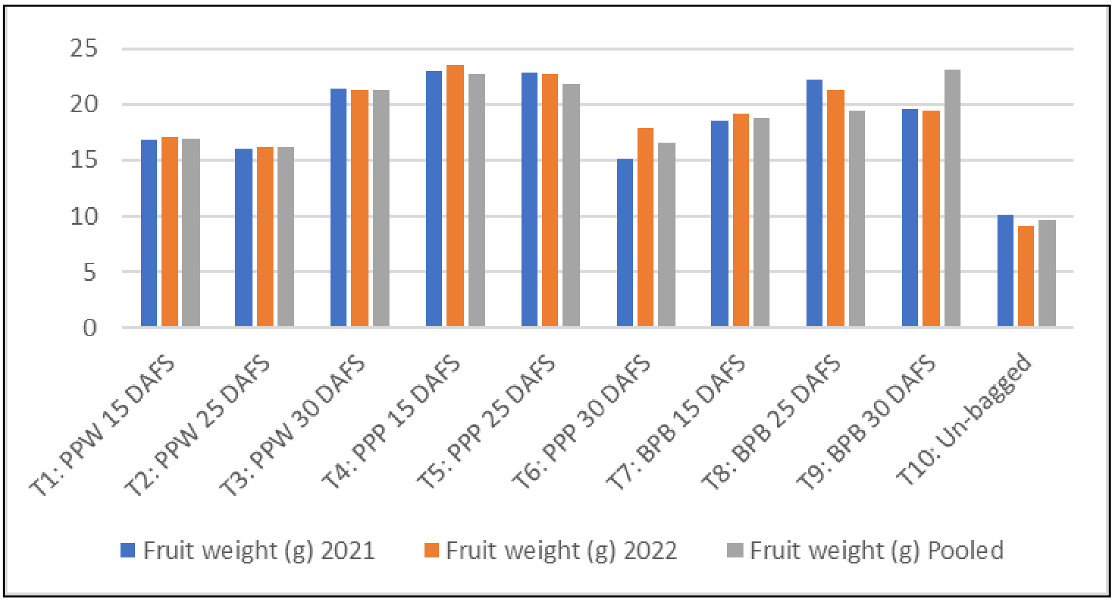



**Fig 4.20 Fruit weight variation in fruits under different bagging materials**

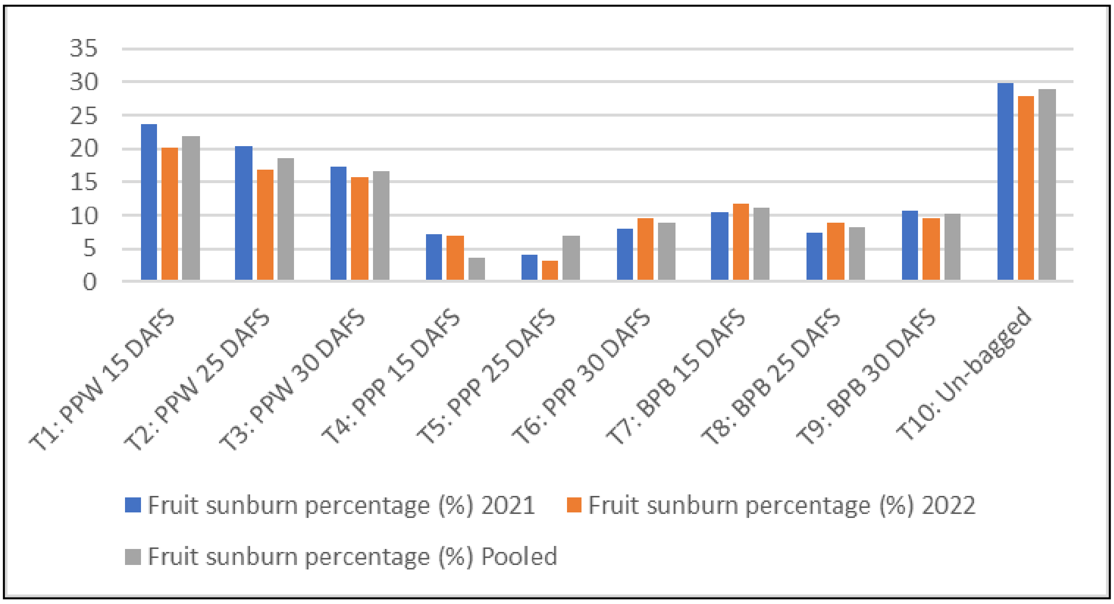



**Fig 4.21 Incidence of fruit sunburn under different bagging treatments**

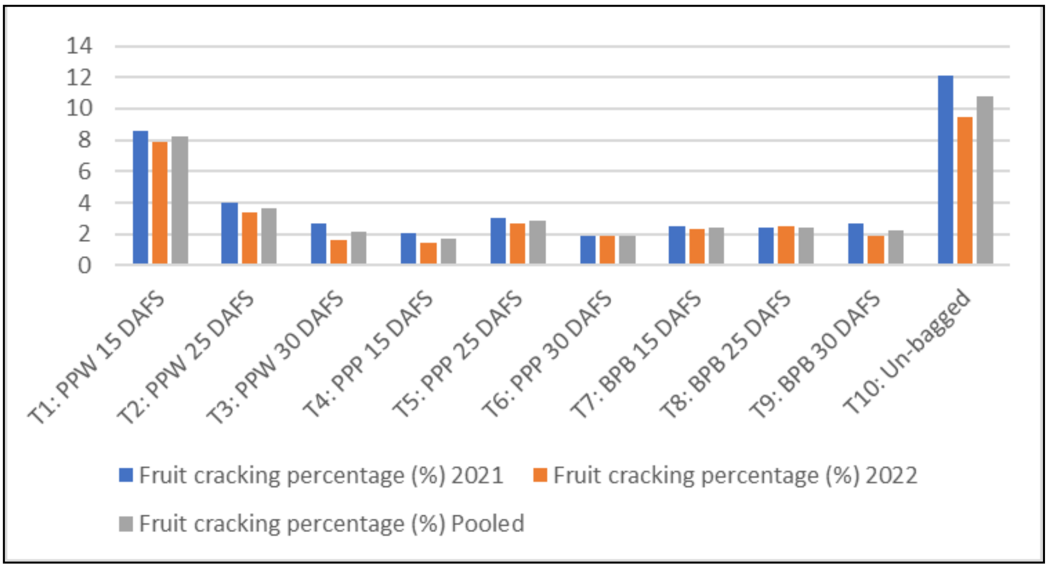



**Fig 4.22 Fruit cracking percentage under different bagging treatments**

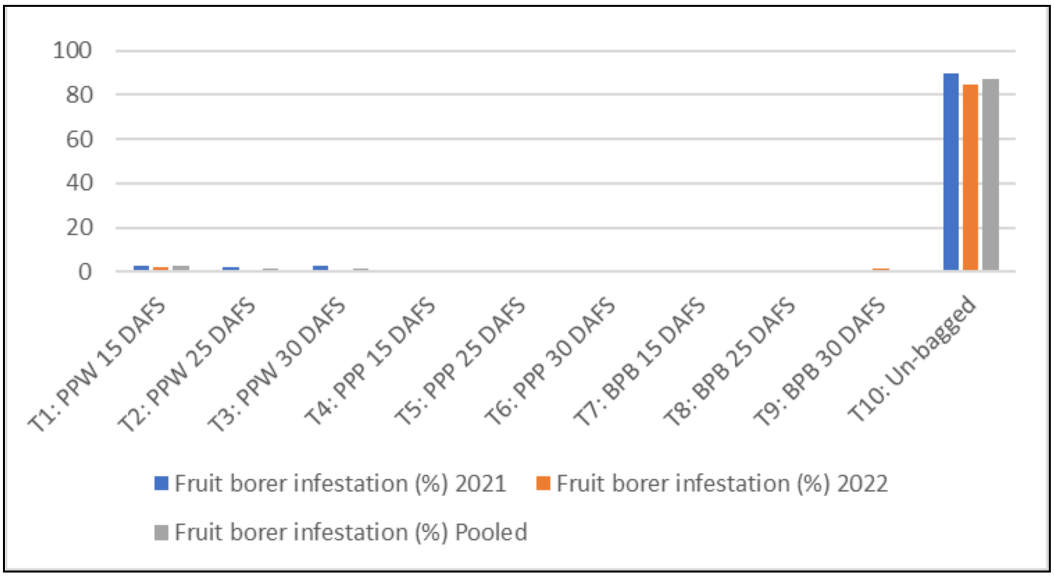



**Fig 4.23 Effect of bagging on fruit borer infestation in litchi**

**Table. 4.9. Effect of various bagging materials on fruit quality attributes**

| Treatments | Fruit colour | Fruit weight (g) | | | Fruit sunburn percentage (%) | | | Fruit cracking percentage (%) | | | Fruit borer infestation (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| **$T_1$: PPW 15 DAFS** | Purple red | 16.84 | 17.06 | 16.95 | 23.67 | 20.16 | 21.91 | 8.54 | 7.87 | 8.20 | 2.67 | 2.19 | 2.43 |
| **$T_2$: PPW 25 DAFS** | Moderate Purple Red A | 16.09 | 16.23 | 16.16 | 20.42 | 16.84 | 18.63 | 4.00 | 3.34 | 3.67 | 2.00 | 0.82 | 1.41 |
| **$T_3$: PPW 30 DAFS** | Deep purple red B | 21.43 | 21.26 | 21.34 | 17.38 | 15.81 | 16.59 | 2.67 | 1.58 | 2.12 | 2.66 | 0.00 | 1.33 |
| **$T_4$: PPP 15 DAFS** | Deep purple red B | 22.92 | 23.50 | 22.75 | 7.09 | 6.87 | 3.59 | 2.03 | 1.40 | 1.71 | 1.08 | 0.00 | 0.54 |
| **$T_5$: PPP 25 DAFS** | Moderate Purple Red A | 22.84 | 22.66 | 21.77 | 4.00 | 3.18 | 6.98 | 3.00 | 2.64 | 2.82 | 0.53 | 0.00 | 0.26 |
| **$T_6$: PPP 30 DAFS** | Deep purple red B | 15.12 | 17.93 | 16.52 | 7.97 | 9.66 | 8.81 | 1.87 | 1.92 | 1.89 | 1.00 | 0.00 | 0.50 |
| **$T_7$: BPB 15 DAFS** | Moderate Purple Red A | 18.54 | 19.12 | 18.83 | 10.38 | 11.66 | 11.02 | 2.54 | 2.34 | 2.44 | 0.02 | 0.04 | 0.03 |
| **$T_8$: BPB 25 DAFS** | Deep purple red B | 22.21 | 21.33 | 19.51 | 7.42 | 8.88 | 8.15 | 2.37 | 2.50 | 2.43 | 0.14 | 0.00 | 0.07 |
| **$T_9$: BPB 30 DAFS** | Deep purple red B | 19.59 | 19.44 | 23.12 | 10.60 | 9.65 | 10.12 | 2.67 | 1.85 | 2.26 | 1.00 | 1.22 | 0.56 |
| **$T_{10}$: Un-bagged** | Moderate Purple Red A | 10.20 | 9.16 | 9.68 | 29.80 | 27.95 | 28.87 | 12.07 | 9.48 | 10.77 | 89.67 | 84.66 | 87.16 |
| **SEm±** | - | **0.16** | **0.65** | **0.53** | **0.14** | **1.3** | **0.95** | **0.15** | **1.81** | **0.38** | **0.17** | **1.72** | **0.78** |
| **CD@5%** | - | **0.51** | **1.94** | **1.72** | **0.45** | **3.89** | **3.09** | **0.50** | **5.43** | **1.25** | **0.51** | **5.15** | **2.55** |

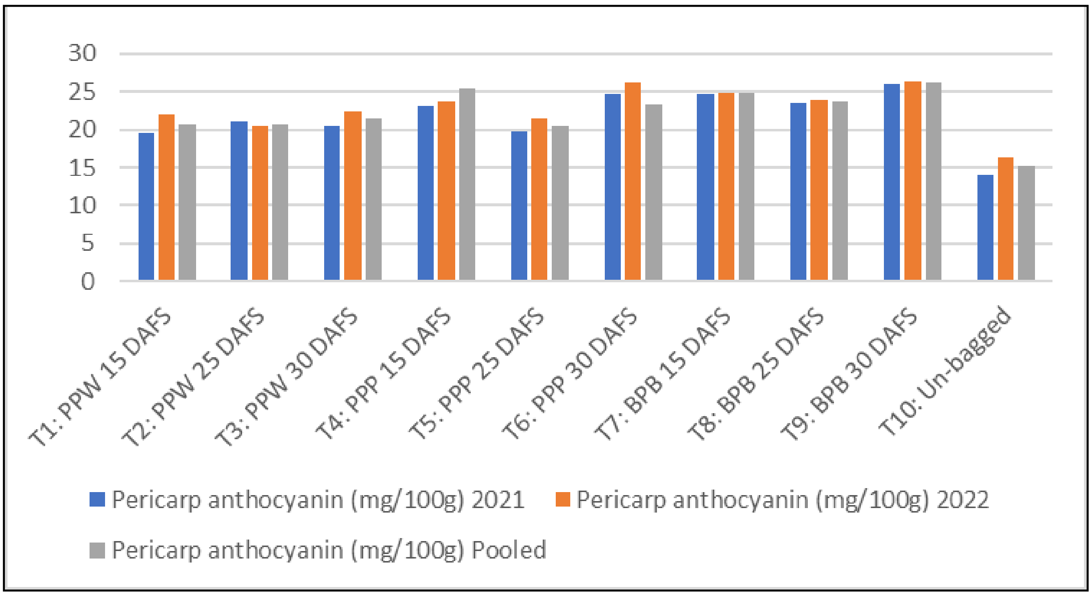



**Fig 4.24 Pericarp anthocyanin content in fruits covered under different bagging materials**

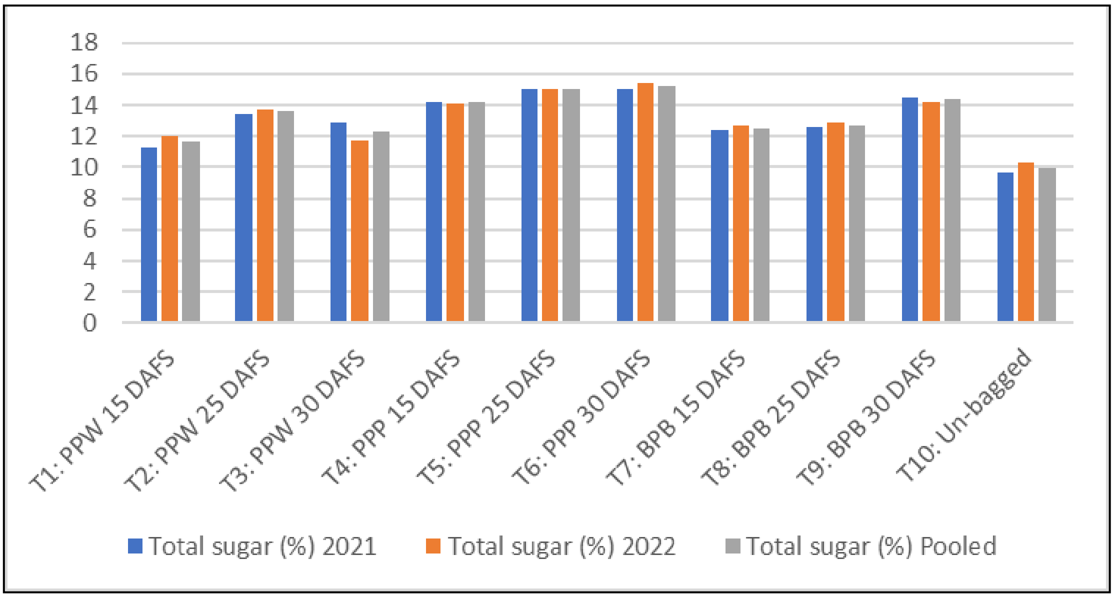



**Fig 4.25 Total sugar (%) in fruits covered under different bagging materials**

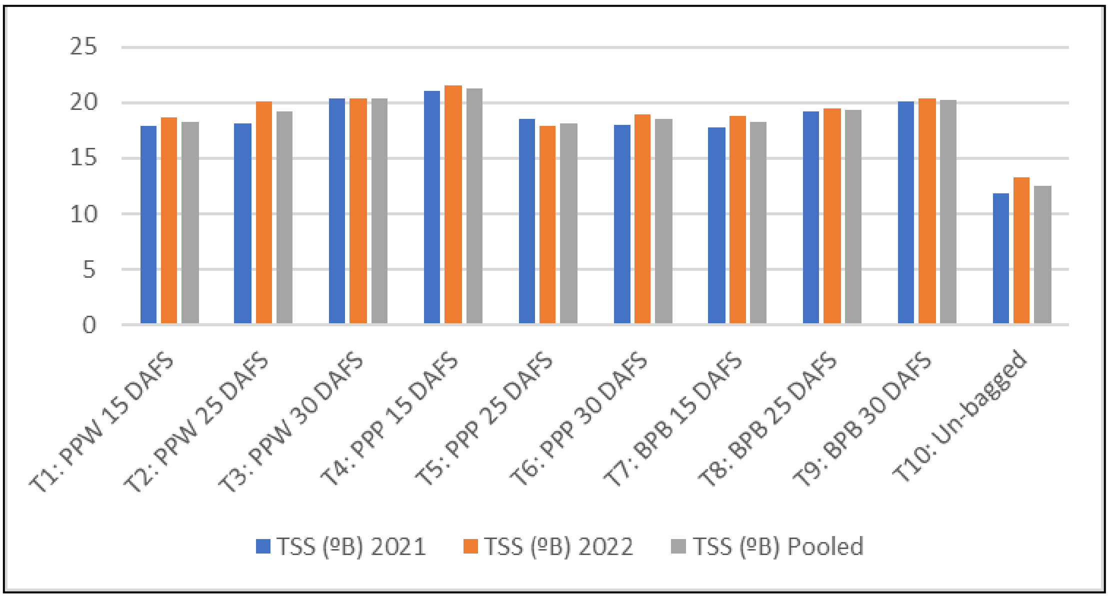



**Fig 4.26 Total Soluable Solids(ºB) in fruits covered under different bagging materials**

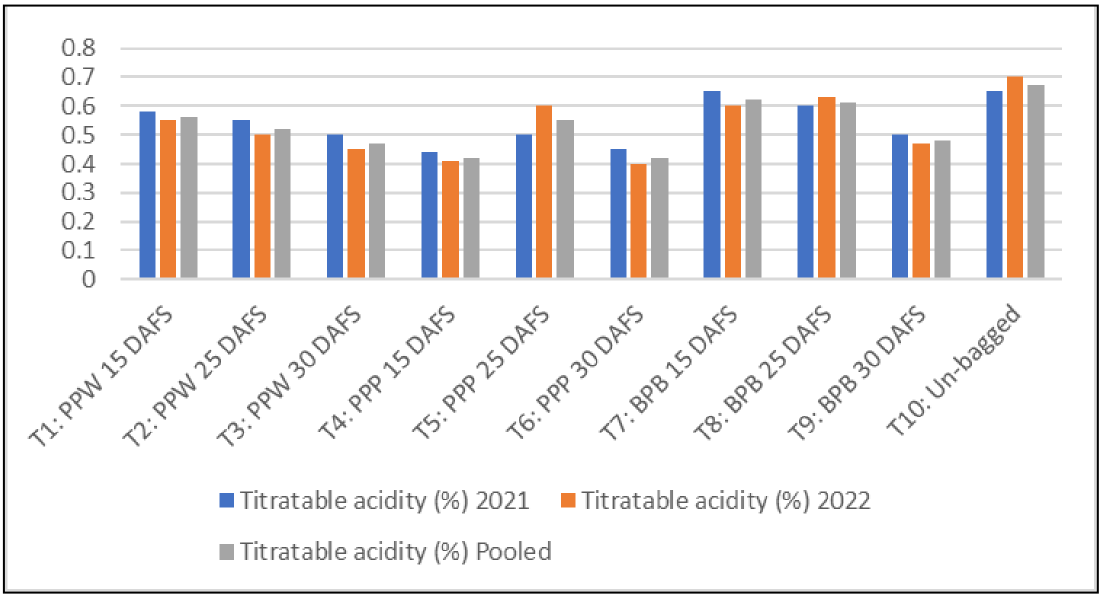



**Fig 4.27 Titratable acidity (%) in fruits covered under different bagging materials**

### 4.2.7 Total sugar (%)

Data on effect of different bagging time and bagging materials on total sugar in litchi was recorded and presented in table 4.10 and fig 4.25. It is evident that different bagging material and bagging time had a significant effect on total sugars (%) of litchi. The maximum total sugars of litchi fruit (15.21 %) were recorded in pink polypropylene bags in combination with 30 days after fruit set and minimum (9.96 %) in control (un-bagged) fruits. Which was at par with PPP 25 DAFS (15.01 %) and BPB 30 DAFS (14.34 %) respectively.

It is revealed from the given data that total sugar was significantly influenced by bagging experiment. This might be due to the breakdown of polysaccharides into water soluble sugars such as glucose, fructose and sucrose. This increase in total sugars of bagged fruits could be attributed to enhanced carbohydrate metabolism. The enhanced level of total sugars inside the bagged fruits might be due to enzymatic activity like sucrose synthase and sucrose phosphate synthase. The sucrose synthase is an enzyme, plays a major role in sucrose decomposition. The activity of sucrose synthase in bagged fruits increases during fruit development and found higher than unbagged fruits. These results are in conformity with the results of Harhash and Al-Obeed (2010) in date palm and Shinde *et al*. (2015) in mango.

### 4.2.8 Total Soluble Solids (°B)

The perusal of data given in table 4.10 and fig 4.26 revealed that there was significant effect of different bagging materials on T.S.S. of litchi fruits. The increases in T.S.S. of litchi fruit vary from 12.52 to 21.30 °Brix. The maximum T.S.S. (21.30 °Brix) was recorded in litchi fruits bagged with pink polypropylene bags in combination with 15 days after fruit set followed by white polypropylene bags (20.39 °Brix) and brown paper bags (20.26 °Brix) in combination with 30 days after fruit set and minimum was in unbagged fruits (12.52 °Brix).

These research findings are supported by Chand *et al*., (2020) total soluble solids in fruits were recorded significantly higher by bagging and was reported to be highest in treatment PPP at 15 DAFS (19.23 $^{o}$Brix) and PPP at 30 DAFS (18.48 $^{o}$Brix) in 2017.

Pre-harvest fruit bagging is a physical protection technique that affects the qualitative character of the fruit by changing the micro-environment inside the fruit growth activities during development (Son and Lee, 2008). The covered panicles had more total soluble solids than the unbagged, because the higher temperature under the bags favoured the conversion of starch into sugars. Data regarding increase in total soluble solids by bagging had been reported by several workers *viz*., Harhash and Al-Obeed (2010) in date palm and Debnath and Mitra (2008) in litchi reported that fruit bagging improved total soluble solids.

### 4.2.9 Titratable acidity (%)

It is evident from the data presented in table 4.10 and fig 4.27 that there were significant effects of different bagging materials on titratable acidity of litchi fruits. The acidity varied from 0.42 to 0.67 %. Minimum acidity (0.42 %) was recorded in litchi fruit bagged with pink polypropylene bags in combination with 15 days after fruit set and maximum (0.67 %) in unbagged fruits *i.e*., in control.

From the above results, a significant decrease in acidity was observed in bagged fruits as compared to control. This can be explained as the harvesting of bagged as well as unbagged fruits was taken at the same date and bagging resulted in early maturation of fruits due to improved micro-climate. Thus, acidity decreases with maturation of fruits with exception of banana and pineapple. Lower acidity may be due to utilization of organic acids in metabolic activity like respiration and biodegradable process (Ulrich, 1970). These findings are in conformity with the findings of Wu *et al*. (2009), Ni *et al*. (2011), Singh *et al*. (2007) who also found the highest acidity content in open condition compare to bagged fruits in guava. Chand *et al*., (2020) also reported that acidity of litchi fruits was observed minimum *i.e*., 0.26 percent in PPP at 30 DAFS and maximum acidity was recorded in un-bagged fruits 0.31 percent in the year 2017.

**4.2.10 TSS: acid ratio**

Data furnished in table 4.10 and fig 4.28 indicates that there was a significant effect of different bagging materials and bagging time on the TSS: acid ratio on litchi fruits. The maximum TSS: acid ratio of litchi fruit (50.34) was recorded in pink polypropylene bags in combination with 15 days after fruit set whereas, it was minimum in unbagged fruits (18.53). Which was at par with PPP 30 (43.68) DAFS.

From the above findings, it has been observed that TSS/acid ratio was appreciably influenced by bagging at days after fruit set and bagging materials. The TSS/acid ratio higher in bagged fruit might be due to higher total soluble solids and lower rate of acidity. These results are in conformity with the results of Debnath and Mitra (2008) and Meena *et al*. (2016). These findings are also in agreement with those reported by Wanichkul and Subrugroeng (2011) in carambola, Ma *et al*. (2009) in peach and Shah *et al*. (2020) in litchi.

**4.2.11 Mean temp of microclimate inside bags (˚C)**

The perusal of data given in table 4.11 and fig 4.29 revealed that there was significant effect of different bagging materials on mean temp of microclimate inside bags. The increases in temp of inside bags vary from 34.99 to 37.08 ˚C. The maximum temp (37.08 ˚C) was recorded in bagged with pink polypropylene bags followed by white polypropylene bags (36.35 ˚C) and minimum was in brown paper bags (34.99 ˚C).

Similar findings by Debnath and Mitra (2008) reported that the microclimate temperature inside bags increased by 1.36 to 1.63°C due to cellophane paper bags but it decreased by 1.30 and 1.38°C due to brown paper bag and news paper bag, respectively.

### 4.2.12 Mean RH of microclimate inside bags (%)

It is evident from the data presented in table 4.11 and fig 4.30 that there was significant effect of different bagging materials on mean relative humidity of microclimate inside bags. The increases in RH of inside bags vary from 27.09 to 31.71 %. The maximum RH (31.71 %) was recorded in bagged with brown paper bags and minimum was in un-bagged treatment (27.09 percent).

These research findings are supported by Purbey and kumar (2015) mean relative humidity inside bags are shown highest in butter paper bags (41.67 %) compare to unbagged treatment (33.25 %). Debnath and Mithra (2008) reported that irrespective of type and colour of bagging materials, relative humidity (RH) of microclimate increased by 1.58 to 2.12% due to bagging. Increase in RH was more for news-paper and brown paper bags compared with cellophane paper bags.

### 4.2.13 Light intensity of microclimate inside bags (100 lux)

Data on effect of different bagging materials on light intensity of microclimate inside bags was recorded and presented in table 4.11 and fig 4.31. The range of light intensity inside bags vary from 31.43 to 216.99 hundred lux. The maximum light intensity (216.99 hundred lux) was recorded in un-bagged treatment followed by white polypropylene bags (202.06 hundred lux) and minimum was in brown paper bags (31.43 hundred lux).

Debnath and Mitra (2008) resulted significant effect of bagging on reduced the light intensity of microclimate compared with outside environment (71.2 thousand lux). Light intensity varied between 3.82 and 6.85 thousand lux due to different colours of cellophane paper bags but it was markedly reduced (< 1.55 thousand lux) due to brown paper and news paper bags.

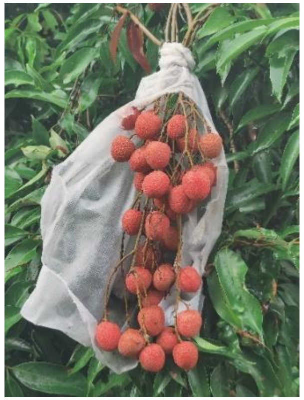
### 4.2.14 Growing degree days (˚Days)

Data given in table 4.11 and fig 4.32 indicates that there was significant effect of different bagging material on fruit growing dree days. Minimum dree days (1,990.17 ˚ Days) was observed in brown paper bags and maximum was observed in pink polypropylene bag fruits 2,115.50 ˚Days followed by white polypropylene bags (2,060 ˚Days). The un-bagged (control) fruits attained commercial maturity with accumulated heat units (GDD) of 1,955.17 °Days.

Debnath and Mitra (2008) resulted significant effect of bagging on the accumulated heat units due to microclimate of different bagging treatments varied between 1377.55 and 1594.87°C. Bagging of fruits in semi-transparent-cellophane paper bag caused commercial maturity of fruit by 62 days with the lowest GDD of 1377.55°C.

**PPW 15 DAFS**

**PPW 25 DAFS**



**PPW 30 DAFS**

**PPP 15 DAFS**

**PPP 25 DAFS**

**PPP 30 DAFS**

**BPB 15 DAFS**

**BPB 25 DAFS**

**BPB 30 DAFS**

**Control (Un- bagged)- Fruits**

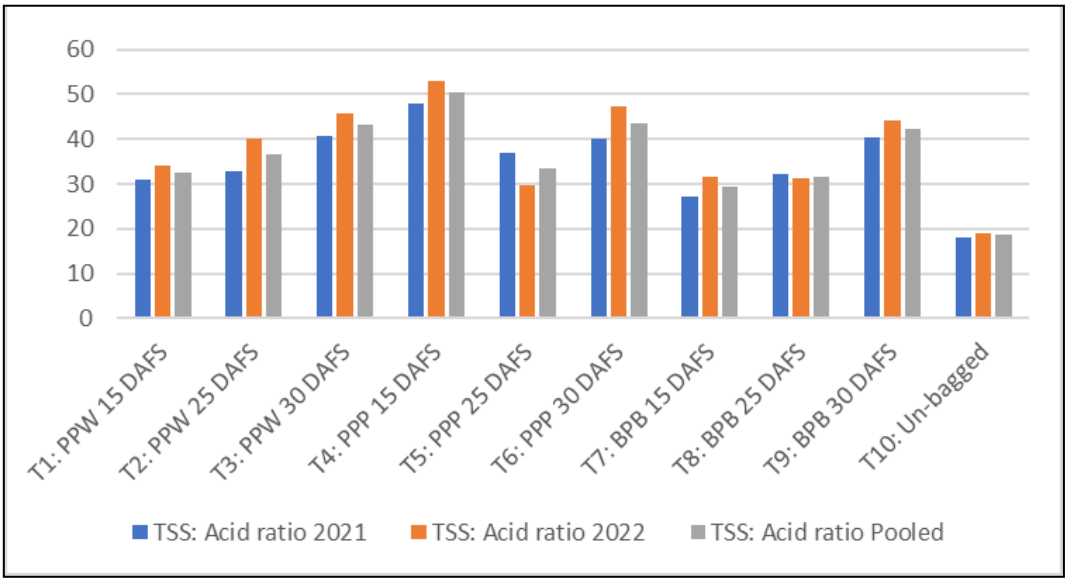



**Fig 4.28 TSS: acid ratio in fruits covered under different bagging materials**

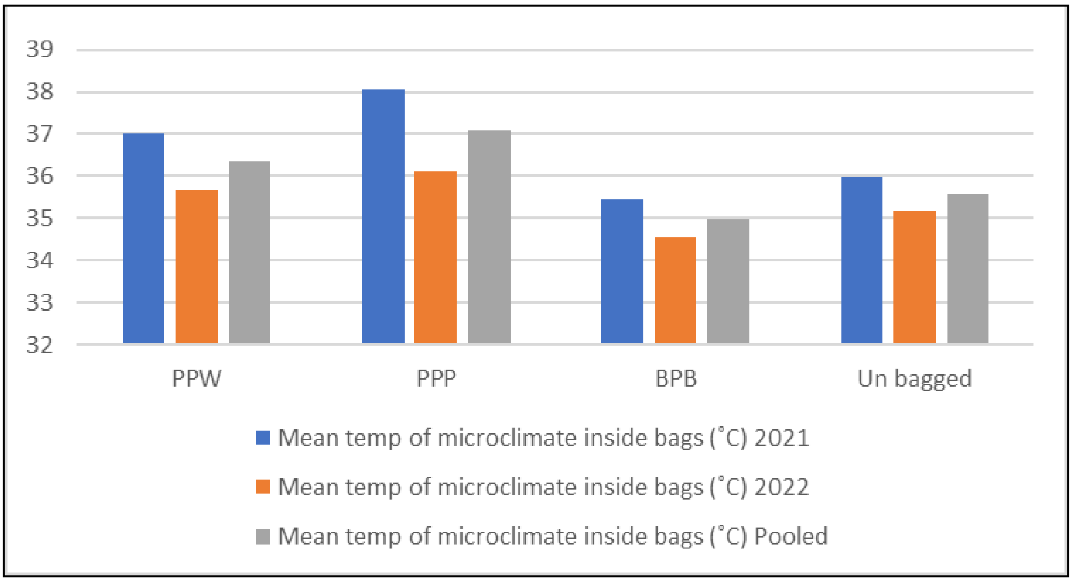



**Fig 4.29 Mean temperature(ºC) of microclimate inside bags**

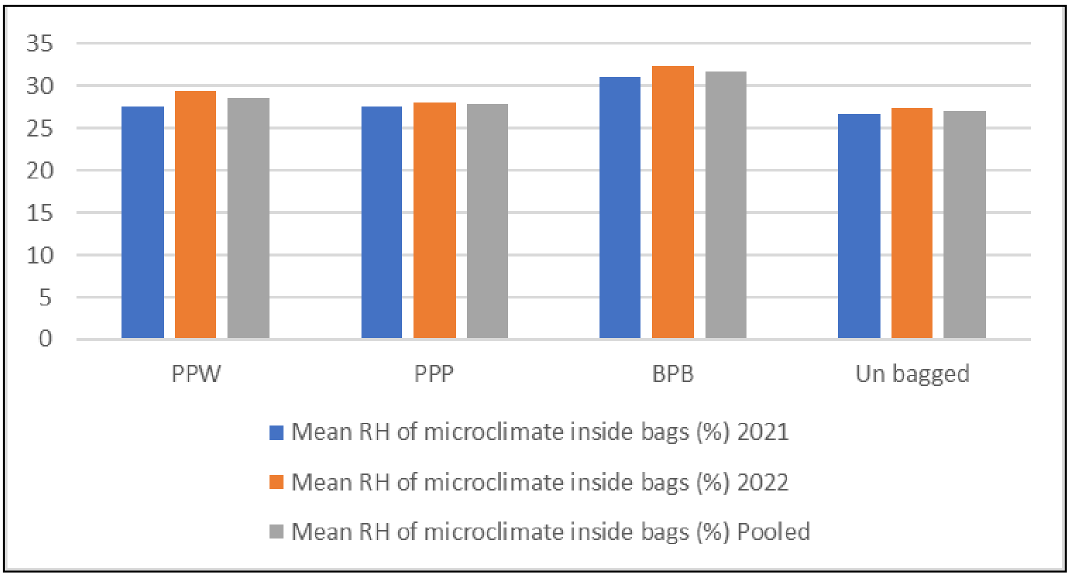



**Fig 4.30 Mean Relative humidity (%) of microclimate inside bags**

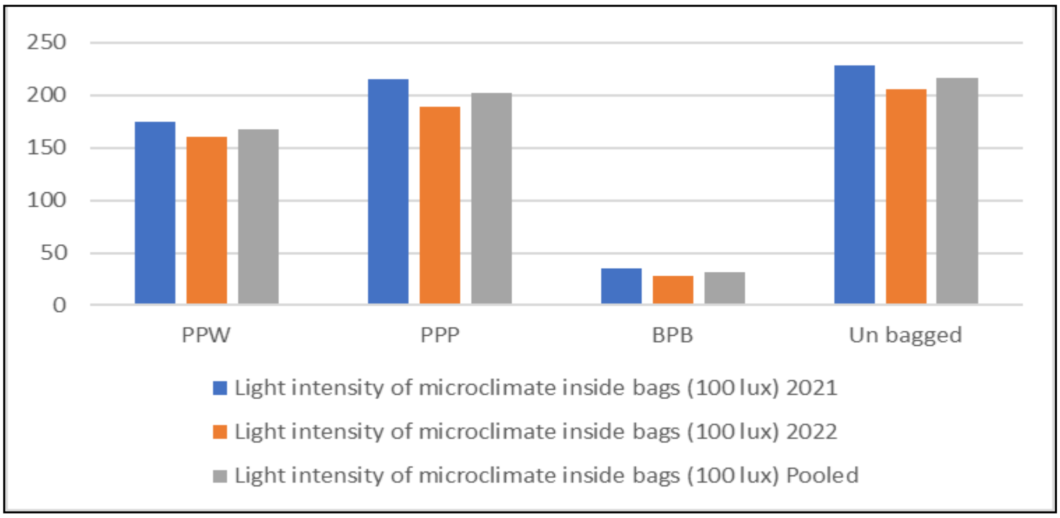



**Fig 4.31 Light intensity(lux) inside bags**

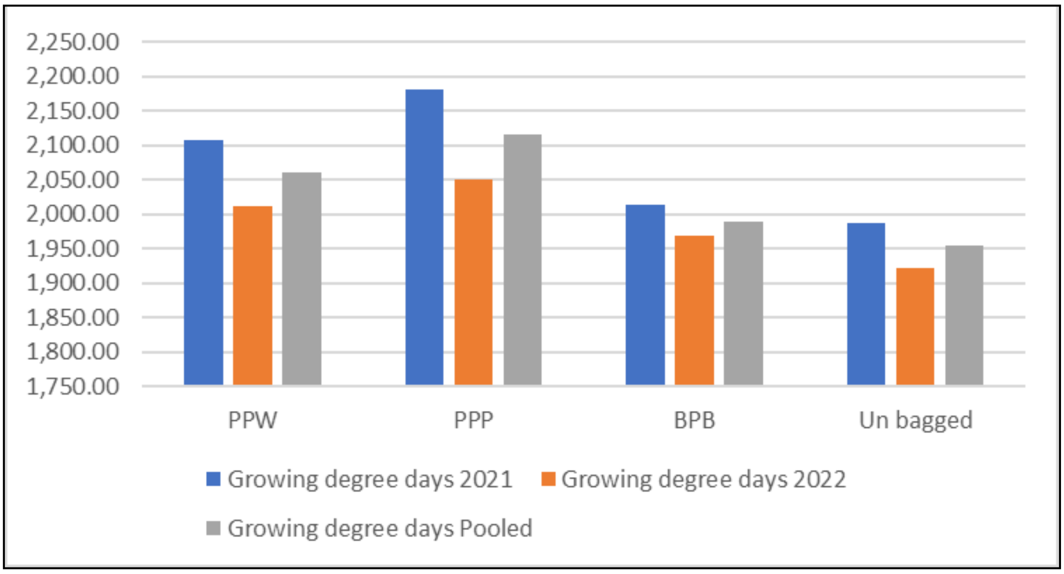



**Fig 4.32 Mean growing degree days of fruits covered under different bagging materials**

**Table. 4.10. Effect of various bagging materials on bio chemical parameters of litchi fruits**

| Treatments | Pericarp anthocyanin (mg/100g) | | | Total sugar (%) | | | TSS (ºB) | | | Titratable acidity (%) | | | TSS: acid ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** |
| **$T_1$: PPW 15 DAFS** | 19.45 | 21.99 | 20.72 | 11.29 | 12.00 | 11.64 | 17.89 | 18.65 | 18.27 | 0.58 | 0.55 | 0.56 | 30.84 | 34.13 | 32.48 |
| **$T_2$: PPW 25 DAFS** | 21.02 | 20.43 | 20.72 | 13.48 | 13.76 | 13.62 | 18.14 | 20.10 | 19.12 | 0.55 | 0.50 | 0.52 | 32.98 | 40.20 | 36.59 |
| **$T_3$: PPW 30 DAFS** | 20.44 | 22.34 | 21.39 | 12.90 | 11.72 | 12.31 | 20.38 | 20.40 | 20.39 | 0.50 | 0.45 | 0.47 | 40.76 | 45.72 | 43.24 |
| **$T_4$: PPP 15 DAFS** | 23.12 | 23.66 | 25.39 | 14.23 | 14.09 | 14.16 | 21.06 | 21.55 | 21.30 | 0.44 | 0.41 | 0.42 | 47.86 | 52.83 | 50.34 |
| **$T_5$: PPP 25 DAFS** | 19.70 | 21.39 | 20.54 | 15.00 | 15.03 | 15.01 | 18.48 | 17.90 | 18.19 | 0.50 | 0.60 | 0.55 | 36.96 | 29.83 | 33.39 |
| **$T_6$: PPP 30 DAFS** | 24.61 | 26.18 | 23.39 | 15.01 | 15.41 | 15.21 | 18.00 | 18.95 | 18.47 | 0.45 | 0.40 | 0.42 | 40.00 | 47.37 | 43.68 |
| **$T_7$: BPB 15 DAFS** | 24.63 | 24.87 | 24.75 | 12.37 | 12.64 | 12.50 | 17.68 | 18.85 | 18.26 | 0.65 | 0.60 | 0.62 | 27.20 | 31.65 | 29.42 |
| **$T_8$: BPB 25 DAFS** | 23.51 | 23.79 | 23.65 | 12.54 | 12.83 | 12.68 | 19.23 | 19.50 | 19.36 | 0.60 | 0.63 | 0.61 | 32.05 | 31.24 | 31.64 |
| **$T_9$: BPB 30 DAFS** | 25.94 | 26.28 | 26.11 | 14.49 | 14.20 | 14.34 | 20.12 | 20.40 | 20.26 | 0.50 | 0.47 | 0.48 | 40.24 | 44.25 | 42.24 |
| **$T_{10}$: Un-bagged** | 14.14 | 16.36 | 15.25 | 9.64 | 10.29 | 9.96 | 11.80 | 13.25 | 12.52 | 0.65 | 0.70 | 0.67 | 18.15 | 18.92 | 18.53 |
| **SEm±** | **0.15** | **0.2** | **0.51** | **0.16** | **0.75** | **0.27** | **0.16** | **0.49** | **0.37** | **0.01** | **0.04** | **0.02** | **0.18** | **4.10** | **2.17** |
| **CD@5%** | **0.51** | **0.65** | **1.68** | **0.55** | **2.45** | **0.89** | **0.52** | **1.59** | **1.20** | **0.03** | **0.15** | **0.08** | **0.56** | **13.30** | **7.04** |

**Table. 4.11. Effect of various bagging materials on mean microclimate available inside bag**

| Treatments | Mean temp of microclimate inside bags (˚C) | | | Mean RH of microclimate inside bags (%) | | | Light intensity of microclimate inside bags (100 lux) | | | Growing degree days (º Days) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** | **2021** | **2022** | **Pooled** |
| **PPW** | 37.03 | 35.67 | 36.35 | 27.62 | 29.37 | 28.49 | 174.62 | 160.37 | 167.49 | 2,108.16 | 2,011.85 | 2,060.00 |
| **PPP** | 38.06 | 36.10 | 37.08 | 27.56 | 28.12 | 27.84 | 215.25 | 188.87 | 202.06 | 2,181.56 | 2,049.45 | 2,115.50 |
| **BPB** | 35.43 | 34.55 | 34.99 | 31.06 | 32.37 | 31.71 | 35.12 | 27.75 | 31.43 | 2,012.9 | 1,968.85 | 1,990.17 |
| **Un bagged** | 35.97 | 35.17 | 35.57 | 26.75 | 27.43 | 27.09 | 228.62 | 205.37 | 216.99 | 1,987.74 | 1,922.6 | 1,955.17 |
| **SEm±** | **0.19** | **0.17** | **0.26** | **0.67** | **0.65** | **0.27** | **3.39** | **3.85** | **4.32** | **1.13** | **2.04** | **19.19** |
| **CD@5%** | **0.62** | **0.55** | **1.24** | **2.18** | **2.11** | **1.29** | **11.02** | **12.50** | **20.16** | **5.28** | **8.69** | **89.47** |

### 4.3 To study the effect of plant bio regulators and chemicals on flowering and fruiting of litchi cv. Shahi

The data pertaining to the effect of different bio regulators and chemicals on improvement of flowering and fruiting intensity of litchi were statistically analysed and the results are presented in the tables, justified with proper scientific reasons and supported by possible literature and discussed under the following appropriate headings:

#### 4.3.1 Date of panicle initiation

The date of panicle initiation as observed during the year 2021 and 2022 are presented in table 4.12, which revealed that among all the treatments, earliest panicle initiation was observed in treatment $T_3$ (ethrel @ 400 ppm) initiated the panicle initiation at the earliest *i.e.*, on 29$^{th}$ January and 27$^{th}$ January, respectively during the year 2021 and 2022 followed by $T_2$ ($K_2HPO_4$ @1%) *i.e.*, on 30$^{th}$ January during both the years, respectively. In general, all the treatments initiated early panicle emergence as compared to $T_4$ ($GA_3$ @ 100 ppm) *i.e.*, on 27$^{th}$ February and 25$^{th}$ February during both the years, respectively.

Similar results had been reported by Dongariyal (2017) who observed early panicle initiation in litchi on 16$^{th}$ February in treatment $T_1$ (ethrel @ 400 ppm) and $T_2$ ($KNO_3$ @ 1%) whereas in $T_8$ ($K_2HPO_4$ @ 1% + $KNO_3$ @ 1%) and $T_{13}$ (control), first panicle emerged on 19$^{th}$ February. The results obtained are also supported by the findings of Mandal *et al*. (2014) who reported earliest panicle emergence by application of ethrel. Rambun (2001) also found that application of ethephon as a foliar application significantly advanced the flowering and panicle initiation in litchi cv. Mauritius. This might be due to early maturation of shoots that induces early panicle initiation and lateral expansion and promotes compact flower panicles.

**$KNO_3$ 1%**

**$K_2HPO_4$ 1%**

**Ethrel 400ppm**

**$GA_3$ 100 ppm**

**$KNO_3$ 1% + $K_2HPO_4$ 1%**

**$KNO_3$ 1% + Ethrel 400ppm**

**$KNO_3$ 1% + $GA_3$ 100 ppm**

**$K_2HPO_4$ 1% + Ethrel 400ppm**

**$K_2HPO_4$ 1% + $GA_3$ 100 ppm**

**No- spray**

**PLATE 4.11. Flowering percentage of different PGRs & chemical treatments**

### 4.3.2 Advancement of flowering (days)

The data on advancement of flowering presented in table 4.12 and fig 4.33 showed that all the treatments had a significant effect on early flowering as compared to control in cv. shahi during the year 2021 and 2022. The earliest flowering (9 days) was recorded in Treatment $T_3$ (ethrel @ 400 ppm) fallowed by $T_2$ ($K_2HPO_4$ @1%) and $T_1$ ($KNO_3$ @ 1%) *i.e.*, 8 and 6 days early than the control (no- spray). In the treatment $T_4$ ($GA_3$ @ 100 ppm) 2 days delayed flowering occurred than control.

Similar result was observed by Prasad *et al*. (2018) foliar spray of ethrel at 400 ppm advanced the flowering by 5.33 days followed by 4.67 days advancement with foliar spray of $K_2HPO_4$ (1%) + $KNO_3$ (1%) and $KH_2PO_4$ (1%) + $KNO_3$ (1%). Dalal *et al*. (2005) who reported application of $KNO_3$ @ 1.5 % advanced the flowering by 4-5 days in mango cv. Pairy. Our results are also supported by work of Maloba *et al*. (2014) who found advancement in flowering by treating the trees with $KNO_3$ in mango cv. Ngowe. Tandel and Patel (2011) also reported application of $KNO_3$ @ 2% advanced the flowering in mango cvs. Alphonso, Kesar and Rajapuri.

### 4.3.3 Total flowers per panicle (number)

The data presented in table 4.12 reveals that total number of flowers per panicle varied from 255.56 to 881.03 with significant differences among the treatments. However maximum number of flowers (881.03) were observed in $T_2$ ($KH_2PO_4$ @ 1 %) treatment whereas minimum flowers (255.56) was reported in control (no-spray). On the other hand, all the treatments had a significant effect on total number of flowers as compared to control.

The results obtained are in support with the findings of Mitra and Sanyal (2001) who reported that application of $KNO_3$ induced flowering in litchi cv. Bombai. The results are also supported by Maloba *et al*. (2014) who reported increased number of flowers per panicle by the application of $KNO_3$ in mango cv. Ngove. Increase in number of flowers/panicle due to different forms of potassium might be due to increased concentrations of zeatin or zeatin riboside which are flower induction promoters present in it (Guevara *et al*. 2012).

### 4.3.4 Sex ratio (F-M %)

The data depicted in table 4.12 and fig 4.34 shows a significant difference among all the treatments regarding sex ratio. The sex ratio (female: male) varied from 0.77 to 6.66 per cent during the both years in different treatments.

During 2020-21, sex ratio was maximum (6.78) with $T_4$ ($GA_3$ @ 100ppm) significantly higher than the rest of the treatments. It was minimum (1.34) with $T_{10}$ (no spray). A similar trend was recorded during 2021-22, where sex ratio was maximum (6.54) with $T_4$ ($GA_3$ @ 100ppm). It was minimum (0.20) with $T_{10}$ (no spray). The pooled data revealed that among all the treatments minimum sex ratio (0.77) was observed in control (no-spray) whereas, $T_4$ ($GA_3$ @ 100ppm) recorded the maximum sex ratio (6.66). Minimum sex ratio means highest male flower per panicle and maximum sex ratio means lowest male flower per panicle.

Kumar *et al*., (2017) reported number of female flowers/panicle was maximum (86.33) trees sprayed with $KH_2PO_4$ (1%). Spray of ethrel (400 ppm) has least sex ratio due to very large no. of male flower per panicle (118.59) while control trees had lowest number of female flowers per panicles (36.50). The chemical treatment increased the percentage of hermaphrodite flowers over control, resulting in higher sex ratio, which might be due to the availability of more nutrients to the panicles (Oosthuyse, 1996).

### 4.3.5 Time taken to fruit set (days)

The data of time taken to fruit set shown in table 4.13 and fig 4.35 show that all the PGRs & chemicals significantly reduced the time taken to fruit set as compared to $T_4$ ($GA_3$ @ 100ppm) and $T_{10}$ (no spray). The time taken to fruit set by all the treatments varied from 22.50 to 34.50 days. Among all the treatments minimum time (22.50 days) taken to fruit set was recorded in $T_3$ (ethrel @ 400 ppm) followed by $T_2$ ($KH_2PO_4$ @ 1 %) *i.e.*, 23.50 days, whereas treatments $T_4$ ($GA_3$ @ 100ppm) took maximum time (34.50 days) for fruit set.

Similar results related to ethrel was observed by Mandal *et al*. (2014) who suggested that the foliar application of ethrel reduced the time period for fruit setting by 4-5 days and induced the higher percentage of fruit set than control in litchi. Prasad *et al*. (2018) reported that minimum time (24 days) taken for fruit set was observed in the foliar spray of $K_2HPO_4$ (1%) + $KNO_3$ followed by $KH_2PO_4$ (1%) + $KNO_3$ (1%).

### 4.3.6 Days to mature after fruit set

As shown in table 4.13 and fig 4.36 it is clear that the days taken to maturity among all the treatments varied from 50.50 to 61.00 days. The minimum days for maturity (50.50 days) was observed in $T_3$ (ethrel @ 400 ppm) and $T_2$ ($K_2HPO_4$ @ 1%) treatments whereas the $T_4$ ($GA_3$ @ 100ppm) reported maximum days for maturity (61.00 days).

Dongariyal, (2017) recorded the minimum days for maturity (51 days) was observed in $T_1$ (ethrel @ 400 ppm) and $T_7$ ($KH_2PO_4$ @ 2%) treatments whereas the $T_{13}$ (control) reported maximum days for maturity.

**Pistillate flowers**

**Male flowers**

**Bee vector**

**PLATE 4.12. Male, female flowers and pollinators in litchi cv. Shahi**

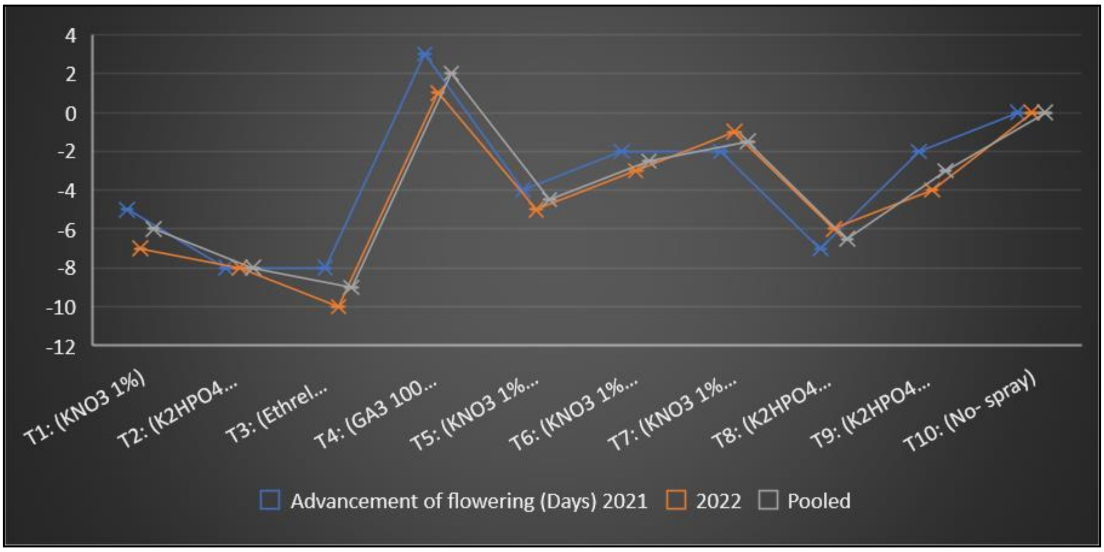



**Fig 4.33 Advancement of flowering (Days) in different PGRs & chemical treatments**

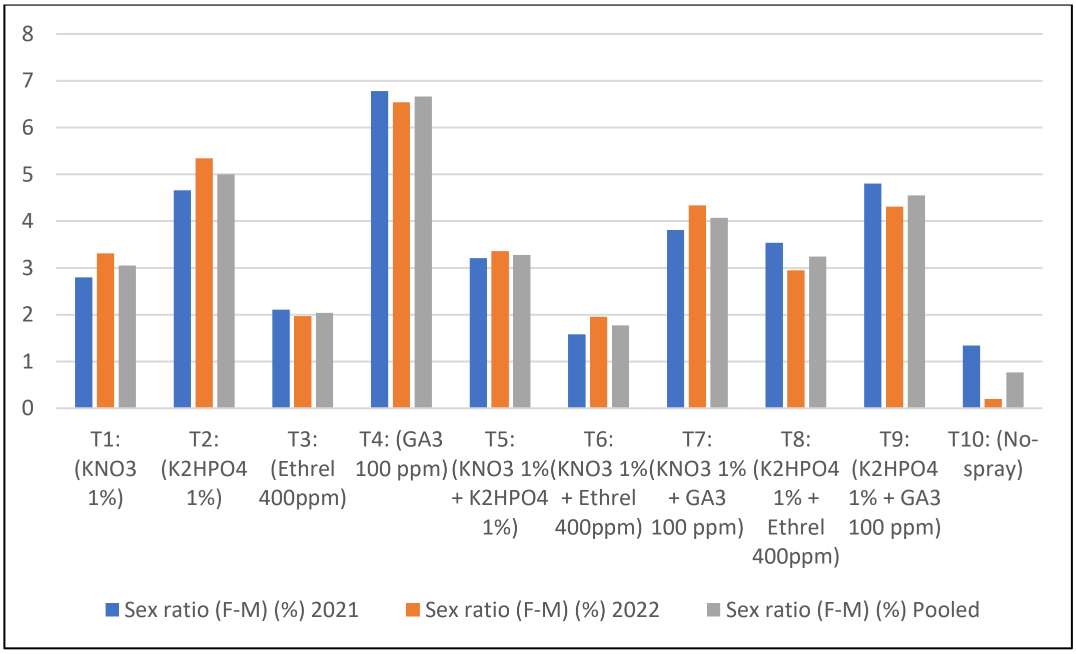



**Fig 4.34 Sex ratio (F:M) of different PGRs & chemicals treatments**

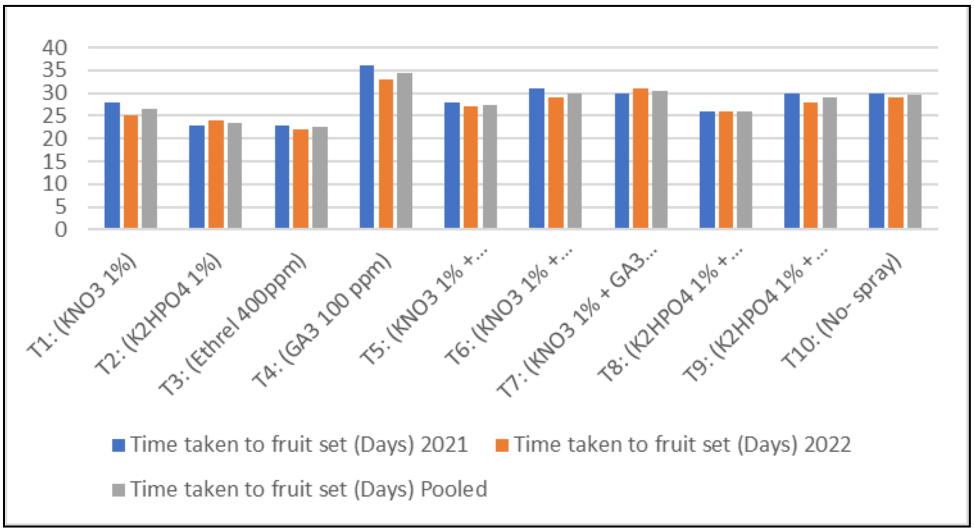



**Fig 4.35 Time taken to fruit set (Days) of different treatments**

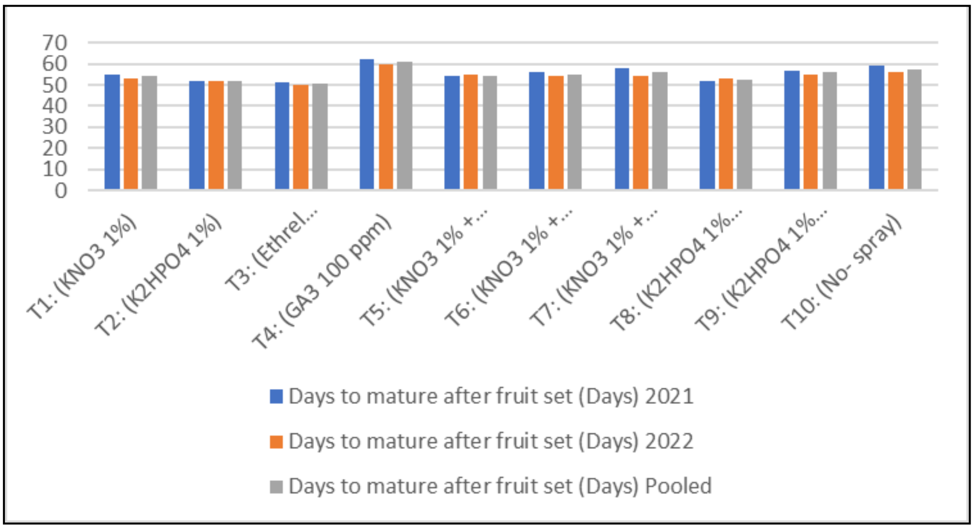



**Fig 4.36 Days to mature after fruit set under different treatments**

**Table. 4.12. Effect of PGRs & chemicals on flowering traits**

| Treatments | Date of Panicle initiation (Date) | | | Advancement of flowering (Days) | | | Total flowers/ panicle (number) | | | Sex ratio (F-M) (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| $T_1$: ($KNO_3$ 1%) | 04.02.21 | 02.02.22 | 03-Feb | -5 | -7 | -6 | 420.26 | 582.66 | 501.46 | 2.80 | 3.31 | 3.05 |
| $T_2$: ($K_2HPO_4$ 1%) | 30.01.21 | 30.01.22 | 30-Jan | -8 | -8 | -8 | 875.92 | 886.14 | 881.03 | 4.66 | 5.34 | 5.00 |
| $T_3$: (Ethrel 400ppm) | 29.01.21 | 27.01.22 | 28-Jan | -8 | -10 | -9 | 850.67 | 811.33 | 831.00 | 2.11 | 1.97 | 2.04 |
| $T_4$: ($GA_3$ 100 ppm) | 27.02.21 | 25.02.22 | 26-Feb | +3 | +1 | +2 | 520.87 | 447.00 | 483.93 | 6.78 | 6.54 | 6.66 |
| $T_5$: ($KNO_3$ 1% + $K_2HPO_4$ 1%) | 06.02.21 | 05.02.22 | 05-Feb | -4 | -5 | -4.5 | 830.29 | 854.00 | 842.14 | 3.21 | 3.36 | 3.28 |
| $T_6$: ($KNO_3$ 1% + Ethrel 400ppm) | 15.02.21 | 12.02.22 | 13-Feb | -2 | -3 | -2.5 | 590.80 | 662.00 | 626.40 | 1.58 | 1.96 | 1.77 |
| $T_7$: ($KNO_3$ 1% + $GA_3$ 100 ppm) | 16.02.21 | 17.02.22 | 16-Feb | -2 | -1 | -1.5 | 643.27 | 606.36 | 624.81 | 3.81 | 4.34 | 4.07 |
| $T_8$: ($K_2HPO_4$ 1% + Ethrel 400ppm) | 09.02.21 | 12.02.22 | 10-Feb | -7 | -6 | -6.5 | 500.14 | 405.23 | 452.68 | 3.54 | 2.95 | 3.24 |
| $T_9$: ($K_2HPO_4$ 1% + $GA_3$ 100 ppm) | 23.02.21 | 20.02.22 | 22-Feb | -2 | -4 | -3 | 822.00 | 710.67 | 766.33 | 4.80 | 4.31 | 4.55 |
| $T_{10}$: (No- spray) | 20.02.21 | 22.02.22 | 21-Feb | 0 | 0 | 0 | 245.80 | 265.33 | 255.56 | 1.34 | 0.20 | 0.77 |
| **SEm±** | - | - | - | - | - | - | **1.32** | **52.86** | **41.42** | **0.16** | **0.31** | **0.29** |
| **CD@5%** | - | - | - | - | - | - | **4.30** | **158.27** | **134.39** | **0.52** | **0.94** | **0.95** |

**Table. 4.13. Effect of PGRs & chemicals on fruit parameters**

| Treatments | Time taken to fruit set (Days) | | | Days to mature after fruit set (Days) | | | Days to harvest after fruit set (Days) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| $T_1$: ($KNO_3$ 1%) | 28.00 | 25.00 | 26.50 | 55.00 | 53.00 | 54.00 | 66.00 | 65.00 | 65.50 |
| $T_2$: ($K_2HPO_4$ 1%) | 23.00 | 24.00 | 23.50 | 52.00 | 52.00 | 52.00 | 61.00 | 62.00 | 61.50 |
| $T_3$: (Ethrel 400ppm) | 23.00 | 22.00 | 22.50 | 51.00 | 50.00 | 50.50 | 59.00 | 60.00 | 59.50 |
| $T_4$: ($GA_3$ 100 ppm) | 36.00 | 33.00 | 34.50 | 62.00 | 60.00 | 61.00 | 72.00 | 68.00 | 70.00 |
| $T_5$: ($KNO_3$ 1% + $K_2HPO_4$ 1%)) | 28.00 | 27.00 | 27.50 | 54.00 | 55.00 | 54.50 | 62.00 | 63.00 | 62.50 |
| $T_6$: ($KNO_3$ 1% + Ethrel 400ppm) | 31.00 | 29.00 | 30.00 | 56.00 | 54.00 | 55.00 | 68.00 | 66.00 | 67.00 |
| $T_7$: ($KNO_3$ 1% + $GA_3$ 100 ppm) | 30.00 | 31.00 | 30.50 | 58.00 | 54.00 | 56.00 | 70.00 | 67.00 | 68.50 |
| $T_8$: ($K_2HPO_4$ 1% + Ethrel 400ppm) | 26.00 | 26.00 | 26.00 | 52.00 | 53.00 | 52.50 | 63.00 | 65.00 | 64.00 |
| $T_9$: ($K_2HPO_4$ 1% + $GA_3$ 100 ppm) | 30.00 | 28.00 | 29.00 | 57.00 | 55.00 | 56.00 | 66.00 | 64.00 | 65.00 |
| $T_{10}$: (No- spray) | 30.00 | 29.00 | 29.50 | 59.00 | 56.00 | 57.50 | 69.00 | 70.00 | 69.50 |
| SEm± | - | - | - | - | - | - | - | - | - |
| CD@5% | - | - | - | - | - | - | - | - | - |

### 4.3.7 Days to harvest after fruit set

The data on days taken to harvesting depicted in table 4.13 and fig 4.37 showed that all the treatments had a significant effect on advancement of harvesting date. Among all the treatments minimum days taken for harvesting (59.50 days) was observed in $T_3$ (ethrel @ 400 ppm) treatment, whereas the treatment $T_4$ ($GA_3$ @ 100ppm) recorded the maximum days for harvesting (70.00 days). The duration taken for harvesting in all the treatments varied from 59.50 to 70.00 days.

Dongariyal, (2017) recorded among all the treatments $T_1$ (ethrel @ 400 ppm) recorded the maximum advancement in harvesting (5 days) compared to control. Similar effect of ethrel regarding harvesting attributes was observed by Kacha *et al.* (2012) in phalsa and Venkatesan and Tamilmani (2013) in mango cv. Neelam.

### 4.3.8 Total sugar (%)

The data presented in table 4.14 and fig 4.38 shows that all the treatments significantly affected total sugar content. During 2020-21, total sugar per cent was maximum (21.87 %) in $T_4$ ($GA_3$ @ 100ppm) whereas it was minimum (10.00 %) with $T_1$ ($KNO_3$ @ 1%) treatment. A similar trend was recorded during 2021-22, where total sugar per cent was maximum (22.63 %) with $T_4$ ($GA_3$ @ 100ppm) whereas it was minimum (10.19 %) with $T_1$ ($KNO_3$ @ 1%) treatment. The pooled analysis of total sugar content indicated that maximum total sugar content (22.25 %) was found in treatment $T_4$ ($GA_3$ @ 100ppm) followed by $T_3$ (ethrel @ 400 ppm) (20.43 %). On the other hand, minimum total sugar content (10.09 % and 10.53 %) was found in treatment $T_1$ ($KNO_3$ @ 1%) and $T_{10}$ (no spray).

Sucrose, fructose and glucose are the main sugars present in the aril of litchi fruit. It seems that ethephon might have caused an increase in hydrolytic activities in the fruits which resulted in increased sugar content in this treatment.

Singh *et al.* (1987) reported that seed and fruit weight had strong positive correlation with total sugar, ascorbic acid, protein contents in litchi, while a significant negative correlation with acidity and phenol content. Similar results were also obtained by Bal *et al*. (1992). This might be due to the conversion of sugars and other polysaccharides into soluble sugars lead to the increase in the reducing and total sugar of a ber fruits.

### 4.3.9 Total Soluble Solids (ºB)

The data presented in table 4.14 and fig 4.39 shows that all the treatments significantly increased the Total soluble solids. The pooled data of 2021 & 2022 showed that maximum TSS content (20.30 ºB) was observed in treatment $T_4$ ($GA_3$ @ 100ppm) followed by $T_3$ (ethrel @ 400 ppm) (18.09 ºB) while the minimum TSS content (14.82 ºB) was recorded in $T_1$ ($KNO_3$ @ 1%).

Similar results were found by Dongariyal (2017) in litchi cv. Rose Scented. Increase in TSS content was mostly due to the increase in sugar content which depends mostly upon conversion of starch on hydrolysis. Crane (1956) reported that auxins content caused mobilization of soluble carbohydrates into fruits. In the present experiment, the ethephon probably promoted such mobilisation in the fruits. The increase in total soluble solids levels with ethrel application might have been due to the greater spread in flowering and fruit set, which resulted in reduction in competition between individual fruitlets for nutrients and carbohydrates.

### 4.3.10 Titratable acidity (%)

The data presented in table 4.14 and fig 4.40 shows that all the treatments significantly reduced the acidity per cent. A critical examination of pooled data indicated that treatments $T_{10}$ (no spray) resulted in maximum acidity per cent (0.71), Which was at par with $T_2$ ($K_2HPO_4$ @ 1%) (0.69 %) and $T_6$ ($KNO_3$ @ 1% + ethrel @ 400 ppm) (0.68 %) respectively. Whereas, the minimum acidity

(0.43 % and 0.53 %) was recorded with $T_4$ ($GA_3$ @ 100ppm) and $T_3$ (ethrel @ 400 ppm).

Chundawat *et al*. (1977) who revealed that application of ethephon at 500 ppm two weeks before harvesting decreased acidity of a plum fruit cvs. Dabba and Motia. Observation of reduced acidity by application of ethrel has been supported by Abbas *et al*. (1994) in jujube fruits. The decrease in acidity may be due to the inverse correlation between soluble solids and acidity. Ethrel application increases the rate of ethylene production due to which fructose, glucose and sucrose contents in fruit increase significantly which leads to the increase in soluble solids and decrease in titratable acidity (Park, 1996). Ruffner *et al*. (1975) that the acidity and non-reducing sugars under the influence of chemicals might been due to fastly conversion of acids into sugar, and reducing sugar by the reaction involving the reversal of glycolytic path way or might be used in respiration or both. Thus, treatment with least acidity content resulted in maximum total sugar and reducing sugar content.

### 4.3.11 TSS: acid ratio

The data presented in table 4.14 and fig 4.41 shows that all the treatments significantly affected TSS: acidity ratio. During 2020-21, TSS: acid ratio was maximum (50.45) with $T_4$ ($GA_3$ @ 100ppm) whereas it was minimum (22.67) with $T_2$ ($K_2HPO_4$ @ 1%). A similar trend was recorded during 2021-22, where TSS: acidity ratio was maximum (43.54) with $T_4$ ($GA_3$ @ 100ppm) whereas it was minimum (20.91) with $T_2$ ($K_2HPO_4$ @ 1%). The pooled analysis revealed that the treatments $T_4$ ($GA_3$ @ 100ppm) and $T_3$ (ethrel @ 400 ppm) showed highest TSS: acid ratio *i.e*., 46.99 and 33.57. Whereas $T_2$ ($K_2HPO_4$ @ 1%) as well as $T_{10}$ (no spray) resulted in lowest TSS: acid ratio *i.e*., 21.79 and 22.67 respectively.

Similar results were found by Dongariyal (2017) in litchi cv. Rose Scented, Sheibert *et al.* (2000) in Pear cv. Triumph and Bal *et al*. (1992) in Ber.

Increase in TSS: acidity ratio by the application of ethrel is due to increase in TSS and decrease in acidity. This may be due to early and rapid degradation of acid and its conversion into sugars (Korunga *et al*., 2007).

| | | |
|---|---|---|
|  |  |  |
| **$KNO_3$ 1%** | **$K_2HPO_4$ 1%** | **$K_2HPO_4$ 1%** |
|  |  |  |
| **$GA_3$ 100 ppm** | **$KNO_3$ 1% + $K_2HPO_4$ 1%** | **$KNO_3$ 1% + Ethrel 400ppm** |

| | | | |
|---|---|---|---|
|  |  |  |  |
| **$KNO_3$ 1% + $GA_3$ 100 ppm** | **$K_2HPO_4$ 1% + Ethrel 400ppm** | **$K_2HPO_4$ 1% + $GA_3$ 100 ppm** | **No- spray** |

**PLATE 4.13. Effect of PGRs and Chemicals spray on Fruit set of Litchi cv. Shahi**

| | | | | |
|---|---|---|---|---|
|  |  |  |  |  |
| **$KNO_3$ 1%** | **$K_2HPO_4$ 1%** | **$K_2HPO_4$ 1%** | **$GA_3$ 100 ppm** | **$KNO_3$ 1% + $K_2HPO_4$ 1%** |

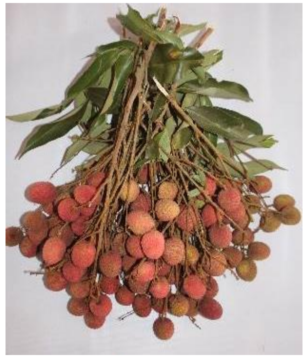
| | | | | |
|---|---|---|---|---|
|  |  |  |  |  |
| **$KNO_3$ 1% + Ethrel 400ppm** | **$KNO_3$ 1% + $GA_3$ 100 ppm** | **$K_2HPO_4$ 1% + Ethrel 400ppm** | **$K_2HPO_4$ 1% + $GA_3$ 100 ppm** | **No- spray** |

**PLATE 4.14. Harvested fruits under the trial on PGRs and Chemicals spray of Litchi cv. Shahi**

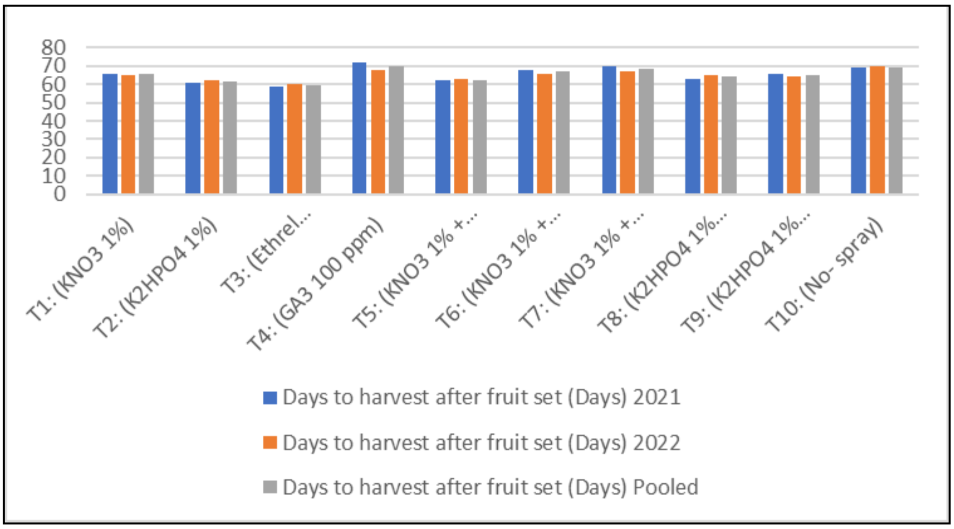



**Fig 4.37 Days to harvest after fruit set in different treatments of PGRs and Chemicals**

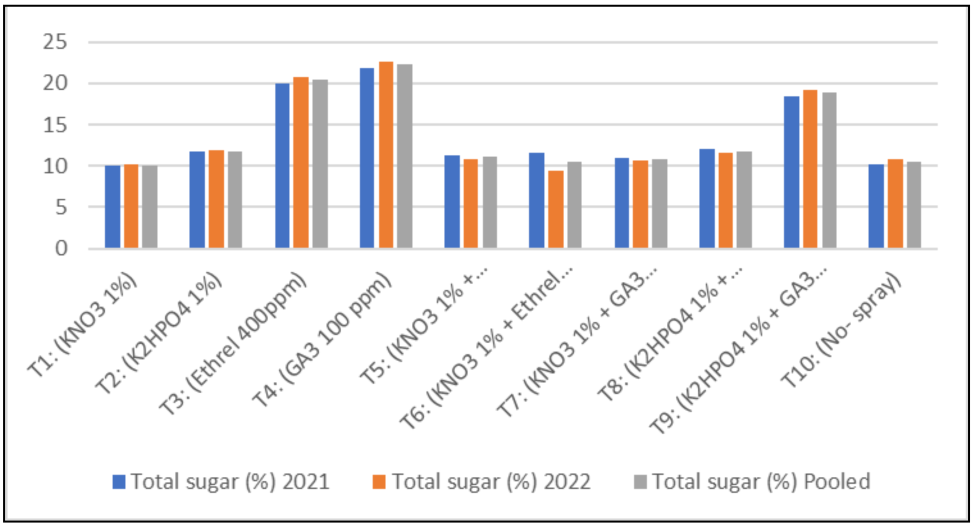



**Fig 4.38 Total Sugar (%) content of different treatments**

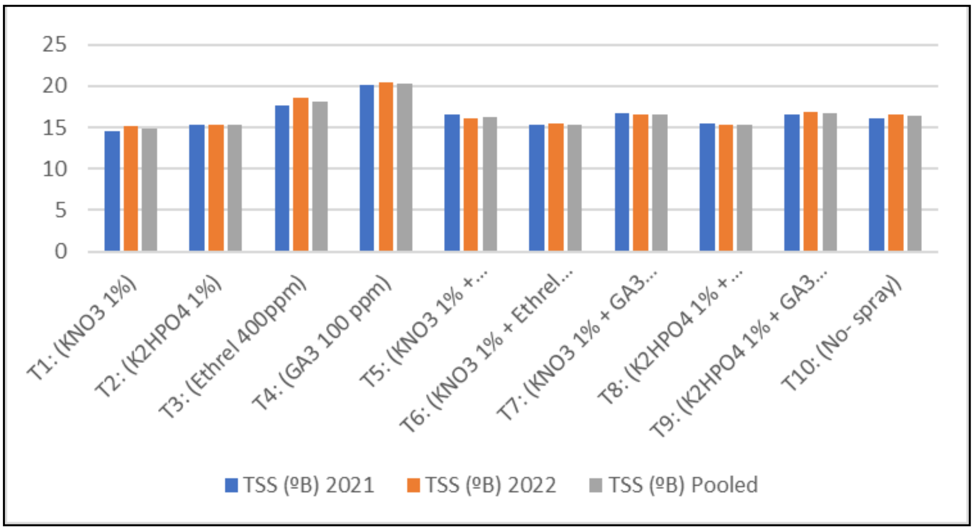



**Fig 4.39 TSS (ºB) content of different PGRs & chemicals treatments**

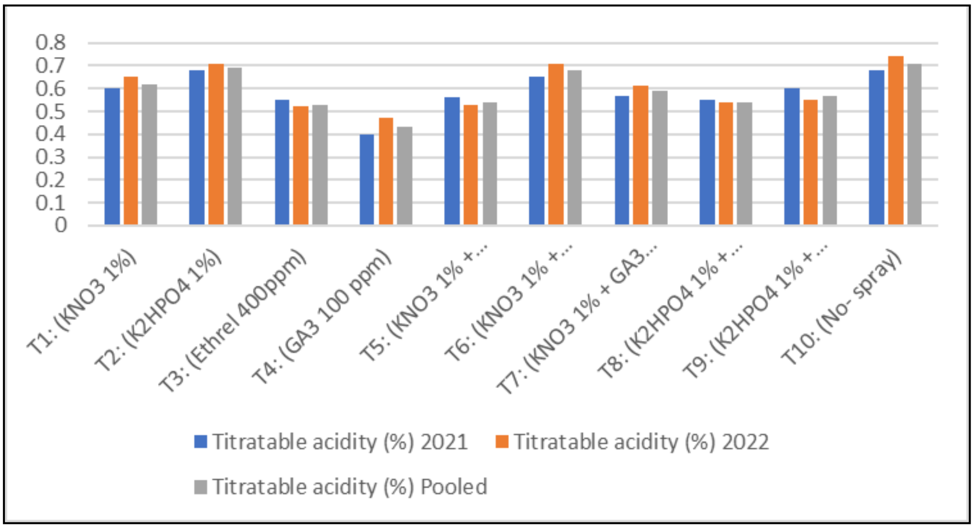



**Fig 4.40 Titratable acidity content of different PGRs & chemicals treatments**

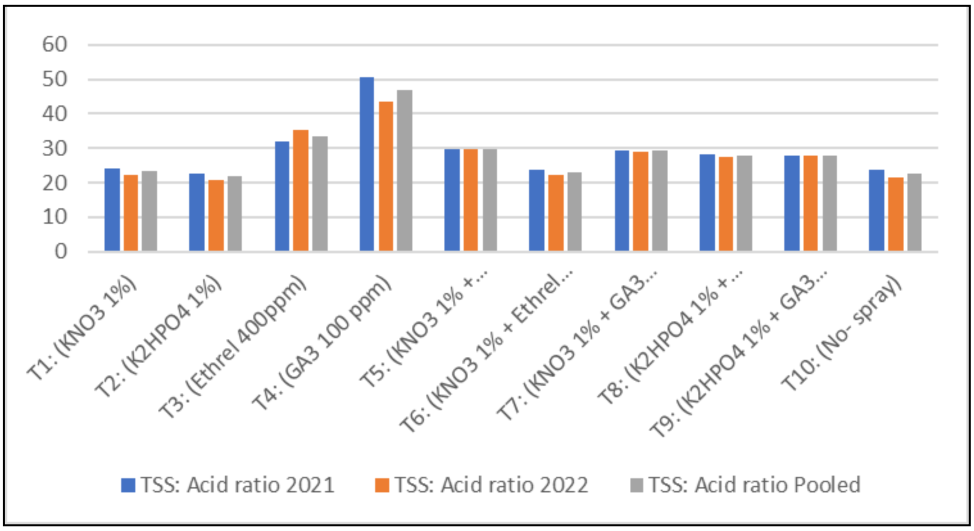



**Fig 4.41 TSS: acid ratio of different PGRs & chemicals treatments**

**Table. 4.14. Effect of PGRs & chemicals on bio chemical traits of litchi fruits**

| Treatments | Total sugar (%) | | | TSS (ºB) | | | Titratable acidity (%) | | | TSS: Acid ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| **$T_1$: ($KNO_3$ 1%)** | 10.00 | 10.19 | 10.09 | 14.52 | 15.13 | 14.82 | 0.60 | 0.65 | 0.62 | 24.20 | 22.36 | 23.28 |
| **$T_2$: ($K_2HPO_4$ 1%)** | 11.68 | 11.96 | 11.82 | 15.38 | 15.36 | 15.37 | 0.68 | 0.71 | 0.69 | 22.67 | 20.91 | 21.79 |
| **$T_3$: (Ethrel 400ppm)** | 20.04 | 20.83 | 20.43 | 17.59 | 18.60 | 18.09 | 0.55 | 0.52 | 0.53 | 31.98 | 35.16 | 33.57 |
| **$T_4$: ($GA_3$ 100 ppm)** | 21.87 | 22.63 | 22.25 | 20.18 | 20.43 | 20.30 | 0.40 | 0.47 | 0.43 | 50.45 | 43.54 | 46.99 |
| **$T_5$: ($KNO_3$ 1% + $K_2HPO_4$ 1%))** | 11.34 | 10.81 | 11.07 | 16.54 | 16.13 | 16.33 | 0.56 | 0.53 | 0.54 | 29.53 | 29.70 | 29.61 |
| **$T_6$: ($KNO_3$ 1% + Ethrel 400ppm)** | 11.67 | 9.38 | 10.52 | 15.33 | 15.46 | 15.39 | 0.65 | 0.71 | 0.68 | 23.58 | 22.07 | 22.82 |
| **$T_7$: ($KNO_3$ 1% + $GA_3$ 100 ppm)** | 10.94 | 10.61 | 10.77 | 16.68 | 16.50 | 16.59 | 0.57 | 0.61 | 0.59 | 29.26 | 29.02 | 29.14 |
| **$T_8$: ($K_2HPO_4$ 1% + Ethrel 400ppm)** | 12.04 | 11.59 | 11.81 | 15.47 | 15.33 | 15.40 | 0.55 | 0.54 | 0.54 | 28.12 | 27.37 | 27.74 |
| **$T_9$: ($K_2HPO_4$ 1% + $GA_3$ 100 ppm)** | 18.47 | 19.28 | 18.87 | 16.59 | 16.80 | 16.69 | 0.60 | 0.55 | 0.57 | 27.65 | 27.81 | 27.73 |
| **$T_{10}$: (No- spray)** | 10.26 | 10.81 | 10.53 | 16.14 | 16.56 | 16.35 | 0.68 | 0.74 | 0.71 | 23.73 | 21.61 | 22.67 |
| **SEm±** | **0.34** | **0.70** | **0.47** | **0.15** | **1.02** | **0.20** | **0.02** | **0.03** | **0.02** | **0.69** | **2.81** | **1.27** |
| **CD@5%** | **1.13** | **2.29** | **1.53** | **0.50** | **3.07** | **0.67** | **0.07** | **0.09** | **0.07** | **2.24** | **9.13** | **4.12** |

## 4.4 To study the effect of various mulch materials on fruiting and quality of litchi fruits cv. China

The experimental results pertaining to effect of various mulch materials on soil moisture, nutrient conserving, flowering, fruiting and quality attributes of litchi fruits are presented and discussed in this chapter. The findings were justified with possible scientific reasons available in literature.

### 4.4.1 Soil moisture content- before and after mulching (%)

The data presented in table 4.15 and fig 4.42 & 4.43 shows that all the treatments significantly affected percentage of soil moisture in the litchi during both the years as compared to control. The per cent of soil moisture at before mulching was showed not much variance in different treatments as compared with after mulching.

During 2020-21, the increased soil moisture retention percentage range from -1.36 to 14.80 per cent after mulching with different material. It was recorded maximum (14.80 %) in $T_1$ (Black polythene mulch) whereas it was minimum (-1.36 %) in trees under $T_8$ (no-mulch). A similar trend was recorded during 2021-22, where soil moisture percentage increased from -2.70 to 15.50 per cent. Among the treatments maximum (15.50 %) under the treatment of $T_1$ (Black polythene mulch) whereas it was minimum (-2.70 %) in $T_8$ (no-mulch).

It might be due to High moisture retention ability of plastic mulches could be due to less evaporation from soil. The water vapours that evaporate from the soil surface gets trapped in the plastic and dropped back into the upper soil surface which increases the soil moisture content in the root zone (Khan *et al*. 2016). Yogaraj, (2016) also supported with the similar findings of high soil moisture (21.25 %) was recorded in plants mulched with black polythene followed by silver polythene mulch (18.36 %) and they were on par with each other. While, black polythene mulch was significantly superior over un-mulched (control) plants (11.43 %). Kumari and Khare, (2019) also revealed that maximum soil moisture content was observed in plastic mulch (inorganic method) followed by dry leaves mulch (organic method) and then in the un-mulched tree. Marked increment in moisture content of the soil was recorded in plastic mulch before and after the mulching treatment. Moisture content increases from 11.9 % to 20.67% in inorganic mulch. Such an improvement in soil hydrothermal regime with mulching was also reported by Ghosh and Bauri (2003) in mango.

**4.4.2 Available soil nitrogen- before and after mulching (kg/ha)**

The data presented in table 4.15 and fig 4.44 & 4.45 shows that all the treatments significantly affected on available soil nitrogen during both the years as compared to control.

During 2020-21, soil nitrogen content was increased from 4.80 to 27.56 kg/ha after mulching with different organic and in organic materials, it was recorded maximum under the treatment of $T_1$ (black polythene mulch) *i.e.*, 27.56 kg/ha followed by $T_2$ and $T_7$ (white polythene mulch and leguminous cover crop-soyabean mulch) *i.e.*, 22.39 and 19.30 kg/ha, whereas minimum (4.80 kg/ha) with $T_8$ (no-mulch) treatment. A similar trend was recorded during 2021-22, where nitrogen content increased from 3.35 to 30.07 kg/ha after mulching. Among the treatments maximum (30.07 kg/ha) soil available nitrogen recorded under $T_1$ (black polythene mulch) whereas it was minimum (3.35 kg/ha) with $T_8$ (no-mulch) treatment.

The increased level of nitrogen due to mulching indicates that diffusion of nitrogen into the roots grown under the mulches was greater than un-mulched plots (Das *et al.* 2016). Kumari and Khare (2019) reported that the increased available soil nutrition was recorded under plastic mulch treatments than control. Same conclusion was also obtained by Dutta and Majumder (2009) in the guava orchard. Muhammad *et al*. (2009) also reported similar findings in chilli, organic mulch helps in reduction of nitrate leaching, improve soil physical properties, prevent soil erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle and enhanced biological activity.

### 4.4.3 Available soil phosphorus- before and after mulching (kg/ha)

The data presented in table 4.16 and fig 4.46 & 4.47 shows that all the treatments significantly affected on available soil phosphorus during both the years as compared to control.

During 2020-21, soil phosphorus content was increased from 0.30 to 4.19 kg/ha after mulching with different organic and in organic materials, it was recorded maximum under the treatment of $T_1$ (black polythene mulch) *i.e.*, 4.19 kg/ha followed by $T_2$ and $T_4$ (white polythene mulch and paddy straw mulch) *i.e.*, 4.18 and 3.10 kg/ha, whereas minimum (0.30 kg/ha) with $T_8$ (no-mulch) treatment. A similar trend was recorded during 2021-22, where phosphorus content increased from 0.56 to 6.24 kg/ha after mulching. Among the treatments maximum (6.24 kg/ha) soil available phosphorus recorded under $T_2$ (white polythene mulch) followed by $T_1$ (black polythene mulch) *i.e.*, 5.70 kg/ha, whereas it was minimum (0.56 kg/ha) with $T_8$ (no-mulch) treatment.

Different mulches increased the phosphate content of leaves because surface soil is kept moist for a longer time (Russell, 1975). Mahmoud and Sheren (2014) also reported that increase in the soil mineral content with organic and inorganic mulches may be due to addition of nutrients from the organic mulches by decomposition and more favourable condition created inside the mulch like higher soil temperature and moisture, upon decomposition of organic mulches releases certain organic acids to soil resulting in low pH which may increase the availability of nutrients in soil.

| | | | |
|---|---|---|---|
| | | | |
| **Black polythene mulch** | **White polythene mulch** | **Dry grass mulch** | **Paddy straw mulch** |

| | | | |
|---|---|---|---|
| | |  | |
| **Dry banana leaf mulch** | **Banana pseudostem mat mulch** | **Soyabean mulch** | **Control (No- mulch)** |

**PLATE 4.15. Overview of experimental plots used different mulch materials in litchi**

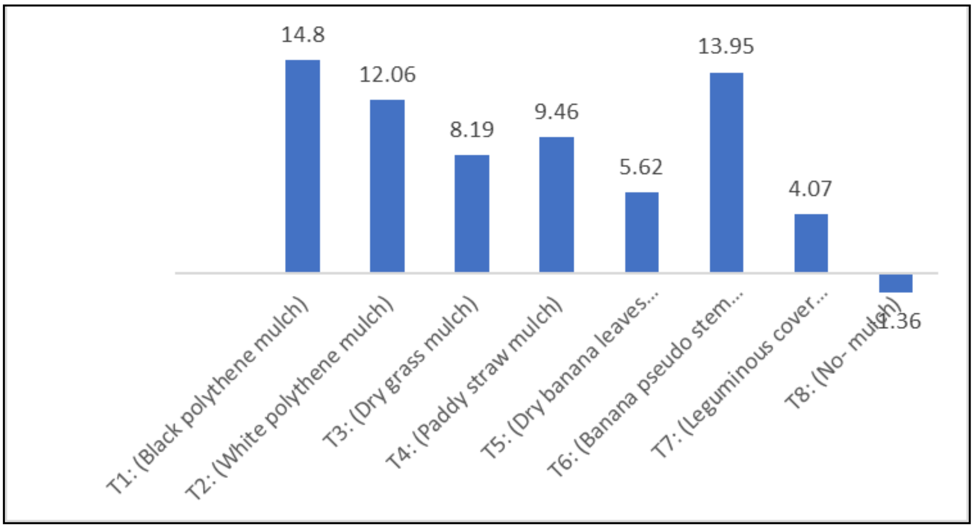



**Fig 4.42 Available soil moisture percentage under different treatments in 2021**

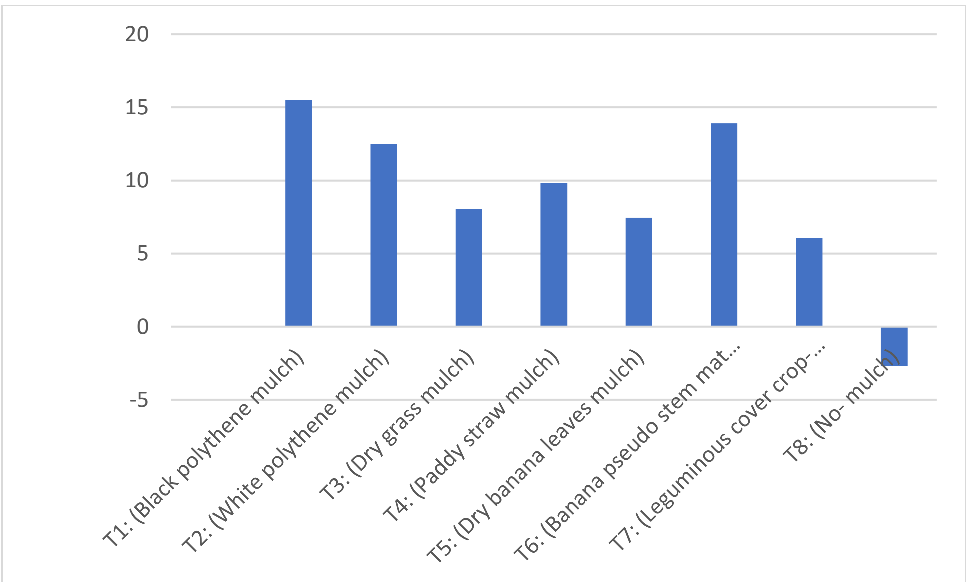



**Fig 4.43 Available soil moisture percentage under different treatments in 2022**

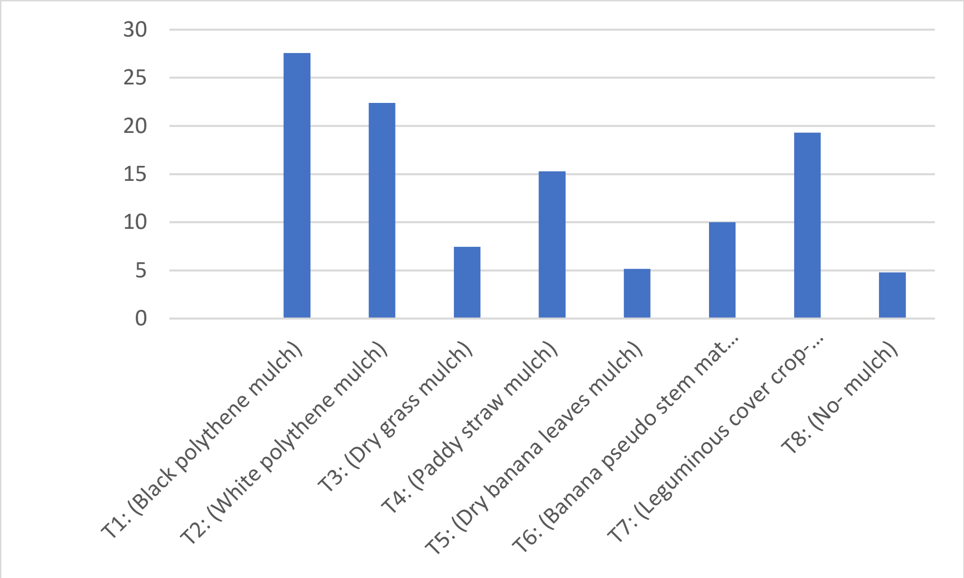



**Fig 4.44 Available soil nitrogen (kg/ha) content under different treatments in 2021**

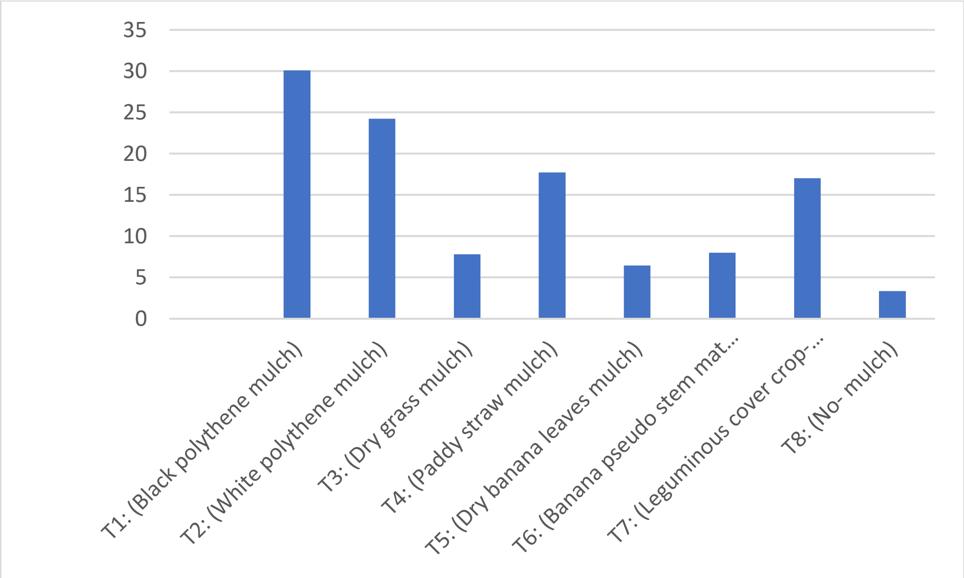



**Fig 4.45 Available soil nitrogen(kg/ha) content under different treatments in 2022**

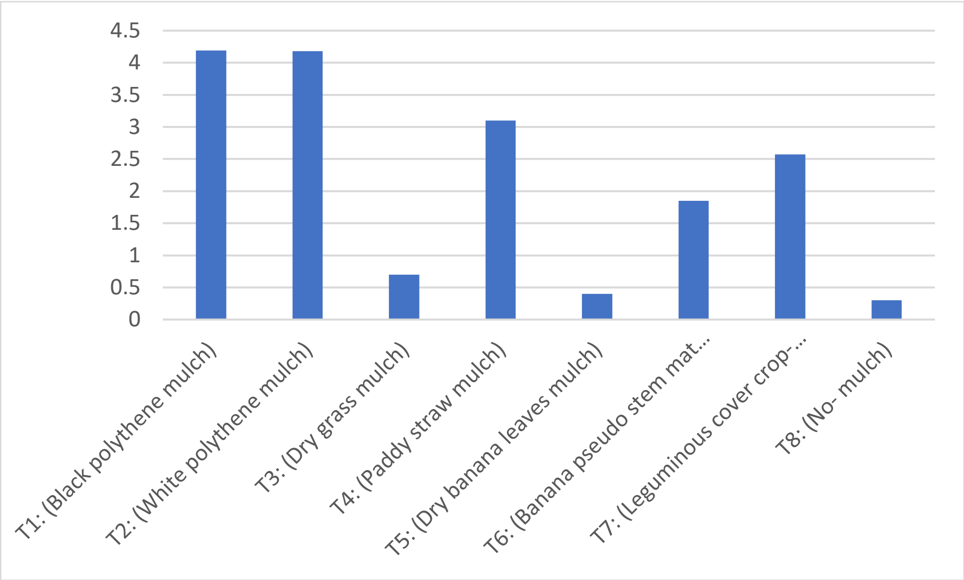



**Fig 4.46 Available soil $P_2O_5$ (kg/ha) content under different treatments in 2021**

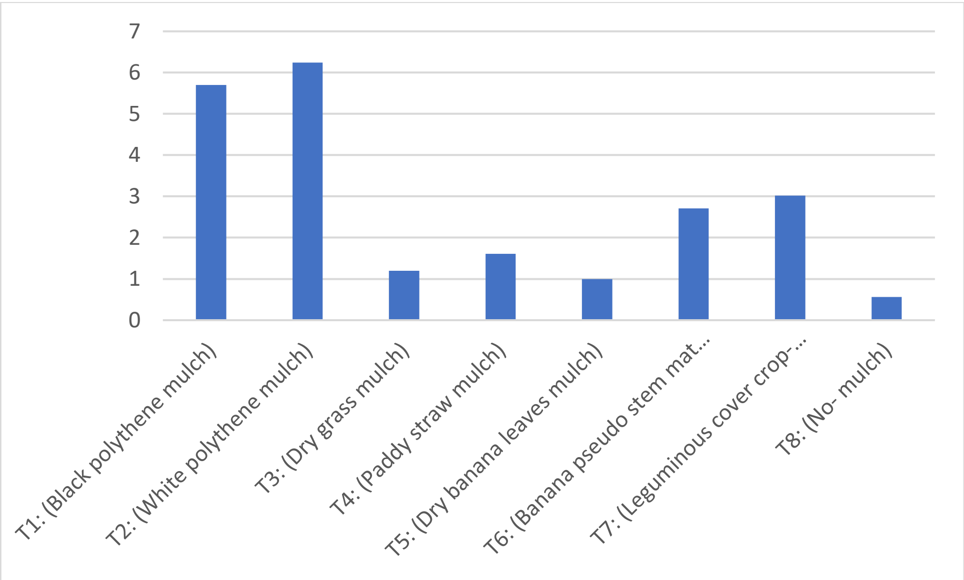



**Fig 4.47 Available soil $P_2O_5$ (kg/ha) content under different treatments in 2022**

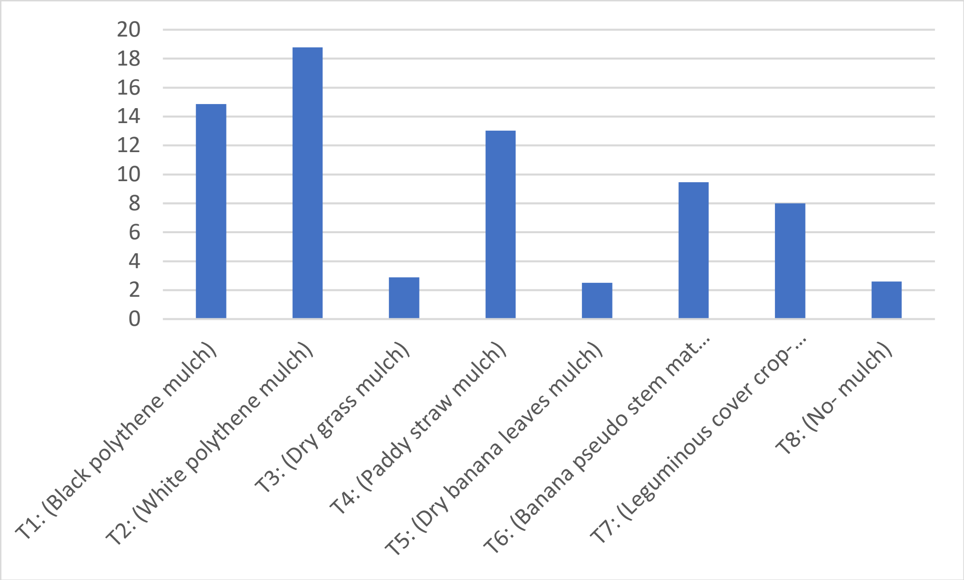



**Fig 4.48 Available soil $K_2O$ (kg/ha) content under different treatments in 2021**

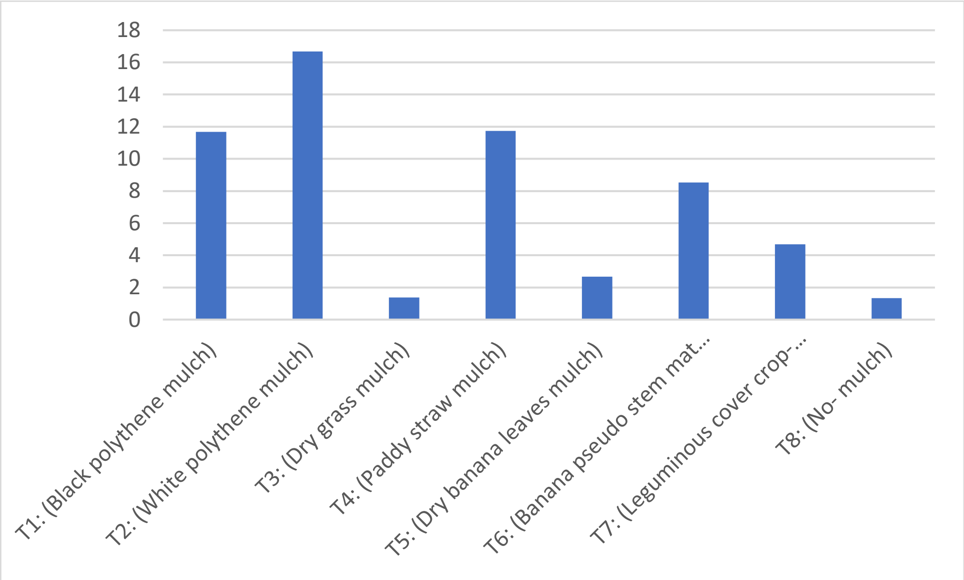



**Fig 4.49 Available soil $K_2O$ (kg/ha) content under different treatments in 2022**

### 4.4.4 Available soil potassium- before and after mulching (kg/ha)

The data presented in table 4.16 and fig 4.48 & 4.49 shows that all the treatments significantly affected on available soil potassium during both the years as compared to control.

During 2020-21, soil potassium content was increased from 2.51 to 18.78 kg/ha after mulching with different organic and in organic materials, it was recorded maximum under the treatment of $T_2$ (white polythene mulch) *i.e.*, 18.78 kg/ha followed by $T_1$ (black polythene mulch) *i.e.*, 14.87 kg/ha, whereas minimum (2.51 kg/ha) with $T_5$ (dry banana leaves mulch) treatment. A similar trend was recorded during 2021-22, where potassium content increased from 1.33 to 16.68 kg/ha after mulching. Among the treatments maximum (16.68 kg/ha) soil available potassium recorded under $T_2$ (white polythene mulch) whereas it was minimum (1.33 kg/ha) with $T_8$ (no-mulch) treatment.

Black polythene mulch proved very effective and had the highest content of available soil mineral contents followed by paddy straw and paddy husk while the least N, P &K was found in control treatments. Higher available nutrient pool in the soil under polythene mulch was the result of mineralization of organic matter (Das and Dutta, 2018). Similar result was also obtained by Dutta and Majumder (2009) in guava. The highest potassium uptake under mulched plots may be due to presence of a higher moisture regime, maintenance of optimum level of soil temperature and a reduction in temperature fluctuation (Russell, 1975).

**Table. 4.15. Effect of various mulching materials on available soil moisture & nutrients**

| Treatments | Soil moisture (%) | | | | | | Available soil nitrogen (kg/ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | | | 2022 | | | 2021 | | | 2022 | | |
| | Before mulch | After mulch | Change (±) | Before mulch | After mulch | Change | Before mulch | After mulch | Change | Before mulch | After mulch | Change |
| $T_1$: (Black polythene mulch) | 11.25 | 26.05 | 14.80 | 11.90 | 27.40 | 15.50 | 386.50 | 414.06 | 27.56 | 350.17 | 380.24 | 30.07 |
| $T_2$: (White polythene mulch) | 11.88 | 23.94 | 12.06 | 12.50 | 25.00 | 12.50 | 342.17 | 364.56 | 22.39 | 333.21 | 357.46 | 24.25 |
| $T_3$: (Dry grass mulch) | 12.29 | 20.48 | 08.19 | 12.36 | 20.41 | 08.05 | 344.50 | 351.94 | 07.44 | 317.97 | 325.78 | 07.81 |
| $T_4$: (Paddy straw mulch) | 11.87 | 21.33 | 09.46 | 12.97 | 22.80 | 09.83 | 357.20 | 372.47 | 15.27 | 340.92 | 358.66 | 17.74 |
| $T_5$: (Dry banana leaves mulch) | 10.21 | 15.83 | 05.62 | 10.40 | 17.86 | 07.46 | 340.56 | 345.71 | 05.15 | 322.83 | 329.27 | 06.44 |
| $T_6$: (Banana pseudo stem mat mulch) | 12.46 | 26.41 | 13.95 | 12.20 | 26.10 | 13.90 | 366.50 | 376.50 | 10.00 | 360.18 | 368.17 | 07.99 |
| $T_7$: (Leguminous cover crop- Soyabean mulch) | 10.18 | 14.25 | 04.07 | 10.67 | 16.71 | 06.04 | 319.70 | 339.00 | 19.30 | 308.56 | 325.58 | 17.02 |
| $T_8$: (No- mulch) | 12.92 | 11.56 | -01.36 | 12.40 | 9.70 | -02.70 | 331.42 | 336.22 | 04.80 | 328.61 | 331.96 | 03.35 |

**Table. 4.16. Effect of various mulching material on available soil nutrients**

| Treatments | Available soil $P_2O_5$ (kg/ha) | | | | | | Available soil $K_2O$ (kg/ha) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | | | 2022 | | | 2021 | | | 2022 | | |
| | Before mulch | After mulch | Change | Before mulch | After mulch | Change | Before mulch | After mulch | Change | Before mulch | After mulch | Change |
| $T_1$: (Black polythene mulch) | 48.54 | 52.73 | 4.19 | 47.28 | 52.98 | 5.70 | 146.94 | 161.81 | 14.87 | 141.83 | 153.50 | 11.67 |
| $T_2$: (White polythene mulch) | 43.83 | 48.01 | 4.18 | 41.40 | 47.64 | 6.24 | 155.62 | 174.40 | 18.78 | 152.64 | 169.32 | 16.68 |
| $T_3$: (Dry grass mulch) | 46.13 | 46.83 | 0.70 | 44.01 | 45.21 | 1.20 | 143.22 | 146.11 | 2.89 | 141.58 | 142.96 | 1.38 |
| $T_4$: (Paddy straw mulch) | 49.11 | 52.21 | 3.10 | 44.56 | 46.17 | 1.61 | 151.28 | 164.30 | 13.02 | 149.54 | 161.27 | 11.73 |
| $T_5$: (Dry banana leaves mulch) | 43.18 | 43.58 | 0.40 | 40.72 | 41.72 | 1.00 | 144.46 | 146.97 | 2.51 | 142.50 | 145.17 | 2.67 |
| $T_6$: (Banana pseudo stem mat mulch) | 41.97 | 43.82 | 1.85 | 38.23 | 40.94 | 2.71 | 135.78 | 145.23 | 9.45 | 132.28 | 140.81 | 8.53 |
| $T_7$: (Leguminous cover crop- Soyabean mulch) | 50.17 | 52.74 | 2.57 | 46.28 | 49.30 | 3.02 | 139.50 | 147.50 | 8.00 | 136.82 | 141.50 | 4.68 |
| $T_8$: (No- mulch) | 41.61 | 41.91 | 0.30 | 37.94 | 38.50 | 0.56 | 137.64 | 140.24 | 2.60 | 136.91 | 138.24 | 1.33 |

### 4.4.5 Flowering percentage (%)

The effect of different mulching treatments (table 4.17 and fig 4.50) was found to be significantly induced the flowering in the litchi during both the years as compared to control. Pooled data of two consecutive years, showed highest percentage (74.44 %) of flowering was found in $T_1$ (black polythene mulch) and the lowest (40.94 %) in $T_8$ (no-mulch). which was at par with $T_6$ (banana pseudo stem mat mulch) and $T_7$ (leguminous cover crop- soyabean mulch) and the value were 72.34 and 72.11 per cent respectively.

These results are supported with findings of Mondal and Chattopadhya (1994) reported that flowering attributes showed significant results when soil cover was used in the orchard of custard apple. Similar findings by Rangkham (2015) reported that mulching with hydrogel treatment was showed high intensity of flowering in litchi than un-mulched treatment. The results are in line with the findings of Mal *et al*. (2006) who reported that a greater number of flowers recorded in plants under black polythene mulch in pomegranate cv. Ganesh.

### 4.4.6 Fruit set per panicle (%)

The data presented in table 4.17 and fig 4.51 shows that all the treatments significantly increased the percent of fruit set per panicle. The pooled data of 2021 & 2022 showed that maximum fruit set percentage content (36.78 %) was observed in treatment $T_1$ (black polythene mulch) while the minimum fruit set percentage content (31.41 %) was recorded in $T_8$ (no-mulch). which was at par with $T_2$ (white polythene mulch), $T_6$ (banana pseudo stem mat mulch), $T_4$ (paddy straw mulch) and $T_7$ (leguminous cover crop- soyabean mulch) and the value were 36.61, 36.06, 35.22 and 35.17 per cent respectively.

Bakshi *et al.* (2014) also reported highest number of fruits per plant in black polythene mulch in strawberry cv. Chandler. It might be due to better weed control was found under the effect of mulch and drip irrigation which reduced the competition for nutrients and soil moisture, it leads to better flowering and fruiting percentage.

### 4.4.7 Fruit drop (%)

The data on percentage of fruit drop depicted in table 4.17 and fig 4.52 showed that all the treatments had a significant effect on fruit drop per cent. Among all the treatments minimum fruit drop (68.09 %) was observed in $T_1$ (black polythene mulch) treatment, whereas the treatment $T_8$ (no-mulch) recorded the maximum percentage (83.82 %).

Joshi *et al.* (2011) observed significant reduction in fruit drop and fruit cracking in litchi with the application of mulch and they have also recorded that the application of drip irrigation at 100% of estimated irrigation water requirement significantly lowered the fruit drop and fruit cracking.

### 4.4.8 Fruit retention per panicle (number)

The data of fruits per panicle shown in table 4.17 and fig 4.53 showed that all the treatments significantly increasing the number of fruits retention on panicle compared with $T_8$ (no-mulch). Among all the treatments minimum number of fruits (10.56) retained was recorded in $T_8$ (no-mulch), whereas treatments $T_1$ (black polythene mulch) recorded maximum (13.53) number of fruits per panicle, followed by $T_2$ (white polythene mulch), T6 (banana pseudostem mat mulch), $T_7$ (leguminous cover crop- soyabean mulch) and $T_4$ (paddy straw mulch) *i.e.*, 13.10, 13.10, 12.86 and 12.49 respectively.

Singh *et al.* (2015) recorded maximum number of fruits in guava cv. Allahabad Safeda under plastic mulch with drip irrigation. Pradhan *et al.* (2010) observed highest fruit yield in mango under 80 % irrigation with plastic mulch. Joshi *et al.* (2011) also recorded high yield in litchi irrigated with 100 % estimated water requirement coupled with plastic mulch.

| | | | |
|---|---|---|---|
|  |  |  |  |
| **Black polythene mulch** | **White polythene mulch** | **Dry grass mulch** | **Paddy straw mulch** |

| | | | |
|---|---|---|---|
|  |  |  |  |
| **Dry banana leaf mulch** | **Banana pseudostem mat mulch** | **Soyabean mulch** | **Control (No- mulch)** |

**PLATE 4.16. Flowering under different mulching treatments**

### 4.4.9 Fruit weight (g)

The data presented in table 4.18 and fig 4.54 reveals that weight of fruit varied from 9.87 to 18.28 g with significant differences among the treatments. However highest fruit weight (18.28 g) was observed in $T_6$ (banana pseudo stem mat mulch) followed by $T_1$ (black polythene mulch) i.e., 18.23 g. Whereas lowest (9.87 g) was reported in $T_8$ (no-mulch). On the other hand, all the treatments had a significant effect on fruit weight as compared to control.

Kumari and Khare (2019) reported similar findings of physical estimation of the fruit, the weight (23.5g) was found maximum in plastic mulched trees followed by dry leaves mulched trees having fruit weight (21.8g). Similarly, Das and Dutta (2018) in mango recorded that, black polythene mulch showed maximum fruit weight (263.42 g). Bhandari *et al.* (2017) fruit weight under black polythene mulch could be due to better soil moisture conservation and better soil temperature.

### 4.4.10 Fruit length (g)

The data pertaining to effect on different organic and inorganic mulching treatments on fruit length of litchi are presented in table 4.18 and results indicated that maximum length of fruit (4.07 cm) under the treatment of $T_1$ (black polythene mulch) and minimum (3.34 cm) under $T_3$ (dry grass mulch) which was at par with $T_6$ (banana pseudo stem mulch) and the value were 3.95 cm respectively.

The organic and inorganic mulching provided consistently improved available soil moisture in plant basin due to which the plant roots remained probably active throughout the irrigation season resulted in optimum availability of nutrient and proper translocation of food materials which accelerate the fruit growth and development. The results are in line with the findings of Chattopadhyay and Patra (1993) who reported that larger fruit size in terms of (length 7.34 cm and breadth 7.47 cm) were obtained under black polythene mulch which was due to more plant growth and development under micro-climate condition resulting in better nutrient uptake in pomegranate.

### 4.4.11 Fruit width (g)

The data pertaining to effect on different mulching treatments on fruit breadth of litchi are presented in table 4.18 & fig 4.56 and results indicated that maximum breadth of fruit (3.71 cm) under the treatment of $T_1$ (black polythene mulch) and minimum (2.51 cm) under $T_3$ (dry grass mulch).

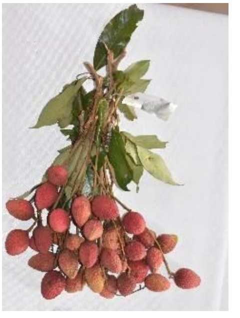
Bakshi *et al*. (2014) also recorded the maximum fruit length (3.40 cm) and breadth (2.34 cm) under black polythene mulch in strawberry. Higher fruit breadth was recorded in plants mulched with black polythene in pomegranate was also reported by Ghosh and Bera (2015).

|  |  |  |  |
|---|---|---|---|
| **Black polythene mulch** | **White polythene mulch** | **Dry grass mulch** | **Paddy straw mulch** |

|  |  |  |  |
|---|---|---|---|
| **Dry banana leaf mulch** | **Banana pseudostem mat mulch** | **Soyabean mulch** | **Control (No- mulch)** |

**PLATE 4.17. Fruit set in different mulching treatments**


Black polythene mulch


White polythene mulch


Dry grass mulch


Paddy straw mulch


Dry banana leaf mulch


Banana pseudostem mat mulch


Soyabean mulch


Control (No- mulch)

**PLATE 4.18. Harvested fruits under different mulching treatments**

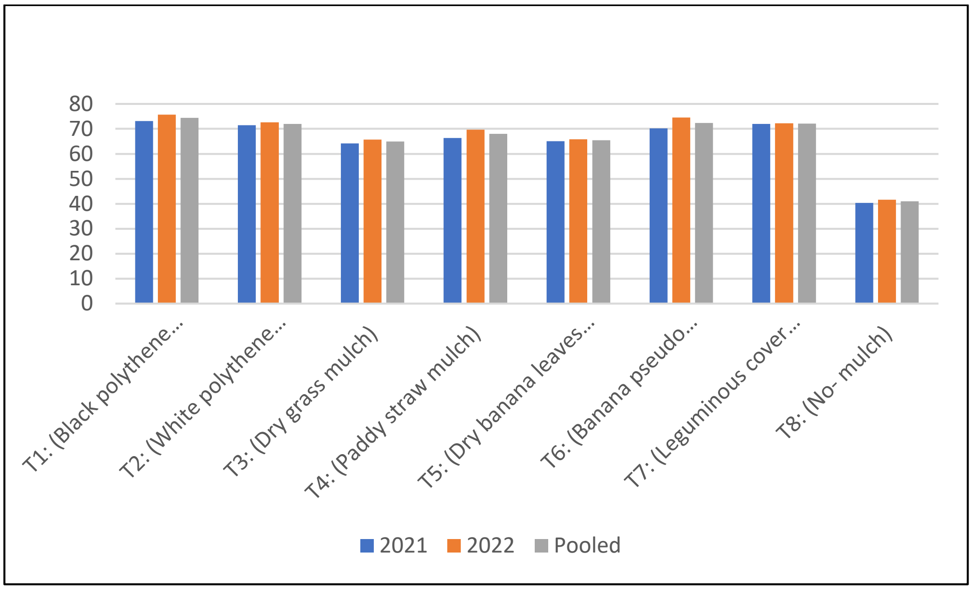



**Fig 4.50 Flowering (%) of different mulching treatments**

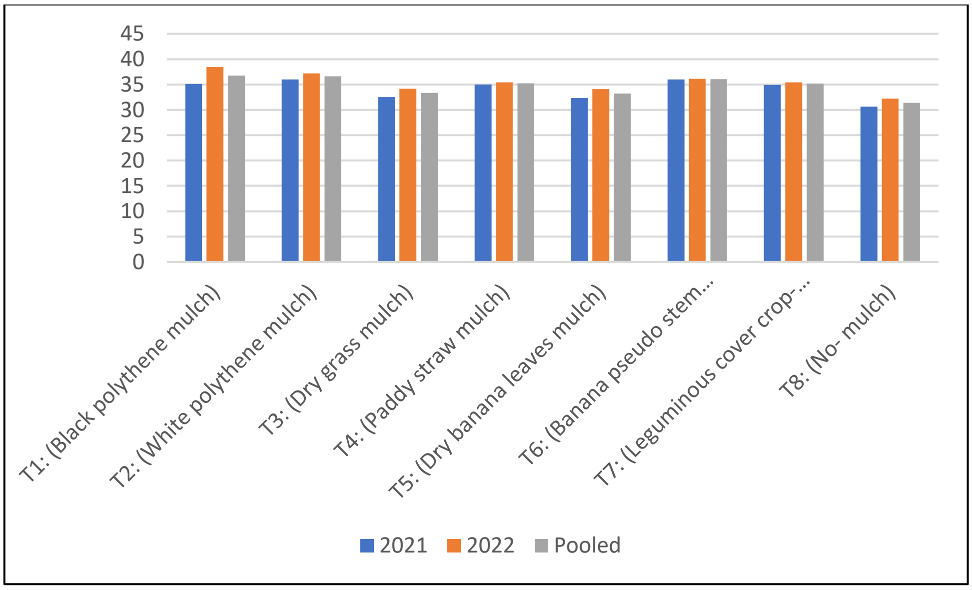



**Fig 4.51 Fruit set per panicle under different mulching treatments**

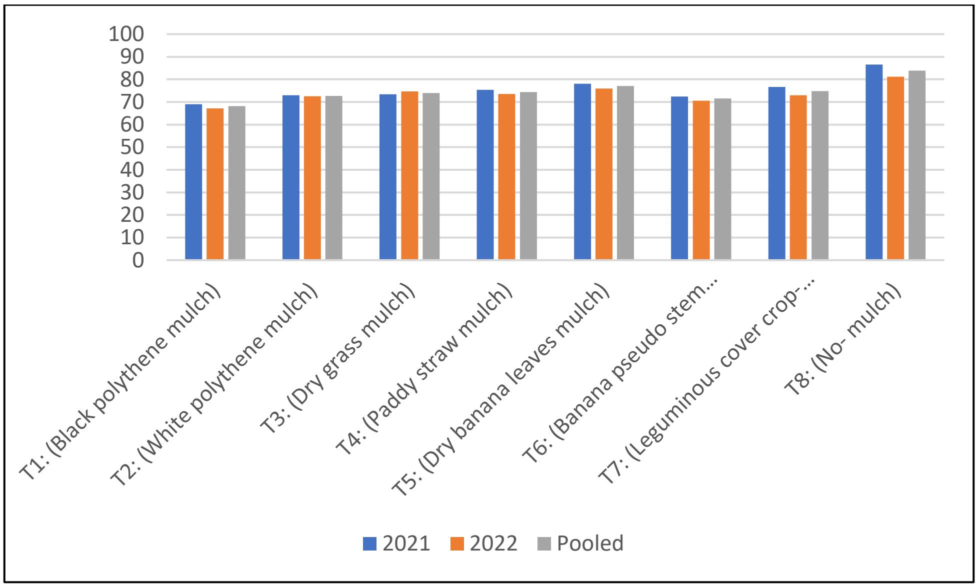



**Fig 4.52 Fruit drop (%) of different mulching treatments**

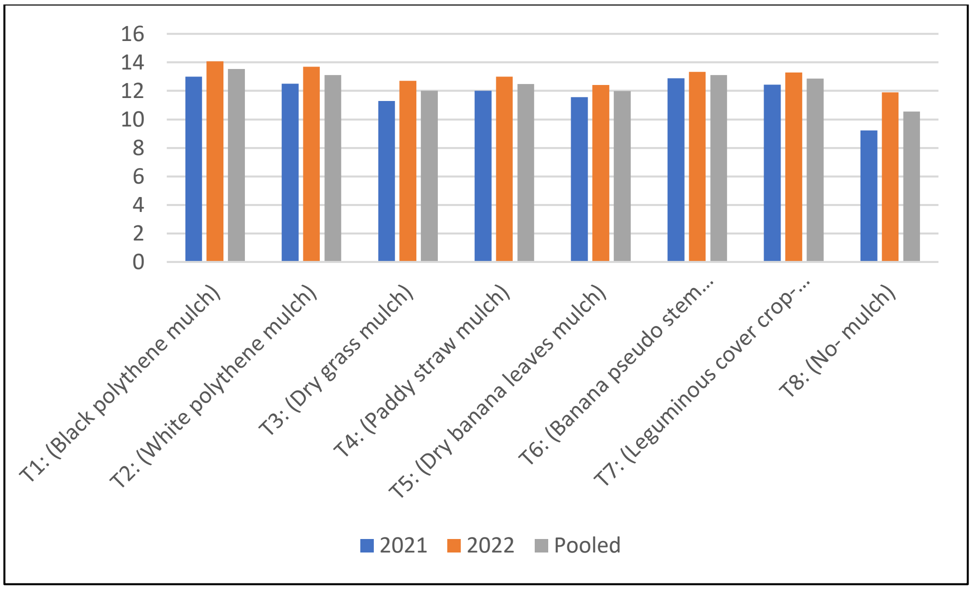



**Fig 4.53 Fruit retention per panicle number under different mulching treatments**

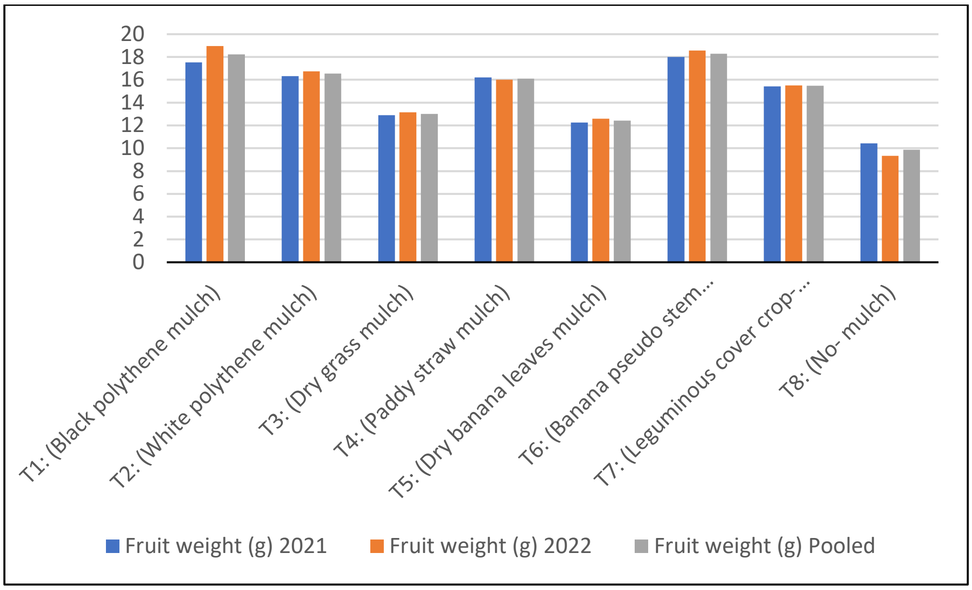



**Fig 4.54 Fruit weight (g) under different mulching treatments**

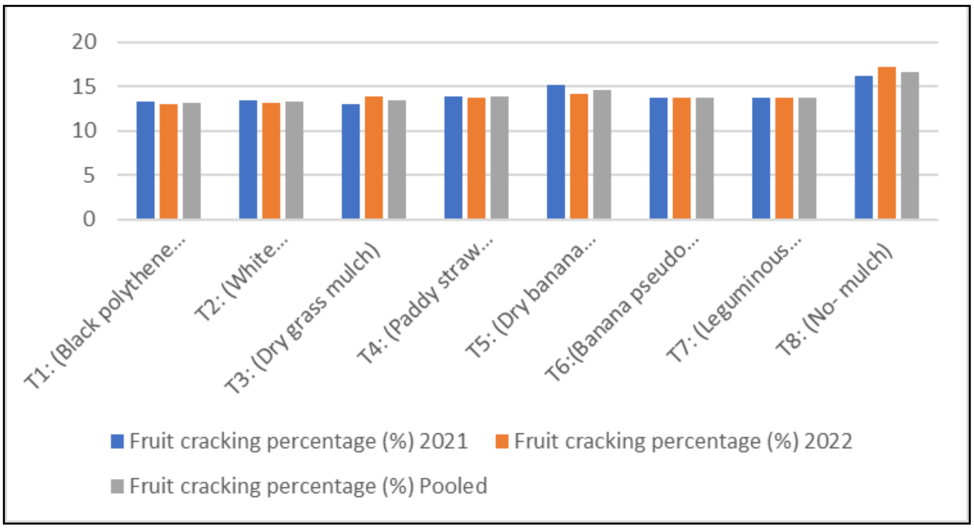



**Fig 4.55 Fruit cracking (%) under different mulching treatments**

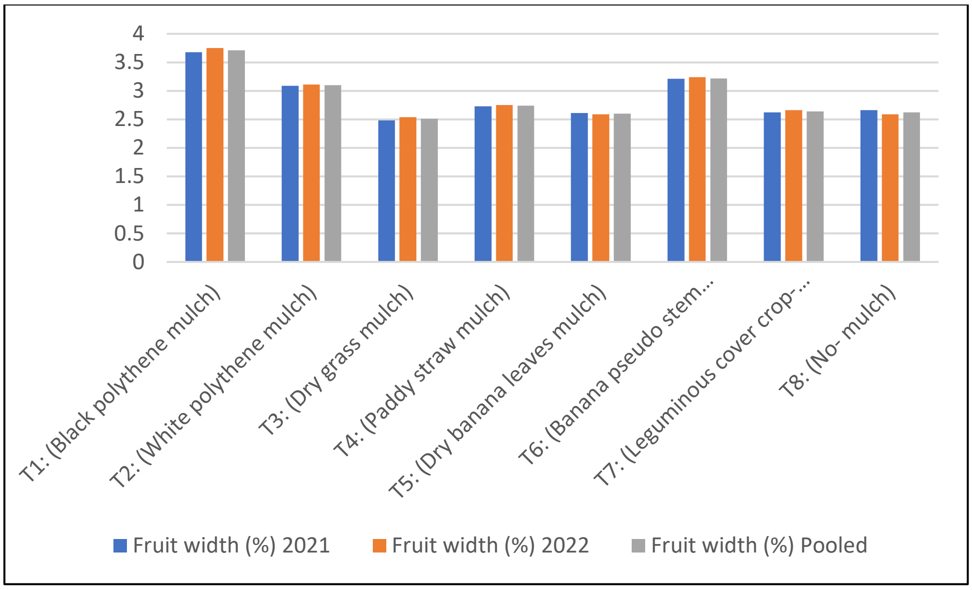



**Fig 4.56 Fruit width variation under different treatments of mulching**

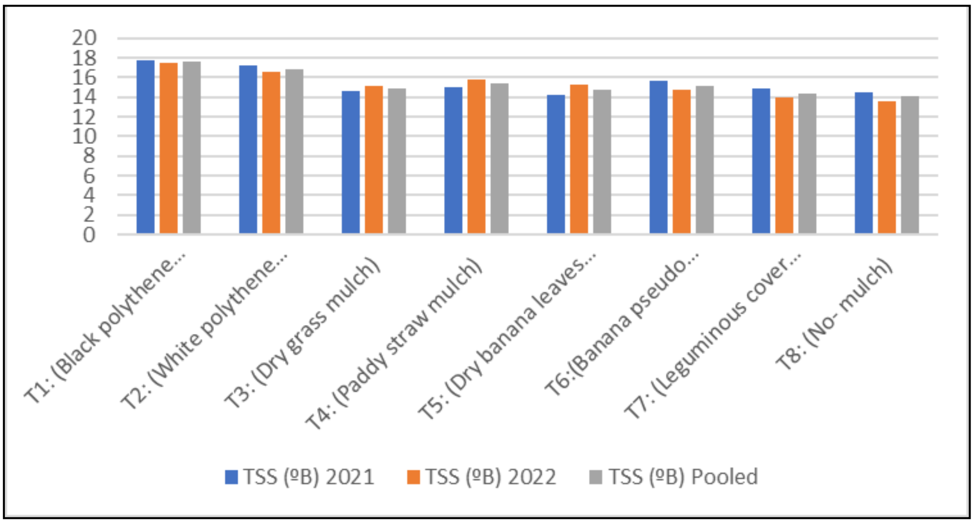



**Fig 4.57 TSS (ºB) content of fruits under different mulching treatments**

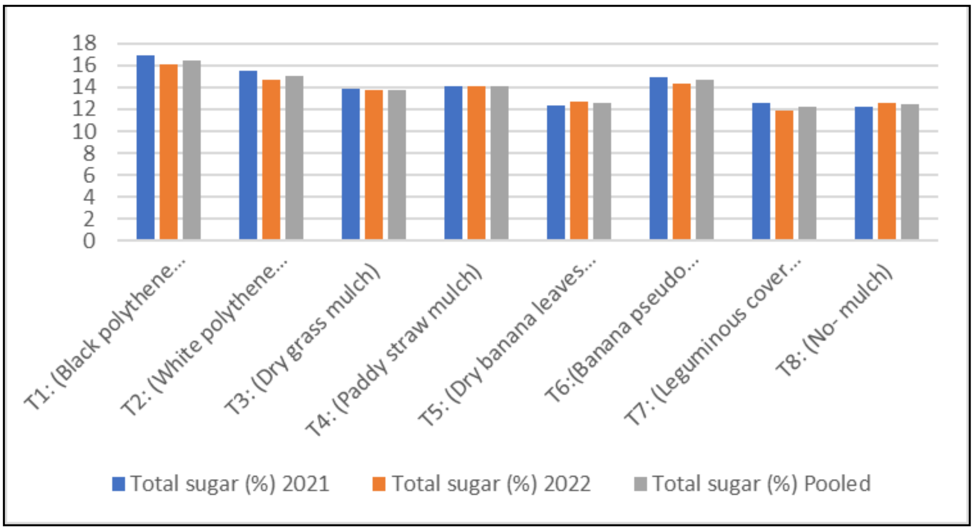



**Fig 4.58 Total sugar content (%) of fruits under various mulching treatments**

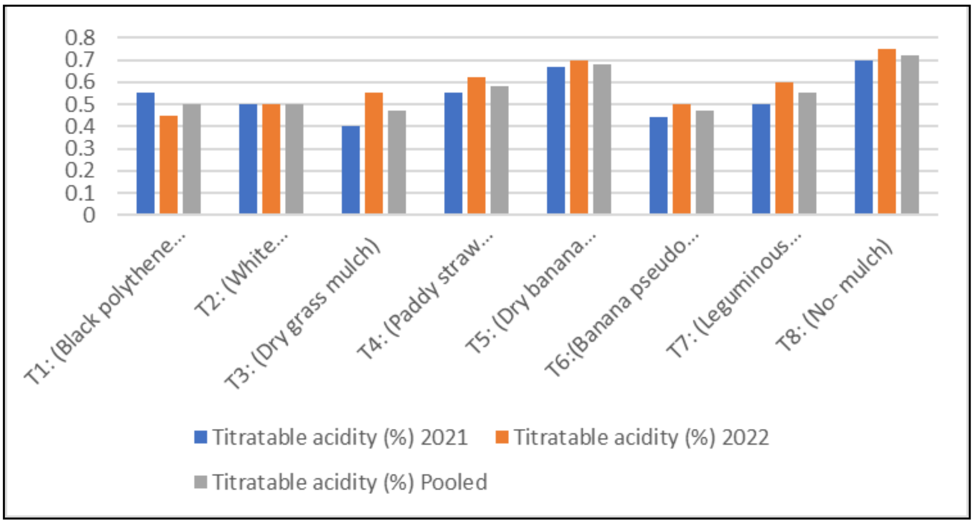



**Fig 4.59 Titratable acidity content (%) of fruits under different mulching treatments**

**Table. 4.17. Effect of various mulching material on flowering and fruiting parameters**

| Treatments | Flowering percentage (%) | | | Fruit set percentage/ panicle (%) | | | Fruit drop percentage (%) | | | Fruit retention/panicle (number) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| **$T_1$: (Black polythene mulch)** | 73.15 | 75.73 | 74.44 | 35.12 | 38.45 | 36.78 | 69.00 | 67.19 | 68.09 | 12.99 | 14.08 | 13.53 |
| **$T_2$: (White polythene mulch)** | 71.45 | 72.61 | 72.03 | 36.00 | 37.22 | 36.61 | 72.90 | 72.60 | 72.75 | 12.50 | 13.70 | 13.10 |
| **$T_3$: (Dry grass mulch)** | 64.12 | 65.66 | 64.89 | 32.50 | 34.15 | 33.32 | 73.33 | 74.66 | 73.99 | 11.30 | 12.70 | 12.00 |
| **$T_4$: (Paddy straw mulch)** | 66.33 | 69.74 | 68.03 | 34.99 | 35.45 | 35.22 | 75.41 | 73.50 | 74.45 | 12.00 | 12.99 | 12.49 |
| **$T_5$: (Dry banana leaves mulch)** | 65.00 | 65.87 | 65.43 | 32.33 | 34.12 | 33.22 | 78.08 | 75.93 | 77.00 | 11.56 | 12.41 | 11.98 |
| **$T_6$: (Banana pseudostem mat mulch)** | 70.20 | 74.49 | 72.34 | 36.00 | 36.12 | 36.06 | 72.44 | 70.63 | 71.53 | 12.88 | 13.33 | 13.10 |
| **$T_7$: (Leguminous cover crop-Soyabean mulch)** | 72.00 | 72.22 | 72.11 | 34.93 | 35.42 | 35.17 | 76.70 | 73.00 | 74.85 | 12.43 | 13.30 | 12.86 |
| **$T_8$: (No- mulch)** | 40.30 | 41.58 | 40.94 | 30.63 | 32.20 | 31.41 | 86.52 | 81.12 | 83.82 | 9.23 | 11.90 | 10.56 |
| **SEm±** | **0.28** | **0.58** | **0.69** | **0.70** | **0.01** | **0.51** | **0.91** | **0.90** | **1.01** | **0.39** | **0.04** | **0.33** |
| **CD@5%** | **0.95** | **1.98** | **2.35** | **2.40** | **0.04** | **1.73** | **3.10** | **2.75** | **3.43** | **1.35** | **0.16** | **1.12** |

**Table. 4.18. Effect of various mulching material on fruit yield and yield attributes**

| Treatments | Fruit weight (g) | | | Fruit length (cm) | | | Fruit width (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| $T_1$: (Black polythene mulch) | 17.52 | 18.95 | 18.23 | 4.00 | 4.15 | 4.07 | 3.68 | 3.75 | 3.71 |
| $T_2$: (White polythene mulch) | 16.33 | 16.75 | 16.54 | 3.80 | 3.94 | 3.87 | 3.09 | 3.11 | 3.10 |
| $T_3$: (Dry grass mulch) | 12.89 | 13.14 | 13.01 | 3.28 | 3.41 | 3.34 | 2.48 | 2.54 | 2.51 |
| $T_4$: (Paddy straw mulch) | 16.21 | 16.00 | 16.10 | 3.73 | 3.74 | 3.73 | 2.73 | 2.75 | 2.74 |
| $T_5$: (Dry banana leaves mulch) | 12.24 | 12.60 | 12.42 | 3.61 | 3.74 | 3.67 | 2.61 | 2.59 | 2.60 |
| $T_6$: (Banana pseudostem mat mulch) | 18.00 | 18.56 | 18.28 | 3.92 | 3.99 | 3.95 | 3.21 | 3.24 | 3.22 |
| $T_7$: (Leguminous cover crop- Soyabean mulch) | 15.43 | 15.52 | 15.47 | 3.52 | 3.65 | 3.58 | 2.62 | 2.66 | 2.64 |
| $T_8$: (No- mulch) | 10.42 | 9.33 | 9.87 | 3.43 | 3.42 | 3.42 | 2.66 | 2.59 | 2.62 |
| **SEm±** | **0.19** | **1.01** | **0.35** | **0.03** | **0.06** | **0.03** | **0.01** | **0.13** | **0.02** |
| **CD@5%** | **0.67** | **3.43** | **1.21** | **0.12** | **0.20** | **0.10** | **0.03** | **0.44** | **0.07** |

#### 4.4.12 Fruit cracking percentage (%)

Data given in table 4.19 and fig 4.55 indicates that there was significant effect of different mulching material on fruit cracking. Minimum fruit cracking (13.15 %) was observed in $T_1$ (black polythene mulch) followed by $T_2$ (white polythene mulch) *i.e.*, 13.35 % which was significant over all treatments and maximum was observed in $T_8$ (un-mulched) fruits 16.70 per cent.

Joshi *et al*. (2011) observed significant reduction in fruit cracking in litchi with the application of mulch and drip irrigation. The organic and inorganic mulching materials improved available soil moisture and nutrients in plant basin due to which the treatments plants showed less cracking percentage.

#### 4.4.13 Yield (kg/tree)

The data in table 4.19 depicted that effect of different mulching materials in respect to litchi yield was found to be significant due to variant treatments. The average yield during both the years ranged from 11.01 to 18.00 kg/tree in various treatments. Highest yield (18.00 kg/tree) was recorded in $T_1$ (black polythene mulch) fallowed by $T_6$ (banana pseudo stem mat mulch) *i.e*., 17.10 kg/tree and the lowest (11.01 kg/tree) in trees under $T_8$ (un-mulch).

Similarly, Bakshi *et al*. (2014) evaluated the effect of mulching material on yield of strawberry and reported that maximum yield per plant was under black polythene because of larger fruit owing to better hydrothermal regime of soil and complete weed-free environment. Das and Dutta (2018) also recorded yield (243.72 fruits/tree) in polythene mulch, while un-mulched (control) gave the minimum values (192.72 fruits/tree) in mango. Such beneficial effect of mulching was also observed by Borthakur and Bhattacharya (1992) in guava who reported that the polyethylene treatment significantly increases the growth of plants which subsequently increase the fruit physical characters.

### 4.4.14 Total Soluble Solids (ºB)

The data presented in table 4.19 and fig 4.57 shows that all the treatments significantly increased the Total soluble solids. The pooled data of 2021 & 2022 showed that maximum TSS content (17.66 ºB) was observed in treatment $T_1$ (black polythene mulch) followed by $T_2$ (white polythene mulch) (16.87 ºB) while the minimum TSS content (14.08 ºB) was recorded in $T_8$ (un-mulched).

Das and Dutta (2018) reported maximum (19.20 ºB) TSS in black polythene mulch than un-mulched treatment. Increase in fruit quality with mulching might be due to the effect of leaf potassium and an increased rate of photosynthesis which cumulatively improved the fruit quality. Iqbal *et al.* (2015) also reported similar findings that the total soluble solids were recorded highest in black polythene (10.73 ºB) followed by paddy straw mulch (10.20 ºB) while, the treatment un-mulched control produced the fruits of minimum TSS (9.70 ºB) in aonla.

**Table. 4.19. Effect of various mulching material on bio chemical attributes of litchi**

| Treatments | Fruit cracking percentage (%) | | | Yield (kg/tree) | | | TSS (ºB) | | | Total sugar (%) | | | Titratable acidity (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled | 2021 | 2022 | Pooled |
| **$T_1$: (Black polythene mulch)** | 13.26 | 13.04 | 13.15 | 17.34 | 18.67 | 18.00 | 17.82 | 17.50 | 17.66 | 16.89 | 16.14 | 16.51 | 0.55 | 0.45 | 0.50 |
| **$T_2$: (White polythene mulch)** | 13.51 | 13.20 | 13.35 | 16.59 | 17.57 | 17.08 | 17.19 | 16.55 | 16.87 | 15.50 | 14.64 | 15.07 | 0.50 | 0.50 | 0.50 |
| **$T_3$: (Dry grass mulch)** | 13.00 | 13.90 | 13.45 | 12.46 | 13.19 | 12.82 | 14.62 | 15.20 | 14.91 | 13.84 | 13.76 | 13.80 | 0.40 | 0.55 | 0.47 |
| **$T_4$: (Paddy straw mulch)** | 13.94 | 13.75 | 13.84 | 14.28 | 14.34 | 14.31 | 15.00 | 15.75 | 15.37 | 14.05 | 14.07 | 14.06 | 0.55 | 0.62 | 0.58 |
| **$T_5$: (Dry banana leaves mulch)** | 15.16 | 14.18 | 14.67 | 12.02 | 12.25 | 12.13 | 14.26 | 15.30 | 14.78 | 12.38 | 12.69 | 12.53 | 0.67 | 0.70 | 0.68 |
| **$T_6$:(Banana pseudostem mat mulch)** | 13.68 | 13.70 | 13.69 | 17.00 | 17.21 | 17.10 | 15.61 | 14.75 | 15.18 | 14.97 | 14.34 | 14.65 | 0.44 | 0.50 | 0.47 |
| **$T_7$: (Leguminous cover crop- Soyabean mulch)** | 13.70 | 13.79 | 13.74 | 12.42 | 12.50 | 12.46 | 14.87 | 14.00 | 14.43 | 12.56 | 11.86 | 12.21 | 0.50 | 0.60 | 0.55 |
| **$T_8$: (No- mulch)** | 16.23 | 17.18 | 16.70 | 10.53 | 11.49 | 11.01 | 14.52 | 13.65 | 14.08 | 12.27 | 12.59 | 12.43 | 0.70 | 0.75 | 0.72 |
| **SEm±** | **0.38** | **0.004** | **0.31** | **0.36** | **0.22** | **0.24** | **0.61** | **0.44** | **0.40** | **0.12** | **0.49** | **0.24** | **0.03** | **0.02** | **0.03** |
| **CD@5%** | **1.29** | **0.015** | **1.08** | **1.25** | **0.77** | **0.83** | **2.10** | **1.51** | **1.37** | **0.43** | **1.67** | **0.83** | **0.11** | **0.08** | **0.12** |

### 4.4.15 Total sugar (%)

The data presented in table 4.19 and fig 4.58 shows that all the treatments significantly affected total sugar content. The pooled analysis of total sugar content indicated that maximum total sugar content (16.51 %) was found in treatment $T_1$ (black polythene mulch) followed by $T_2$ (white polythene mulch) (15.02 %). On the other hand, minimum total sugar content (12.21 % and 12.43 %) was found in treatment $T_7$ (leguminous cover crop- soyabean mulch) and $T_8$ (no-mulch).

These observations are in conformity with the results obtained by Chattopadhyay and Patra (1993) who recorded higher percentage of total sugars (10.8 %) in pomegranate under black polythene mulch. The maximum formation of sugars with ripening of fruits is evident as disappearance of starch as reported by Joshi and Roy (1985). Increased sugars might be due to slow hydrolysis of starch to sugars and the gradual build-up of sugars during ripening (Kulkarni and Yewale (2012).

### 4.4.16 Titratable acidity (%)

The data presented in table 4.19 and fig 4.59 shows that all the treatments significantly reduced the titratable acidity per cent. A critical examination of pooled data indicated that treatments $T_8$ (no-mulch) resulted in maximum acidity per cent (0.72) whereas, the minimum acidity (0.47 % and 0.47 %) was recorded with $T_3$ (dry grass mulch) and $T_6$ (banana pseudo stem mulch).

Iqbal *et al*. (2015) reported that maximum titratable acidity (1.92%) was recorded in fruits under un-mulched plants while the least titratable acidity (1.64%) was recorded under black polythene mulching in aonla. Maximum acidity was obtained in control may be due to reduced cell size and cell division due to less turgor pressure and internal auxin content. Highest percentage of acidity was also recorded by El-Tawell and Farag, 2015 in un-mulched plants of pomegranate.

# SUMMARY AND CONCLUSION

The present investigation entitled "**Effect of different technological interventions on yield and quality of litchi grown in Nagaland**" has been conducted in the research experimental block of Horticulture department, School of Agriculture Sciences and Rural Development, Nagaland University, Medziphema campus, Nagaland during 2020-21 and 2021-22. Experiments under the first objective was laid out in Factorial Randomized Block Design and the other three objectives were laid out in Randomized Block Design with three replications each, to assess the effect of girdling, bagging, spray of PGR and chemicals and mulching materials on intensity of flowering, yield and quality attributes of litchi.

The results thus obtained during the period of investigation are summarized objective wise in this chapter:

### 5.1.1 To study the effect of different levels & widths of girdling on bearing potential of litchi cv. China

The effect of various treatments of girdling on performance of growth, yield and biochemical attributes of litchi was showed significant difference in among the treatments.

#### 5.1.1.1 Growth and flowering attributes

The different levels, widths of girdling and their interaction effect significantly influenced the flowering percentage, fruit set number at clove stage but the level of girdling shown non-significant with wound healing period, appearance of girdle portion and days to flower after girdling. Among the interaction effect, $G_2L_2$ (50 % & 4 mm) treatment was found maximum flowering percentage (90.04 %) and fruit set at clove stage (103.26) as compared with un-girdled trees (44.07 % and 56.83).

#### 5.1.1.2 Fruit attributes

The different levels, widths of girdling and their interaction effect significantly influenced the fruit length, width but the level of girdling shown non-significant with fruit drop percentage at clove stage, fruit drop percentage at harvest stage and fruit retention per panicle. Among the interaction effect, $G_2L_2$ (50 % & 4 mm) treatment was found maximum fruit retention per panicle (19.83), fruit length (4.00 cm), width (3.54 cm) and minimum fruit drop percentage at clove stage (74.59 %) whereas un-girdle trees showed maximum fruit drop at clove (93.03 %) and harvest stage (84.17 %) and minimum fruit retention per panicle (7.66).

**5.1.1.3 Yield attributes**

Different levels, widths and their interaction of girdling effect significantly influenced the fruit weight, yield of litchi but the level of girdling shown non-significant with pulp weight, pulp percentage and seed weight. Among the interaction effect, $G_2L_2$ (50 % & 4 mm) treatment was found maximum fruit weight (17.22 g), pulp weight (10.49 g), pulp percentage (60.87 %) and yield (17.72 kg/tree).

**5.1.1.4 Bio-chemical parameters**

The different levels, widths and their interaction of girdling effect showed less significantly influenced the chemical characters of litchi fruits. The maximum TSS (16.26 ºB), TSS: acid ratio (27.15) and total sugar (14.72 %) was recorded in $L_2$ (4 mm) width of girdling while titraTable acidity (0.71 %) and C/N ratio of leaves after girdling (4.22 %) was found maximum in $L_3$ (6 mm) of girdling.

Among the interaction effects, $G_2L_2$ (50 % & 4 mm) treatment was found maximum total sugar (16.03 %), TSS (18.01 ºB), TSS: acid ratio (33.81) and minimum titratable acidity (0.53 %).

**5.1.2 To study the effect of bagging on quality of litchi fruits cv. Shahi**

The effect various bagging material and time of bagging significantly influenced on fruit quality improvement parameters.

**5.1.2.1 Fruit quality parameters**

The effect various bagging materials and time of bagging significantly influenced the fruit quality parameters. The fruit colour was noticed when fruits were bagged 30 days after fruit set *i.e.*, deep purple red colour as compared to the unbagged fruits with moderate purple red colour. The maximum anthocyanin content (26.11 mg/100g), fruit weight (23.12 g) and minimum borer infestation (< 1%) was recorded in brown paper bag at 30 DAFS while maximum TSS (21.30 ºB), TSS: acid ratio (50.34) and minimum acidity (0.42 %), fruit cracking percentage (1.71 %) and sunburn (3.59 %) was recorded in pink polypropylene bag at 15 DAFS as compared to un-bagged fruits was recorded lowest anthocyanin content (15.25 mg/100g), fruit weight (9.68g), TSS (9.96 ºB), TSS: acid ratio (18.53) and highest acidity (0.67 %), borer infestation (87.16%), fruit cracking (10.77%) and sunburn (28.87%) percentage.

#### 5.1.2.2 Mean microclimate available inside bag

Effect of different bagging materials and time of bagging on microclimate (temp, RH, light and degree days) inside bags was shown significant difference among the treatments. The highest temperature (37.08 ºC) and growing degree days (2,115.50 ºDays) was recorded under Polypropylene Pink (PPP) bag whereas highest relative humidity (31.71 %) and lowest temperature (34.99 ºC), light intensity (31.43 lux) and growing degree days (1,990.17 ºDays) was recorded in Brown paper bag (BPB) as compared to un-bagged fruits shown lowest RH (27.09 %) and highest light intensity (216.99 lux).

### 5.1.3 To study the effect of plant bio regulators and chemicals on flowering and fruiting of litchi cv. Shahi

The effect of different bio regulators, chemicals and its combinations on improvement of flowering and fruiting intensity of litchi were shown statistically significant among the different treatments.

#### 5.1.3.1 Flowering attributes

The pooled data of 2021 & 2022 shown treatment $T_3$ (ethrel @ 400 ppm) earliest panicle initiation (28-January) and advance of flower (-9 days) induction, while $T_2$ ($K_2HPO_4$ @ 1%) recorded maximum number of flowers per panicle. Whereas $T_4$ ($GA_3$ @ 100 ppm) was recorded delayed panicle initiation (26-February) and flower induction

(+2 days) than $T_{10}$ (no-spray) (21-February). With respect to sex ratio (F-M) $T_4$ has shown highest (6.66 %) as compare with $T_{10}$ (0.77 %).

### 5.1.3.2 Fruiting attributes

The effect of various bio regulators and chemicals were significantly influenced the fruit quality parameters. The treatment $T_3$ (ethrel @ 400 ppm) was shown less number days taken to fruit set (22.50 days), days taken to mature (50.50 days) and days taken to harvest (59.50 days), whereas $T_4$ ($GA_3$ @ 100 ppm) was taken more number days *i.e.*, 34.50, 61.00 and 70.00 days respectively.

### 5.1.3.3 Bio chemical traits

The bio chemical parameters of different plant bio regulators and chemicals sprayed treatments showed significant difference. Among the treatments $T_4$ ($GA_3$ @ 100 ppm) was recorded highest TSS (20.30 ºB), TSS; acid ratio (46.99), total sugar (22.5 %) and lowest acidity (0.43 %) whereas $T_1$ ($KNO_3$ @ 1%) was recorded lowest TSS (14.82 ºB), total sugar (10.09 %) and $T_{10}$ (no-spray) recorded high acidity (0.71 %).

### 5.1.4 To study the effect of various mulch materials on fruiting and quality of litchi fruits cv. China

The effect of various mulch materials (organic and inorganic) on soil moisture, nutrient conserving, flowering, fruiting and quality attributes of litchi shown significant difference among the treatments.

### 5.1.4.1 Available soil moisture and nutrients

During 2021 and 2022, the increased soil moisture retention was recorded maximum (14.80 and 15.50 %) in $T_1$ (Black polythene mulch) whereas it was minimum (-1.36 and -2.70 %) in trees under $T_8$ (no-mulch).

During 2021 and 2022, the increased soil available nitrogen was recorded maximum under the treatment of $T_1$ (black polythene mulch) *i.e.*, 27.56 and 30.07 kg/ha whereas minimum (4.80 and 3.35 kg/ha) with $T_8$ (no-mulch) treatment. The increased soil available phosphorus was recorded maximum under the treatment of $T_1$ (black polythene mulch) and $T_2$ (white polythene mulch) *i.e.*, 4.19 and 6.24 kg/ha whereas minimum (0.30 and 0.56 kg/ha) with $T_8$ (no-mulch) treatment in 2021 & 2022. With respect to potash, it was recorded maximum under the treatment of $T_2$ (white polythene mulch) *i.e.*, 18.78 and 16.68 kg/ha, whereas minimum (2.51 and 1.33 kg/ha) with $T_5$ (dry banana leaves mulch) and $T_8$ (no-mulch) treatment.

### 5.1.4.2 Flowering and fruiting attributes

Different organic and inorganic mulching materials were shown significant variance on flower and fruit characteristics of litchi. Among the different treatments the $T_1$ (black polythene mulch) was showed highest flowering percentage (74.44 %), fruit set percentage per panicle (36.78 %), fruit retention per panicle (13.53), yield (18.00 kg/tree) and lowest fruit drop percentage (68.09 %) and cracking percentage (13.15 %) as compared with $T_8$ (no-mulch) *i.e.*, 40.94 %, 31.41 %, 10.56, 11.01 kg/tree, 83.82 % and 16.70 % respectively. The treatment $T_6$ (banana pseudostem mat mulch) was showed highest fruit weight followed by $T_1$ (black polythene mulch) *i.e.*, 18.28 and 18.23 g as compared with $T_8$ (no-mulch) 9.87 g. the treatment $T_1$ (black polythene mulch) was also showed highest fruit length (4.07 cm) and width (3.71 cm) fallowed by $T_6$ (banana pseudostem mat mulch) *i.e.*, 3.95 and 3.22 cm, whereas lowest was recorded trees under $T_1$ (dry grass mulch) *i.e.*, 3.34 and 2.51 cm.

### 5.1.4.3 Bio-chemical parameters

The pooled data treatment $T_1$ (black polythene mulch) was showed maximum TSS content (17.66 ºB) and total sugar (16.51 %) content as compared with treatment $T_8$ (no-mulch) 14.08 ºB and 12.23 per cent. The treatment $T_6$ (banana pseudo stemmat mulch) was shown lowest acidity (0.47 %) whereas highest recorded under $T_8$ (no-mulch) 0.72 per cent.

## 5.2 Conclusion

It may be concluded that the different experiments on technological interventions of litchi grown in Nagaland were found to provide effective results in terms of yield and quality.

- Girdling of 50% level with 4mm width on primary branches was found to give best results in improving yield and yield attributing characteristics of litchi fruits.
- Bagging with PPP at 15 DAFS and BPB at 30 DAFS were found better with respect to fruit quality and bio-chemical parameters of litchi by creating microclimate inside bags.
- PGR sprays of $GA_3$ 100 ppm and Ethrel 400 ppm was observed to perform better in respect to flowering, fruiting advancement and quality improving attributes.

- In the case of mulching, black polythene, banana pseudo stem mat and soyabean as cover crop under mulching were found to give best results in retaining moisture, available nutrients content and fruit yield.
- Organic mulching materials (paddy straw, banana pseudostem mat and leguminous cover crop- soyabean) were shown better results as equal to inorganic (black and white polythene) mulching materials and it was completely decomposed in soil and improve the soil fertility by minimizing the soil erosion, less weeds, maintain soil moisture and nutrients in sub surface of soil.

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