ORGANIC NUTRIENT MANAGEMENT AND CROP REGULATION IN GRAPES IN MIZORAM

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BY

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SUBMITTED

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN HORTICULTURE, AROMATIC AND MEDICIANAL PLANTS OF MIZORAM UNIVERSITY, AIZAWL

Dedicated to My Loving FAMILY

Mizoram University, Aizawl

(A Central University under the Act of Parliament)

Department of Horticulture, Aromatic & Medicinal Plants

उद्यानिकी, सगन्ध एवं औषधीय पादप विभाग

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CERTIFICATE

This is to certify that **Mr. C. Lalhriatpuia** has prepared a Thesis under my Supervision on the topic "**Organic Nutrient Management and Crop Regulation in Grapes in Mizoram**" in partial fulfillment for the award of the Degree of Doctor of Philosophy (Ph.D.) in the Department of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl.

This thesis has been the outcome of his original work and it does not form a part of other thesis submitted for the award of any other degrees.

He is duly permitted to submit the Thesis.

Prof. T.K. HAZARIKA

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DECLARATION BY THE CANDIDATE

Mizoram University

December, 2021

I, **C. Lalhriatpuia**, hereby declare that the subject matter of the thesis entitled "**Organic Nutrient Management and Crop Regulation in Grapes in Mizoram*"*** is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge, to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institutes.

This is being submitted to the Mizoram University for the Degree of Doctor of Philosophy in Horticulture, Aromatic and Medicinal Plants.

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BD:	Bio-dynamic
°Brix:	Degree brix
°C:	Degree centigrade
CFU:	Colony forming units
Cm:	Centimeter
CPP:	Cow Pat Pit
et al:	And other
Fig:	Figure
FYM:	Farm Yard Manure
g:	Gram (s)
Ha:	Hectare
i.e:	That is
INM:	Integrated nutrient management
Kg:	Kilogram (s)
MSS:	Mean sum of square
Ml:	Milliliter

M:	Meter
m^3:	Meter cube
Max:	Maximum
Min:	Minimum
MOC:	Mustard oil cake
N:	Nitrogen
NC:	Neem cake
/:	Per
%:	Per cent
ppm:	Parts per million
PM:	Pig manure
POM:	Poultry manure
RDF:	Recommended dose of Fertilizer
S.Em.:	Standard error of mean
t/ha:	Tons per hectare
TSS:	Total soluble solids
Var:	Variety
viz:	Namely
VC:	Vermicompost

Introduction

Grape (*Vitis vinifera* L.) is one of the perennial deciduous woody vines cultivated in the temperate, tropical and subtropical regions of the world. It belongs to the family Vitaceae and is most widely distributed due to its genotypic diversity and broad range of environmental adaptation (Patil *et al*., 2012). Contrary to the other fruit crops, grape is not only used as a fruit in its multiple uses (fresh fruit, fruit juice, dried fruit etc.), but it is the basis for the production of high value added products such as wine and spirits. The fruit also has secondary metabolism producing colour pigments, tannins, flavor and aroma compounds (Singh and Singh, 2011).

In India, it is grown on an area of 139 thousand ha with an annual production of 2920 thousand tonnes and a productivity of 21.02 tonnes/ha (Anon, 2018). In our country, 74.5 per cent of produced grape is available for table purpose, nearly 22.5 per cent is dried for raisin production, 1.5 per cent for wine making and 0.5 per cent is used for juice making (Somkuwar *et al*., 2013). In India, it is being grown mainly in Maharashtra, Karnataka, Tamil Nadu, Mizoram and Andhra Pradesh. Maharashtra occupies the top slot in cultivation and production of grapes in the whole country having 105.50 thousand ha area under cultivation (about 75.89 % of the country) with production of 2286.44 thousand metric tonnes with productivity of 21.67 tonnes per hectare (Anon, 2018).

Mizoram occupied fourth position among all the grape growing states of India with a production of 18.00 thousand tonnes from an area of 2.45 thousand hectares with a productivity of 7.35 tonnes per hectare (Anon, 2018). Grape cultivation in Mizoram has been initiated by the Horticulture Department, government of Mizoram especially at Hnahlan village and as well as some nearby villages of Champhai district of Mizoram. "Bangalore Blue" is the most common cultivar of grapes cultivated in the state. Hnahlan village, near the Indo-Myanmar border, noted for its extensive grape cultivation, is now striving to become the largest grape producing village in India and is famous for its production of grapes and grape wine called ‘Zawlaidi’. Around 80 per cent of the villagers are engaged in grape cultivation, after forsaking the primitive shifting cultivation 10 years ago and were now reaping the 'fruits of their labour'.

However, cultivation practices followed were of conventional method with indiscriminate use of fertilizers and other inorganic inputs and due to which the soil lost its biological dynamics. Since, most of the farmers are cultivating the crop as a rainfed crop without any organic amendments, the yield is also not satisfactory. Therefore, the use of available resources like organic and microbial inoculants in an integrated approach is the only option in present day context to maintain the soil fertility as well as to boost the productivity.

Fertilizers and organic manures constitute important inputs in the production of fruit crops. Plants require essential mineral nutrients to complete their life cycle and the quantities required for optimum growth and production vary with species. Among different fruit crops, grapes are heavy feeder of nutrients and require all the three major nutrients for their growth, development and yield. The requirements of these nutrients are generally supplied by chemical fertilizers. But, excessive and unbalanced use of chemical fertilizers may lead to health and ecological hazards, depletion of physico-chemical properties of the soil and ultimately poor crop yields (Singh and Singh 2009). In addition, excess chemical fertilization could be the main cause of pollution in surface and ground water as well as soil and now become diseased and desolate under the influence of indiscriminate and uncontrolled use of inorganic fertilizers (Hazarika *et al.,* 2011).

Therefore, reducing dependency on chemical fertilizers and conserving the natural resources in alignment with sustainable crop production are vital issues in present times. There is an urgent need to reorient the research priorities towards developing an alternate system in crop production which is cheaper, better, and safer with minimum eco hazards. The best alternative for sustainable production of crops is to minimize the ill effects of inorganic cultivation and promoting the organic cultivation of crops. Organic farming is a production system that largely excluded the use of synthetically produced fertilizers, pesticides, growth regulators, and livestock feed additives. Besides, fertilizers there are several sources of plant nutrients like organic manures, biofertilizers, crop residues, animal residues, animal manures, legumes, green manure, off-farm organic waste, etc. Organic manure provides essential nutrients improving soil health for sustainable agriculture.

Organic horticulture is a agricultural production management system that promotes and enhances biodiversity, biological cycles and soil biological activity (Research Institute of Organic Farming, 2000; Alternative Farming Systems Information Centre, 2005). The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals and humans. In horticultural crops, there is ample scope of organic farming to obtain superior quality produce to ascertain nutritional security for better human health. On farm produced quality organic inputs from locally available bio-resources form an integral component of organic agriculture.

Organic manures are bulky in nature, but contain all the essential nutrients including micronutrients which are required for the growth and development of crops. Use of organic manures has been recognized as the most efficient practice for stimulation of various biological transformations in the soil, leading to soil fertility and health (Narayanaswamy *et al.,* 2006). Application of organic manures to soil not only improve soil physical properties, pH, water holding capacity but also add important nutrients to the soil, thus increase the nutrient availability and its ultimate absorption by plant (Hazarika *et al.,* 2014).

Organic manures reduce the amount of toxic compounds (such as nitrates) produced by conventional fertilizers in crops, hence improving the quality of produce as well as human health. Increased consumer awareness of food safety issues and environmental concerns has contributed to development of organic farming over the last few years (Worthington, 1998; Worthington, 2001).

Use of bio-fertilizers helps in restoring the soil fertility and improves physic-chemical and biological properties of soil. These essential substances are the bio stimulants, which act as growth booster by inflicting positive effects on plant nutrition and protect crop against diseased conditions (Asghar *et al.,* 2002).

The use of microbial inoculants is considered as the alternative source to meet the nutrient requirements of crops.The enhancement of soil fertility assumes importance not only for sustainable agricultural productivity but also for nutritional status of fruits in rain fed conditions. The use of bio-fertilizers is being sought to maintain and improve soil quality and productivity levels at low input cost. Through better conservation of C, N and P, use of sole or co-inoculation of bio-inoculants, viz *Azotobacter*, *Azospirillum* and *Pseudomonas striata* and arbuscular mycorrhizal fungi which are the components of organic farming regulate steady supply of nitrogen and phosphorus during plant growth (Singh and Singh 2006). Bio-fertilizers are known to exert indirect effects on soil microbiological activities which in turn help the plant to grow better, besides direct effect on nitrogen fixation and P mobilization (Rana and Chandel, 2003). Bio-fertilizers such as *Azospirillum, Azotobacter,* PSB, and VAM have potential practical applications to increase crop productivity through increased biological nitrogen fixation, increased availability or uptake of nutrients through phosphate solubilisation or increased absorption, stimulation of plant growth or by rapid decomposition of organic residues. *Azospirillum* and *Azotobacter* help the plants indirectly though better nitrogen fixation or improving the nutrient availability in the soil. They have the ability to fix 20-200 kg N ha^{-1} and increase crop yield by 10-50 per cent (Bashan, 1998). *Azospirillum* also produce growth promoting substances like IAA and GA and their phyto-hormones go a long way in enhancing the crop growth (Govindarajan and Thangaraju, 1998). Inoculation of these N -fixing microorganisms in the soil not only increases the yield but also save 20-40% nitrogen inputs (Hazarika *et al.*, 2014). While, phosphate solubilizing bacteria‘s (PSB) are used to increase the availability of phosphorus in soil.

Biodynamic preparations is a recent introduction in organic farming which uses no synthetic chemical fertilizers and pesticides, and instead emphasizes building up the soil with compost additions and animal and green manures, controlling pests naturally, rotating crops, and diversifying crops and livestock. In biodynamic preparations eight specific preparations added to their soils, crops, and composts to enhance soil and crop quality and to stimulate the composting process. The eight preparations are made from cow manure, silica, flowers of yarrow, chamomile, dandelion and valerian, oak bark, and the whole plant of stinging nettle. Biodynamic practices show promise in mitigating some of the adverse effects of conventional agriculture on the environment.

Complementary use of organic manures and bio-fertilizers not only helps to maintain higher crop productivity but also sustain higher soil fertility. Moreover long term sustainability of productivity could be achieved only through interaction of organic sources of nutrients with bio-fertilizers (Hedge *et al*., 1992). In view of the factors like increasing demand of organically grown fruits by consumers coupled with unsustainable productivity, organic farming is claimed to be most benign alternative, for which the role of organic manures and bio-fertilizers become important for sustainable production with quality fruits (Singh *et al*., 2014).

Under the above circumstances, there is a renewed interest among the researchers to identify the alternative sources of nutrients to meet the nutrient demand of the crop in an eco-friendly manner and also to retain the physical, chemical and biological properties of the soil without any loss and to maintain quality demand of the crop. As a result, several organic and bio-fertilizer sources have emerged as viable alternative source of fertilizer in crop nutrient programme and being increasingly used in crop production.

Over cropping can reduce the fruit quality in the current season, and can also result in poor bud- break, delayed growth and reduced fruit yield in the following season (Nick *et al*., 1996). Retention of more crop load on the vine reduces the quality of final produce harvested in terms of size, appearance; colour etc. maintenance of crop load is a key step in getting good quality bunches either for local market or for exporting the grapes in the international market (Somkuwar *et al.*, 2010).

Crop regulations as a mean of improving clusters, berry and fruit quality have been recommended by many workers (Ahmed and Zargar, 2005; Thakre *et al.*, 2013; Chandel and Singh, 2015). As far as crop regulation is concerned, it is a way to force a tree for its rest and to produce profuse blossom and fruits during flushes (Thakre *et al*., 2013). The operation also aims to regulate into a uniform and good quality fruit and to maximize the production as well as profit to the grower (Singh, 2001).

Pruning had a significant effect on the tree height, tree spread, canopy volume and fruit yield (Kumar and Rattanpal, 2010). Balanced pruning is the standard cultural practice used to control grapevine crop level and regulate vine vigour. Some table grape cultivars developed, tend to be vigorous and produce an over abundant amount of fruiting clusters. Extra clusters retained through bloom may result into reduced berry set per cluster. Due to heavy load on the vine, cluster drying from tip is also observed in the majority of vineyards. A practice commonly used to decrease cluster compactness and improve berry size is cluster thinning. When fewer clusters on the vine are retained, the grape clusters have more berries set on the rachies and larger berries results (Somkuwar *et al.*, 2014). Girdling, thinning and application of plant growth regulators can cause various beneficial effects on the vine by affecting berry set, berry size, cluster compactness and other physical and chemical characteristics (Ahmed and Zargar, 2005).Control of fruit set is mandatory for seedless table grape production because of its influence on yield and fruit quality. Berry removal can be achieved manually, in a very expensive operation (50–80 labour days/ha) and/or chemically through the application of the growth regulator gibberellic acid (Di Lorenzo *et al.*, 2011). Fruit thinning is necessary to improve size and quality of fruits, besides reducing limb breakage and maintain optimum crop load and vegetative growth for sustainable production (Chandel and Singh, 2015).

In grapes, application of plant growth regulators influenced the vegetative growth, flowering, fruiting, yield and post-harvest production. It had also been noted that excessive fruit drop can be controlled by the exogenous application of plant growth regulators. Today‘s great progress in plant growth regulators use has come in areas of fruit thinning and retardation of pre-harvest drop (Bisht *et al.,* 2018). The auxin and gibberellins are widely used to control the fruit drop and to improve the quality of grapes (Suman *et al.,* 2017). Use of gibberellins has positive effect on the length and width of the berries when dipped in optimum concentration. Moreover, larger berry size is obtained if it is used in combination with girdling of the trunk (Weaver *et al*., 1959). Ethephon gave satisfactory results regarding export pack-out, export-quality berry colour at harvest and post-cold-storage quality of grape berries (Lombard *et al.,* 2004).

Keeping the all above background information in mind, the present investigation “Organic nutrient management and crop regulation in Grapes in Mizoram**”** was undertaken with the following objectives:

Objectives

1. To study the effect of organic manures, bio-fertilizers and bio-dynamic preparations on growth, yield and quality of Grapes in Mizoram.
2. To analyze the soil health of grape plantation under the influence of organics, bio-fertilizers, bio-control agent and bio-dynamic preparations.
3. To study the economics of grape cultivation under organic nutrients.
4. To assess the impact of crop regulation on growth, yield, quality and economics of grapes.

Review of Literature

Evidences are well documented in support of using integration of organic nutrients in horticultural production system. Combined application of organic manures and bio-fertilizers play an important role for the growth and development of the plant. The use of bio-fertilizers along with other organic manures seems to be an important approach for increasing yield of the crop and also helps in efficient management of diseases and pests.

The literature pertaining to recent research works conducted in India and abroad on the influence of organics on growth, yield, quality and economics of production of different fruits have been reviewed in this chapter.

2.1. Plant growth

2.1.1. Effect of organic manures on plant growth

Marathe *et al*. (2016) reported that farm yard manure (FYM), vermicompost (VC), poultry manure (PM), and *in situ* green manuring (GM) improved the growth and yield of pomegranate (*Punica granatum* L.) cv. 'Bhagwa'

Garhwal *et al*. (2014) carried out a study on seven years old healthy Kinnow trees at Central Institute of Arid Horticulture, India to study the effect of organic manures on growth of kinnow mandarin trees and concluded that application of 80 Kg farm yard manure (FYM) per plant significantly increased tree growth and trunk diameter (9.47%).

Shaheen *et al.* (2013) carried out a study on 10 years old "Superior Seedless" grapevies to study the effect of organic nutrients on growth and found out that application of 50% (compost, rock phosphate and feldspar) + 50% of the NPK mineral recommended fertilizers + bio-fertilizer was the best management system for ensuring the best vegetative growth in grapevines.

Mugnai *et al.* (2013) studied the effect of compost on growth, yield and quality of *Vitis vinifera* cv. Chardonnay and concluded that long term application of compost have positive effect on soil organic matter content, nitrate content which eventually effect the growth of the vines positively.

Fawzi *et al.* (2010) carried out a study on "Le Conte" Pear grown in the orchard of Cairo to investigate the effect of organic farmyard manure (FYM), Nile compost (COM), biofertilizes (Bio) as combination between (phosphorene and nitrobeine), and sprays of magnesium sulphate single or combination and found that combined application significantly increased vegetative growth (shoot length and leaf area), leaf minerals content (N, P, K and Mg), yield as well as physical and chemical properties of the fruits compared to untreated trees.

Umar *et al.* (2009) studied the effect of FYM integrated with urea and *Azotobacter* on growth on Strawberry cv. Chandler in the Research orchard of Division of Fruit Science, Faculty of Agriculture and found that strawberry plants attained the maximum plant height, spread, and maximum leaf area with the application of 25 per cent nitrogen through FYM augmented with *Azotobacter*.

Morlat (2008) conducted a field experiment on the effect of different forms of organic manures on Carbernet franc vine in a Loire Valley Vineyard on different parameters such as growth, yield, rooting system and found that optimum application of organic manures effect the growth of vines better as compared to higher dose as it was unprofitable and no further benefits in term of vine durability.

Mostafa (2008) carried out an investigation on Flame seedless grapes to study the effect of organic manures and bio-fertilizers on growth of grapevines and he concluded that replacing 75% of RDN for grapevines by organic as well as using 50% of RDN combined with sulphur application were very useful in improving growth of the vines.

In an experiment conducted by Kanamadi *et al*. (2004) on banana cv. Rajapuri to study the effect of organic and inorganic fertilizers found that with the application of farm yard manure (FYM) and neem cake combination had maximum pseudostem girth in banana cv. Rajapuri.

2.1.2. Effect of bio-fertilizers on plant growth

Gastol and Świątkiewicz (2015) reported that the influence of different biofertilizers (AMF liquid/granular inocula, humic and seaweed extracts) on the growth and yielding of 'Topaz'/M.26 apple planted on SARD soils in Poland had positive effect the trees growth, polyphenol content of the fruit, better rooting and higher fruit yield.

Parewa *et al.* (2014) in their study of plant growth promoting rhizobacteria on the influence of different crops concluded that combined application of *Azospirillum*, *Azotobacter* and inorganic nitrogen fertilizer enhanced the plant height, number of leaves and girth in banana compared to non-inoculated control.

Mohamed *et al.* (2013) revealed that Valencia orange trees (*Citrus Sinensis*) treated with Magnetite, Diatoms and biofertilizer (mixture of *Cyanobacteria* and

Azolla) resulted in higher vegetative growth, increased plant girth and better fruit quality.

Khalil (2012) in his investigation on Flame seedless grapevines treated with three bio-fertilizers *viz.* Nitrobeine, Phosphorein and Halex stated that there were significant increases in shoot length, leaf area, nutrient content in leaf petiole, berry quality etc.

Kundu *et al.* (2011) carried out a study to find out the effect of bio-fertilizer and inorganic fertilizer in Amrapali mango trees with three levels of inorganic fertilizers (100% NPK, 75% NPK and 50% NPK) applied alone and in combinations with different bio-fertilizers (*Azotobacter, Azospirillum* and VAM). Among sixteen treatments, the efficiency of inorganic fertilizer at three levels was more when supplemented with both *Azotobacter* and VAM.

Ozdemir *et al*. (2010) examined the effect of Arbuscular Mycorrhizal (AM) fungus species *Glomus mosseae* and *Glomus intraradices* on growth and leaf nutrition status of grapevine rootstocks, '5 BB' (*Vitis berlandieri* x *Vitis riparia*), '1613 C' (*Vitis solonis* x *Vitis riparia* cv. 'Gloire de Montpellier'), '41 B' (*Vitis vinifera* L. cv. 'Chasselas' x *Vitis berlandieri*) and *Vitis vinifera* L. cv. 'Early Cardinal', and found that development of the grapevine genotypes was significantly affected by mycorrhizal inoculation. Both fungi promoted significant increases in shoot and root growth of the vines.

Karakurt *et al.* (2010) conducted a study on plant growth rhizobacteria strains *Agrobacterium rubi* A-18, *Bacillus subtilis* OSU142, *Burkholderia gladioli* OSU-7 and *Pseudomonas putida* BA-8 on growth and leaf nutrient content of 'Starking Delicious', 'Granny Smith', 'Starkrimson Delicious', 'Starkspur Golden Delicious' and ‘Golden Delicious’ apple cultivars grafted on semi-dwarf rootstock MM-106 and found that applications of bacterial strains increased the leaf number and area as well as number of annual shoots and their diameter of the apple trees.

Osman *et al*. (2010) carried out an investigation to study the effect of organic and bio N-fertilization on growth, productivity of Fig and they concluded that poultry manure + *Azotobacter* + poultry manure + *Azospirillum* gave the highest number of new shoot, shoot length, leaf area, and total chlorophyll.

Osman *et al*. (2010) studied the effect of Mineral and Bio-NPK Soil application on vegetative growth of young olive trees and reported that there was significant increase in the vegetative growth of the plants treated with kotengin + biofertilizer + K, as compared to untreated control.

Dutta *et al.* (2010a) revealed that *Azotobacter* + *Azospirillum* + VAM + 2 kg FYM showed maximum plant height, plant girth and number of fruits per plant in papaya.

Singh and Singh (2009) reported that application of *Azotobacter* + *Azospirillum* + 60 kg N ha^{-1}+ 100 ppm GA_3 in strawberry cv. Sweet Charlie resulted in higher plant height, number of leaves, leaf area, crowns per plant, and total biomass.

El-Boray *et al.* (2006) in their investigation with apple tree inoculated with nitrogen fixing bacteria (*Azotobacter chroococcum* and *Baccilus polymixa*) revealed that there was significant increase in the vegetative growth of the apple trees.

Soliman, (2001) observed that banana plants inoculated with free nitrogen fixing bacteria, mycorrhizal fungi and yeast increased the pseudostem height, total number of leaves and the dimension of the third leaf from the top.

2.1.3. Effect of biodynamic preparations on plant growth

Malsawmkimi and Hazarika (2018) reported that integrated application of FYM + CPP + BD 500 + BD 501 (T_6) resulted in maximum plant height, plant girth, canopy spread and canopy volume of Khasi mandarin trees in Mizoram, India.

Doring *et al.* (2015) in a field trial on grapes reported that use of the biodynamic preparations had influence on vine growth, development, trunk diameter, number of leaves and cane development.

Pathak and Ram (2012) revealed that with the application of BD 500 and BD 501, which are rich in microbial consortia, macro and micro nutrients and plant growth promoting substances and immunity enhancers to tree crops have positive effect on the plant vigour, soil nutrient content and overall quality of the crops.

Punam *et al*. (2012) conducted an experiment on the effect of organic management treatments on the productivity and quality of lemon grass *(Cymbopogon citratus)* and revealed that highest plant height and maximum number of offshoots was observed with the integrated application of organic manure+ BD-500.

In a study conducted by Ram and Nagar (2004) on the effect of different organic treatments in combination with biodynamic preparations on overall growth of guava cv. Allahabad Safeda reported that there were maximum plant vegetative growth, plant height, plant girth when BD preparations are applied and maximum increase in plant spread with application of CPP.

2.2. Yield attributing characters and yield

2.2.1. Effect of organic manures on yield attributing characters and yield

Negi *et al.* (2021) reported that organic manures (FYM, vermicompost and forest litter) application in strawberry (*Fragaria ananassa* Duch. cv. Chandler) resulted in maximum increase in yield per plant and yield per plot.

Elsadic *et al.* (2017), reported that organic manure and NPKS as soil application had positively affect yield components of fruit, number of fruits/strand, fruit number/bunch, fruit set percent and total fruit yield / palm.

Ennab (2016) revealed that application of farmyard manure positively affect the number of fruits yield in Eureka lemon trees.

Kumar and Kumar (2013) recorded that in mango maximum number of fruits per tree and yield per tree with application of 75 kg vermicompost per tree followed by 50 kg vermicompost per tree.

Shivakumar *et al.* (2012) observed application of farm yard manure equivalent to 100% RDN yielded more fruit number and fruit weight in papaya.

Fayed (2010) revealed that organic fertilizers: camel, sheep and chicken manures application resulted in fruit set and yield in twenty years old "Endory, Frantoyo, Shemlaly and Zafaraney" olive cultivars.

Amiri and Fallahi (2009) found that application of deep litter cow manure @ 30 t ha^{-1} or deep litter poultry manure @ 10 t ha^{-1} resulted increased yield and fruit size, in ‘Golden Delicious’ apple (*Malus domestica* Bork).

Macit *et al*. (2007) compared five short-day strawberry (*Fragaria x ananassa* Duch) cultivars viz. Sweet Charlie, Redlans Hope, Kabarla, Festival and Camarosa to evaluate their yield, quality and nutritional status under organic and conventional growing conditions and reported that there were significant differences in average fruit weight among cultivars in organic and conventional system.

2.2.2. Effect of bio-fertilizers on yield attributing characters and yield

Fikry *et al.* (2020) revealed that on 5 year old Murcott tangerine (*Citrus reticulata*, Blanco.) treated with N at 100% N /tree/year or 25% (N) mineral + 75% (N) using EM1 resulted in better fruit growth, and yield of the trees.

Morsey *et al.* (2015) reported that in "Anna" apple trees budded on MM106 rootstock, by using different biostimulants and biofertilizers increased fruiting parameters (fruit set, tree yield and yield increment).

Rozpara *et al.* (2014) reported that 'Ariwa' apple trees treated with bio-fertilizers: Micosat, BF Amin, BF Quality, Humus UP, Humus Active + Activit PM, Tytanit, and Vinassa significantly improved the number of fruits, fruit weight and yield.

Dutta *et al*. (2014) reported that guava plants treated with *Azospirillum*+ *Azotobacter* + VAM showed maximum fruit weight.

Godage *et al.* (2013) concluded that guava (*Psidium guajava* L.) cv. Allahabad Safeda applied with 75% N + 75% P2O5 +100% K2O+ *Azotobacter* + PSB resulted significantly higher number of flowers per branch, fruit set per branch and fruit retention, fruit diameter, fruit weight and pulp weight, yield attributing characters, number of fruits per tree and fruit yield per tree.

In an investigation conducted by Sharma *et al*. (2013) reported that bio-fertilizer is the chief source of different micronutrients which play an important role in regulation fruit length and diameter of Guava by enhancing metabolic activities in plant cells.

Dwivedi *et al.* (2012) conducted an experiment on 'Red Fleshed' guava and observed that maximum fruit yield for the rainy and winter season crop was 38.2 and 19.0 kg/tree respectively with 250g *Azotobacter* + 20 kg FYM.

Devi *et al*. (2012) recorded higher fruit weight (230.5g) by application of neem cake and vermicompost + *Azotobacter*+ phosphorous solubilizers + potash mobilizers and maximum numbers of fruits per plant and maximum yield by using farm yard manure + *Azotobacter* + phosphorous solubilizers + potash mobilizers in guava.

Dutta *et al*. (2010a) revealed that *Azotobacter* + *Azospirillium* + VAM + 2 kg FYM showed maximum plant height, plant girth and number of fruits per plant in Papaya.

Sharma *et al.* (2009) reported that application of poultry manure augmented with *Azotobacter* and *Azospirillum* showed maximum fruit weight in guava.

Singh and Singh (2008) studied the response of nitrogen fixing bacteria in conjunction with chemical fertilizers and plant bio regulators on the yield of strawberry cv. Sweet Charlie and found that highest fruit set, and optimum fruit yield was recorded in plants inoculated with *Azotobacter* and *Azospirillum* along with 60 kg N ha^{-1} (50% N of the standard dose) and 100 ppm GA_3.

Ram and Pathak (2006) reported that in guava, maximum number of fruits and yield were consistently recorded for 2 years from the trees applied with 20kg FYM inoculated with *Azotobacter*.

Dey *et al.* (2005) reported that application of phosophate solubilizers significantly influenced fruit weight of guava over the control.

Shenawi and Sayed (2005) revealed that application of 100 kg FYM + 3 litres bio-fertilizers per plant per year caused significant increase in number of hands per bunch of Grand Naine banana.

Sharma (2002) reported that there was significant increase in the bunch weight and yield with *Azotobacter* and organic supplements over 100 per cent fertilizer.

Sudhakar *et al.* (2000) in their field experiment to evaluate three nitrogen fixing bacteria (NFBs) namely *Azotobacter*, *Azospirillum* and *Beijerinckia* as foliar bio-fertilizers on mulberry (*Morus* spp.) found that addition of *Azotobacter* resulted significantly greater yield.

2.2.3. Effect of biodynamic preparations on yield attributing characters and yield

Malsawmkimi and Hazarika (2018) reported that integrated application of POM + CPP + BD 500 + BD 501 (T_9) recorded maximum yield/ha of Khasi mandarin in Mizoram, India.

Doring *et al* (2015) conducted a field trial on *Vitis vinifera* L. cv. Riesling by using organic and biodynamic treatments and their results revealed that the integrated organic and the biodynamic treatments showed significantly higher growth and yield attributing characters and yield of grapevine

Jennifer *et al.* (2010) reported that bio dynamically treated grapes recorded highest average cluster per vine, yield and berry weight than organically managed grapes.

Zaller and Kopke (2004) studied the effects of applications of traditionally composted farmyard manure (FYM) and two types of bio dynamically composted FYM and found that biodynamic preparation affect the yield of crops positively.

2.3. Quality parameters of fruits

2.3.1. Effect of organic manures on fruit quality

Negi *et al.* (2021) reported that there was significant improvement in fruit quality parameters including ascorbic acid, total sugar, total phenolic content, and antioxidant capacity by application of organic manures (FYM, vermicompost and forest litter) in strawberry (*Fragaria ananassa* Duch. cv. Chandler).

Sau *et al.* (2017), reported that application of liquid organic manures in mango trees cv. Himsagar resulted in higher biochemical qualities like TSS (19.70° Brix) and total sugars along with prolonged shelf life of 10 days.

Joshi *et al.* (2015) stated that application of vermicompost in plants increased pH of juice, TSS of juice, micro and macro nutrients, carbohydrate and protein content and improved the quality of the fruits.

Sharma *et al.* (2013) studied the effect of organic manures + mineral fertilization on quality and shelf life guava (*Psidium guajava* L.) Cv. Sardar and concluded that highest fruit length, breadth and fruit weight were recorded respectively in trees receiving 25% of N tree^{-1} through FYM + 75% of N tree^{-1} through inorganic fertilizer.

Lal *et al*. (2012) investigated the effect of organic manure on yield and quality of litchi (*Litchi chinensis*) cv. Rose Scented by using soil application of vermicompost, poultry manure, farmyard manure, and control and highest total soluble and ascorbic acid and total sugar content was recorded in FYM 150 kg/plant, followed by FY 125 kg/plant.

Roussos and Gasparatos (2009) compared the organic and conventional management of apple (*Malus* × *domestica* Borkh.) in terms of fruit quality. Their study revealed that the organic management systems resulted in better fruit quality attributes, in terms of total soluble solids, juice pH, titratable acidity and colour indexes.

Marzouk and Kassem (2011) reported that with application of chicken manure (CM), cow dung (CD) and composted domestic refuse (CDR) in Zaghloul cultivar of date palm increased the TSS, sugar, fruit weight, flesh weight, length, diameter and dry weight.

Marathe *et al*. (2011) observed that fruit quality in sweet orange can be achieved with the sole application of FYM.

Barakat *et al*. (2011) revealed that all organic fertilizers treatments recorded lowest titratable acidity in fruits than control in banana. Fruit quality parameters, particularly TSS (16.2^{o} brix) were improved with application of 10 kg FYM.

Patel and Naik (2010) noted that organic manures and bio-fertilizers have direct role in fruit quality in mango**.**

Singh *et al.* (2010) conducted a field experiment to evaluate the effect of bio-inoculants and inorganic fertilizers on the performance of strawberry and reported maximum TSS, TSS/acidity ratio, total sugars and ascorbic acid with the co-inoculation with *Azotobacter* + *Azospirillum* + *Pseudomonas striata.*

Ravishankar *et al*. (2010) reported that the application of FYM 20 kg/plant recorded maximum total soluble solids, ascorbic acid, total sugar and the least value of titrable acidity in Coorg Honey Dew papaya.

Moniem *et al.* (2008) concluded that application of Organic N sources namely Banana compost caused a promising promotion on yield, hand and finger weight of William's banana compared to the mineral source. However, FYM was favourable for improving fruit quality in terms of increasing finger weight, total soluble solids, total sugars and in decreasing starch and total acidity.

Srivastava *et al*. (2002) noted that application of VAM improved fruit quality of Satsuma mandarin trees.

Ram and Rajput (2000) recorded that treatment with FYM recorded the highest acidity in Guava.

2.3.2. Effect of bio-fertilizers on fruit quality

Mosa *et al.* (2018) revealed that application of bioproducts: Fertigo (Manure), Micosat, Humus UP, Humus Active + Aktywit PM, BioFeed Quality, BioFeed Amin, Vinassa, Florovit Natura and Florovit Eko in apple trees enriched with *Pantoea* sp., *Pseudomonas fluorescens*, *Klebsiella oxytoca* and *Rhizobium* sp. bacterial strains resulted in significantly better fruit quality parameters.

Vanilarasu and Balakrishnamurthy (2014) reported that the treatment *Azospirillum*, PSB and *Trichoderma harzianum* registered maximum values of quality attributes in terms of TSS, acidity, ascorbic acid, non-reducing and total sugars besides enhancing the shelf life and reduced physiological loss in weight in banana cv Grand Naine.

Dutta *et al*. (2014) reported that guava plants treated with *Azospirillum*+ *Azotobacter* + VAM showed maximum TSS, total sugar and ascorbic acid.

Pesakovic *et al.* (2013) studied the effect of strawberry (*Fragaria* X *ananassa* Duch.) treated with the three different fertilizers, i.e. liquid inoculum of diazotrophic bacteria *Klebsiella planticola* (PGPR1), liquid inoculum combined of *Azotobacter, Derxia* and *Bacillus* genera (PGPR2) and Multi KMg fertilizer and found that the most desirable fruit quality parameters was recorded in plants treated with PGPR1.

Dadashpour and Jouki (2012) studied the influence of different organic nutrient combinations on yields and quality of strawberry cv. Kurdistan in Iran by using organic nutrient combinations including the recommended dose of N, P and K through chemical fertilizer as control and reported that manure + *Azotobacter* + woodash + phosphorus solubilizing bacteria + oil cake improved significantly quality of fruit about total sugars, total soluble solids (TSS), acidity and TSS: acidity ratio.

Dwivedi *et al.* (2012) recorded maximum TSS and vitamin C for rainy season and winter season crop with application of VAM in 'Red Fleshed' guava.

Cavalcante (2012) observed that application of biofertilizers, liquid cattle manure obtained from anaerobic processes @ (0.0, 0.6, 1.2, 1.8, and 2.4 L $plant^{-1}$) on yellow passion fruit plants in Brazil significantly increased fruit length, width, pulp percentage, skin diameter, mass, soluble solids, and titratable acidity.

Dadashpour and Jouki (2012) observed that combine application of manure + Azotobacter + wood ash + oil cake + PSB significantly improved the total sugars, acidity, TSS : acidity ratio and total soluble solids (TSS) in strawberry cv. Kurdistan.

Sharma *et al.* (2011) revealed that application of Azotobacter, Azospirillum and full dose of N in poultry manure significantly increase the fruit nutrient status of guava.

El Mohamed *et al.* (2009) reported that application of humic acid at 15.0% (v/v) and commercial biofertilizers i.e., phosphorien, microbien and cearalien were useful to increase the quality of fruits in Mandarin (*Citrus reticulate* Blanco).

Maksoud *et al.* (2009) stated that application of antioxidants (ascorbic acid or citric acid) each at 1000 and 2000 ppm and biofertilizer 'Phosphorine' 5 gm/tree on olive trees significantly increase the fruit quality and flesh oils content.

Singh and Singh (2009) reported that application of *Azotobacter* + *Azospirillum* + 60 kg N ha^{-1}+ 100 ppm GA_3 in strawberry cv. Sweet Charlie resulted in better fruit quality.

Sharma *et al.* (2009) studied the effect of organic manures and bio fertilizers on physico-chemical characteristics of guava (*Psidium guajava* L.) cv. Sardar and found that application of *Azotobacter,* and *Azospirillum* along with poultry manure and cent per cent nitrogen resulted in maximum TSS, ascorbic acid content and total sugar in guava fruits.

Yadav *et al.* (2008) observed that application of FYM and inorganic fertilizers alongwith *Azotobacter* and PSB resulted in maximum fruit size, juice percentage, average fruit weight, ascorbic acid, TSS, maximum sugars and pulp/stone ratio in phalsa (*Grewia subinequalis* D.C).

Dey *et al.* (2005) evaluated the response of 2 free-living nitrogen-fixers (*Azotobacter* and *Azospirillum*) and 3 phosphate-solubilizers (vesicular arbuscular mycorrhiza (*Glomus mossae*), *Microphos* and *Phosphobactrin*) on guava (*Pisidium guajava*) and found that there were significant increase in fruit weight, fruit length, fruit diameter, TSS and TSS: acid ratio and ascorbic acid content.

Suresh and Hasan (2001) reported that application of *Azospirillum* with 50 per cent recommended dose of Nitrogen on Dwarf Cavendish banana (Musa AAA) increased the TSS and reduced total sugars. However, application of *Azospirillum* combined with *Phosphobacteria* along with 100 per cent recommended dose of Nitrogen & potassium increased the total sugar content in the fruit.

2.3.3. Effect of biodynamic preparations on fruit quality

Malsawmkimi and Hazarika (2018) reported that integrated application of FYM + CPP + BD 500 + BD 501 recorded highest TSS, Ascorbic acid, TSS: acid ratio and lowest titratable acidity in Khasi mandarin fruits.

Doring *et al.* (2015) conducted an experiment to study the effect of organic and biodynamic management practices on quality parameters of grapevines. Their study revealed the integration of organic and the biodynamic treatments showed significantly better quality fruits as compared to using alone.

Shwetha (2007) reported that biodynamic preparation and 'panchgavya' in combination or alone with other nutrient management practices had been found to improve the quality of several crops.

Pathak *et al.* (2005) revealed by integration of 50 kg FYM and CPP 500 g resulted in good quality fruits in terms of TSS and total sugars in papaya cv. Pusa Delicious.

2.4. Soil nutrient status

2.4.1. Effect of organic manures on soil nutrient status

Wani *et al.* (2017) revealed that integration of 75% NPK through inorganic fertilizers + 25 % by vermicompost resulted in maximum nitrogen, phosphorus, available zinc, iron, calcium, manganese and copper content. However, 100 % through FYM + vermicompost + poultry manure resulted in highest amount of potassium and magnesium.

Adak *et al.* (2014) conducted an experiment on mango orchard and reported that the build-up of available nitrogen was more dependent on addition of vermicompost than FYM in soil.

Manyuchi *et al.* (2013) studied the impact of vermicompost and vermiwash on soil nutrient status and concluded that application of vermicompost @ 1 kg increased soil zinc, manganese and iron content. Whereas increased vermiwash quantities resulted in increased soil iron content but resulted in decreased copper content. Combine application of vermicompost and vermiwash resulted in enhanced soil copper and iron content but decreased the zinc and manganese content.

Giannattasio *et al.* (2013) in their study on impact of fermented manure product (Preparation 500) applied in biodynamic agriculture revealed that fermented manure derivative called Preparation 500 sprayed on field resulted in increased soil fertility.

Pfiffner and Mader (2012), in their long-term study on the population of earthworm namely *Nicodrilus longus* (Ude), *N. nocturnus* (Evans), *N. caliginosus* (Savigny) and *Allolobophora rosea* (Savigny) in biodynamic farming compared to conventional method concluded that earthworm biomass and density, the presence of anecic species, and the number of juveniles were significantly higher in the biological than in the conventional or unfertilized plots.

Marathe *et al.* (2011) concluded that green manuring using sunhemp and FYM applied along with 50% NPK by inorganic fertilizers resulted in higher available Nitrogen, Phosphorus, Potassium and organic carbon in the soil.

Zhao *et al.* (2009) revealed that application of Farm yard manures (FYM) on soil resulted in higher increase in SOC, available-N, available-P, and higher activities of protease, urease, and alkaline-phosphatase. However, soil treated with straw had higher levels of potential soil respiration, soil water retention, microbial biomass, soil porosity, invertase, catalase and lower bulk density than farmyard manure treatment.

Verma and Charan (2009) revealed that application of farm yard manure and organic manures maximized soil pH, moisture content, available NPK and organic carbon in apple orchard.

Bhaskaran *et al.* (2009) reported that application of organic manures and pig manures in the soil has significantly soil nutrient status in the soil. Moreover, Vermicompost application also positively affects the amount of nutrients, hormones, and enzymes, and has stimulatory effect on plant growth.

Verma and Charan (2009) revealed that soil moisture, pH, organic carbon and available N, P and K were recorded maximum under farm yard manure and organic manure in apple.

Ullah *et al.* (2008) conducted a field experiment at Horticultural Farm, Bangladesh Agricultural University (BAU) reported that soil organic matter, soil pH and availability of N, P, K and S in soil were increased by organic manure application.

Arancon *et al.* (2006) reported that the application of vermicompost to soil is considered as a good management practice in any agricultural production system because of the stimulation of soil microbial growth and activity, subsequent mineralization of plant nutrients, and increased soil fertility and quality.

Ferreras *et al.* (2006) carried out an investigation to study the effect of vermicompost from household solid waste (HSW), horse and rabbit manure (HRM), and chicken manure (CM) on soil properties and concluded that the proportion of water stable soil aggregates (Ws) was significantly higher ($p < 0.05$) in HSW, HRM and CM at 20 Mg ha^{-1}. The proportion of ethanol stable soil aggregates (Es) was significantly higher in HSW, HRM and CM at 20 Mg ha^{-1}, and CM at 10 Mg ha^{-1}. After the first amendment application, HSW and HRM resulted in higher soil organic carbon (SOC).

Kaur *et al.* (2005) in their study on the impact of organic manures on soil physical and biological properties reported that application of farmyard manure, poultry manure, and sugarcane filter cake alone or in combination with chemical fertilizers improved the soil organic C, total N, P, and K status. Application of organic manures in combination of chemical fertilizers resulted in higher soil microbial biomass. Basal and glucose-induced respiration, potentially mineralizable N, and arginine ammonification were higher in soils amended with organic manures.

Zaller and Kopke (2004) studied the effects of applications of traditionally composted farmyard manure (FYM) and two bio dynamically composted FYM on soil chemical properties, microbial biomass and respiration and found that biodynamic preparation did not affect soil microbial biomass, dehydrogenase activity and decomposition during 62 days. However, after 100 days, decomposition was significantly faster in plots which received completely prepared FYM than in plots which received no FYM.

Yadav and Vijaykumari (2003) reported that application of organic manures in the soil improves the performance of crops by better moisture content in the soil, favourable soil condition and structures along with improved nutrient content in the soil. It also improves the soil aeration and available nutrients to plants.

2.4.2. Effect of bio-fertilizers on soil nutrient status

Debska *et al.* (2016) determine the effects of the bio-fertilizer UGmax on soil total organic carbon (TOC), dissolved organic carbon (DOC), and the fractional composition of organic matter (C of humic acids (CHAs), C of fulvic acids (CFAs), and C in humins) in the humus horizon of an arable field and concluded that TOC content was 6.3 % higher while the DOC content was 0.19 percentage points lower after 3 years of bio-fertilizer use.

Mir *et al.* (2013) observed that there were significant increase in soil nutrient contents such as Nitrogen (405.56%), Phosphorus (22.02%), Potash (419.00 %), organic carbon (1.90%) and soil pH (6.89) if integration of bio-fertilizer with organic manures such as vermicompost, FYM, green manure sun hemp were applied to the soil of Pomegranate orchards.

Sharma *et al.* (2012) in their investigation on the effect of bio-fertilizers on soil properties and concluded that application on bio fertilizers improves the soil microorganisms' population, nutrient uptake of certain minerals, microbial community structure and functions in positive ways.

Marathe *et al.* (2012) suggested that there were significant increase in soil microbial population when Biofertilizers such as PSB, *Azotobacter* are combined with vermicompost, FYM, wheat straw on nitrogen equivalent basis and green manuring with sun hemp were applied to the soil.

Dutta and Kundu (2012) conducted an experiment in new alluvial zones of West Bengal to study the impact of biofertilizers on soil nutrient status of Himsagar mango concluded that combination of *Azospirillum* + AM + *Azotobacter* + PSM showed maximum available N, P and K and organic carbon in the soil

Nazir *et al.* (2012) revealed that combined application of *Azotobacter* + PSB + oilcakes + poultry manure + wood ash maximized the population of *Azotobacter* and PSB while available nitrogen and phosphorus of the soil were increased by application of oil cake + wood ash + PSB + poultry manure + *Azospirillum*.

Similarly, Nazir *et al.* (2012) carried out field experiments to find out the effect of integrated organic nutrient resources on soil fertility and soil microbial population and maximum population of *Azotobacter* and PSB were observed with poultry manure + *Azotobacter* + wood ash+ Phosphate solubilising bacteria + oil cake, whereas, maximum available nitrogen and phosphorus was reported with poultry manure + *Azospirillum* + Wood ash + Phosphate solubilising bacteria + oil cake.

Likewise, Singh *et al*. (2010) conducted a field experiment to evaluate the effect of bio-inoculants and inorganic fertilizers on the performance of strawberry and reported that multi inoculation of *Azotobacter* + *Azospirillum* + PSB and *Azotobacter* + *Azospirillum* + AM fungi increased available soil N and P by 1.81, 16.9, 1.60 and 15.1% over their initial levels, respectively.

Barassi *et al.* (2007) studied the effect of *Azospirillum* spp. on soil properties and found that *Azospirillum* inoculation could contribute to solubilize and acquire essential mineral nutrients, making scarce nutrients more readily available in the soil for plants.

Chen (2006) investigated the effect of combined use of chemical, organic fertilizers and bio-fertilizer on soil fertility and concluded that soil organic matter relatively increase the numbers of beneficial microorganism in the rhizosphere around the crop and enhance the colonization of *mycorrhizae*, which improves P supply, it also enhance root growth and better soil structure. Bio-fertilizer such as *Azotobacters* and *Azospirillum* increased the fixation of nitrogen in the soil and PSB application increased available phosphate in the soil significantly.

Kannan *et al.* (2005) revealed that application of *Azospirillum* along with FYM and vermicompost favourably influenced the soil physical, chemical and biological environment such as bulk density, water holding capacity, organic carbon, available nitrogen, beneficial bacterial and fungal population over the inorganics alone applied plot.

Yedidia *et al.* (2001) studied the effect of *Trichoderma harzianum* on microelement concentrations and found that crop inoculated with *T. harzianum* have better root colonization and release soil nutrients more profoundly. A significant increase in the concentration of Cu, P, Fe, Zn, Mn and Na was observed in inoculated roots.

Ahmed *et al.* (2005) revealed that *Azotobacter* help in compensating the nitrogenous fertilizer even in non- leguminous crop like mango.

2.4.3. Effect of bio-dynamic preparations on soil nutrient status

Rana *et al.* (2015) revealed that biological health, physical and chemical qualities of soil were improved when using organic manures were added along with *'panchgavya'* and biodynamic preparations.

Carpenter-Boggs *et al.* (2000) in their investigation on effect of organic and biodynamic components on soil biology reported that both biodynamic and non-biodynamic composts increased soil microbial biomass, respiration, dehydrogenase activity, soil C, earthworm population and biomass, and metabolic quotient of respiration per unit biomass.

2.5. Leaf nutrient content

2.5.1. Effect of organic manures on leaf nutrient content

Sau *et al.* (2017) reported that application of liquid organic manures in mango trees cv. Himsagar resulted in increased available N, P and K both in leaf.

Yadav *et al.* (2016) found that application of integrated plant nutrient supply (IPNS) through balanced fertilization of organic and microbial inoculants in strawberry cv. Chandler resulted in leaf nutrient concentration and productivity on long term basis for sustainable fruit production.

Milosevic and Milosevic (2015) revealed that leaf nutrient content of apple was significantly when fertilized with natural zeolite (Agrozel) and/or cattle manure.

Adak *et al.* (2014) reported that organic manures (FYM, vermicompost, mulching,) and inorganic (N, P, K) substrates in mango orchards significantly increased leaf nutrients concentrations as compared to control in mango orchard.

Melosevic *et al.* (2013) observed that leaf nutrient content of 'Roxana' apricot was positively affected by application of natural zeolite and organic manures.

Sharma *et al.* (2011) in their investigation on nutrient status of 'Sardar' guava under organic manures and bio-fertilizers recorded maximum leaf nitrogen, phosphorus, potassium, calcium, magnesium; and maximum fruit nitrogen, phosphorus, potassium, calcium, magnesium in the plant applied through poultry manure.

Hargreaves *et al*. (2008) suggested that application of organic compost tea made from of ruminant and municipal solid waste significantly increased Na in raspberries.

Medhi *et al.* (2007) reported that highest available P_2O_5, leaf P and K in leaves of Khasi mandarin was observed in the treatment receiving Mustard Oil Cake (MOC) and organic manures.

2.5.2. Effect of bio-fertilizers on leaf nutrient status

Perazzoli *et al.* (2020) reported that bio-fertilizer application has positive effect on nutrient content of leaves favoring enhanced fruit production in pear trees.

In an investigation conducted by Sau *et al.* (2017) they revealed that application of *Azotobacter chorococcum* + *Azospirillum brasilense* + AM (*Glomus musseae*) + Panchagavya 3% in Mango trees resulted in higher N, P and K content in the leaves.

Pathak *et al.* (2017) reported that use of various bioinoculants like *Azotobacter*, *Azospirillum* and VAM along with PGPRs improve the leaf nutrient content in fruit crops.

Adak *et al.* (2014) reported that mango orchard fertilized with *Azotobacter*, PSB and *Trichoderma harzianum* and inorganic (N, P, K) substrates around the tree basin enhanced the leaf nutrients concentrations in organic and inorganic amended soils as compared to control.

Hoda *et al.* (2013) found that Valencia orange trees (*Citrus Sinensis*) budded on Volkamer lemon rootstock (*Citrus Volkameriana*) fertilized with Magnetite, Diatoms and bio-fertilizer (mixture of *Cyanobacteria* and *Azolla*) significantly increased the leaf nutrient content.

Sharma *et al.* (2011) found that 'Sardar' guava raised under bio-fertilizers indicated maximum leaf nitrogen, phosphorus, potassium, calcium, magnesium as compared to the plant applied with *Azotobacter* and *Azospirillium*.

Singh and Singh (2009) reported that application of *Azotobacter* + *Azospirillum* + 60 kg N ha^{-1}+ 100 ppm GA_3 in strawberry cv. Sweet Charlie resulted in higher number of leaves, leaf area, crowns per plant.

Medhi *et al.* (2007) reported that in Khasi Mandarin treated with bio-fertilizers (*Azotobacter* and PSB) and K_2O resulted in increased available P_2O_5, leaf P and K in the leaves.

2.5.3 Effect of bio-dynamic preparations on leaf nutrient status

Jariene *et al.* (2019) reported that application of BD 500 and 501 on white mulberry (*Morus alba* L.) significantly increased the total phenolic and flavonoid concentrations in the leaves. Using the two preparations together (500 + 501) had significant effects on quercetin-acetylhexoside and kaempferol-acetylhexoside accumulation in the mulberry leaves.

Meissner *et al.* (2019) reported that integrated, organic and biodynamic application enhanced the available P and K of the leaves as well as lowering incidence of acetic acid rot.

Botelho *et al.* (2015) reported that mature vineyard (*Vitis vinifera* L., cv. Sangiovese) sprayed with BD 500, 500 K, fladen and 501 showed lower stomatal conductance and lower leaf water potential. Moreover, it led to an increase in leaf enzymatic activities of endochitinase (EC 3.2.1.14), exochitinase (β-N-acetylhexosaminidase, EC 3.2.1.52 and chitin 1,4-β-chitobiosidase) and β-1,3-glucanase (EC 3.2.1.39).

2.6. Economics of cultivation

Integration of organics with bio-fertilizers are reported to be superior to any other fertilizer management in respect of economics of cultivation in different crops.

2.6.1 Effect of organic manures on economics of cultivation

Thakur and Thakur (2014) revealed that plum cv. Santa Rosa treated with 75% NPK + bio fertilizers + green manuring (sunhemp @ 25 g seeds/tree) basin recorded the maximum benefit-cost ratio and annual net income.

Garhwal *et al*. (2014) recorded maximum B: C ratio was in the application of 60kg FYM and maximum net returns were found in the application of 80 kg FYM per plant in Kinnow Mandarin.

Shivakumar *et al*. (2012) also reported that FYM alone produced higher fruit yield and the B:C ratio was maximum against application of chemical fertilizers in papaya.

Yadav *et al.* (2010) reported that N substitution by FYM provided highest B:C ratio than vermicompost due to its lower cost of production in strawberry.

Rahulkumar (2003) registered higher net returns and B: C ratio by using organic manure in banana.

2.6.2. Effect of bio-fertilizers on economics of cultivation

Srivastava *et al.* (2014) reported that in Papaya, treatment combination of PSB + *Azotobacter* + 50% NPK + FYM recorded highest cost: benefit ratio which was due to reduced cost of chemical fertilizers and larger fruit production as compared to other treatments.

Atom (2013) in his study on the effect of inorganic bio fertilizers on quality and yield of Sardar guava revealed that the net and gross monetary returns and highest benefit: cost ratio (3.15) were reported in PSB + *Azotobacter* + FYM + 100% RDF.

Shukla *et al.* (2009) studied the effect of Integrated Nutrient Management (INM) under high density planting of guava (cv. Sardar) and found that integrated application of 50 Kg FYM + 50 per cent recommended dose of NPK + 250 g *Azotobacter* gave maximum B:C ratio (2.53:1).

2.6.3. Effect of biodynamic preparation on economics of cultivation

Trivedi *et al.* (2013) revealed that by spraying BD 501, there were maximum net returns of Rs. 23966.00 ha^{-1} while untreated control resulted in lowest net returns of Rs. 17356.00 ha^{-1}. Silicon BD exhibit maximum B: C ratio with 2.24 while lowest B: C was obtained from untreated control (1.55).

2.7 Crop Regulation

2.7.1 Effect of crop regulation on growth

Chandel and Singh (2015) reported that chemical as well as manual thinning significantly increased growth and vigour of tree, leaf to fruit ratio and of better grade fruits of nectarine.

Thakre *et al*. (2013) studied the effect of various methods of crop regulation in guava under double-hedge row system of planting and revealed that the maximum new shoot emergence for winter season crop was observed with removal of all leaves and flowers by hand. Maximum flower bud emergence, number of fruits, yield and cost: benefit ratio was recorded one leaf pair pruning of fruited shoots only.

2.7.2 Effect of crop regulation on yield

Saraginovski and Kiprijanovski (2021) studied the effect of short pruning on quality of peach trees. Their results revealed that short pruning with heading of the bearing branches recorded maximum the growth of the TCSA, the number of thinned fruitlets, the number of fruit and yield per tree.

Chandel and Singh (2015) reported that among the chemical thinning treatments, application of 300 ppm ethrel judiciously thinned fruitlets, improve the size and weight of the fruits without any adverse effect on the total yield. Spray of 300 ppm ethrel induced optimum fruit thinning, gave highest yield with better size of fruits.

Looney *et al.* (2015) revealed that application of GA_4, GA_{4+7} mixture (1:1) or GA_4+iso GA_7 (a less active isomer) weekly for four weeks, commencing at petal fall in Cox's Orange Pippin apple reduced fruit set and seed number per fruit and increased average fruit weight.

Modlibowska (2015) reported that applications of 1: 1 mixture of gibberellins A_4 and A_7 to either frost damaged or artificially decapitated Bramley's Seedling apple flowers resulted in increased fruit set and yield. It also increased the crop in an orchard without pollinators.

Somkuwar *et al.* (2014) studied the effect of cluster thinning on bunch yield, berry quality and biochemical changes in local clone of table grape cv. Jumbo

Seedless (Nana Purple) and found that highest bunch weight, berry weight and berry diameter was recorded at 23 numbers of clusters per vine.

Burge *et al.* (2012) reported that on well pollinated kiwifruit vines (*Actinidia deliciosa* cv. Hayward) a reduction in fruit numbers by flower thinning increased mean fruit weight. Reducing fruit numbers to less than 330 per metre of T-bar row increased yield of fruit in the two large size grades.

Somkuwar *et al.* (2010) studied the effect of bunch load on berry growth in Tas-A-Ganesh grafted on different rootstocks and found that with the increase in bunch load, there was reduction in the shoot growth. Highest bunch weight of 413.20g was recorded when 40 bunches were retained on the vines of Tas-A-Ganesh grafted on Dogridge rootstock.

Ahmad and Zargar (2005) studied the effect of trunk girdling, flower thinning, GA_3 and ethepon application on quality characteristics in grape cv. Perlette and reported that trunk girdling coupled with GA_3 and ethepon resulted in maximum bunch weight, bunch length, bunch breadth and bunch size.

2.7.3 Effect of crop regulation on fruit quality

Saraginovski and Kiprijanovski (2021) studied the effect of short pruning on quality of peach trees. Their results revealed that short pruning with heading of the bearing branches recorded maximum average weight of the fruits and the diameter of the fruits.

Deshmukh *et al*. (2017) reported that Flordasun peach fruits thinned at 20 DAFB and spaced at 20 cm recorded enhanced fruit weight, length, diameter and improved fruit skin colour, highest TSS, TSS: acid ratio, ascorbic acid and lowest titratable acidity.

Peng and Rabe (2015) suggested that summer trunk girdling on 'Mihowase' Satsuma resulted in improved fruit colour, total soluble solids (TSS) level and TSS/TA (titratable acidity) ratio in the first season.

Johnson (2015) revealed that removal of first axillary flower or fruitlet 5 or 37 d after full-bloom, respectively, increased the firmness of 'Cox' apples at harvest and after storage in 1.25% O_2 (<1% CO_2) at 3.5°C. Fruits from thinned trees were larger, less dense and contained more K and less Ca than those from unthinned trees.

Somkuwar *et al.* (2014) studied the effect of cluster thinning on bunch yield, berry quality and biochemical changes in local clone of table grape cv. Jumbo Seedless (Nana Purple) and found that maximum TSS, reducing sugars, total proteins and total carbohydrates was recorded by keeping 23 numbers of clusters per vine.

Hehnen *et al.* (2012) reported that mechanical blossom thinning of apple [*Malus domestica* (Borkh.)] resulted in increased fruit size, firmness, advanced ripening i.e. starch breakdown, sweetness versus, largest malic acid content 0.43% and more red blush, i.e. fruit coloration.

Barandoozi and Talaie (2009) reported that application of GA_3 and GA_{4+7} on apples (*Malus domestica* Borkh) at the concentrations 10-20 mg l^{-1} and GA_{4+7} at 5-10 mg l^{-1} during petal fall increased the weight of fruit significantly. It also resulted in considerable decrease in russeting of apple fruits.

Ramteke *et al*. (2008) studied the effect of cluster clipping and berry thinning on yield and quality of Thompson Seedless grapes grafted on Dogridge rootstock and reported that maximum berry diameter was obtained in 50% cluster retained and berry thinning treatment. The maximum berry weight and highest yield/vine was recorded in 75% cluster retention and berry thinning treatment.

Ban *et al.* (2007) revealed that ethephon (2-chloroethylphosphonic acid) application on rabbiteye blueberry fruit resulted in decrement of titratable acidity, anthocyanin accumulation and fruit softening. Ethephon promote the fruit ripening, but the stimulatory effects of ethephon on fruit ripening were different in degree on each ripening characters.

Link (2000) revealed that mechanical or chemical flower and fruit thinning significantly affect fruit quality by increasing size, colour, skin performance, firmness and sugar and acid content of the fruit. Moreover, it also enhanced inorganic components, especially calcium and potassium.

2.7.4 Effect of crop regulation on Economics of cultivation

Gurjar *et al*. (2018) conducted an experiment to study the effect of crop regulation on Guava fruit and revealed maximum gross return and Net return and highest cost benefit ratio under application of 800 ppm NAA.

Singh and Saini (2013) studied the effect of pruning and fruit thinning on yield and fruit quality in six-year-old peach cv. Shan-i-Punjab trees. Their results revealed that the highest benefit cost ratio was obtained by imposing 50% pruning of fruited shoots and cutting of dead and diseased wood during early January followed by fruit thinning in mid- March.

Sarker *et al.* (2006) reported that in guava crop regulation through shoot bending is one of the best way to produce better quality fruits with maximum cost; benefit ratio during the off-season.

Materials and Methods

The present investigation entitled “Organic nutrient management and crop regulation in Grapes in Mizoram” was performed at Vengthar and Vengsang village of Champhai District, Mizoram, for two fruiting seasons i.e. 2016- 2017 and 2017-2018. Two experimental fields were used for conducting experiments *viz*., (a) Effect of organic manures and bio-dynamic preparations on growth, yield and quality of Grapes cv. Bangalore Blue and (b) Effect of Crop regulation on growth, yield and quality of Grapes cv. Bangalore Blue. The details about the materials used and methodology followed during the course of the experimentation are given as under.

3.1 Experimental site

Both the experiments were carried out at the farmer’s field located at Vengthar and Vengsang village of Champhai District, Mizoram.

3.2 Soil status of the experimental field

In order to determine the inherent fertility status of the soil, representative soil samples were collected at random from a depth of 0-15 cm, 15-30 cm and 30-45 cm before starting the experiments and composited for mechanical and chemical analysis. The results of the mechanical composition of the soil are presented in Table 3.1 and 3.2.

Table 3.1: Initial chemical properties of the soil of the experimental plot 1

Soil depth (cm)	Soil pH	Organic Carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
0-15	4.25	0.62	439.36	61.38	161.13
15-30	4.02	0.59	422.71	59.72	151.76
30-45	3.95	0.53	409.91	55.66	144.32

Table 3.2: Initial chemical properties of the soil of the experimental plot 2

Depth of soil (cm)	Soil pH	Organic Carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
0-15	4.61	0.65	455.43	64.74	15253
15-30	4.59	0.57	441.78	62.61	149.22
30-45	4.40	0.55	439.28	58.63	145.36

Table 3.3: Methods employed for soil analysis

Soil pH	Glass Electrode Method (Jackson, 1973)
Organic Carbon	Wet Digestion Method (Walkley and Black, 1934)
Available N	Modified Kjeldahl's Method (Jackson, 1973)
Available P_2O_5	Bray's Method (Jackson, 1973)
Available K_2O	Flame Photometric Method (Jackson, 1973)

Table 3.4 Nutrient composition of various organic manures and biodynamic preparations used for the study

Organic manures	N (%)	P (%)	K (%)
Farm Yard Manure	0.85	0.35	0.10
Vermicompost	0.89	0.25	0.85
Pig manure	0.85	0.74	0.65
Neem Cake	4.95	1.25	1.42
Cow Pit Pat	1.49	1.18	1.79
BD 500	1.55	1.21	2.76
BD 501	1.72	1.35	2.69

3.3 Weather and climatic conditions

Champhai District falls in subtropical zone with occurrence of mild summer between the months of May and August and cold winter from December to January respectively. From September to November and February to April, Champhai experience mild and favourable winter. The district experiences monsoon from June to September with the occurrence of pre-monsoon rains during the month of May and post-monsoon rains in the month of October.

The meteorological data recorded during the period of experimentation are presented in Fig. 3.1 and 3.2 respectively.

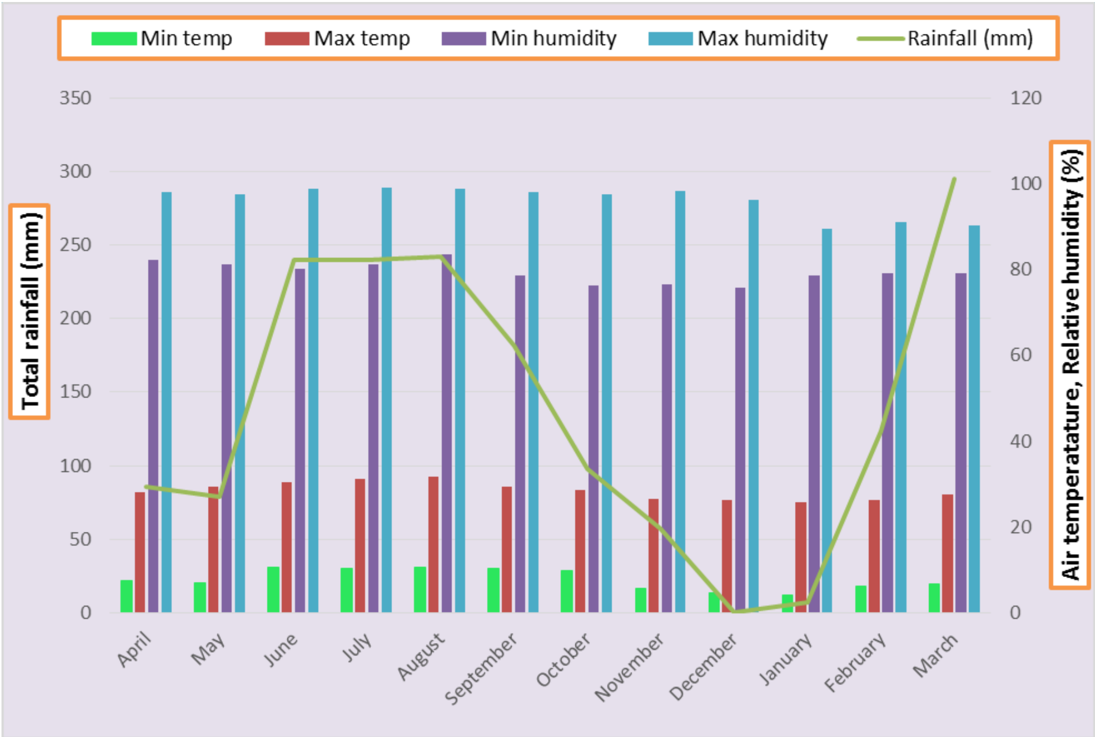

Fig. 3.1: Air Temperature, total rainfall and relative humidity of the experimental site during the first year of study (2016 - 2017)

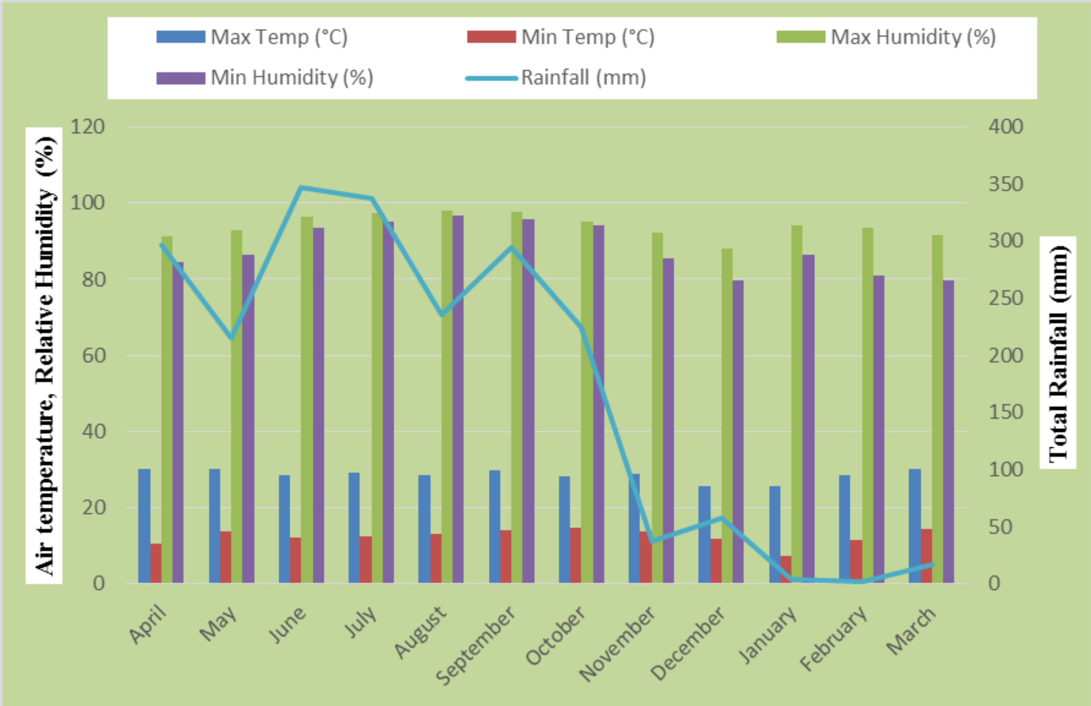

Fig. 3.2: Air Temperature, total rainfall and relative humidity of the experimental site during the second year of study (2017 - 2018)

3.4 Experimental details

Two sets of experimentations were conducted. The first set used different combinations of organic manures and bio-dynamic preparations while the other set used different crop regulation practices and the effect of both were studied on growth, yield and quality of grapes cv. Bangalore blue.

3.4.1 Experiment No 1: Effect of organic manures and bio-dynamic preparations on growth, yield and quality of Grapes cv. Bangalore Blue

3.4.1.1 Location of the experiment

The present experiment was conducted at Vengthar village of Champhai District. The experimental location has an average elevation of 1387 meters and located at 93̊ 20’ 3” E longitude and 23̊ 29’ 30” N latitude.

3.4.1.2 Experimental design and layout

The present investigation was laid out in a Randomized Block Design (RBD) comprising of fourteen treatments and three replications. There were 6 plants per plots with each plot having the size of 54 m^2 and total there were forty two plots and the total area of experimental field was 2268 m^2. The layout of the experiments is presented in Fig. 3.3.

The detailed technical programme for the 1st experiment was as follows:

Design	: RBD
No. of treatments	: 14
No. of replications	: 3
Spacing	: 3 x 3 m
No. of plants per plot	: 6
Plot size	: 54 m^2
Total experimental area	: 2268 m^2

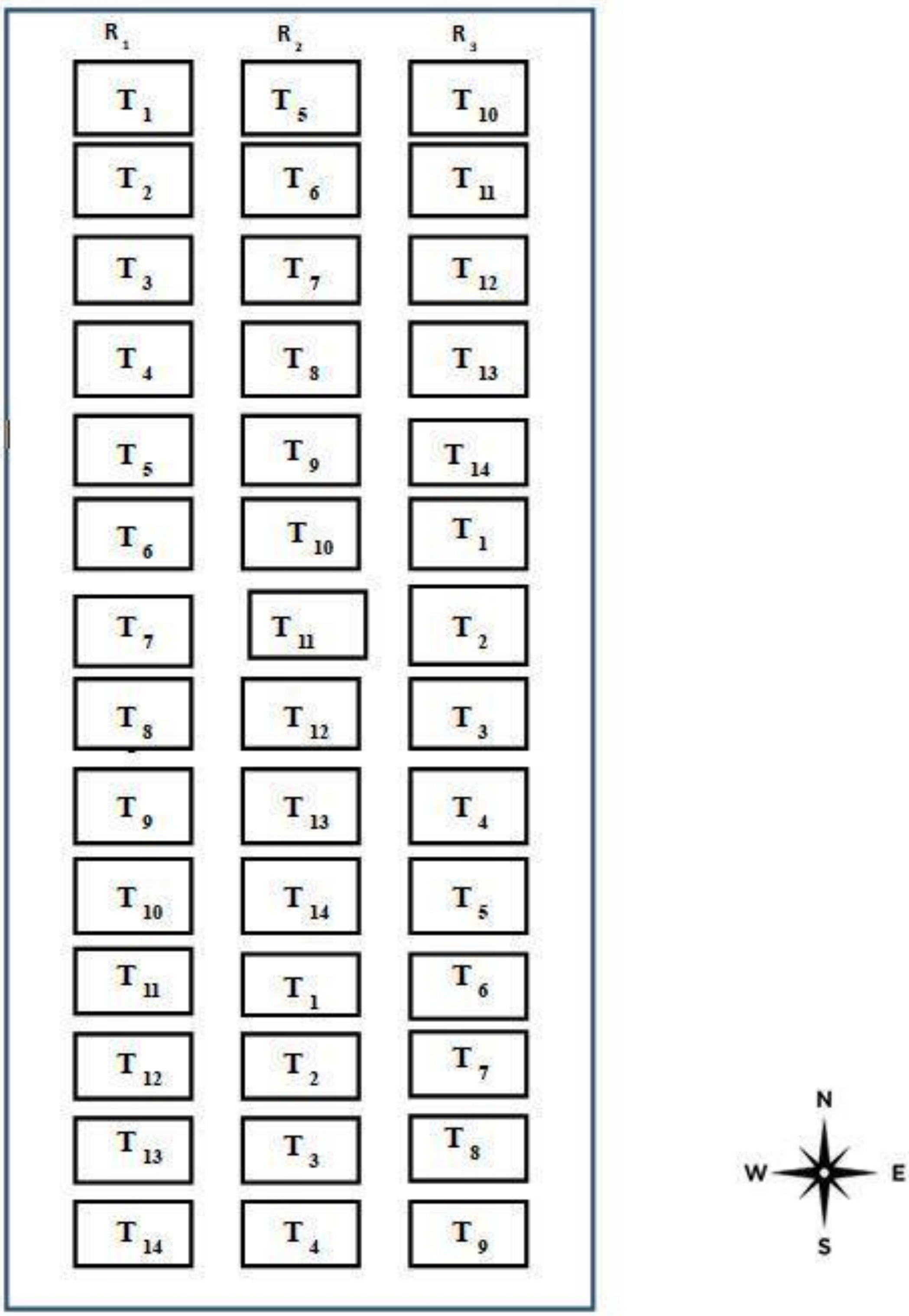

Fig. 3.3: Layout of the Experiment 1

3.4.1.3 Treatment details

T_1=Farm Yard Manure (FYM) +*Azospirillum* + Phosphate solubilizing bacteria (PSB) + Potash solubilizing bacteria (KSB)

T_2= Vermicompost (VC) +*Azospirillum* + PSB + KSB

T_3= Neem cake (NC) + *Azospirillum* + PSB + KSB

T_4= Pig manure (PIM) +*Azospirillum* + PSB + KSB

T_5=FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum*

T_6= VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum*

T_7= NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum*

T_8= PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum*

T_9=FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + Cow Pat Pit (CPP) + Bio Dynamic (BD) 500 + BD 501

T_{10}= VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501

T_{11}= NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501

T_{12}= PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501

T_{13}= Control (without any manures and fertilizers)

T_{14}= Farmers Practice (FP)

3.4.1.4 Time and dosage of organic manures, bio-fertilizers, bio-control agent and bio-dynamic preparations

The organic manures were applied during February-March. The quantity of organic manure *i.e.* FYM, VC, PIM and NC applied per plant were calculated based on the 100% of nitrogen requirement of the farmer's practice of fertilizers (448g N, 322g P, and 600g K/plant/year).

Bio-fertilizers and Bio- control agents *viz. Azospirillum*, PSB, KSB and *Trichoderma harzianum* were applied @ 100 g/plant. Biodynamic preparations *viz.*

CPP were applied @ 250 g/plant and BD 500 and BD 501 were drenched on soil and sprayed on crop respectively.

Three Biodynamic preparations viz. CPP, BD 500 and BD 501 were used during the investigation and their details are given below:

Cow pat, commonly known as CPP is a specialized compost, prepared by mixing cow manure with crushed egg shell and basalt dust, and then put into a 12 inch deep pit lined with bricks. The mixture is then allowed to ferment for 3-4 months by mixing with BD 502-507. Usually after fermentation, 30-35 kg of CPP is obtained from 60 kg of cow dung. CPP was applied @ 250 g/plant by mixing with 10 litres of water and sprinkled over the soil. To encourage bacterial development, the whole mixture was stirred for 10 minutes. It was applied in the evening time.

BD 500 was prepared by stuffing the dung of lactating cow inside a horn and buried in the soil during autumn equinox (September) and taken out during the spring equinox (March). The humified dung from horn is then taken out and stored in an earthen pot away from sunlight. To prepare the spray solution for 1 hectare, 62.5 g of this humified material was dissolved in 40 litres of warm water (40°C) and then stirred continuously for 1 hour (alternately in clock-wise and counter clock wise directions. The liquid mixture was sprinkled on the soil surface as big droplets using knapsack sprayer. BD 500 was applied during lunar descending period as per the biodynamic calendar when the effects are believed to be optimized (Briton, 1998).

BD 501 is commonly known as ‘cow horn silica’, prepared by mixing quartz crystals with alum powder grounding them till they give a fine consistency, and then this mixture is stuffed into cow horn and buried during the spring equinox and taken out during autumn equinox. The prepared material is then stored in glass bottle. For preparing the spray solution of BD 501, 2.5 g of BD 501 is dissolved in 40 litres of water in the same way as that of BD 500. Within one hour, the mixture should be sprayed on the foliage as fine mist before 9:00 a.m. As per the biodynamic calendar, BD 501 should be applied when moon is opposite to Saturn.

3.4.2 Experiment No. 2: Effect of Crop regulation on growth, yield and quality of Grapes cv. Bangalore Blue

3.4.2.1 Location of the experiment

The experiment was carried out at Vengsang village of Champhai District. The place has an elevation of 1535 meters and 23̊ 27’ 7” N latitude and 93̊ 18’ 38” E longitude.

3.4.2.2 Experimental design and layout

There were nineteen treatments and three replications in this experiment and was laid out in a randomized block design (RBD). There were six plants in each replication and total there were fifty seven plots each having an area of 54 m^2 and the total area of the experimental field was 3078 m^2. The lay out of the experiment is presented in Fig. 3.4

The detailed technical programme for the 2nd experiment was as follows:

Design	: RBD
No. of treatments	: 19
No. of Replication	: 3
Spacing	: 3 x 3 m
No. of plants per plot	: 6
Plot size	: 54 m^2
Total experimental area	: 3078 m^2

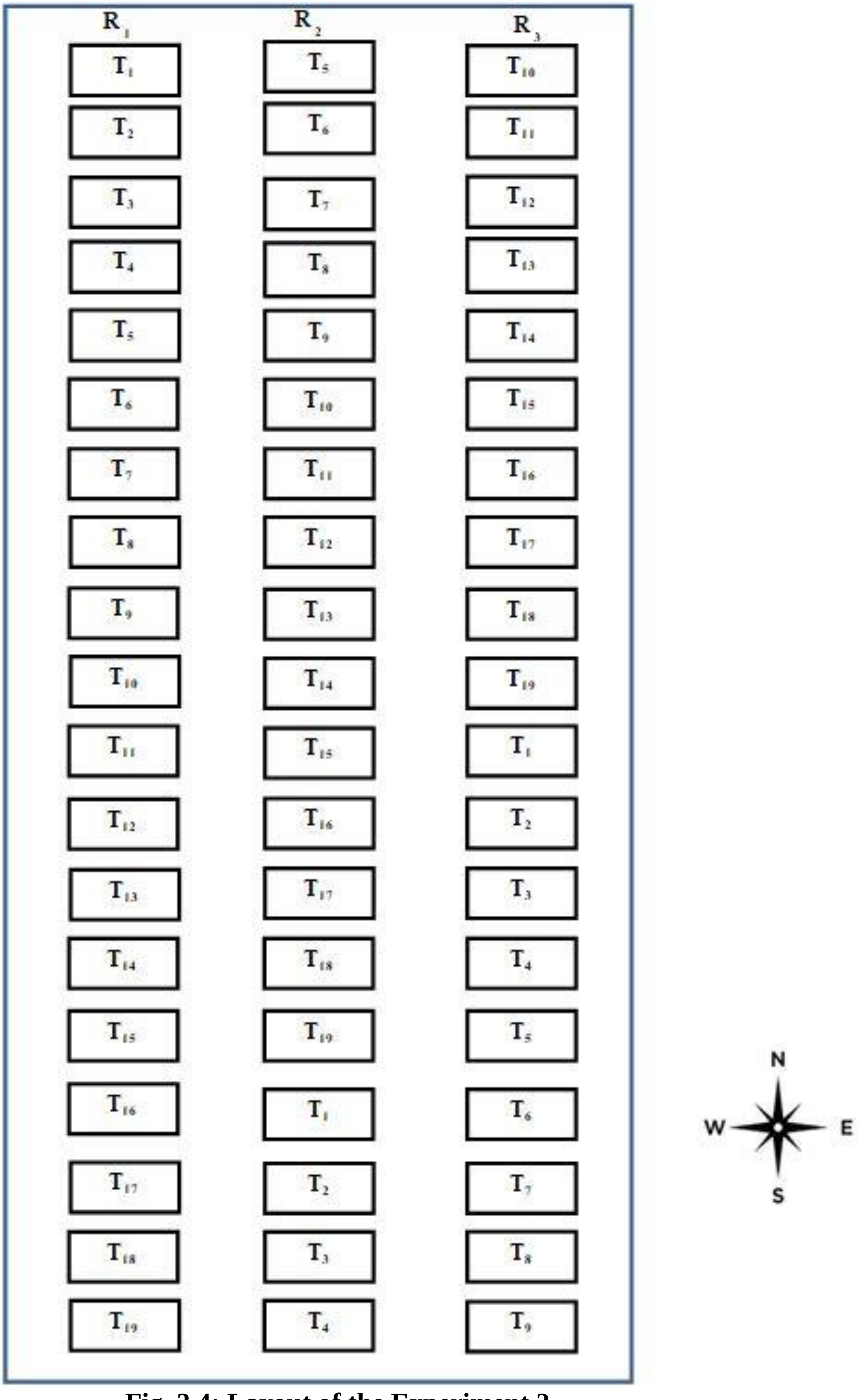

Fig. 3.4: Layout of the Experiment 2

3.4.2.3 Treatment details:

T_1 = Control

T_2= Flower thinning

T_3= Manual Berry thinning

T_4= Trunk Girdling

T_5 = GA_3

T_6= Ethephon

T_7= Flower thinning +GA_3

T_8= Flower thinning +Ethephon

T_9= Flower thinning +GA_3 +Ethephon

T_{10}= Manual Berry thinning +GA_3

T_{11}= Manual Berry thinning +Ethephon

T_{12} = Manual Berry thinning +GA_3 +Ethephon

T_{13} = Trunk Girdling +Flower thinning

T_{14} = Trunk Girdling +Manual Berry thinning

T_{15} = Trunk Girdling +GA_3

T_{16} = Trunk Girdling +Ethephon

T_{17} = Trunk Girdling +GA_3 +Ethephon

T_{18} = Trunk Girdling +Flower thinning +GA_3 +Ethephon

T_{19} = Trunk Girdling +Manual Berry thinning +GA_3 +Ethephon

3.4.2.4 Time and methods of Crop regulation

The flower thinning was done at 50 per cent bloom by brushing of flower clusters and then clipping the terminal portion with the help of scissors. GA_3 was applied at 50 ppm concentration by dipping clusters at 50 per cent bloom. Ethephon was applied at 500 ppm concentration at verasion stage through bunch dipping. Trunk girdling was done at fruit stage with the help of a sharp knife by removing 4 mm wide strip of bark along with phloem above the ground on the main trunk of vines. Berry thinning was done after fruit set when fruits were of pea size and 20 per cent fruitlets were thinned.

3.5 Observations recorded

3.5.1 Plant Growth characters

3.5.1.1 Shoot length (cm)

The individual shoot length in each vine was measured by using measuring tape from the base of the shoot to the tip and average was expressed in cm.

3.5.1.2 Shoot diameter (mm)

The diameter of individual shoot in each vine was measured by using vernier caliper at broadest portion and the average was taken and expressed in mm.

3.5.1.3 Internodal length (cm)

The average intermodal length in each shoot was measured using measuring tape and expressed in cm.

3.5.1.4 Cane diameter (mm)

The average diameter of individual cane was measured using vernier caliper at broadest portion and the average were taken and expressed in mm.

3.5.1.5 Per cent of fruitful cane (%)

The number of canes able to produce berry was counted and divided by the total number of canes and expressed in percentage.

3.5.1.6 Berry set per cent (%)

Berry set per cent was counted by dividing the number flowers able to set berries by the total number of flowers and expressed in percentage.

3.5.1.7 Berry drop per cent (%)

It was counted by dividing the number of berries dropped by the no. of berries set and expressed in per cent.

3.5.1.8 Berry retention per cent (%)

Berry retention per cent was measured by dividing the fruits retained till maturity by the number of berries set and expressed in per cent.

3.5.1.9 Shot berries (%)

It was calculated by counting the average number of shot berries in each bunch and expressed in percentage.

3.5.1.10 Unripe berries (%)

It was calculated by counting the average number of unripe berries in each bunch and expressed in percentage.

3.5.1.11 Total crop duration

The duration (days) from fruit set to harvesting of berries was counted and expressed as total crop duration.

3.5.1.12 Bunch weight (g)

It was calculated by weighing the individual bunch and expressed in gram.

3.5.1.13 Bunch length (cm)

The length of the whole bunch from the stack end was taken using vernier calipers and was expressed in cm.

3.5.1.14 Bunch breadth (cm)

The breadth of the bunch at its maximum widest position was taken using vernier calipers and expressed in cm.

3.5.1.15 Bunch size (cm^2)

It was calculated by multiplying the length and the breadth of the bunch and was expressed in cm^2.

3.5.1.16 Berry number per bunch

It was calculated by counting the number of berries in each bunch under each replication.

3.5.1.17 Bunch number per vine

It was calculated by counting the number of bunches in each vine under each replication.

3.5.1.18 Bunch compactness

The bunch compactness was calculated as the weight per square centimeter of bunch size.

3.5.1.19 Yield / vine (kg)

The total berry weight in one vine was calculated and expressed in kg.

3.5.1.20 Yield per ha

It was calculated by multiplying the average weight/vine with the total number of plants per hectare and expressed in tonnes per hectare.

3.5.2. Berry Physical parameters

For measuring the physical parameters of the berries, 20 randomly selected berries were taken from each replication and average was calculated out.

3.5.2.1 Individual berry weight (g)

Individual berry weight was measured with the help of electronic balance and expressed in gram (g).

3.5.2.2 Berry longitudinal diameter (cm)

It was measured by taking the longitudinal length between two extreme poles of the berry with the help of vernier calipers and expressed in cm.

3.5.2.3 Berry transversal diameter (cm)

The berry transversal diameter was measured by taking the horizontal length of the berry with the help of vernier calipers and expressed in cm.

3.5.2.4 Berry volume (cc)

The berry volume was measured by dipping the fruit in the water through water displacement method and was expressed in cc.

3.5.2.5 Hundred berry weights (g)

The weight of 100 representative berries was taken with the help of digital weighing balance and expressed in g.

3.5.2.6 Skin thickness (mm)

The thickness of the berry skin was measured with vernier calipers and expressed in mm.

3.5.2.7 Pedicel thickness (mm)

The thickness of the berry pedicel was measured with vernier calipers and expressed in mm.

3.5.2.8 Seed weight (g)

The average seed weight was measured with the help of electronic balance and expressed in g.

3.5.2.9 Seed length (cm)

The seed length was measured with the help of vernier calipers and expressed in cm.

3.5.2.10 Seed width (cm)

The seed width was measured with the help of vernier calipers by taking the distance between broadest portions of the seed and expressed in cm.

3.5.2.11 Seed number

The total number of seeds per fruit was counted and average was recorded.

3.5.3. Quality parameters

3.5.3.1 Moisture (%)

Moisture content of the fruit was determined by the oven dry method as described by Rangana (1986).

3.5.3.2 Juice (ml)

The juice of the fruits was extracted with the help of juice extractor and expressed in ml.

3.5.3.3 Total soluble solids (TSS) (%)

TSS of the fruit was determined by Zeiss Hand Refractometer and after temperature corrections the results were expressed in percentage .

3.5.3.4 Titratable acidity (%)

It was determined by using by adopting the standard methods of AOAC, 1989. To estimate the titratable acidity, mortar with pestle was used to ground 10 g of pulp and 100 ml of distilled water was added to it followed by filtration. Ten ml of filtrate was titrated against 0.1 N NaOH using phenolphthalein indicator. Titratable acidity was expressed in percentage in terms of anhydrous citric acid by using the following formula:

$$\text{Titratable acidity} = \frac{\text{Titre value x Normality of alkali x Volume made up x Eq. weight of citric acid}}{\text{Weight of sample x Aliquot X 1000}} \text{ X } 100$$

3.5.3.5 Reducing sugars (%)

The reducing sugars of the fruits were estimated by using the methods of AOAC (1989). 4 ml of saturated lead acetate solution and 2 ml of sodium oxalate were added to 10 g of pulp which was grounded in mortar and the volume was made up to 100 ml with distilled water, centrifuged and then filtered. The filtrate was titrated against 10 ml of boiling Fehling's solution mixture (5 ml of Fehling's solution A and 5 ml of Fehling's Solution B) using methylene blue as indicator. Deep brick red colour of the solution indicated the end point and the reducing sugar was determined with the following formula and the value was expressed in percentage.

$$\text{Reducing sugar} = \frac{\text{Factor X Volume made up}}{\text{Titrate value X Weight of sample.}} \text{ X } 100$$

Where Factor = 0.05 (mg of invert sugar)

3.5.3.6 Total sugars (%)

The total sugars were determined by the methods suggested in AOAC (1989). From the solution that was prepared for reducing sugar, 25 ml of the solution was taken and 2.5 ml of the concentrated HCL was added to it and kept overnight. The solution was then neutralized with 1N NaOH and the volume was made up to 75 ml with distilled water and titrated against 10 ml boiling Fehling's solution mixture using methylene blue as indicator. From the titre value, percentage of total sugar was calculated as follows:

Total Sugar = (% sucrose + % reducing sugar)

Sucrose % = (% Total invert sugar - % reducing sugar) X 0.95

$$\%\text{Total invert sugar} = \frac{\text{Factor x Volume made up x Volume of stock solution}}{\text{Titre value x weight of the sample x Aliquot taken}} \text{ X } 100$$

3.5.3.7 Non- reducing sugars (%)

Non-reducing sugars was obtained from the differences between total sugar and reducing sugar as

Non – reducing sugar = (Total sugar – reducing sugar) X 0.95

3.5.3.8 Sugar-acid ratio

The sugar acid ratio was calculated by dividing the total sugars by titratable acidity as follows

$$\text{Sugar: acid ratio} = \frac{\text{Total sugars (\%)}}{\text{Titrable acidity (\%)}}$$

3.5.3.9 Ascorbic acid (mg 100g^{-1})

Freed's (1966) visual titration method was followed for estimating the ascorbic acid content of the fruit pulp and the result was expressed as mg 100g^{-1}. For the purpose, 0.5 g of fruit pulp was grounded in a mortar with 25 ml of 4% oxalic acid, filtered through Whatman No. 1 filter paper and the filtrate was collected in a 50 ml volumetric flask. The volume was made up to 50 ml with 4 % oxalic acid. 5 ml of the extract was taken with 5 ml of oxalic acid and titrated against standard 2, 6 –

dichlorophenol indophenol dye until the solution changed to pink colour which persists for at least 15 seconds. The amount of ascorbic acid was calculated by using the dye factor as follows:

$$\text{Standard dye factor} = \frac{0.5}{\text{Dye factor (titrate value)}}$$

$$\text{Ascorbic acid} = \frac{\text{Standard dye factor X titrate value X vol. make up}}{\text{Vol. of sample taken (ml/g) X volume of aliquot taken}} \text{X100}$$

3.5.3.10 Anthocyanin

The anthocyanin content of the berries was calculated spectrophotometrically. For estimation of Anthocyanin, 1 g of sample was taken in a conical flask. 50 ml of methanolic HCl (85: 15 v/v) was added to it. The mixture was kept for about 24 hours by closing the mouth of the flask. Then the volume was made up to 100 ml. The density of the colour was then read with the help of UV VIS spectrophotometer at 445 nm.

$$\text{Total optical Density} = \frac{\text{Absorbance X volume made up X 100}}{\text{Sample weight}}$$

$$\text{Anthocyanin content} = \frac{\text{Total Optical Density}}{98.2}$$

3.5.3.11 Total carotenoids

The total carotenoid content was determined according to Rodriguez-Amaya (1999).

5 g of sample and 3g of celite powder were grounded with 50 ml acetone and filtered through Whatman no.4 filter paper, 40 ml of petroleum ether (PE) was taken in a 500 ml separating funnel. There after the solution was washed 3-4 with distill

water to discard the lower aqueous phase without discarding the upper phase. The upper phase was collected in 50 ml volumetric flask and 15 g of anhydrous sodium sulphate was added to remove the residual water. The solution was again filtered and volume was made up to PE. The absorbance was recorded at 450 nm in a UV-VIS spectrophotometer and total carotenoid content (µg).

Calculation

$$\text{Total carotenoid } (\mu g/g) = \frac{\text{Absorbance X Volume (ml) X } 10^4}{\text{Absorbance coefficient (2592) X Sample weight}} \text{X100}$$

3.5.3.12 Raisin recovery

After the bunch harvest, 5.0 kg grapes from each treatment were treated with ethyl oleate and sodium carbonate and were kept for drying. After drying, the per cent raisin recovery was estimated.

3.5.3.13 Protein

The protein content was estimated by using Lowry's method. 0.1 mL of sample was taken and added 0.1 mL of 2 N NaOH. Then, hydrolyze at 100°C for 10 min in a heating block or boiling water bath. The hydrolysate is cooled to room temperature and 1 mL of freshly mixed complex-forming reagent. The solution is allowed to stand at room temperature for 10 min. 0.1 mL of Folin reagent is added and let the mixture stand at room temperature for 30–60 min (not exceeding 60 min). The reading of the absorbance was taken at 750 nm if the protein concentration is below 500 µg /mL or at 550 nm and if the protein concentration was between 100 and 2000 µg/mL. A standard curve of absorbance function of initial protein concentration was plotted and uses it to determine the unknown protein concentrations.

3.5.3.14 Starch

The starch content was estimated by following the method as described by Hedge and Hofreiter, (1962). One hundred mg of the sample was homogenized in hot 80 per cent ethanol to remove sugars. The residue was retained after centrifugation. The residue was washed with hot 20 per cent ethanol till the washings did not give colour with anthrone reagent. The residue was dried well in a water bath. To the residue, five ml of water and 6.5 ml of 52 per cent perchloric acid were added. The extract was retained after centrifugation. The extraction was repeated with fresh perchloric acid. The extracts were pooled after centrifugation and the volume was made up to 100 ml with 52 per cent perchloric acid. To 0.2 ml of the extract, 0.8 ml of distilled water and 4 ml of anthrone reagent were added. The reaction mixture was heated for 8 min. in a boiling water bath and cooled rapidly. The colour intensity was read at 630 nm using a spectrophotometer. D-glucose was used as a standard and the starch content was expressed as percentage. The starch content of the sample was calculated by using the standard curve of glucose and multiplied by a factor 0.9 to arrive at the starch content. The experiment was conducted in triplicate and the mean was recorded.

3.5.3.15 Carbohydrate

100 mg of the leaf sample taken into a boiling tube and hydrolyse by keeping it in a boiling water bath for three hours with 5mL of 2.5 N-HCl and cool to room temperature after that the sample was neutralize with solid sodium carbonate until

the effervescence ceases. Final volume was made up to 100 ml and then centrifuges 10000 rpm for 20 minutes.

The supernatant was collected and 0.5-1mL of aliquots was taken for analysis. The standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1mL of the working standard. '0' serves as blank and volume to 1mL was made in all the tubes including the sample tubes by adding distilled water. Then 4mL of anthrone reagent was added and the samples was heated for eight minutes in a boiling water bath and cool rapidly and read the green to dark green colour at 630nm. A standard graph was drawn by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. From the graph the amount of carbohydrate present in the sample was calculated (Sadasivam and Manickam, 1992).

Calculation:

Amount of Carbohydrate present in 100mg of the sample,

$$= \frac{\text{mg of Glucose}}{\text{Volume of test sample}} \times 100$$

3.5.3.16 Total phenols

Shoot tips along with a pair of freshly emerged leaves were taken for analysis of total phenol content. Foliar sample (approx. 500 mg) was homogenized in a mortar by adding 80 per cent ethanol. It was then centrifuged at 10,000 rpm for 20 min. and the supernatant was filtered using filter paper Whatman No. 42. The residue was re-extracted (5 times) with 80 per cent ethanol and the supernatant collected were evaporated to dryness (60 °C) on a water bath. Residues were dissolved in 5 ml of distilled water from which about 0.2 ml was taken and total volume was made upto 3 ml with distilled water. To this, fresh Folin-Ciocalteau reagent (0.5 ml) was added. After 3 min., 2 ml of Na2 C03 (20 %) solution was added to each tube, mixed thoroughly and placed on a hot water bath (58 °C) exactly for one min. It was then cooled to room temperature and absorbance (650 nm) was measured against blank (Mallik and Singh, 1980).

Preparation of standard curve: Twenty mg of catechol was first dissolved in a small volume of distilled water and then volume was made up to 100 ml. In five stopper test tube (10 ml) 0.2, 0.4, 0.6, 0.8 and1.0 ml aliquot of catechol was taken and volume was made to 3 ml with distilled water followed by addition of 0.5 ml Folin-Ciocalteau reagent. After 3 min., 2 ml of 20 per cent $Na_2 CO_3$ was added and mixed thoroughly. A blank was run simultaneously taking 3 ml of distilled water instead of catechol. All the tubes were placed in boiling water bath (100 °C) for exactly one minute, cooled and then absorbance was measured at 650 nm using spectrophotometer. The instrument was adjusted to zero optical density (OD) using a blank.

3.5.4. Plant leaf analysis

For the estimation of leaf nutrient status under different treatments, leaf samples were randomly collected from plants of each treatment. The leaves opposite to the bunch were collected 45 days after pruning for leaf analysis. All the collected leaf samples were washed by using distilled water to clean any dusts and were placed in 70°C hot air oven for 72 hours to dry them. Micro grinder was used to grind the dried samples, sieved and stored in brown paper sachets.

3.5.4.1 Estimation of nitrogen

Total nitrogen was estimated as per Micro kjeldhal method as described by Humphries (1956).

Digestion

Nitrogen content of the leaf was determined by Micro kjeldhal method (Humphries, 1956). One hundred mg of oven-dried leaf was taken into a micro kjeldhal digestion flask. Two ml of 5% Salicylic acid dissolved in conc. H_2SO_4 was added and mixed well. After 20 minutes, 0.3 g of Sodium thiosulphate was added and heated gently until fumes disappeared. After cooling the contents of the flask, 60 mg of catalyst (a mixture of 1 gm copper sulphate, 8 g potassium sulphate and 1 gm of selenium dioxide) followed by 1 ml of conc. H_2SO_4 were added. The contents of the flask were digested until they turn apple green in colour. The flask was cooled and the contents were made up to a known volume.

Distillation

Ten ml aliquot from volumetric flask were transferred to Paranas Micro kjeldhal distillation flask. To this, 10 ml of 40% NaOH solution along with 2 ml of glass distilled water were added. The contents were heated by a bunsen burner. The liberated ammonia was collected in 2 % boric acid solution containing a drop of double indicator (83.3 mg of bromocresol green, 16.6 mg of methyl red dissolved in 10 ml of 93% ethanol). The contents were titrated against N/50 H_2SO_4. A blank was run simultaneously using all the reagents and the value of the blank was deducted from the value of the sample before calculation. One ml of N/50 H_2SO_4 corresponds 0.00028 g of N which forms the basis for calculation of N content in the sample.

3.5.4.2 Estimation of phosphorus

The estimation of Phosphorus from leaf sample was determined by colorimetric method as described by Jackson (1973).

Digestion

One gm of dried and grinded leaf sample was transferred into 250 ml conical flask. 20 ml of dried diacid mixture (comprising of 4 parts of nitric acid and 1 part of perchloric acid) was added to this flask. The samples were digested on electric hot plate. The digestion was continued till 2-3 ml of clear digested material was left in the conical flasks. After complete digestion, the samples were diluted to 100 ml with the help of distilled water.

Phosphorus was estimated by vanado molybdo phosphoric acid method (Jackson, 1973). Five ml of extract (digested sample) was taken in 25 ml of volumetric flask. To this flask, 20 ml of working solution was added and final volume was made to 25 ml with distilled water. The contents were mixed and used for estimation of phosphorus on Spectronic- 20 D at 470 nm wavelength using red filter. The colour intensity (yellow) was recoded and the phosphorus content was depicted with the help of standard curve.

3.5.4.3 Estimation of potassium

The estimation of Potassium from leaf sample was determined by Flame photometric method as described by Jackson (1973).

Digestion

The Digestion was same as that of estimation of phosphorous

Distillation

The digested samples were diluted to 100 ml with distilled water. Five ml of this prepared sample was diluted to 50 ml with distilled water. The samples vis-à-vis to standard is fed one by one to the instrument and readings were recorded in ppm.

3.5.4.4 Leaf dry matter

It was estimated by drying the samples hot air oven till a constant weight.

3.5.4.5 Carbohydrate

100mg of the leaf sample taken into a boiling tube and hydrolyze by keeping it in a boiling water bath for three hours with 5mL of 2.5 N-HCl and cool to room temperature after that the sample was neutralize with solid sodium carbonate until the effervescence ceases. Final volume was made up to 100 ml and then centrifuges 10000 rpm for 20 minutes.

The supernatant was collected and 0.5-1mL of aliquots was taken for analysis. The standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1mL of the working standard. '0' serves as blank and volume to 1mL was made in all the tubes including the sample tubes by adding distilled water. Then 4mL of anthrone reagent was added and the samples was heated for eight minutes in boiling water bath and cool rapidly and read the green to dark green colour at 630nm. A standard graph was drawn by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. From the graph the amount of carbohydrate present in the sample was calculated (Sadasivam and Manickam, 2008).

Calculation:

$$\text{Carbohydrate} = \frac{\text{Mg of Glucose}}{\text{Volume of test sample}} \times 100$$

3.5.4.6 C/N ratio

It was calculated by using the following formula:

$$\text{C/N Ratio} = \frac{\text{Total carbohydrate}}{\text{Total nitrogen}}$$

3.5.4.7 Leaf chlorophyll

The chlorophyll-a, chlorophyll b and total chlorophyll of the leaves were estimated by following the methods of Arnon (1949).

The results thus obtained were compared with control. A pre weighted (250 mg) quantity of fresh leaf material was grounded into fine paste. 10 ml of 80% acetone was added into it. The extract was centrifuged and the green supernatant was obtained. Using small quantities of acetone, the extract was centrifuged repeatedly till the lachate became colorless. The supernatant was taken together and was made up to 25 ml with 80% acetone. The extract was kept away from direct sunlight. The optical density of the extract was read at 480, 510, 645, 652 and 663 wavelengths using spectrophotometer. The samples were analyzed in duplicates. From the optical densities, the chlorophyll contents were calculated by using the following formula:

Chlorophyll a (mg/g) = 12.7 (OD 663) – 2.69 (OD 645) X v/1000xw

Chlorophyll b (mg/g) = 22.9 (OD 645) – 4.68 (OD 663) X v/1000xw

Total Chlorophyll (mg/g) = OD 652 X 1000/34.5 X v/1000Xw

Where OD = Optical density

V = Final vol. of 80% acetone (25 ml)

W = Wt. of sample taken (0.25 g)

3.5.4.8 Leaf micronutrients analysis

Leaf micronutrients viz. Fe, Mn, Cu, and Zn was estimated with the help of Atomic absorption spectrophotometer. It was estimated by using 10 ml of 100 ml prepared sample, which was further diluted to 5ml with distilled water. The micronutrients of leaf were computed on dry weight basis and expressed as ppm.

3.5.5. Soil Analysis

3.5.5.1 Preparation of soil sample

Soil samples from each replication were collected at 15 – 30 cm depth with the help of soil auger. The samples were then thoroughly mixed and dried in shade, pulverized, to pass through 0.2 mm sieve and kept in polythene bag for chemical analysis. Soil samples are taken from the area where manures were applied, around the rhizosphere of the plants. The soil auger was cleaned and clean plastic bags were used for collecting the soil samples.

3.5.5.2. Soil health parameters

3.5.5.2.1 Soil pH

Soil pH was determined by potentiometric method (Jackson, 1973). For the purpose, soil water suspension was prepared at the ratio of 1:2 and the pH of the suspension was estimated with the help of pH meter with glass electrode.

3.5.5.2.2 Soil moisture

It was estimated by following the method of Hillel, 1971.

3.5.5.2.3 Soil organic carbon

Organic carbon content of the sample was estimated by the “Wet digestion method” as described by Walkley and Black (1934) and expressed in percentage. Organic carbon content of the soil was estimated by oxidizing the soil with a mixture of 1(N) potassium dichromate ($K_2Cr_2O_7$) and concentrated sulphuric acid (H_2SO_4) and back titrating the excess $K_2Cr_2O_7$ with ferrous ammonium sulphate solution after adding Barium Diphenyl Amine Sulphonate indicator and ortho phosphoric acid.

3.5.5.2.4 Total inorganic carbon

The Total inorganic carbon (TIC) was estimated as $CaCO_3$ by using acid neutralization method (Page *et al.*, 1982).

3.5.5.2.5 Total carbon

The Total carbon was calculated by adding SOC and TIC.

3.5.5.2.6 Total nitrogen

Total nitrogen was calculated by the methods of Jackson, 1973. It was analyzed by concentrated sulphuric acid (H_2SO_4) digestion for the sample soils in the presence of 'Se' Catalyst and K_2SO_4 (to raise the temperature). The liberated NH_3 was absorbed in standardized acid and later it was titrated with standard alkali (Jackson, 1973).

3.5.5.2.7 C: N ratio

Soil C: N ratio was estimated by dividing the total carbon by the total N.

$$\text{C:N ratio} = \frac{\text{Total C}}{\text{Total N}}$$

3.5.5.2.8 Cation exchange capacity (CEC)

The CEC of the soil sample was estimated by the methods of Jackson (1973) by leaching the soil with neutral 1 (M) ammonium acetate (NH_4OAc) solution. The leachate was distilled with magnesium oxide (MgO). The liberated ammonia was absorbed in 4% boric acid and estimated by titration with standard sulphuric acid using phenolphthalein indicator.

3.5.5.2.9 Available nitrogen

Available nitrogen was determined by "Alkaline potassium permanganate method" as outlined by Subbiah and Asija, (1956). For its determination, 5 g of soil sample was taken in digestion tube with a little distilled water. Then, 25 ml of 0.32% of $KMnO_4$ was added to sample and the digestion tubes were fitted to the distillation unit. 25 ml of 2.5% NaOH solution was added through distillation unit and 25 ml of 2.5% boric acid was taken in conical flask with mixed indicator. The distilled NH_3 from tubes collected in the receiver solution and the distillate was titrated against 0.02 N H_2SO_4 solutions. The nitrogen in the plant sample was determined by using the following formula and expressed in Kg/ha.

$$\text{Available N (kg/ha)} = (S-B) \times 125.44$$

Where, S & B stands for titre values of sample and blank, respectively

3.5.5.2.10 Available phosphorus

Available phosphorus content of the soils was determined by the method as suggested by Page *et al*. (1982). Soil (2.5 g) was taken in a 100 ml conical flask, a pinch of Olsen's reagent (0.5 M NaHCO3) was added to it and the flask was shaken thoroughly to mix the ingredients. Then, the solution was filtered and 5 ml of filtrate was taken in a 25 ml volumetric flask and 5 ml ammonium molybdate, 1 ml freshly prepared $SnCl_2$ solution were added and volume was made up to 25 ml by addition of distilled water. The optical density (OD) was taken at 660 nm.

Available P (kg ha-1) = (Q x V x 2.24)/A x S

Where, Q = quantity of phosphorus in mg/l measured from standard curve

V = Volume of interacting reagent

A = Volume of aliquot

S = Weight of sample

3.5.5.2.11 Available potassium

Available potassium content of the soil sample was extracted by neutral normal ammonium acetate as outlined by Jackson (1973). The potassium content of the sample was determined with the help of Flame photometer and expressed as available K_2O (Kg/ha). Soil (5 g) was taken in a 250 ml conical flask. 25 ml of (1 N) CH_3COONH_4 solution was added to it. The flask was shaken for 30 minutes, the solution was filtered and filtrate was diluted to 50 ml with (1 N) CH_3COONH_4 solution and the readings were measured by Flame photometer using standard curve.

Available K = 56R

Where R = concentration of potassium in sample obtained from standard curve.

3.5.5.2.12 Micronutrient content

Micronutrients (Fe, Mn, Cu, and Zn) was calculated by using the methods of Lindsay and Norvell, (1978). For the estimation of micronutrients, soil samples were extracted with diethylene triamine penta acetic acid (DTPA), buffered at pH 7.3 + 0.05 for two hours and filtered through Whatman No. 42 filter paper. Available Fe, Cu, Zn and Mn in the extract were determined on double Bean Atomic Absorption Spectrophotometer.

3.5.5.3 Soil microbial analysis

Soil samples was taken from the rhizosphere and microbial populations was counted before initiation of the experiment and after completion of the experiment. Serial dilution plating method was followed for microbial population count (Vincent, 1970).

3.5.5.3.1 Soil collection

The representative soil samples were collected from the root rhizosphere of Bangalore Blue grapes which was treated with different organic amendments in three replications.

3.5.5.3.2 Culture media

For estimation of microbial count during the experiment, various culturing media viz. Bacteria, Fungi, Actinomycete were utilized.

The culture media used and their compositions are as follows

3.5.5.3.2.1 Nutrient Agar (NA) media for bacteria

1) Beef extract – 3 g
2) Peptone – 5 g
3) Agar – 15 g
4) Distilled water – 1000 ml

3.5.5.3.2.2 Potato Dextrose Agar (PDA) media for fungus

1) Potato piller – 250 g
2) Glucose – 20 g
3) Agar – 15 g
4) Distilled water – 1000 ml
5) pH – 6

3.5.5.3.2.3 Knight's media for Actinomycetes

1) Glucose – 1 g
2) Monopotassium phosphate KH_2PO_4 – 1 g
3) $NaNO_3$ – 0.1 g

4) KCl – 0.1 g

5) $MgSO_4$, $7H_2O$ – 0.1 g

6) Agar – 15 g

7) Distilled water – 1000 ml

8) pH – 7.0-7.2

3.5.6 Economics of cultivation and Benefit: Cost ratio

The economics of the individual treatment was calculated based on the total cost of cultivation and gross income and were expressed on per hectare basis.

The expenditures both recurring and non-recurring required during the cropping period were computed based on the investment on preparatory cost including planting materials, FYM, vermicompost, Biofertilizers, biodynamics, inorganic fertilizers, intercultural operations, plant protection and harvesting as well as carrying operations. Net return was calculated by subtracting gross expenditure from the gross return on per hectare basis.

3.5.6.1 Benefit: Cost ratio

The benefit-cost ratio was calculated from the value of total expenditure and gross return based on the benefit obtained on per rupee cost in different treatments separately. Benefit: cost ratio was calculated as below

$$\text{B: C ratio} = \frac{\text{Net returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

3.6 Statistical analysis

The data obtained from different observations during field experimentation and laboratory analysis were subjected to Fisher's method of analysis of variance

(ANOVA) by randomized block design. The statistical analysis of the data on the mean values of individual characters was analysed using M Stat software. Significance and non-significance of the variance due to different treatments were determined by calculating the respective ‘F’ value and comparing with the appropriate value of ‘F’ at 5 per cent probability level (Panse and Sukhatme, 1985).

By comparing different treatments among themselves critical difference were calculated at 5% probability level. Standard error Differences (S.Ed.) was calculated by using the following formula:

$$\text{S.Ed.} = \sqrt{\frac{2 \text{ X Error mean square}}{\text{Number of replications}}}$$

The significance and non-significance of treatments at 5 per cent probability level were calculated by multiplying the S.Ed with appropriate tabulated values for Error Degrees of Freedom.

Results

The present investigation entitled "Organic Nutrient Management and Crop Regulation in Grapes in Mizoram" was carried out at farmer's field of Vengthar and Vengsang village of Champhai District, Mizoram for two consecutive fruiting years i.e. 2016- 2017 and 2017-2018. The observations on various growth, yield attributing characters and yield, berry physical parameters, quality, soil and leaf nutrient contents of Grapes cv. Bangalore Blue are presented in this chapter under following headings.

4.1 1st Experiment: Effect of organic manures and bio-dynamic preparations on growth, yield and quality of Grapes cv. Bangalore Blue

4.1.1 Plant growth characters

4.1.1.1 Shoot length (cm)

The perusal of data presented in Table 4.1.1 indicates that different organic manures and bio-dynamic preparations had significant influence on shoot length during both the years of study. During 2016-2017, the maximum shoot length (119.17 cm), was obtained in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* (T_6), while the least (115.45 cm) was recorded in control (T_{13}). Similarly, during 2017-2018, the maximum was recorded in (125.80 cm) in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) and the lowest was (115.04 cm) was in control (T_{13}). However, pooled data for both years indicated that the maximum shoot length (122.23 cm) was recorded from the plants applied with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum*

+ CPP + BD 500 + BD 501 (T_9) which were significantly higher than all other treatments. Among all the treatments, the T_{13} recorded minimum shoot length (115.25 cm).

4.1.1.2 Shoot diameter (mm)

During 2016-2017, among all the treatments, the maximum shoot diameter (20.69 mm) was observed in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501(T_{12}) while, the minimum (16.47 mm) was recorded in (control) T_{13} (Table 4.1.1). During 2017-2018 PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the maximum shoot diameter (20.97 mm) which was significantly higher than rest of the treatments and the minimum (16.49 mm) was in control (T_{13}). It is clear from pooled data that significant differences were observed among the treatments with respect to shoot diameter. Among all the treatments, the maximum (20.83 mm) was recorded with PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{12}) while, the minimum (16.48 mm) was recorded in control (T_{13}).

4.1.1.3 Internodal length (cm)

Significant variations were recorded among all the treatments with respect to internodal length in both the years of studies as well as in pooled data (Table 4.1.1). For the year 2016-2017, the maximum internodal length (12.26 cm) was recorded in NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}) which was significantly higher than all other treatments, while the minimum was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (9.85 cm). Similarly, in 2017-2018, the maximum (12.59 cm) was observed in NC + *Azospirillum* + PSB + KSB +

Trichoderma harzianum + CPP + BD 500 + BD 501 (T_{11}), whereas, the minimum was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (9.88 cm). The pooled data showed that NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}) showed the maximum value (12.43 cm) followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (12.15 cm), but these two were found statistically *at par* , while the lowest was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (9.87 cm).

4.1.1.4 Cane diameter (mm)

It is evident from the data presented in the Table 4.1.1 and that during 2016-2017, the maximum cane diameter (6.67 mm) was recorded in NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}), while the lowest (3.47 mm) was recorded in control (T_{13}). Similarly, during 2017-2018, the maximum (6.73 mm) was recorded in NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}), whereas, the minimum was in control (4.07 mm). The analysis of pooled data revealed that the maximum cane diameter (6.70 mm) was recorded with NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}) which was significantly higher than all other treatments. It was followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (5.68 mm) while, the least (3.77 mm) was recorded in control.

Table 4.1.1 Effect of organic manures and bio-dynamic preparations on shoot length, shoot diameter, internodal length, cane diameter

Treatments	Shoot length (cm)			Shoot diameter (mm)			Internodal length (cm)			Cane diameter (mm)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	115.73	116.96	116.34	18.60	18.83	18.72	11.51	11.73	11.62	4.87	4.88	4.88
T_2	115.97	116.68	116.33	18.17	18.32	18.25	10.98	11.03	11.01	4.80	4.83	4.82
T_3	116.94	115.69	116.32	17.65	18.00	17.83	10.72	10.75	10.74	4.15	4.29	4.22
T_4	115.18	116.97	116.07	18.33	18.36	18.34	11.21	11.32	11.27	4.66	4.68	4.67
T_5	119.02	119.22	119.12	19.26	19.67	19.47	11.84	12.03	11.93	5.14	5.36	5.25
T_6	119.17	119.85	119.51	19.39	19.46	19.42	11.21	11.09	11.15	5.03	5.13	5.08
T_7	115.99	117.32	116.66	18.54	18.80	18.67	11.68	11.73	11.71	4.66	4.73	4.70
T_8	119.07	119.72	119.44	19.03	19.20	19.11	11.55	11.60	11.57	4.78	4.85	4.81
T_9	118.67	125.80	122.23	19.64	19.77	19.70	9.85	9.88	9.87	4.35	5.01	4.68
T_{10}	118.03	124.14	121.09	20.06	20.10	20.08	12.06	12.25	12.15	5.63	5.72	5.68
T_{11}	119.15	120.86	120.00	19.07	19.23	19.15	12.26	12.59	12.43	6.67	6.73	6.70
T_{12}	118.00	122.72	120.36	20.69	20.97	20.83	11.43	11.48	11.46	5.14	5.20	5.17
T_{13}	115.45	115.04	115.25	16.47	16.49	16.48	12.03	12.17	12.10	3.47	4.07	3.77
T_{14}	115.96	116.56	116.26	17.61	17.64	17.63	11.14	11.35	11.25	4.19	4.46	4.32
Sem ±)	0.34	0.33	0.30	0.22	0.12	0.15	0.11	0.12	0.12	0.17	0.13	0.14
CD (0.05)	0.99	0.96	0.62	0.64	0.34	0.32	0.32	0.35	0.25	0.49	0.37	0.30

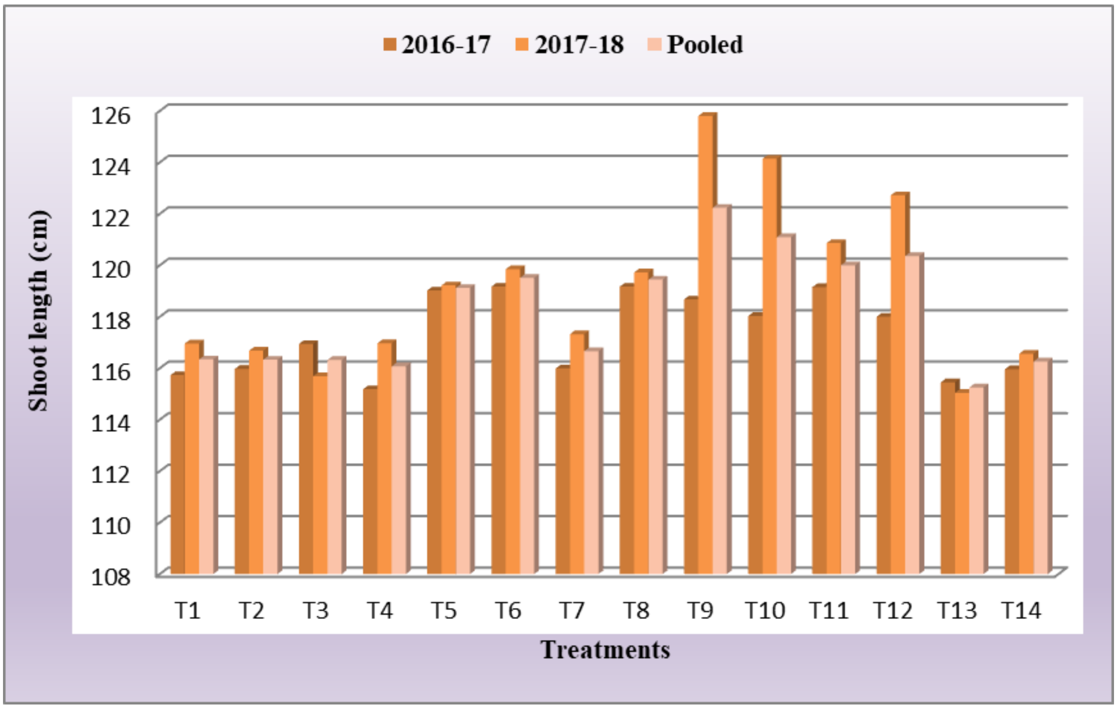

Fig. 4.1.1 Effect of organic manures and bio-dynamic preparations on shoot length

4.1.2 Yield attributing characters and Yield

4.1.2.1 Per cent of fruitful cane (%)

Significant differences were recorded among the treatments with respect to per cent of fruitful cane during the two years of experimentation as well as in pooled analysis. The perusal of data presented in Table 4.1.2 revealed that FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the maximum fruitful cane (92.10 % and 95.59 %) during 2016-2017 and 2017-2018 respectively, while, the minimum was recorded in control (T_{13}) in both years of investigation (73.16 % and 78.04%). The analysis of pooled data revealed that, treatment FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the maximum fruitful cane (93.85 %), which was significantly higher than all other treatments, while, the minimum (75.60%) was recorded in control (T_{13}).

4.1.2.2 Berry set per cent (%)

The perusal of data shown in Table 4.1.2 showed that organic manures and bio-dynamic preparations had significant impact in berry set per cent. During 2016-2017, among all the treatments, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the highest berry set per cent (39.30 %). Similarly, in 2017-2018 also, the same treatment recorded the maximum value (39.84 %). Among all the treatments, control (T_{13}) recorded the minimum berry set per cent (30.07% and 30.09%) during both the years of study. The pooled analysis highlighted that, the maximum berry set (39.57 %) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9),whereas, minimum (30.08 %) was recorded in control (T_{13}).

4.1.2.3 Berry drop per cent (%)

It is clearly seen from the data presented in Table 4.1.2 that berry drop per cent varied significantly among the treatments during both the years of experimentation. Among all the treatments, the minimum berry drop per cent (41.46 %) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while maximum (59.13 %) was observed in control (T_{13}) during 2016-2017. During 2017-2018, the minimum berry drop per cent (40.82 %) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while, the maximum was recorded in control (58.30%). The results of pooled data showed that minimum berry drop per cent (41.14%) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), which was followed by NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_7) (41.89 %), whereas, the maximum berry drop per cent (58.71%) was in control (T_{13}).

4.1.2.4 Berry retention per cent (%)

Data shown in Table 4.1.2 and indicated that there was significant differences among the treatments with respect to berry retention per cent in both the two year of investigation as well as in the pooled data. The berry retention per cent varied between 40.87 and 58.54 in 2016- 2017 and 41.70 and 59.18 in 2017-2018. The pooled data revealed that the highest berry retention (58.86 %) was in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) followed by NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_7) (58.12 %), while the minimum (41.29 %) was recorded in treatment Control (T_{13}).

4.1.2.5 Shot berries (%)

It is obvious from the data presented in Table 4.1.3that both the organics and biodynamic preparations had good impact on shot berries per cent during the two years of investigations. During 2016-2017 and 2017-18, the minimum shot berries (2.59 and 2.20 %) was observed in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) which was significantly higher than all other treatments, while, the maximum was observed in control (T_{13}) (13.09 and 13.04 %). Pooled data of the two years revealed that minimum shot berries (2.40 %) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), but both of them were statistically *at par*, whereas, the maximum (13.07 %) was found in control (T_{13}).

Table4.1.2 Effect of organic manures and bio-dynamic preparations on per cent of fruitful cane, berry set per cent, drop per cent and retention per cent

Treatments	Per cent of fruitful cane			Berry set per cent			Berry drop per cent			Berry retention per cent		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	85.96	87.15	86.56	34.75	35.58	35.17	46.63	45.59	46.11	53.37	54.41	53.89
T_2	84.89	86.60	85.75	34.11	34.24	34.17	46.74	46.20	46.47	53.26	53.80	53.53
T_3	82.44	85.48	83.96	31.67	31.84	31.76	54.96	54.46	54.71	45.04	45.54	45.29
T_4	83.41	86.44	84.93	33.31	33.47	33.39	50.25	50.09	50.17	49.75	49.91	49.83
T_5	86.99	88.93	87.96	36.08	36.25	36.17	43.61	43.01	43.31	56.39	56.99	56.69
T_6	86.04	88.32	87.18	35.00	35.12	35.06	46.00	45.71	45.86	54.00	54.29	54.15
T_7	83.21	86.34	84.78	32.94	32.99	32.96	42.35	41.42	41.89	57.65	58.58	58.12
T_8	85.71	87.63	86.67	34.21	34.31	34.26	45.33	44.18	44.75	54.67	55.82	55.25
T_9	92.10	95.59	93.85	39.30	39.84	39.57	41.46	40.82	41.14	58.54	59.18	58.86
T_{10}	87.37	91.48	89.43	38.75	38.92	38.84	44.18	42.93	43.56	55.82	57.07	56.45
T_{11}	84.15	90.07	87.11	31.46	33.07	32.27	51.52	48.66	50.09	48.48	51.34	49.91
T_{12}	87.69	90.15	88.92	35.72	35.87	35.79	44.69	44.18	44.44	55.31	55.82	55.56
T_{13}	73.16	78.04	75.60	30.07	30.09	30.08	59.13	58.30	58.71	40.87	41.70	41.29
T_{14}	78.07	82.44	80.26	30.73	30.83	30.78	58.20	57.15	57.68	41.80	42.85	42.32
Sem ±)	1.06	0.78	0.83	0.46	0.33	0.38	0.88	0.51	0.68	1.24	0.72	0.68
CD (0.05)	2.19	1.61	1.71	1.35	0.95	0.78	2.56	1.48	1.41	2.56	1.48	1.41

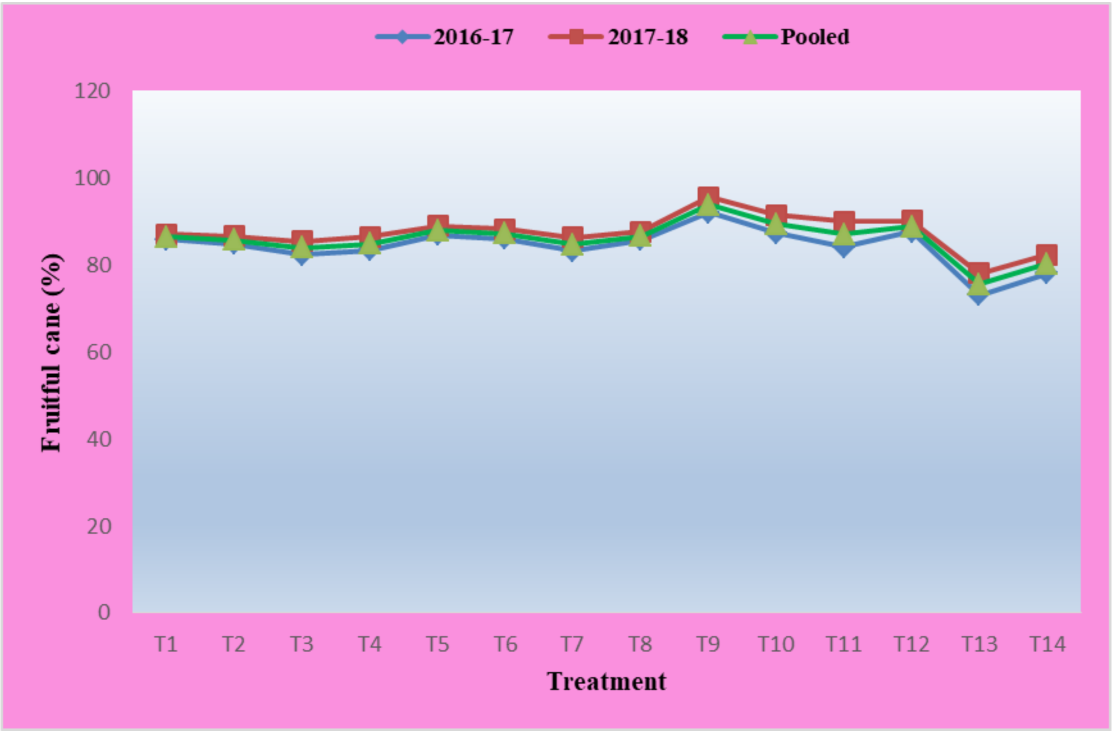

Fig. 4.1.2 Effect of organic manures and bio-dynamic preparations on fruitful cane (%)

4.1.2.6 Unripe berries (%)

A high degree of differences were recorded among the various treatments with regards to unripe berries per cent (Table 4.1.3). During 2016-17 and 2017-18, among all the treatments, the minimum unripe berries (7.19 and 7.02 %) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), while the maximum (24.62 and 28.24 %) was observed in T_{13} (control). Similarly, pooled data of the two years revealed that the minimum unripe berries (7.11 %) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) while, the maximum (26.43 %) was observed in control (T_{13}).

4.1.2.7 Total crop duration (days)

It is obvious from the data (Table 4.1.3) that both organic and bio-dynamic preparations had remarkable impact on total crop duration during the two years of investigations. During 2016-2017, the total crop duration ranged between 46.32 days to 63.34 days and during 2017-2018, it was 44.39 days to 63.74 days. Pooled data of the two years revealed that the shortest total crop duration (45.35 days) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 50 (T_{10}) (47.78 days), while, the longest total crop duration (63.54 days) was observed in T_{13} (control).

4.1.2.8 Bunch weight (g)

Perusal of the data presented in Table 4.1.3 revealed that the treatments differed significantly with respect to Bunch weight. During 2016-2017, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the highest bunch weight (785.04 g), while control showed the lowest bunch weight (408.21 g). Similarly, during 2017-2018, highest bunch weight (807.33 g) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) and the lowest was observed (419.38 g) in control (T_{13}). However, pooled data revealed that the highest bunch weight (796.19 g) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) and the lowest (413.80 g) was observed in control.

4.1.2.9 Bunch length (cm)

It is revealed from the data presented in Table 4.1.4 that the treatments varied significantly with respect to bunch length during both the years of experimentations. Among the different treatments, during 2016-2017and 2017- 2018, the maximum bunch length (21.47 cm and 21.84 cm) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) which was significantly higher than all other treatments, while, the minimum (13.63 cm and 13.71 cm) was recorded in control (T_{13}). From the pooled data, it was revealed that among the various treatments, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the maximum bunch length (21.66 cm), while, control (T_{13}) recorded the minimum (13.67cm).

Table 4.1.3 Effect of organic manures and bio-dynamic preparations on shot berries, unripe berries, total crop duration, bunch weight

Treatments	Shot berries (%)			Unripe berries (%)			Total crop duration			Bunch weight (g)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	6.06	4.32	5.19	11.45	9.99	10.72	50.56	48.74	49.65	588.39	607.33	597.86
T_2	8.82	8.18	8.50	14.19	13.43	13.81	54.59	51.31	52.95	599.05	615.14	607.09
T_3	11.35	10.63	10.99	20.74	20.41	20.57	55.85	52.85	54.35	549.95	584.64	567.29
T_4	6.23	6.02	6.13	12.10	11.58	11.84	53.91	51.53	52.72	533.39	575.80	554.60
T_5	7.37	5.88	6.63	7.19	7.02	7.11	48.86	46.88	47.87	633.09	671.20	652.14
T_6	9.30	9.22	9.26	14.20	13.77	13.98	49.24	47.17	48.21	629.36	654.15	641.75
T_7	13.03	10.78	11.90	21.58	20.19	20.88	53.46	51.30	52.38	625.74	634.58	630.16
T_8	5.60	5.14	5.37	11.94	11.53	11.74	51.38	49.89	50.64	606.00	624.30	615.15
T_9	4.37	4.16	4.27	10.53	9.48	10.01	50.35	51.05	50.70	785.04	807.33	796.19
T_{10}	5.39	4.95	5.17	12.04	11.98	12.01	49.11	46.44	47.78	775.32	797.35	786.34
T_{11}	8.83	7.73	8.28	19.43	19.19	19.31	51.53	49.13	50.33	690.98	714.00	702.49
T_{12}	2.59	2.20	2.40	13.52	13.05	13.28	46.32	44.39	45.35	647.59	677.52	662.55
T_{13}	13.09	13.04	13.07	24.62	28.24	26.43	63.34	63.74	63.54	408.21	419.38	413.80
T_{14}	8.49	8.11	8.30	22.84	22.70	22.77	58.46	58.35	58.40	464.15	489.59	476.87
Sem ±)	1.05	0.57	0.96	1.09	0.84	1.27	0.96	0.76	0.77	13.00	10.72	10.78
CD (0.05)	3.06	1.65	1.97	3.16	2.45	2.61	1.97	1.56	1.59	26.73	22.04	22.16

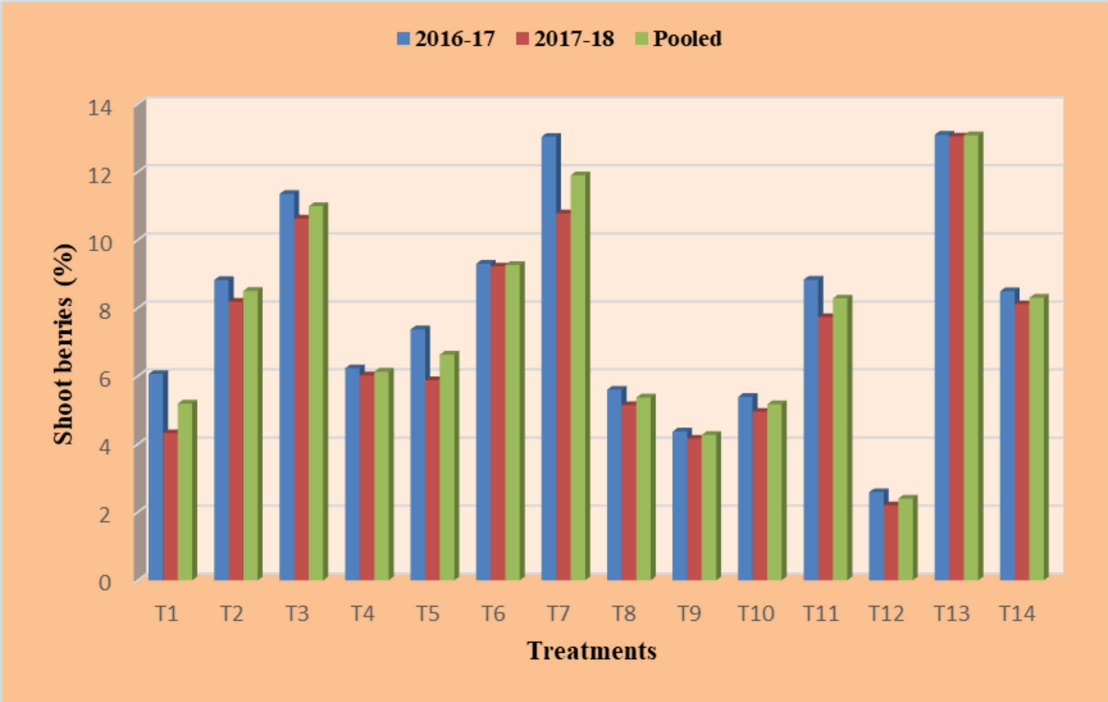

Fig. 4.1.3 Effect of organic manures and bio-dynamic preparations on shot berries

4.1.2.10 Bunch breadth (cm)

It is obvious from the data (Table 4.1.4) that both organics and bio-dynamics preparations had remarkable impact on bunch breadth. Among all the treatments, the maximum bunch breadth (12.79 and 13.23 cm) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 50 (T_{10}) (11.60 cm) and VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* (T_6) (12.06 cm), while the minimum (7.12 and 7.26 cm) was recorded in control (T_{13}) during the two years of investigations. Pooled data showed that the maximum bunch breadth of 13.01 cm was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) which was significantly higher than other treatments. It was followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* (T_6) (11.73 cm), whereas, the minimum (7.19 cm) was recorded in control (T_{13}).

4.1.2.11 Bunch size (cm^2)

The perusal of the data presented Table 4.1.4 revealed that both the organic manures and bio-dynamic treatments had huge impact on bunch size for both the years of investigations. During 2016-2017, the highest bunch size (274.72 cm^2) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) while the lowest (97.06 cm^2) was recorded in control (T_{13}). Similarly, for the year 2017-2018, the highest (288.86 cm^2) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) and the least (99.51 cm^2) was in control (T_{13}). Pooled data of the two years revealed that the highest bunch size (281.79 cm^2) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501

(T_9) which was significantly higher than all other treatments, while, the least (98.29 cm^2) was observed in control (T_{13}).

4.1.2.12 Berry number per bunch

The data presented in Table 4.1.5 revealed that number of berries per bunch varied significantly among the different treatments. The highest number of berries per bunch (182.90 and 192.03) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) during the year 2016-2017 and 2017- 2018 respectively. Pooled data of both the years revealed that the highest number of berries per bunch (187.46) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) which was significantly higher than all other treatments. The least berry number per bunch (98.33) was recorded in control (T_{13}).

4.1.2.13 Bunch number per vine

Significant variation was observed among the treatments with respect to number of bunches per vine. For the year 2016-2017, the number of bunches per vine varied between 30.54– 50.62, while, in 2017- 2018, it was between 30.74 – 53.05. The pooled data revealed that, the maximum number of bunches per vine (51.84) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) which was significantly higher than all other treatments, whereas, the minimum (30.64) was observed in control (T_{13}).

4.1.2.14 Bunch compactness (g cm^{-2})

The bunch compactness of the vine varied significantly among the treatments as revealed in Table 4.1.5. For the year 2016-2017, the maximum bunch compactness (5.91 g cm^{-2}) was observed in FYM +*Azospirillum* + PSB + KSB +

Trichoderma harzianum + CPP+ BD 500 + BD 501 (T_9). Similarly, during 2017-2018 also the same treatment recorded the highest bunch compactness (5.87 g cm^{-2}), while the minimum (2.86 and 2.80 g cm^{-2}) was recorded in control (T_{13}) in both the years. Pooled data of the two years revealed that the maximum bunch compactness (5.89 g cm^{-2}) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) which was significantly higher than all other treatments, while the lowest (2.83 g cm^{-2}) was recorded in control (T_{13}).

4.1.2.15 Yield per vine (kg)

The data of yield per vine are shown in Table 4.1.6. It is revealed from the data presented in the Table that various organic manures and bio-dynamic treatments had significant impact on yield per vine during the two years of investigations. During 2016-2017 and 2017-2018, the highest yield per vine (29.57 and 31.46 kg respectively) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while the lowest was recorded in control (T_{13}) (8.70 and 9.75 kg). Pooled data of the two years indicated that the highest yield per vine of 30.52 kg was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while the least (9.23) was observed in control (T_{13}).

4.1.2.16 Yield per ha (t ha^{-1})

Remarkable differences were recorded among the various treatments with respect to yield per hectare in both the years of studies and pooled analysis (Table 4.1.6). For 2016-17, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the highest yield per hectare (32.86 t ha^{-1}), while, control (T_{13}) recorded the least (9.67 t ha^{-1}). Similar trend was also recorded during the year, 2017- 18, the highest (34.96 t ha^{-1}) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T9), and the lowest (10.84 t ha^{-1}) was recorded in control (T_{13}). In pooled analysis, the maximum yield per hectare (33.91 tonnes) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) which was significantly higher than all other treatments, while, the least (10.25 t ha^{-1}) was observed in control.

Table 4.1.4 Effect of organic manures and bio-dynamic preparations on bunch length, breadth and bunch size

Treatments	Bunch length (cm)			Bunch breadth (cm)			Bunch size (cm^2)		
	2016-17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**
T_1	18.72	18.75	18.74	8.57	8.75	8.66	160.31	163.98	162.15
T_2	19.80	20.01	19.90	8.17	8.43	8.30	161.65	168.74	165.20
T_3	14.57	14.81	14.69	7.30	7.36	7.33	106.40	108.98	107.69
T_4	18.17	18.47	18.32	8.97	9.03	9.00	162.87	166.77	164.82
T_5	19.27	19.69	19.48	10.57	10.88	10.73	203.48	214.33	208.91
T_6	18.97	19.13	19.05	11.40	12.06	11.73	215.31	230.72	223.02
T_7	17.15	17.63	17.39	8.13	8.22	8.18	139.73	144.84	142.29
T_8	20.50	20.51	20.51	9.50	9.59	9.55	195.23	196.70	195.97
T_9	21.47	21.84	21.66	12.79	13.23	13.01	274.72	288.86	281.79
T_{10}	19.62	19.83	19.73	11.60	11.76	11.68	227.26	233.20	230.23
T_{11}	14.54	14.75	14.65	8.06	8.25	8.15	117.25	121.64	119.45
T_{12}	18.23	18.64	18.44	9.77	10.70	10.23	177.71	199.68	188.70
T_{13}	13.63	13.71	13.67	7.12	7.26	7.19	97.06	99.51	98.29
T_{14}	16.06	16.09	16.08	7.99	8.07	8.03	128.30	129.87	129.08
Sem ±)	0.46	0.2	0.36	0.25	0.18	0.24	5.93	3.96	5.5
CD (0.05)	1.34	0.58	0.74	0.74	0.52	0.49	17.24	11.52	11.32

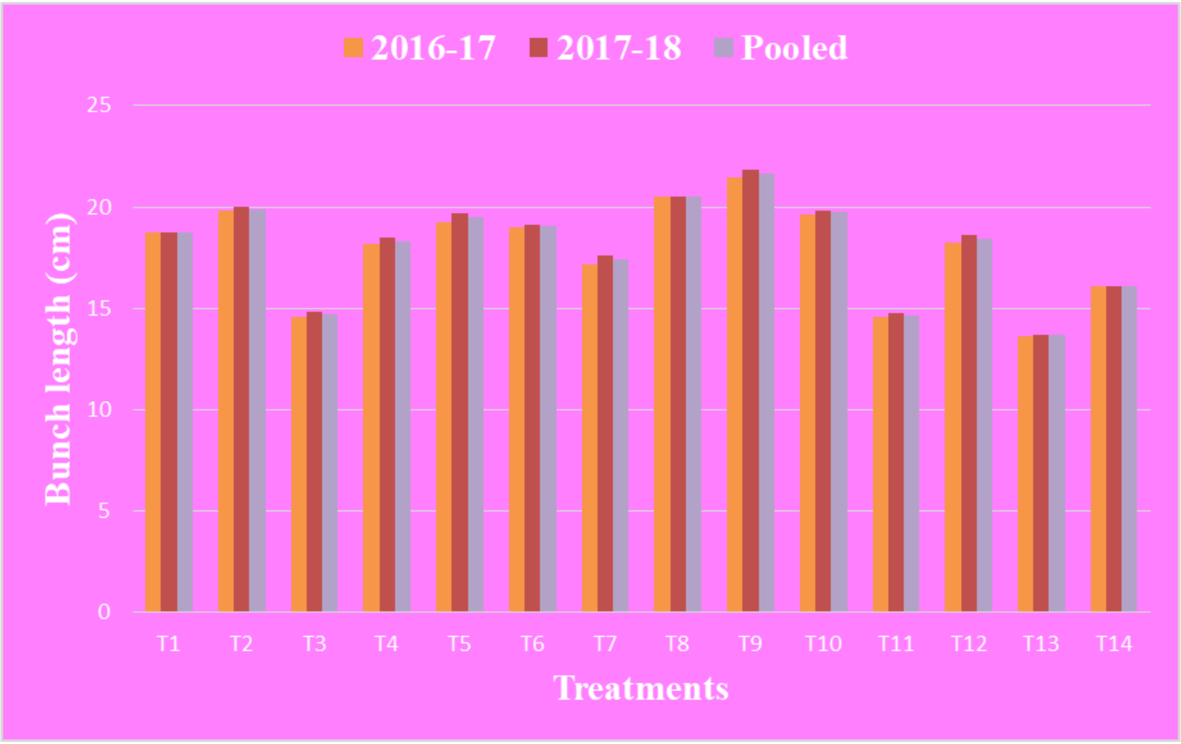

Fig. 4.1.4 Effect of organic manures and bio-dynamic preparations on Bunch length

Table 4.1.5 Effect of organic manures and bio-dynamic preparations on berry number per bunch, bunch number per vine and bunch compactness

Treatments	Berry number per bunch			Bunch number per vine			Bunch compactness (g cm^{-2})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	148.93	160.46	154.70	46.59	47.85	47.22	3.68	3.71	3.69
T_2	150.75	161.85	156.30	44.74	46.91	45.83	3.71	3.66	3.68
T_3	143.55	153.12	148.34	42.52	45.12	43.82	5.18	5.37	5.27
T_4	138.13	144.29	141.21	43.97	46.87	45.42	3.28	3.45	3.37
T_5	160.30	171.22	165.76	47.61	49.43	48.52	3.12	3.13	3.13
T_6	164.03	174.50	169.27	46.44	48.27	47.35	2.93	2.84	2.88
T_7	155.76	164.04	159.90	44.39	50.17	47.28	4.52	4.38	4.45
T_8	155.13	161.14	158.13	46.30	47.77	47.04	3.14	3.18	3.16
T_9	182.90	192.03	187.46	50.62	53.05	51.84	5.91	5.87	5.89
T_{10}	177.09	185.33	181.21	48.46	51.05	49.76	3.41	3.42	3.42
T_{11}	172.86	181.01	176.94	47.09	49.01	48.05	4.21	4.21	4.21
T_{12}	166.90	175.38	171.14	47.82	48.54	48.18	3.66	3.41	3.54
T_{13}	96.27	100.39	98.33	30.54	30.74	30.64	2.86	2.80	2.83
T_{14}	116.20	125.61	120.90	35.99	36.28	36.14	3.62	3.77	3.70
Sem ±)	3.37	3.5	2.33	0.47	1.26	0.66	0.20	0.11	0.12
CD (0.05)	6.94	7.21	4.8	0.97	2.59	1.36	0.41	0.23	0.25

Table 4.1.6 Effect of organic manures and bio-dynamic preparations on yield vine^{-1} & yield ha^{-1}

Treatments	Yield / vine (Kg)			Yield per ha (t ha^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	23.98	25.11	24.55	26.65	27.89	27.27
T_2	21.75	23.11	22.43	24.17	25.67	24.92
T_3	17.34	18.75	18.04	19.26	20.83	20.04
T_4	22.60	24.45	23.52	25.11	27.17	26.14
T_5	22.79	24.04	23.42	25.32	26.71	26.01
T_6	19.79	20.76	20.27	21.99	23.06	22.52
T_7	18.51	20.98	19.75	20.57	23.31	21.94
T_8	21.54	23.09	22.32	23.94	25.66	24.80
T_9	29.57	31.46	30.52	32.86	34.96	33.91
T_{10}	24.20	25.53	24.87	26.89	28.37	27.63
T_{11}	21.08	22.19	21.63	23.42	24.65	24.03
T_{12}	22.34	22.78	22.56	24.82	25.31	25.06
T_{13}	8.70	9.75	9.23	9.67	10.84	10.25
T_{14}	12.49	12.71	12.60	13.88	14.12	14.00
Sem ±)	1.08	0.78	0.79	1.20	0.86	0.87
CD (0.05)	2.22	1.6	1.62	2.47	1.78	1.80

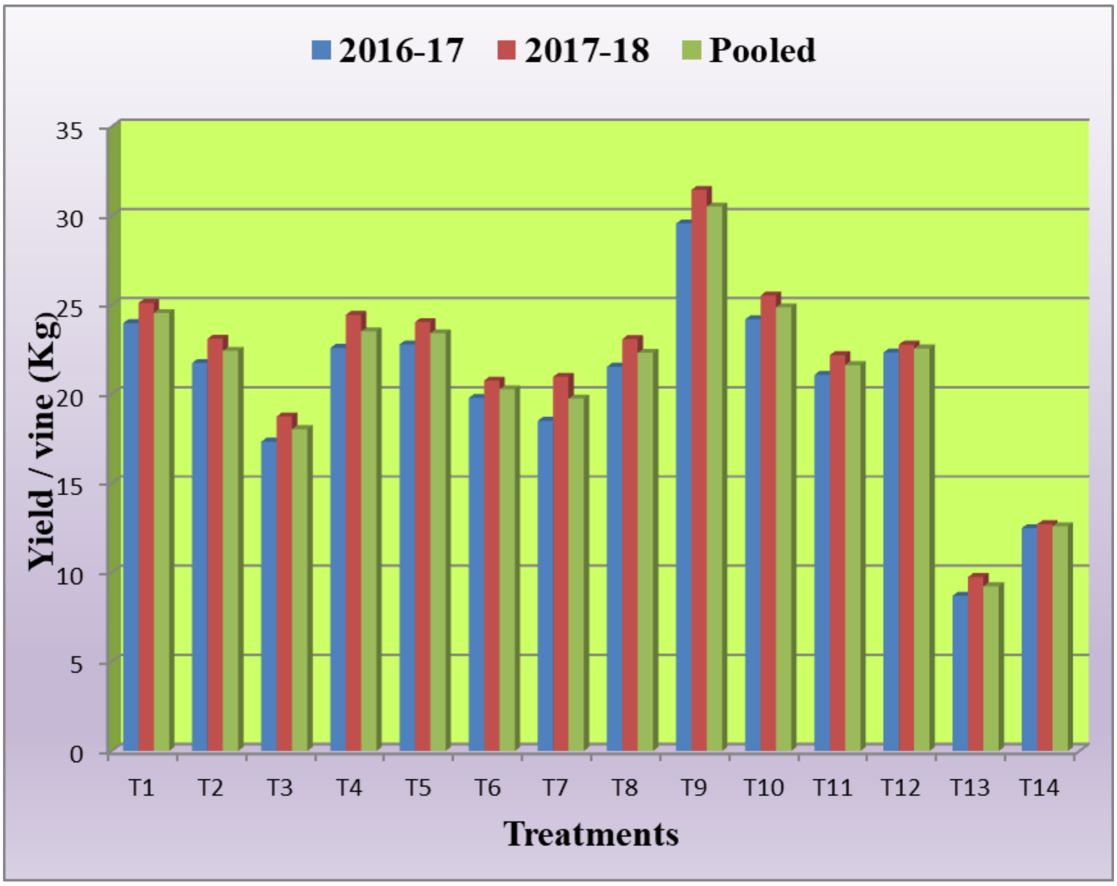

Fig. 4.1.5 Effect of organic manures and bio-dynamic preparations on Yield/ vine

4.1.3 Berry Physical parameters

4.1.3.1 Individual berry weight (g)

Individual berry weight differed significantly among the various organic and biodynamic preparations as shown in Table 4.1.7. The highest Individual berry weight (6.13 and 6.15 g) were recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) during 2016- 2017 and 2017- 2018, respectively. Pooled data of the treatments revealed that highest (6.14 g) individual berry weight was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) which was statistically higher than all other treatments, while, the least was recorded in control (T_{13}) (3.75 g).

4.1.3.2 Berry longitudinal diameter (cm)

Data with regards to berry longitudinal diameter are depicted in Table 4.1.7 which shows that it differs significantly among the treatments during the two years of investigation. Among all the treatments, the maximum berry longitudinal diameter (2.57 cm) was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}) during 2016-2017. The same treatment recorded the highest berry longitudinal diameter (2.85 cm) during 2017-2018 also. The minimum berry longitudinal diameters for both years were recorded in control (T_{13}) (1.85 and 1.97 cm respectively). Pooled data of the two years revealed that the maximum berry longitudinal diameter (2.71 cm) was observed in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}). It was followed by FYM +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP +

BD 500 + BD 501 (T_9) (2.38 cm). Among all the treatments, the least berry longitudinal diameter (1.91) was observed in T_{13} (control).

4.1.3.3 Berry transversal diameter (cm)

The given data on berry transversal diameter of berries influenced by various organic manures and bio-dynamic preparation are shown in Table 4.1.7. The perusal of the data depicted that noticeable variations were recorded on all the treatments with respect to the given parameters. During 2016-2017, the transversal diameter of the berries differed between 1.63 and 2.06 cm, while, during 2017-2018, it was between 1.70 and 2.50 cm. Pooled data for the two years revealed that VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}) showed the maximum berry transversal diameter (2.28 cm), followed by PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8) (2.06 cm) whereas, control revealed the least berry transversal diameter (1.67 cm).

4.1.3.4 Berry volume (cc)

The perusal of data presented in Table 4.1.7 clearly shows that different treatment had significant impact on berry volume during the two years of experimentation. For the year 2016- 2017, the maximum berry volume was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}) (14.99 cc), while, in 2017-2018 also the same treatment recorded the maximum value (15.08 cc), whereas, the minimum (12.65 and 12.86 cc) was recorded in control (T_{13}) in both the years. Pooled data of the two years revealed that maximum berry volume (15.03 cc) was observed in VC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}), followed by FYM

+*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) (14.85 cc), whereas the minimum was observed in control (T_{13}) (12.75 cc).

Table 4.1.7 Effect of organic manures and bio-dynamic preparations on individual berry weight, longitudinal diameter, transversal diameter and berry volume

Treatments	Individual berry weight (g)			Berry longitudinal diameter (cm)			Berry transversal diameter (cm)			Berry volume (cc)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	4.95	5.06	5.00	2.18	2.35	2.26	1.92	2.07	1.99	14.03	14.37	14.20
T_2	4.38	4.48	4.43	2.18	2.23	2.20	1.85	1.94	1.90	14.08	14.20	14.14
T_3	4.05	4.08	4.07	2.03	2.06	2.04	1.68	1.70	1.69	13.54	13.58	13.56
T_4	4.76	4.82	4.79	2.10	2.24	2.17	1.86	1.91	1.89	13.41	13.53	13.47
T_5	4.45	4.80	4.63	2.29	2.45	2.37	2.01	2.06	2.04	14.83	14.87	14.85
T_6	5.03	5.17	5.10	2.21	2.37	2.29	1.92	2.16	2.04	14.21	14.45	14.33
T_7	4.68	4.71	4.70	2.03	2.14	2.08	1.69	1.86	1.77	13.21	14.21	13.71
T_8	4.84	5.02	4.93	2.24	2.47	2.35	1.95	2.17	2.06	14.41	14.61	14.51
T_9	6.13	6.15	6.14	2.15	2.62	2.38	1.89	2.09	1.99	13.50	14.54	14.02
T_{10}	5.06	5.13	5.09	2.57	2.85	2.71	2.06	2.50	2.28	14.99	15.08	15.03
T_{11}	4.88	5.06	4.97	2.03	2.27	2.15	1.84	1.94	1.89	13.23	13.45	13.34
T_{12}	5.36	5.41	5.39	2.10	2.41	2.25	1.87	2.10	1.99	13.27	14.73	14.00
T_{13}	3.74	3.77	3.75	1.85	1.97	1.91	1.63	1.70	1.67	12.65	12.86	12.75
T_{14}	3.82	3.85	3.83	1.92	2.07	1.99	1.68	1.84	1.76	12.83	13.09	12.96
Sem ±)	0.20	0.09	0.15	0.06	0.06	0.07	0.05	0.08	0.06	0.14	0.16	0.11
CD (0.05)	0.57	0.25	0.31	0.19	0.18	0.14	0.15	0.22	0.14	0.42	0.46	0.23

4.1.3.5 Hundred berry weights (g)

Significant variations were observed among the treatments with respect to hundred berry weights (Table 4.1.8) during the two years of investigations. The data depicted in the Table shows that for the year 2016-2017, the highest hundred berry weights (606.71 g) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), whereas lowest was recorded in control (T_{13}) (368.39 g). In 2017-2018 also, the same treatment recorded the highest hundred berry weights (609.36 g), whereas the lowest was recorded in control (T_{13}) (369.41 g). Pooled data of the two years showed that the highest (608.03 g) hundred berry weights was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), whereas the least (368.90 g) was observed in control (T_{13}).

4.1.3.6 Skin thickness (mm)

It is apparent from the data presented in the Table 4.1.8 that various organic manures and biodynamic treatment had remarkable impact on skin thickness of grape berries. During 2016-2017, the maximum skin thickness (0.089 mm) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8) whereas the minimum was recorded in T_{13}(0.047 mm). Similarly, during 2017-2018, the same treatment recorded the maximum (0.093 mm) skin thickness, while the least (0.052 mm) was in T_{13} (control). Pooled analysis data of the revealed that the maximum skin thickness (0.091 mm) was obtained in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8), while, the least (0.050 mm) was obtained in control (T_{13}).

4.1.3.7 Pedicel thickness (mm)

There was a remarkable difference among the treatments with respect to pedicel thickness (Table 4.1.8). For the year 2016-2017, the maximum pedicel thickness was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8) (3.51 mm) and the minimum was in control (T_{13}) (2.73 mm). Likewise, for the year, 2017-2018 also, the same treatments revealed the maximum and minimum (4.13 mm and 2.98 mm respectively). The pooled data revealed that maximum pedicel thickness (3.82 mm) was obtained in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8) which was significantly higher than all other treatments except VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (3.62 mm) with which it was found statistically *at par* . The least pedicel thickness (2.86 mm) was observed in control (T_{13}).

4.1.3.8 Seed weight (g)

Perusal of the data presented in the Table 4.1.8 revealed that the seed weight was remarkably affected by various treatments. During 2016-2017, the maximum seed weight (0.081 g) was recorded in control (T_{13}) while least (0.061 g) was in PIM +*Azospirillum* + PSB + KSB (T_4). Similarly, in 2017-2018, control (T_{13}) revealed the maximum (0.081 g) value and PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) resulted the minimum (0.056 g) value. Pooled analysis depicted that control (T_{13}), recorded the maximum seed weight (0.081 g) followed by FYM +*Azospirillum*+ PSB + KSB + *Trichoderma harzianum* (T_5), (0.080 g), while the least (0.062 g) was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}).

Table 4.1.8 Effect of organic manures and bio-dynamic preparations on hundred berry weights, skin thickness, pedicel thickness & seed weight

Treatments	Hundred berry weights (g)			Skin thickness (mm)			Pedicel thickness (mm)			Seed weight (g)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	485.50	498.08	491.79	0.065	0.068	0.067	3.33	3.29	3.31	0.072	0.069	0.071
T_2	432.40	440.50	436.45	0.061	0.065	0.063	3.16	3.36	3.26	0.079	0.073	0.076
T_3	399.61	401.85	400.73	0.055	0.057	0.056	3.29	3.17	3.23	0.070	0.065	0.068
T_4	467.72	476.96	472.34	0.060	0.062	0.061	2.87	3.66	3.26	0.061	0.073	0.067
T_5	440.00	472.97	456.49	0.071	0.072	0.072	3.26	3.34	3.30	0.079	0.082	0.080
T_6	497.26	510.88	504.07	0.070	0.071	0.071	2.92	3.44	3.18	0.077	0.073	0.075
T_7	449.84	465.15	457.49	0.056	0.056	0.056	3.01	3.17	3.09	0.072	0.067	0.069
T_8	473.30	496.69	484.99	0.089	0.093	0.091	3.51	4.13	3.82	0.066	0.075	0.070
T_9	606.71	609.36	608.03	0.066	0.069	0.068	3.27	3.38	3.33	0.070	0.071	0.071
T_{10}	480.82	499.73	490.28	0.082	0.085	0.084	3.35	3.89	3.62	0.078	0.076	0.077
T_{11}	500.10	508.76	504.43	0.076	0.081	0.079	3.29	3.41	3.35	0.074	0.072	0.073
T_{12}	530.61	502.47	516.54	0.072	0.075	0.073	2.87	3.37	3.12	0.067	0.056	0.062
T_{13}	368.39	369.41	368.90	0.047	0.052	0.050	2.73	2.98	2.86	0.081	0.081	0.081
T_{14}	375.27	378.66	376.96	0.060	0.060	0.060	3.25	3.11	3.18	0.073	0.071	0.072
Sem ±)	28.86	15.57	16.94	0.002	0.001	0.001	0.18	0.08	0.13	0.010	0.000	0.003
CD (0.05)	59.33	32.02	34.83	0.004	0.003	0.003	0.54	0.23	0.27	0.020	0.010	0.007

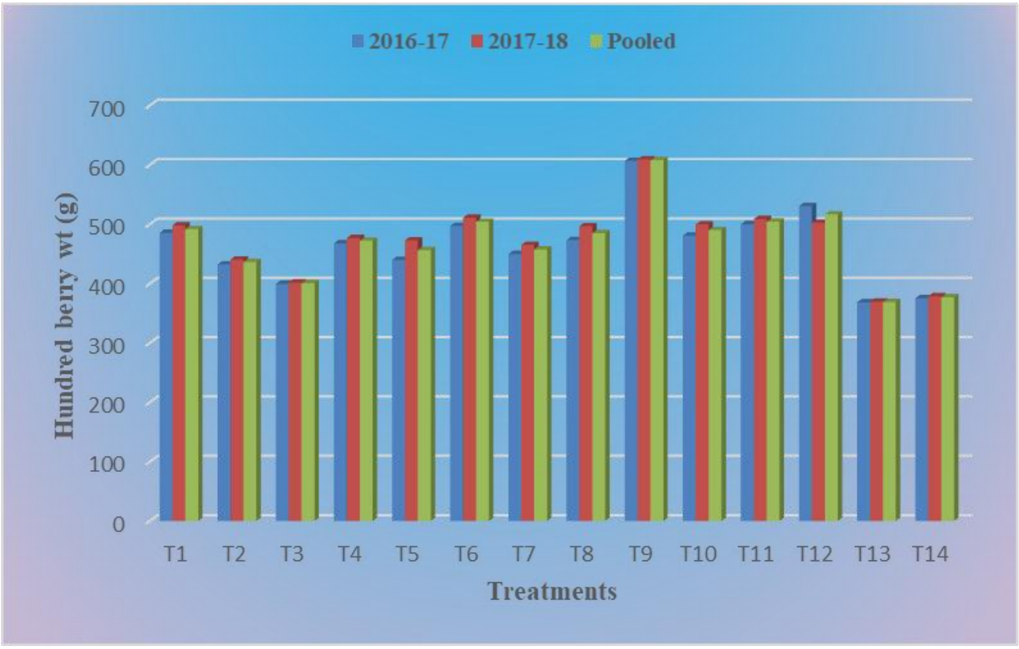

Fig. 4.1.6 Effect of organic manures and bio-dynamic preparations on hundred berry weight

4.1.3.9 Seed length (cm)

The data depicted in the Table 4.1.9 revealed that there were remarkable variations among the treatments with respect to seed length. For the year 2016-2017, the maximum seed length (0.767 cm) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) and the minimum (0.682 cm) was in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9). During 2017-2018, the maximum (0.769 cm) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) and minimum (0.688 cm) was recorded in control (T_{13}). The pooled data revealed that maximum seed length (0.7473 cm) was found in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), while the minimum (0.699 cm) was recorded in control (T_{13}).

4.1.3.10 Seed width (cm)

The treatments differed significantly with respect to seed width as presented in Table 4.1.9. During 2016-2017, the maximum seed width (0.486 cm) was recorded in NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}), while, in 2017-2018, it was maximum in NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_7) (0.492 cm), while, in both the years, the minimum was recorded in control (0.417 and 0.349 cm respectively). Pooled data revealed that the maximum seed width (0.485 cm) was obtained in NC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_7). It was followed by PIM +*Azospirillum* + PSB + KSB (T_4) (0.482 cm), whereas, the minimum seed width was obtained in control (0.383 cm).

4.1.3.11 Seed number

Noticeable variations were observed with regards to seed number among the treatments during the two years of experimentations and pooled analysis (Table 4.1.9). During 2016-17, and 2017-18, the maximum seed number (3.36 and 3.25) was recorded in control (T_{13}), while, the minimum (1.96 and 2.19) was recorded in FYM +*Azospirillum* + PSB + KSB (T_1) in both the years of study. The pooled analysis revealed that, the maximum seed number (3.31) was found in control (T_{13}) which was statistically *at par* with T_{14} and T_8 (3.29 and 3.12 respectively), while, the minimum (2.08) was recorded in T_1.

Table 4.1.9 Effect of organic manures and bio-dynamic preparations on seed length, width & number

Treatments	Seed length (cm)			Seed width (cm)			Seed number		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	0.728	0.766	0.747	0.471	0.477	0.474	1.96	2.19	2.08
T_2	0.700	0.752	0.726	0.451	0.486	0.469	2.48	2.46	2.47
T_3	0.749	0.744	0.747	0.462	0.480	0.471	2.18	2.31	2.24
T_4	0.723	0.734	0.728	0.480	0.484	0.482	2.38	2.25	2.32
T_5	0.767	0.728	0.747	0.473	0.487	0.480	2.38	2.98	2.68
T_6	0.763	0.694	0.728	0.452	0.461	0.457	2.40	3.06	2.73
T_7	0.726	0.747	0.737	0.478	0.492	0.485	2.81	2.82	2.82
T_8	0.705	0.752	0.729	0.475	0.479	0.477	3.23	3.01	3.12
T_9	0.682	0.769	0.726	0.458	0.446	0.452	2.56	2.75	2.65
T_{10}	0.717	0.737	0.727	0.453	0.476	0.465	2.27	2.59	2.43
T_{11}	0.712	0.726	0.719	0.486	0.464	0.475	2.11	2.51	2.31
T_{12}	0.729	0.752	0.741	0.461	0.479	0.470	2.68	2.84	2.76
T_{13}	0.710	0.688	0.699	0.417	0.349	0.383	3.36	3.25	3.31
T_{14}	0.704	0.716	0.710	0.422	0.430	0.426	3.25	3.33	3.29
Sem ±)	0.020	0.020	0.010	0.010	0.010	0.010	0.13	0.09	0.09
CD (0.05)	0.050	0.060	0.030	0.040	0.030	0.020	0.38	0.27	0.19

4.1.4 Quality parameters:

4.1.4.1 Moisture (%)

Significant variation was observed among the treatments with respect to moisture percentage of the fruits. It is evident from the data presented in Table 4.1.10 that during 2016-2017, among all the treatments, the minimum moisture (78.89 %) was recorded in NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}), while, in 2017-2018, the minimum was recorded in PIM +*Azospirillum* + PSB + KSB (T_4) (80.68 %). Among all the treatments, the maximum moisture was obtained in control (T_{13}) (82.33 and 83.11%) in both the years. Pooled analysis revealed that the minimum moisture (79.80%) was recorded in PIM +*Azospirillum* + PSB + KSB (T_4), followed by NC + *Azospirillum* + PSB + KSB (T_3) (80.28 %), while, the maximum (82.72 %) was recorded in T_{13} (control).

4.1.4.2 Juice (%)

Perusal of the data presented in Table 4.1.10 revealed that there were remarkable variations among the treatments with respect to juice content of the fruits. For the year 2016-2017, the juice content ranged between 60.10 and 68.90 per cent, while, during 2017-2018, it was between 61.02 and 69.42 per cent. Pooled analysis of the two years revealed that VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) showed the maximum juice content (69.16 %), followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (65.04 %) whereas, FYM +*Azospirillum* + PSB + KSB (T_1) revealed the minimum juice content (60.56 %) among all the treatments.

4.1.4.3 Total soluble solids (TSS) (°B)

The data presented in Table 4.1.10 evidenced that different treatments had significant impact on TSS of the fruits in the two years of experimentation. For the year 2016- 2017, the maximum TSS was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD (T_{10}) (20.53 °B), while, in 2017-2018 also the same treatment recorded the maximum value (21.57 °B). The minimum TSS (15.02 and 15.58 °B) was obtained in control (T_{13}) during both the years. Pooled analysis of the two years revealed that maximum TSS (21.05 °B) was obtained in VC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD (T_{10}) followed by (20.61 °B), FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) while the minimum was in control (T_{13}) (15.30 °B).

4.1.4.4 Titratable acidity (%)

It is clear from the data depicted in Table 4.1.10 that the acidity of the berries varied remarkably with various organic manures and bio-dynamic treatments in the two years of investigations. For the year 2016-2017 and 2017-2018, the minimum titratable acidity (0.63 and 0.66 %) was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD (T_{10}) while the maximum was recorded in control (T_{13}) (0.87 and 0.88%). Pooled data of both the years showed that the minimum (0.64 %) acidity was obtained in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD (T_{10}), while the maximum (0.87 %) was in control (T_{13}).

4.1.4.5 TSS: Acid ratio

Marked variations were recorded among the treatments with respect TSS: acid ratio (Table 4.1.10). Among all the treatments, during 2016- 2017 and 2017-2018, the maximum TSS: Acid was recorded with VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD (T_{10}) (32.80 and 32.92) respectively. Pooled data of the two years showed the maximum TSS: Acid content (32.86) was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD (T_{10}) which was significantly higher than other treatments, followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (30.33), while the minimum (17.53) was recorded in control (T_{13}).

4.1.4.6 Reducing sugar (%)

Various organic manures and biodynamic treatments had remarkable impacts on reducing sugar in Bangalore blue grapes as depicted in the Table 4.1.11. For the year 2016-2017, the maximum reducing sugars (12.56 %) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) whereas the minimum (10.12 %) was obtained in T_{13}. Likewise, during 2017-2018, the same treatments showed the maximum and minimum value (13.85 and 10.18 % respectively). Pooled analysis of data for the two years showed that maximum reducing sugars (13.20 %) was obtained in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) which was significantly higher than all other treatments, while the least (10.15 %) was obtained in control (T_{13}).

4.1.4.7 Total sugars (%)

Significant variations were observed with respect to total sugars of the berries during both the years of experimentation. The data presented in Table 4.1.11 revealed that during 2016-2017 and 2017-18, the maximum total sugars (13.93 % and 15.39 %) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), whereas the minimum (11.29 and 11.37 %) was in control (T_{13}). Pooled analysis of data for the two years evidenced that the maximum total sugars (14.66 %) was found in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) which was significantly higher than all other treatments. It was followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) (14.06 %), while the minimum (11.33 %) was obtained in control (T_{13}).

4.1.4.8 Non- reducing sugar (%)

Data presented in Table 4.1.11 evidenced that various organics and bio-dynamic treatments differed remarkably with respect to non-reducing sugars during the two years of investigations. Among the different treatments, VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recorded the maximum non-reducing sugars (1.74 and 1.85 %) for the year 2016-2017 and 2017-2018 respectively. Pooled analysis of data for the two years revealed that the maximum non- reducing sugars (1.80 %) was found in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) which was significantly higher than all other treatments, while the minimum (1.41 %) was obtained in control (T_{13}).

4.1.4.9 Sugar-acid ratio

Significant variation was observed among the treatments with respect to sugar: acid ratio of the fruits. During 2016-17, the maximum sugar: acid ratio (22.26) was observed in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). During 2017-2018, also, the same treatment recorded the maximum value (23.48). Among all the treatments, control (T_{13}) recorded the minimum sugar-acid ratio (12.98 and 13.00) for both the years. Pooled analysis of data revealed that the maximum sugar: acid ratio (22.88) was observed in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) which was significantly higher than all other treatments. While, the minimum was recoded in control (12.99 %).

Table 4.1.10 Effect of organic manures and bio-dynamic preparations on moisture, Juice, TSS, titratable acidity & TSS: acid ratio

Treatments	Moisture (%)			Juice (%)			Total soluble solids (TSS) (°B)			Titratable acidity (%)			TSS: Acid ratio		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	81.83	81.97	81.90	60.10	61.02	60.56	17.24	18.91	18.07	0.78	0.82	0.80	22.07	23.17	22.62
T_2	80.90	81.02	80.96	62.23	62.37	62.30	17.88	19.08	18.48	0.82	0.83	0.83	21.73	23.04	22.39
T_3	79.12	81.43	80.28	60.63	61.40	61.02	16.80	17.94	17.37	0.85	0.83	0.84	19.75	21.74	20.75
T_4	78.92	80.68	79.80	63.71	64.08	63.89	16.32	17.65	16.99	0.84	0.82	0.83	19.52	21.56	20.54
T_5	81.02	81.71	81.36	62.74	63.74	63.24	18.93	20.02	19.48	0.68	0.71	0.69	28.02	28.30	28.16
T_6	81.68	82.80	82.24	61.02	62.90	61.96	18.80	19.88	19.34	0.72	0.73	0.73	26.13	27.19	26.66
T_7	81.84	82.05	81.95	65.56	60.53	63.04	18.68	19.47	19.08	0.72	0.75	0.74	25.88	25.84	25.86
T_8	80.83	81.16	80.99	63.44	63.64	63.54	18.08	19.18	18.63	0.73	0.75	0.74	24.79	25.60	25.19
T_9	80.58	82.29	81.44	64.90	65.18	65.04	19.85	21.36	20.61	0.66	0.70	0.68	30.26	30.41	30.33
T_{10}	80.75	81.49	81.12	68.90	69.42	69.16	20.53	21.57	21.05	0.63	0.66	0.64	32.80	32.92	32.86
T_{11}	78.89	82.00	80.45	61.47	63.15	62.31	19.54	20.84	20.19	0.72	0.72	0.72	27.14	28.86	28.00
T_{12}	79.56	81.41	80.49	64.18	63.46	63.82	19.23	20.44	19.84	0.76	0.71	0.73	25.65	28.74	27.20
T_{13}	82.33	83.11	82.72	61.33	61.45	61.39	15.02	15.58	15.30	0.87	0.88	0.87	17.27	17.80	17.53
T_{14}	80.91	82.37	81.64	63.37	63.17	63.27	15.22	16.34	15.78	0.86	0.86	0.86	17.63	19.11	18.37
Sem ±	0.52	0.51	0.40	1.19	0.99	1.01	0.19	0.20	0.10	0.02	0.01	0.01	0.91	0.51	0.51
$CD_{0.05}$	1.52	1.48	0.83	3.47	2.87	2.09	0.39	0.42	0.21	0.06	0.03	0.03	1.88	1.05	1.05

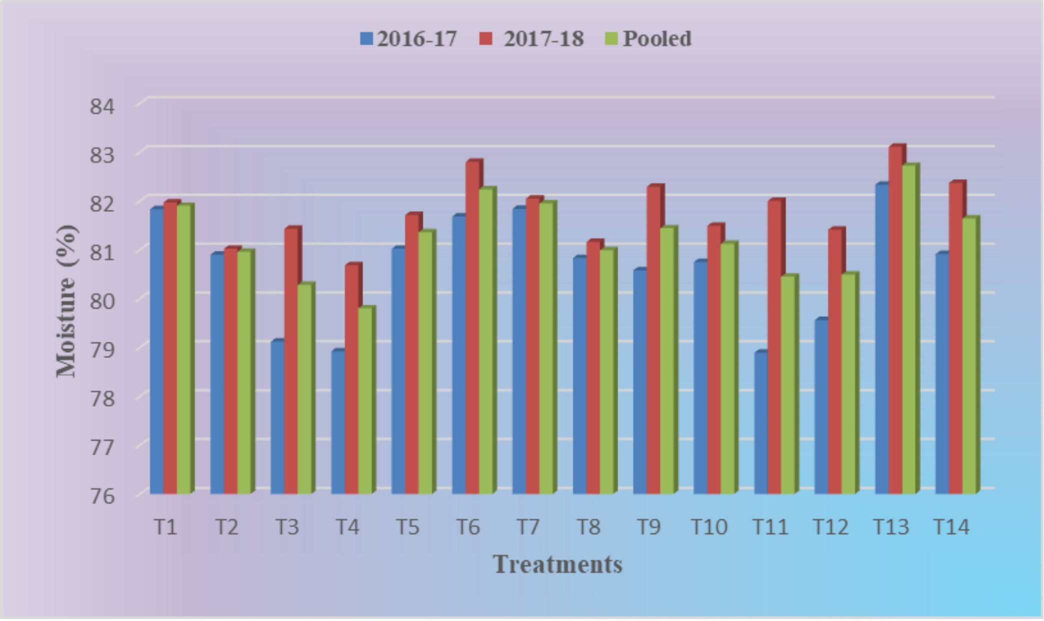

Fig. 4.1.7 Effect of organic manures and bio-dynamic preparations on moisture per cent

4.1.4.10 Ascorbic acid (mg $100g^{-1}$)

Marked variations were recorded among the treatments with respect to ascorbic acid (Table 4.1.12). Among all the treatments, during 2016- 2017 and 2017-2018, the maximum ascorbic content was recorded with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (25.13 and 25.20 mg $100g^{-1}$) respectively. Pooled data of the two years showed the maximum ascorbic acid content (25.17 mg $100g^{-1}$) was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) which was significantly higher than other treatments, followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (23.98 mg $100g^{-1}$), while, the minimum (20.76 mg $100g^{-1}$) was recorded in control (T_{13}).

Table 4.1.11 Effect of organic manures and bio-dynamic preparations on reducing sugar, total sugars, non- reducing sugar & sugar-acid ratio

Treatments	Reducing sugar (%)			Total sugars (%)			Non- reducing sugar (%)			Sugar-acid ratio		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	10.73	10.81	10.77	12.04	12.21	12.13	1.56	1.65	1.60	15.42	14.97	15.18
T_2	10.81	10.90	10.86	12.13	12.30	12.21	1.56	1.65	1.61	14.75	14.85	14.80
T_3	10.96	11.08	11.02	12.26	12.42	12.34	1.55	1.59	1.57	14.41	15.05	14.72
T_4	11.09	11.27	11.18	12.37	12.58	12.48	1.54	1.56	1.55	14.80	15.37	15.08
T_5	11.47	12.38	11.93	12.81	13.87	13.34	1.59	1.78	1.69	18.95	19.61	19.26
T_6	11.20	12.24	11.72	12.53	13.73	13.13	1.58	1.77	1.68	17.43	18.79	18.09
T_7	11.18	12.05	11.61	12.57	13.49	13.03	1.65	1.72	1.69	17.41	17.92	17.67
T_8	11.34	12.57	11.95	12.74	13.99	13.36	1.66	1.71	1.68	17.47	18.67	18.05
T_9	12.05	13.21	12.63	13.40	14.73	14.06	1.70	1.82	1.76	20.45	20.97	20.69
T_{10}	12.56	13.85	13.20	13.93	15.39	14.66	1.74	1.85	1.80	22.26	23.48	22.88
T_{11}	11.30	12.66	11.98	12.67	14.13	13.40	1.66	1.76	1.71	17.60	19.57	18.57
T_{12}	11.15	12.41	11.78	12.49	13.85	13.17	1.66	1.72	1.69	16.65	19.48	17.96
T_{13}	10.12	10.18	10.15	11.29	11.37	11.33	1.40	1.42	1.41	12.98	13.00	12.99
T_{14}	10.30	10.38	10.34	11.52	11.61	11.56	1.45	1.47	1.46	13.34	13.58	13.45
Sem ±)	0.13	0.17	0.11	0.13	0.17	0.1	0.01	0.01	0.01	0.63	0.43	0.34
CD (0.05)	0.28	0.36	0.22	0.27	0.35	0.21	0.03	0.03	0.02	1.29	0.89	0.70

4.1.4.11 Anthocyanin (mg g^{-1})

There were noticeable variations among the treatments with respect to anthocyanin content of the berries during the two years of investigations. The data presented in the Table 4.1.12 revealed that in 2016-2017, anthocyanin varied between 2.18 and 4.04 mg g^{-1}, while, it was between 2.20 and 3.96 mg g^{-1} in 2017-2018. The pooled analysis of the two years revealed that among all the treatments, VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) showed the maximum anthocyanin content (4.00 mg g^{-1}), which was significantly higher than all other treatments. The minimum anthocyanin (2.19 mg g^{-1}) was found in control (T_{13}).

4.1.4.12 Total carotenoids (µg g^{-1})

The total carotenoids content of the berries are depicted in Table 4.1.12. The data presented in the Table revealed that total carotenoids content of the berries differs significantly among the treatments. For the year 2016-2017, the maximum total carotenoids (10.76 µg g^{-1}) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). In 2017- 2018 also, the same treatment revealed the maximum value (10.77 µg g^{-1}). The pooled analysis revealed that the maximum total carotenoids content (10.76 µg/g) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) which was significantly higher than all other treatments, whereas, the least (6.92 µg g^{-1}) was recorded in control (T_{13}).

4.1.4.13 Raisin recovery (%)

The treatments differed significantly with respect to raisin recovery from the berries during the two years of investigation as shown in Table 4.1.12. During 2016-

2017, the maximum raisin recovery (25.78 %) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) which was significantly higher than all other treatments, while, in 2017-2018, the same treatment also recorded the maximum recovery (25.55 %). Pooled analysis of data declared the maximum raisin recovery (25.66 %) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), followed by in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (23.95 %), whereas the minimum (20.72 %) was found in control (T_{13}).

Table 4.1.12 Effect of organic manures and bio-dynamic preparations on ascorbic acid, anthocyanin, total carotenoids & raisin recovery

Treatments	Ascorbic acid (mg 100g^{-1})			Anthocyanin (mg g^{-1})			Total carotenoids (µg g^{-1})			Raisin recovery (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	22.47	23.07	22.77	3.13	3.37	3.25	8.19	8.28	8.24	23.28	23.62	23.45
T_2	22.09	21.94	22.02	3.18	3.34	3.26	7.81	7.95	7.88	22.80	23.40	23.10
T_3	21.48	20.92	21.20	2.85	3.01	2.93	7.77	7.73	7.75	21.76	22.51	22.14
T_4	22.05	21.78	21.91	3.11	3.13	3.12	8.19	8.28	8.23	22.89	22.82	22.85
T_5	23.69	23.68	23.69	3.47	3.47	3.47	9.29	8.87	9.08	25.78	25.55	25.66
T_6	23.24	22.45	22.85	3.16	3.38	3.27	8.71	8.72	8.71	23.73	23.97	23.85
T_7	22.04	20.94	21.49	2.86	3.04	2.95	7.94	8.36	8.15	22.81	22.50	22.66
T_8	23.30	21.72	22.51	3.25	3.14	3.19	8.22	8.29	8.26	22.99	22.79	22.89
T_9	23.91	24.05	23.98	3.59	3.48	3.54	10.76	10.77	10.76	23.44	24.33	23.89
T_{10}	25.13	25.20	25.17	4.04	3.96	4.00	9.47	9.65	9.56	23.96	23.93	23.95
T_{11}	23.15	21.66	22.41	2.68	3.17	2.93	7.99	9.52	8.75	22.87	23.79	23.33
T_{12}	23.63	23.23	23.43	3.13	3.29	3.21	8.14	8.55	8.34	23.35	23.56	23.46
T_{13}	20.74	20.78	20.76	2.18	2.20	2.19	6.70	7.14	6.92	20.44	21.01	20.72
T_{14}	21.97	21.77	21.87	2.43	2.49	2.46	6.98	7.39	7.19	21.18	21.49	21.34
Sem ±)	0.36	0.29	0.34	0.12	0.09	0.1	0.24	0.25	0.26	0.37	0.37	0.39
CD (0.05)	1.05	0.84	0.71	0.34	0.28	0.21	0.71	0.74	0.54	1.08	1.06	0.81

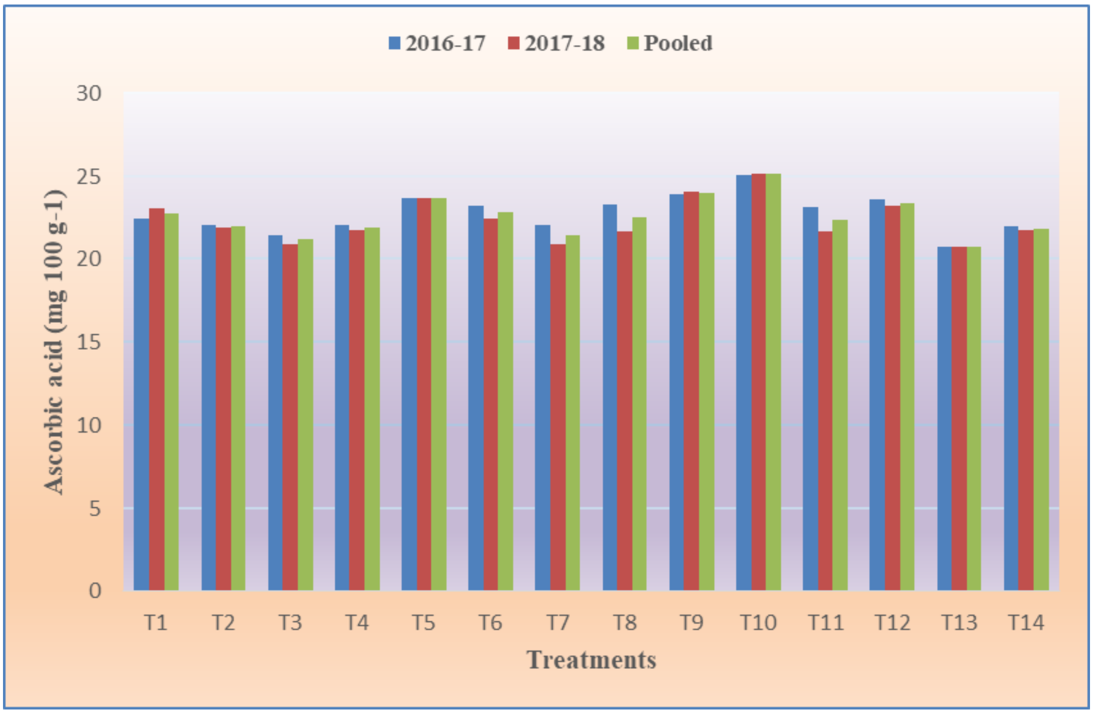

Fig. 4.1.8 Effect of organic manures and bio-dynamic preparations on Ascorbic Acid

4.1.4.14 Protein (mg g^{-1})

The data presented in the Table 4.1.13 shows that protein content of the berries varied significantly with respect to different organic manures and biodynamic treatments. For 2016-2017, the protein content of the berries ranged from 4.80 to 7.07 mg g^{-1}, while, during 2017-2018, it ranged between 5.17 to 7.24 mg g^{-1}. Pooled analysis of data revealed that the maximum protein (7.15 mg g^{-1}) was obtained with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while the minimum (5.00 mg g^{-1}) was in T_{13} (control).

4.1.4.15 Starch (mg g^{-1})

Starch content of the berries was significantly influenced by various treatments during the two years of experimentation (Table 4.1.13). For 2016-17, the maximum starch content was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (4.06 mg g^{-1}). Similarly, during 2017-18, VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recorded the maximum value (4.19 mg g^{-1}). The minimum starch content was recorded with control (T_{13}) for both the years. Pooled data of the treatments showed the maximum starch content (4.13 mg g^{-1}) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while the lowest was in control (T_{13}) (2.51 mg g^{-1})

4.1.4.16 Carbohydrate (mg g^{-1})

It is clearly evidenced from the data presented in Table 4.1.13, that the carbohydrate content of the berries varied remarkably among the various organic manures and biodynamic treatments. During 2016-2017, the carbohydrate content of the berries varied between 53.92 and 80.47 mg g^{-1}, while it was 57.06 to 82.30 mg g^{-1}

in 2017-2018. Pooled analysis of data revealed the maximum carbohydrate of the berries (81.39 mg g^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), however, the minimum (55.49 mg g^{-1}) was recorded in T_{13} (control).

4.1.4.17 Total phenols (mg g^{-1})

Various organic manures and bio-dynamic treatments had significant impact on total phenols content of the berries during the two years of investigations. In 2016-2017, the maximum total phenols (0.88 mg g^{-1}) was recorded with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). In 2017-2018 also, the same treatment recorded the maximum total phenols (0.88 mg g^{-1}), whereas it was minimum in control (T_{13}) (0.60 and 0.65 mg g^{-1}) during both the years respectively. Pooled analysis of data revealed that the maximum total phenols (0.88 mg g^{-1}) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) which was significantly higher than all other treatments. However, the minimum (0.62 mg g^{-1}) was recorded in control (T_{13}).

Table 4.1.13 Effect of organic manures and bio-dynamic preparations on protein, starch, carbohydrate & total phenols

Treatments	Protein (mg g^{-1})			Starch (mg g^{-1})			Carbohydrate (mg g^{-1})			Total phenols (mg g^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	5.60	5.73	5.67	3.43	3.60	3.51	60.54	69.02	64.78	0.71	0.73	0.72
T_2	5.10	5.37	5.23	3.43	3.58	3.51	60.41	69.52	64.96	0.71	0.74	0.73
T_3	4.80	5.43	5.12	3.32	3.50	3.41	59.26	68.91	64.08	0.69	0.76	0.72
T_4	5.77	5.80	5.78	3.24	3.40	3.32	59.64	67.81	63.72	0.70	0.77	0.73
T_5	6.22	6.33	6.28	3.63	3.72	3.68	70.31	70.58	70.45	0.73	0.84	0.79
T_6	6.03	6.10	6.07	3.62	3.71	3.67	67.87	72.18	70.03	0.74	0.86	0.80
T_7	5.73	5.93	5.83	3.56	3.67	3.62	65.25	70.49	67.87	0.75	0.85	0.80
T_8	5.90	6.08	5.99	3.44	3.61	3.53	62.36	73.78	68.07	0.75	0.83	0.79
T_9	6.03	6.30	6.17	3.95	4.02	3.98	73.44	74.80	74.12	0.79	0.85	0.82
T_{10}	7.07	7.24	7.15	4.06	4.19	4.13	78.99	79.48	79.24	0.88	0.88	0.88
T_{11}	5.50	5.73	5.62	3.83	3.96	3.89	76.60	76.85	76.72	0.74	0.75	0.75
T_{12}	5.63	6.10	5.87	3.67	3.83	3.75	80.47	82.30	81.39	0.70	0.72	0.71
T_{13}	4.83	5.17	5.00	2.27	2.74	2.51	53.92	57.06	55.49	0.60	0.65	0.62
T_{14}	5.17	5.57	5.37	2.75	2.95	2.85	58.87	61.90	60.39	0.64	0.67	0.66
Sem ±)	0.26	0.31	0.2	0.07	0.08	0.06	1.09	1.15	0.83	0.01	0.01	0.01
CD (0.05)	0.54	0.65	0.43	0.14	0.16	0.13	2.24	2.38	1.71	0.04	0.03	0.02

4.1.5 Plant leaf analysis

4.1.5. 1 Leaf Nitrogen (%)

Nitrogen status of the leaves was significantly impacted with different treatments (Table 4.1.14). In 2016-2017, the maximum leaf total nitrogen content (3.87 %) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the minimum (3.06 %) was in control (T_{13}). Similarly, during 2017-2018, the same treatments also recorded the maximum and minimum value (3.78 and 3.12 %). Pooled analysis of the data showed the maximum leaf nitrogen (3.82 %) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) which was significantly higher than all other treatments. It was followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (3.54 %), while, the minimum (3.09 %) was recorded in control.

4.1.5.2 Leaf phosphorus (%)

It is revealed from the data presented in Table 4.1.14 that phosphorus content of the leaves differed remarkably among all the various treatments. In 2016-2017, the maximum phosphorus content (0.269 %) of the leaves was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). For the year 2017- 2018, the same treatment recorded the maximum value (0.273 %). Pooled data analysis revealed that the maximum leaf phosphorus (0.271 %) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) which was significantly higher than all other treatments, while the minimum (0.219 %) was in control (T_{13}).

4.1.5.3 Leaf Potassium (%)

Remarkable difference was observed among the treatments with respect to leaf potassium content during the two years of investigations. The data presented in the Table 4.1.14 revealed that in 2016-2017, leaf K varied from 1.18 and 1.71 % and it was between 1.24 and 1.71 % for the year 2017-2018. The pooled analysis of data for the two years shows that VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recorded the maximum leaf K content (1.71 %) which was significantly higher than all other treatments, while, the minimum was recorded in control (T_{13}) (1.21 %).

4.1.5. 4 Leaf dry matter (g)

Dry matter of leaf differed remarkably among the various treatments in the two years of experimentation as shown in Table 4.1.14. During 2016-2017, the maximum leaf dry matter (0.171 g) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) which was significantly higher than rest of the treatments, while, in 2017-2018 also, the same treatment revealed the maximum value (0.170 g). Pooled data for the two years showed the maximum leaf dry matter (0.171 g) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9), followed by in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (0.168 g), while, control (T_{13}) recorded the minimum value (0.107 g).

4.1.5.6 Carbohydrate (%)

Table 4.1.15 showed that the carbohydrate content of the leaves varied remarkably with different organic manures and biodynamic treatments. For the year 2016-2017, the carbohydrate content of the leaves ranged between 13.21 and 13.62

per cent, while, it was 13.25 to 13.66 per cent in 2017-2018. Pooled analysis of the data for both the years revealed that the maximum carbohydrate (13.64 %) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), while, the minimum (13.23 %) was T_{13} (control).

4.1.5. 7 C: N ratio of leaf

Leaf C: N ratio was significantly differed with various treatments during the two years of experimentation (Table 4.1.15). During 2016-17, minimum C: N ratio of leaf was obtained in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (4.67). Similar results were also found in 2017-18, with minimum C: N ratio of 4.89. The maximum C: N ratio was found in control (T_{13}) during the two years. Pooled analysis data showed the minimum C:N ratio of 4.78 was found in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) (4.93). While, the maximum (6.17) was in control (T_{13}).

Table 4.1.14 Effect of organic manures and bio-dynamic preparations on leaf nitrogen, phosphorus, potassium & dry matter

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)			Leaf dry matter (g)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	3.28	3.36	3.32	0.260	0.259	0.259	1.49	1.54	1.52	0.141	0.158	0.150
T_2	3.23	3.31	3.27	0.255	0.254	0.254	1.47	1.50	1.48	0.137	0.149	0.143
T_3	3.17	3.15	3.16	0.239	0.238	0.239	1.39	1.38	1.39	0.150	0.135	0.143
T_4	3.30	3.27	3.29	0.259	0.254	0.256	1.49	1.49	1.49	0.148	0.146	0.147
T_5	3.45	3.44	3.44	0.260	0.258	0.259	1.47	1.57	1.52	0.165	0.151	0.158
T_6	3.33	3.29	3.31	0.254	0.252	0.253	1.49	1.48	1.48	0.159	0.153	0.156
T_7	3.21	3.25	3.23	0.243	0.244	0.244	1.40	1.37	1.39	0.146	0.145	0.146
T_8	3.39	3.38	3.39	0.259	0.255	0.257	1.38	1.41	1.39	0.149	0.152	0.150
T_9	3.52	3.55	3.54	0.269	0.273	0.271	1.59	1.61	1.60	0.171	0.170	0.171
T_{10}	3.87	3.78	3.82	0.258	0.263	0.260	1.71	1.71	1.71	0.170	0.166	0.168
T_{11}	3.22	3.34	3.28	0.250	0.248	0.249	1.42	1.50	1.46	0.161	0.151	0.156
T_{12}	3.38	3.49	3.44	0.255	0.255	0.255	1.54	1.52	1.53	0.152	0.152	0.152
T_{13}	3.06	3.12	3.09	0.219	0.219	0.219	1.18	1.24	1.21	0.107	0.106	0.107
T_{14}	3.16	3.19	3.18	0.234	0.228	0.231	1.24	1.35	1.29	0.122	0.117	0.120
Sem ±)	0.04	0.03	0.02	0.004	0.004	0.003	0.03	0.02	0.02	0.010	0.010	0.005
CD (0.05)	0.08	0.09	0.06	0.009	0.009	0.006	0.10	0.06	0.05	0.020	0.020	0.011

4.1.5.8 Leaf chlorophyll

4.1.5.8.1 Chlorophyll a (mg g^{-1})

Significant differences was observed among the organic and bio-dynamic preparations on chlorophyll a of the grape leaves in both years of investigations as depicted in Table 4.1.16. During 2016-2017, the highest chlorophyll a (1.523 mg g^{-1}) was found in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) and lowest (1.243 mg g^{-1}) in control (T_{13}). During 2017-2018, also, the highest and lowest chlorophyll a (1.537 and 1.263 mg g^{-1}) was recorded in the same treatments. Pooled analysis of data clearly revealed that PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the highest chlorophyll a (1.530 mg g^{-1}) but it was statistically *at par* with FYM +*Azospirillum* + PSB + KSB (T_1) (1.528 mg g^{-1}). The least leaf chlorophyll a content was recorded in T_{13} (control) (1.253 mg g^{-1}).

4.1.5.8.2 Chlorophyll b (mg g^{-1})

Application of organic manures and bio-dynamic preparations influenced remarkably the chlorophyll b content of the leaves during the two years of experimentation (Table 4.1.16). During 2016-2017, the chlorophyll b content of leaf ranged from 0.24 to 0.56 mg g^{-1} and in 2017-2018, it was between 0.26 to 0.57 mg g^{-1}. The pooled data revealed that PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the maximum chlorophyll b (0.56 mg g^{-1}), while, control (T_{13}) recorded the minimum value (0.25 mg g^{-1}).

4.1.5.8.3 Total chlorophyll (mg g^{-1})

Perusal of the data presented in Table 4.1.16 revealed that marked differences was recorded with respect to total chlorophyll content during the two years of experimentation. During 2016-2017 and 2017-2018, the maximum total chlorophyll (2.08 and 2.11 mg g^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while, the minimum was recorded in T_{13} (control) (1.49 and 1.52 mg/g). Pooled analysis of data showed that the maximum total chlorophyll content (2.09 mg g^{-1}) was found in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while, the minimum 1.50 (mg/g) was obtained in T_{13} (control).

4.1.5.9 Micronutrient content of leaves

4.1.5.9.1 Iron (ppm)

Various organic manures and bio-dynamic treatments had marked impact on Fe content of leaves during the two years of investigations (Table 4.1.17). In 2016-2017, the maximum Fe content (272.93 ppm) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the minimum was in T_{12} (PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501) (238.79). For the year 2017-2018, VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), recorded the maximum (271.44 ppm), and PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the minimum (243.86 ppm). Pooled analysis of data revealed that maximum Fe (272.18 ppm) was found in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), which was *at par* with control (T_{13}) (269.40 ppm) and FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (261.00 ppm). However, the minimum Fe content (241.33 ppm) was found in T_{12} (PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501).

4.1.5.9.2 Mn (ppm)

Table 4.1.17 displays the data regarding the leaf Mn content. In 2016- 2017, the maximum Mn (26.29 ppm) was recorded with PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), whereas the minimum (22.95 ppm) was in control (T_{13}). In 2017-2018, the same treatments recorded the maximum and minimum Mn content (26.90 ppm and 23.36 ppm respectively). Pooled analysis of the data revealed that, the maximum Mn of the leaf (26.60 ppm) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) which was significantly higher than all other treatments, while, the minimum was in T_{13} (control) (23.15 ppm).

4.1.5.9.3 Cu (ppm)

Leaf copper content was remarkably influenced by various treatments during the two years of experimentations (Table 4.1.17). The presented data showed that the Cu content of leaf ranged from 7.41 to 8.93 ppm in 2016-2017 and 7.92 to 9.25 ppm in 2017-2018. Pooled data revealed that the maximum Cu content (9.09 ppm) was found in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), which was significantly higher than all other treatments, except, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) (8.74 ppm), with which it was found statistically *at par*, while, the minimum (7.72 ppm) was recorded in control (T_{13}).

4.1.5.9.4 Zn (ppm)

Data regarding Zn content of the leaves revealed that various organic manures and bio-dynamic treatments (Table 4.1.17) had significant effect on Zn content of leaves. In 2016-2017, the Zn content of the leaves varied from 21.28 and 26.68 ppm, while, it was between 22.60 to 28.16 ppm in 2017-2018. The pooled data showed that the maximum Zn content (27.42 ppm) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma* *harzianum* + CPP + BD 500 + BD 501(T_{12}), while the minimum (21.94 ppm) was recorded in control (T_{13}).

Table 4.1.15 Effect of organic manures and biodynamic preparations on carbohydrate & C: N ratio of leaf

Treatments	Carbohydrate (%)			C: N ratio of leaf		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	13.60	13.57	13.59	4.96	5.05	5.00
T_2	13.50	13.48	13.49	5.23	5.46	5.35
T_3	13.44	13.41	13.42	5.74	5.77	5.75
T_4	13.50	13.49	13.50	5.26	5.46	5.36
T_5	13.54	13.56	13.55	4.89	4.98	4.93
T_6	13.51	13.53	13.52	5.32	5.21	5.26
T_7	13.36	13.43	13.40	5.61	5.62	5.61
T_8	13.45	13.52	13.48	5.28	5.28	5.28
T_9	13.47	13.50	13.49	4.67	4.89	4.78
T_{10}	13.55	13.58	13.57	5.33	5.34	5.34
T_{11}	13.37	13.47	13.42	5.65	5.82	5.74
T_{12}	13.62	13.66	13.64	5.51	5.41	5.46
T_{13}	13.21	13.25	13.23	6.23	6.10	6.17
T_{14}	13.32	13.37	13.35	5.80	5.84	5.82
Sem ±)	0.03	0.04	0.03	0.09	0.06	0.07
CD (0.05)	0.08	0.12	0.07	0.26	0.17	0.15

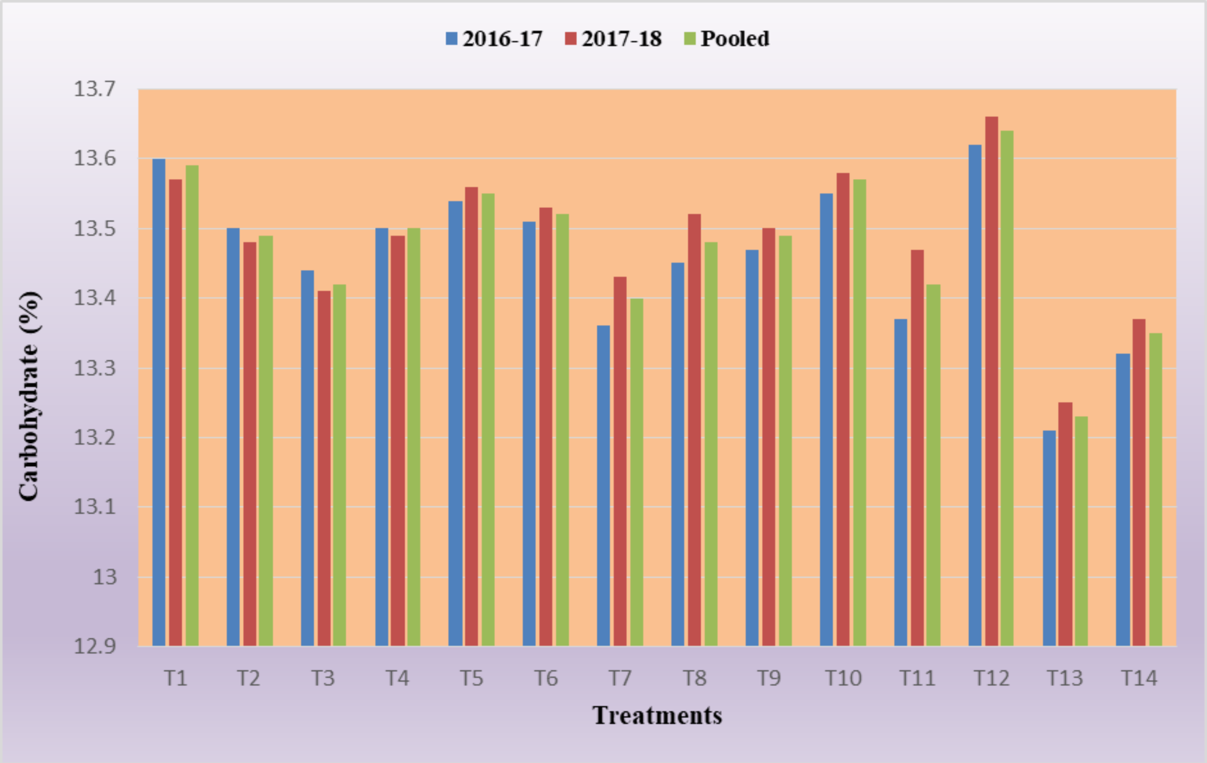

Fig. 4.1.9 Effect of organic manures and bio-dynamic preparations on leaf carbohydrates (%)

Table 4.1.16 Effect of organic manures and bio-dynamic preparations on chlorophyll a, chlorophyll b & total chlorophyll

Treatments	Chlorophyll a (mg g^{-1})			Chlorophyll b (mg g^{-1})			Total chlorophyll (mg g^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	1.520	1.537	1.528	0.49	0.52	0.50	2.01	2.06	2.03
T_2	1.473	1.480	1.477	0.42	0.45	0.44	1.89	1.93	1.91
T_3	1.377	1.393	1.385	0.35	0.36	0.36	1.73	1.75	1.74
T_4	1.483	1.497	1.490	0.42	0.44	0.43	1.91	1.94	1.92
T_5	1.507	1.530	1.518	0.51	0.53	0.52	2.02	2.06	2.04
T_6	1.473	1.510	1.492	0.42	0.45	0.44	1.90	1.96	1.93
T_7	1.390	1.403	1.397	0.36	0.39	0.38	1.75	1.80	1.77
T_8	1.447	1.467	1.457	0.41	0.44	0.43	1.86	1.90	1.88
T_9	1.430	1.503	1.467	0.44	0.47	0.45	1.87	1.97	1.92
T_{10}	1.493	1.500	1.497	0.42	0.49	0.45	1.91	1.99	1.95
T_{11}	1.403	1.443	1.423	0.32	0.34	0.33	1.73	1.79	1.76
T_{12}	1.523	1.537	1.530	0.56	0.57	0.56	2.08	2.11	2.09
T_{13}	1.243	1.263	1.253	0.24	0.26	0.25	1.49	1.52	1.50
T_{14}	1.327	1.353	1.340	0.34	0.35	0.35	1.67	1.70	1.69
Sem ±)	0.020	0.020	0.010	0.02	0.03	0.02	0.03	0.03	0.02
CD (0.05)	0.050	0.050	0.030	0.06	0.08	0.05	0.09	0.09	0.05

Table 4.1.17 Effect of organic manures and bio-dynamic preparations on iron, manganese, copper & zinc

Treatments	Iron (ppm)			Manganese (ppm)			Copper (ppm)			Zinc (ppm)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	248.19	265.76	256.98	24.07	25.27	24.67	8.35	8.84	8.59	24.59	25.32	24.96
T_2	247.32	259.61	253.47	23.61	25.24	24.42	8.01	8.37	8.19	23.75	25.15	24.45
T_3	252.44	252.95	252.69	23.03	23.83	23.43	7.44	8.11	7.78	22.04	24.04	23.04
T_4	239.98	253.39	246.69	24.45	25.16	24.80	8.47	8.70	8.58	23.72	24.80	24.26
T_5	247.58	256.76	252.17	23.68	25.22	24.45	8.57	8.90	8.74	23.67	25.99	24.83
T_6	250.45	245.94	248.20	24.37	25.49	24.93	8.42	8.75	8.59	22.96	25.14	24.05
T_7	254.67	248.66	251.66	22.96	24.75	23.86	8.23	8.60	8.42	22.30	23.62	22.96
T_8	255.42	257.48	256.45	24.34	25.14	24.74	8.07	8.71	8.39	23.25	25.11	24.18
T_9	260.55	261.44	261.00	24.31	25.53	24.92	7.83	8.30	8.06	23.60	25.23	24.41
T_{10}	272.93	271.44	272.18	24.06	24.41	24.23	8.93	9.25	9.09	24.55	26.48	25.51
T_{11}	248.14	252.53	250.34	23.22	25.24	24.23	7.89	8.18	8.03	22.41	24.42	23.42
T_{12}	238.79	243.86	241.33	26.29	26.90	26.60	8.23	8.47	8.35	26.68	28.16	27.42
T_{13}	272.78	265.86	269.40	22.95	23.36	23.15	7.41	8.03	7.72	21.28	22.60	21.94
T_{14}	265.56	243.95	254.75	23.30	23.97	23.64	7.68	7.92	7.80	21.92	23.14	22.53
Sem ±)	5.24	4.72	5.06	0.52	0.43	0.51	0.27	0.24	0.22	0.44	0.38	0.37
CD (0.05)	15.24	13.72	10.4	1.51	1.25	1.06	0.79	0.69	0.46	1.28	1.11	0.77

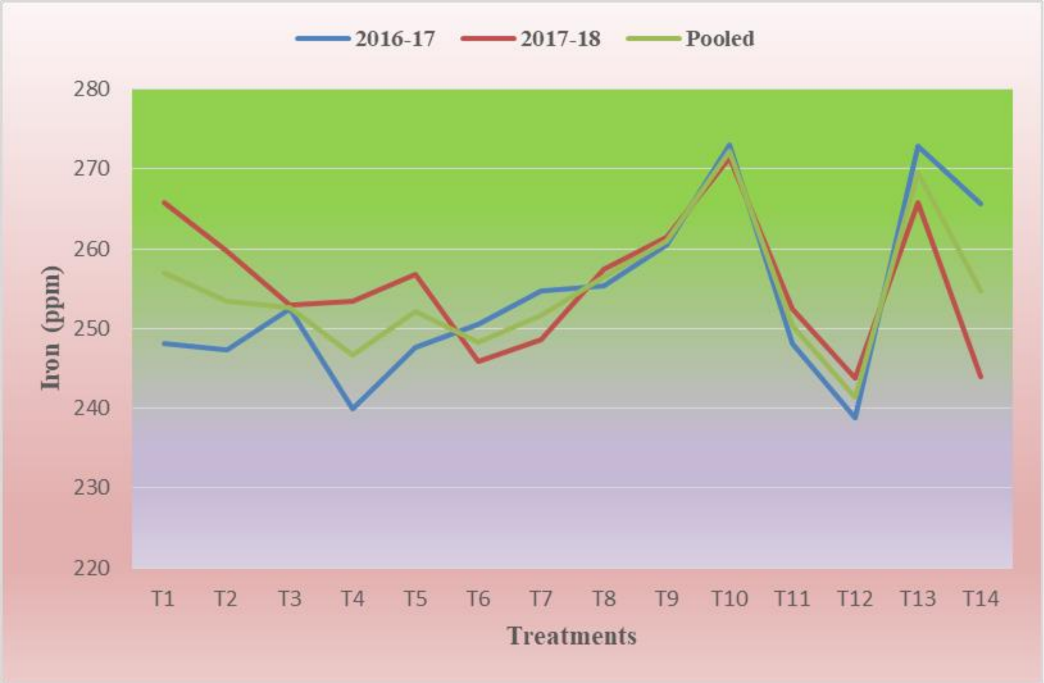

Fig. 4.1.10 Effect of organic manures and bio-dynamic preparations on leaf iron content

4.1.6 Soil Analysis

4.1.6.1 Soil health parameters

4.1.6.1.1. Soil pH

From the data presented in Table 4.1.18, it is revealed that the soil pH differed remarkably among the organic manures and bio-dynamic preparations in the two years of investigations. During 2016-17, the maximum soil pH (4.91) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_9) followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (4.85). Similarly, for the year 2017-2018, the maximum and minimum soil pH (4.91 and 4.84) was recorded in the same treatments. Pooled analysis of the data revealed that the significantly highest (4.92) soil pH was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_9). It was followed by T_{10} (4.84). However, the minimum (4.08) was obtained in control (T_{13}).

4.1.6.1.2 Soil moisture (%)

Noticeable differences were observed among the treatments with regards to soil moisture content as presented in Table 4.1.18. In the year 2016-2017, the maximum soil moisture (34.04 %) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9), whereas the minimum (24.19 %) was in control (T_{13}). Likewise, in 2017-2018, the same treatments recorded the maximum and minimum soil moisture (34.74 and 24.76 %). Pooled analysis of data for both the years revealed that FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) recorded the maximum soil moisture (34.39%). It was followed by T_{10} (33.09 %). However, the minimum was found in T_{13} (24.47 %).

4.1.6.1.3 Soil organic carbon (g kg^{-1})

Perusal of the data presented in the Table 4.1.18 revealed that various organic manures and bio-dynamic preparations had remarkable impact on soil organic carbon during the two years of experimentation. In the year 2016-2017, soil organic carbon ranged from 6.05 to 7.40 g kg^{-1} while in 2017-2018, it was between 6.08 and 7.44 g kg^{-1}. Pooled data revealed that soil organic carbon content was found maximum (7.42 g kg^{-1}) in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), which was significantly higher than all other treatments. However, the minimum (6.07 g kg^{-1}) was recorded in control (T_{13}).

4.1.6.1.4 Total inorganic carbon (g kg^{-1})

The data presented in Table 4.1.18 depicted that various organic manure and bio-dynamic treatments impacted a marked influence on total inorganic carbon of the soil during the two years of experimentations. Among all the treatments, during 2016- 2017 and 2017-2018, the maximum total inorganic carbon (2.08 and 2.37 g kg-1) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), whereas, the minimum (1.46 and 1.85 g kg^{-1}) was recorded in control (T_{13}). Pooled analysis of data revealed that maximum total inorganic carbon (2.23g kg^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), which was significantly higher than all other treatments. However, the minimum (1.65 g kg^{-1}) was obtained in control (T_{13}).

4.1.6.1.5 Total carbon (g kg^{-1})

Noticeable differences were seen among the different treatments in the two years as well as in pooled data with regards to total carbon of the soils as depicted in Table 4.1.19. In the year 2016-2017, the maximum total carbon (9.48 g kg^{-1}) was found in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), whereas, the minimum (7.51 g kg^{-1}) was in T_{13} (control). In 2017-2018, also the same treatments (T_{10} and T_{13}) recorded the maximum and minimum total carbon (9.81 and 7.93 g kg^{-1}). Pooled analysis revealed that the maximum total carbon (9.65 g kg^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}). However, the minimum (7.72 g kg^{-1}) was recorded in control (T_{13}).

Table 4.1.18 Effect of organic manures and bio-dynamic preparations on Soil pH, moisture, organic carbon & total inorganic carbon

Treatments	Soil pH			Soil moisture (%)			Soil organic carbon (g kg^{-1})			Total inorganic carbon (g kg^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	4.68	4.76	4.72	31.46	31.89	31.67	6.71	6.78	6.74	1.86	2.03	1.94
T_2	4.55	4.67	4.61	30.50	31.06	30.78	6.61	6.69	6.65	1.79	2.00	1.90
T_3	4.24	4.28	4.26	25.19	25.42	25.30	6.18	6.22	6.20	1.52	1.89	1.71
T_4	4.41	4.60	4.51	28.89	29.91	29.40	6.36	6.50	6.43	1.66	2.00	1.83
T_5	4.57	4.65	4.61	32.34	32.66	32.50	6.89	6.91	6.90	1.91	2.30	2.10
T_6	4.67	4.76	4.71	31.39	31.91	31.65	6.77	6.82	6.80	1.85	2.23	2.04
T_7	4.21	4.30	4.26	25.58	26.07	25.82	6.19	6.23	6.21	1.53	1.82	1.67
T_8	4.45	4.63	4.54	31.17	31.42	31.29	6.58	6.64	6.61	1.83	2.14	1.99
T_9	4.91	4.91	4.92	34.04	34.74	34.39	6.17	6.22	6.19	1.49	1.89	1.69
T_{10}	4.85	4.84	4.84	32.87	33.32	33.09	6.82	6.89	6.86	1.92	2.26	2.09
T_{11}	4.35	4.36	4.36	26.32	26.68	26.50	7.14	7.21	7.18	2.04	2.33	2.19
T_{12}	4.79	4.71	4.76	29.05	29.73	29.39	7.40	7.44	7.42	2.08	2.37	2.23
T_{13}	4.05	4.12	4.08	24.19	24.76	24.47	6.05	6.08	6.07	1.46	1.85	1.65
T_{14}	4.15	4.26	4.20	24.49	24.95	24.72	6.13	6.17	6.15	1.53	1.87	1.70
Sem ±)	0.05	0.05	0.04	0.63	0.38	0.46	0.03	0.04	0.03	0.01	0.03	0.01
CD (0.05)	0.11	0.11	0.09	1.29	0.78	0.94	0.07	0.08	0.06	0.04	0.06	0.03

4.1.6.1.6 Total Nitrogen (g kg^{-1})

From the data presented in Table 4.1.19, it is clearly evidenced that the treatments differed remarkably with regards to total nitrogen content of the soil. For the year 2015-16, among all the treatments, PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), recorded the maximum total nitrogen content of the soil (0.667 g kg^{-1}), while, control (T_{13}) recorded the minimum (0.503 g kg^{-1}). Similarly, during the year, 2017-18, the same treatments (T_{10} and T_{13}) recorded the maximum and minimum total nitrogen content of soil (0.711 and 0.523 g kg^{-1}). Pooled data of analysis revealed that the maximum total nitrogen (0.689g kg^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}). However, the minimum (0.513 g kg^{-1}) was recorded in control (T_{13}).

4.1.6.1.7 C: N ratio

Perusal of the data presented in the Table 4.1.19revealed that various organic manures and bio-dynamic treatments significantly influenced the C: N ratio of the soil. During, 2016-2017, 2017-2018, and pooled analysis, the maximum soil C: N ratio (14.95, 15.24 and 15.10) were recorded in farmer's practice (T_{14}), while, the minimum was in recorded in Neem cake (NC) + *Azospirillum* + PSB + KSB (T_3), PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8) and VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* (T_6) (13.63, 13.31 and 13.44) respectively for 2016-2017, 2017-2018 and Pooled analysis respectively.

4.1.6.1.8 Cation Exchange Capacity (CEC) (meq 100g^{-1})

Significant variations were observed among the treatments with regards to CEC of the soils as presented in Table 4.1.19. For the year 2016-2017 and 2017-

2018, the maximum CEC (19.08 and 19.89 meq 100g^{-1}) was recorded in (PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501) T_{12}, while the minimum was recorded in control (16.13 and 16.27 meq 100g^{-1}) (T_{13}). Pooled analysis of data showed that the maximum CEC (19.49 meq 100g^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) which was significantly higher than all other treatments. It was followed by T_{10} (18.76 meq 100g^{-1}). However, the minimum (16.20 meq 100g^{-1}) was recorded in control (T_{13}).

Table 4.1.19 Effect of organic manures and bio-dynamic preparations on total carbon, total nitrogen, C: N ratio & cation exchange capacity (CEC)

Treatments	Total carbon (g kg^{-1})			Total Nitrogen (g kg^{-1})			C: N ratio			Cation Exchange Capacity (CEC) (meq 100g^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	8.57	8.81	8.69	0.617	0.640	0.629	13.89	13.76	13.82	16.79	18.42	17.61
T_2	8.40	8.69	8.54	0.598	0.619	0.609	14.04	14.03	14.03	16.69	17.67	17.18
T_3	7.70	8.11	7.91	0.565	0.587	0.576	13.63	13.82	13.72	16.25	16.40	16.33
T_4	8.02	8.50	8.26	0.584	0.613	0.599	13.73	13.87	13.79	16.57	18.04	17.31
T_5	8.80	9.21	9.00	0.650	0.687	0.668	13.54	13.41	13.48	17.37	18.51	17.94
T_6	8.62	9.05	8.84	0.639	0.676	0.658	13.48	13.39	13.44	16.78	18.21	17.49
T_7	7.72	8.05	7.88	0.543	0.566	0.555	14.21	14.23	14.22	16.22	16.45	16.34
T_8	8.41	8.78	8.59	0.630	0.660	0.645	13.35	13.31	13.33	16.74	17.82	17.28
T_9	8.74	9.15	8.95	0.625	0.670	0.648	13.98	13.66	13.81	17.24	18.32	17.78
T_{10}	9.18	9.55	9.37	0.652	0.700	0.676	14.08	13.64	13.86	18.17	19.34	18.76
T_{11}	7.66	8.10	7.88	0.551	0.577	0.564	13.89	14.04	13.97	16.28	16.70	16.49
T_{12}	9.48	9.81	9.65	0.667	0.711	0.689	13.98	13.80	14.01	19.08	19.89	19.49
T_{13}	7.51	7.93	7.72	0.503	0.523	0.513	14.93	15.16	15.04	16.13	16.27	16.20
T_{14}	7.66	8.04	7.85	0.512	0.527	0.520	14.95	15.24	15.10	16.22	16.37	16.30
Sem ±)	0.04	0.05	0.04	0.006	0.008	0.005	0.14	0.20	0.12	0.06	0.25	0.13
CD (0.05)	0.08	0.11	0.08	0.011	0.017	0.010	0.29	0.41	0.26	0.13	0.52	0.28

4.1.6.1.9 Available Nitrogen (kg ha^{-1})

Data presented in Table 4.1.20 revealed that various organic manures and bio-dynamic treatments exerted a significant impact on the available N in the soil for the two years of investigations. Among the various treatments, the average available nitrogen varied from 449.61 to 862.43 kg ha-^{1} during 2016-2017 and 470.33 to 875.30 kg ha^{-1} in 2017-2018. Pooled data of both the years exhibited that, the maximum available N (868.86 kg ha^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), which was significantly higher than all other treatments. It was followed by VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (821.89 kg ha^{-1}). However, the minimum (459.97 kg ha^{-1}) was recorded in control (T_{13}).

4.1.6.1.10 Available Phosphorus (kg ha^{-1})

The data with regards of available P are depicted in Table 4.1.20. It is revealed from the data presented in the Table that various organic manures and bio-dynamic preparations significantly impact the available P content on soil. During 2016-2017, among all the treatments, the maximum available P (155.85 kg ha^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) whereas, the minimum (120.54 kg ha^{-1}) was in control (T_{13}). During the year 2017-2018, similar trend was observed as that of first year, maximum (163.76 kg ha^{-1}) was in T_{10} and the minimum (126.74 kg ha^{-1}) in control (T_{13}). Pooled analysis of data revealed that PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) observed the maximum available soil P (159.81 kg ha-1) which was significantly higher than all other treatments, it was followed by T_9 (156.12 kg ha^{-1}). However, the minimum (123.64 kg ha^{-1}) was recorded in control (T_{13}).

4.1.6.1.11 Available Potassium (kg ha^{-1})

Significant variations were observed among the treatments with respect to available soil K as depicted in Table 4.1.21. During 2016-2017 and 2017-2018, the maximum potassium content (624.32 and 664.69 kg ha^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) and the minimum (417.58 and 435.81 kg ha^{-1}) was recorded in control (T_{13}). Pooled analysis of the data revealed that the maximum K content (644.50 kg ha^{-1}) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (549.01 kg ha^{-1}), whereas the minimum (426.69 kg ha^{-1}) was recorded in control (T_{13}).

4.1.6.1.12 Soil micronutrients

4.1.6.1.12.1 Iron (ppm)

Among the different treatments, the maximum Fe content (77.88 ppm and 79.13) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) and VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) during 2016-2017 and 2017-2018 respectively, while, the minimum (53.84 and 54.70 ppm) was recorded in control (T_{13}) during the two years of investigations (Table 4.1.21). The pooled analysis of data revealed that maximum Fe content was found in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (74.60 ppm) while, the minimum (54.27 ppm) was recorded in control (T_{13}).

4.1.6.1.12.2 Manganese (ppm)

Perusal of the data presented in the Table 4.1.21, it is evidenced that the organic and bio-dynamic preparations had large impact on Mn content of the soil. During 2016-2017, the maximum Mn content of the soil (29.69 ppm) was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{10}), while, the minimum was in control (T_{13}) (24.19 ppm). For the year 2017-2018, PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) recorded the maximum (31.08 ppm) andcontrol (T_{13}) recorded the minimum Mn content (24.84 ppm) of soil. Pooled data showed that Mn content in soil was maximum (29.93 ppm) in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), but it was *at par* with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). However, among all the treatments, the minimum Mn content was recorded in control (T_{13}) (24.51 ppm).

4.1.6.1.12.3 Copper (ppm)

During 2016-2017 and 2017-2018, the maximum Cu content was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) (2.597 and 2.733 ppm) while the minimum was in control (2.113 and 2.193 ppm) (Table 4.1.21). Pooled analysis of the data revealed that maximum Cu content (2.665 ppm) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) which was significantly higher than all other treatments. However, the minimum Cu content (2.153 ppm) was observed in control (T_{13}).

4.1.6.1.12.4 Zinc (ppm)

It is evident from the data presented in Table 4.1.21 that various organic manures and bio-dynamic treatments largely impact soil Zn content. During the year, 2016-2017, among all the treatments, the maximum Zn content (2.20 ppm) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), and the minimum (1.603 ppm) was recorded in control (T_{13}). Likewise, for 2017-2018 also, the same two treatments recorded the maximum (2.417 ppm) and minimum value (1.627 ppm) with respect to Zn content of the soil. The pooled analysis revealed that, the maximum Zn content (2.308 ppm) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), which was higher than all other treatments. However, minimum (1.615 ppm) was observed in control (T_{13}).

Table 4.1.20 Effect of organic manures and bio-dynamic preparations on available nitrogen, phosphorus & potassium

Treatments	Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg ha^{-1})			Available Potassium (kg ha^{-1})		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	772.91	786.92	779.91	139.18	142.12	140.65	454.87	496.84	475.86
T_2	660.27	675.05	667.66	130.42	135.55	132.99	445.92	484.58	465.25
T_3	633.97	648.34	641.16	124.68	128.07	126.37	422.39	440.53	431.46
T_4	713.58	727.75	720.67	140.30	144.14	142.22	432.20	469.69	450.94
T_5	761.31	783.43	772.37	143.02	149.39	146.21	491.23	547.46	519.35
T_6	750.23	765.67	757.95	139.88	142.58	141.23	450.17	512.93	481.55
T_7	630.43	643.51	636.97	133.49	137.23	135.36	428.98	451.56	440.27
T_8	697.07	710.56	703.81	141.79	146.96	144.37	439.96	492.35	466.16
T_9	742.77	757.76	750.27	148.73	155.70	152.22	454.44	557.95	506.20
T_{10}	817.56	826.22	821.89	150.79	161.45	156.12	493.24	604.78	549.01
T_{11}	687.47	707.09	697.28	141.34	146.35	143.85	421.95	463.26	442.61
T_{12}	862.43	875.30	868.86	155.85	163.76	159.81	624.32	664.69	644.50
T_{13}	449.61	470.33	459.97	120.54	126.74	123.64	417.58	435.81	426.69
T_{14}	517.71	534.68	526.20	132.61	139.31	135.96	423.87	457.09	440.48
Sem ±)	8.79	9.16	8.11	1.70	2.20	1.56	5.51	13.57	6.05
CD (0.05)	18.09	18.83	16.69	3.51	4.52	3.22	11.34	27.90	12.44

Table 4.1.21 Effect of organic manures and bio-dynamic preparations on Iron, Manganese, Copper & Zinc of soil

Treatments	Iron (ppm)			Manganese (ppm)			Copper (ppm)			Zinc (ppm)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	65.64	65.82	65.73	26.41	27.13	26.77	2.423	2.500	2.462	1.817	2.083	1.950
T_2	61.81	62.72	62.27	25.94	26.57	26.26	2.397	2.427	2.412	1.780	1.957	1.868
T_3	57.42	57.97	57.70	25.17	25.61	25.39	2.147	2.187	2.167	1.620	1.637	1.628
T_4	59.76	60.07	59.92	25.74	26.41	26.08	2.367	2.400	2.383	1.753	1.870	1.812
T_5	68.05	69.22	68.64	27.84	28.55	28.19	2.597	2.733	2.665	1.970	2.223	2.097
T_6	66.36	68.01	67.18	27.02	27.94	27.48	2.567	2.580	2.573	1.867	2.173	2.020
T_7	56.61	57.16	56.88	25.08	25.08	25.08	2.207	2.220	2.213	1.620	1.667	1.643
T_8	65.67	66.31	65.99	26.93	27.62	27.28	2.453	2.520	2.487	1.773	2.127	1.950
T_9	77.88	70.26	74.07	28.38	28.94	28.66	2.463	2.490	2.477	2.003	2.277	2.140
T_{10}	70.08	79.13	74.60	29.69	29.16	29.43	2.520	2.575	2.548	2.127	2.327	2.227
T_{11}	56.02	56.59	56.31	24.97	25.01	24.99	2.317	2.353	2.335	1.613	1.623	1.618
T_{12}	68.87	69.80	69.33	28.78	31.08	29.93	2.450	2.477	2.463	2.200	2.417	2.308
T_{13}	53.84	54.70	54.27	24.19	24.84	24.51	2.113	2.193	2.153	1.603	1.627	1.615
T_{14}	55.97	56.30	56.14	24.62	24.80	24.71	2.263	2.403	2.333	1.610	1.633	1.622
Sem ±)	1.19	0.97	1.71	0.21	0.23	0.31	0.016	0.026	0.016	0.020	0.040	0.022
CD (0.05)	2.45	2.01	3.52	0.43	0.48	0.65	0.034	0.053	0.033	0.041	0.083	0.045

4.1.6.2. Soil microbial analysis

4.1.6.2.1 Bacterial count (×10^4 CFU g^{-1})

During the two years of experimentation, it was observed that soil bacterial count showed significant differences among the treatments as shown in Table 4.1.22. All the treatments of organic amendment revealed higher bacterial count in soil as compared to control (T_{13}). Among all the treatments, PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), recorded significantly highest bacterial count (48.72, 50.95 and 49.84 ×10^4 CFU g^{-1} of soil) followed by T_{10} (46.45, 49.20 and 47.83 ×10^4 CFU g^{-1} of soil) in the two years as well as in pooled data. Control (T_{13}) recorded the minimum bacterial count (23.69, 24.67 and 24.18×10^4 CFU $g^{-1}$of soil) during the two years as well as in pooled analysis.

4.1.6.2.2 Fungal count (×10^4 CFU g^{-1})

It is clearly evidenced from the data presented on Table 4.1.22, that significant difference was observed among the treatments with respect to fungi count in soil. During 2016-2017, 2017-2018 and pooled analysis, the maximum fungal count obtained was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (41.05, 55.55 and 48.30 ×10^4 CFU g^{-1} of soil respectively) followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (39.68, 52.56 and 46.12 ×10^4 CFU g^{-1} soil). Among all the treatments, the minimum fungal count (21.78, 33.08 and 27.43 ×10^4 CFU g^{-1} of soil) was found in control (T_{13}) during both the years and in pooled data.

4.1.6.2.3 *Actinomycetes* count (×10^4 CFUg^{-1})

It is clearly seen from the presented data in Table 4.1.22 that various organic manures and bio-dynamic preparations significantly influenced the *Actinomycetes* count of the soil. The maximum *Actinomycetes* count was recorded with PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) (38.38, 51.70 and 45.04 ×10^4 CFU g^{-1} of soil) respectively followed by FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) (37.62, 50.46 and 44.04 ×10^4 CFU g^{-1}) of soil. The minimum *Actinomycetes* count of 22.26, 28.60 and 25.43 ×10^4 CFU g^{-1} of soil was found in control (T_{13}) during the two years as well as in pooled data.

Table 4.1.22 Effect of organic manures and bio-dynamic preparations on bacterial, fungal & *Actinomycetes* count

Treatments	Bacterial count (×10^4 CFUg^{-1})			Fungal count (×10^4 CFUg^{-1})			*Actinomycetes* count (×10^4 CFU		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1	38.54	41.14	39.84	36.95	46.38	41.67	33.96	44.15	39.06
T_2	37.30	39.32	38.31	36.47	45.18	40.82	33.51	41.09	37.30
T_3	29.68	30.56	30.12	29.96	39.61	34.79	28.42	31.22	29.82
T_4	36.94	38.15	37.55	35.43	43.76	39.60	32.87	38.66	35.77
T_5	42.30	44.02	43.16	38.68	48.90	43.79	35.81	47.35	41.58
T_6	39.34	41.05	40.20	37.91	46.05	41.98	34.89	46.21	40.55
T_7	31.34	33.68	32.51	31.62	42.47	37.05	29.99	34.63	32.31
T_8	37.87	40.14	39.00	36.87	47.33	42.10	34.42	44.15	39.28
T_9	45.54	48.35	46.95	39.68	52.56	46.12	37.62	50.46	44.04
T_{10}	46.45	49.20	47.83	41.05	55.55	48.30	36.96	48.64	42.80
T_{11}	35.22	36.89	36.05	35.22	44.08	39.65	30.60	36.29	33.45
T_{12}	48.72	50.95	49.84	39.13	51.32	45.23	38.38	51.70	45.04
T_{13}	23.69	24.67	24.18	21.78	33.08	27.43	22.26	28.60	25.43

T_{14}	25.15	26.82	25.99	25.55	41.07	33.31	24.64	30.62	27.63
Sem ±)	0.81	0.6	0.58	0.95	1.03	0.52	0.31	0.87	0.48
CD (0.05)	1.68	1.24	1.2	1.29	2.13	1.07	0.64	1.8	0.99

4.1.7 Economics of cultivation and Benefit: Cost ratio

The data presented in Table 4.1.24 revealed that the highest gross expenditure (Rs 6,42,742.90) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (Rs. 6,09, 236.70) whereas the lowest (Rs. 3,97,763.30) was observed with control (T_{13}). Among all the treatments, the highest gross income of Rs. 30,51,900.00 was observed with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (Rs. 24,86,700.00), while the lowest (Rs. 7,17,500.00) was recorded with control (T_{13}). Among all the treatments, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) resulted in maximum net returns (Rs. 24,09,157.11), followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (Rs. 18,77,463.31), while the minimum net returns (Rs 3,19,736.75) was obtained in control (T_{13}).

Among all the treatments, the highest benefit cost ratio (3.75) was recorded with treatment FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) it was followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (3.08) while the lowest benefit: cost ratio (0.80) was observed in control (T_{13}).

Table 4.1.23: Gross expenditure, gross income, net income and B: C ratio under the influence of organics and bio-dynamics

Treatment	Gross Expenditure (Rs)	Gross Income (Rs)	Net Income (Rs)	B:C ratio
T_1	582126.20	2454300.00	1872173.77	3.22
T_2	548620.00	2242800.00	1694179.98	3.09
T_3	541909.80	1803600.00	1261690.20	2.33
T_4	531855.70	2352600.00	1820744.30	3.42
T_5	609056.90	2340900.00	1731843.13	2.84
T_6	575550.70	2026800.00	1451249.34	2.52
T_7	568840.40	1974600.00	1405759.56	2.47
T_8	558786.30	2232000.00	1673213.66	2.99
T_9	642742.90	3051900.00	2409157.11	3.75
T_{10}	609236.70	2486700.00	1877463.31	3.08
T_{11}	602526.50	2162700.00	1560173.53	2.59
T_{12}	592472.40	2255400.00	1662927.64	2.81
T_{13}	397763.30	717500.00	319736.75	0.80
T_{14}	445519.10	980000.00	534480.92	1.20

4.2 2nd Experiment: Effect of Crop regulation on growth, yield and quality of Grapes cv. Bangalore Blue

4.2.1 Plant growth characters

4.2.1.1 Shoot length (cm)

It is evident from the data presented in Table 4.2.1 that during 2016-2017, among all treatments, the maximum shoot length (119.88 cm) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}). During 2017- 2018 also, the same treatment, recorded the maximum value (126.28 cm) with respect to shoot length. Among all the treatments, the minimum shoot length (115.96 and 116.14 cm) was recorded in control (T_1) in both years of the studies. The pooled analysis of the data revealed that the maximum shoot length (123.08 cm) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) which was significantly higher than all other treatments. Among all the treatments, control (T_1) recorded the minimum shoot length (116.05 cm).

4.2.1.2 Shoot diameter (mm)

The study of data presented in Table 4.2.1 showed that different crop regulations had significant impact on shoot diameter during the two years of study. During 2016-2017, the maximum shoot diameter (21.01 mm) was observed in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) while the minimum (16.35 mm) was in control (T_1). Likewise, during 2017-2018, the maximum shoot diameter (21.75 mm) was observed in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) and the least (17.04 mm) was in control (T_1). It is clear from pooled data that there were significant differences among the treatments with respect to shoot diameter. Maximum shoot diameter (21.38 mm) was recorded under Trunk girdling

+flower thinning + GA_3 + ethephon (T_{18}) which was significantly higher than all other treatments, while, minimum (16.69 mm) was observed in control (T_1).

4.2.1.3 Internodal length (cm)

Significant variations were observed among the treatments with respect to internodal length in both the years as well as in pooled data (Table 4.2.2). For the year 2016-2017, maximum internodal length (12.58 cm) was recorded by Manual Berry thinning + GA_3 + ethephon (T_{12}). Similarly, during 2017-2018, also, the same treatment recorded the highest internodal length (13.27 cm). The pooled data showed that Manual Berry thinning + GA_3 + ethephon (T_{12}) showed the maximum internodal length (12.92 cm), followed by GA_3 (T_5) with a value of 11.98 cm, while the lowest was recorded in control (10.43 cm).

4.2.1.4 Cane diameter (mm)

It is clear from the given data in the Table 4.2.2 that during 2016-2017, the maximum cane diameter (6.71 mm) was recorded in Flower thinning + GA_3 + ethephon (T_9), while the lowest (3.77 mm) was in control (T_1). Similarly, during the year 2017-2018, the same treatment recorded the maximum cane diameter (7.34 mm), whereas, the lowest was in control (4.78 mm). The analysis of pooled data revealed that the maximum cane diameter (7.02 mm) was recorded with Flower thinning + GA_3 + ethephon (T_9) which was significantly higher than all other treatments. It was followed by Manual Berry thinning + GA_3 (T_{10}) (5.83 mm) while, least (4.28 mm) was recorded in control.

4.2.2 Yield attributing characters and Yield

4.2.2.1 Per cent of fruitful cane (%)

Significant differences were recorded among the treatments with correspondence to per cent of fruitful cane during the two years of experimentation. The perusal of data shown in Table 4.2.3 indicated that Trunk Girdling + flower thinning + GA_3 + ethephon (T_{18}) showed maximum fruitful cane (91.27 % and 96.30%) during 2016-2017 and 2017-2018 respectively, while, the minimum was observed in control (T_1) in both years of investigation (69.09 % and 78.33%). In pooled data, Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}) showed the maximum fruitful cane (93.79 %), while minimum (73.71%) was observed in control (T_1).

Table 4.2.1 Effect of crop regulation on shoot length & shoot diameter

Treatments	Shoot length (cm)			Shoot diameter (mm)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	115.96	116.14	116.05	16.35	17.04	16.69
T_2	116.86	117.22	117.04	17.19	17.96	17.58
T_3	117.03	117.06	117.05	17.71	18.18	17.95
T_4	116.81	117.45	117.13	18.17	18.68	18.43
T_5	118.44	119.37	118.90	19.32	19.84	19.58
T_6	118.98	120.47	119.73	19.70	20.09	19.90
T_7	116.51	117.67	117.09	19.18	19.15	19.17
T_8	118.13	119.80	118.96	19.22	19.01	19.11
T_9	119.32	120.99	120.15	19.47	19.94	19.70
T_{10}	118.53	123.23	120.88	19.73	20.07	19.90
T_{11}	118.65	120.62	119.64	18.68	19.31	18.99
T_{12}	117.94	122.58	120.26	19.14	19.74	19.44
T_{13}	116.29	117.35	116.82	18.27	18.84	18.56
T_{14}	116.48	117.13	116.81	18.48	18.95	18.72
T_{15}	117.82	118.70	118.26	18.91	18.35	18.63
T_{16}	118.30	118.59	118.44	18.27	18.36	18.32
T_{17}	118.78	119.41	119.09	19.12	19.12	19.12
T_{18}	119.48	120.37	119.93	21.01	21.75	21.38
T_{19}	119.88	126.28	123.08	19.24	19.75	19.49
Sem ±)	0.56	0.75	0.44	0.51	0.28	0.31
CD (0.05)	1.14	1.52	0.89	1.04	0.57	0.64

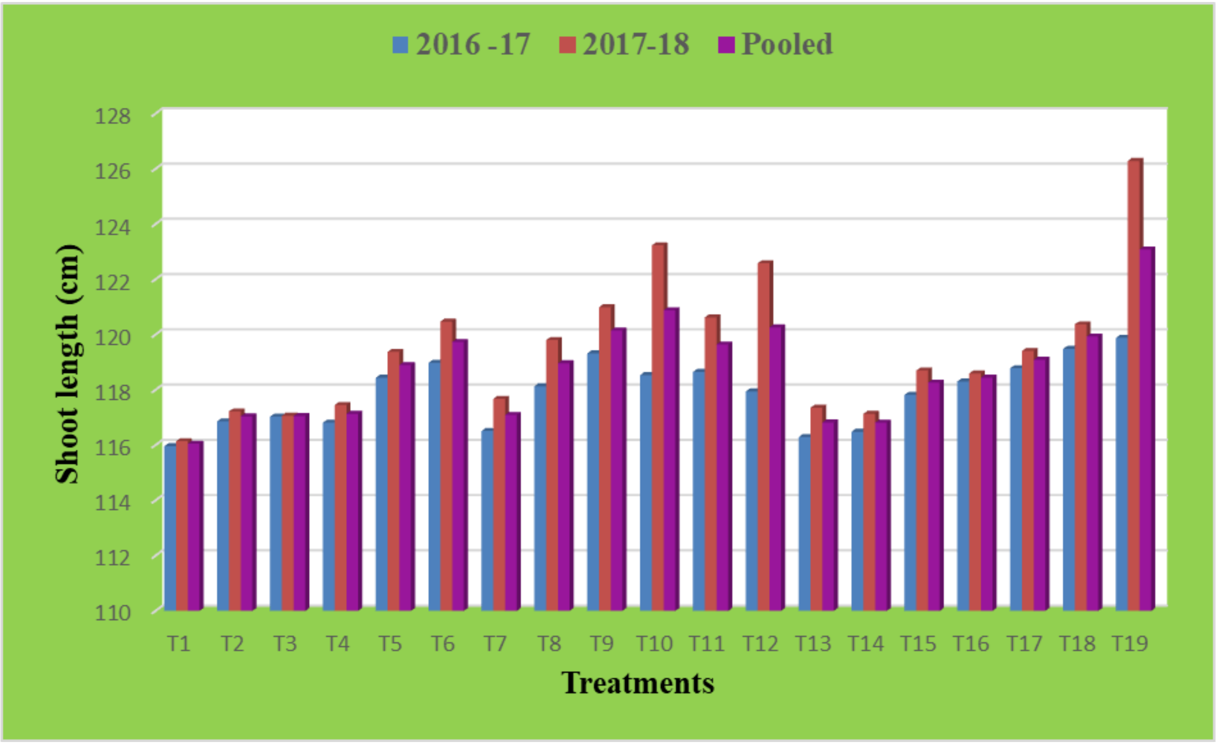

Fig. 4.2.1 Effect of crop regulation on shoot length

Table 4.2.2 Effect of crop regulation on internodal length & cane diameter

Treatments	Internodal length (cm)			Cane diameter (mm)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	10.05	10.82	10.43	3.77	4.78	4.28
T_2	10.89	11.44	11.17	4.58	5.05	4.82
T_3	10.89	11.20	11.05	4.53	4.37	4.45
T_4	11.19	11.45	11.32	4.69	4.77	4.73
T_5	11.85	12.10	11.98	4.82	5.25	5.04
T_6	11.63	11.18	11.40	5.33	5.63	5.48
T_7	11.84	11.94	11.89	4.69	4.75	4.72
T_8	11.08	11.27	11.18	4.54	4.57	4.56
T_9	11.25	11.26	11.26	6.71	7.34	7.02
T_{10}	11.93	12.30	12.12	5.72	5.93	5.83
T_{11}	10.83	11.51	11.17	4.58	4.97	4.78
T_{12}	12.58	13.27	12.92	5.44	5.42	5.43
T_{13}	11.55	11.66	11.60	4.84	4.39	4.62
T_{14}	11.16	11.13	11.14	4.69	4.68	4.69
T_{15}	11.24	10.99	11.12	4.64	4.55	4.59
T_{16}	10.89	11.23	11.06	4.88	5.00	4.94
T_{17}	11.17	11.36	11.27	5.22	5.05	5.14
T_{18}	11.06	11.77	11.42	5.33	5.47	5.40
T_{19}	11.61	12.06	11.83	4.36	5.00	4.68
Sem ±)	0.31	0.28	0.20	0.28	0.25	0.18
CD (0.05)	0.62	0.57	0.42	0.58	0.51	0.37

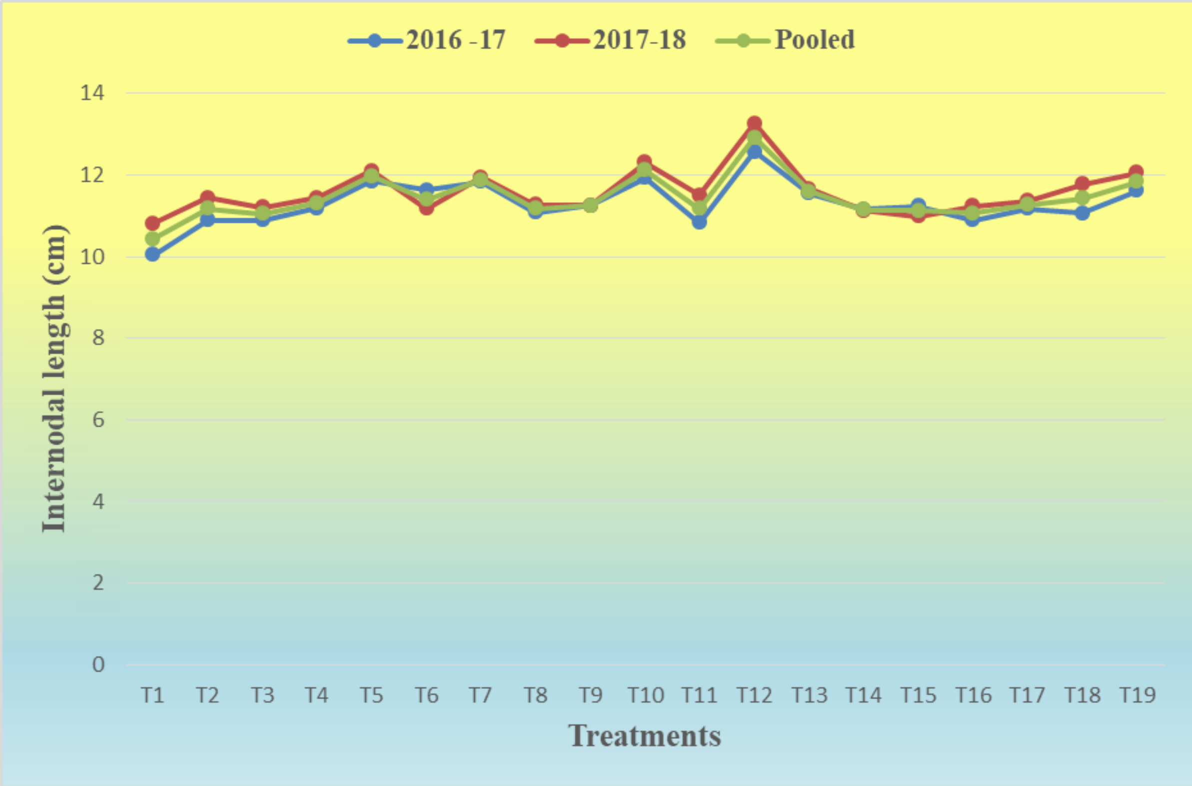

Fig. 4.2.2 Effect of crop regulation on internodal length

4.2.2.2 Berry set per cent (%)

The perusal of data shown in Table 4.2.3 showed that crop regulations had significant impact in berry set per cent. During 2016-2017 and 2017-2018, among all the treatments, Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) showed the maximum berry set per cent (39.30 and 39.84 %) respectively, while, control (T_1) recorded the minimum berry set per cent (30.07% and 30.09%) during both the years of study. The pooled analysis highlighted that, the maximum number of berry set (39.57 %) was recorded in Trunk Girdling + manual berry thinning + GA_3 + ethephon (T_{19}), whereas minimum (30.08 %) was recorded in control (T_1).

4.2.2.3 Berry drop per cent (%)

It is clearly seen from the data presented in Table 4.2.4 that berry drop per cent differed significantly among the treatments during both the years of experimentation. During 2016-2017 and 2017-2018, the minimum berry drop per cent (41.46 and 40.82 %) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) while, the maximum (58.59 and 57.33 %) was in control (T_1). The results of pooled data revealed that minimum berry drop per cent (41.14%) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), followed by Flower thinning + GA_3 (T_7) (41.93 %) whereas, the maximum (57.96 %) was in control (T_1).

4.2.2.4 Berry retention per cent (%)

Data shown in Table 4.2.4 indicated significant differences among the treatments regarding berry retention per cent in both the two year of investigation as well as in the pooled data. During 2016- 2017, the berry retention per cent varied from 41.41 to 58.54 and in 2017-2018, it was 42.67 and 59.18. The pooled data revealed that the highest berry retention (58.86 %) was in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) followed by Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) (56.41 %), while the minimum (42.04 %) was in control (T_1).

4.2.2.5 Shot berries (%)

It is obvious from the data presented in Table 4.2.5 that crop regulations had impact on shot berries per cent during the two years of investigations. During 2016-2017 and 2017-2018, the lowest shot berries (2.92 and 2.54%) was observed in Manual Berry thinning + GA_3 + ethephon (T_{12}). Pooled data of the two years revealed that minimum shot berries (2.73 %) was recorded in Trunk girdling (T_{12}), which was significantly higher than all other treatments, whereas, the maximum (13.43 %) was found in control (T_1).

4.2.2.6 Unripe berries (%)

A high degree of differences were recorded among the various treatments with regards to unripe berries per cent (Table 4.2.5). Among all the treatments, the lowest unripe berries (8.31 and 6.57 %) was observed in flower thinning + GA_3 + ethephon (T_9), while the maximum (25.59 and 24.61 %) was observed in T_1 (control). The pooled data of the two years revealed that the minimum unripe berries (7.44 %) was observed in flower thinning + GA_3 + ethephon (T_9) while, the maximum (25.10 %) was observed in control (T_1).

Table 4.2.3 Effect of crop regulation on per cent of fruitful cane & berry set per cent

Treatments	Per cent of fruitful cane (%)			Berry set per cent (%)		
	2016 -17	**2017-18**	**Pooled**	**2016 -17**	**2017-18**	**Pooled**
T_1	69.09	78.33	73.71	30.07	30.09	30.08
T_2	72.44	81.30	76.87	30.73	30.83	30.78
T_3	76.55	82.39	79.47	31.67	31.84	31.76
T_4	79.35	84.74	82.05	33.31	33.47	33.39
T_5	80.59	86.21	83.40	36.08	36.25	36.17
T_6	81.84	87.43	84.63	35.00	35.12	35.06
T_7	82.96	88.85	85.91	32.94	32.99	32.96
T_8	81.69	85.72	83.71	32.43	33.06	32.74
T_9	84.09	89.99	87.04	32.24	35.47	33.86
T_{10}	82.58	86.38	84.48	38.75	38.92	38.84
T_{11}	85.12	90.77	87.94	31.46	33.07	32.27
T_{12}	86.46	91.59	89.03	35.72	35.87	35.79
T_{13}	83.92	86.71	85.32	34.12	35.58	34.85
T_{14}	84.56	87.32	85.94	34.11	34.24	34.17
T_{15}	85.50	87.87	86.69	34.06	34.33	34.20
T_{16}	88.54	93.59	91.06	34.88	35.31	35.09
T_{17}	89.50	94.34	91.92	34.93	35.35	35.14
T_{18}	91.27	96.30	93.79	36.33	36.96	36.64
T_{19}	89.99	95.42	92.71	39.30	39.84	39.57
Sem ±)	0.54	0.63	0.43	0.71	0.47	0.43
CD (0.05)	1.10	1.27	0.88	1.44	0.95	0.86

Table 4.2.4 Effect of crop regulation on berry drop per cent & berry retention per cent

Treatments	Berry drop per cent (%)			Berry retention per cent (%)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	58.59	57.33	57.96	41.41	42.67	42.04
T_2	47.95	57.15	52.55	52.05	42.85	47.45
T_3	54.02	54.06	54.04	45.98	45.94	45.96
T_4	49.90	49.25	49.57	50.10	50.75	50.43
T_5	44.00	43.47	43.74	56.00	56.53	56.26
T_6	45.66	44.50	45.08	54.34	55.50	54.92
T_7	42.26	41.59	41.93	57.74	58.41	58.07
T_8	44.38	43.48	43.93	55.62	56.52	56.07
T_9	42.99	42.58	42.78	57.01	57.42	57.22
T_{10}	44.18	43.35	43.77	55.82	56.65	56.23
T_{11}	50.57	48.56	49.56	49.43	51.44	50.44
T_{12}	44.96	43.85	44.41	55.04	56.15	55.60
T_{13}	46.36	45.25	45.81	53.64	54.75	54.20
T_{14}	45.81	44.75	45.28	54.19	55.25	54.72
T_{15}	44.58	43.72	44.15	55.42	56.28	55.85
T_{16}	44.03	43.40	43.71	55.97	56.60	56.29
T_{17}	44.18	43.80	43.99	55.82	56.20	56.01
T_{18}	43.33	43.84	43.59	56.67	56.16	56.41
T_{19}	41.46	40.82	41.14	58.54	59.18	58.86
Sem ±)	3.38	0.73	1.66	3.38	0.73	1.66
CD (0.05)	6.84	1.47	3.37	6.84	1.47	3.37

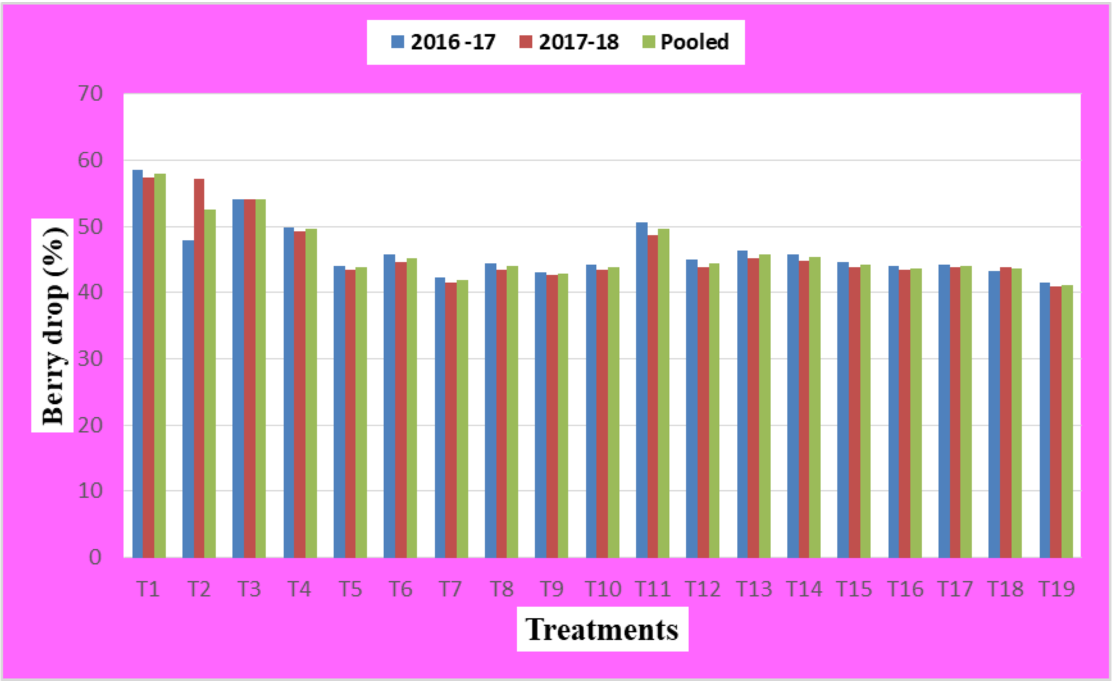

Fig. 4.2.3 Effect of crop regulation on berry drop (%)

Table 4.2.5 Effect of crop regulation on shot berries & unripe berries

Treatments	Shot berries (%)			Unripe berries (%)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	14.00	12.86	13.43	25.59	24.61	25.10
T_2	9.58	8.11	8.84	24.08	21.70	22.89
T_3	12.53	10.69	11.61	21.74	19.44	20.59
T_4	7.02	5.93	6.48	13.34	10.22	11.78
T_5	8.45	6.78	7.61	11.85	9.81	10.83
T_6	10.39	9.59	9.99	15.35	12.86	14.10
T_7	13.99	10.78	12.39	22.49	19.25	20.87
T_8	6.46	5.78	6.12	13.12	10.71	11.92
T_9	6.46	7.63	7.04	8.31	6.57	7.44
T_{10}	9.57	8.76	9.16	16.82	13.51	15.16
T_{11}	9.85	7.70	8.78	20.37	17.95	19.16
T_{12}	2.92	2.54	2.73	15.57	11.91	13.74
T_{13}	7.60	6.64	7.12	12.21	11.94	12.08
T_{14}	9.94	8.85	9.40	15.16	14.48	14.82
T_{15}	8.34	8.00	8.17	16.80	16.02	16.41
T_{16}	6.69	6.73	6.71	16.07	14.75	15.41
T_{17}	6.03	5.04	5.53	14.39	13.16	13.78
T_{18}	5.39	4.00	4.69	12.13	10.70	11.42
T_{19}	6.12	5.53	5.83	14.55	13.20	13.87
Sem ±)	1.27	0.85	0.97	1.42	1.07	1.18
CD (0.05)	2.58	1.72	1.97	2.87	2.16	2.40

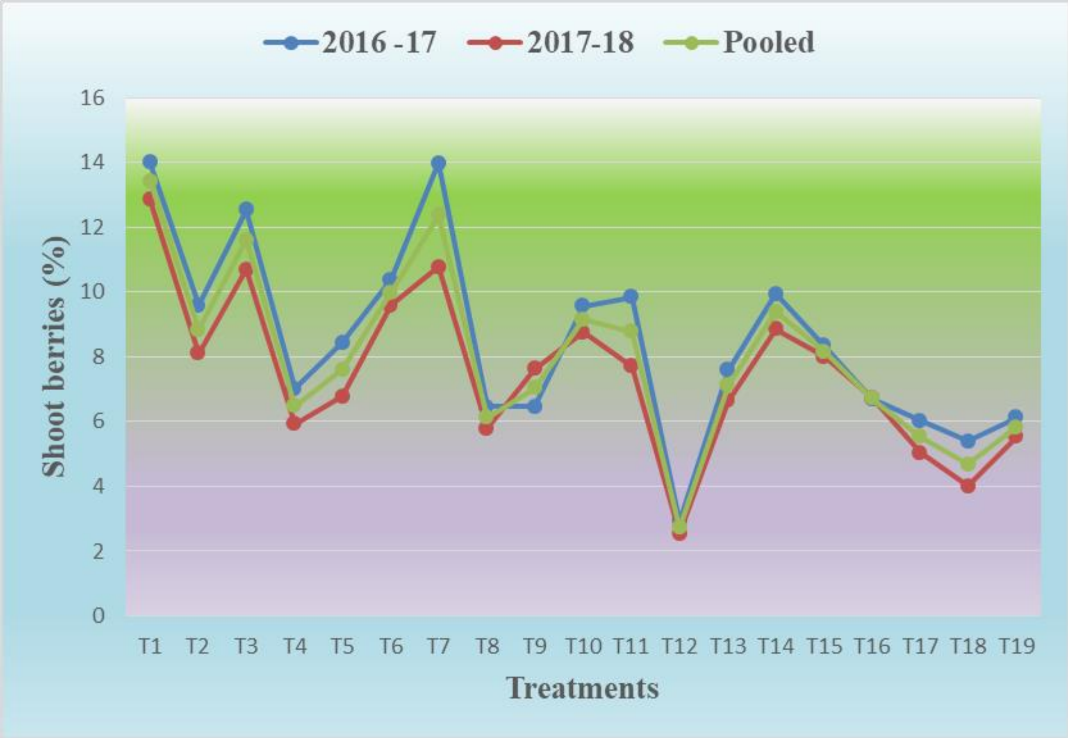

Fig. 4.2.4 Effect of crop regulation on shot berries (%)

4.2.2.7 Total crop duration (days)

It is obvious from the data (Table 4.2.6) that crop regulations had remarkable impact on total crop duration of grapevines during the two years of investigations. During 2016-2017, the total crop duration ranged between 39.08 days 65.28 days while, during 2017-2018, it was between 37.67 days to 63.62 days. Pooled analysis of the data revealed that the shortest total crop duration (38.38 days) was recorded in Trunk girdling + GA_3 (T_{15}), followed by Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}) (39.85 days), while, the longest (64.45 days) was observed in T_1 (control) which was significantly lower than all other treatments.

4.2.2.8 Bunch weight (g)

Relevant data on bunch weight of different treatments are shown in Table 4.2.6. It is clear from the data that during 2016-2017, Trunk girdling + manual Berry thinning + GA_3 + ethephon (T_{19}) showed the highest bunch weight (798.26 g), while the lowest (408.61 g) was recorded in control. Similarly, during 2017-2018, the highest bunch weight (805.19 g) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) and the lowest was (418.57 g) in control (T_1). However, pooled data revealed that the highest bunch weight (801.73 g) was observed in Trunk Girdling + manual berry thinning + GA_3 + ethephon (T_{19}) and the lowest (413.59 g) was in control.

4.2.2.9 Bunch length (cm)

It is clearly seen from the presented data (Table 4.2.7) that bunch length differed significantly among different treatments during the two years of experimentations. During 2016-2017 and 2017- 2018, the longest bunch length (22.47 cm and 24.32 cm) was recorded in Trunk girdling +flower thinning + GA_3 +

ethephon (T_{18}) while the shortest (14.63 cm and 15.59 cm) was in control (T_1). From the pooled data, it is recorded that bunch length ranged between 15.11 and 23.39 cm. Among the various treatments, Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}) recorded the longest bunch length (23.39 cm) and the shortest (15.11 cm) was in control (T_1).

4.2.2.10 Bunch breadth (cm)

It is obvious from the data presented in Table 4.2.7 that crop regulations had remarkable impact on bunch breadth. The highest bunch breadth (14.19 and 14.93 cm) was recorded with Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), while the lowest (8.12 and 8.53 cm) was in control (T_1) during the two years of investigations. Pooled data showed that the longest bunch breadth of 14.56 cm was observed in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) which was significantly higher than other treatments. It was followed by Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (12.78 cm), whereas, the lowest (8.33 cm) was recorded in control (T_1).

4.2.2.11 Bunch size (cm^2)

Perusal of the data presented in Table 4.2.8 revealed that various treatments had huge impact on bunch size for both the two years of investigations. During 2016-2017, the highest bunch size (318.77 cm^2) was recorded in Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}), while the lowest (118.82 cm^2) was in control (T_1). Similarly, during 2017-2018, the highest (363.14 cm^2) was recorded in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) and the least (132.87 cm^2) was in control (T_1). Pooled analysis of the data revealed that the highest bunch size (340.95 cm^2) was observed in Trunk girdling + flower thinning + GA_3 + ethephon (T_{18})

which was significantly higher than all other treatments, while, the least (125.85 cm^2) was in control (T_1).

4.2.2.12 Berry number per bunch

The presented data in Table 4.2.8 revealed that berry number per bunch differed significantly in different treatments. During 2016-2017 and 2017- 2018, the highest berry number per bunch (180.05 and 185.78) was recorded with Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}). Pooled analysis of the data shows that highest berry number per bunch (182.92) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) which was significantly higher than all other treatments. The least (114.69) was recorded in control (T_1).

4.2.2.13 Bunch number per vine

Significant variations were recorded among the treatments (Table 4.2.9) with respect to bunch number per vine. For the year 2016-2017, the bunch number per vine varied between 29.78– 48.77, while, in 2017- 2018, it varied between 30.79 – 50.15. The pooled analysis of the data revealed that, the maximum bunch number per vine (49.46) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) which was significantly higher than all other treatments, whereas, the minimum (30.28) was observed in control (T_1).

4.2.2.14 Bunch compactness (g cm^{-2})

The bunch compactness of the vine differed significantly among all the treatments as revealed in Table 4.2.9. For the year 2016-2017, the maximum bunch compactness (4.39 g cm^{-2}) was observed in manual berry thinning + ethephon (T_{11}). Similarly, during 2017-2018, the maximum (3.76 g cm^{-2}) was recorded in manual berry thinning + ethephon (T_{11}). Ethephon (T_6) recorded the minimum bunch compactness (2.10 and 1.93 g cm^{-2}) in both the years. Pooled data of the two years revealed that the maximum bunch compactness (4.08 g cm^{-2}) was observed in manual berry thinning + ethephon (T_{11}) which was significantly higher than all other treatments, while the lowest (2.02 g cm^{-2}) was in Ethephon (T_6).

4.2.2.15 Yield / vine (kg)

The data of yield per vine are shown in Table 4.2.10. Different crop regulations treatments had significant impact on yield per vine during the two years of investigations. For the year 2016-2017, the highest yield per vine (29.37 kg) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}). During 2017-2018 also, the same treatment (T_{19}) recorded the highest yield per vine (30.90 kg). Pooled data of the two years indicated that the highest yield per vine of 30.13 kg was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), while the least (9.35) was observed in control (T_1).

4.2.2.16 Yield per ha (t ha $^{-1}$)

Remarkable differences were recorded among the treatments (Table 4.2.10**)** with respect to yield per hectare in the two years and pooled analysis. For the year 2016-17 and 2017-18, Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) showed the highest yield per hectare (32.63 and 34.33 t ha $^{-1}$), while, control (T_1) revealed the least (9.63 and 11.14 t ha $^{-1}$). The pooled analysis of the data revealed that, maximum yield per hectare (33.48 t ha $^{-1}$) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) which was significantly higher than all other treatments, while, the least (10.39 t ha $^{-1}$) was observed in control.

Table 4.2.6 Effect of crop regulation on total crop duration & bunch weight

Treatments	Total crop duration (days)			Bunch weight (g)		
	2016 -17	**2017-18**	**Pooled**	**2016 -17**	**2017-18**	**Pooled**
T_1	65.28	63.62	64.45	408.61	418.57	413.59
T_2	64.53	62.10	63.32	429.18	454.18	441.68
T_3	63.75	59.20	61.47	460.35	477.08	468.72
T_4	60.98	57.57	59.28	497.49	529.86	513.68
T_5	61.26	56.23	58.74	545.18	559.55	552.37
T_6	47.13	46.26	46.70	512.12	526.50	519.31
T_7	59.30	55.34	57.32	554.11	572.09	563.10
T_8	45.41	44.50	44.96	574.99	592.27	583.63
T_9	45.27	44.72	45.00	723.46	761.95	742.71
T_{10}	58.51	54.65	56.58	607.23	618.98	613.11
T_{11}	43.83	43.26	43.55	617.76	631.97	624.87
T_{12}	43.76	43.00	43.38	623.99	648.93	636.46
T_{13}	57.50	54.38	55.94	659.99	676.62	668.30
T_{14}	56.60	53.65	55.12	683.18	698.08	690.63
T_{15}	39.08	37.67	38.38	748.96	773.48	761.22
T_{16}	41.90	41.36	41.63	713.46	725.64	719.55
T_{17}	41.35	40.16	40.76	766.91	792.29	779.60
T_{18}	40.51	39.20	39.85	786.07	800.41	793.24
T_{19}	55.54	53.16	54.35	798.26	805.19	801.73
Sem ±)	0.80	0.64	0.56	10.93	13.26	11.64
CD (0.05)	1.62	1.3	1.14	22.09	26.81	23.52

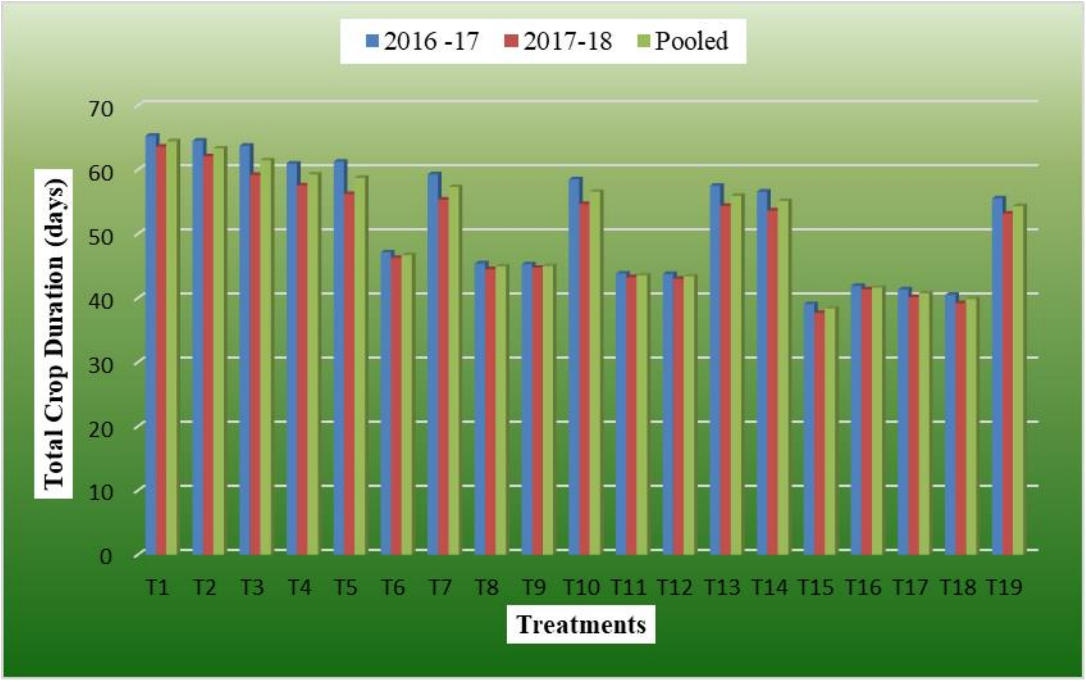

Fig. 4.2.5 Effect of crop regulation on total crop duration

Table 4.2.7 Effect of crop regulation on bunch length & bunch breadth

Treatments	Bunch length (cm)			Bunch breadth (cm)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	14.63	15.59	15.11	8.12	8.53	8.33
T_2	17.00	17.83	17.42	8.80	9.29	9.04
T_3	15.57	16.51	16.04	8.35	8.57	8.46
T_4	19.16	20.26	19.71	10.00	10.57	10.28
T_5	20.25	19.99	20.12	11.60	12.33	11.97
T_6	19.85	20.92	20.38	12.35	13.10	12.72
T_7	18.08	19.08	18.58	9.32	9.99	9.66
T_8	21.41	21.05	21.23	10.56	11.36	10.96
T_9	20.84	22.40	21.62	9.76	11.70	10.73
T_{10}	19.28	20.61	19.94	10.32	11.55	10.94
T_{11}	15.70	17.30	16.50	9.01	9.73	9.37
T_{12}	19.16	20.09	19.63	10.59	11.52	11.06
T_{13}	19.70	20.75	20.23	9.54	10.24	9.89
T_{14}	20.49	21.89	21.19	8.96	10.05	9.51
T_{15}	20.47	21.64	21.06	9.98	11.20	10.59
T_{16}	20.36	22.55	21.46	10.35	11.24	10.79
T_{17}	20.67	22.82	21.75	10.68	12.02	11.35
T_{18}	22.47	24.32	23.39	14.19	14.93	14.56
T_{19}	20.77	23.02	21.90	12.46	13.10	12.78
Sem ±)	0.68	0.64	0.53	0.38	0.44	0.37
CD (0.05)	1.38	1.29	1.08	0.78	0.9	0.76

Table 4.2.8 Effect of crop regulation on bunch size & berry number per bunch

Treatments	Bunch size (cm^2)			Berry number per bunch		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	118.82	132.87	125.85	110.82	118.56	114.69
T_2	149.61	165.63	157.62	116.53	123.55	120.04
T_3	130.03	141.48	135.76	121.79	135.39	128.59
T_4	191.52	213.76	202.64	127.72	142.19	134.96
T_5	234.73	246.64	240.68	133.20	146.53	139.86
T_6	244.31	274.31	259.31	140.03	154.06	147.05
T_7	168.47	190.81	179.64	144.47	157.13	150.80
T_8	226.41	239.19	232.80	149.87	161.21	155.54
T_9	203.16	261.87	232.52	174.24	178.05	176.14
T_{10}	199.37	237.87	218.62	153.66	163.95	158.81
T_{11}	141.70	168.29	155.00	157.67	167.84	162.76
T_{12}	202.79	231.64	217.22	176.10	182.30	179.20
T_{13}	187.89	212.62	200.25	160.07	168.98	164.53
T_{14}	183.64	219.98	201.81	164.39	171.67	168.03
T_{15}	204.18	242.37	223.28	168.87	172.95	170.91
T_{16}	210.84	253.28	232.06	172.90	176.36	174.63
T_{17}	220.48	274.46	247.47	176.87	183.36	180.11
T_{18}	318.77	363.14	340.95	178.91	184.55	181.73
T_{19}	258.95	301.68	280.32	180.05	185.78	182.92
Sem ±)	8.97	12.06	8.68	0.98	2.8	1.30
CD (0.05)	18.14	24.37	17.56	1.98	5.67	2.62

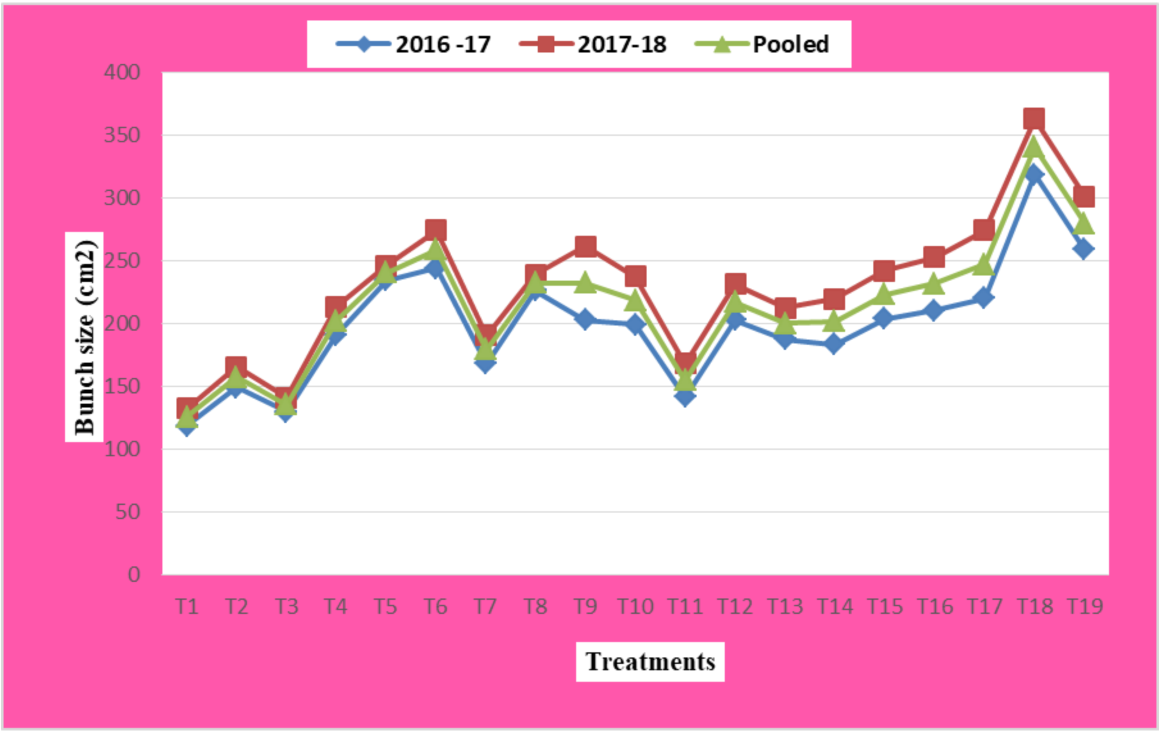

Fig. 4.2.6 Effect of crop regulation on Bunch size

Table 4.2.9 Effect of crop regulation on bunch number per vine & bunch compactness

Treatments	Bunch number per vine			Bunch compactness (g cm^{-2})		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	29.78	30.79	30.28	3.44	3.16	3.30
T_2	30.31	31.86	31.08	2.88	2.74	2.81
T_3	31.00	32.50	31.75	3.54	3.37	3.46
T_4	32.39	33.62	33.01	2.61	2.48	2.54
T_5	37.52	41.13	39.32	2.33	2.28	2.31
T_6	38.89	42.03	40.46	2.10	1.93	2.02
T_7	40.10	43.44	41.77	3.31	3.02	3.17
T_8	40.98	44.25	42.61	2.56	2.49	2.53
T_9	41.52	44.80	43.16	3.56	2.92	3.24
T_{10}	42.14	45.99	44.07	3.08	2.61	2.85
T_{11}	42.90	46.64	44.77	4.39	3.76	4.08
T_{12}	43.54	47.30	45.42	3.08	2.81	2.94
T_{13}	34.13	36.34	35.24	3.52	3.19	3.35
T_{14}	34.74	37.05	35.89	3.74	3.18	3.46
T_{15}	45.31	47.89	46.60	3.67	3.19	3.43
T_{16}	45.93	48.28	47.11	3.40	2.87	3.13
T_{17}	47.06	48.81	47.94	3.48	2.90	3.19
T_{18}	48.09	49.74	48.91	3.04	2.66	2.85
T_{19}	48.77	50.15	49.46	2.51	2.22	2.36
Sem ±)	0.34	0.49	0.28	0.16	0.14	0.13
CD (0.05)	0.70	0.99	0.56	0.32	0.29	0.27

Table 4.2.10 Effect of crop regulation on yield per vine & yield per ha

Treatments	Yield / vine (Kg)			Yield per ha (t ha^{-1})		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	8.67	10.03	9.35	9.63	11.14	10.39
T_2	10.62	11.42	11.02	11.80	12.69	12.25
T_3	13.11	13.64	13.37	14.56	15.16	14.86
T_4	17.80	18.81	18.30	19.77	20.90	20.33
T_5	18.79	21.51	20.15	20.88	23.90	22.39
T_6	18.02	20.73	19.38	20.02	23.04	21.53
T_7	18.78	21.14	19.96	20.87	23.49	22.18
T_8	19.07	22.20	20.63	21.18	24.66	22.92
T_9	25.09	27.62	26.35	27.87	30.68	29.28
T_{10}	21.60	24.60	23.10	24.00	27.33	25.67
T_{11}	21.40	24.31	22.86	23.77	27.01	25.39
T_{12}	21.18	24.94	23.06	23.53	27.71	25.62
T_{13}	18.47	20.41	19.44	20.52	22.68	21.60
T_{14}	17.53	19.61	18.57	19.47	21.78	20.63
T_{15}	23.66	25.95	24.81	26.29	28.83	27.56
T_{16}	24.69	27.07	25.88	27.43	30.08	28.75
T_{17}	23.27	27.39	25.33	25.85	30.43	28.14
T_{18}	25.23	29.23	27.23	28.03	32.48	30.25
T_{19}	29.37	30.90	30.13	32.63	34.33	33.48
Sem ±)	1.03	1.09	0.96	1.15	1.22	1.07
CD (0.05)	2.09	2.22	1.95	2.32	2.46	2.16

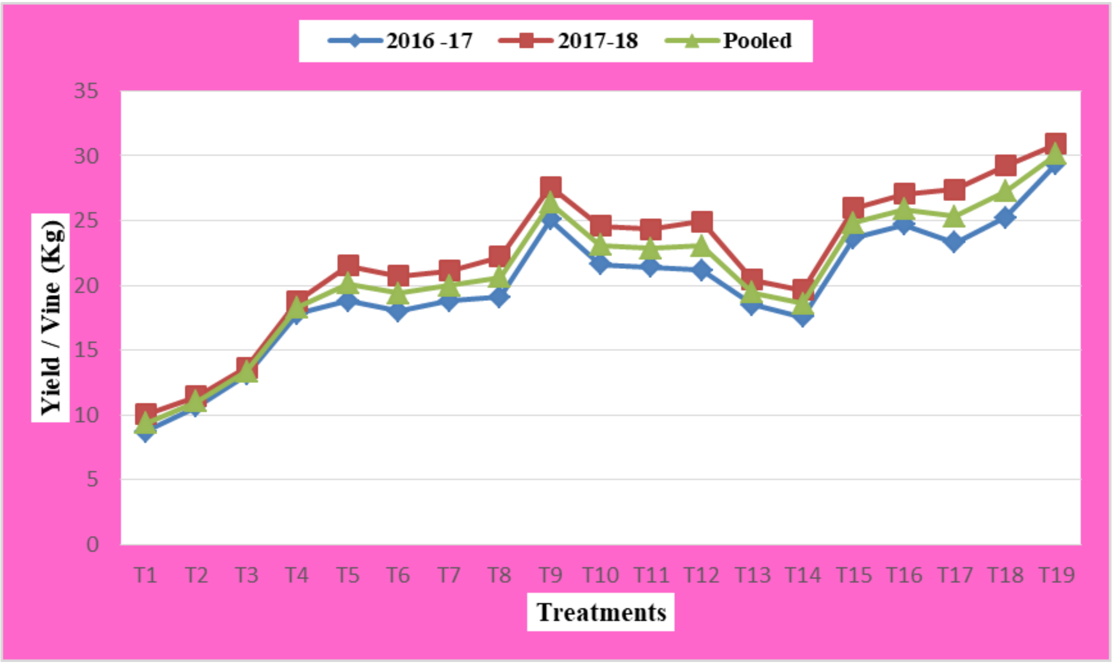

Fig. 4.2.7 Effect of crop regulation on yield/ vine

4.2.3 Berry Physical parameters-

4.2.3.1 Individual berry weight (g)

Individual weight of the berries differs noticeably with different crop regulation practices as shown in Table 4.2.11. Among all the treatments, the highest berry weight (7.05 and 7.73 g) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) during 2016- 2017 and 2017- 2018, respectively. Pooled data revealed that Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) recorded the highest (7.39 g) individual berry weight which was statistically higher than all other treatments, while, the least was recorded in control (T_1) (4.44 g).

4.2.3.2 Berry longitudinal diameter (cm)

Data with regards to berry longitudinal diameter are depicted in Table 4.2.11. The longitudinal diameter of berries varied significantly with different crop regulation practices during the two years of investigation. During 2016-2017, the maximum berry longitudinal diameter (3.06 cm) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}). The same treatment also recorded the highest berry longitudinal diameter (3.70 cm) during 2017-2018. Among all the treatments, the minimum berry longitudinal diameters was recorded in control (T_1) (1.97 and 2.01 cm respectively) for both years. The pooled analysis of the data revealed that the maximum berry longitudinal diameter (3.38 cm) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), followed by Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) (2.91 cm), while, the least (1.99) was observed in T_1 (control).

Table 4.2.11 Effect of crop regulation on individual berry weight & berry longitudinal diameter

Treatments	Individual berry weight (g)			Berry longitudinal diameter (cm)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	4.12	4.75	4.44	1.97	2.01	1.99
T_2	4.64	4.76	4.70	2.10	2.13	2.12
T_3	4.91	4.94	4.93	2.16	2.18	2.17
T_4	4.93	5.05	4.99	2.24	2.34	2.29
T_5	4.82	4.91	4.87	2.29	2.37	2.33
T_6	4.99	5.12	5.06	2.34	2.41	2.38
T_7	4.94	5.05	4.99	2.28	2.38	2.33
T_8	5.09	5.18	5.14	2.38	2.45	2.42
T_9	5.04	5.14	5.09	2.43	2.51	2.47
T_{10}	4.86	5.24	5.05	2.29	2.39	2.34
T_{11}	5.20	5.41	5.30	2.08	2.21	2.14
T_{12}	5.14	5.42	5.28	2.17	2.45	2.31
T_{13}	5.24	5.38	5.31	2.24	2.36	2.30
T_{14}	5.42	5.71	5.57	2.51	2.61	2.56
T_{15}	5.63	5.86	5.75	2.51	2.66	2.59
T_{16}	5.72	6.08	5.90	2.57	2.83	2.70
T_{17}	5.97	6.34	6.15	2.61	2.92	2.77
T_{18}	6.24	6.96	6.60	2.76	3.07	2.91
T_{19}	7.05	7.73	7.39	3.06	3.70	3.38
Sem ±)	0.22	0.22	0.20	0.11	0.11	0.10
CD (0.05)	0.46	0.45	0.41	0.23	0.22	0.21

4.2.3.3 Berry transversal diameter (cm)

The perusal of the data depicted in Table 4.2.12 revealed that the transversal diameter of berries influenced by various crop regulations. During 2016-2017, the berry transversal diameter differed between 1.76 and 2.10 cm, while, during 2017-2018, it was between 1.90 and 2.64 cm. Pooled data for the two years revealed that Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) recorded the maximum berry transversal diameter (2.37 cm), followed by Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) (2.17 cm) whereas, control revealed the least berry transversal diameter (1.83 cm).

4.2.3.4 Berry volume (cc)

Significant differences were observed among the treatments with respect to berry volume during the two years of experimentation as revealed from the data presented in Table 4.2.12. For the year 2016- 2017 and 2017-2018, the maximum berry volume was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (15.19 and 15.74 cc), whereas, the minimum (12.79 and 12.91 cc) was in control (T_1). Pooled data of the two years revealed that maximum berry volume (15.47 cc) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), followed by 14.93 cc in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) whereas the minimum was in control (T_1) (12.85 cc).

4.2.3.5 Hundred berry weights (g)

It is undeniable from the data presented in Table 4.2.13 that hundred berry weights varied remarkably with various treatments during the two years of investigations. For the year 2016-2017, the maximum hundred berry weights (697.30 g) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), whereas the lowest was in control (T_1) (406.18 g). In 2017-2018 also, the same treatments recorded the highest and lowest hundred berry weights (765.36 and 471.54 g). Pooled data of the two years showed that the highest hundred berry weights (731.33 g) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), whereas the least (438.86 g) was in control (T_1).

4.2.3.6 Skin thickness (mm)

It is seen from the data presented in Table 4.2.13 that various treatments had remarkable impact on skin thickness of grape berries. During 2016-2017, among all treatments, the maximum skin thickness (0.087 mm) was recorded in manual berry thinning + GA_3 + ethephon (T_{12}) whereas the minimum (0.043 mm) was in control (T_1). Similarly, during 2017-2018, the same treatment recorded the maximum and minimum value (0.088 and 0.046 mm). Pooled analysis of the data showed that the maximum skin thickness (0.088 mm) was obtained in manual berry thinning + GA_3 + ethephon (T_{12}) which was statistically *at par* with Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) (0.086) mm, while, the least (0.044 mm) was in control (T_1).

4.2.3.7 Pedicel thickness (mm)

The data with regards to pedicel thickness are shown in Table 4.2.14 revealed remarkable differences among the treatments. For the year 2016-2017, the maximum pedicel thickness was obtained in flower thinning + GA_3 (T_7) (3.74 mm) and the minimum in control (T_1) (2.78 mm). For the year, 2017-2018 also, the same treatments revealed the maximum and minimum value (4.15 and 3.08 mm). The pooled data revealed that maximum pedicel thickness (3.95 mm) was obtained in thinning + GA_3 (T_7) which was significantly higher than all other treatments. The least pedicel thickness (2.93 mm) was observed in control (T_1).

4.2.3.8 Seed weight (g)

Seed weight was remarkably affected by various treatments during the two years of investigations (Table 4.2.14). During 2016-2017, the maximum seed weight (0.083 g) was recorded in Trunk Girdling +flower thinning (T_{13}) while least (0.061 g) was obtained in Flower thinning + GA_3 + ethephon (T_9) and Manual Berry thinning + GA_3 (T_{10}). Similarly, in 2017-2018, Trunk Girdling +flower thinning (T_{13}) revealed the maximum (0.085 g) and Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), resulted in minimum (0.053 g) value. Pooled analysis of the two years data depicted that the maximum seed weight (0.084 g) was obtained in Trunk Girdling +flower thinning(T_{13}), while the least (0.059 g) was obtained in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}).

4.2.3.9 Seed length (cm)

The data depicted in the Table 4.2.15 showed that remarkable variations were observed among the treatments with respect to seed length. For the year 2016-2017, the maximum seed length (0.773 cm) was recorded in GA_3 (T_5) and the minimum (0.481 cm) was in control (T_1). During 2017-2018, the maximum (0.764 cm) was in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), and minimum (0.652 cm) was in Trunk girdling +flower thinning (T_{13}). The pooled data revealed that maximum seed length (0.756 cm) was found in GA_3 (T_5), while the minimum (0.660 cm) was recorded in Trunk girdling +flower thinning (T_{13}).

4.2.3.10 Seed width (cm)

The treatments differed significantly with respect to seed width as presented in Table 4.2.15. During 2016-2017 and 2017-2018, the highest seed width was recorded in manual berry thinning (T_3) and manual berry thinning + GA_3 + ethephon (T_{12}) (0.563 and 0.545 cm), while, the minimum was in Control (T_1) and manual Berry thinning + GA_3 + ethephon (T_{19}) (0.408 and 0.399 cm.). Pooled data revealed that the maximum seed width (0.539 cm) was obtained in manual berry thinning + GA_3 + ethephon (T_{12}). It was followed by manual berry thinning (T_3) (0.520 cm), whereas, the minimum was in T_{19} (0.412 cm).

Table 4.2.12 Effect of crop regulation on individual berry transversal diameter & berry volume

Treatments	Berry transversal diameter (cm)			Berry volume (cc)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	1.76	1.90	1.83	12.79	12.91	12.85
T_2	1.79	1.90	1.84	13.01	13.10	13.06
T_3	1.84	1.91	1.87	13.85	14.03	13.94
T_4	1.89	1.95	1.92	13.55	13.72	13.63
T_5	2.03	2.08	2.06	14.86	14.88	14.87
T_6	1.96	2.09	2.03	14.33	14.53	14.43
T_7	1.83	1.98	1.91	13.37	14.02	13.70
T_8	1.94	2.07	2.01	14.48	14.62	14.55
T_9	2.07	2.09	2.08	13.99	14.14	14.06
T_{10}	1.96	2.02	1.99	13.91	14.10	14.00
T_{11}	2.00	2.06	2.03	13.50	13.59	13.55
T_{12}	1.96	2.03	2.00	13.46	13.87	13.67
T_{13}	2.00	2.09	2.04	14.20	14.35	14.27
T_{14}	1.96	2.03	1.99	14.16	14.44	14.30
T_{15}	1.99	2.02	2.01	14.26	14.42	14.34
T_{16}	2.00	2.11	2.05	14.36	14.47	14.42
T_{17}	2.01	2.05	2.03	14.60	14.77	14.69
T_{18}	2.01	2.33	2.17	14.83	15.02	14.93
T_{19}	2.10	2.64	2.37	15.19	15.74	15.47
Sem ±)	0.06	0.05	0.04	0.27	0.23	0.24
CD (0.05)	0.12	0.11	0.09	0.55	0.48	0.50

Table 4.2.13 Effect of crop regulation on hundred berry weights & skin thickness

Treatments	Hundred berry weights (g)			Skin thickness (mm)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	406.18	471.54	438.86	0.043	0.046	0.044
T_2	455.36	466.58	460.97	0.045	0.050	0.048
T_3	483.65	485.91	484.78	0.049	0.054	0.052
T_4	485.40	495.48	490.44	0.052	0.057	0.055
T_5	472.92	483.23	478.08	0.058	0.062	0.060
T_6	491.09	503.89	497.49	0.061	0.066	0.063
T_7	483.85	495.78	489.81	0.063	0.068	0.066
T_8	502.55	509.45	506.00	0.066	0.070	0.068
T_9	497.37	510.37	503.87	0.069	0.073	0.071
T_{10}	480.85	515.43	498.14	0.072	0.076	0.074
T_{11}	512.33	532.70	522.52	0.075	0.078	0.077
T_{12}	508.34	533.28	520.81	0.087	0.088	0.088
T_{13}	514.94	527.05	521.00	0.056	0.065	0.060
T_{14}	534.40	563.12	548.76	0.061	0.072	0.066
T_{15}	558.43	578.22	568.32	0.081	0.083	0.082
T_{16}	569.62	599.39	584.51	0.083	0.084	0.084
T_{17}	589.15	626.60	607.88	0.084	0.085	0.085
T_{18}	617.32	689.66	653.49	0.085	0.087	0.086
T_{19}	697.30	765.36	731.33	0.078	0.081	0.080
Sem ±)	23.92	22.33	21.36	0.0009	0.0013	0.0008
CD (0.05)	48.35	45.14	43.17	0.0018	0.0026	0.0018

Table 4.2.14 Effect of crop regulation on pedicel thickness & seed weight

Treatments	Pedicel thickness (mm)			Seed weight (g)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	2.78	3.08	2.93	0.068	0.063	0.066
T_2	3.26	3.31	3.29	0.075	0.074	0.075
T_3	3.31	3.37	3.34	0.071	0.075	0.073
T_4	2.98	3.49	3.24	0.063	0.066	0.064
T_5	3.37	3.36	3.37	0.080	0.083	0.081
T_6	3.16	3.27	3.22	0.063	0.068	0.065
T_7	3.74	4.15	3.95	0.072	0.058	0.065
T_8	2.91	2.95	2.93	0.069	0.070	0.069
T_9	2.87	2.95	2.91	0.061	0.064	0.062
T_{10}	3.14	3.23	3.18	0.061	0.069	0.065
T_{11}	3.33	3.50	3.42	0.075	0.076	0.075
T_{12}	2.98	3.21	3.09	0.067	0.075	0.071
T_{13}	3.37	3.43	3.40	0.083	0.085	0.084
T_{14}	3.24	3.38	3.31	0.081	0.077	0.079
T_{15}	3.25	3.30	3.28	0.067	0.072	0.070
T_{16}	3.22	3.28	3.25	0.061	0.066	0.064
T_{17}	3.31	3.41	3.36	0.068	0.074	0.071
T_{18}	3.45	3.81	3.63	0.078	0.080	0.079
T_{19}	3.12	3.38	3.25	0.064	0.053	0.059
Sem ±)	0.16	0.13	0.13	0.01	0.008	0.007
CD (0.05)	0.34	0.27	0.27	0.02	0.016	0.014

Table 4.2.15 Effect of crop regulation on seed length & seed width and seed number

Treatments	Seed length (cm)			Seed width (cm)			Seed number		
	2016 -17	**2017-18**	**Pooled**	**2016 -17**	**2017-18**	**Pooled**	**2016 -17**	**2017-18**	**Pooled**
T_1	0.481	0.670	0.694	0.408	0.453	0.431	3.29	3.00	3.15
T_2	0.713	0.721	0.717	0.428	0.434	0.431	3.33	3.31	3.32
T_3	0.742	0.741	0.741	0.563	0.478	0.520	2.23	2.28	2.25
T_4	0.670	0.690	0.680	0.439	0.448	0.443	2.46	2.43	2.45
T_5	0.773	0.738	0.756	0.479	0.486	0.483	2.36	2.49	2.42
T_6	0.712	0.710	0.711	0.413	0.467	0.440	2.34	3.21	2.77
T_7	0.739	0.663	0.701	0.469	0.433	0.451	2.84	2.69	2.76
T_8	0.720	0.736	0.728	0.457	0.464	0.461	2.45	2.50	2.48
T_9	0.669	0.706	0.687	0.422	0.461	0.442	2.67	2.64	2.66
T_{10}	0.709	0.722	0.716	0.439	0.449	0.444	2.15	2.04	2.10
T_{11}	0.712	0.728	0.720	0.486	0.480	0.483	2.21	2.14	2.18
T_{12}	0.628	0.718	0.673	0.533	0.545	0.539	2.58	2.83	2.71
T_{13}	0.668	0.652	0.660	0.447	0.425	0.436	2.06	2.27	2.16
T_{14}	0.710	0.736	0.723	0.466	0.474	0.470	2.57	2.47	2.52
T_{15}	0.726	0.735	0.730	0.464	0.477	0.471	2.78	2.82	2.80
T_{16}	0.669	0.723	0.696	0.455	0.481	0.468	2.82	3.08	2.95
T_{17}	0.717	0.745	0.731	0.481	0.496	0.489	2.71	3.15	2.93
T_{18}	0.732	0.754	0.743	0.493	0.504	0.498	2.18	2.76	2.47
T_{19}	0.734	0.764	0.749	0.426	0.399	0.412	2.59	3.19	2.89
Sem ±)	0.055	0.040	0.037	0.050	0.020	0.031	0.23	0.26	0.20
CD (0.05)	0.113	0.080	0.075	0.100	0.050	0.063	0.47	0.54	0.41

4.2.3.11 Seed number

Noticeable variations were obtained among the treatments with regards to seed number (Table 4.2.15) during the two years of experimentations. During 2016-17, the maximum seed number (3.33) was obtained in flower thinning (T_2), while, in 2017-2018, the same treatment also recorded the maximum value (3.31). The minimum (2.06 and 2.04) seed number was obtained in Trunk girdling + flower thinning (T_{13}) and Manual berry thinning + GA_3 (T_{10}) in the two years of studies. In case of Pooled data, the maximum seed number (3.32) was recorded in Flower thinning (T_2) while, the minimum (2.10) was recorded in Manual berry thinning + GA_3 (T_{10}).

4.2.4 Quality parameters

4.2.4.1 Moisture (%)

Data depicted in Table 4.2.16 shows that moisture per cent differed remarkably with various crop regulations during the two years of investigations. During 2016-2017 and 2017-2018, manual berry thinning + GA_3 + ethephon (T_{12}) recorded the minimum moisture content (79.16 and 78.37 %). The maximum moisture content (%) in the two years was obtained in Flower thinning + GA_3 + ethephon (T_9) (85.10 and 82.62% respectively). Pooled analysis of the two years revealed that the minimum moisture (78.77%) was found in manual berry thinning + GA_3 + ethephon (T_{12}) while the maximum (83.86 %) was recorded in Pig manure + flower thinning + GA_3 + ethephon (T_9).

4.2.4.2 Juice (%)

Significant differences were observed among the treatments with respect to juice content as influenced by crop regulations (Table 4.2.16). For the year 2016-2017, the juice content ranged between 61.73 and 71.13 per cent, while, during 2017-2018, it ranged between 62.94 and 72.32 per cent. Pooled analysis of the two years data revealed that Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) showed the maximum juice content (71.73 %). It is followed by Trunk Girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (68.68 %) whereas, Trunk girdling +flower thinning (T_{13}) revealed the minimum juice content (61.55 %).

4.2.4.3 Total soluble solids (TSS) (°B)

The data presented in Table 4.2.17 showed that different treatments had significant impact on TSS of the berries. For the years 2016- 2017 and 2017-2018, the maximum TSS was recorded in Trunk girdling +flower thinning + GA_3 +

ethephon (T_{18}) (20.50 and 21.71 °B), while the minimum (15.03 and 15.32 °B) was recorded in Flower thinning + GA_3 + ethephon (T_9) and control (T_1). Pooled analysis of the data revealed that maximum TSS (21.10 °B) was obtained in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), followed by Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (20.43 °B) in while the minimum was obtained in control (T_1) (15.17 °B).

4.2.4.4 Titratable acidity (%)

It is clear from the data depicted in Table 4.2.17 that acidity of the berries varied remarkably with various crop regulations in the two years of investigations. The data shown in the Table revealed that for the year 2016-2017, the minimum titratable acidity (0.608 %) was recorded in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), while the maximum was recorded in control (T_1) (0.864 %). In 2017-2018, also the same two treatments recorded the minimum and maximum value with respect to titratable acidity (0.602 and 0.884 %). Pooled data of both the years showed that the minimum (0.605 %) acidity was obtained in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), while the maximum (0.874 %) was in control (T_1).

4.2.4.5 TSS: Acid Ratio

Marked variations were recorded among the treatments with respect to TSS: acid ratio content of the berries (Table 4.2.17). Among all the treatments, the maximum TSS: acid ratio was recorded with Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), (33.71 and 36.09) in 2016- 2017 and 2017-2018 respectively. Pooled data of the two years showed the maximum TSS: acid ratio (34.89) was obtained in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), which was statistically at par with Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), (32.76). The minimum TSS: acid ratio (17.36) was obtained in control (T_1).

4.2.4.6 Reducing sugars (%)

The perusal of the data presented in Table 4.2.18 clearly revealed that various crop regulations remarkably impact the amount of reducing sugars in Bangalore blue grapes. For the year 2016-2017, the maximum reducing sugars (14.39 %) was recorded in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), whereas the minimum (10.14 %) was in control (T_1). Similarly, during 2017-2018, the Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), showed the maximum (14.90 %) reducing sugars, whereas the minimum (10.37 %) was obtained in control (T_1). Pooled analysis of data for the two years showed that maximum reducing sugars (14.64%) was obtained in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), which was significantly higher than all other treatments, while the least (10.26%) was obtained in control (T_1).

4.2.4.7 Total sugars (%)

The presented data in Table 4.2.18 showed that during 2016-2017 and 2017-2018, the maximum total sugars (15.93 and 16.44 %) were found in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), whereas the minimum (11.31 and 11.61 %) was in T_1 (control). Pooled analysis of data for the two years revealed that the maximum total sugars (16.18 %) was found in Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}) which was statistically at par with Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (16.00 %), while the minimum (11.46 %) was in control.

4.2.4.8 Non- reducing sugars (%)

Data presented in Table 4.2.19 declared that non-reducing sugars of the grape berries differed remarkably by various crop regulation treatments during the two years of investigations. Among all the treatments, Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}) recorded the maximum non-reducing sugars (1.86 and 1.88 %) for the years 2016-2017 and 2017-2018 respectively. Pooled analysis of data revealed that the maximum non- reducing sugars (1.87 %) was found in Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}) which was significantly higher than all other treatments, while the minimum (1.44 %) was obtained in control (T_1).

4.2.4.9 Sugar-acid ratio

Table 4.2.19 revealed that there were noticeable variations among the treatments with respect to sugar: acid ratio. During 2016-2017 and 2017-2018, the maximum sugar: acid ratio (26.19 and 27.32) was found in Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}), while the minimum (13.10 and 13.15) was recorded in T_1 (control). Pooled analysis of data revealed that the maximum sugar: acid ratio (26.75) was recorded in Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}), which was statistically at par with Trunk Girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (25.67), while the minimum (13.11) was recorded in control.

Table 4.2.16 Effect of crop regulation on moisture & juice

Treatments	Moisture (%)			Juice (%)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	83.36	81.93	82.64	62.20	62.54	62.37
T_2	81.72	81.28	81.50	63.73	64.05	63.89
T_3	79.84	79.40	79.62	61.73	62.94	62.34
T_4	79.53	79.23	79.38	63.83	64.46	64.15
T_5	83.71	81.98	82.85	64.05	64.80	64.43
T_6	81.20	79.90	80.55	61.90	62.93	62.41
T_7	83.98	82.39	83.19	64.62	65.65	65.14
T_8	80.40	79.41	79.91	61.98	63.24	62.61
T_9	85.10	82.62	83.86	62.67	63.66	63.17
T_{10}	83.25	82.38	82.81	65.03	66.00	65.51
T_{11}	79.32	78.72	79.02	61.93	62.95	62.44
T_{12}	79.16	78.37	78.77	64.85	65.64	65.25
T_{13}	82.22	81.04	81.63	61.11	62.00	61.55
T_{14}	81.72	80.56	81.14	63.05	64.05	63.55
T_{15}	84.09	82.64	83.37	65.69	66.33	66.01
T_{16}	81.98	80.81	81.39	63.44	64.77	64.11
T_{17}	84.28	82.00	83.14	67.05	67.89	67.47
T_{18}	84.89	82.61	83.75	71.13	72.32	71.73
T_{19}	83.73	81.90	82.81	68.21	69.15	68.68
Sem ±)	0.64	0.66	0.61	0.97	0.93	0.91
CD (0.05)	1.31	1.35	1.23	1.96	1.88	1.84

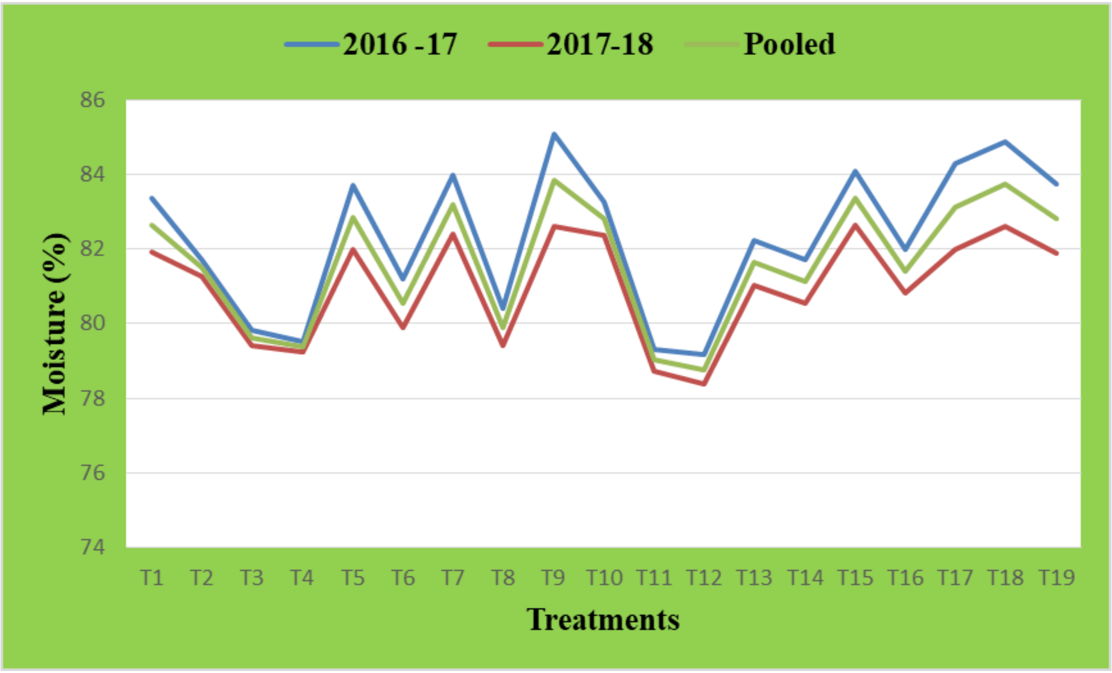

Fig. 4.2.8 Effect of crop regulation on moisture content (%)

Table 4.2.17 Effect of crop regulation on TSS & titratable acidity

Treatments	Total soluble solids (TSS)			Titratable acidity			TSS: Acid ratio		
	2016 -17	**2017-18**	**Pooled**	**2016-17**	**2017-18**	**Pooled**	**2016 -17**	**2017-18**	**Pooled**
T_1	15.03	15.32	15.17	0.864	0.884	0.874	17.39	17.36	17.37
T_2	15.67	15.91	15.79	0.839	0.849	0.844	18.68	18.76	18.72
T_3	15.94	16.33	16.13	0.837	0.844	0.841	19.05	19.38	19.21
T_4	16.43	16.84	16.64	0.819	0.814	0.816	20.07	20.69	20.38
T_5	16.95	17.84	17.40	0.666	0.665	0.666	25.61	26.93	26.18
T_6	17.52	17.94	17.73	0.694	0.758	0.726	25.39	23.76	24.43
T_7	17.63	18.46	18.05	0.625	0.614	0.620	28.20	30.09	29.14
T_8	18.10	19.00	18.55	0.776	0.751	0.763	23.41	25.39	24.38
T_9	19.22	19.82	19.52	0.863	0.831	0.847	22.34	23.87	23.09
T_{10}	18.32	19.10	18.71	0.641	0.631	0.636	28.68	30.39	29.53
T_{11}	18.55	19.39	18.97	0.733	0.714	0.724	25.37	27.14	26.23
T_{12}	19.74	20.19	19.97	0.679	0.654	0.666	29.14	30.97	29.98
T_{13}	18.87	19.61	19.24	0.846	0.816	0.831	22.39	24.04	23.19
T_{14}	19.01	19.73	19.37	0.876	0.842	0.859	21.81	23.48	22.62
T_{15}	19.27	19.93	19.60	0.680	0.658	0.669	28.44	30.35	29.38
T_{16}	19.64	20.07	19.85	0.731	0.713	0.722	27.26	28.53	27.89
T_{17}	19.89	20.41	20.15	0.680	0.630	0.655	29.45	32.41	30.85
T_{18}	20.50	21.71	21.10	0.608	0.602	0.605	33.71	36.09	34.89
T_{19}	20.15	20.70	20.43	0.632	0.615	0.624	31.88	33.68	32.76
Sem ±)	0.16	0.24	0.13	0.039	0.034	0.032	1.45	1.34	1.22
CD (0.05)	0.32	0.49	0.26	0.079	0.070	0.066	2.93	2.72	2.47

Table 4.2.18 Effect of crop regulation on reducing sugar & total sugars

Treatments	Reducing sugar (%)			Total sugars (%)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	10.14	10.37	10.26	11.31	11.61	11.46
T_2	10.65	11.07	10.86	11.87	12.31	12.09
T_3	10.92	11.53	11.23	12.16	12.77	12.47
T_4	11.36	11.82	11.59	12.63	13.08	12.85
T_5	11.58	12.12	11.85	12.87	13.40	13.14
T_6	12.18	12.25	12.22	13.49	13.55	13.52
T_7	12.69	12.36	12.53	14.01	13.67	13.84
T_8	12.79	12.56	12.67	14.15	13.89	14.02
T_9	13.69	14.37	14.03	15.16	15.82	15.49
T_{10}	13.04	12.91	12.97	14.41	14.24	14.32
T_{11}	13.03	13.38	13.21	14.43	14.73	14.58
T_{12}	14.02	14.42	14.22	15.50	15.90	15.70
T_{13}	13.13	13.99	13.56	14.54	15.35	14.95
T_{14}	13.29	14.10	13.70	14.73	15.49	15.11
T_{15}	13.35	14.14	13.74	14.79	15.55	15.17
T_{16}	13.54	14.22	13.88	15.01	15.64	15.33
T_{17}	14.16	14.58	14.37	15.64	16.07	15.86
T_{18}	14.39	14.90	14.64	15.93	16.44	16.18
T_{19}	14.23	14.74	14.49	15.74	16.27	16.00
Sem ±)	0.17	0.14	0.12	0.17	0.14	0.12
CD (0.05)	0.35	0.3	0.24	0.35	0.29	0.24

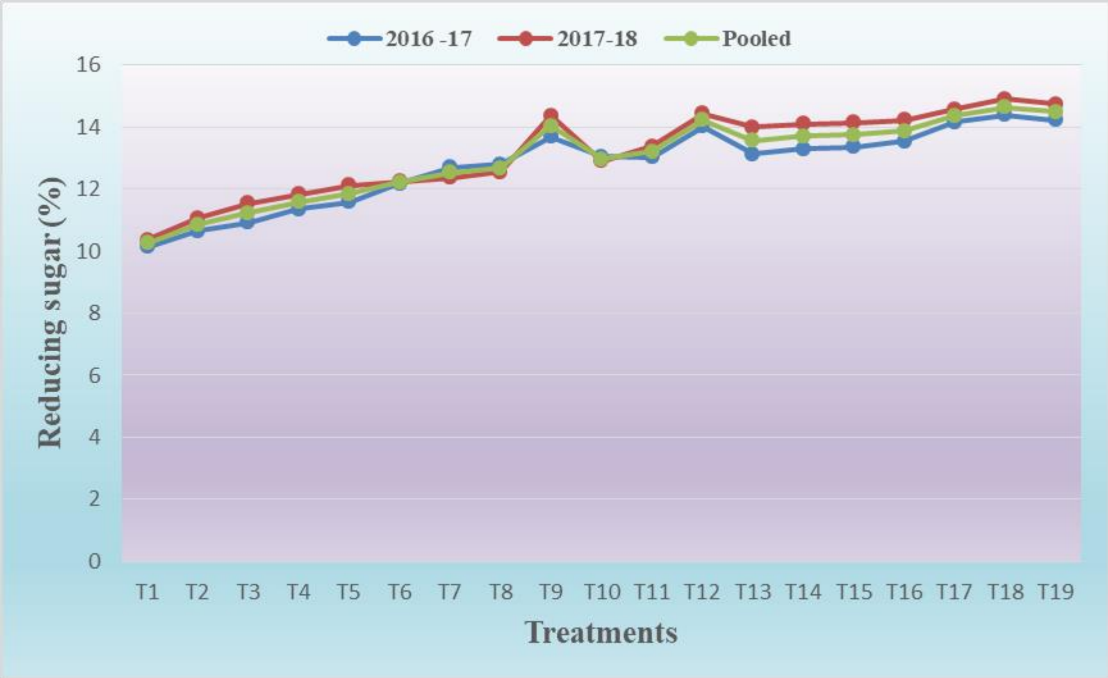

Fig. 4.2.9 Effect of crop regulation on reducing sugars (%)

Table 4.2.19 Effect of crop regulation on non- reducing sugar & sugar-acid ratio

Treatments	Non- reducing sugar (%)			Sugar-acid ratio		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	1.40	1.47	1.44	13.10	13.15	13.11
T_2	1.46	1.49	1.47	14.14	14.52	14.33
T_3	1.49	1.50	1.50	14.54	15.17	14.85
T_4	1.52	1.53	1.53	15.43	16.06	15.75
T_5	1.56	1.55	1.56	19.44	20.23	19.77
T_6	1.59	1.57	1.58	19.52	17.94	18.63
T_7	1.60	1.59	1.60	22.41	22.29	22.35
T_8	1.65	1.61	1.63	18.31	18.55	18.43
T_9	1.78	1.77	1.78	17.65	19.06	18.34
T_{10}	1.66	1.62	1.64	22.56	22.63	22.60
T_{11}	1.69	1.65	1.67	19.74	20.62	20.16
T_{12}	1.80	1.81	1.80	22.89	24.39	23.57
T_{13}	1.70	1.67	1.69	17.25	18.83	18.02
T_{14}	1.74	1.70	1.72	16.90	18.43	17.64
T_{15}	1.74	1.72	1.73	21.82	23.67	22.73
T_{16}	1.78	1.75	1.76	20.82	22.24	21.52
T_{17}	1.81	1.82	1.82	23.16	25.53	24.29
T_{18}	1.86	1.88	1.87	26.19	27.32	26.75
T_{19}	1.82	1.86	1.84	24.89	26.47	25.67
Sem ±)	0.01	0.01	0.01	1.13	0.98	0.94
CD (0.05)	0.03	0.03	0.02	2.28	1.99	1.91

4.2.4.10 Ascorbic acid (mg $100g^{-1}$)

Marked variations were recorded among the treatments with respect to ascorbic acid content of the berries (Table 4.2.20). Among all the treatments, the maximum ascorbic content was recorded with Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}) (25.19 and 25.40 mg $100g^{-1}$) in 2016- 2017 and 2017-2018 respectively. Pooled data of the two years showed the maximum ascorbic acid content (25.29 mg $100g^{-1}$) was obtained in Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}) which was significantly higher than other treatments, followed by Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (24.24 mg $100g^{-1}$). The minimum ascorbic acid content (20.62 mg $100g^{-1}$) was obtained in control (T_1).

4.2.4.11 Anthocyanin (mg g^{-1})

There were noticeable variations among the treatments with respect to anthocyanin content of the berries during the two years of investigations. The data presented in the Table 4.2.20 revealed that in 2016-2017, anthocyanin varied between 2.29 and 4.09 mg g^{-1} and in 2017-2018, it ranged between 2.20 and 4.21 mg g^{-1} respectively. The pooled analysis of the data revealed that manual berry thinning + GA_3 + ethephon (T_{12}) recorded the maximum anthocyanin (4.15 mg g^{-1}), while, control (T_1) recorded the minimum anthocyanin (2.25 mg g^{-1}).

4.2.4.12 Total carotenoids (µg g^{-1})

The total carotenoids content of the berries differed significantly among the treatments as depicted in the Table 4.2.21. For the year 2016-2017, the maximum total carotenoids content (10.84 µg g^{-1}) was found in Flower thinning + GA_3 +

ethephon (T_9). In 2017- 2018, the same treatment revealed the maximum total carotenoids (11.26 µg g^{-1}). The pooled analysis of data revealed that the maximum total carotenoids content (11.05 µg g^{-1}) was recorded with Flower thinning + GA_3 + ethephon (T_9), which was significantly higher than all other treatments, while the least (6.79 µg g^{-1}) was recorded in control (T_1).

4.2.4.13 Raisin recovery (%)

Significant variations were observed among the different crop regulation treatments with respect to raisin recovery during the two years of investigation (Table 4.2.21). During, 2016-2017, the maximum raisin recovery (25.65 %) was recorded with Trunk girdling + GA_3 + ethephon (T_{17}). Likewise, in 2017-2018, the same treatment recorded the maximum raisin recovery (25.99 %). Pooled analysis of data declared the maximum raisin recovery (25.82 %) was recorded with Trunk girdling + GA_3 + ethephon (T_{17}), followed by Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) (24.41 %), whereas the minimum (20.60 %) was found in control (T_1).

4.2.4.14 Protein (mg g^{-1})

The protein content of the berries varied significantly with respect to different crop regulations practices as presented in Table 4.2.22. For 2016-2017, the protein content ranged from 4.77 to 7.17 mg g^{-1}, while, in 2017-2018, it ranged between 5.03 to 7.37 mg g^{-1}. Pooled analysis of data for both the years revealed that the maximum protein (7.27 g 100g^{-1}) was obtained with Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{18}), while the minimum (4.90 mg g^{-1}) was recorded in T_1 (control).

4.2.4.15 Starch (mg g^{-1})

Starch content of the berries were significantly influenced by various treatments during the two years of experimentation (Table 4.2.22). For 2016-17, the maximum starch content was found in flower thinning flower thinning + GA_3 + ethephon (T_9) (4.34 mg g^{-1}). Similarly, in 2017-18, flower thinning + GA_3 + ethephon (T_9) recorded the maximum value (4.89 mg g^{-1}). Pooled data revealed that flower thinning + GA_3 + ethephon (T_9) recorded the maximum starch content (4.62 mg g^{-1}), while the lowest (2.08mg g^{-1}) was recorded in control (T_1).

4.2.4.16 Carbohydrate (mg g^{-1})

It is clearly observed from the data presented in Table 4.2.23 that carbohydrate content of the berries varied remarkably with various crop regulations treatments. In 2016-2017, the carbohydrate content ranged from 51.90 and 81.62 mg g^{-1}, while, in 2017-2018, it ranged between 56.12 to 83.13 mg g^{-1}. Pooled analysis of data for both the years revealed the maximum carbohydrate content (82.37 mg g^{-1}) was recorded in manual berry thinning + ethephon (T_{11}), while the minimum (54.01 mg g^{-1}) was in T_1 (control).

4.2.4.17 Total phenols (mg g^{-1})

Various crop regulations significantly influenced the total phenols of the berries (Table 4.2.23) during the two years of investigations. In 2016-2017, the maximum total phenols (0.86 mg g^{-1}) was recorded in Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}), while, during, 2017-2018, the same treatment recorded maximum value (0.88 mg g^{-1}). During 2016-2017 and 2017-2018, the minimum total phenols were found in control (T_1) (0.59 and 0.63 mg g^{-1}). Pooled analysis of data for both the years revealed the maximum total phenols (0.87 mg g^{-1})

was found in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), which was statistically at par with Trunk Girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (0.86 mg g^{-1}). However, the minimum (0.61 mg g^{-1}) was found in control (T_1).

Table 4.2.20 Effect of crop regulation on ascorbic acid & anthocyanin

Treatments	Ascorbic acid (mg $100g^{-1}$)			Anthocyanin (mg g^{-1})		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	20.56	20.68	20.62	2.29	2.20	2.25
T_2	21.29	21.43	21.36	2.45	2.46	2.46
T_3	21.15	21.23	21.19	2.90	2.98	2.94
T_4	21.86	21.68	21.77	3.10	3.18	3.14
T_5	23.26	23.65	23.45	3.43	3.46	3.44
T_6	21.68	21.95	21.81	3.06	3.11	3.09
T_7	23.30	23.58	23.44	3.48	3.56	3.52
T_8	21.09	21.51	21.30	2.64	2.75	2.70
T_9	21.14	21.77	21.46	2.65	2.81	2.73
T_{10}	23.42	23.58	23.50	3.52	3.60	3.56
T_{11}	22.21	22.20	22.21	2.59	2.93	2.76
T_{12}	23.58	23.79	23.68	4.09	4.21	4.15
T_{13}	22.79	23.21	23.00	3.18	3.21	3.20
T_{14}	22.21	22.54	22.38	3.19	3.28	3.24
T_{15}	23.66	24.01	23.83	3.62	3.75	3.69
T_{16}	23.18	23.45	23.32	3.34	3.42	3.38
T_{17}	23.60	24.02	23.81	3.56	3.67	3.62
T_{18}	25.19	25.40	25.29	3.64	3.89	3.77
T_{19}	24.06	24.42	24.24	3.63	3.66	3.65
Sem ±)	0.51	0.44	0.44	0.12	0.13	0.12
CD (0.05)	1.04	0.89	0.90	0.25	0.27	0.24

Table 4.2.21 Effect of crop regulation on total carotenoids & raisin recovery

Treatments	Total carotenoids (μg g^{-1})			Raisin recovery (%)		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	6.70	6.87	6.79	20.37	20.83	20.60
T_2	7.06	7.33	7.20	21.17	21.35	21.26
T_3	7.71	7.81	7.76	21.43	22.07	21.75
T_4	7.73	7.83	7.78	22.07	22.53	22.30
T_5	8.33	8.43	8.38	22.84	23.26	23.05
T_6	7.76	7.83	7.79	21.85	22.31	22.08
T_7	8.42	8.58	8.50	22.85	23.39	23.12
T_8	7.66	7.72	7.69	22.40	22.60	22.50
T_9	10.84	11.26	11.05	22.47	22.68	22.58
T_{10}	8.48	8.66	8.57	23.01	23.46	23.24
T_{11}	7.82	7.90	7.86	22.28	22.67	22.48
T_{12}	8.55	8.68	8.61	23.39	23.53	23.46
T_{13}	7.76	8.04	7.90	22.70	23.22	22.96
T_{14}	7.84	8.02	7.93	23.02	23.19	23.11
T_{15}	8.73	8.85	8.79	23.71	23.76	23.74
T_{16}	8.35	8.51	8.43	23.13	23.43	23.28
T_{17}	8.67	8.95	8.81	25.65	25.99	25.82
T_{18}	9.55	9.94	9.75	24.18	24.64	24.41
T_{19}	7.60	7.68	7.64	23.68	23.82	23.75
Sem ±)	0.18	0.16	0.11	0.33	0.26	0.26
CD (0.05)	0.38	0.33	0.22	0.67	0.54	0.52

Table 4.2.22 Effect of crop regulation on protein & starch

Treatments	Protein (mg g^{-1})			Starch (mg g^{-1})		
	2016 -17	**2017-18**	**Pooled**	**2016 -17**	**2017-18**	**Pooled**
T_1	4.77	5.03	4.90	2.00	2.16	2.08
T_2	5.13	5.30	5.22	2.12	2.47	2.30
T_3	4.87	5.13	5.00	2.31	3.02	2.67
T_4	5.70	5.70	5.70	2.68	2.98	2.83
T_5	6.33	6.33	6.33	2.93	3.11	3.02
T_6	5.97	6.07	6.02	3.08	3.39	3.23
T_7	5.70	6.43	6.07	3.16	3.82	3.49
T_8	5.77	6.03	5.90	3.33	3.99	3.66
T_9	5.43	5.63	5.53	4.34	4.89	4.62
T_{10}	6.10	6.23	6.17	3.44	4.21	3.82
T_{11}	5.67	6.07	5.87	3.55	4.31	3.93
T_{12}	5.80	6.27	6.03	4.15	4.31	4.23
T_{13}	5.43	5.90	5.67	3.61	4.36	3.98
T_{14}	5.33	5.77	5.55	3.76	4.43	4.09
T_{15}	5.90	6.30	6.10	3.91	4.50	4.20
T_{16}	6.00	6.23	6.12	3.99	4.58	4.29
T_{17}	6.10	6.27	6.18	4.22	4.66	4.44
T_{18}	7.17	7.37	7.27	4.27	4.78	4.53
T_{19}	6.27	6.43	6.35	4.04	4.15	4.09
Sem ±)	0.26	0.23	0.19	0.07	0.12	0.06
CD (0.05)	0.52	0.48	0.40	0.15	0.26	0.13

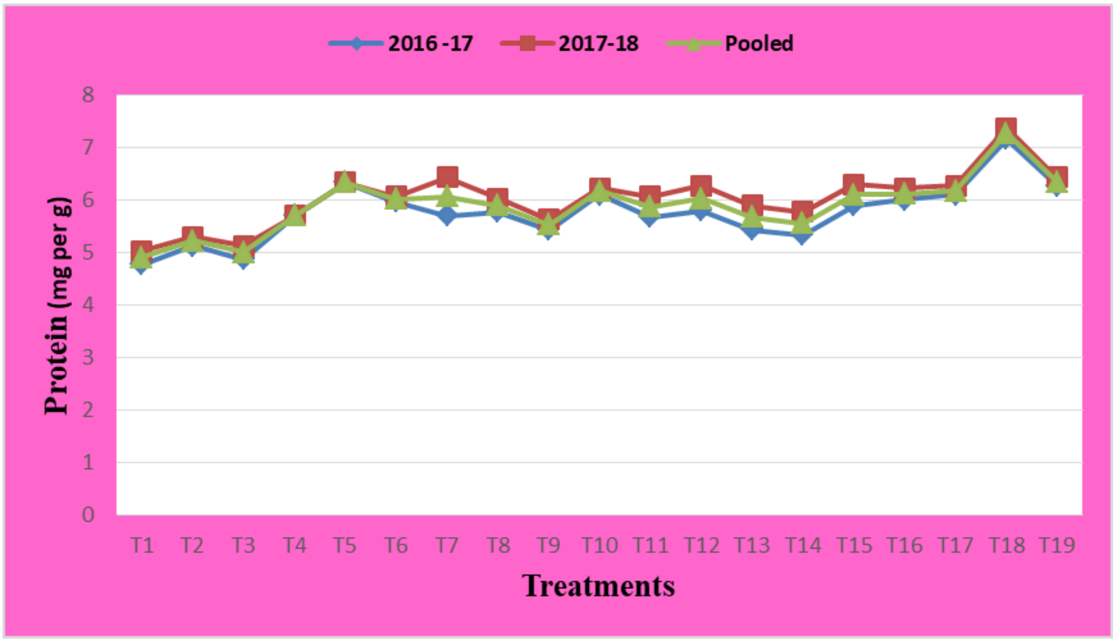

Fig. 4.2.10 Effect of crop regulation on protein content of berries

Table 4.2.23 Effect of crop regulation on carbohydrate & total phenols

Treatments	Carbohydrates Content (mg g^{-1})			Total Phenols (mg g^{-1})		
	2016 -17	2017-18	Pooled	2016 -17	2017-18	Pooled
T_1	51.90	56.12	54.01	0.59	0.63	0.61
T_2	54.97	57.34	56.15	0.59	0.64	0.62
T_3	58.07	59.70	58.89	0.60	0.68	0.64
T_4	60.25	62.40	61.33	0.61	0.67	0.64
T_5	62.40	65.56	63.98	0.63	0.68	0.65
T_6	64.95	68.63	66.79	0.64	0.70	0.67
T_7	67.82	72.90	70.36	0.66	0.72	0.69
T_8	69.65	74.74	72.20	0.68	0.73	0.71
T_9	78.40	80.82	79.61	0.79	0.82	0.80
T_{10}	71.13	76.26	73.70	0.69	0.74	0.72
T_{11}	81.62	83.13	82.37	0.70	0.76	0.73
T_{12}	79.00	80.81	79.91	0.81	0.83	0.82
T_{13}	74.74	77.76	76.25	0.72	0.77	0.74
T_{14}	75.49	77.96	76.73	0.74	0.77	0.76
T_{15}	76.51	78.53	77.52	0.76	0.79	0.78
T_{16}	77.65	79.21	78.43	0.78	0.81	0.79
T_{17}	79.59	81.75	80.67	0.82	0.85	0.84
T_{18}	80.51	82.11	81.31	0.86	0.88	0.87
T_{19}	72.92	77.08	75.00	0.84	0.87	0.86
Sem ±)	0.64	0.63	0.41	0.01	0.01	0.01
CD (0.05)	1.30	1.28	0.84	0.02	0.02	0.01

4.2.5 Economics of cultivation and Benefit: Cost ratio

Perusal of the data pertaining to Table 4.2.24 revealed that the highest gross expenditure (Rs. 4,89,657.55) was recorded with Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), followed by (Rs. 4,88,748.55) in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) whereas it was observed lowest (Rs. 4,60,670.55) in control (T_1). The highest gross income (Rs. 23,43,600.00), was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), it was followed by (Rs. 21,17,500.00) was observed in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), while, the lowest gross income (Rs. 7,27,300.00) was observed in control (T_1). Among all the treatments, the highest net income (Rs. 18,53,942.45) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), followed by Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), (16,28,751.45), while the lowest net income (Rs. 2,66,629.45) was recorded in control (T_1). Among all the treatments, the highest B:C ratio (3.79) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), which was followed Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}) (3.33) while the lowest (0.58) was recorded in control.

Table 4.2.24 Gross expenditure, gross income, net income and B: C ratio under the influence of crop regulation

Treatments	Gross Expenditure (Rs)	Gross Income (Rs)	Net Income (Rs)	B:C ratio
T_1	460670.55	727300.00	266629.45	0.58
T_2	465215.55	857500.00	392284.45	0.84
T_3	466124.55	1040200.00	574075.45	1.23
T_4	466730.55	1423100.00	956369.45	2.05
T_5	467033.55	1567300.00	1100266.45	2.36
T_6	471780.55	1507100.00	1035319.45	2.19
T_7	471578.55	1552600.00	1081021.45	2.29
T_8	476325.55	1604400.00	1128074.45	2.37
T_9	482688.55	2049600.00	1566911.45	3.25
T_{10}	472487.55	1796900.00	1324412.45	2.80
T_{11}	477234.55	1777300.00	1300065.45	2.72
T_{12}	483597.55	1793400.00	1309802.45	2.71
T_{13}	471275.55	1512000.00	1040724.45	2.21
T_{14}	472184.55	1444100.00	971915.45	2.06
T_{15}	473093.55	1929200.00	1456106.45	3.08
T_{16}	477840.55	2012500.00	1534659.45	3.21
T_{17}	484203.55	1969800.00	1485596.45	3.07

T_{18}	488748.55	2117500.00	1628751.45	3.33
T_{19}	489657.55	2343600.00	1853942.45	3.79

Discussion

The present investigation entitled "Organic nutrient management and crop regulation in Grapes in Mizoram" was performed at Vengthar and Vengsang village of Champhai District, Mizoram, for two fruiting seasons i.e. 2016-2017 and 2017- 2018 in order to develop an efficient organic production technology and to reduce the cost of production and to improve soil nutrients status for better yield and quality of Bangalore Blue grapes. The results of the present investigation presented in the preceding chapter have been discussed in this chapter in the light of the findings of other workers and with the appropriate reasonings under various heads and subheads.

5.1 1st Experiment: Effect of organic manures and bio-dynamic preparations on growth, yield and quality of Grapes cv. Bangalore Blue

5.1.1 Plant growth characters

Integration of organic manures and bio-dynamic preparations influenced the vegetative growth of the grape cv. Bangalore Blue over the control during the two years of investigations. Among all the treatments, the pooled data revealed that the maximum shoot length (122.23 cm) was recorded from the plants applied with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). With respect to shoot diameter, the maximum (20.83 mm) shoot diameter was recorded with PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{12}) which was significantly higher than all other treatments.

The results of two years data as well as the pooled analysis revealed that integration of organics and bio-dynamic preparations were also significantly influenced the intermodal length and cane diameter of the grape vines as compared to control (without any manures and fertilizers) and farmers practice. The pooled data showed that NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}) showed the maximum intermodal length (12.43 cm) and cane diameter (6.70 mm) followed by VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) while, the least was recorded in control.

The positive results with combined application of organics and bio-dynamic preparations in improving the vegetative growth of grapes might be due to the improvement of soil physical, chemical and biological properties through supplying macro and micronutrients. Besides supplying beneficial nutrients, organics *viz.* FYM, PIM, NC and VC also improve the soil aeration, water holding capacity and porosity leading to better vegetative growth of the plant (Singh *et al.*, 2010). The increased vegetative growth by PSB and KSB inoculation might be due to the fact that fixation of N2 and solubilization of sparingly soluble phosphorus by nitrogen fixing bacteria and P-solubilizing/mobilizing microorganisms, respectively, that played important role in the assimilation of numerous amino acids which helped in increasing the photosynthesis efficiency and the vegetative growth of the plants (Rana and Chandel 2003). *Trichoderma harzianum* and *Azospirillum* increases the health of plants by protecting and providing them with beneficial nutrients through Nitrogen fixation. *Trichoderma harzianum* act as a defense mechanism for protecting the plants from infection which may hampers the developments and vegetative growth of plants (Nusaibah and Musa, 2019). Similarly, application of bio-dynamic preparations to the soil improves the soil fertility by stimulating humus formation, increasing microbial life, and promoting root growth which ultimately increases the growth of the plants (Lioyd, 2005). Our study is also supported by the findings of Goldstein *et al.* (2019) who reported that bio-dynamic preparations increases the overall vegetative growth of plants. Our study is in close conformity with the findings of Garhwal *et al.* 2014 who reported that application FYM and Bio-dynamic preparations significantly influenced the vegetative growth parameters of fruits. Hong et al (2018) also reported increase in intermodal length in grapes with the application of organic manures.

5.1.2 Berry set, berry drop, and yield

Integration of organic manures and bio-dynamic preparations had marked influence on berry set and berry retention of grapes. The pooled data revealed that the maximum per cent of fruitful cane (93.85 %), berry set (39.57 %), and berry retention (58.86 %) was recorded in the vines treated with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). Our study is in close conformity with the studies of Stranishevskaya et al. (2021) who also obtained maximum fruitful cane by using bio-organic fertilizer based on organic waste in grape cv. variety Bastardo Magarachsky. The increased nutrient availability from the organic manure might have increased the various endogenous hormonal level in the plant tissues which might be responsible for enhanced pollen germination and tube growth, which ultimately increased the berry set as well as berry retention per plant (Nantha Kumar and

Veeragavantham, 1990). Further, the better vegetative growth due to organics might have resulted in increased production of flowers and resulted in higher per cent fruit set (Ninama, 2013). Our study is in close conformity with the findings of Rathi (2004), who reported that maximum fruit set per cent were observed with poultry manure in Gola pear. Similar, results have been obtained by Hassan *et al*. (2015) who observed highest fruit set per cent with poultry manure in 'Manzanillo' Olives. Hong et al (2018) also reported increase in intermodal length in grapes with the application of organic manures.

In the present investigation, among all the treatments, the minimum berry drop (41.14%) was recorded in the vines treated with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) whereas, whereas, the maximum (58.71%) was in control (T_{13}). The maximum berry drop in control may be due to poor vegetative growth, low production of fruiting shoots, poor fruit set and more fruit drop. Abou El-Khashab *et al*. (2005) reported that organic fertilization maintained adequate mineral contents in leaves during growth cycles of the olive trees for having economical yield; it also increased fruit set percentage and reduced fruit dropping waves. Our results are in conformity with Alakh *et al*., (2016) who observed the lowest fruit drop per cent with treatment combination of FYM, vermicompost, poultry manure and neem cake. Similar findings were also reported by Hegazi *et al*. (2007) and Abou El-khasab *et al*. (2005).

Unripe berries, are small immature berries that grow on climbing vines. Unripe grapes have a very acidic flavor. The pooled data revealed that the The minimum unripe berries (7.11 %) was recorded in FYM + *Azospirillum* + PSB + KSB + *Trichoderma* *harzianum* (T_5), whereas, the maximum (26.43 %) was recorded in control (T_{13}). The root cause of unripe berries in grapes is the poor fertilization. While this is most often attributed to nutritional deficiencies more particularly boron which is needed to synthesis the auxin and facilitate the movement of carbohydrates in the vine. In the present investigation, the minimum unripe berries with combined application of FYM along with *Azospirillum*, PSB, KSB, *Trichoderma harzianum* and bio-dynamics might be due to more auxins synthesis in this particular treatment which is facilitated by more micronutrient productions due to combined action of N fixing P solubilizing and K mobilizing bio-fertilizers.

In grapes, the shot berries are formed due to delayed pollination and fertilization or due to inadequate flow of carbohydrates into the set berries. In the present investigation, the minimum shot berries (2.40 %) was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}). The combined application of organics, organic manures with bio-fertilizers and bio-dynamics to reduce the shot berries in might be due to proper pollination and fertilization alongwith adequate flow of carbohydrates in these treatments to set sufficient number of normal berries.

Total crop duration of a crop is considered to be one of the practical considerations which affect the yield of a crop. In the present investigation, the minimum total crop duration (45.35 days) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while, the maximum (63.54 days) was observed in T_{13} (control). The least crop duration in organically treated treatments might be due to the fact that organically treated plants came into flowering early, which specifies that there was a balance of nutrients which is sufficient for optimum growth in order to induce flowering. Another reason for earliness in flowering could be higher net assimilation rate accounting for better growth leading to early production of endogenous metabolites in optimum levels permitting early flowering (Yadav *et al*., 2011a). The maximum total crop duration in control might be due to poor vegetative growth as compared to the plants under the various organic treatments. This could be due to insufficient production of carbohydrates in the leaves which might be the reason of late flowering (Gogoi, 1992). Our study is in close conformity with the findings of Nayyer (2014) in Banana, Tripathi *et al.* (2010) and Singh and Singh (2009) in strawberry, who got advanced crop duration with organic inputs.

The highest bunch weight (796.19 g), bunch length (21.66 cm), bunch breath (13.01 cm) and bunch size (281.79 cm^2) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) and the lowest (413.80 g; 13.67cm; 7.19 cm and 98.29 cm^2 respectively) was in control. The increase in bunch weight and bunch size with the use of organic manures, biofertilizers and bio-dynamic components might be due to better availability and uptake of nutrient by plant roots and enhancing the source-sink relationship by increasing the movement of carbohydrates from the leaves to the fruits (Baraily and Deb, 2018). Our study is in close conformity with the studies of Stranishevskaya et al. (2021) who also obtained maximum bunch weight per vine by using bio-organic fertilizer based on organic waste in grape cv. variety Bastardo Magarachsky.

Berry number and bunch number are another two very important parameters to better understand the reasons and mechanisms of the yield differences in the different management systems of grapes. In the present investigation, significant variation was observed among the treatments with respect to berries and bunch number. The results revealed that among the treatments, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), recorded maximum berries per bunch (187.46) and bunches per vine (51.84). This may be due to the fact that combined application of FYM and bio-dynamic components release sufficient amount of essential nutrients which in turn increase more release of photosynthetic assimilates leads to more number of fruits per plant. The increase in number of berries and bunches could probably be due to better utilization of nutrients within the plants with maximum translocation of nitrogen to the top. Continuous and steady availability of essential plant nutrients due to the addition of organic manures like vermicompost, wood ash and FYM in combination with microbial consortium might have enhanced the availability of more amount of growth promoting substances and primary nutrients adding up to all the essential nutrients (Yadav *et al*., 2011b). Our study is in close conformity with the studies of Stranishevskaya et al. (2021) who also obtained maximum berries per bunch and bunches per vine by using bio-organic fertilizer based on organic waste in grape cv. variety Bastardo Magarachsky.

In grapes, bunch compactness is assessed as the quotient of bunch weight and bunch length. In the present investigation, the maximum bunch compactness (5.89 g cm^{-2}) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* +

CPP+ BD 500 + BD 501 (T_9), while, the least (2.83 g cm^{-2}) was recorded in control (T_{13}). Differences in nutrient supply, physiological performance, vigor as well as water availability in different treatments might have caused differences in bunch compactness. In the integrated treatments combining organics alsong with bio-fertilizers and bio-dynamic components might have increased the transpiration rate which might have contributed to the increase of cluster weights in the respective treatments. Our study is in the line of conformity with the studies of Döring et al (2015) who also reported maximum bunch compactness by using organics alongwith bio-dynamic components.

The highest yield per vine (30.52 kg) and yield per hectare (33.91 tonnes) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) in both seasons as well as in pooled analysis. The maximum yield with FYM along with bio-fertilizers and bio-dymanic components might be due to the fact that these organic manures increased nutrient elements in the soil which enhanced uptake of nutrients and water caused to higher photosynthesis leading to an increase of the assimilation rates which ultimately increased the yield of the plant. Sharma *et al*., (2017) observed that yield of cumin increased significantly with application of organic manure along with BD 500 + BD 501. Our study is in close conformity with the studies of Stranishevskaya et al. (2021) who also obtained maximum yield per vine and yield per hectare by using bio-organic fertilizer based on organic waste in grape cv. variety Bastardo Magarachsky.

5.1.3 Berry physical parameters

In the present studies, physical parameters such as berry weight, (6.14 g) and hundred berry weights (608.03 g) was recorded maximum in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while, berry longitudinal diameter, transversal diameter and berry volume were observed maximum in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}), in both the years as well as in pooled analysis. Our study is in close conformity with the studies of Stranishevskaya *et al.* (2021) who also obtained maximum berry weight and hundred berry weight by using bio-organic fertilizer based on organic waste in grape cv. variety Bastardo Magarachsky. Being the store house of all plant nutrients including trace elements the organic manures might have released them gradually and steadily, which in turn contributed towards the balanced nutrition of crop throughout the cropping period which ultimately resulted in enhancement in yield attributes (Hazarika and Ansari, 2010).

The increase in berry length, diameter, and volume in the treatments combined with organic manures along with bio fertilizers and bio-dynamics might be due to an increased photosynthetic ability of plants fertilized with organic manures, which in turn favoured and increased accumulation of dry matter (Verma, 2016). Berry size, and berry weight are highly correlated with dry matter content, balanced level of hormone and nitrogen fixers which are known for accumulation of dry matter and their translocation as well as synthesis of different growth regulators (Kachot *et al.*, 2001). The increase in berry volume was attributed to the corresponding increase in length and diameter and also due to balanced availability of macro and micro-nutrients and growth promoting substances, produced by organic manures, this may lead to better metabolic activities in the tree which ultimately lead to high protein and carbohydrate synthesis. Similar results are in consonance with Sharma *et al*. (2009). Similar result were obtained by Kumar (2010) who also observed maximum fruit length, fruit weight, fruit breath and fruit volume in mango when poultry manures were applied. Nazir *et al.* (2015) in strawberry and Hong et al. (2018) in grapes also reported increase in berry longitudinal, transverse diameter and volume with the application of organic manures.

Skin plays a fundamental role for the grape composition and wine quality along with the viticulture and winemaking processes, as they are the most important source of aroma and polyphenol compounds. The skin of a grape berry consists of a layer of epicuticular waxes, a layer of cuticle that covers the epidermis, and then an underlying outer hypodermis (Battista et al., 2015; Keller, 2020). Skin thickness is obtained as the sum of the thickness of all three layers (i.e., cuticle + epidermis + hypodermis). Thickness is one of the most important grape skin morphological characteristics affecting the gas exchange regulation, berry susceptibility to fungal diseases and resistance to mechanical injuries. In the present investigation, the maximum skin thickness (0.091 mm) and pedicel thickness (3.82 mm) was obtained in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8), while, the least (0.050 mm and 2.86 mm) was obtained in control (T_{13}). The increase in skin thickness due to combined application of organics with bio-fertilizrrs alongwith bio-dynamic componnts might be due to accumulation of more metabolites in the skin, including sugars, organic acids, amino acids, and some polyphenols such as flavonols and hydroxycinnamic acids in these particular treatments as compared to control (Carbonneau et al., 2015). The increase in pedicel thickness with combined application of PIM alongwith bio fertilizers and bio-control agents *Azospirillum*, PSB, KSB and *Trichoderma harzianum* might be due to the fact that the biofertilizers might have increased the secretion of plant growth regulators more particularly GA3 in the plant which have a direct correlation with the peroxidase activity within the pedicel and peroxidase contributed the pedicel thickening.

The seed weight, seed length, seed width and seed number of the berries also varied significantly among the treatments. PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the minimum seed weight (0.062 g), while, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), recorded the maximum seed length (0.7473 cm), and NC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_7), recorded maximum seed width (0.485 cm). The least seed number (2.08) was recorded in FYM +*Azospirillum* + PSB + KSB (T_1). Increased seed weight with combined application of organics and bio-dynamic components may be due to the fact that organics and bio-dynamics have solubilised inorganic phosphate which causes greater accumulation of food reserves into the seed (Thakur, 2009). The more seed weight with the same treatment might be also due to the fact that organic manures increases various photosynthetic and metabolic activities resulted in better absorption of water ensured better growth of plants and higher fruit weight which is directly related to seed number (Thakur, 2009).

5.1.4 Berry quality characters

The results of the present investigation revealed that the quality parameters of the grape berries were significantly influenced by application of organic manures and bio-dynamic preparations in both the years as well as in pooled analysis. Among all the treatments, the minimum moisture content (79.80%) was recorded in PIM +*Azospirillum* + PSB + KSB (T_4), while, the maximum (82.72 %) was recorded in T_{13} (control). Similarly, VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recoded the maximum juice (69.16 %) content. The decrease in moisture content in the organically treated fruits might also be due to osmotic withdrawal of moisture content from the skin of the fruit to the pulp and decrease moisture content (Yadav *et al.*, 2011c).

It has also been suggested that combined application of vermicompost along with bio-fertilizers and bio-dynamic components increase the mobilization of carbohydrates to the developing fruit and increase berry size. In addition, due to steady balance of nutrient availability to the plant and secretion of growth promoting hormones by applying biofertilizers the size of the fruit increases. A positive relation between the fruit size and fruit juice content is reported by previous researcher (Nazir et al. 2015). Our results are in close conformity with the findings of Prabakaran and Pichal (2003) and Ninama (2013) in acid lime.

Among all the treatments, the maximum TSS (21.05 °B), and TSS: Acid ratio (32.86), was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). Interestingly, plants receiving organic manures have produced better fruit quality attributes which might be due to better growth of plants which favoured the increase in higher TSS. Increased TSS in berries due to inoculation of free-living nitrogen-fixing bacteria might be due to steady supply of nutrients by the bio-inoculants throughout the growth period. This increased the vigour of vines and increased leaf area with higher synthesis of assimilates due to enhanced rate of photosynthesis. Such effects might be attributed to increased rate of mobility of photosynthetic products from leaves to developing fruits, thereby increasing TSS in berry fruit (Singh and Singh 2006). However, decline in TSS under recommended dose of fertilizers might be due to the fact that most of the metabolites were consumed by excessive vegetative growth, whereas a little amount were left for storage in the berries (Haynes and Goh 1987). The increase in TSS: acidity content of the fruits might be due to the conversion of reserved starch and other insoluble carbohydrates present in the fruits into soluble sugar. Also the improvement in the fruit quality could be attributed to increased continuous supply of nutrients along with higher concentration of soil enzymes, soil microorganisms. Transformation of plant nutrient in soil, production of growth promoting substances by microorganisms and rapid mineralization also might be responsible (Baraily and Deb, 2018). Similar results were also reported by Peck *et al*. (2009) who recorded that fruits from organic production system had higher TSS and TSS: acid ratio than fruits from integrated fruit production system. Higher TSS with incorporation of FYM and BD500 had also been reported by Ram and Pathak (2007) in guava. Jayasree and George (2006) also reported that application of biodynamic preparations (BD 500 and BD 501) increased fruit quality in chilli. Wu et al. (2021) also reported increase in TSS with the application of organics in grapes.

Among all the treatments, the minimum acidity (0.64 %) was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). The lower titratable acidity (%) could be attributed to the addition of organic manures like vermicompost, with microbial consortium which supplements abundant amount of nutrients, moisture and growth promoting substances which helps in enhancement of metabolic and hormonal activities of the plant promoting production of more photosynthates which is stored in the fruits in the form of starch and carbohydrates. Reduction of titratable acidity of the fruits with the application of various organic manures in combination with microbial consortium could be due to the positive influence of organic nutrients in the process of conversion of acid into sugar and into their derivatives (Singh *et al*., 2010). These results are in consensus with the findings of Yadav *et al.* (2011a) in papaya and Abd El-Naby (2000), Soorianathasundarum *et al*. (2001), Bhavidoddi (2003) Ganeshamurthy *et al*. (2004), Patel (2008) and Shivakumar (2010) in Banana. The maximum acidity in control might be due to synthesis of more organic acids as a result of improved foliage which might have kept the berry temperature lower by shading them and thus resulting in lower loss of acids in respiration. Similar results were also reported by Macit *et al.* (2007) in strawberry and Gautam *et al*. (2012) in mango. Ram *et al.* (2014) also reported decrease in titratable acidity due to application of different organic sources of nutrients along with bio-fertilizers and bio-dynamic preparations.

The highest value of ascorbic acid (25.17 mg $100g^{-1}$) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501

(T_{10}). The higher ascorbic acid (mg/100g) could be attributed to the addition of organic manures like vermicompost, in combination with biofertilizers and bio-dynamic components might be due to supplement of abundant amount of nutrients, moisture and growth promoting substances which helps in enhancement of metabolic and hormonal activities of the plant promoting production of more photosynthates which is stored in the fruits in the form of starch and carbohydrates. It is a very well known fact that during the process of ripening when the matured fruit transforms into its ripe form they undergoes physical, physiological and biochemical changes. These could be due to the presence of active enzymes and the conversion of starch to dextrose, glucose and sucrose. The increase in ascorbic acid content might also be due to an increase in sugar content at the ripening stage. Our results are in the line of conformity with the findings of Ram *et al.* (2014), who reported increase in ascorbic acid due to combined application of CPP and BD 500. The highest ascorbic acid content in fruits might also be due to the catalytic activity of several enzymes which participate in the biosynthesis of ascorbic acid and its precursor (Bhobia *et al*., 2006).

The result revealed that reducing sugars (13.20 %), non- reducing sugars (1.80 %), total sugars (14.66 %), sugar: acid ratio (22.88), was recorded maximum in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). Significant increase in total sugar and reducing sugar content of the fruits might be due to the conversion of reserved starch and other insoluble carbohydrates present in the fruits into soluble sugar. Increase in reducing sugar, non-reducing sugar, total sugar, and sugar: acid ratio with organic manures application may be attributed to the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits (Verma, 2016). The highest sugar content with the combined application of organic manures with bio dynamic components might be due to translocation of photosynthates and accumulation of more food reserve within the plant, particularly in the fruits (Crane, 1969).

The improvement in sugar acid ratio of fruits may be due to the balanced absorption of macro and micro nutrients which have exerted regulatory role as an important constituent of endogenous factors in affecting the quality of the fruits (Babita, 2011). Osman *et al*. (2010) observed total sugars, reducing and non- reducing sugars content in fig fruits. Similarly, Dhakeri *et al*. (2013) reported that application of FYM significantly increased the total sugar and reducing sugars of fruits. Higher reducing sugar with incorporation of FYM + BD-500 has also been reported by Ram and Pathak (2007). Our findings are in close conformity with the findings Singh *et al.* (2010) in ber, Baksh *et al.* (2008) in guava.

Anthocyanins are the pigments of red grapes and, with few exceptions, they are located in the skin of the berries, within the vacuoles (Mattivi et al. 2006). Anthocyanins begin to accumulate in grape berries at veraison and their concentration increases up to a maximum value as a function of some factors such as the cultivar, seasonal conditions, production area and viticulture practices (Downey et al. 2006). In the present investigation, among all the treatments, VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recorded the maximum anthocyanin (4.00 mg g^{-1}) while, the minimum (2.19 mg g^{-1}) was found in control (T_{13}). Our study is in the line of conformity with the findings of Mulero et al. (2010), and Miele et al. (2015) who also reported that Anthocyanin content of organically grown grapes were higher than the conventionally grown grapes. Umar et al. (2009) also reported increase in anthocyanin content of strawberry fruits by using organics with bio-fertilizers.

Carotenoids play important roles in human nutrition through their provitamin A activity, but also by acting as antioxidants, for prevention of age related macular degeneration or skin protection against UV radiation (Krinsky and Johnson, 2005). The most important carotenoids (85% from all the carotenoids present) identified in grapes are ß-carotene and lutein, the rest of them being neochrome, neoxanthin, violaxanthin, luteoxanthin, flavoxanthin, zeaxanthin and cis-isomers of lutein and ß-carotene (Mendes-Pinto *et al*., 2004). Carotenoids are directly involved in grapes aroma because they can suffer degradation reactions. In the present investigation, among all the treatments, VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recorded the maximum total carotenoids content (10.76 µg/g), while, the minimum (6.92 µg g^{-1}) was found in control (T_{13}). Our study is in the line of conformity with the studies of Bunea *et al.* (2012) who reported increased in total carotenoids in grapes due to application of organic nutrition.

Starch is known to be the main reserve compound in grapevine storage tissue. Carbohydrates are mainly stored as starch in different parts of the grapevine during the growing season. Soluble carbohydrates represented only a small part (< 7 % of dry weight, DW) of the total non-structural carbohydrates (TNC). In the roots and trunks, the starch content fluctuated during the growing season, reaching the lowest values between budbreak and flowering depending on the year, and the highest values between harvest and leaf fall (Zufferey et al., 2012).The leaf fruit ratio (source-sink), not only substantially influenced the soluble sugar content in berries but also the starch concentrations at harvest. Higher leaf-fruit ratios resulted in increased starch concentrations. In the present investigation, the maximum starch (4.13 mg g^{-1}) of the berries was obtained with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), might be due to higher source sink ratio in these treatments due to combined application of organics, bio-fertilizers and bio-dynamic components. Our study is in the line of conformity with the findings of Song et al. (2016) who also reported that treatment with high concentrations of the organic fertilizer elevated the starch content.

Proteins represent less than 1% of the fresh mass of fruit and vegetable tissues. The proteins of fruits and vegetables are built from amino acids, but other related simple nitrogenous compounds also occur. Fruits are low in proteins, but tree nuts are a good source of high-quality proteins. A number of non-protein nitrogenous compounds including free amino acids, chlorophylls, polyamines or alkaloids are also present in fruits and vegetables (Vicente et al., 2014). In our investigation, among all the treatments, the maximum protein (7.15 mg g^{-1}), of the berries was obtained with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while the minimum (5.00 mg g^{-1}) was in T_{13} (control). There is enough evidence to suggest that organic crops are superior to conventional ones with respect to protein content (Worthington, 1998). Compared to crops grown with chemical fertilizers, organically grown crops generally have a better protein quality (Woese et al., 1997). In the present investigation, the higher protein content in organically grown berries might be due to higher level of nitrogen and amino acids in these treatments which increases the protein content of the berries (Weston and Barth, 1997).

Phenolic compounds are ubiquitous secondary metabolites in plants that are essential for growth, reproduction and protection against pathogens and radiations. The phenolic compounds of grapes include flavonoids (anthocyanins, flavonols and tannins), non-flavonoid (phenolic acids) compounds and stilbenes. In grapes, flavonoids are the most abundant class of phenolic compounds and they exhibit variable evolution during the development and ripening of grapes (Boido et al. 2011, Liang et al. 2012). In the present investigation, the maximum total phenols (0.88 mg g^{-1}) of the berries was obtained with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while the minimum (0.62 mg g^{-1},) was in T_{13} (control). The increase in phenolics with the organic inputs might be due to the fact that organic agriculture does not use synthetic pesticides and fertilizers and plants being more susceptible to the pathogens action produce higher amount of phenolic compounds (Soleas et al., 1997). Mulero et al. (2010), Miele et al. (2015) and Bunea *et al.* (2012) also reported higher phenolic content of organically grown grapes as compared to conventionally grown grapes.

The carbohydrates synthesized by leaves during photosynthesis have many functions. They are the building blocks of organic compounds, store energy, and form support structures, such as cellulose, hemi-cellulose, and gluco-protein. All plant parts can store carbohydrates, either temporarily (C reserves accumulated in leaves during day time then used under stress conditions or during the night), or for a longer time, such as in the canes, trunks and roots (Keller, 2010) In grapevines, the total non-structural carbohydrates (TNC) in roots and wood fractions play a key role for the quality potential at harvest. Indeed, TNC are not only involved in the protection against frost (Keller, 2010), but they also take part in the leaf area development, shoot growth as well as in the flower induction (Murisier and Aerny, 1994). Furthermore, it is also established that rapid accumulation of soluble solids in berries at veraison is mainly due to the mobilization of TNC previously stored in the permanent organs. In the present investigation, the maximum carbohydrate (81.39 mg g^{-1}) with PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), might be due to more mobilization of stored TNC to the berries which influenced more carbohydrate assimilation in the berries.

Raisins are highly produced value-added products that are extracted from grape processing. The maximum raisin recovery (25.66 %) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), whereas, the minimum (20.72 %) was found in control (T_{13}). In all the organically treated fruits, there is higher raisin content as compared to untreated control. The maximum raisin recovery in organically treated grapevines might be due to better accumulation of sugars more particularly glucose and fructose levels in the fruits (Ambotu, 2015). The size of berry affects the rate of water loss during drying. The smaller berries lost water more rapidly than larger berries due to the higher relative area of skin to the flesh

(Sharma, 2013). The maximum raisin recovery in organically treated berries might be due to larger size of the berries in organically treated berries.

5.1.5 Plant Leaf analysis

Significant variations were observed among the treatments with respect to nutrient content of the leaves. The maximum leaf nitrogen (3.82 %) and K (1.71 %), was recorded in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). Application of organic manures in combination with microbial consortium and bio-dynamic components makes continuous and steady availability of all essential plant nutrients and growth promoting substances from the very beginning of the vegetative stage upto the completion of cropping period which increases the nutrient content of the leaves (Yadav *et al*., 2011b). The addition of vermicompost might have improved the physical condition of soil, root network and more moisture retention and thus increase the absorption of water and nutrients in turn improved the nutrient contents of the leaves (Babita, 2011). The application of vermicompost along with biofertilizers and biodynamic components must have enhanced mineralization of organic nitrogen thus making more nitrogen available to the plant. The increase in leaf nitrogen content may also be due to acceleration in microbial N fixation, improvement in soil aeration and better moisture retention in root zone, and thus improve the availability of various micro and micro nutrients. Similar result was reported by Pattanayak *et al.* (2001) and Gupta *et al.* (2005). These results are in line with Anitha and Prema (2003) who reported that vermicompost facilitate better absorption and translocation of mineral nutrients to the plant system and increases the leaf nutrient status of the plant. Our study is in the line of conformity with the findings of Ozdemir et al. (2008) in grapevine who also reported increase in leaf N with the application of organics.

The high potassium under the influence of organics might be due to higher availability of potassium as the organic sources themselves contributed potassium to the nutrient pool and minimized the loss due to leaching by retaining potassium ions on exchange site that would have increased the released of potassium ion, resulting in increased uptake (Santhi *et al*., 1999). Ozdemir et al. (2008) reported increase in leaf K with the application of organics in grapevine.

The maximum leaf phosphorus (0.271 %) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). Increase in leaf phosphorus content in grapes leaves with the application of FYM along with bio-dynamic components might be due to the inherent capacity of FYM to improve soil physico-chemical properties, which facilitates the absorption of mineral nutrition from the soil resulting in improved nutrient leaf contents (Morselli, 2009). The rich source of soil micro-organisms present in FYM must have helped in the solublization of fixed P to soluble form thus making it easily available to the plant. Similar, results were obtained by Bhobia *et al*. (2005) in guava and Dutta *et al*. (2010) in litchi cv. Bombai. Ozdemir et al. (2008) reported increase in leaf P with the application of organics in grapevine.

The maximum Fe (272.18 ppm) and Cu (9.09 ppm) of the leaves was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the maximum Mn (26.60 ppm) and Zn (27.42 ppm) was recorded in T_{12} (PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501). This result could have been due to the fact that addition of vermicompost in the soil resulted in increased the uptake of nutrients by plants which ultimately increases the availability of micronutrients by increasing the enzymatic activities especially dehydrogenase and hydrolase (Chaudhary *et al.* 2004). Due to the combined role of vermicompost and bio-dynamic preparations in improved soil properties, increased microbial population and more solublization of bound nutrients thus making them available freely to the plant. Our results are in close conformity with the observations of Venkatesh *et al*. (1998) who also reported that application of vermicopost increased the Cu content of the leaves of grapes. Our study is in the line of conformity with the findings of Ozdemir et al. (2008) in grapevine who also reported increase in leaf Fe, Zn, Cu and Mn with the application of organics.

A satisfactory general balance must exist between carbohydrates and nitrogen supply in the plants before conditions are suitable for good growth and fruit development (Kunte *et al.* 2005). Carbon is important because it is an energy-producing factor and nitrogen, because it builds tissue. The importance of the Nitrogen Carbon (NC) ratio concept has been known since 1918 or earlier, as documented by the work of Kraus and Kraybill (Chandler 2012). Carbon sprayed on crops and soils, has been an effective way of slowing vegetative growth and speeding fruiting. In the present investigation, the minimum C: N ratio (4.78) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9), while, maximum leaf carbohydrate (13.64 %) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}). The minimum C: N ratio in this particular treatment might be due to highest carbohydrates and highest N content of the plant leaves which in turn lowers the C:N ratio of the leaves.

The maximum leaf dry matter (0.171 g) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). The reasons for the increase in dry weight of leaves with combined application of FYM and bio-dynamic preparations might be due to the fact that these combination would have helped in the plant metabolic activity through the supply of required nutrients, which are involved in biochemical synthesis of many phytohormones which in turn increased the leaf dry matter as well as total carbohydrate content of the leaves (Aran Kumar, 2009).

The highest chlorophyll a (1.530 mg g^{-1}), chlorophyll b (0.56 mg g^{-1}), and total chlorophyll (2.09 mg g^{-1}) were observed in plants treated with PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the highest while, the least was recorded in T_{13} (control). The increased in chlorophyll content due to combined influence of PIM, biofertilizers and bio-dynamics may be attributed to the decreased chlorophyll degradation and increased chlorophyll synthesis (Venkatesh, 2012). Higher photosynthetic activity is a good indication of physiologically efficient plants which primarily depends upon the leaf chlorophyll content. Organic manures are very efficient in maintaining a better photosynthetic efficiency, which is in turn responsible for maintaining a better physiological status of the plant (Maroto *et al.*, 2003). The efficiency of photosynthesis is indicated by the leaves chlorophyll content, where the solar energy is converted into chemical energy. N, P and K were utilized efficiently by the plant, which resulted in producing maximum photosynthates in terms of high biomass and translocating the assimilated materials to the developing sink. Nitrogen and potassium play an important role in the functioning of chlorophyll ultimately influencing the growth and producing leaves of maximum size. These results are in conformity with the results reported by Kuttimani *et al*. (2013). Our study is in close conformity with the findings of Kumar *et al.* (2007) who also reported increased in total chlorophyll content of leaves increased with organics. Jariene *et al*. (2014) noted that combination of BD preparations (500 + 501) substantially increased the chlorophyll content in leaves of potato.

5.1.6 Soil analysis

5.1.6.1 Soil health parameters

In the present investigations, application of various organic treatments significantly influenced the available macro and micro nutrients in soil profile. Available form of Nitrogen is always in a state of dynamic change and therefore its content in soil is highly variable. The maximum available N (868.86 kg ha^{-1}), P (159.81 kg ha-1), K (644.50 kg ha^{-1}) of the soil was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) in both the years and in pooled analysis. The N content (an indicator of available N pool) of the soil after final picking of berries significantly increased over control in all the treatments. The increased availability of N due to application of bio-organics could be attributed to the greater multiplication of microbes which converted organically bound N to inorganic form (Archana, 2013). Such an increase in the available N might possibly be attributed to the availability of *Azospirillum* for atmospheric N fixation in the rhizosphere throughout the entire cropping period. Workneh *et al.* (1993) reported similar results. *Azospirillum* is known to be capable of fixing N equivalent to 25-30 kg ha^{-1} alone. Soil which was managed organically exhibited greater potential for N fixation as well as greater biological activity of inoculated microorganisms (Melero *et al*., 2006). Such build up might be due to the fact that pH value rises as a result of organic sources and thus lowered the oxidation reduction process. Organic acid and microbial product of decomposition from organic sources solubilizes the insoluble compounds by interacting with their specific binding cations and clay minerals. The lowest available N was recorded in treatment with control, without any organic manures, this could be due to leaching and other losses with chemical fertilizers as compared to organic manures. Therefore, it was seen that application of organic sources was found to be good in enhancing the nitrogen availability in soil (Reddy *et al.,* 2007; Biswas, 2008 and Umlong, 2010). Organic matter is the vital source of nitrogen in the soil. When organic fertilizers are add on to the soil in order to fill up organic matter storage, nitrogen is one of the prime nutrients supplied to soil. Vermicompost and farmyard manure seemed to significantly elevated the nitrogen content of soil (Uz and Tavali, 2014). Ram *et al.* (2014) also reported increase in N content of the soil due to application of different organic sources of nutrients alongwith biofertilizers and bio-dynamic preparations.

Increase in the available phosphorus could be attributed to the improvement of soil condition due to the phosphate solubalizing and mineralizing ability of the microorganisms from the soluble form of phosphorus sources (Tao *et al*., 2008). It is established that application of PSB along the organic manure significantly increased the available phosphorus status in soil which might be attributed to the production of organic acids which acts as chelating agent and form stable complexes with Fe and Al which are available in acid soil and thereby release phosphorus from clutches of Fe and Al to the soil solution (Biswas, 2008 and Umlong, 2010). Ram *et al.* (2014) also reported increase in P content of the soil due to application of different organic sources of nutrients along with bio-fertilizers and bio-dynamic preparations.

In case of available potassium highest value was recorded under treatment applied with PIM along with biofertilizers and biodynamic components and microbial consortium. Such increase could be due to release of potassium from these organic amendments and also due to solubilisation of mineral based potassium or native potassium. Besides, it might be also due to prevention of leaching loss due to retention of more potassium by organic components while inorganic fertilizers could have released potassium at a faster rate. Srikanth *et al*. (2000) reported positive influence of organic manure on available potassium. The increase in K_2O may also be attributed to the initial content of potash in the organic supplements which on decomposition contributed to the available K-pool; it could also be ascribed to the fact that combined application of organic and inorganic sources might have caused mineralization by solubilizing the insoluble compounds through the action of organic acids, released during decomposition and thereby minimize the losses due to fixation. These results were similar to the findings by Bahadur *et al.* (2006); Biswas (2008) and Umlong (2010). Ram *et al.* (2014) also reported increase in K content of the soil due to application of different organic sources of nutrients alongwith biofertilizers and bio-dynamic preparations.

In the present investigation, the increased nutrient status of soil with the combined application of PIM and bio-dynamics might be due to the fact that organics are beneficial for improving the physical structure and biological properties of the soil. It adds various growth hormones such as auxins and gibberellins and some of the enzymes, such as phosphatase, cellulase etc. to the soil. Furthermore, the application of organic manures in the field enhances the quality of soils by increasing microbial activity (Norman, 2005). The organic manures contain nutrients in forms that are readily taken up by the plants such as nitrates, exchangeable phosphorus and soluble potassium (Edwards & Burrows 1988; Orozco *et al*., 1996). Higher protease and acid phosphate activity in organic manures treated soils might be responsible for higher nitrogen and phosphorus content in soil. The dynamic changes of available phosphorus in soil is attributed to the release of phosphorus from the mineralization, reduction of ferric phosphate to ferrous phosphate and increase in the solubility of the ferric phosphate and aluminum phosphate caused by an increase in pH value of the soil. The finding is in agreement with the findings of Sarkar (2012) and Kundu (2015). Stever (1999) also reported that an increase in soil quality by incorporating biodynamic preparations on crop. Amrawat *et al*. (2013) also reported that BD 500 can stimulates microorganisms and inturn increasing the availability of nutrients including trace elements.

The maximum Mn (29.93 ppm), and Zn content (2.308 ppm) of the soil was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while, maximum Fe (74.60 ppm) of the soil was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (74.60 ppm). Similarly, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) recorded the maximum Cu content (2.665 ppm). Increase in DTPA extractable ions (Fe, Cu, Zn and Mn) can be ascribed to the addition of these micronutrients by organics and their release from native sources on account of solubilizing action of organic acids produced during decomposition process (Singh *et al.*, 2010). Such an increase in these micronutrients appeared to be due to mineralization of organically bound forms and formation of stable water complexes or organic chelates of higher stability, which decrease their susceptibility to absorption, fixation and/or precipitation (Jagtap *et al.*, 2007). The higher availability of micro nutrients in organically treated plots might be because of its inherent capacity to add good amount of organic carbon content to soil which hasten process of mineralization of organically bound micronutrients present in native soil (Singh *et al.*, 2010). Marathe *et al.* (2009) and Reddy and Reddy (1999) reported that significant increase in available Fe, Zn, Mn and Cu were observed with organic manures, over control. In the present investigation, there was a reduction in micronutrients content in the treatments receiving only inorganic fertilizers. It was attributed to non-replenishment of micronutrients through chemical fertilizers. Ram *et* *al.* (2014) also reported increase in Zn, Cu and Mn content of the soil due to application of different organic sources of nutrients along with bio-fertilizers and bio-dynamic preparations.

Soil moisture content was recorded maximum (34.39%) in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_9) in both the years well as in pooled data. This increased in soil moisture content may be described due to improved soil structure by the combined application of organics viz. FYM and bio-dynamic preparations (Chaudhary *et al.*, 2003). Our study is in the line of conformity with the findings of Laxminarayana (2006), who reported that water holding capacity of soil was progressively improved with the application of organic manures as compared to inorganic fertilizers.

The significantly highest soil pH (4.92) was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_9). Increase in pH in the organic treatments could be due to the deactivation of Al^{3+} and concomitant release of basic cations due to the addition of organic matter (Gogoi *et al.*, 2010). Higher pH might also be due to the increase in microbial activities in the root zone which decomposes organic manures and also fix unavailable form of mineral nutrient into available forms in soil which in turn substantiates crop requirement and also improves organic carbon level and stabilizes soil pH. Tekasangla *et al.* (2005) reported similar results in cauliflower. Higher value of soil pH was obtained with application of organic manures as compared to NPK fertilizers (Moyin-Jesu, 2018). Wakene *et al.*, (2005) also reported addition of organic matter especially FYM into tropical soils enhances the soil pH through development of soil acidity due to production of organic acids during decomposition of organic manures. Verma and Bhardwaj (2005) reported an increased in pH in apple orchard soils due to application of FYM. The results are in accordance with the findings of Srikanth *et al*. (2000).

Significantly highest soil organic carbon (7.42 g kg^{-1}), inorganic carbon (2.23g kg^{-1}), total carbon (9.65 g kg^{-1}) and total nitrogen (0.689g kg^{-1}) of the soil was found in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), in both the years of experimentations. Organic carbon of soil acts as a source and sink of nutrients for microbial population, which through microbial transformation regulates the availability of different nutrients. The net increase in organic carbon was seen to be much higher with organic manures in combination with microbial consortium which might probably be due to application of organic inputs and their different acid releasing behaviour. Verma and Bhardwaj (2005) reported that improvement in soil organic carbon content in the organically treated plots might be due to the direct addition of organic matter through organic manure and recycling of organic materials in the form of organic residues. The subsequent decomposition of organic matter might have resulted in the enhanced organic carbon content of the soil. Similar observation was made by Yadav *et al*. (2007). Hebbara et al. (2006) and Rong *et al.* (2016) reported that organic manure had a positive influence on soil Carbon accumulation. Our study is in the line of conformity with the studies of Ndung'u et al. (2021) and Ghosh et al. (2021) who also reported increase in total carbon, organic carbon and total inorganic carbon content of soil in organically managed crops.

Significantly lowest C: N ratio (13.33) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* (T_6) while, the highest (15.10) was found in Farmer's practice (T_{14}). The organic amendments had greater effect in decreasing C: N ratio as compared to inorganic fertilizers. It is well established fact that narrow range of the C: N ratio increase the fertility levels of soil. C: N ratio is directly related to organic carbon and total nitrogen content of the soil. In the present investigation, the lower C: N ratio in this particular treatment might be due to lower organic C and higher total nitrogen content of the soil. Higher C/N ratio indicates slow degradation of substrate, and the lower the C/N ratio, the higher is the efficiency level of mineralization by the species (Kohli, 2016). High soil C/N ratio can slow down the decomposition rate of organic matter and organic nitrogen by limiting the soil microbial activity ability, whereas low soil C/N ratio could accelerate the process of microbial decomposition of organic matter and nitrogen (Shunfeng *et al*., 2013).These findings are in close agreement with the observation of Sitaramalakshmi *et al*. (2013) who also reported decrease in C:N ratio due to application of organic matter.

The maximum CEC (19.49 meq $100g^{-1}$) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), while, the minimum (16.20 meq $100g^{-1}$) was recorded in control (T_{13}). Sahu *et al*. (2014) reported that organic amendments are an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture holding capacity of soils, increasing the soil cation exchange capacity (CEC).

The increase in cation exchange capacity of the soil might be due to the increased organic matter in the soil. The organic matter is negatively charged component of the soil and hence it might have increased the CEC of the soil. These findings are in conformity to that of Prakash *et al*. (2002) and Mishra (2004), who revealed an increase in CEC of soil by the incorporation of organic manures. In the present investigation, the lowest CEC was observed in control (T_{13}), which is in the line of conformity with the findings of Sen (2003), who also observed addition of inorganic fertilizers (NPK) reduced the cation exchange capacity of the soil.

In the present investigation, total nitrogen content of soil significantly increases with the application of organic matter in soil. The maximum (0.689g kg^{-1}) of the soil was found maximum in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}). It is well established fact that the addition of organic matter in soil increases total nitrogen in soil. Our results confirm the findings of Pawar (2012) and Kumar *et al*. (2012).

5.1.6.2 Bacterial, fungi and *Actinomycetes* count

In the present investigation, significantly highest fungal count (48.30 $\times 10^4$ CFU g^{-1} of soil) was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) while, control (T_{13}) recorded the minimum value (27.43 × CFU $g^{-1}$of soil), while, highest bacterial count (49.84 $\times 10^4$ CFU g^{-1} of soil), and *Actinomycetes* count (45.04 $\times 10^4$ CFU g^{-1} of soil) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}). Among all the treatments, control (T_{13}) recorded the minimum value (24.18×10^4 and 25.43×10^4 CFU g^{-1} of soil). The use of organic manure in combination with biofertilizers and biodynamic components has been acknowledged as a fruitful means for increasing or improving soil microbial diversity and population and also increasing crop yield (Zink and Allen, 1988). This could be due to improved microbial and enzymatic activities in soil with the application of organic sources of nutrient. It was noted that the biological properties were higher in the soil treated with organic sources. Utilization of organic manure is recognized to stimulate and enhance the stable soil structure, fungal and bacterial population and biological activity (Chaoui *et al*., 2003). The increased microbial population with biofertilizers might also be due to synergistic effect of these beneficial micro-organisms, enhanced P-solubilization and plant growth-promoting substances around the plant rhizosphere which increased microbial population in the grape rhizosphere. Combined application of vermicompost and PIM alongwith bio-dynamic preparations provides adequate biomass as a feed for the microbes and helps in increasing microbial population in soil (Amir, 2011). Higher levels of enzyme activity have been reported by many researchers in soils treated with vermicompost and organic manure compared to inorganic fertilizers which in turn increased the microbial population of the soil (Krishna Kumar *et al.*, 2005; Chang *et al.*, 2007). Our study is in close conformity with the findings Singh *et al*. (2010) who reported increase in bacterial population due to application of biofertilizers. Krishna Kumar *et al.* (2005) and Ram *et al.* (2014) also reported increase in microbial population viz., bacteria, fungi and *Actinomycetes* conspicuously due to application of different organic sources of nutrients alongwith biofertilizers and bio-dynamic preparations. The lowest population of microbes in the soil applied with chemical fertilizers might be due to the low natural population and lower availability of organic substrates in the soil (Bhawalkar, 1991).

5.1.7 Economics of cultivation

The economics of cultivation is considered to be one of the most important factors responsible for deciding the adaptation of any improved practice by the grower. Another important criterion for any grower in order to determine the usefulness and acceptance of any treatment is the benefit-cost ratio. In the present investigations, economic analysis of various treatments showed that among all the treatments, the highest gross income (Rs. 30,51,900.00), net returns (Rs. 24,09,157.11), and benefit cost ratio (3.75) was observed with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) while the lowest was recorded in control (T_{13}) (Rs. 7,17,500.00; Rs 3,19,736.75 and 0.80). The highest gross income, net return and B:C ratio in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) may be due to higher yield and comparatively low cost of FYM. The lowest net returns and benefit: cost ratio in control may be due to low yield. Shivakumar *et al.* (2012) also reported that the higher net return and B:C ratio could be either due to higher fruit yield or due to cost of the manures. Musmade *et al.* (2009) in Kagzi Lime reported beneficial effects of organic manures with high benefit: cost ratio. The similar findings of increased cost: benefit ratio were also reported Singh et al. (2010b) in strawberry by using bio-fertilizers.

5.2 2nd Experiment: Effect of Crop regulation on growth, yield and quality of Grapes cv. Bangalore Blue

Trunk girdling or the removal of a ring of phloem is a horticultural practice that results in an accumulation of carbohydrates and used to influence tree growth and development and fruit growth, especially in citrus, grape, peach, and other fruit trees (Goren et al. 2004). Girdling interrupts the phloem pathway and consequently changes the pattern of distribution of photosynthates, mineral nutrients and plant bioregulators. By girdling, the flow of sap stops, carbohydrates and starch accumulate above the girdle, and also in production and translocation of certain plant hormones are arrested (Davie et al. 1995). Moreover, it influences the metabolic activity of shrubs, primarily by increasing carbohydrate accumulation above the girdle and reducing the sink strength for photosynthate below the girdle (Nordgren et al. 2003). In addition, reduction in stomatal conductance and increase in leaf water potential have been observed in girdled shrubs (Williams et al. 2000).

Gibberlic acid as GA_3 is a growth regulator that is widely used during fruit set stage to increase size of seedless berries. GA_3 had potential impact on grape quality where the impact depended on grape varieties (Rusjan, 2010). A positive correlation was observed between GA_3 application and amount of nutrients like N, P or K absorbed which enhanced the enlargement of grape berries and sink capacity of grape cluster to absorb water or nutrients such as potassium (Zhenning et al, 2008).

5.2.1 Plant growth characters

The crop regulation practices influenced the vegetative growth, yield attributing characters and yield of grapes cv. Bangalore Blue over the control. The results presented in Table 4.2.1 revealed that the maximum shoot length (123.08 cm) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), while, control (T_1) recorded the minimum shoot length (116.05 cm). The increase in shoot length of grapevines might be due to the stimulative effect on cell division in meristem tissues due to trunk girdling and berry thinning. Our results is in the line of conformity with the findings of the Fawzi *et al.* (2019) who reported that trunk girdling and hand thinning results maximum shoot length in Thompson seedless grapevines. Meena *et al.* (2016) also reported that pruning and crop regulation of guava resulted in increase in shoot length.

The treatments varied significantly with respect to shoot diameter of the grapevines (Table 4.2.1). Among the different treatments, the maximum shoot diameter (21.38 mm) was recorded in Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}), while, control (T_1) recorded the minimum shoot diameter (16.69 mm). The maximum shoot diameter with trunk girdling and berry thinning along with plant growth regulators might be due to balance carbohydrate sink strength with sources to maximize dry matter production. Miller *et al.* (1996) reported that crop regulation with trunk girdling and pruning was beneficial with higher shoot diameter of Chambourcin grapevines.

It is revealed from the data presented in Table 4.2.2 that there were significant differences among the treatments with respect to internodal length. The highest internodal length (12.92 cm) was recorded in manual berry thinning + GA_3 +

ethephon (T_{12}), which was significantly higher than all other treatments, while the lowest was recorded in control (10.43 cm). The increase in internodal length due to trunk girdling and berry thinning might be due to the prevention of translocation of carbohydrates to the root system thus making it available for shoot growth. Our results are in the line of conformity with the findings of Edson *et al.* (1993) and El-Kenawy (2018), who suggested that berry thinning increases the internodal length of grapevines.

Among all the treatments, the maximum cane diameter (7.02 mm) was recorded in Flower thinning + GA_3 + ethephon (T_9) which was significantly higher than rest of the treatments while control (T_1) recorded the lowest cane diameter (4.28 mm) (Table 4.2.2). Our results are in the line of conformity with the findings of El-Kenawy (2018), who suggested that flower thinning increases the cane diameter of grapevines.

5.2.2 Berry set, berry drop, and yield

Among all the treatments, the maximum fruitful cane (93.79 %), was recorded in Trunk girdling + flower thinning +GA_3 + ethephon (T_{18}) showed the maximum fruitful cane, which was significantly higher than rest of the crop regulations. Dry (2000) suggested that canopy management such as pruning, girdling, shoot trimming etc. resulted in renewing of fruitfulness in grapes while replacement of relatively fruitful primary shoots with less fruitful secondary shoots decrease the average shoot fruitfulness which ultimately increases the per cent of fruitful cane in grapes.

In the present investigation, the maximum berry set (39.57 %), berry retention (58.86 %) and minimum berry drop (41.14%) was recorded in Trunk Girdling + manual berry thinning +GA_3 + ethephon (T_{19}), whereas the minimum berry set (30.08 %), berry retention (42.04%), and maximum berry drop (57.96 %) was recorded in control (T_1). The impact of girdling on fruit set has been studied by various researchers, with consistent results. Early spring trunk girdling increased fruit set and flower bud formation on apple trees (Autio and Greene, 1994; Hoying and Robinson, 1992).

Different girdling treatments increased the level of carbohydrates, especially during initial 4-6 weeks of heavy fruitlet abscission which ultimately increases the C/N ratio in the treated branch, it might have enhanced the inflorescence development and which had a significant effect on fruit retention (Khandakar et al., 2011). With respect to fruit retention, our study is in close conformity with the previous findings of Khandakar et al. (2011) in Syzygium samarangense and Ibrahim et al. (2016) in Washington navel orange, who also reported increase in fruit retention with trunk girdling.

The minimum berry drop in girdled treatment might be due to the fact that girdling treatment increased the C/N ratio and carbohydrate content thus reduced the fruitlet abscission and reduced berry drop percentage. Our results are supported by the findings of Shao *et al.* (1998).

The minimum shot berries (2.73 %), was recorded in manual berry thinning +GA_3 + ethephon (T_{12}), whereas, the maximum (13.43 and 25.10 %) was in control (T_1). Our study is in close conformity with the findings of Abu-Zinada (2015), who also reported minimum percentage of shot berries in 'Parletta' seedless grapes by using berry thinning and GA_3.

The minimum unripe berries (7.44 %) was recorded in Flower thinning +GA_3 + ethephon (T_9), whereas, the maximum (13.43 and 25.10 %) was in control (T_1). Downey et al. (2006) who found that grape berry color development had been reported to be influenced by a number of factors such as cultivar, cultural practices, location as well as girdling. Crupi et al., (2016) who mentioned that girdling gave the highest content of malvidin and peonidin which mainly responsible for the color stability of the skins) of seedless red table grape. Our study is in the line of conformity with the findings of El-Kenawy (2018) who reorted also minimum unripe berries in Crimson seedless grapevines with flower thinning.

Among all the treatments the minimum crop duration (38.38 days) was recorded in Trunk girdling +GA_3 (T_{15}), whereas, the maximum (64.45 days) was recorded in control. The beneficial effect of trunk girdling and berries thinning along with plant growth regulators might be due to their effect in earliness of flowing and reducing flower duration which ultimately reduce the total crop duration of the berries. Our study is in the line of conformity with the findings of Gawankar *et al.* (2019) who reported that trunk girdling significantly reduced the time needed for inflorescence emergence and the duration of flowering and which ultimately reduced the total crop duration of grape vines.

The maximum bunch weight (801.73 g) was observed in Trunk Girdling + manual berry thinning +GA_3 + ethephon (T_{19}) and the lowest (413.59 g) was in control. GA_3 has been routinely used for seedless grape production to increase berry and bunch weight (Lu et al., 1995). GA_3 has a beneficial effect on cell division and cell enlargement, thus on a higher accumulation of sugar and water without changing pressure potential, which in consequence translate into larger berry and bunch size during harvest (Perez and Gomez, 2000; Casonova et al., 2009). The present results are in accordance with those reported by Reynolds and Sevigny (2004) in ‘Sovereign Coronation’ table grapes and Abu-Zahra and Salameh (2012) in Black Magic grapes and Abu-Zinada (2015) on 'Parletta' Seedless Grape, who also reported maximum bunch weight with the application of trunk girdling and GA_3.

The maximum bunch length (23.39 cm), bunch breath (14.56 cm), and bunch size (340.95 cm^2) was observed in Trunk Girdling + flower thinning +GA_3 + ethephon (T_{18}) and the lowest (15.11 cm, 8.33 cm and 125.85 cm^2) was in control. Girdling temporarily interrupts phloem transport and is expected to increase carbohydrate and other metabolites above the girdling zone (Li et al., 2003). Thus, the hypotheses around girdling are that the higher level of carbohydrates or the higher level of growth promoting PGRs such as auxin, gibberellin and cytokinin promote an increase in berry size and berry number which ultimately increases the bunch size. Our study is in close conformity with the findings of Abu-Zahra and Salameh (2012) and Abu-Zinada (2015) on 'Parletta' Seedless Grape who also reported increased bunch size with combined application of trunk girdling and GA_3.

The maximum berry per bunch (182.92) and bunch per vine (49.46) was observed in Trunk girdling + manual berry thinning +GA_3 + ethephon (T_{19}). The least values (114.69, and 30.28) was recorded in control (T_1). Girdling can improve carbohydrate availability to fruits and as a consequent lead to an increase in fruit-set and yield as well as number of berries (Goren *et al.,* 2003; Rivas *et al.,* 2004). In this context, all the girdled branches produced the higher number of fruits than the untreated control fruit.

Casanova *et al*. (2009), observed that girdling had no negative effect on the number of harvested bunches per vine the year following the scoring year, both in ‘Emperatriz’ and ‘Aledo’ cultivars. Our results are in close conformity with the findings of Abu-Zahra and Salameh (2012) who also reported increased berry numbers per bunch with combined application of trunk girdling and $GA_{3.}$ Abu-Zinada (2015) also reported increase in bunch number per vine with the combined application of GA_3, Girdling and Pruning on 'Parletta' Seedless Grape.

. The maximum bunch compactness (4.08 g cm^{-2}) was observed in manual berry thinning + ethephon (T_{11}) which was significantly higher than all other treatments, while the lowest (2.02 g cm^{-2}) was in Ethephon (T_6). Our study is in close conformity with the findings of Ahmad and Zargar (2005), Abu-Zahra and Salameh (2012) and Abu-Zinada (2015) who also reported variation in cluster compactness in grape berries with different pruning and growth regulators.

The highest yield per vine (30.13 kg) and yield per hectare (33.48 t ha^{-1}) was observed in Trunk girdling + manual berry thinning +GA_3 + ethephon (T_{19}), while the least (9.35 kg and 10.39 t ha^{-1} was observed in control (T_1). Yield is a complex character and is characterized by an increase in number of fruits and also due to increase in weight of individual fruit. Girdling is a practice used in order to control the excessive vegetation and thereby improving the crop yield due to increase of fruit set and fruit size (Raffo *et al*., 2011). In the present investigation, the increase yield with trunk girdling might be due to the fact that trunk girdling resulted in higher flower bud initiation, and thus fruit set, leading to higher yield. Our study is in close conformity with the findings of Singh *et al.* (2016) who reported that trunk girdling and GA is very effective in increasing the fruit yield of pear. Increase in fruit yield with the girdling also reported by Chanana and Gill (2008) in grapes, Nikola *et al.* (2009) in 'Elstar' apple, Raffo *et al.* (2011) in 'Bartlett' pear, Huang *et al.* (2012) in 'Nuomici' and 'Guiwei' cultivars of litchi and Fallahi et al. (2018) in Aztec Fuji apple. The present results may also be due to the fact that gibberellins enhanced the translocation and mobilization of shared metabolites or photosynthates from source to sink. Further, it could be partly due to increase in auxin synthesis in ovaries.

5.2.3 Berry physical parameters

The results of the present investigation revealed that the physical parameters of the grape berries were significantly influenced by crop regulations (Table 4.2.11). The present studies indicated that the maximum individual berry weight (7.39 g) and hundred berry weights (731.33 g) was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), followed by Trunk girdling + flower thinning + GA_3 + Ethephon (T_{18}), (6.60 g) whereas the lowest was recorded in control (4.44 g and 438.86 g). It might be due to the fact that GA_3 show indirect effect through auxin stimulation on the cell elongation by the enlargement of vacuoles and loosening of cell wall after increasing its plasticity, which lead to increase in fruit weight. In addition, girdling and GA_3 sprays may have a synergistic effect on increasing berry size. Study conducted by Wo-Jun *et al.* (2001) in 'Fujiminori' grapes and Sharma and Singh (2009) in strawberry support the findings. The present results are in accordance with those reported by Reynolds and Sevigny (2004) in 'Sovereign Coronation' table grapes, Ahmad and Zargar (2005) in

Perlette, Jin Young *et al.* (2005) in ‘Red Globe’ grapes and Fallahi et al. (2018) in Aztec Fuji apple. Abu-Zinada (2015) also reported maximum hundred berry weight with the combined application of GA_3, girdling and Pruning on 'Parletta' Seedless Grape.

The data given in Table 4.2.11 showed that there was a significant difference in berry longitudinal diameter among the different treatments. Among all the treatments, the maximum berry longitudinal diameter (3.38 cm), was recorded in vines treated with Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), followed by Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}) (2.91 cm). Singh *et al.* (2016) also reported that trunk girdling and GA is very effective in increasing the longitudinal diameter of the fruits. The uses of GA_3 was found to increase berry size due to increase sink strength for accumulating nutrients, such as K (Ropar and Williams, 1989; Zhenming et al., 2008). Also girdling grapevines increases carbohydrate concentration above girdle and resulted in larger berries as the transport of sugars from leaves to the root system is effectively blocked (Ropar and Williams, 1989). The present results are in accordance with Dokoozlian *et al.* (2001) in ‘Autumn Royal’ and Wo-Jun *et al.* (2001) in ‘Fujiminori’ grapes. Lakshamanan *et al.* (1992) also reported the positive effect of GA_3 on berry length in various varieties of grapes as ‘Tas-e-Ganesh’, ‘Anab-e-Shahi’, ‘Thompson Seedless’ etc. Similar findings were also reported by Rahemi and Atahhoseini (2004) in pomegranate and Amoros *et al.* (2004) in loquat.

Trunk girdling with berry thinning and growth regulators also increased berry transversal diameter. Among all the treatments, the maximum berry transversal diameter (2.37 cm), was recorded in Trunk girdling + manual berry thinning + GA_3 + ethephon

(T_{19}), whereas, the lowest was recorded in control (1.83 cm). Our study is in close conformity with the findings of Singh *et al.*, (2016) who reported that trunk girdling and GA is very effective in increasing the berry transversal diameter. Increase in berry transversal diameter with GA was also registered Wo-Jun *et al.* (2001) in 'Fujimoniri' grapes. Increase in berry size with Trunk girdling along with berry thinning and growth regulators might be pertained to the fact that gibberellins indirectly affected the level of auxin that ultimately caused cell elongation by enlargement of vacuoles and loosening of cell wall after increasing its palatability. Increase in fruit size by Trunk girdling has also been reported by Smit *et al.* (2005) in 'Early Ben Chretein' pear, Sousa *et al.* (2008) in 'Rocha' pear, Reginato and Mesa (2011) in 'Castlebrite' apricot and Murakami (2012) in 'Rainbow Red' kiwifruit.

Trunk girdling + manual berry thinning +GA_3 + ethephon (T_{19}) recorded the highest berry volume (15.47 cc), while, the least was recorded in control (T_1) (12.85 cc). These results are harmony with those reported by Kriedemann and Lenz (1972) who found that alternative changes in the hormone balance of the vine after girdling may have a role on increasing berry volume. Abd El-Wahab (2006), Abu-Zahra (2010) and Abu- Zahra and Salmeh (2012) mentioned that girdling the trunk recorded the highest values for berry volume.

The maximum skin thickness (0.088 mm) was obtained in manual berry thinning +GA_3 + ethephon (T_{12}), while, the least (0.044 mm) was in control (T_1). Our study is in the line of conformity with the findings of Wright (2000) who also reported increase in skin thickness of 'Fairchild' mandarins with different berry thinning and growth regulators.

The maximum pedicel thickness (3.95 mm), was obtained in flower thinning+GA_3 (T_7), while, the least (2.93 mm) was in control (T_1). Increased pedicel thickness with the application of trunk girdling and GA_3 was also reported previously by a number of researchers (Dokoozlian, 1999; Zoffoli et al. 2009)

The maximum seed weight (0.084 g) was obtained in Trunk girdling + flower thinning (T_{13}), while the least (0.059 g) was obtained in Trunk girdling + manual berry thinning +GA_3 + ethephon (T_{19}). Our present study is in accordance with the study of Reynolds and Sevigny (2004) in 'Sovereign Coronation' table grapes who also reported lowest number of seeds with trunk girdling and GA_3.

In the present investigation, the maximum seed width (0.539 cm) was obtained in Manual berry thinning +GA_3 + ethephon (T_{12}), while the least (0.412 cm) was obtained in Trunk girdling + flower thinning (T_{19}). Similarly, maximum seed length (0.756 cm) was recorded in GA_3 (T_5), while the minimum (0.660 cm) was in Trunk girdling + flower thinning (T_{13}). The maximum seed number (3.32) was recorded in flower thinning (T_2) while, the minimum (2.10) was recorded in manual berry thinning +GA_3 (T_{10}). Groot *et al.* (1987) reported that the role of endogenous gibberellin (GA) in seed and fruit development was significant and showed negative correlations with the total number of seeds per fruit. The seed size and width however increased. This may be due to the physiological effect GA has on the formation of seeds. Similarly, Liu *et al.*, (1996) reported that crop regulation coupled with exogenous GA_3 may reduce the number of seed while increasing the weight and size of seeds. However, spraying of gibberellins 4 and 7 (GA_{4+7}) at the rosette stage were found to increase the number of seeds (Gray *et al.,* 1986). Urwiler *et al.* (1986) suggest that application of Ethephon concentration may increase the seed size and weight. Our present study is in accordance with those reported by Reynolds and Sevigny (2004) in 'Sovereign Coronation' table grapes who also reported lowest number of seeds with application of GA_3.

5.2.4 Berry quality characters

The minimum moisture (78.77%) was found in manual berry thinning + GA_3 + ethephon (T_{12}) while the maximum (83.86 %) was recorded in Pig manure + flower thinning +GA_3 + ethephon (T_9). The decrease in moisture in manually thinned fruits might be attributed due to its utilization in the hydrolysis of insoluble reserved metabolites into soluble metabolites.

Trunk Girdling + flower thinning +GA_3 + ethephon (T_{18}) showed the maximum juice content (71.73 %), which was significantly higher than all other treatments. The higher amount of juice content by the application of ethephon might be due to softening of berries leading to better juice extraction (Ahmad and Zargar, 2005). The results of present study are in accordance with the findings of Wright (2000) in 'Fairchild' mandarins, Nawaz *et al.* (2008) in Kinnow mandarin and Saleem *et al.* (2008) in 'Blood Red' Sweet orange.

Similarly, among all the treatments, the significantly highest TSS (21.10 ^{o}Brix) was recorded in Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}). Increase in TSS during maturation process may be due to the conversion of starch and other polysaccharides into simple sugars. The increased TSS in the juice of trunk girdling, berry thinning and GA_3 might be due to the increased mobilization of carbohydrates from the source to fruits by auxin treatments. The present results are in accordance with those reported by Reynolds and Sevigny (2004) in ‘Sovereign Coronation’ table grapes and Kaur *et al.* (2008) in ‘Perlette’ grapes. Increase in TSS with girdling have also been reported by Fujishima *et al.* (2005), Yamane and Shibayama (2007) in gapes and Fallahi et al. (2018) in Aztec Fuji apple.

Among all the crop regulation treatments, the maximum TSS: acid ratio (34.89) was recorded in Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}) which was significantly higher than all other treatments except Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) (32.76) with which it was found statistically at par. The minimum TSS: acid ratio (17.36) was obtained in control (T_1). Ethephon either alone or in combination with trunk girdling, berry thinning or GA_3 and their possible combinations exhibited increased TSS : acid ratio (Ahmad and Zargar, 2005). This may also be pertained to the fact that growth regulator application and girdling resulted in an increase in TSS content and decrease in acidity level of fruit than control, leading to higher level of TSS: acid ratio. These results support the earlier findings by Wu and Lin (2003) in loquat and Chanana and Gill (2006) in ‘Florda Prince’ peach and Abu-Zinada (2015) on 'Parletta' Seedless Grape.

Trunk Girdling + flower thinning +GA_3 + ethephon (T_{18}) recorded the maximum reducing sugars (14.64%), non- reducing sugars (1.87 %) , total sugars (16.18 %) and sugar: acid ratio (26.75) whereas, control (T_1) revealed the minimum (10.26%, 11.46%, 1.44 % and 13.11). The increase in total sugar with combined application of Trunk Girdling along with flower thinning, GA_3 and ethephon might be partly due to increased membrane permeability, which permitted the acids stored in cell vacuole to respire at a faster rate and partly because of transformation of organic acids into sugars (Singh et al. 1992). Verreynne *et al.* (2001) reported that girdling enhanced the total sugar content in Marisol' Clementine's. Fruits from the girdle branch yielded the higher amount total sugars which may be due to carbohydrate availability and starch content high in upper part of girdle. These results are in agreement with the findings of Kazutoshi *et al.* (2009), who reported that sugar content increased in Japanese persimmon, in phloem ringed plants compared to the control. Our study is in the line of conformity with the studies of Ahmad and Zargar (2005) and Khandaker et al. (2011), who reported the positive effects of the girdling treatment on the total sugar content in the fruits. The maximu sugar: acid ratio in this treatment might be due to maximum total sugar and minimum acidity of fruit, leading to highest sugar: acid ratio.

It is revealed from the data presented in Table 4.2.17 that crop regulation with Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}) recorded the lowest titratable acidity (0.605 %) whereas the highest acidity (0.874%) was recorded in untreated control. Decreased acid content brings sweet taste in the fruit which leads to better acceptability of fruit by the consumer. The reduction in acidity is accompanied by increased accumulation of total soluble solids in grapes clearly suggests increased catabolism of organic acids into soluble sugars as earlier suggested Ahmad and Zargar, (2005). Singh *et al.*, (2016) reported that trunk girdling and GA is very effective in decreasing the berry titratable acidity Reynolds and Sevigny (2004) and Kaur *et al.* (2008) also observed similar trend of reduction of acidity with the use of GA_3 and trunk girdling in grapes. Acidity was also found to decrease with the girdling by Fujishima *et al.* (2005) in 'Pione' grapes, Chanana and Gill (2006) in 'Flroda Prince' peach and Huang *et al.* (2012) in 'Nuomici' and 'Guiwei' litchi. The maximum acidity in control might be due to minimum total soluble solid and sugars content present in control (Khan, 2013).

Trunk Girdling + flower thinning +GA_3 + ethephon (T_{18}) showed the maximum ascorbic acid content (25.29 mg $100g^{-1}$) whereas, Trunk girdling + flower thinning (T_{13}) revealed the minimum (20.62 mg $100g^{-1}$). It is well established that girdling determine the crop load and fruit size, which can influence the nutritional composition of fruits (especially nitrogen) and may indirectly affect the vitamin C content (Lee & Kader 2000). Our study is in close conformity with the findings of Zhao et al. (2013), who reported that girdling in mid-May increased ascorbic acid in apple.

Anthocyanin pigments are responsible for the red, purple, and blue colors of many fruits and also they have possible health benefits as dietary an-tioxidants (Ronald & Wrolstad 2001). Girdling accelerated ripening and also had positive effects on anthocyanin accumulation in the fruits (Khandaker et al. 2011). In grapes, anthocyanins are responsible for the color of the red and black grape berries and their concentration in the berry skin increases during berry ripening (Mullins *et al.* 1992). Grape berry color development has been reported to be influenced by a number of factors such as cultivar, cultural practices, location as well as exogenous application of abscisic acid and ethephon and girdling (Downey et al., 2006). In the present investigation, the maximum anthocyanin (4.15 mg g^{-1}) was recorded with manual berry thinning +GA_3 + ethephon (T_{12}), while, the least (2.25 mg g^{-1}) was recorded in control (T_1). Noel (1970) suggested that girdling in fruit trees can increase carbohydrate supply during fruit maturation, leading to the enhancement of red coloration by increasing anthocyanin synthesis. Girdling apple trees 10 days after petal fall only slightly improved red color in two of three cultivars but increased background yellow color development of fruit skin (Schumacher et al., 1986). Wargo et al. (2004) reported that midsummer trunk girdling increased red coloration and intensity and improved market-grade pack out in 'Jonagold' apple. Our study is in close conformity with the findings of Fallahi et al. (2018) and Pereira et al. (2020) in grapes who reported that trunk girdling increased anthocyanin concentrations in the skin/pulp tissues.

The presence of carotenoids in grapes is well-documented, having been demonstrated that â-carotene and some xanthophylls (neoxanthin, flavoxanthin, and lutein) are abundant before veraison, and subsequently decreasing dramatically (Razungles et al. 1988; Razungles et al. 1996). Three other xanthophylls, namely, violaxanthin, luteoxanthin, and 5,6- epoxylutein, appear after veraison, (Razungles et al. 1996). Carotenoids are known as precursors of C13-norisoprenoid compounds (Marais et al., 1989; Kotseridis et al., 1998;), which have been identified in grapes and are known to be responsible for the typical aroma of some varieties. In the present investigation, the maximum total carotenoids content (11.05 µg g^{-1}) was recorded with flower thinning +GA_3 + ethephon (T_9), while, the least (6.79 µg g^{-1}) was recorded in control (T_1). Our study is in close conformity with the findings of Khandaker et al (2011) who also reported increase in carotenoid content due to trunk girdling.

The maximum raisin recovery (25.82 %) was recorded with Trunk girdling +GA_3 + ethephon (T_{17}), whereas, the minimum (20.60 %) was found in control (T_1). Ambotu et al. (2020) reported that crop regulation increases sugar accumulation and TSS of the fruit which ultimately impact the overall resin recovery in grapes. Dokoozlian *et al.* (1984) also suggested that pre-harvest spray of ethephon in grapes gave the highest fruit and raisin recovery in the first season. Our results are in the line of conformity with the findings of Schultz (2006) who suggested that GA_3 application increased berry size and loosen up bunches which increases the sugar content and resulted in better raisin recovery.

In the present investigation, the maximum protein (7.27 g $100g^{-1}$), was reported with Trunk girdling + flower thinning +GA_3 + ethephon (T_{18}), while the minimum (4.90 mg g^{-1}) was in T_1 (control). The higher protein content due to Trunk girdling and flower thinning along with GA_3 and ethephon might be due to better metabolic activities which aggravates level of nitrogen and amino acids which ultimately increases the protein content of the berries.

The maximum starch (4.62 mg g^{-1}) was obtained with Flower thinning +GA_3 + ethephon (T_9), while the minimum (2.08 mg g^{-1}) was in T_1 (control). It is reported that Girdling treatment increased the starch content of pruned cane (Yamane and Shibayama, (2006) and Rivas et al. 2008). It may be due to the accumulation of chlorophyll content and increased photosynthesis in the girdled branch (Khandaker et al. 2011).

The maximum carbohydrate (82.37 mg g^{-1}) was obtained with manual berry thinning + ethephon (T_{11}), while the minimum (54.01 mg g^{-1}) was in T_1 (control). Removal of a strip of phloem from the main trunk by girdling actually blocks the transport of sugars to the roots; large amounts of carbohydrates produced by photosynthesis will accumulate in vegetative organs above the girdle or be used for fruit development. Girdling has been shown to increase the carbohydrate concentration above the girdle in *Vitis vinifera* L. (Roper & Williams 1989). In citrus, girdling a few weeks before flowering increased carbohydrate concentration in various vegetative shoots (Rivas et al. 2008).

Phenolic compounds in fruits are important, because they can exhibit antioxidant properties. In the present investigation, the maximum total phenols (0.87 mg g^{-1}) was obtained with Trunk girdling + flower thinning +GA_3 + ethephon (T_{18}), while the minimum (0.61 mg g^{-1}) was in T_1 (control) Our findings agree with those of Kubota *et al.* (2001), to prove trunk girdling had a significant effect on total phenolic content, who reported that girdling significantly increased the PAL enzyme activity and total phenolic content in the peach fruits. In addition, trunk girdling significantly changed the phenolic composition of mature berries, specifically, total flavan-3-ols content and individual flavan-3-ols, (+)-catechin and (-)-epicatechin levels and monomeric flavonols such as myricetin glycoside, quercetin-glucoside and quercetin-rhamnoside were significantly higher after girdling (Tyagi et al. 2020). It has been reported that trunk girdling increased total phenolic content in peach fruit (Kubota et al. 1993).

5.2.5 Economics of cultivation

The highest gross income (Rs. 23,43, 600.00), net income (Rs. 18,53,942.45) and B:C ratio (3.79) was observed in Trunk girdling + manual berry thinning +GA_3 + ethephon (T_{19}), while, the lowest (Rs. 7,27,300.00; Rs. 2,66,629.45 and (0.58) was recorded in control. The highest gross income, net return and B:C ratio in Trunk girdling + manual berry thinning +GA_3 + ethephon (T_{19}), may be due to higher yield and comparatively low cost of production. The lowest net returns and benefit: cost ratio in control may be due to low yield. Our study is in close conformity with the findings of Wright (2000) who also reported maximum net returns and gross receipt in 'Fairchild' mandarins by using different trunk girdling treatments.

Summary and Conclusion

The present investigation entitled "*Organic Nutrient Management and Crop Regulation in Grapes in Mizoram*" was carried out during 2016-2017 and 2017-2018 at farmer's field located at Vengthar and Vengsang village of Champhai District, Mizoram.

The salient findings emerged out from the present investigation are summarized below:

Experiment No 1: Effect of organic manures and bio-dynamic preparations on growth, yield and quality of Grapes cv. Bangalore Blue

1. The maximum shoot length (122.23 cm) was recorded from the plants applied with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 +

BD 501 (T_9) whereas, control (T_{13}) recorded the minimum shoot length (115.25 cm and 16.48 mm).

2. The maximum shoot diameter (20.83 mm) was recorded from the plants applied with PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{12}) whereas, control (T_{13}) recorded the minimum shoot diameter (16.48 mm).
3. Among all the treatments, NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}) showed the maximum intermodal length (12.43 cm), while the lowest was recorded in control (9.87 cm).
4. The maximum cane diameter (6.70 mm) was recorded with NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}) while, the least (3.77 mm) was recorded in control.
5. FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the maximum fruitful cane (93.85 %), while, the minimum (75.60 %) was recorded in control (T_{13}).
6. The maximum berry set (39.57 %), berry retention (58.86 %) and minimum berry drop (41.14 %) was recorded in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while, the minimum berry set (30.08 %), berry retention (41.29 %) and maximum berry drop (58.71 %) was recorded in control (T_{13}).

7. The minimum shot berries (2.40 %) was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), whereas, the maximum (13.07 %) was recorded in control (T_{13}).
8. The minimum unripe berries (7.11 %) was recorded in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), whereas, the maximum (26.43 %) was recorded in control (T_{13}).
9. The minimum total crop duration (45.35 days) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while, the maximum total crop duration (63.54 days) was observed in T_{13} (control).
10. The highest bunch weight (796.19 g), bunch length (21.66 cm), bunch breath (13.01 cm) and bunch size (281.79 cm^2) was observed in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) and the lowest (413.80 g; 13.67cm; 7.19 cm and 98.29 cm^2 respectively) was in control.
11. The highest number of berries per bunch (187.46), bunches per vine (51.84) and bunch compactness (5.89 g cm^{-2}) was observed in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9), while, the least (98.33, 30.64 and 2.83 g cm^{-2}) was recorded in control (T_{13}).
12. The highest yield per vine (30.52 kg) and yield per hectare (33.91 tonnes) was observed in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9), while the least (9.23 kg and 10.25 t ha^{-1} respectively) was observed in control (T_{13}).

13. The maximum berry weight (6.14 g) was observed in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while, the minimum (3.75 g, 1.91 cm, 1.67 cm and 12.75 cc). was recorded in control (T_{13})
14. The maximum berry longitudinal diameter (2.71 cm), transversal diameter (2.28 cm) and berry volume (15.03 cc) was observed in VC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}), while, the minimum (1.91 cm, 1.67 cm and 12.75 cc). was recorded in control (T_{13})
15. The highest hundred berry weights (608.03 g) was recorded in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), whereas the least (368.90 g) was in control (T_{13}).
16. The maximum skin thickness (0.091 mm) and pedicel thickness (3.82 mm) was obtained in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8), while, the least (0.050 mm and 2.86 mm) was obtained in control (T_{13}).
17. PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the minimum seed weight (0.062 g), while the maximum (0.081 g,) was recorded in control (T_{13}).
18. FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), recorded the maximum seed length (0.7473 cm), while the least (0.699 cm,) was recorded in control (T_{13}).
19. NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_7), recorded the maximum seed width (0.485 cm), while, the least (0.062 g, 0.699 cm, 0.383 cm and 2.08) was recorded in control (T_{13}).

20. Control (T_{13}), recorded the maximum seed number (3.31) while the least (2.08) was recorded in FYM + *Azospirillum* + PSB + KSB (T_1).

21. The minimum moisture (79.80%) was recorded in PIM + *Azospirillum* + PSB + KSB (T_4), while, the maximum (82.72 %) was recorded in T_{13} (control).

22. VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) showed the maximum juice (69.16 %), whereas, FYM + *Azospirillum* + PSB + KSB (T_1) revealed the minimum juice content (60.56 %) among all the treatments.

23. The maximum TSS (21.05 °B), TSS: Acid ratio (32.86), reducing sugars (13.20 %), non- reducing sugars (1.80 %), total sugars (14.66 %), sugar: acid ratio (22.88), and ascorbic acid content (25.17 mg $100g^{-1}$) was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the minimum 15.30 °B, 17.53, 10.15 %, 1.41 %, 11.33 %, 12.99 % and 20.76 mg $100g^{-1}$) was recorded in control (T_{13}).

24. The minimum acidity (0.64 %) was obtained in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while the maximum (0.87 %) was in control (T_{13}).

25. Among all the treatments, VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recorded the maximum anthocyanin (4.00 mg g^{-1}) and total carotenoids content (10.76 µg/g), while, the minimum (2.19 mg g^{-1} and 6.92 µg g^{-1}) was found in control (T_{13}).

26. The maximum raisin recovery (25.66 %) was recorded with FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), whereas, the minimum (20.72 %) was found in control (T_{13}).

27. The maximum protein (7.15 mg g^{-1}), starch (4.13 mg g^{-1}), and total phenols (0.88 mg g^{-1}) of the berries was obtained with VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while the minimum (5.00 mg g^{-1}, 2.51 mg g^{-1}, and 0.62 mg g^{-1},) was in T_{13} (control).

28. The maximum carbohydrate (81.39 mg g^{-1}) of the berries was obtained with PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while the minimum (55.49 mg g^{-1}) was in T_{13} (control).

29. The maximum leaf nitrogen (3.82 %) and K (1.71 %), was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the minimum (3.09 % and 1.21 %).) was recorded in control.

30. The maximum leaf phosphorus (0.271 %), and leaf dry matter (0.171 g) was observed in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9), while, the minimum (0.219 % and 0.107 g).was in control (T_{13}).

31. The maximum leaf carbohydrate (13.64 %) was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), while, the minimum (13.23 %) was T_{13} (control).

32. The minimum C: N ratio of 4.78 was found in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9), while, the maximum (6.17) was in control (T_{13}).

33. PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the highest chlorophyll a (1.530 mg g^{-1}), chlorophyll b (0.56 mg g^{-1}), and total chlorophyll (2.09 mg g^{-1}), while, the least was recorded in T_{13} (control) (1.253, 0.25 and 1.50 (mg/g)), .

34. The maximum Fe (272.18 ppm) was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the minimum (241.33, ppm) was recorded in T_{12} (PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501).

35. The maximum Mn (26.60 ppm), of the leaf was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) while, the minimum (23.15, and 7.72 ppm) was recorded in T_{13}.

36. The maximum Cu (9.09 ppm) of the leaf was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the minimum (7.72 ppm) was recorded in T_{13}.

37. The pooled data showed that the maximum Zn content (27.42 ppm) was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), while the minimum (21.94 ppm) was recorded in control (T_{13}).

38. The significantly highest soil pH (4.92), and soil moisture (34.39%). was recorded in FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500

+ BD 501(T_9). However, the minimum (4.08 and 24.47 %).) was obtained in control (T_{13}).

39. The soil organic carbon (7.42 g kg^{-1}), inorganic carbon (2.23g kg^{-1}), total carbon (9.65 g kg^{-1}) and total nitrogen (0.689g kg^{-1}) of the soil was found maximum in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while the minimum (6.07, 1.65, 7.72 and 0.513 g kg^{-1}) was recorded in control (T_{13}).

40. The maximum C: N ratio (15.10) was found in Farmer's practice (T_{14}), while, the minimum (13.33) was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* (T_6).

41. The maximum CEC (19.49 meq $100g^{-1}$) was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}), while, the minimum (16.20 meq $100g^{-1}$) was recorded in control (T_{13}).

42. The maximum available N (868.86 kg ha^{-1}), P (159.81 kg ha-1), K (644.50 kg ha^{-1}), Mn (29.93 ppm) , and Zn content (2.308 ppm) of the soil was recorded in PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), while, the minimum (459.97, 123.64, 426.69 kg ha^{-1}, 24.51 and 1.615 ppm) was recorded in control (T_{13}).

43. The maximum Fe (74.60 ppm) of the soil was recorded in VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (74.60 ppm), while, the minimum (54.27 ppm) was recorded in control (T_{13}).

44. The maximum Cu content (2.665 ppm) was recorded with FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5) which was significantly higher than all other treatments. However, the minimum Cu content (2.153 ppm) was observed in control (T_{13}).

45. VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recorded the maximum fungal count (48.30×10^4 CFU g^{-1} of soil), while, control (T_{13}) recorded the minimum value (27.43 × CFU $g^{-1}$of soil). .

46. PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) recorded significantly highest bacterial count (49.84×10^4 CFU g^{-1} of soil), and *Actinomycetes* count (45.04×10^4 CFU g^{-1} of soil), while, control (T_{13}) recorded the minimum value (24.18×10^4 and 25.43×10^4 CFU $g^{-1}$of soil) .

47. Among all the treatments, the highest gross income (Rs. 30,51,900.00), net returns (Rs. 24,09,157.11), and benefit cost ratio (3.75) was observed with FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) while the lowest was recorded in control (T_{13}) (Rs. 7,17,500.00; Rs 3,19,736.75 and 0.80).

Conclusion

Based on the summary of the present investigation, the following conclusions have been drawn from the present investigation:

- Among all the treatments, FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) is the best treatment in respect of growth and yield of grapes cv. Bangalore Blue in Mizoram.

- VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) is the best treatment in terms of quality parameters of the berries.
- Treatment PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) is the best treatment among all in terms of improvement in soil health.
- From the cost of cultivation, FYM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) is the best treatment with highest net income and benefit: cost ratio.

Experiment no. 2: Effect of Crop regulation on growth, yield and quality of Grapes cv. Bangalore Blue

1. The maximum shoot length (123.08 cm) was recorded in Trunk girdling + manual berry thinning + GA3 + ethephon (T_{19}), while, control (T_1) recorded the minimum shoot length (116.05 cm).
2. The maximum shoot diameter (21.38 mm) was recorded in Trunk girdling +flower thinning + GA3 + ethephon (T_{18}), while, control (T_1) recorded the minimum shoot diameter (16.69 mm).
3. Manual berry thinning + GA3 + ethephon (T_{12}) showed the maximum internodal length (12.92 cm), while, the lowest was recorded in control (10.43 cm) .
4. Flower thinning + GA3 + ethephon (T_9) showed the maximum cane diameter (7.02 mm), while, the lowest was recorded in control (4.28 mm) .
5. Trunk girdling +flower thinning + GA3 + ethephon (T_{18}) showed the maximum fruitful cane (93.79 %), while, the lowest was recorded in control (73.71%) .

6. The maximum berry set (39.57 %), berry retention (58.86 %) and minimum berry drop (41.14%) was recorded in Trunk Girdling + manual berry thinning + GA_3 + ethephon (T_{19}), whereas the minimum berry set (30.08 %), berry retention (42.04%), and maximum berry drop (57.96 %) was recorded in control (T_1).
7. The minimum shot berries (2.73 %), was recorded in manual berry thinning + GA_3 + ethephon (T_{12}), whereas, the maximum (13.43 and 25.10 %) was in control (T_1).
8. The minimum unripe berries (7.44 %) was recorded in Flower thinning + GA_3 + ethephon (T_9), whereas, the maximum (13.43 and 25.10 %) was in control (T_1).
9. The minimum total crop duration (38.38 days) was recorded in Trunk girdling + GA_3 (T_{15}), while, the maximum (64.45 days) was observed in T_1 (control).
10. The maximum bunch weight (801.73 g), was observed in Trunk Girdling + manual berry thinning + GA_3 + ethephon (T_{19}) and the lowest (413.59 g) was in control.
11. The maximum bunch length (23.39 cm), bunch breath (14.56 cm), and bunch size (340.95 cm^2) was observed in Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}) and the lowest (15.11 cm, 8.33 cm and 125.85 cm^2) was in control.
12. The maximum berry per bunch (182.92) and bunch per vine (49.46) was observed in Trunk girdling +manual berry thinning + GA_3 + ethephon (T_{19}). The least values (114.69, and 30.28) was recorded in control (T_1).
13. The maximum bunch compactness (4.08 g cm^{-2}) was observed in manual berry thinning + ethephon (T_{11}) which was significantly higher than all other treatments, while the lowest (2.02 g cm^{-2}) was in Ethephon (T_6).

14. The highest yield per vine (30.13 kg) and yield per hectare (33.48 t ha $^{-1}$) was observed in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), while the least (9.35 kg and 10.39 t ha $^{-1}$ was observed in control (T_1).
15. Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}) recorded the highest individual berry weight (7.39 g), berry longitudinal diameter (3.38 cm), berry transversal diameter (2.37 cm), berry volume (15.47 cc), and hundred berry weights (731.33 g) while, the least was recorded in control (T_1) (4.44 g, 1.99 cm, 1.83 cm, 12.85 cc and 438.86 g).
16. The maximum skin thickness (0.088 mm) was obtained in manual berry thinning + GA3 + ethephon (T_{12}), while, the least (0.044 mm) was in control (T_1).
17. The maximum pedicel thickness (3.95 mm), was obtained in flower thinning + GA_3 (T_7), while, the least (2.93 mm) was in control (T_1).
18. The maximum seed weight (0.084 g), was obtained in Trunk girdling + flower thinning (T_{13}), while the least (0.059 g) was obtained in Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}).
19. The maximum seed width (0.539 cm) was obtained in Manual berry thinning + GA_3 + ethephon (T_{12}), while the least (0.412 cm) was obtained in Trunk girdling +flower thinning (T_{19}).
20. The maximum seed length (0.756 cm) was recorded in GA_3 (T_5), while the minimum (0.660 cm) was in Trunk girdling +flower thinning (T_{13}).
21. The maximum seed number (3.32) was recorded in flower thinning (T_2) while, the minimum (2.10) was recorded in manual berry thinning + GA_3 (T_{10}).

22. The minimum moisture (78.77%) was found in manual berry thinning + GA_3 + ethephon (T_{12}) while the maximum (83.86 %) was recorded in Pig manure + flower thinning + GA_3 + ethephon (T_9).

23. Trunk Girdling +flower thinning + GA_3 + ethephon (T_{18}) showed the maximum juice content (71.73 %), whereas, Trunk girdling + flower thinning (T_{13}) revealed the minimum (61.55 %).

24. Trunk Girdling + flower thinning + GA_3 + ethephon (T_{18}) showed the maximum TSS (21.10 °B), TSS: acid ratio (34.89), reducing sugars (14.64%), non- reducing sugars (1.87 %), total sugars (16.18 %), sugar: acid ratio (26.75) and ascorbic acid content (25.29 mg $100g^{-1}$) whereas, control (T_1) revealed the minimum (15.17 °B, 17.36, 10.26%, 11.46%, 1.44 %, 13.11 and 20.62 mg $100g^{1}$).

25. The minimum acidity (0.605 %) was obtained in Trunk girdling +flower thinning + GA_3 + ethephon (T_{18}), while the maximum (0.874 %) was in control (T_1).

26. The maximum anthocyanin (4.15 mg g^{-1}) was recorded with manual berry thinning + GA_3 + ethephon (T_{12}), while, the least (2.25 mg g^{-1}) was recorded in control (T_1).

27. The maximum total carotenoids content (11.05 µg g^{-1}) was recorded with flower thinning + GA_3 + ethephon (T_9), while, the least (6.79 µg g^{-1}) was recorded in control (T_1).

28. The maximum raisin recovery (25.82 %) was recorded with Trunk girdling + GA_3 + ethephon (T_{17}), whereas, the minimum (20.60 %) was found in control (T_1).

29. The maximum protein (7.27 g $100g^{-1}$), was obtained with Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}), while the minimum (4.90 mg g^{-1}) was in T_1 (control).

30. The maximum starch (4.62 mg g^{-1}) was obtained with flower thinning + GA_3 + ethephon (T_9), while the minimum (2.08 mg g^{-1}) was in T_1 (control).

31. The maximum carbohydrate (82.37 mg g^{-1}) was obtained with manual berry thinning + ethephon (T_{11}), while the minimum (54.01 mg g^{-1}) was in T_1 (control).

32. The maximum total phenols (0.87 mg g^{-1}) was obtained with Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}), while the minimum (0.61 mg g^{-1}) was in T_1 (control).

33. The highest gross income (Rs. 23,43, 600.00), net income (Rs. 18,53,942.45) and B:C ratio (3.79) was observed in Trunk girdling +manual berry thinning + GA3 + ethephon (T_{19}), while, the lowest (Rs. 7,27,300.00; Rs. 2,66,629.45 and (0.58) was recorded in control.

Conclusion:

Based on the summary of the results, the following conclusions have been drawn from the present investigation:

- Among all the treatments, Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), is the best crop regulation practice for growth and yield of Bangalore Blue grapes.
- The application of Trunk girdling + flower thinning + GA_3 + ethephon (T_{18}), is the best crop regulation practices for producing the best quality berries.

- With respect to economics of cultivation, Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), is the best combination of organics and bio-fertilizers for giving maximum net return as well as B: C ratio.

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Annexure-I

Table: DETAILS OF ECONOMICS OF CULTIVATION PER HECTARE (In Rs.) OF EXPERIMENT 1

Cultivar: Bangalore Blue, Plant Population: 1111 Spacing: 3 X 3 m, wages: Rs 300 per manday.

Items	Treatments								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9

I. Preparatory cost Land preparation, ploughing and harrowing	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00
Digging and filling up of pits	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00
Cost of planting materials @Rs 75/seedling	83325.00	83325.00	83325.00	83325.00	83325.00	83325.00	83325.00	83325.00	83325.0
Planting of seedlings (15 mandays)	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00
Cost of Fencing	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.00	60000.0
II. Infrastructure Store and pump house	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.0
Labor room	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.0
Agricultural equipments and implements	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.0
III. Manuring Manures and fertilizers as per treatment	179537.60	146363.14	139719.36	129764.80	206201.60	173027.14	166383.36	156428.80	239554.1
Application of fertilizer Basal and top dressing(10 md)	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
IV. Irrigation Tube-well/submersible pump	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.0
Cost of Drip (Turboline) with Fertigation	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.0
IV. Intercultural operations Interculture (10 md)	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
Training & Pruning	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.0
V. Plant protection botanicals	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00
Application of Plant protection	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
VI. Harvesting (20 md)	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00
VII. Packaging (10 md)	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
Total Expenditure	576362.60	543188.10	536544.40	526589.80	603026.60	569852.10	563208.40	553253.80	636379.1
Miscellaneous	5763.63	5431.88	5365.44	5265.90	6030.27	5698.52	5632.08	5532.54	6363.79

cost (1% of total expenditure)									
Gross expenditure	582126.20	548620.00	541909.80	531855.70	609056.90	575550.70	568840.40	558786.30	642742.9
Yield (t/ha)	27.27	24.92	20.04	26.14	26.01	22.52	21.94	24.80	33.91
Return @Rs 90/kg for organic @Rs. 70 for inorganic	2454300.00	2242800.00	1803600.00	2352600.00	2340900.00	2026800.00	1974600.00	2232000.00	3051900.
Gross Income (Rs.)	2454300.00	2242800.00	1803600.00	2352600.00	2340900.00	2026800.00	1974600.00	2232000.00	3051900.
Net Income	1872173.77	1694179.98	1261690.20	1820744.30	1731843.13	1451249.34	1405759.56	1673213.66	2409157.
C: B Ratio	3.22	3.09	2.33	3.42	2.84	2.52	2.47	2.99	3.75

Annexure-II

CS OF CULTIVATION PER HECTARE (In Rs.) OF EXPERIMENT 2

t Population: 1111 Spacing: 3 X 3 m, wages: Rs 300 per manday.

	Treatments											
	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}	T_{18}	T_{19}
00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00
00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00	6500.00
5.0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0	83325.0 0
00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00	4500.00
.0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0	60000.0 0
.0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0	45000.0 0

0.0	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00
0.0	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00	10000.00
4.4	59284.46	59284.46	59284.46	59284.46	59284.46	59284.46	59284.46	59284.46	59284.46	59284.46	59284.46	59284.46
00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
0.0	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00	85000.00
0.0	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00	45000.00
00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
0.0	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00	15000.00
00	4500.00	4500.00	5400.00	5400.00	5400.00	10500.00	11400.00	6000.00	6000.00	6000.00	10500.00	11400.00
00	8000.00	11300.00	3300.00	8000.00	11300.00	-	-	3300.00	8000.00	11300.00	11300.00	11300.00
00	3000.00	6000.00	3000.00	3000.00	6000.00	-	-	3000.00	3000.00	6000.00	6000.00	6000.00
00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00	3500.00
00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00
00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00

09.	471609.5	477909.5	467809.5	472509.5	478809.5	466609.5	467509.5	468409.5	473109.5	479409.5	483909.5	484809.5
09	4716.09	4779.09	4678.09	4725.09	4788.09	4666.09	4675.09	4684.09	4731.09	4794.09	4839.09	4848.09
78.	476325.55	482688.55	472487.55	477234.55	483597.55	471275.55	472184.55	473093.55	477840.55	484203.55	488748.55	489657.55
8	22.92	29.28	25.67	25.39	25.62	21.60	20.63	27.56	28.75	28.14	30.25	33.48
00	1604400.00	2049600.00	1796900.00	1777300.00	1793400.00	1512000.00	1444100.00	1929200.00	2012500.00	1969800.00	2117500.00	2343600.00
00	1604400.00	2049600.00	1796900.00	1777300.00	1793400.00	1512000.00	1444100.00	1929200.00	2012500.00	1969800.00	2117500.00	2343600.00
21	1128074.45	1566911.45	1324412.45	1300065.45	1309802.45	1040724.45	971915.45	1456106.45	1534659.45	1485596.45	1628751.45	1853942.45
9	2.37	3.25	2.80	2.72	2.71	2.21	2.06	3.08	3.21	3.07	3.33	3.79

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Publications:

1. Hazarika, T.K., **Lalhriatpuia, C**., Ngurthankhumi, R., Lalruatsangi, E., Lalhmachhuani, H. 2021. Edible Coatings in Extending the Shelf Life of Fruits: A Review.

Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.A-5725.

2. H. Lalhmachhuani1, T. K. Hazarika, **C. Lalhriatpuia,** Thangjam Premabati and T. Robert Singh. 2021. *In vitro* propagation and antioxidant properties of hatkora (*Citrus macroptera*) from North-East India. *Res. on Crops* 22 (1): 87-95.
3. **C. Lalhriatpuia**, Malsawm Kimi and T. K. Hazarika. 2021. Influence of crop regulations on growth, yield and quality of grapes (*Vitis vinifera*) in North-East India. *Res. on Crops* 22 (1): 96-103.

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1. Presented Oral paper on "Organic Manures and Bio-Dynamic Preparations on Growth, Yield and Quality of Grapes CV. BangaloreBlue"in the 2nd Annual Convention of North East (India) Academy of Science and Technology (NEAST) & International Seminar on Recent Advances in Science and Technology (IRSRAST) during 16th–18th November 2020 (Virtual) organized by NEAST, Mizoram University, Aizawl-796004, Mizoram (India)
2. Presented oral paper on 'Effect of crop regulation on growth, yield and quality of grapes cv. Bangalore Blue' in the International E-Conference on 'Advances and Future Outlook in Biotechnologyand Crop Improvement for Sustainable Productivity' organised by the Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru during 24-27th November, 2020

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ABSTRACT

ORGANIC NUTRIENT MANAGEMENT AND CROP REGULATION IN GRAPES IN MIZORAM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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DEPARTMENT OF HORTICULTURE, AROMATIC AND MEDICIANAL PLANTS

SCHOOL OF EARTH SCIENCES AND NATURAL RESOURCES MANAGEMENT

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ABSTRACT

ORGANIC NUTRIENT MANAGEMENT AND CROP REGULATION IN GRAPES IN MIZORAM

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN HORTICULTURE, AROMATIC AND MEDICIANAL PLANTS OF MIZORAM UNIVERSITY, AIZAWL

Abstract

The present investigation entitled "Organic nutrient management and crop regulation in Grapes in Mizoram" was performed at Vengthar and Vengsang village of Champhai District, Mizoram, for two fruiting seasons i.e. 2016- 2017 and 2017-2018 to study the effect of organic manures, bio-fertilizers and bio-dynamic preparations on growth, yield and quality of Grapes cv. Bangalore Blue in Mizoram, to analyze the soil health of grape plantation under the influence of organics, bio-fertilizers, bio-control agent and bio-dynamic preparations, to study the economics of grape cultivation under organic nutrients and to assess the impact of crop regulation on growth, yield, quality and economics of grapes.

There were two set of experiments for the present study as detailed below.

1st Experiment: Effect of organic manures and bio-dynamic preparations on growth, yield and quality of Grapes cv. Bangalore Blue

The experiment was conducted during 2016-2018 at Vengthar village of Champhai District, Mizoram. The experiment was laid out in Randomised block design (RBD) with fourteen treatments viz. T_1=Farm Yard Manure (FYM) +*Azospirillum* + Phosphate solubilizing bacteria (PSB) + Potash solubilizing bacteria (KSB), T_2= Vermicompost (VC) +*Azospirillum* + PSB + KSB, T_3= Neem cake (NC) + *Azospirillum* + PSB + KSB, T_4= Pig manure (PIM) +*Azospirillum* + PSB + KSB, T_5=FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum,* T_6= VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum*, T_7= NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum,* T_8= PIM +*Azospirillum* + PSB + KSB +

Trichoderma harzianum, T_9=FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + Cow Pat Pit (CPP) + Bio Dynamic (BD) 500 + BD 50, T_{10}= VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501, T_{11}= NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501, T_{12}= PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501, T_{13}= Control (without any manures and fertilizers), T_{14}= Farmers Practice (FP). The pooled analysis of two year data indicated that integrated application of organic manures with bio-dynamic components resulted significantly superior results in terms of growth, yield, and quality of fruits.

The Organic manure with bio-dynamic preparations improved the plant growth characters of the vines. The maximum shoot length (122.23 cm) was recorded from the plants applied with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) whereas, shoot diameter was maximum (20.83 mm) in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{12}). NC + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{11}) recorded the maximum intermodal length (12.43 cm) and cane diameter (6.70 mm).

With respect to the yield attributing characters and yield, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9) recorded the maximum fruitful cane (93.85 %), berry set (39.57%), berry retention (58.86 %) and minimum berry drop (41.14%). Similarly, the minimum shot berries (2.40 %) and minimum crop duration (45.35 days) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), whereas, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), recorded the minimum unripe berries (7.11 %). The highest bunch weight (796.19 g), bunch length (21.66 cm), bunch breath (13.01 cm), bunch size (281.79 cm^2), number of berries per bunch (187.46), bunches per vine (51.84) and bunch compactness (5.89 g cm^{-2}) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9). The same treatment also recorded the highest yield per vine (30.52 kg) and yield per hectare (33.91 tonnes).

Physical characters of the berries were also significantly influenced by different organic manures and bio-dynamic preparations. The maximum berry weight (6.14 g) and hundred berry weights (608.03 g) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_9), while, the maximum berry longitudinal diameter (2.71 cm), transversal diameter (2.28 cm) and berry volume (15.03 cc) was observed in VC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP+ BD 500 + BD 501 (T_{10}). Similarly, the maximum skin thickness (0.091 mm) and pedicel thickness (3.82 mm) was obtained in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_8), while, PIM + *Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the minimum seed weight (0.062 g). FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), recorded the maximum seed length (0.7473 cm), while, NC +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_7), recorded the maximum seed width (0.485 cm), while, the least seed number (2.08) was recorded in FYM +*Azospirillum* + PSB + KSB (T_1).

The quality parameters of the grape berries were significantly influenced by application of organic manures and bio-dynamic preparations. Among all the treatments, the minimum moisture content (79.80%) was recorded in PIM

+*Azospirillum* + PSB + KSB (T_4). VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) recoded the maximum juice (69.16 %), TSS (21.05 °B), TSS: acid ratio (32.86), reducing sugars (13.20 %), non- reducing sugars (1.80 %), total sugars (14.66 %), sugar: acid ratio (22.88), ascorbic acid (25.17 mg $100g^{-1}$), minimum acidity (0.64 %), maximum anthocyanin (4.00 mg g^{-1}) and total carotenoids (10.76 µg/g). The maximum raisin recovery (25.66 %) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5), whereas, the maximum protein (7.15 mg g^{-1}), starch (4.13 mg g^{-1}) and total phenols (0.88 mg g^{-1}) of the berries was obtained with VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}). PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), recorded the maximum carbohydrate (81.39 mg g^{-1}) of the berries.

Significant variations were observed among the treatments with respect to leaf parameters of grapevines. The maximum leaf N (3.82 %) and K (1.71 %), was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, leaf phosphorus (0.271 %), and leaf dry matter (0.171 g) was observed in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). The maximum leaf carbohydrate (13.64 %) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}). The minimum C: N ratio of 4.78 was found in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9). PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}) recorded the highest chlorophyll a (1.530 mg g^{-1}), chlorophyll b (0.56 mg g^{-1}), and total chlorophyll (2.09 mg g^{-1}). The maximum Fe (272.18 ppm) and Cu (9.09 ppm) of the leaves was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}), while, the maximum Mn (26.60 ppm) and Zn (27.42 ppm) was recorded in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}).

There was significant impact of organic manures and bio-dynamic preparations on soil parameters. The significantly highest soil pH (4.92), and soil moisture (34.39%). was recorded in FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_9). The soil organic carbon (7.42 g kg^{-1}), inorganic carbon (2.23g kg^{-1}), total carbon (9.65 g kg^{-1}) and total nitrogen (0.689g kg^{-1}), CEC (19.49 meq $100g^{-1}$), available N (868.86 kg ha^{-1}), P (159.81 kg ha-1), K (644.50 kg ha^{-1}), Mn (29.93 ppm) and Zn (2.308 ppm) of the soil was found maximum in PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{12}), The maximum C: N ratio (15.10) was found in Farmer's practice (T_{14}), while, the minimum (13.33) was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* (T_6). The maximum Fe (74.60 ppm) of the soil was recorded in VC +*Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) (74.60 ppm), while, Cu content (2.665 ppm) was recorded with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* (T_5). VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) also recorded the maximum fungal count (48.30 $\times 10^4$ CFU g^{-1} of soil), while, PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) recorded highest bacterial (49.84 $\times 10^4$ CFU g^{-1} of soil), and *Actinomycetes* count (45.04 $\times 10^4$ CFU g^{-1} of soil).

With respect to the economics of production, among all the treatments, the highest gross income (Rs. 30,51,900.00), net returns (Rs. 24,09,157.11), and benefit cost ratio (3.75) was observed with FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) while the lowest was recorded in control (T_{13}) (Rs. 7,17,500.00; Rs 3,19,736.75 and 0.80).

The following conclusions have been drawn from the present investigation:

Among all the treatments, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) is the best treatment in respect of growth and yield of grapes cv. Bangalore Blue in Mizoram. VC + *Azospirillum* + PSB + KSB+ *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_{10}) is the best treatment in terms of quality parameters of the berries. Treatment PIM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501(T_{12}) is the best treatment among all in terms of improvement in soil health. From the cost of cultivation, FYM +*Azospirillum* + PSB + KSB + *Trichoderma harzianum* + CPP + BD 500 + BD 501 (T_9) is the best treatment with highest net income and benefit: cost ratio.

2nd Experiment: Effect of Crop regulation on growth, yield and quality of Grapes cv. Bangalore Blue

To standardize the crop regulation practice for grapevines cv. Bangalore Blue for Mizoram, the experiment was conducted at Vengsang village of Champhai District, Mizoram during 2016-2018. There were nineteen treatments viz., T_1 = Control, T_2= Flower thinning, T_3= Manual Berry thinning, T_4= Trunk Girdling, T_5 = GA_3, T_6= Ethephon, T_7= Flower thinning +GA_3, T_8= Flower thinning +Ethephon, T_9= Flower thinning +GA_3 +Ethephon, T_{10}= Manual Berry thinning +GA_3, T_{11}= Manual

Berry thinning +Ethephon, T_{12} = Manual Berry thinning +GA_3 +Ethephon, T_{13} = Trunk Girdling +Flower thinning, T_{14} = Trunk Girdling +Manual Berry thinning, T_{15} = Trunk Girdling +GA_3, T_{16} = Trunk Girdling +Ethephon, T_{17} = Trunk Girdling +GA_3 +Ethephon, T_{18} = Trunk Girdling +Flower thinning +GA_3 +Ethephon and T_{19} = Trunk Girdling +Manual Berry thinning +GA_3 +Ethephon

The results of the present investigation revealed that different crop regulation practices significantly improved growth, yield attributing characters and yield as well as berry physical and quality parameters.

With respect to the growth characters of the vines, the maximum shoot length (123.08 cm) was recorded in Trunk girdling +manual berry thinning +GA_3 +ethephon (T_{19}), while, shoot diameter (21.38 mm) was recorded in Trunk girdling +flower thinning +GA_3 +ethephon (T_{18}). Manual berry thinning +GA_3 +ethephon (T_{12}) showed the maximum internodal length (12.92 cm), while, flower thinning +GA_3 +ethephon (T_9) showed the maximum cane diameter (7.02 mm).

Crop regulation practices also improved the yield attributing characters and yield of the grapevines. Trunk girdling +flower thinning +GA_3 +ethephon (T_{18}) showed the maximum fruitful cane (93.79 %), while, the maximum berry set (39.57 %), berry retention (58.86 %) and minimum berry drop (41.14%) was recorded in Trunk Girdling +manual berry thinning +GA_3 +ethephon (T_{19}). Among all the treatments, the minimum shot berries (2.73 %), was recorded in manual berry thinning +GA_3 +ethephon (T_{12}), whereas, unripe berries (7.44 %) was recorded in Flower thinning +GA_3 +ethephon (T_9). The minimum total crop duration (38.38 days) was recorded in Trunk girdling +GA_3 (T_{15}). Trunk Girdling +manual berry thinning +GA_3 +ethephon (T_{19}) recorded the maximum bunch weight (801.73 g), while, bunch length (23.39 cm), bunch breath (14.56 cm), and bunch size (340.95 cm^2) was recorded maximum in Trunk Girdling +flower thinning +GA_3 +ethephon (T_{18}). The maximum berry per bunch (182.92) and bunch per vine (49.46), highest yield per vine (30.13 kg) and yield per hectare (33.48 t ha^{-1}) was observed in Trunk girdling +manual berry thinning +GA_3 +ethephon (T_{19}).

With respect to the physical characters of the berries, Trunk girdling +manual berry thinning +GA_3 +ethephon (T_{19}) recorded the highest individual berry weight (7.39 g), berry longitudinal diameter (3.38 cm), berry transversal diameter (2.37 cm), berry volume (15.47 cc), and hundred berry weights (731.33 g). The maximum skin thickness (0.088 mm) was obtained in manual berry thinning +GA_3 +ethephon (T_{12}), while, the pedicel thickness (3.95 mm), was obtained in flower thinning+GA_3 (T_7). The maximum seed weight (0.084 g), was obtained in Trunk girdling +flower thinning (T_{13}), while seed width (0.539 cm) was obtained in Manual berry thinning +GA_3 +ethephon (T_{12}). GA_3 (T_5), recorded the maximum seed length (0.756 cm) and flower thinning (T_2) recorded the maximum seed number (3.32).

There was significant impact of crop regulation on the quality parameters of the fruits. The minimum moisture (78.77%) was found in manual berry thinning +GA_3 +Ethephon (T_{12}). Trunk Girdling +flower thinning +GA_3 +ethephon (T_{18}) showed the maximum juice (71.73 %), TSS (21.10 °B), TSS: acid ratio (34.89), reducing sugars (14.64%), non- reducing sugars (1.87 %), total sugars (16.18 %), minimum acidity (0.605 %) sugar: acid ratio (26.75) and ascorbic acid content (25.29 mg $100g^{-1}$). The maximum anthocyanin (4.15 mg g^{-1}) was recorded with manual berry thinning +GA_3 +ethephon (T_{12}), while, the total carotenoids content (11.05 µg g^{-1}) was recorded with flower thinning +GA_3 +ethephon (T_9). The maximum raisin recovery (25.82 %) was recorded with Trunk girdling +GA_3 +ethephon (T_{17}). The maximum protein (7.27 g 100g^{-1}) and total phenols (0.87 mg g^{-1}) was obtained with Trunk girdling + flower thinning +GA_3 +ethephon (T_{18}). The starch (4.62 mg g^{-1}) was obtained with Flower thinning +GA_3 +ethephon (T_9), while the carbohydrate (82.37 mg g^{-1}) was obtained with manual berry thinning + ethephon (T_{11}).

With respect to the economics of cultivation of grapevines under crop regulation, the highest gross income (Rs. 23,43, 600.00), net income (Rs. 18,53,942.45) and B:C ratio (3.79) was observed in Trunk girdling +manual berry thinning +GA_3 +ethephon (T_{19}).

The following conclusions have been drawn from the second experiment:

Among all the treatments, Trunk girdling + manual berry thinning + GA_3 + ethephon (T_{19}), is the best crop regulation practice for growth and yield of Bangalore Blue grapes. The application of Trunk girdling +flower thinning +GA_3 +ethephon (T_{18}), is the best crop regulation practices for producing the best quality berries. With respect to economics of cultivation, Trunk girdling +manual berry thinning +GA_3 +ethephon (T_{19}), is the best combination of organics and bio-fertilizers for giving maximum net return as well as B: C ratio.