EFFECT OF CROPPING AND MANAGEMENT TECHNIQUES ON CHILLI (*CAPSICUM ANNUUM* L.) PRODUCTION UNDER RAIN-FED FARMING.

ZANGMO ZANGMO

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
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has been approved by the Graduate School as partial fulfillment of the requirements for the Master of Science in Agricultural Science of Naresuan University

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Keywords Cropping system/techniques, raised bed, intercropping, pruning, flower removing, management practices, legume crop, rain-fed farming, chilli crop, production, growth, yield, analysis, soil moisture

ABSTRACT

Chilli under rain-fed farming generally provides low yield due to unreliable and unpredictable rainfall. Chilli production in Bhutan is the rainfed farming and farmers from western regions mostly depend thier income sources from chilli production. Therefore,1. pretest and posttest interview was conducted to assess farmers knowledge and adoption on cropping and management techniques. 2. an experiment of 4*4 + 1 (control) factorial design was conducted to assess growth and yield of chilli. The cropping level (CL) consisted of CL1.1 Farmers raised bed method (FRBM), CL1.2 Modified raised bed method (MRBM), CL1.3 Intercroping in FBRM, CL1.4 Intercroping in MRBM, Cc (FRBM-control) and management levels (ML) comprised of ML2.1 -Pruning in FRBM, ML2.2- Pruning in MRBM, ML2.3- 1st bottom three removal in FRBM, ML2.4-1st bottom three flower removal in MRBM and Mc (control) -no pruning and no flower removal in FRBM. The interview data was analyzed using chi-square, code analysis. Growth and yeild data were analyzed using Anova and general linear model.

The result showed plant height was noted highest in TL1.4 *2.3, stem diameter in TL1.2*.2.3, leaf length in TL1.2*2.2, leaf breadth in TL1.2*2.4 and maximum number of leaves per plant in TL1.1*2.4, 85 DAT. However, plant height

and number of leaves per plants were noticed the lowest in Cc*Mc, stem diameter and leaf length in TL1.1 *2.1, and leaf breadth in TL 1.3 * 2.1. The fruit weight, fruit length and fruit diameter were recorded the highest in TL1.2* 2.3, number of fruits per plant in TL1.2*2.4, fruit length with pedicel in 1.2 *2.2 and fruit diameter at apex in TL1.1*2.2. The fruit weight was found the lowest in Cc*Mc, no of fruits in TL1.3*2.1, Fruit length with pedicel in TL1.4*2.2 and without pedicel in TL1.1*2.2, fruit diameter and fruit diameter at apex in TL1.3*2.3 The soil moisture was recorded the lowest Mbar in TL1.2 * 2.4 on July month which calibrated as the least water requirement. The soil properties such as soil moist was observed the highest in TL1.2* 2.4, OC% in 1.2 * 2.4, pH in 1.4 *2.4 , N% in TL 1.2* 2.4, P in TL1.4* 2.4, K in TL 1.2 * 2.4. Farmers' interview with regards to the techniques found that almost all farmers (90%) accepted the chilli planted in modified raised bed and 60% of farmers accepted to carry out 1st bottom three flower removal of chilli in modified raised bed.

The study showed that there were significant diferences in growth and yield of cropping and management levels. Similary, there were interactions between cropping and mangement levels on all growth parameters except stem diameter and yield parameters such as number of fruits per plant and fruit length without pedicel. In both experiment and farmer's interview, the significant highest in growth and yield parameters of cropping levels were found in chilli planted in modified raised bed (CL1.2) and lowest in control (Cc). Likewise, in management levels, the significant highest was shown in both 1st bottom three flower removal in farmers raised bed and modified raised bed (ML2.3 & ML2.4) whereas lowest was found in control (Mc). Therefore the study concluded that chilli planted in modified raised bed, 1st bottom three flower removal of chilli in farmers raised bed and 1st bottom three flower removal of chilli in modified raised bed method are the best recommended techniques which can be used under rain-fed farming. However, study needs to conduct on different season and different elevation for further varification.

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ABBREVIATION

Agrifarming	= Agriculture farming
BAFRA	= Bhutan Agriculture and Food Regularity Authority
C:N	= Carbon and Nitrogen ratio
CL	=cropping level
CNR	= College of Natural Resources
DAT	= Days after transplanting
DAT	= days after transplanting
FAO	= Food Agriculture Organization
Fr brd	= fruit breadth
Fr dia	= diameter of the fruit
Fr len	= Fruit length
Fr no	= number of fruits
Fr pedi	= fruit length with pedicel
Fr W pedi	= fruit length without pedicel
Fr wt	= fruit weight
FRBM	= farmers raised bed method
FRFRBM	= flower removing in farmers raised bed method
FRMRBM	= flower removing in modified raised bed method
Ft	= Feet (foot)
FR	=Flower removal
FYM	= Farm yard manure
Gm	=gram
Ha	= Alternative hypothesis
HDU	= Horticulture development Unit
Ho	= Null hypothesis
IFRM	= intercropping in farmers raised bed method
IMRBM	= intercropping in modified raised bed method
JICA	= Japan International Cooperation Agency
Lf brd	= leaf breadth
Lf len	= leaf length

Lf no	= leaf number
Lf pet	= leaf with petiole
Lf wt pet	= leaf without petiole
m	= Meter
Masl	= Meter above sea level
Mbar	= milli bar
Mg/I	= (I) milligram
ML	= Managament level
mm	= Millimeter
Mngt	=management
MRBM	= modified raised bed method
MT	= Metric ton
NPK	= Nitrogen Phosphorous Potassium
NU	= Naresuean University
OC	=organic carbon
PFRBM	= Pruning in farmers raised bed method
pH	= Power of hydrogen ion concentration
Pl ht	= Plant height
PMRBM	= pruning in modified raised bed method
q/ha	= quintal per hectare
RCBajo	= Research Centre, Bajo
SNV	= Stichting Nederlandse Vrijwilligers
St dia	= Stem diameter
STDEV	= standard deviation
STERR	= standard error
TL	= treatment level
WAT	= Week after transplanting

CHAPTER I

INTRODUCTION

1.1 Background and Significance of the Study

Cropping system is "an important component of a farming system, represents a cropping pattern used on a farm and their interaction with farm resources, other farm enterprises and available technology which determine their makeup". Therefore, cropping system is cropping pattern and its management to obtain benefits from a given resource under definite environmental conditions (Rana & Rana, 2011).

The components in cropping system area take place with an advancement of technology. Mixtures and rotations in the traditional cropping system were established by the farmers based on their experience to adapt specific ecological and sociological conditions to obtain yield, whereas modern scientific cropping was developed based on the three pillars such as genotype, geometry of planting and management practices with the dimension of increase production per unit time and space. Genotype is the seed genetics make up, geometry of planting is the shape of planting pattern on the land surface and spacing of individual plant in the area and management practices are the practices of crop production such as cropping system, method of stand establishment, variety choice, pest management and harvesting techniques (Rana & Rana, 2011).

The cropping systems in rain-fed areas are local and traditional. Both mixed cropping and intercropping are used in poor fertility soil, considering as the mixed farming activities which form the mainstay of farming systems (Devendra, 2012). The production remains low in rain-fed areas, throughout the year due to frequent drought condition, inconsistent, unreliable and low rainfall distribution and poor soil condition. Thus, emphasizes are on to the land maintenance and soil-quality enhancement through agricultural conservation practices, balanced fertilization, using bio-fertilizers and microorganisms, carbon sequestration, efficient crops, cropping systems, best plant types, management of land and water on watershed basis and adoption of a farming-systems approach (Sharma *et al.*, 2009) .

Based on the shape of the planting pattern on the land, raised bed farming is one of the cropping systems carrying out everywhere. The advantages of raised bed method facilitate drainage and aeration freely which prevent waterlogging, improve root growth and proliferation which strengthen the loose structure, minimize subsidence, increase soil organic matter and increase plant water use that increase production and reduce deep drainage and water table recharge (Hamilton *et al*., 2005). According to Hamilton *et al.* (2005) farmers who are practicing raised bed farming are obtaining higher yield from a narrower range of soil types (sand over clay and gravelly sand over clay) and seasons that were generally normal to slightly wetter than normal. Raised beds are prepared to determine a deepened seedbed which should not be dense and should not constrain root growth with a substantial proportion of pores for good aeration, infiltration and drainage. It should have short distance and a practical height from the bed centres to the base of a furrow for a substantial gradient to encourage lateral drainage. He *et al.* (2015) expressed that raised bed has increased soil water content from 0 to 0.3 meter (m) or 0 to 0.98 feet (ft) with depth of >8% and reduced bulk density by 5.1%. The study conducted by (Shrivastava *et al*., 2018) found that the average yield on raised bed planting was 15.15 quintal/hectare (q/ha) (3.74 mt/acre) whereas the average yield was 11.95 q/ha (2.95 mt/acre) on the flat bed planting. However (Tshering, 2016), personal communication on 10th March, 2016, expressed that the soil incorporated with the nutrient on the raised bed gets eroded during the application of water from the both sides of one-meter breadth where two rows of plants are transplanted, thereby receiving less amount of water and nutrient by transplanted plants at the sides of the bed. Thus, modification of the raised beds felt to be important by raising small ridge at the side of the bed to address the water and nutrient depletion from the side beds especially in areas having scanty rainfall. These enhancements in soil properties and water use are of significant importance for food security and sustainable agriculture. Rana and Rana (2011) viewed that cropping system on raised bed should be progressed based on climate, soil and water condition, understanding the potential production through effectively use of available resources. It is also accomplished by adopting intensive cropping such as multiple cropping and intercropping.

Intercropping is practiced everywhere, especially under rain-fed conditions to enhance total productivity per unit area and time by planting more than one crop in the same plot and to wisely utilize land resources and farming inputs. Intercropping of chilli with dwarf beans (Phaseolus vulgaris) is the practice that has been increasingly adopted by the farmers recently. Inter-cropping chilli matures in 120 days with dwarf beans maturing after 60 days that may improve the farmers' incomes generation while comparing to the income of sole cropping of either crops (De Costa & Perera, 1998). Intercropping chilli is more beneficial than growing chilli alone in many situations especially where agricultural land use is limited. Most of the vegetable crops are commonly intercropped with the beans. Beans have both bush and climbing varieties that make the best companion for both rosette form and climbing vegetables. For instance, dwarf beans are usually intercropped with the climbing crops or vigorous vegetable and pole beans are intercropped with the bushy vegetables (Suresha *et al*., 2010).

Intercropping system is crucial for the farmers owning less or limited land. This system is appropriate to Bhutan since most of the Bhutanese farmers have small and marginal farming land with the average farm size of 3.4 acres per household, making the farming challenging (Tobgay, 2006). Despite less land holding, farmers can maximize their farm income by vertical expansion either through cultivating more than once per year or intercropping (intensive farming). Intercropping is effective in terms of soil conservation, soil fertility improvement, use of natural resources and pest and disease reduction. In addition, it reduces the risks of total loss of crops, better control over erosion, control of weeds and possibility of higher sources of profits. It uses land efficiently and effectively which is an important factor for sustainable farming. Many findings have shown the advantages of intercropping with leguminous crops (Abou-Hussein *et al.*, 2005). Under rain-fed farming system, nitrogen-fixing legumes such as beans, soya beans, pigeon pea etc play an important role as sources of organic fertilizer. These leguminous crops have the ability to sustain soil fertility in smallholder farming systems. Poor soil fertility adapts legume crop well and therefore be intercropped on a substantial proportion of the area (Mapfumo *et al.*, 2001)

Intercropping is necessary to provide crop management practices that maximize the productivity of adopted cropping system (De Costa & Perera, 1998).

The management practices such as pruning of plants and removing of flowers/fruits also influence production, affecting the fruit size and its composition due to source and sink relationship (Ferreira *et al.*, 2016) in rain-fed cropping system. A decrease in fruit load favours the distribution of dry mass to the vegetative parts of the plant as fruit is the major sink of the plant. The heavy fruit loads are correlated with lower leaf areas. Hence, a positive association between leaf number and fruit quality is characterized by higher average weight, diameter, length and thickness of flesh of the produced fruits (Ferreira *et al.*, 2016). Pruning enhances new shoots to grow faster, thereby promotes faster to bloom. An effect of pruning provides improved photosynthetic efficiency, plant growth, and optimization of vegetative and reproductive balance (Thakur *et al.*, 2018). According to Thakur *et al.* (2018) the pruning of pepper involves the reduced number of branches which allows light interception and improve quality and quantity. Pruning to four stems provides higher marketable yield than those pruned to two or one stem. Besides, excessive vegetative growth with small fruits takes place due to no or light pruning. According to Maboko *et al.* (2012) removing the first two flowers augment root development which later increase vegetative growth before fruit set. Hence, a strong root system with well vegetative growth improves fruit bearing and fruit size. Weak root system leads to poor uptake of water and nutrient which later affects to the yield and quality of chilli. As stated by Ghebremariam (2007) hot chilli fruit size increases with intensity of pruning. The increase in fruit number is due to potentiality for competition between fruits and the consequent reduction in fruit size. Pruning some of the flowers or fruit from crops results in re-distribution to the remaining fruit which increases the size. Therefore, management techniques augment both the quality and the yield under rain-fed farming. In Asia, rain-fed area of agricultural land accounts around 83.1% comparing to irrigated land of 16.6% (Devendra, 2016). Rain-fed farming is the farming practice that depends exclusively on precipitation for plant growth and development for the production. Dryland farming is also a part of rain-fed farming where farming takes place in semi-arid areas with annual precipitation less than 25-50 %. Therefore, dryland or rain fed agriculture is the farming which requires distinctive cultural techniques and farming systems during a considerable part of the year under conditions of moderate to severe moisture stress to enhance successful and stable agricultural production (Brouwer & Heibloem, 1986). Dryland farming is of growing importance worldwide due to the increasing demand for food and fiber.

Worldwide, rain-fed farming is gaining importance because of an increasing demand on food and fiber. About 82% of the rural poor live in rain-fed land. They are vulnerable to the climatic fluctuations (Devendra, 2016). Crops fail when there is lack of rain. To address the problems of rain-fed agriculture, strong policy framework and action and understanding in relations to food insecurity, poverty, sustainability, natural resources and self-reliance should put into place (Devendra, 2016). As articulated by Ashrafuzzaman *et al.* (2011) shortage of water restricts the growth and development of chilli crop. It is therefore sensitive to water deficit. Young seedlings of chilli cannot tolerate both water deficit and excess soil moisture while older plants can tolerate deficit or excess water but can affect the yield. Chilli is also sensitive to heavy rainfall. The water stress during the time of floral initiation, flowering, and during fruit development, diminish quality and the yield. To increase the yield of chilli from shortage or excess water, proper cultural management including water management is necessary.

In Bhutan, farming is generally a small scale, dominated by rain-fed dry land and wetland husbandry. Agriculture sector plays an important role in terms of Bhutan's economy which provides livelihoods to approximately 57% of the total population. Farmers depend on monsoon rain, accounting 60 to 90% of annual precipitation. The farming community face a big challenge due to uneven mountainous terrain dominated by rain-fed farming (Stichting Nederlandse Vrijwilligers [SNV], 2018). They also face many challenges such as irrigation water shortage, manpower shortage, marginal land holding, high transportation costs and marketing, far-flung and scattered location of rural households (Grosjean & Jarvis, 2017). In areas where there is no irrigation channel or small water source, farmers fully rely upon the rainfall. Thus, delayed rain during crop development and drying of water sources are causing irrigation problems, relying farmers on environment and the interventions of agriculture ministry (Palden, 2016). Although regular raise of farmers' income needs suitable farming practices and enhance crop yield, a hindrance in irrigation development and neglected farmland hinders growing vegetable production especially chilli production (JICA, 2016).

Chilli (Capsicum annuum L.) is the indispensable commercial vegetable crop grown extensively in tropical and subtropical regions of the world (Suresha *et al.*, 2010). Chilli production in the world is about 37.62 million tonnes (38.22 million MT) in the total area of 20.20 million hectares (41.91 milliion acres) (Geetha & Selvarani, 2017). Chilli is grown widely under rain-fed conditions with exceptionally high yields in areas having rainfall of about 600 to 1250 millimeter (mm) (Tebal, 2011). As figured by Madden (2012) the crop water need for chili is 600-900 mm per total growing area though it is dependent upon climate, transpiration characteristics and growing duration. Chilli is used as a spice and recently, it is used in making beverages and medicines throughout the world. Chilli contains numerous medicinal properties. For instance, it stimulates good digestion and has endrophins which is the nature pain killer to relieve pains. Chilli eye drops can be used as a cure for headaches. It's powder is rubbed on the fingernails and thumbs of kids to avoid sucking their thumbs and biting their nails (Mehta, 2017). Chillies have the nutritional value, flavor, aroma, texture and colour. They contain low sodium and cholesterol free, high vitamin A, vitamin C, vitamin E, and a good source of potassium and folic acid. Fresh green chilli have more vitamin C than citrus fruits. Fresh red chili contains more vitamin A than carrot (Than *et al.*, 2008). The red pigmentation of chili is due to the pigment capsanthin and its pungency is due to capsaicin (Rohini *et al*., 2017)

Chilli is gaining popularity throughout American continent mainly for flavouring, thus large scale of cultivation has been carried out since then. Chillies are also one of the most important crops in India used as spice, condiment, sauce and pickle (Velayutham & Damodaran, 2015). The recent figure states that the world's largest producer and exporter of chillies is India, growing many different varieties of chilli including the hottest chillies. About 25% of world's total production of chilli is contributed by India and Indian chillies are dominated in the international market (Mehta, 2017), remaining India as the first position by exporting approximately 30% from its total production. As per Geetha and Selvarani (2017) India produces around 13.98 million MT of production annually followed by China with a production of around 3.05 million MT. About 36.57% of the world chilli production is contributed by India followed by China 7.97%. India also leads in terms of maximum area coverage under chilli cultivation.

Chilli is one of the important crops grown all over 20 districts of Bhutan. It is the indispensable vegetable crops consume by every Bhutanese in every meal and prepare various dishes (Ueda & Samdup, 2010). There are mainly three varieties of chilli. They are baegop ema, sha ema and super solo. Baegop ema and sha ema are used for fresh and dried while super solo is for fresh and salad purposes (Bajo, 2016) mainly for early production. The most popular dish, chilli cheese cuisine (emadatsi), is a mixture of chillies and cheese enjoyed by the whole country. It is the preferred cash crop for most of the farmers as they generate high returns per unit area achieved in one season (Dorji *et al*., 2009). Chilli in Bhutan is the main farm produce since it is the most important ingredient for the Bhutanese palate. Surplus production is used for both consumption and sale. Chillies are used both at domestic and the agro-industry for pickle making as the value addition product. Red chillies of late harvest are dried on the rooftops and also strung on a rope and hung in the windows. Dry green chillies are prepared of fresh green chilies blanched in hot water and dried. White chillies are immature green chilies sliced in half and dried. The advantage of dried chillies are easy to carry due to light weight and also fetch a high price than green chilies because of their taste and long shelf-life (Dorji *et al.*, 2015).

1.2 Purposes of the Study

- To examine the growth, yield, soil moisture content and soil chemical properties under different cropping and cultural management techniques.
- To evaluate farmers' acceptance and adoption on technologies of different cropping method and management practices

1.3 Statement of the Problems

In Bhutan, few decades back, chillies were mainly grown in a small scale at a kitchen-garden with little or no inputs. In recent years, farmers in Thimphu, Punakha, Paro, and Wangdue have started growing chillies on a commercial scale. In 2012, the highest chilli production was from Paro District followed by Punakha and Wangdue (Dorji *et al.*, 2015). According to Wangchuck (2015)even though chillies in Bhutan are grown all the regions of the country, a considerable amount was imported from India, especially during the winter in off season to meet the demand of the people. However, banning of import Indian chilli containing high pesticides with effect from June, 2013 by the Bhutan Agriculture and Food Regularity Authority (BAFRA) has encouraged Bhutanese farmers to grow in larger scale to fulfil high domestic market demand (Wangchen, 2017) thus, generating premium prices and income for the Bhutanese farmers. During offseason chillies are not sufficient to meet the demand of the consumers and the few left-over chillies are sold at extremely high price, alarming the poor people. Chilli grown under rain-fed areas obtain low yield though the figures on yield of rain-fed chillies are not documented. The best example is, the yield of Indian dry chillies under rain-fed condition yields 0.2-0.4 metric tons (MT)/acre whereas under irrigated condition fetches 0.6-1 MT/acre (Reddy, 2015). Generally, Bhutan figure showed that chilli growing area in 2016 and 2017 were 5538 and 7571 acres with the yields of 9907 and 13606 MT respectively. There were no yield differences in 2016 and 2017 (1.78 MT/acre in 2016 and 1.79 MT/acre in 2017). As comparing to the world production of about 7.11million MT in 3.7 million acres of land the chilli in 2016 (Geetha & Selvarani, 2017), the production of Bhutan was 9907 MT in 5538 acres which was extremely low. There are many factors triggering to low yield. The low yields in rain-fed areas are due to irregular, unpredictable and low rainfall in addition to no irrigation facility (Sharma *et al.*, 2009). The abiotic factors such as rainfall, relative humidity and temperature occurring in the environment cannot be brought under control until efficient structure is constructed. Other factors such as improper cropping system, poor cultural management and poor soil condition that affect low yield in chilli can be corrected using the right techniques. Therefore, there is a need to assess growth, yield, moisture content and soil chemical properties of chilli under different cropping system using different bed raised, intercropping, the management techniques such as pruning and bottom 1st three flowers removal.

1.4 Scope of the Study

Research at farmer's field during march, 2019 by involving 20 farmers at Kabisa, Punakha. Assessed the best cropping and management techniques in terms of growth and yield of chilli under rain fed farming. Farmers acceptance and adoption on technologies after observation and the results.

1.5 Basic Assumption (Preliminary Agreement)

As a part of Master thesis under Faculty of Agricultural Science, Natural Resources and Environment, Naresuan University (NU), Phitsanulok, Thailand.

1.6 Hypotheses of the Study

Ho= There is no significant difference in growth and yield of chili under different cropping and cultural management techniques and there is no significant difference in farmers' adoption on these technologies

Ha= There is significant difference in growth and yield of chili under different cropping and management techniques and there is significant difference in farmers' adoption on these technologies.

CHAPTER II

LITERATURE REVIEW

2.1 Related Works and Studies

Cropping system is the cropping design, type and management of the crops in time and space to obtain benefits from a given resource base under precise environmental conditions (Rana & Rana, 2011). Cropping techniques need the basic important steps for the successful growth and development of plants which result better crop production in cropping crops. Selection of the better cropping field, preparation of the suitable cropping field, selection of crop species in particular climate zone, preparation of the crop plants or varieties, proper sowing, management, harvesting, judicious collection and proper storage are the steps of cropping techniques that lead to successful crop production (Patel, 2016).The objectives of cropping system are to apply and sustain cropping system, apply combine scientific knowledge in practice and practical farming knowledge in science, integrate cropping system in land use, assess different structural design, management factor and environment factors change the output of cropping system. According to Eckersten (2017) the cropping system research is “to design, develop, assess and stimulate innovation of multifunctional and sustainable cropping systems". Therefore, the cropping system comprises crops, crop sequence and crop and soil management through intercropping and other various techniques.

In intercropping system, management practices provide favorable environment to all the components, favoring interaction among the component crops and minimize competition among the component. The land is prepared to establish an ideal area to minimize the stress for the seedlings. Depending upon the crops, bed is prepared. For instance, deep rooted crops grow well in deep ploughing soil while shallow rooted crops respond to shallow bed. Small seed require fine seedbed, some seeds such as cotton, and maize are planted on ridges while other seeds are sown on flat seedbed. In intercropping, the crops are arranged in such that sugarcane is planted in furrow and intercrop is sown on ridges. In flat seedbed, groundnut and red gram are intercropped Ridges and trenches are formed in rice and maize intercropping. Maize is planted on ridges and rice in trenches. Puddling for rice, ridges and furrows for vegetables, maize and cotton and flat seedbed for several other crops (Rana & Rana, 2011).

Intercropping methods can be determined by proper planting geometry, planting time and selection of compatible crops (Duragannavar 2011) especially, compared with corresponding sole crops, yield advantages have been recorded in many intercropping systems, including wheat/maize, barley and annual medicine crops (Wang *et al*., 2015). Chilli intercropping with varieties of vegetables provide better potential to use the land and other resources to the maximum level. Production can be improved by selection of vegetables carefully, contradicting the duration and growth paces, thereby adjusting the demand of above and underground resources (Suresha *et al.*, 2010).

Chili (Capsicum annum L.) belongs to the genus capsicum, under the solanaceae family. Chillies in different part of the world are known by different names such as chillies, chile, hot peppers, bell peppers, red peppers, pod peppers, cayenne peppers, paprika, pimento and capsicum. It was believed to be originated from South America (Tiwari, 2009). Many varieties are produced with different quality characteristics from the mild to the strongest pungent smell. Recently, there are more than 400 varieties found all over the world (Mehta, 2017). Chilies are the most integral ingredient used in daily life in different cuisines around the world due to their pungency, taste, flavor and color to the dishes. Depending upon the varieties, chilies are used as vegetable, pickles, spice and condiments. The world leading production of chili is India followed by China and Pakistan. India only provides global production ranges between from 50 to 60 per cent (Geetha & Selvarani, 2017).

Chilli plant grows well in the tropical and sub-tropical areas. It grows best in warm and humid climate with the temperature of 20-25ºC (Reddy, 2015). Planting time of chilli is determined by the climate such as the length of a growing season and temperature. Both low and high temperature will affect the production. For instance, at temperature below 10-12ºC, the plant inhibits growing and at 6°C, the leaves appear dying and flower abortion takes place. An increase in temperature over 35°C will also die the leaves and abort the flower. Hence, it requires very constant temperature ranges where the minimums and maximums temperature need to be close by. An optimum temperature of 25-28ºC and 16-18ºC during the day and night respectively fulfil the ideal temperature growing under protection. Overcast weather for the long period causes poor fruit set and crop loss. Variation in temperature results poor fruit quality and thus reduces yields. Hot chilli thrives higher temperatures than sweet chillies (Ayres, 2014). According to Berke *et al.* (2005) sweet chilli grows very well at the temperature between 21 and 24°C. Both decrease and increase in temperature below 18°C or exceed over 27°C for prolonged periods hamper plant growth and yield. It tolerates daytime temperatures over 30°C, if the night temperatures are within 21-24°C. It is a photoperiod crop and humidity-insensitive which means day-length and relative humidity hardly affect flowering or fruit set. Chilli in Bhutan grows best at 15-32ºC (Bajo, 2016). For the growth and development, it requires a warm humid climate and to enhance fruit maturity, it needs warm and dry weather (Ikisan, nd). Therefore, for the growth of chilli, an ideal temperature required is between 21-32ºC

Chilli grows in a wide range of soils. Chilli under rain-fed condition prefers black soils that retains moisture for long periods whereas under irrigated condition, it prefers well drained soils of either deltic soils and sandy loams. Low soil moisture during blossom development and fruit formation results the de-blossoming of bud and fruit drops (Reddy, 2015). Sweet chilli is grown well in loam or silty-loam soil with good water-holding capacity. It grows on a ranges of soil types with well drained (Berke et al., 2005). Horticulture development unit HDU (2013) figured that plants grow well in area having gentle slope of well-drained soil with pH of 5.0-7.0. Crops must avoid planting in areas previously planted with the solanaceous crops, okra and papaya. In Bhutan, it grows well in loamy to clay loamy soil with pH range of 5.5 to 6.8 (Bajo, 2016). As provided by Berke *et al*. (2005) chilli grows the best in soil pH of 5.5 and 6.8.

A relative humidity between 65-85% is the optimum for the growth, development and production of chilli. Pollen release and distribution on the stigma is affected, if there is high relative humidity. High humidity also provides a favourable condition for the development of foliar diseases. Whereas, low relative humidity results infertility, as the pollen dries out before germination of the pollen on the stigma, leading to small, misshapen or flat fruit. High temperature with low relative humidity will cause rapid evaporation from the leaves of the chilli and if the root system is not able to provide water as per the water volume required, the plants will lead to partial wilting of the growth tip which increases the incidence of blossom end rot (Ayres, 2014). Excessive rainfall is harmful to the plant because it defoliates and rots of the plant. For the rain-fed crop, an annual precipitation of 25-30 inches is required for the plants to grow well (Reddy, 2015). Based on (HDU, 2013) an annual rainfall between 600 to 1250 mm fulfils the water requirement by the plants. Low humidity leads to poor fruit set because of dropping of flower buds. As mentioned by Ikisan, (nd) under rain-fed areas, the crops can be successfully grown with an annual rainfall of 850-1200 mm. High precipitation results poor fruit sets and the bearing fruits tends to rot.

Chillies are cultivated upto an altitude of 2000 masl. However, pungent varieties used for spices are not suitable on higher altitudes (Ikisan, nd). Chilli in India grows during monsoon (June-October). Normally, India has three cropping seasons: from June to July, February to March and from September to October. Chilli in northern India cannot be grown in winter due to low temperature (Katrick, 2014). In Bhutan, chilli grows successfully at an altitude between 250 (southern regions) to 2,600 masl in western Bhutan (Bumthang and Ha Districts). The growing time varies according to different altitude. For instance, in lower elevation below 800 meter above sea level (masl), the growing season starts from November to April, in mid elevation between 800 to 1500 masl, from February to October and in high elevation above 1500 masl, from April till September (Bajo, 2016).

In Bhutan, for early production, nursery is usually raised during December-January, 2018 in poly tunnel since farmer’s transplant paddy right after chilli harvest. As per farmers’ methods, the beds are burned for soil sterilization before sowing of the overnight soaked seeds. The seeds are sown in the well prepared moist beds and covered with the plastic over the beds to increase temperature for enhancing early germination. The seedlings are then taken care till they reach to transplanting height (around 3-4 true leaves). Farmers at Wokhuna village plant chilli variety called super solo with the plant height of 61 cm. It is milder than the local chilli variety sha ema and fruit shape is elongated, shoulder at the calyx area with pointed tips normally.

Fruit length is usually 18.5 cm with width of 4 cm which weighs 80 gm and fruit has thick wall than local sha ema. It is used as fresh vegetable and salad purpose. This chilli is not suitable to dry since it has thicker wall which makes difficult to dry and provide poor quality dry fruit. It is susceptible to Phytopthora wilt and chilli mosaic virus. It grows at an altitude of 100-2600 masl. It can be grown in most of the district (Bajo, 2016).

Nursery can be raised both in green house or in open field either in seed trays or raised beds. Seeds in tray cell are sown one seed per cell. In a seedbed, seeds are either broadcasted or sown in line by covering with one cm layer of soil. The seedbeds are then watered and mulched with organic mulch such as straw, dry grass and any other materials until seeds emerge. The seed-beds can be covered with an insect-proof net. After emergence, seedlings are evenly watered as required. Heavy watering must be avoided to prevent from damping (HDU, 2013). Katrick (2014) suggested that nursery management beds should be prepared under partial shaded area. On the beds, seeds are sown lightly in lines sand and cover thinly with the well-decomposed vermicompost. The beds are then mulched with dry grass until the emergence. Seedlings in nursery will be ready within 40-50 days. In Bhutan, nurseries are well ploughed and pulverized. The beds of 1 m wide, 15-20 cm height with convenient length are prepared. The quality seeds of 0.5 to 1 kg/acre are sown in 2 cm depth in lines keeping a 10 cm gap from one row to another. Nursery in mid elevation is raised early in poly-tunnel for early production. Normal open nursery is raised during the main season of chilli production. Nursery in higher elevation is raised in plastic tunnel to bring forward of one-month season. The seedlings attain 12-15 cm height within 30-60 days and are ready for transplanting (Bajo, 2016).

Chilli seedlings with 5 true leaf stage are transplanted during cool day or late afternoon on the well prepared beds (HDU, 2013). Transplanting takes place 4-6 weeks after sowing seeds. Seedlings are transplanted on the single ridge, double ridges and beds. Depending upon the growth habit and higher yield, the general space maintained is 20*20, 30*30, 45*45, 60*45, 60*60 cm (Katrick, 2014). Transplanting in Bhutan carries out when seedlings are of 12-15 cm height in evening maintaining the spacing of 45 cm between rows and 30 cm between plants in a row with the population of 25,000 per acre. The transplanted seedlings are immediately watered to establish the plants well (Bajo, 2016). Chilli is a shallow rooted plant. Due to shallow root, it has low tolerance to drought and flooding. It demands frequent light irrigation. Thorough uniform irrigation gives optimum soil moisture required for growth and development of plant and fruit. Furrow or drip irrigation is best for chilli plant. Since plants cannot tolerate flooding, draining out after flooding or heavy rain is necessary. More than 48 hours of flooding leads to wilt and die and also promotes Phytophtora blight and bacterial wilt (Berke *et al.*, 2005). Providing supplementary irrigation is to maintain a good moisture level throughout the growth period especially during flowering and fruit development (HDU, 2013). Plants requires available water holding capacity of 100-160 mm/m depth of soil with a consumptive use of 446 mm (Katrick, 2014). Irrigation is also carried out using water cans or hose pipe. Irrigation depends on the soil moisture retention capacity, quantity and frequency of rain and evapo-transpiration of the local weather. Maintaining soil moisture at field capacity after transplant till harvest provides high yield (Bajo, 2016).

Weed affects crop performance. weeding is necessary to avoid competition with nutrient, water, air and space. It is recommended to weed at least 3-4 times depending upon the weed pressure, soil structure and weather (Bajo, 2016). Plastic film is used to control the weeds. Black polythene mulch is good for chilli to control the weed. Using organic mulch improves microbial activity of soil which leads to water stable aggregate formation (Katrick, 2014). Organic mulch such as rice straw, dry grass and other locally available materials are used to prevent soil compaction, erosion and from weeding. Inorganic mulch such as reflective mulch is used to build up less heat in the soil than black plastic mulch which provides some protection from aphids. In areas having hot weather (>25°C nighttime temperature), cover plastic mulch with straw is used to bring down the temperature in the root zone. The other alternative is by irrigating and draining out the field frequently to keep bring down the temperature (Berke *et al*., 2005).

Chilli plants having heavy fruit loads are usually staked to prevent from lodging. Each individual plant is staked before flowering stage. Generally, yields are high in plants that are staked than non-staking plants (Berke *et al.*, 2005).

General recommendation of nutrient in chilli is 20-25 tons of farm yard manure (FYM)/ha during final field preparation. It demands more application of nitrogen (N) during vegetative growth and in maturity. Under rain fed condition, hot chilli requires nitrogen: phosphorous: potassium (N: P: K) at the rate of 100: 50:50 kg /ha and under irrigated condition, it requires N: P: K of 175:75:75 kg/ha of plot. Sweet chilli requires N:P:K of 150:75:50 kg /ha (Katrick, 2014).

As reported by Alsadon *et al*. (2013) pruning plants to 2, 3 or 4 shoots was effective in increasing yield and reducing fruit size. Reducing the limited shoot number allows the increase in fruit quality. Even though, pruning of chilli enhances light penetration inside the plant canopy and augments photosynthesis efficiency and yield, it involves costs of production. Vegetative growth of chilli acts as a powerful sink and the limitation of vegetative growth boosts assimilate transport to root or fruits. Therefore, balancing vegetative and reproductive growth of chilli crops increases both quality and quantity. Vegetative growth has direct association with leaf area, dry matter and stem diameter. However, it has the negative association with fruit yield. Without flower or fruit pruning in temperate zone causes a small portion of pepper flower sets fruits which does not limit the number of fruits produced but limit the fruit retention. Researchers reported there were low fractions of flower setting fruits in pepper. According to Thakur *et al.* (2018)) removing the fruit ten days after fruit set from the first flowering node of bell pepper plants did not increase the separating of dry mass to fruit on upper nodes of the plant. The first flowering node fruit acts as a main sink for photosynthates (10.2%) up to 20 days after flowering with the development of fruit growth, and later becomes a weak pruning at anthesis as compared to pruning at fruit-set had little effect on yield and fruit quality of both crops.

Pruning methods in chilli differ with different branching habits and different plant densities. The pruning practice is carried out to achieve proper balance between fruit number and fruit size by improving the canopy. Shoot pruning is important in proper managing the production area to balance the heavy vegetative growth and fruit load on the colored pepper plants (Alsadon *et al*., 2013). The study by Maboko *et al.* (2012) found that chilli plants that pruned to four stems have significantly increased in marketable fruit yield and was significantly higher percentage in unmarketable yield when plants were pruned to two stems. The study carried out on the effect of pruning on quantitative and qualitative characteristic of tomato revealed that pruning restricts vegetative growth and improved light penetration thereby increases both qualitative and quantitative parameters of tomato fruits (Goda *et al.*, 2014).

Chilli plants grown in a greenhouse need to train to two to four stems. The training of the stems is carried out one month after transplanting. The training allows for better light penetration. A maximum of four stems are used. If many stems are allowed to produce, energy will be diverted to the multiple growing tips, thus, fruit production may slow down. Even though more stem will produce more number of fruits, the fruit produced will be usually smaller and increase later in the season. The plant with fewer stems will produce few with larger fruit. The immature transplant which produce the first flower must remove so as not to hinder future growth. Topping the plants at 30 days provides every fruit to mature, since the sugar produced from the growing tips which has been removed will direct to part of the plant to the fruit (Ayres, 2014).

According to Ryczkowski (2018), there are steps to go for chili pruning. he proclaimed that the chilli seedlings that appear fruits and flower bud must be removed along with pedicel while transplanting. The plants appearing buds within the first three weeks after transplanting must be removed, allowing the young plants to allocate energy to root development and leaf growth. When the plants are 6-12 inches tall, pinching the stem by half inch in a point on the stem junction can be carried out which states that as a general rule, pinch the plant back so at least six nodes remain. The pruned plants should be monitored throughout the growing season from pest and diseases. The ends of the plant’s main stems must pinch off closing the end of the growing season to allow the plants to divert the energy on to the development of remaining fruits rather than vegetative growth before cold winter weather and rain fall starts. These can be applied under rain-fed farming as well.

The total rain-fed areas in South East Asia and South Asia are 99 and 116 million ha respectively and 63% of the rural population live in rain-fed areas and rest 37% in the preferred arable land (Devendra, 2016). Therefore, in areas where irrigation is not possible, rain-fed farming provides an important foundation to agricultural production. In rain-fed area, traditional systems such as border bunds are commonly used. Contouring and other land improvement techniques provide emphasis to agronomic challenges in increasing productivity (Kerr, 1996). Use of plastic-covered ridge to complement a ridge and furrow micro-catchment system used in the low-intensity rainfall area was also conducted. Gravel mulch to hold water in contact with the soil to prolong the time to increase infiltration and reduce evaporation was also carried out. Plastic covered ridges obtained higher yields than the bare ridge plots in corn. From the plot with both plastic covered ridges and gravel mulched furrows obtained the highest yields than the bare ridge and furrow field, and then the bare flat soil control field (Rosegrant *et al*., 2002).

Cropping techniques such as two type of bed raised method (one with normal bed raised and the other one with modified by using raised at the side of the bed) and intercropping on both type of beds will be used as first factor and pruning of chilli plants and removing of 1st three nodes of flowers will be used as second factor as management techniques. In the bed raised method, the normal bed raised of 1 m breadth by 2 m length used by farmer (control) and in the normal bed (1m/2m) of raising the ridged at four side of the bed will be the modified bed as group 2. In the third group, at farmers' raised bed in cropping with beans in three rows will be carried out and in fourth group, the beans will be planted at the ridge of the side of the raised beds. In the second factor, in the first group in farmer's field raised method, pruning the terminal part by keeping 10 cm stem above the ground will be carried out. In second group, Same pruning of plants on the ridge at the side of the raised bed will be conducted. In third group, removing of the first three flowers on farmer's raised method and in the fourth group, removing of the first three flowers of the based on the ridge side of the raised beds will be carried out. In second factor of group 1 and 2, as suggested by (Ryczkowski, 2018) the pruning of the whole plants will be pruned by leaving 10 cm stem to have horizontal growth after one week of transplanting. Second factor of treatment 3 and 4 as stated by (Maboko *et al*., 2012) the flowers of the first three at the base will be removed.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research Procedures of the Study

3.1.1 Population and Sample size (pre-test and post-test sample)

The sample size was used based on table drawn by Krejcie and Morgan (Morgan, 2012) with the population proportion of 0.05 and confidence of 95% with significant difference of 5% (Table 1). At Wookuna village, Kabisa Block under Punakha District, there are 27 households. Using Krejcie and Morgan's table, the population sample size from 25 households was randomly selected for the study. However, 20 farmers were interviewed in both pre-test and post-test since five of the farmers were not available.

Table 1 Assume population proportion of 0.05 and confidence 95%

Population size	Population sample
10	10
15	14
20	19
25	24
30	28
35	32
40	36
45	40
50	44
55	48
60	52
65	56
70	59
75	63

Source: Kenpro (2010)

3.1.2 Code for analysis

After setting the pre-test and post-test questionnaire, the responses provided by the farmers were analyzed using code index for analyzing as given in Table 2. Based on the farmers respond on cropping system, cultural management technologies and their acceptance or rejection on technologies, the code index for analysis were categorized into eight group. The eight codes for analyses are:

Table 2 Code for analysis

Code	**The level of knowing (comprehend knowledge)**
NK	Not knowing at all (The farmers have no knowledge about these technologies
KN	Knowing and not doing (Farmers know some technologies and not practicing)
KD	Knowing and doing (Farmers know all technologies and practicing at least one or two technologies)
NKA	Not knowing but still accepting technology
NKNA	Not knowing not accepting technology
KA	Knowing and accepting technology
KNA	Knowing but not accepting technology
AF	Accepting in future and continue the technology

3.1.3 Experimental site

An experiment of 4*4+1(control) factorial of randomized complete block design (RCBD) was conducted at Wookuna village, Kabisa block in Punakha District from February until July, 2019 since these months are the growing season of chilli depending on rain-fed condition. Kabisa Block (Figure 1) was selected as study area since the farmers grow in large scale farming (0.5 acres to 2 acre) and Punakha is one among the highest chilli production in Bhutan. Wookuna is located at an elevation of 1310 masl. It is located at 27^{o}38.76 Sec N latitude and 89^{o}46.76 Sec E longitude.

3.1.4 Climate

The climate condition of Wookuna, is dry and cool winter and hot and wet summer. It receives much rainfall than in winter. The average annual temperature is 18.3°C and the average rainfall is 3016 mm per year (Climate, nd) . The figure below shows the map of an experimental area to be conducted at Kabisa.

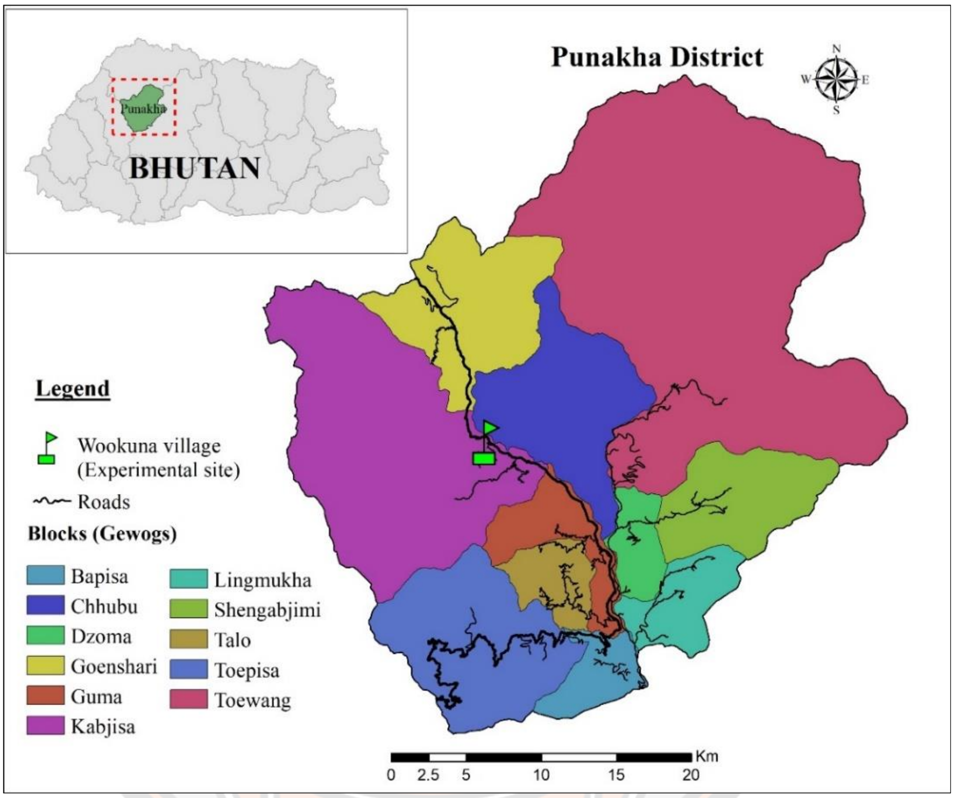

Figure 1 Experimental site at Wookuna village under Kabjisa block, Punakha District

3.1.5 Soil properties

The experiment site has silty clay loam with pH of 6.5. The followings are the soil characteristics found at the experiment plot before transplantation of chilli seedlings (Table 3).

Table 3 Soil properties of the experimental plot

Soil characteristics	Particulars	Composition
Chemical properties	Organic carbon(%)	1.65
	Nitrogen (%)	0.18
	P (Mg/L)	1.99
	K (kg/ha)	500
	Water pH	6.63
	Moist (%)	1.65
Physical properties	Bulk density g/cm3	0.18

3.1.6 Experiment design and plot

The experiment was laid in a 4*4+1(control) factorial of Randomized Complete Block design (RCBD) with three replications (Figure 2). Each plot had the size of 1 meter (m) breath by 2 m length. The experiment comprised of two factors such as cropping levels and management levels. There were five treatment levels in the first factor (CL1.1- Farmers raised bed raised bed method (Figure 3 ‘A’), CL1.2- raised bed at the border (modified raised bed method) (Figure 3 ‘B), CL1.3- beans intercropped in farmers raised bed method and CL1.4 -beans intercropped in modified raised bed method (Figure 5), Cc- farmer raised bed method (control) and five treatments in the second factor (ML2.1- chilli pruning in farmers raised bed method , ML2.2- chilli pruning in modified raised bed method (Figure 6), ML2.3 – 1st bottom three flower removal in farmers raised bed method and ML2.4 -1st bottom three flower removal in modified raised bed method (Figure 7) and Mc- no pruning and no flower removal in farmers raised bed method (Control). In the design, the first four cropping levels and the first four management levels were multiplied with total plots of 16 numbers whereas the last cropping level (control-chilli planted in farmer’s raised bed) and last management level (control-no pruning and no flower removal in farmer’s raised bed method) was kept as one plot becoming 17 plots in each replication as shown in Figure 2.

As per recommended plant spacing of 30 cm plant to plant by 60 cm row to row, there were 5 plants on each row bed in 2 m length by 1 m breadth with the total plants of 10 in each plots. In total, there were 576 number of plants required in the whole plots. Simi dwarf beans were used for intercropping. The beans were intercropped right after one month of transplanting chilli as beans are the fast growing crops. The other cultural practices such as mulching, weeding, hoeing and other cultural operation were used based on the guideline of chilli production. The following was the experiment design.

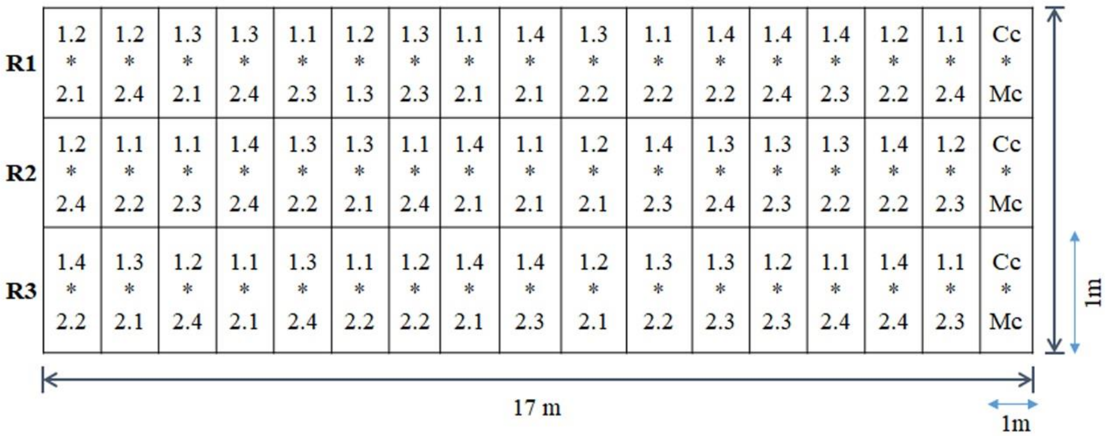

Figure 2 An experimental design of 4*4 +1 (control) factorial, RCBD

1	**Cropping levels**	2	**Management level**
1.1.	Farmers raised bed method (FRBM)	2.1.	Pruning in FRBM
1.2.	Modified raised raised method (MRBM)	2.2.	Pruning in MRBM
1.3.	Intercropping of beans in FRBM	2.3.	1st bottom three flower removal (FR) in FRBM
1.4.	Intercropping of beans in MRBM	2.4.	1st bottom three flower removal (FR) in MRBM
Cc	Control (chilli planting in FRBM)	Mc	No pruning and no flower removal in FRBM (control)

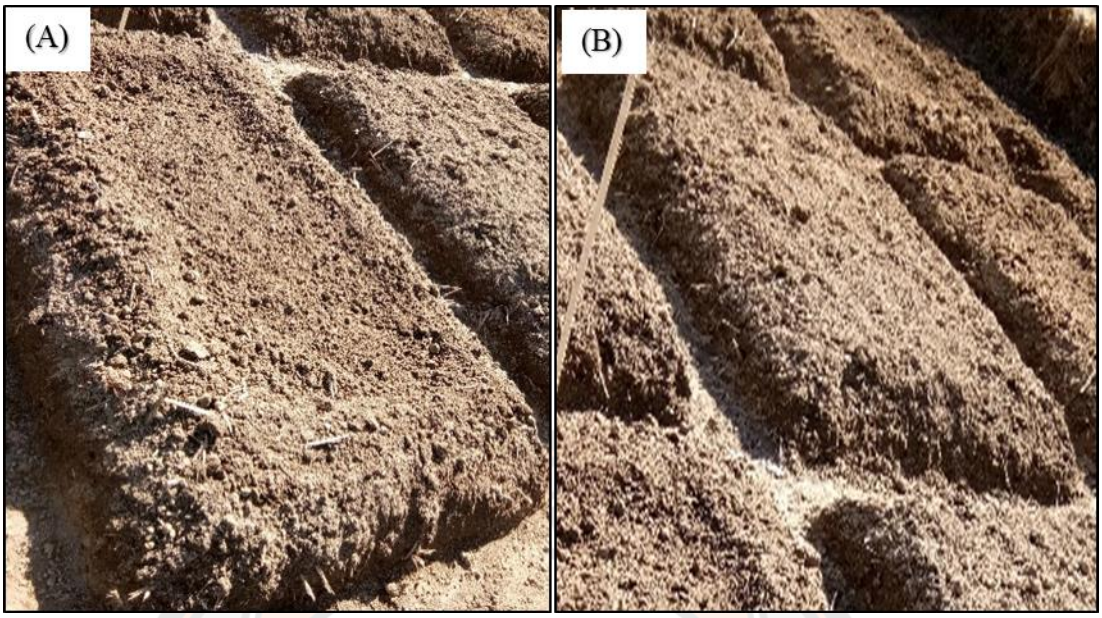

Figure 3 Type of raised bed: (A) Modified raised bed and (B)farmer's raise bed

Figure 4 Bed design in RCBD

Figure 5 Chilli intercropped with beans in both raised beds

Figure 6 Chilli pruned in both raised bed types

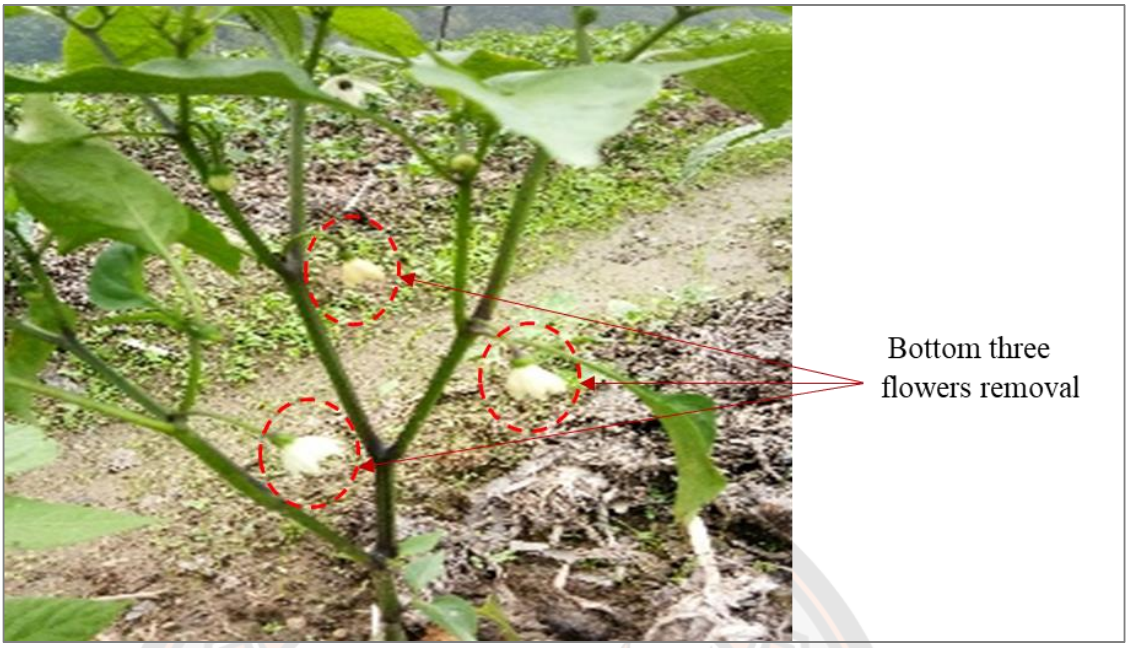

Figure 7 1st bottom three removal of flowers in both raised bed types

3.1.6.1 Experimental details

The main crop for the study is chilli (*Capsicum annum* L) and the variety is super solo. The seedlings were bought from owner of the experimental plot. As described by Bajo (2016), it has the plant height of 61 cm. It is mild hot. Fruit is elongated in shape and has shoulder at the calyx with normally pointed tip. Fruit length is 18.5 cm with width of 4 cm, weighing 80 gm. The fruit has thick wall due to which it is not feasible for drying purpose. It is for fresh vegetable and salad purposes. The variety is susceptible to Phytopthora wilt and chilli mosaic virus. It grows at an altitude of 1000-2600 masl. It can be grown in most of the districts of Bhutan (Bajo, 2016). An actual experiment occupies 102 m^2 (34*3) excluding row and column area in-between and side of beds. The individual plot area consists of 2 m length by 1 m breadth with the bed height of 25 cm. The final field preparation was carried out on 1st March, 2019. The seedlings were transplanted on 2nd March 2019. The plants were planted at the plant to plant and row to row spacing of 30 and 60 cm, accommodating 10 plants in each plot. Therefore, there were the total of 510 number of seedlings (10*17*3). Heading back of chilli stem by leaving 12 cm below ground is conducted 25 days after transplanting (DAT) or on 25th March,2019. After 30 DAT or on 15th April 2019, semi variety beans were intercropped. They were intercropped in rows in the middle and side of the chilli beds. Thus, the plot had three rows of beans intercropped with chilli by maintaining the space of 30 cm plant to plant and 60 cm row to row in the staggering method so that chilli plants don't compete with beans for the canopy space. Removal of 1st three bottom of flowers were carried out 34 DAT or on 19th April, 2019 when plants were bloomed with flowers.

3.1.6.2 Treatment details

There were four cropping levels with one control (Cc) and four management levels with control (Mc). The four cropping levels were CL1.1 chilli transplantation in farmer's raised bed method CL1.2 chilli transplantation in modified raised bed method (modified raised bed is same as farmer's raised bed method but raised a ridge of 10 cm high at all the sides of the bed), CL1.3 beans intercropped in three rows on chilli transplantation in farmers raised bed method, CL1.4 beans intercropped at the ridge sides of chilli transplantation in modified raised bed method and one control (Cc) chilli raised only in farmer's raised bed method (control). The four management levels were ML2.1 pruning (heading back of chilli plants by leaving 12 cm of stem below ground) in farmer's raised bed method, ML2.2 pruning (heading back of chilli plants by leaving 12 cm of stem below ground) in modified raised bed method, ML 2.3 1st bottom three removal chilli flowers in farmer's raised bed method, ML2.4 1st bottom three removal of chilli flowers in modified raised bed method and one control (Mc) no pruning and no flower removal of chilli in farmer's raised bed method.

The farmers bed raised and modified raised bed were prepared during the final field preparation just a day before transplanting of chilli seedlings. Beans were intercropped after 45 days of chilli transplantation on both type of beds as beans were the fast growing plants. Chilli plants were pruned at the same on both the type of raised beds after 23 days of chilli transplantation after chilli seedlings got well-established. The 1st bottom three removal of flowers were carried out after 48 days when the seedlings were blossoming fully.

3.1.7 Experimental layout

3.1.7.1 Field preparation

The field was prepared using power tiller. The soil was made into fine tilth by rotivator. Before transplantation, the beds were prepared based on the specification of the mentioned design using measuring tape, rope and bamboo pegs. The following is the bed designed:

Figure 8 Experiment

3.1.7.2 Transplanting

Chilli seedlings were prepared right after bed preparation keeping the plant to plant spacing of 30 and row to row spacing of 60 cm on 2nd march 2019 which accommodates 10 seedlings in each plot (Figure 9). In each planting hole, two seedlings were planted to replace seedlings if one plant dies out. The weak plant was taken out after 21 days of transplanting after the plants were strong enough to stand in the soil.

Figure 9 Chilli transplantation

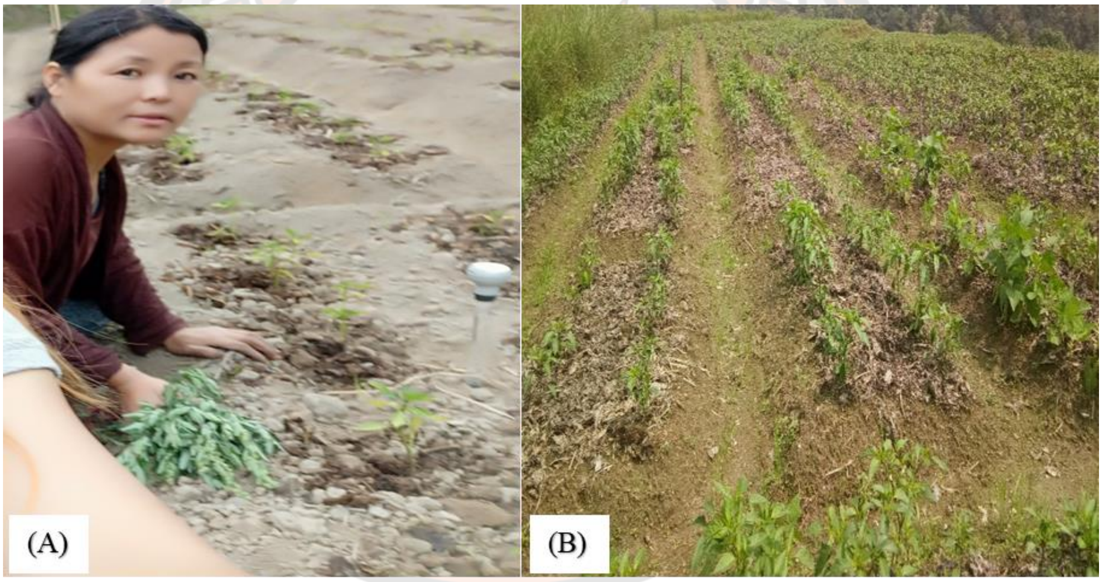

Figure 10 FYM application (A) Compost mulching (B)

3.1.7.3 Other cultural operation

Cultural operations were done as per the chilli production guide. As per Dorji *et al* (2013) the crop requires 72.8 N kg ac-1 (kilogram per acre), 72.8 P_2O_5 kg ac-1 , 80.9 K_2O kg ac-1 and 14 S kg ac-1 and farmers apply 1195 kg ac-1 of FYM is applied annually. However, in this study, the plot of 2 m *1 m, 1 sack (25 kg) full of Farm yard manure was applied at the vicinity of chilli plants after a week of transplanting (Figure 10 (A). Compost was used as both manure and mulch (Figure 10

(B). No irrigation was applied since farmers fully rely on rainfall. Two times weeding and hoeing were done to eradicate weeds and to make the soil loose for aeration and water pores in the soil.

3.1.7.4 Plant protection

No pesticides were applied on plants. There was no problem with the cutworms but during the reproduction stage, some few plants were affected by the blight. So in areas where there was an initial blight, they were uprooted and thrown far away.

3.1.8 Variables in the Research

Research variables were on different cropping system and cultural management techniques. The cropping systems were farmers practice method (control), (Modified raised bed method) at the border, beans intercropped in farmers field practice and beans intercropped at modified raised bed at the border and cultural management practices are pruning in farmers raised bed method, pruning in modified raised bed method, 1st bottom three flower removal in farmers raised bed method and 1st bottom three flower removal in modified raised bed method would have effect on growth and yield parameters. Variables were on pre-test and post- test soil finding the parameters such as NPK content, pH reading and organic carbon (OC) content and even under different cropping system (no intercropping, intercropping with beans). Regarding the evaluation of farmers' acceptance and adoption on technologies of different cropping method and management practices, variables such as not knowing and knowing the technologies and farmer's adoption and rejection of these technologies would be verified.

3.1.9 Research Instruments and Instrument Development

Measuring scale for measuring plant height, leaf length, pod length, vernier caliper for diameter, Rope and measuring tape for layout of experiment, weighing balance for weighing chilli fruit, 3-4 numbers of spade, 2 numbers of hoes, 1-2 pick axe and 1-2 crow bar for field preparation and cultural operation, auger for soil sampling will be required for the experiment. To analyze NPK, OC and pH of the soil, the NPK analyzer machine needs to be carried out. Soil moisture will be measured using Tensiometer.

3.2 Data Collection

3.2.1 Primary Data collection

A structure questionnaire was framed for pre-test and post-test and interview was conducted to the farmers. The pretest questionnaire was highlighted on name of the farmers, gender and age group, their knowledge and information on cropping techniques, intercropping, pruning and removing of the first three flowers, idea on green biomass and also find out their attitude on adoption of any of this technology. The posttest questionnaire was focused on same farmer of reflected name, gender, age, their opinion after viewing the experiment on cropping techniques and intercropping system in these types of bed raised, management practices on pruning and removing of flowers on 1st three nodes, and their perception on adopting these technologies.

The respondent using individual interview was selected from Wookhuna village, Kabisa Block under Punakha District. One-day field day was conducted with regard to the experimental result to find out their acceptance and adoption of the cropping and management system.

3.2.2 Secondary data collection

Numerous published articles and journals were reviewed. Non-published materials such as statistics, reports, online resources were used.

3.2.3 Experiment data collection (Biometric parameters)

The data on biometric parameters such as plant growth and yield parameters were recorded (Annexure 1 & 2). The growth parameters such as plant height, diameter, leaf length, breadh and number of leaves were measured after 35. 50, 70 and 85 days or 5th, 7th,10th and 12th week of transplanting of chilli. Chilli yieild parameters such as single fruit weight, length and diameter were measured during 2nd harvest, whereas number of fruits were counted from 1st harvest until 3rd harvest.

3.2.3.1 Plant growth parameters

The data on biometric parameters such as plant growth and yield parameters were recorded (Annexure 1 & 2). The growth parameters such as plant height, diameter, leaf length, breadth and number of leaves per plant were measured after 35. 50, 70 and 85 days after transplanting (DAT) or 5th, 7th,10th and 12th week after transplanting (WAT) of chilli. Chilli yield parameters such as fruit weight, fruit length, fruit girth and fruit girth at apex were measured during 2nd harvest, whereas number of fruits per plant were counted from 1st harvest until 3rd harvest.

3.2.3.2 Yield parameters

From the same tagged 3 plants, about three uniform fruits were randomly selected to measure the yield parameter such as fruit length (Figure 11'E'), fruit length with pedicel (11 'D'), fruit girth (11 'A'), fruit girth at apex (11 'C') weight of the one fruit (11 'B') except number of fruits per plant were counted from 1st harvest until 3rd harvest. The length of the fruit was measured using measuring scale from base to tip (excluding pedicel), Pedicle length was measured using measuring scale from base till end of pedicel, diameter was recorded using digital vernier caliper based on the widest girth. Weight of one fruit was weighed using digital balance and number of fruits were counted manually. The main yield data was collected on 15th of June, 2019 whereas number of fruits were counted three times: on 2/6/2019 (93 days after transplantation DAT), 15th/6/2019 (104 DAT and 27/6/2019 (120 DAT).

Figure 11 Girth measurement (A), weighing fruit (B), girth measurement at apex (C), length with pedicel (D) and pod length (E)

3.2.4 Soil moisture parameter

The soil moisture from farmers raised and modified bed method were recorded using digital tensiometer. Two numbers of tensiometer, one at farmers raised bed and another at modified raised bed were placed at the same time for one hour to see the moisture content in the soil. The reason for finding soil moisture was to compare and assess the deficit, medium or surplus moisture in the soil for four consecutive months (from transplanting till harvest).

3.2.5 Soil data collection

The pre-soil test before the experiment design was collected and analyzed at the laboratory of College of Natural Resources (CNR), Lobesa, Bhutan. The post-soil data samples after harvesting chilli from the experiment plot were collected from two replications and analyzed at the Laboratory of College of Natural Resources, Lobesa to assess Organic carbon, pH, and NPK content in the soil. Soil samples were collected using the guide of (Gregorich & Carter, 2007). Using auger, soil sample from the depth of 15 cm was collected and mixed in the labelled polythene bag by randomly digging from four sites of same plot and put it in the label polythene bag. The same was done for other treatments and replications. The labelled soil samples were analyzed at the laboratory of College of Natural Resources, Bhutan. Organic carbon was extracted using dry combustion method, Nitrogen by Kjetdahl method, pH using combination electrode, Phosphorus by Bray 2 extraction molybdenum blue method and K by ammonium acetate method by flame photometer.

To determine organic carbon (OC), air-dried, fine, sieved soil (0.5 mm mesh) porcelain crucible of 25 gm was weighed and kept overnight crucible with air-dried soil in hot air oven at 105^{o}C to remove moisture. After cooling, weighed the oven dried soil using 4 digit balance and placed the crucible into muffe furnace set at 400^{o}C and when it reached to set temperature, it was kept for 60 minutes and made it cool for 1 hour. The crucible was removed and put it in glass desiccator for 30 minutes to cool. It was weighed using 4 digit balance and calculated (CNR, nd).

SOM% = ((Wcs-Wf)/ (Wcs-Wc))*100 and calculated SOC%= 0.58*SOM%. Thus, the unit of OC is calculated in percentage (%).

pH was extracted using combination pH electrode. To determine pH, 10 g air-dry soil was weighed and put into a bottle where 10 mL deionizer water was added to prepare a 1:1 soil: water suspension. Prepared 1:5 soil: water suspension by weighing 10 g air dry soil into a bottle and 50 mL deionizer water was added and to prepare 1:5 soil: 0.01 M $CaCl_2$ suspension, weighed 10 g air-dry soil (<2 mm) into a bottle and added 50 mL 0.01 M $CaCl_2$. The suspension was stirred many times for 30 minutes and left without stirring for 1 hour. Then calibrated pH meter based on instruction and immersed the electrode into the soil suspension and recorded the pH value when it reached to equilibrium(CNR, nd).

To find out Phosphorus, 5.00 g of soil in 125 ml erlenmayer flask and 50 ml of Bray extracting solution was shaken for 1-minute right after capping with stopper on the flask. The suspension was filtered using Whatman No.5 paper. The colour was developed using dispense 10 ml of the supernatant into 50 ml volumetric flask where 4.0 mL Reagent C and bulk to volume with distilled water were mixed and kept for 30 minutes. A set of reference standards from 5.0 Mg/L phosphorus solution was prepared. Then recorded the absorbance of the standards and samples at 820 nm wavelength. A graph from the standards data to plot phosphorus concentration against absorbance was prepared and obtained the equation of the line of best fit using linear regression to determine the phosphorus concentration in the sample solutions. The unit was calculated in milligram per liter (Mg/L)(CNR, nd).

To determine total nitrogen, reagents such as mixed indicator (dissolving 0.3125 g methyl red and 0.2062 g methylene blue in 250 ml of 95% ethanol and stiring for 24 h), boric acid solution, sodium Hydroxide, H_2SO_4 98% and standardized 0.1N H_2SO_4 0.1N Hydrochloric Acid Solutions were required. The digestion was done by decomposition of Nitrogen in organic samples using a concentrated acid solution which was achieved by boiling a homogenous sample in concentrated sulphuric acid and digestion catalyst and an ammonium Sulphate solution was found to be the end result. Then the digestion system was preheated to 350^{o}C and took 1 gm sample in digestion tube. The catalyst mixture of 4 grams and 10 ml of Conc. Sulphuric acid to the sample were added and placed in the digestion block along with manifolds till it reached the temperature at 420^{o}C. The digestion tube was removed from the digestion block and kept on cooling stand for 15-20 minutes. Cool digest was then added with 10 ml deionizer water and swirled flask to dissolve salts. Distillation was done adding base to the acid digestion mixture to convert NH_4+ to NH_3 by boiling. Finally, NH_3 gas was condensed and trapped in a receiving solution (H_3BO_3). The distillate was collected and 5 drops of mix indicator was added. Titrated distillate with 0.01 H_2SO_4 and recorded the amount of acid used. Thereafter, calculation was done using the formula below:

$$N\% = \frac{14 \text{ x (normality of acid) x (ml tritant} - \text{ ml blank) x100}}{\text{Sample dry weightx1000}}$$

N unit was calculated in percentage (%).

To determine potassium, 5.0 g air-dry soil (< 2-mm) in a 125-mL Erlenmeyer flask was weighed and 50 ml ammonium acetate solution was added, which was placed in shaker to shake for 30 minutes and the suspension was filtered using Whatman No.5 paper. The solution was kept for determination exchangeable K (Ca, Mg, Na) by Atomic absorption Spectrophotometer. It operated a series of suitable potassium standards, and calibration curve was drawn. The samples (soil extracts) were measured and the emission readings were recorded (CNR, nd). According to the calibration curve, potassium (K) concentrations was calculated using the formula below: For Extractable Potassium in soil, the following formula was used:

$$\text{Extractable K (ppm)} = \text{ppm K (from calibration curve) x } \frac{A}{Wt}$$

Where:

A = Total volume of the extract (mL)

Wt = Weight of air-dry soil (g)

The unit used for potassium was kilogram per hectare (kg/ha)

3.3 Data Analysis

Data was analyzed using statistix 23 (statistic package). The data was interpreted in excel sheet. For the questionnaire survey, codes for analysis and chi-square was used to compare the pretest and posttest of farmers' perception on adoption of the techniques. For the experiment, general linear model using univariate and multivariate was used to find out the interaction and effect of two different factors. One way anova was used to compare the means of the growth, yield parameters, soil moisture, soil data to find the significant different among the variables at p=0.05.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Growth parameter

The growth parameter such as plant height, stem diameter, leaf length, leaf breadth, number of leaves were recorded every after 5th, (35), 7th (50), 10th (70) and 12th (85 DAT) weeks after transplanting on three tagged uniform randomly selected plants from each individual plot of all the replications.

4.1.1 Height parameter (cm)

The result showed that plant height of chilli had an effect on cropping levels (p < 0.05) from 5th week after transplanting (WAT) until 10th WAT and management levels (p< 0.05) throughout the growing period (Table 4 and 5). It also showed that there was an interaction (p<0.00) between cropping and management levels on plant height throughout the period.

The effect of cropping levels at 5th week (35 DAT) performed the highest plant height in CL1.4 (chilli intercropped with beans in modified raised bed method) with 10.63 cm followed by CL1.2 (chilli planted in modified raised bed method) with 9.9 cm and the lowest plant height was in Cc (control- chilli planting on farmers raised bed method) followed by CL1.1 (chilli planted in farmers raised bed method) and CL1.3 (chilli intercropped with beans in farmers raised bed method) with 8.84 and 8.91 cm respectively. Therefore, there was the significant difference in plant height on modified raised bed method and farmers raised bed method. Similarly, at 12th week after transplanting, the highest plant height was performed in CL1.4 (chilli intercropped with beans in modified raised bed method) with 43.83 cm followed by CL1.2 (chilli planted in modified raised bed method) with 43.12 cm and the lowest plant height was in Cc (chilli planted in farmers raised bed method) with 39.69 cm followed by CL1.3 (chilli intercropped with beans in the farmers raised bed method) with 41. 38 cm even though they were not significantly different from each other.

The effect due to management level on plant height performed the highest in management level (ML) 2.4 (chilli plant with 1st bottom three removal of flowers in modified bed method) with 11.92 cm followed by ML2.3 (chilli plant with 1st bottom three removal of flowers in farmers raised bed method) with 11.37 cm on 5th WAT whereas the lowest plant height was observed in ML2.1 (chilli pruning on farmer's raised bed method) with 7.62 cm followed by ML2.2 (chilli pruning on modified raised bed method) with 7.48 cm. At 12th week (85 DAT), the highest plant height was in ML2.3 (chilli plant with 1st bottom three removal on farmer's raised bed method) with 49.21 cm followed by ML2.4 (chilli plant with 1st bottom removal of flowers in modified raised bed method) with 47.21 cm and lowest plant height was in Mc with 7.20 cm.

The combination effect of cropping and management levels on chilli plant height was shown in Table 6 and Figure 12. Throughout the growing period, there were highly significant differences (p=0.00) in plant height among the treatment levels. At 5th week after transplanting (WAT) the highest plant height was shown under treatment level (TL) 1.4*2.4 (chilli intercropped with bean in modified raised bed method and chilli plant with 1st bottom three removal of flowers in modified raised bed method) with 13.53 cm followed by TL1.4*2.3 (chilli intercropped with bean in modified raised bed method and chilli plant with 1st bottom three removal of flower in farmer's raised bed method) with 13.38 and TL1.2* 2.4 (chilli planted in modified raised bed method and chilli plant with 1st three bottom removal of flowers in modified raised bed method) with 13.33 cm and lowest plant height was shown in TL1.3*2.1 (chilli plants intercropped in farmers raised bed method and chilli pruning in farmers raised bed method) with 6.97 followed by TL1.2*2.1 (chilli planted in modified raised bed method and chilli pruning in farmers raised bed method) with 7.13 cm and control Cc*Mc (farmers raised bed method only) with 7.20. At 12th week (85 DAT), the highest plant height was performed in TL1.4*2.3 (chilli intercropped with bean in modified raised bed method and 1st bottom three removal of flowers in farmers raised bed method) with 54.42 cm followed by TL1.2*2.4 (chilli planted in modified raised bed method and chilli plant with 1st three bottom removal of flowers in modified raised bed method) with 50.56 cm and the lowest plant height was poorly performed in TL1.2*2.1 (chilli planted in modified raised bed method and chilli pruning in chilli pruning in farmers raised bed method) with 33.56 cm.

It clearly indicated that throughout the vegetative phase (from 5th week of transplanting till 12th week of transplanting), the plant height due to influence by cropping level was highest in the chilli plants intercropped with beans under modified raised bed method followed by the chilli plants transplanted under modified raised bed method.

The highest plant in modified raised bed method could due to moisture holding capacity in modified raised bed method where the moisture can be retained under field capacity in the modified with 207.67 Mbar during March and 101.33 Mbar in May, 2019. The other reason could be that there is the probability of good companion of chilli with semi dwarf beans since beans fix nitrogen from air which is one of the major nutrients that might be contributing to the chilli plants. Similar result by Markham (2014) reported that the benefits of beans with chilli fix not only nitrogen in the soil but also avoid crowding weeds, assist to block winds in wind prone area and cast the partial shade to the chilli plants. In line with the finding of Naseri (2019), though pole beans and chilli are bad companion, each plants do the roles in improving soil quality such as beans uptake nitrogen and recycle in the soil which improve the vicinity's plants overall health and chilli which produces substance within their root system is effective at getting rid off root rot disease such as Fusarium rot and prevent root rots in other companion plants. According to Naseri (2019) sowing of bean in raised beds during rainy season have soil aeration improvement, root system extension and increase in root rots tolerance. Likewise, Schwartz and Pastor-Corrales (1989) as stated by Naseri (2019) recommended growing beans on raised beds to lower Rhizoctonia root rot (RRR) levels during the wet rainy season.

The plant height due to effect of management at 5th WAT was found highest under modified raised bed method of 1st bottom three removal of chilli flowers followed by farmers raised bed method of 1st bottom three removal of chilli flowers and at 12th WAT was vice versa. The reason for having taller height in both could be both the treatments levels were not pruned whereas, the other two treatment levels were headed back (pruning) leaving 12 cm of stem below ground which might have failed them to compete. 1st bottom three flowers removal might have resulted in increasing the strength for the vegetative growth especially the plant height. The similar result is also with accordance to Ghebremariam (2007) in plants removing two-thirds of the flowers enhanced vegetative growth, resulting in larger plants that had fewer with larger fruits.

Table 4 Average value of effect of cropping levels of chilli on plant height (cm) at 5th, 7th, 10th and 12th week after transplanting (WAT)

CL	Week after transplanting			
	5th	**7th**	**10th**	**12th**
1.1	8.91[b]	10.34[a]	23.75[a]	41.75[a]
1.2	9.99[c]	11.49[b]	24.82[a]	43.12[a]
1.3	8.84[b]	10.31[a]	24.02[a]	41.38[a]
1.4	10.63[c]	12.23[b]	28.44[b]	43.83[a]
Cc	7.20[a]	10.40[a]	24.41[a]	39.69[a]
p value	**	**	**	NS

Value followed by the same letter, the same column is not significantly different at Duncan test (p =0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant.

Table 5 Average value of effect of management levels of chilli on plant height (cm) at 5th, 7th, 10th and 12th week after transplanting (WAT)

ML	Week after transplanting			
	5th	**7th**	**10th**	**12th**
2.1	7.48[b]	7.90[c]	18.80[d]	35.41[c]
2.2	7.62[b]	8.01[c]	21.36[d]	38.10[ab]
2.3	11.37[a]	13.89[a]	32.05[a]	49.35[a]
2.4	11.92[a]	14.56[a]	28.83[b]	47.21[a]
Mc	7.20[b]	10.40[b]	24.41[c]	39.69[b]
p value	**	**	**	**

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p<0.05 and p<0.01, respectively. NS, Not significant.

Table 6 Average value of effect of cropping and management levels of chilli on plant height at 5th, 7th, 10th and 12th WAT in centimeter (cm)

TRT	Cropping level	Management level				
		2.1	**2.2**	**2.3**	**2.4**	**Mc**
5th WAT	1.1	7.92^{c}	7.46^{c}	9.98^{b}	10.30^{b}	
	1.2	7.13^{c}	7.69^{c}	11.81^{ab}	13.33^{a}	
	1.3	6.97^{c}	7.6^{c}	10.30^{b}	10.50^{b}	
	1.4	7.88^{c}	7.73^{c}	13.38^{a}	13.53^{a}	
	Cc					7.2^{c}
	p value	**				
7th WAT	1.1	8.28^{e}	8.04^{e}	12.32^{c}	12.71^{c}	
	1.2	7.69^{e}	7.96^{e}	14.18^{bc}	16.12^{a}	
	1.3	7.21^{e}	8.04^{e}	13.18^{c}	12.79^{c}	
	1.4	8.42^{e}	7.99^{e}	15.88^{ab}	16.62^{a}	
	Cc					10.40^{d}
	p value	**				
10th WAT	1.1	16.73^{f}	21.37^{d-f}	30.71^{ab}	26.20^{b-e}	
	1.2	18.17^{ef}	22.14^{c-f}	30.81^{ab}	28.17b-d	
	1.3	17.69^{f}	23.52^{b-f}	30.43^{a-c}	24.44^{b-f}	
	1.4	22.61^{b-f}	18.42^{ef}	36.23^{a}	36.51^{a}	
	Cc					24.41^{b-f}
	p value	**				
12th WAT	1.1	35.50^{g}	36.97^{fg}	47.87^{a-e}	46.68^{a-e}	
	1.2	33.56^{g}	39.43^{e-g}	48.92^{a-d}	50.56^{ab}	
	1.3	36.31^{g}	41.07^{c-g}	46.20^{a-f}	41.92^{b-g}	
	1.4	36.26^{g}	34.93^{g}	54.42^{a}	49.69^{a-c}	
	Cc					39.69^{d-g}
	p value	**				

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p<0.05 and p<0.01, respectively. NS, Not significant

Cropping levels		**Management level**	
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

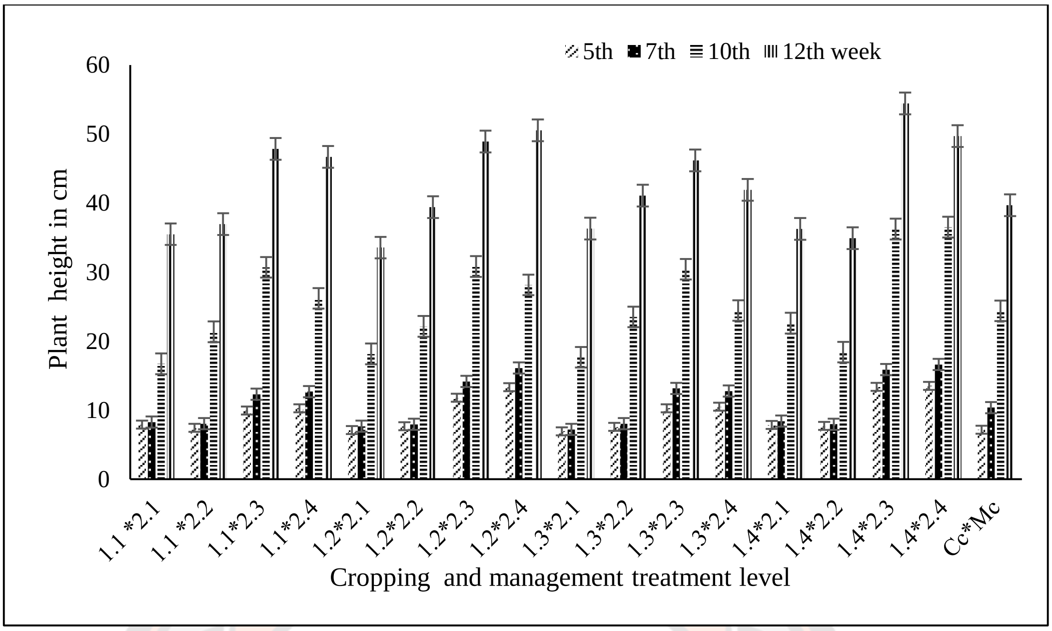

Figure 12 Combination effect of cropping and management on plant height of chilli crop. Error bars denote the standard error of the mean for each treatment.

4.1.2 Stem diameter

The finding showed that there were effects on both cropping level ($p<.05$) throughout the growing period and management levels ($p<.05$) on stem diameter of chilli plants from mid stage until end of growing period, however there was no interaction between cropping and management level ($p>0.05$) on stem diameter of chilli plants throughout the growing period. (Table 7 and 8)**.**

The effect of cropping levels on stem diameter at 5th, 7th, 10th and 12th week is shown in Table 8. At 5th week, the widest stem diameter was recorded in CL1.4 (chilli intercropped with beans in modified raised bed method) with 2.88 mm followed by CL 1.2 (chilli planted in modified raised bed method) with 2.82 mm whereas the narrowest stem diameter was recorded in CL1.3 (chilli intercropped with beans in farmers raised bed method) and Cc (control- chilli planted in farmers raised bed method) with 2.58 and 2.59 mm respectively. At 12th week (85 DAT), the widest stem diameter was recorded in CL1.2 (chilli plants planted in modified raised bed method) with 8.33 mm followed by chilli CL1.3 with 7.39 mm and CL 1.4 with 7.36 cm and narrowest stem diameter was recorded in Cc (control) with 6.38mm.

Therefore, the result interpreted that there was significant difference in stem diameter between modified raised bed method and farmers raised bed method.

The effect of management level of chilli plant on stem diameter at 5^{th}, 7^{th}, 10^{th} and 12^{th} weeks (Table 9). At 5^{th} WAT, the widest stem diameter was recorded in ML2.2 with 2.79 mm followed by ML2.3 with 2.77 mm and the lowest stem diameter was recorded in Mc with 2.59 mm. Thus, there were no significant differences in stem diameter among the management levels. At 12^{th} WAT, the widest stem diameter was recorded in ML2.3 and ML2.4 with 8.25 and 8.18 mm, respectively and the narrowest diameter was recorded in Mc (control) with 6.38 mm.

The combine effect of cropping and management levels of chilli plants on stem diameter at 5^{th}, 7^{th}, 10^{th} and 12^{th} week was shown Table 9. There were no significant differences in stem diameter at 5^{th} and 7^{th} WAT but there were significant differences in stem diameter among treatment levels at 10^{th} and 12^{th} WAT. The widest stem diameter at 5^{th} week was recorded in TL1.4 * 2.1 with 3.05 followed by TL1.4* 2.3 with 2.96 mm and the narrowest stem diameter was in TL1.1*2.4 and 1.3*2.4 with 2.39 and 2.39 mm respectively. At 12^{th} WAT, the widest stem diameter was recorded in TL1.2 *2.4 (9.08mm) followed by1.2*2.3 (8.88 mm) and the smallest diameter was found in TL1.1 * 2.1 with 6.16 mm (Figure 13).

The widest stem diameter is directly related to plant height under CL1.4. The highest plant height and highest stem diameter was found in chilli intercropped with beans in modified raised bed method and chilli planted in modified raised bed method. The highest stem diameter could be due to the beans fixing nitrogen for the benefits of the chilli as nitrogen accelerates vegetative growth of the plants. Similar result expressed by El-Gaid et al. (2014) that due to the nitrogen fixation effect of legume crop on main crop, increase in soil fertility enhances plant growth With the effect of management levels, the highest stem was found in ML2.2 (chilli pruned in modified raised bed method) followed by ML2.3 (1^{st} bottom three removal of chilli flowers in farmers raised bed method). This could be during the initial period when chilli was headed back to 10 cm of chilli stem, the nutrients to be up-taken be vegetative plants might have absorbed by the remaining stem which would have contributed to the thick stem. During the later stage, the stem diameter was exceeded by ML2.3 (1^{st} bottom three removal of flowers in farmers raised bed method and ML2.4 (1st bottom three removal of flowers in modified raised bed method). This could be due to removing of three flowers might have exerted nutrients to the vegetative growth which could have contributed for the growth of the wide stem diameter.

The highest stem diameter throughout the vegetative growth in CL1.2 (chilli planted in modified bed) could be due to continuous availability of retaining moisture which could have easily absorbed by the plants along with the nutrients.

Table 7 Average value of effect of cropping levels of chilli on stem diameter (mm) at 5th, 7th, 10th and 12th week after transplanting (WAT)

CL	Week after transplanting			
	5th	**7th**	**10th**	**12th**
1.1	2.60^{ab}	3.11^{a}	5.22^{b}	7.24^{b}
1.2	2.82^{ab}	3.29^{a}	5.29^{b}	8.33^{c}
1.3	2.58^{a}	3.17^{a}	5.40^{b}	7.39^{b}
1.4	2.88^{b}	3.36^{a}	5.40^{b}	7.36^{b}
Cc	2.59^{a}	3.14^{a}	3.91^{a}	6.38^{a}
p value	*	NS	*	**

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 8 Average value of effect of management levels of chilli on stem diameter (mm) at 5th, 7th, 10th and 12th week after transplanting (WAT)

ML	Week after transplanting			
	5th	**7th**	**10th**	**12th**
2.1	2.70^{a}	3.11^{a}	4.73^{b}	6.68^{bc}
2.2	2.79^{a}	3.23^{a}	5.30^{a}	7.20^{b}
2.3	2.77^{a}	3.37^{a}	5.84^{a}	8.25^{a}
2.4	2.61^{a}	3.21^{a}	5.44^{b}	8.18^{a}
Mc	2.59^{a}	3.14^{a}	3.90^{c}	6.38^{c}
p value	NS	NS	**	**

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 9 Average value of effect of cropping and management levels of chilli on stem diameter at 5th, 7th, 10th and 12th WAT in millimeter (mm)

TRT	Cropping level (mm)	Management level				
		2.1	2.2	2.3	2.4	Mc
5th WAT	1.1	2.50[a]	2.89[a]	2.63[a]	2.39[a]	
	1.2	2.84[a]	2.79[a]	2.90[a]	2.76[a]	
	1.3	2.42[a]	2.92[a]	2.58[a]	2.39[a]	
	1.4	3.05[a]	2.58[a]	2.96[a]	2.91[a]	
	Cc					2.59[a]
	p value	NS				
7th WAT	1.1	2.96[a]	3.28[a]	3.23[a]	2.96[a]	
	1.2a	3.15[a]	3.29[a]	3.46[a]	3.26[a]	
	1.3	2.94[a]	3.26[a]	3.26[a]	3.21[a]	
	1.4	3.40[a]	3.11[a]	3.53[a]	3.40[a]	
	Cc					3.14[a]
	p value	NS				
10th WAT	1.1	4.30[c]	5.46[a-c]	5.93[a]	5.18[a-c]	
	1.2	4.53b[c]	5.24[a-c]	5.75[ab]	5.63[ab]	
	1.3	4.97[a-c]	5.51[a-c]	5.72[ab]	5.40[a-c]	
	1.4	5.13[a-c]	4.97[a-c]	5.98[a]	5.53[a-c]	
	Cc					4.91[a-c]
	p value	*				
12th WAT	1.1	6.16[d]	6.47[cd]	8.43[ab]	7.89[a-d]	
	1.2	7.41[a-d]	7.95[a-d]	8.88[a]	9.08[a]	
	1.3	6.84[b-d]	7.95[a-d]	7.40[a-d]	7.36[a-d]	
	1.4	6.31[d]	6.42[d]	8.28[a-c]	8.41[ab]	
	Cc					6.38[d]
	p value	*				

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant.

Cropping levels		**Management level**	
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

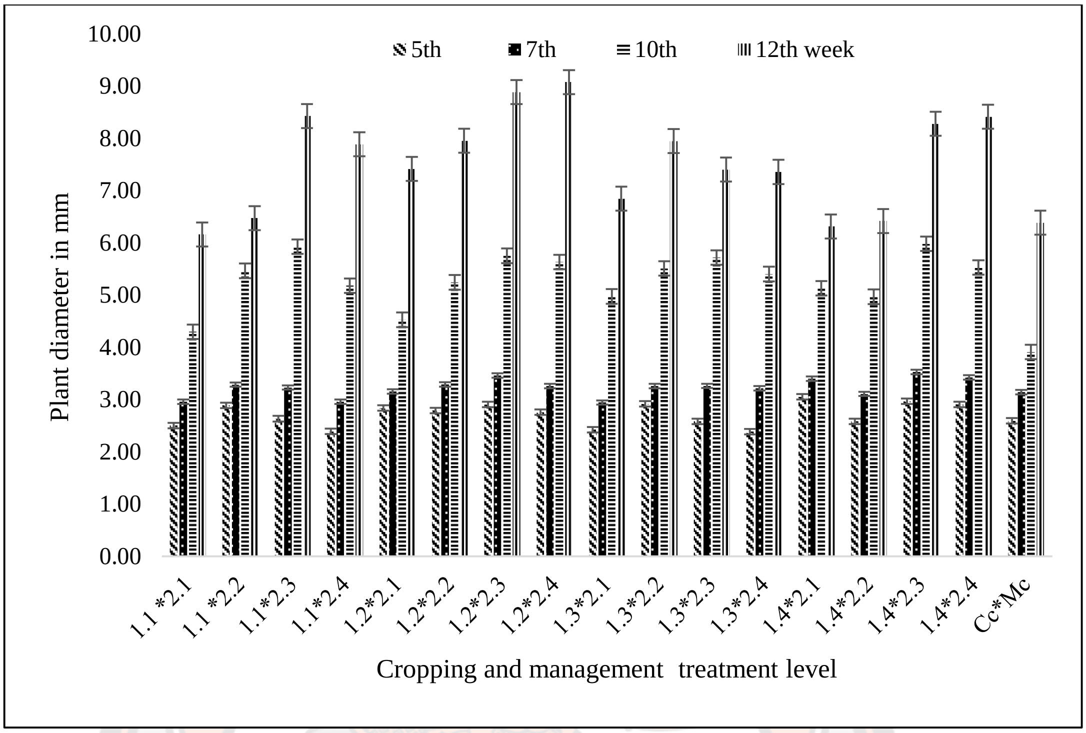

Figure 13 Combination effect of cropping and management on stem diameter of chilli crop. Error bars denote the standard error of the mean for each treatment.

4.1.3 Length of Leaf

The finding showed that there were effects on both cropping (p<0.05) and management levels (p<0.05) on leaf length of chilli plants during the entire vegetative phase (Table 10 and 11). Likewise, there was an interaction between cropping and management levels (p<0.05) on length of leaf of chilli during entire period.

As influenced by the effect of cropping level at 5^{th} (WAT), Cc (control) with 2.30 cm and CL1.2 with 1.58 cm (chilli planted in modified raised bed method) outperformed other cropping levels in terms of leaf length whereas the lowest leaf length was CL1.4 with .33 cm. However, at 12^{th} WAT, CL1.2 (9.71 cm) exceeded Cc (9.39 cm) followed by CL1.4 (9.06 cm) and the lowest leaf length recorded in CL1.1 (8.32cm) (Table 10).

Due to the effect of management level on chilli plants after 5^{th} WAT, the highest leaf length was found in ML2.4 with 2.92 cm followed by ML2.3 with 2.87 cm and the lowest leaf length was found in ML2.1 and ML2.2 with 0.00 and 0.00 cm, respectively. At 12th WAT, the maximum leaf length was found in ML1.3 with 9.49 followed by Mc with 9.39 cm. The lowest was found in ML 2.1 with 8.50 cm (Table 11). The finding showed that there was significantly different in pruning and 1st bottom three removal of chilli flowers but there was no significantly different on farmers raised bed method and modified raised bed method.

There were highly significant differences in combination effect of cropping and management levels on leaf length at 5th, 10th and 12th WAT but significant different at 7th WAT (Table 12). At 5th WAT, the effect of cropping and management level on length of leaves of chilli plants, the highest leaf length was recorded in TL1.3 *2.3 (3.28 cm) followed by TL1.2*2.3 (3.26 cm) and the lowest was recorded in TL1.1*2.1 (0.00), TL1.1*2.2 (0.00) at 5th WAT. At 12 WAT, the highest leaf length was recorded in TL1.2*2.2 (10.48 cm) followed by TL1.4*2.3 (10.24) and lowest was recorded in TL1.1*2.1 (7.57 cm) (Figure 14).

Table 10 Average value of effect of cropping levels of chilli on leaf length (cm) at 5th, 7th, 10th and 12th week after transplanting (WAT)

CL	Week after transplanting			
	5th	**7th**	**10th**	**12th**
1.1	1.47^{b}	3.33^{b}	6.08^{ab}	8.32^{b}
1.2	1.58^{b}	3.86^{a}	6.40^{a}	9.71^{a}
1.3	1.47^{b}	3.70^{a}	6.59^{a}	8.63^{b}
1.4	1.33^{b}	3.86^{a}	6.50^{a}	9.06^{ab}
Cc	2.30^{a}	3.14^{a}	5.78^{b}	9.39^{a}
p value	*	*	*	*

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 11 Average value of effect of management levels of chilli on leaf length (cm) at 5th, 7th, 10th and 12th week after transplanting (WAT)

ML	Week after transplanting			
	5th	**7th**	**10th**	**12th**
2.1	0.00c	2.98b	5.93b	8.50b
2.2	0.00c	3.11b	5.87b	8.73ab
2.3	2.87a	4.44a	6.90a	9.49a
2.4	2.92a	4.23a	6.87a	8.99ab
Mc	2.30b	3.14b	5.78b	9.39a
p value	**	*	*	*

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05). * and **, indicate significance level *p* <0.05 and *p* <0.01, respectively. NS, Not significant

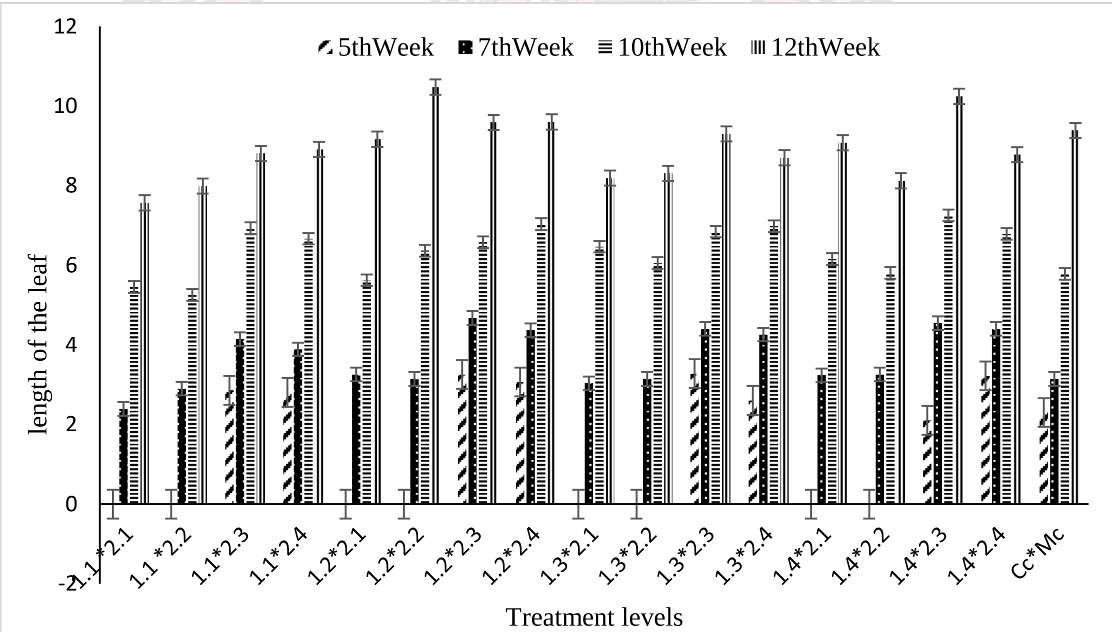

Figure 14 Combination effect of cropping and management on leaf length of chilli crops. Error bars denote the standard error of the mean for each treatment.

Table 12 Average value of effect of cropping and management levels of chilli on leaf length at 5^{th}, 7^{th}, 10^{th} and 12^{th} WAT in centimeter (cm)

TRT	Cropping level (cm)	Management level				
		2.1	**2.2**	**2.3**	**2.4**	**Mc**
5^{th} WAT	1.1	0.00^{d}	0.00^{d}	$2.86^{a\text{-}c}$	$2.80^{a\text{-}c}$	
	1.2	0.00^{d}	0.00^{d}	3.26^{a}	3.07^{ab}	
	1.3	0.00^{d}	0.00^{d}	3.28^{a}	$2.60^{a\text{-}c}$	
	1.4	0.00^{d}	0.00^{d}	2.10^{c}	3.22^{a}	
	Cc					2.30^{bc}
	p value	**				
7^{th} WAT	1.1	2.39^{c}	2.90^{c}	4.14^{a}	3.89^{ab}	
	1.2	3.26^{bc}	3.14^{bc}	4.68^{a}	4.37^{a}	
	1.3	3.03^{bc}	3.14^{bc}	4.40^{a}	4.26^{a}	
	1.4	3.23^{bc}	3.26^{bc}	4.54^{a}	4.40^{a}	
	Cc					$3.14b^{c}$
	p value	**				
10^{th} WAT	1.1	5.46^{fg}	5.26^{g}	$6.93^{a\text{-}d}$	$6.67^{a\text{-}e}$	
	1.2	$5.62^{e\text{-}g}$	$6.37^{a\text{-}g}$	$6.58^{a\text{-}f}$	7.03^{ab}	
	1.3	$6.47^{a\text{-}f}$	$6.06^{b\text{-}g}$	$6.84^{a\text{-}d}$	$6.98^{a\text{-}c}$	
	1.4	6.16^{ab}	$5.81^{c\text{-}g}$	7.26^{a}	$6.79^{a\text{-}e}$	
	Cc					$5.78^{d\text{-}g}$
	p value	**				
12^{th} WAT	1.1	7.57^{c}	7.99^{bc}	$8.81^{a\text{-}c}$	$8.91^{a\text{-}c}$	
	1.2	$9.17^{a\text{-}c}$	10.48^{a}	9.59^{ab}	9.60^{ab}	
	1.3	8.19^{bc}	8.31^{bc}	$9.30^{a\text{-}c}$	$8.70^{a\text{-}c}$	
	1.4	$9.08^{a\text{-}c}$	8.12^{bc}	10.24^{a}	$8.78^{a\text{-}c}$	
	Cc					$9.39^{a\text{-}c}$
	p value	**				

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Cropping levels		**Management level**	
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

4.1.4 Leaf breadth

The data from the leaf breadth parameter showed that there were effects on cropping (p<0.05) and management techniques (p<0.05) on leaf breadth and there was an interaction between cropping and management technique (p<0.05) on leaf breadth throughout the vegetative phase.

The leaf breadth varied significantly due to the effect of different cropping levels of chilli plants from 5th week until 12th WAT. The highest leaf breadth at 5th week after transplanting (WAT) was found in Cc with .91 cm followed by CL1.2 with 0.78 cm whereas the lowest leaf breadth was recorded in CL 1.4 and CL1.1 with 0.60 and 0.66 cm, respectively. Thus, significant differences were found among the different cropping levels. At 12th WAT, the highest leaf breadth was found in CL1.2 (4.44cm) followed by CL1.4 (4.09cm) and the lowest was found in Cc (3.47 cm). The study found that there were significant differences on leaf breadth among different cropping level at 12 DAT as shown in Table 13.

The effect of management of chilli on leaf breadth at 5th WAT was found highest in ML2.4 (1.45cm) followed by ML2.3 (1.25 cm) and the lowest was found both in ML2.1 and 2.2 with 0.00 and 0.00 cm, respectively. At 12th WAT, the highest was found in ML2.3 and ML2.4 with 4.30 and 4.19 cm, respectively and the lowest was found in Mc with 3.47 cm (Table 14).

There were significant differences of leaf breadth on combination effect of cropping and management levels at 5th, 7th, 10th and 12th WAT (Table 15). The joint effect of cropping and management levels on leaf breadth of chilli was found the highest in TL1.4*2.4 with 1.49 cm and the lowest was found in TL1.1*2.1 (0.00), 1.1*2.2 (0.00) at 5th WAT (Figure 15). At 12th WAT, the highest leaf breadth was found in TL1.2*2.4 with 4.94 cm and the lowest was in TL1.3 *2.1 and Cc*Mc with 3.43 and 3.46 cm respectively.

Due to the effect of cropping levels, both leaf length and breadth was found highest in the Cc (control) and lowest was noted in CL1.4. the result showed that the higher the surface of the leaf in Cc, lower the single yield weight and number of fruits in Cc (Table 15 & Figure 15). This could be when the leave surface area is more, there will be more transpiration rate which would have affected the yield of chilli plants and instead of diverting of water to the plants for converting to carbohydrate for food, transpiration from leave surface to air might have affected. Similar result pointed out by variation due to changes in leaf size can substantially alter and have a strong influence on transpiration. Under certain conditions, such as a large leaf size and low wind speed, can significantly influence transpiration by contributing substantially to, resulting in greater transpiration for a larger leaf (Geller & Smith, 1982)

Table 13 Average value of effect of cropping levels of chilli on leaf breadth (cm) at 5th, 7th, 10th and 12th week after transplanting

CL	Week after transplanting			
	5th	7th	10th	12th
1.1	0.66a[b]	1.58[ab]	2.85[ab]	3.89[ab]
1.2	0.78[b]	1.85[c]	2.90[ab]	4.44[c]
1.3	0.67[ab]	1.72[bc]	2.99[ab]	3.78[ab]
1.4	0.60[a]	1.80[c]	3.02[b]	4.09[bc]
Cc	0.91[c]	1.44[a]	2.71[a]	3.47[a]
p value	**	**	*	**

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05). * and **, indicate significance level $p<0.05$ and $p<0.01$, respectively. NS, Not significant

Table 14 Average value of effect of management levels of chilli on leaf breadth (cm) at 5th, 7th, 10th and 12th week after transplanting

ML	Week after transplanting			
	5th	7th	10th	12th
2.1	0.00[d]	1.42[b]	2.72[b]	3.65[bc]
2.2	0.00[d]	1.46[b]	2.76[b]	4.04[ab]
2.3	1.25[b]	2.01[a]	3.13[a]	4.30[a]
2.4	1.45[a]	2.06[a]	3.16[a]	4.19[a]
Mc	0.91[c]	1.44[b]	2.71[b]	3.47[c]
p value	**	*	*	**

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05). * and **, indicate significance level $p<0.05$ and $p<0.01$, respectively. NS, Not significant

Table 15 Average value of effect of cropping and management levels of chilli on leaf breadth at 5th, 7th, 10th and 12th WAT in centimeter (cm).

TRT	Cropping level (cm)	Management level				
		2.1	2.2	2.3	2.4	Mc
5th WAT	1.1	0.00^{c}	0.00^{c}	1.26^{ab}	1.37^{a}	
	1.2	0.00^{c}	0.00^{c}	1.39^{a}	1.42^{a}	
	1.3	0.00^{c}	0.00^{c}	1.46^{a}	1.23^{ab}	
	1.4	0.00^{c}	0.00^{c}	0.90^{b}	1.49^{a}	
	Cc					0.91^{b}
	p value	**				
7th WAT	1.1	1.24^{d}	1.42^{cd}	1.78^{a-c}	1.86^{ab}	
	1.2	1.89^{ab}	1.49^{b-d}	2.09^{a}	2.04^{a}	
	1.3	1.40^{cd}	1.43^{cd}	2.07^{a}	1.98^{a}	
	1.4	1.59^{b-d}	1.49^{b-d}	2.11^{a}	2.02^{a}	
	Cc					1.44^{cd}
	p value	*				
10th WAT	1.1	2.54^{ef}	2.47^{f}	3.27^{a-c}	3.13^{a-d}	
	1.2	2.59^{d-f}	2.94^{a-f}	2.77^{bc-f}	3.30^{ab}	
	1.3	2.91^{a-f}	2.77^{b-f}	3.09^{a-e}	3.21a-c	
	1.4	2.83^{b-f}	2.84^{a-f}	3.41^{a}	2.98^{a-f}	
	Cc					2.71^{c-f}
	p value	*				
12th WAT	1.1	3.62^{c}	3.74^{bc}	4.10^{a-c}	4.09^{a-c}	
	1.2	3.72^{bc}	4.66^{ab}	4.43^{a-c}	4.94^{a}	
	1.3	3.43^{c}	3.81^{bc}	4.01^{a-c}	3.84^{bc}	
	1.4	3.83^{bc}	3.97^{bc}	4.67^{ab}	3.89^{bc}	
	Cc					3.46^{c}
	p value	*				

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Cropping levels		**Management level**	
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

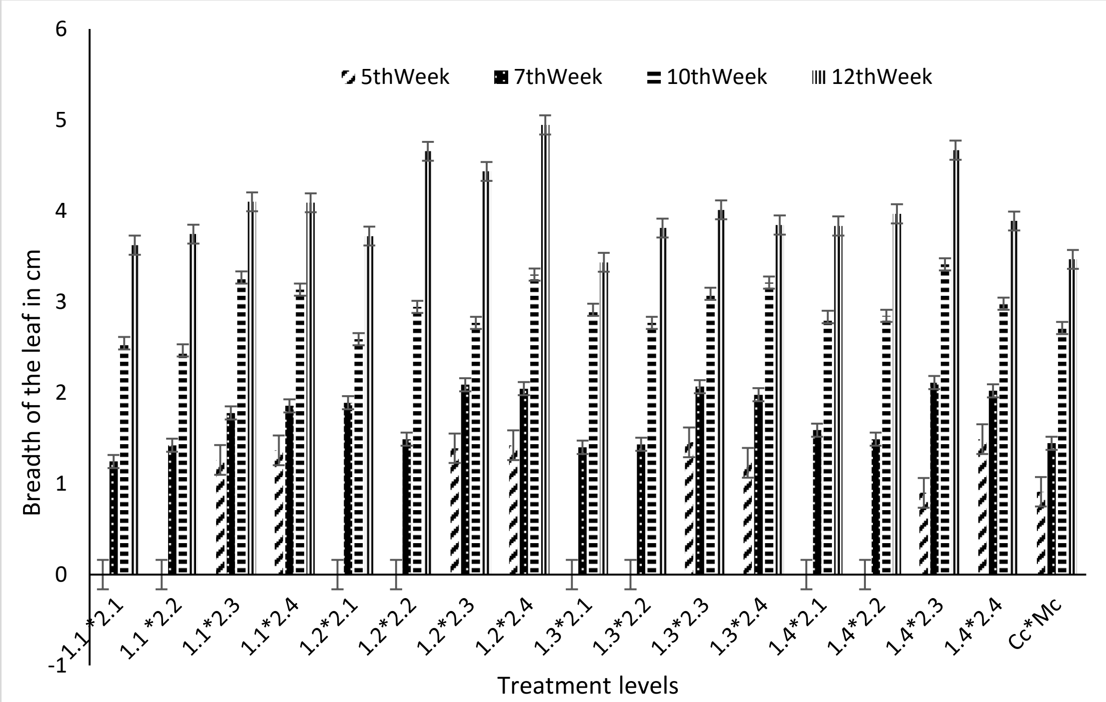

Figure 15 Combination effect of cropping and management on leaf breadth of chilli crop. Error bars denote the standard error of the mean for each treatment.

4.1.5 Leaf number

There were significance differences on effects of cropping ($p<0.05$) and management techniques ($p<0.05$) on leaf number per plant as well as there was significant different in an interaction between cropping and management technique ($p=0.05$) on number of leaves per plant throughout the growing period (Table 16 and 17).

Due to the effect on cropping levels at 5^{th} WAT on number of leaves per plant, Cc outperformed among other cropping levels with 11 numbers of leaves per plant followed by CL1.2 with 6 numbers of leaves per plant. At 12^{th} WAT, the maximum number of leaves per plant was out performed by CL1.1 and CL1.2 with 126 and 124 numbers of leaves per plant. The minimum number of leaves per plant was poorly performed by Cc with 73 leaves.

The effect of management on number of leaves per plant, the maximum number of leaves per plant was found in ML2.3 followed by ML2.4 with 12 and 11 number of leaves per plant at 5^{th} WAT and the minimum number of leaves per plant were found in ML2.1 and ML2.2 with 0.00 and 0.00. Similarly, at 12th WAT, the maximum number of leaves per plant was noted in ML2.3 (140.61) followed by ML2.4 (134.61) at 12th WAT. The minimum was noted in Mc with 72 number of leaves per plant.

The combination effect showed that there were significant differences of number of leaves per plant on cropping and management levels at 5th, 7th, 10th and 12th WAT (Table 18 & Figure 16). Due to the combination effect of cropping and management technique on number of leaves per plant, TL1.4* 2.4 and TL1.1*2.3 outperformed other treatment levels in terms of number of leaves per plant with 13 and 13 at 5th WAT whereas TL1.1*2.1, TL1.1*2.2, TL1.2*2.1, TL1.2*2.4 and other treatment level performed the poorest with 0 number of leaves per plant. At 12th WAT, the maximum number of leaves per plant was found in TL1.1*2.4 with 147 followed by TL1.4*2.4 and TL1.3*2.3 with 144 and 144 number of leaves per plant and the minimum number of leaves per plant was found in Cc*Mc (control) with 73.

The result defined that during the initial vegetative phase, Cc*Mc (control) had the highest number of leaves per plant. But as it reached to the end of vegetative phase, the number of leaves per plant were decreased. The reason could be due to soil moisture content in beginning was 261.67 Mbar which is sufficient enough for the plants to produce more numbers of leaves but as it reached to the end vegetative phase, the soil moisture was 163 Mbar which required more water. The study proved CL1.2 (chilli grown under the modified bed) had more number of leaves per plant (126 numbers) with more no of fruits (22 numbers) and higher weight of single fruit (126 gm). The statement may be true to Mr Tshering who expressed that with the modified raised bed, water retention capacity and nutrient depletion will be less due to raised or ridge structure made at all the borders which might have restricted water with nutrient to outflow while comparing to farmer's raised bed method. Since farmers bed methods don't have ridge at the side and when irrigate through the pipe manually (most Bhutanese farmers practice) or even on heavy rain, there is the chances of losing nutrients with water mostly from the side and since two row plantings are carrying out at the two side of the beds.

Table 16 Average value of effect of cropping levels of chilli on number of leaves (no) per plant at 5th, 7th, 10th and 12th week after transplanting

CL	Week after transplanting			
	5th	7th	10th	12th
1.1	5.75[a]	15.00[ab]	53.69[b]	125.8[b]
1.2	6.19[a]	14.86[ab]	56.67[bc]	123.86[b]
1.3	5.54[a]	15.17[ab]	57.81[bc]	122.00[b]
1.4	5.22[a]	17.03[b]	66.50[c]	116.86[b]
Cc	10.89[b]	13.89a	37.56[a]	72.67[a]
p value	*	*	*	*

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant.

Table 17 Average value of effect of management levels of chilli on number of leaves (no) per plan at 5th, 7th, 10th and 12th week after transplanting

ML	Week after transplanting			
	5th	7th	10th	12th
2.1	0.00[b]	13.53[c]	41.53[bc]	97.11[c]
2.2	0.00[b]	16.11[a]	50.61[b]	115.92[bc]
2.3	11.50[a]	16.11[a]	73.19[a]	140.61[a]
2.4	11.21[a]	15.72[ab]	69.33[a]	134.94[ab]
Mc	10.89[a]	13.89[bc]	37.55[c]	72.67[d]
p value	**	**	**	**

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 18 Average value of effect of cropping and management levels of chilli on number of leaves (nos) per plant at 5th, 7th, 10th and 12th WAT

TRT	Cropping level	Management level				
		2.1	**2.2**	**2.3**	**2.4**	**Mc**
5th WAT	1.1	0.00^{c}	0.00^{c}	13.00^{a}	10.00^{ab}	
	1.2	0.00^{c}	0.00^{c}	12.00^{a}	12.00^{a}	
	1.3	0.00^{c}	0.00^{c}	13.00^{a}	9.00^{ab}	
	1.4	0.00^{c}	0.00^{c}	8.00^{b}	13.00^{a}	
	Cc					11.00^{ab}
	p value	**				
7th WAT	1.1	14.66^{a-c}	16.33^{ab}	16.11^{ab}	12.89^{bc}	
	1.2	9.78^{c}	18.11^{ab}	16.78^{ab}	14.78^{a-c}	
	1.3	14.56^{a-c}	15.55^{ab}	14.56^{ab}	16.00^{ab}	
	1.4	15.11^{a-c}	14.44^{a-c}	19.33^{a}	19.22^{a}	
	Cc					14.00^{a-c}
	p value	**				
10th WAT	1.1	38.11^{e}	42.00^{e}	69.56^{a-c}	65.11b-d	
	1.2	40.44^{e}	53.89^{c-e}	64.89^{b-d}	67.44^{bc}	
	1.3	42.11^{e}	54^{c-e}	69.56^{a-c}	65.56^{b-d}	
	1.4	45.44^{de}	52.56^{c-e}	88.79^{a}	79.22^{ab}	
	Cc					38.00^{e}
	p value	**				
12th WAT	1.1	100.67^{b-e}	100.44^{b-e}	155^{a}	147.00^{ab}	
	1.2	101.89^{b-e}	140.89^{a-c}	126.00^{a-d}	126.67^{a-d}	
	1.3	99.89^{b-e}	129.22^{a-d}	137.11^{a-d}	121.78^{a-e}	
	1.4	86.00^{de}	93.11^{c-e}	144.00^{a-c}	144.33^{a-c}	
	Cc					73.00^{e}
	p value	**				

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Cropping levels		**Management level**	
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

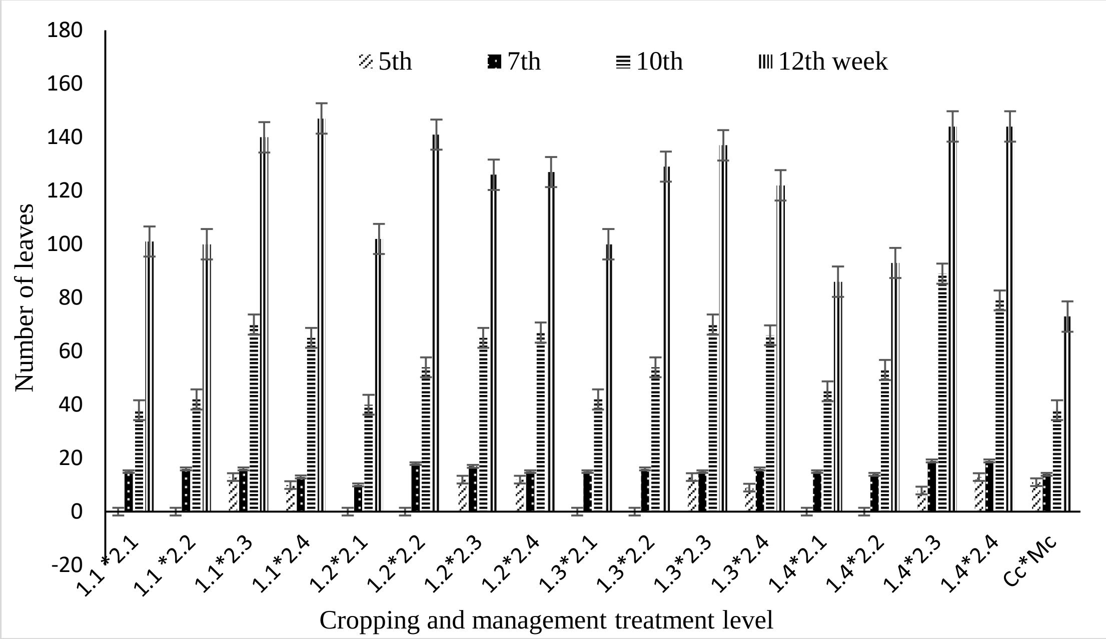

Figure 16 Combination effect of cropping and management on number of leaves of chilli crop. Error bars denote the standard error of the mean for each treatment.

4.2 Yield parameter

Chilli was harvested after 104 days after transplanting. The yield parameter such as fruit weight, fruit number, fruit length with and without pedicel and fruit girth and fruit girth at apex were recorded (Annexure 2) to compare among different cropping and management levels.

4.2.1 Fruit weight

The result stated that there was highly significance different on effect of cropping ($p<0.05$) and significantly different on management technique ($p<0.05$) on chilli fruit weight. On the contrary, there was no significant different ($p>0.05$) in an interaction between cropping and management levels on fruit weight. Thus, there was no influence on interaction of cropping and management levels on the fruit weight.

The significant difference on the effect of the different cropping level on fruit weight was shown in Table 19. The maximum fruit weight due to the effect of cropping levels of chilli planted was noted in CL1.2 with 26.87 gm followed by CL1.1 and CL1.4 with 23.76 and 22.64 gm. The minimum fruit weight was noted in

Cc and CL1.3 with 19.24 and 20.92 gm. Thus, it concluded that maximum fruit weight was noted in chilli planted in modified raised bed method followed by chilli planted in farmers raised bed method and chilli intercropped in modified raised bed method and the minimum was noted in the Cc (chilli planted in farmers raised bed method) and chilli intercropped in farmers raised bed method. Likewise, there was significant difference in mean on effect of different management levels to the weight of fruit. The maximum fruit weights were noted in ML2.3 and ML2.4 with 25.61 and 24.44 gm and the minimum fruit weight was noted in Mc with 19.24 gm (Table 20). It defined that the maximum fruit weights were noted in treatment level of both the plot with 1st bottom three removal of chilli flowers in farmers raised bed method and in modified raised bed method. Whereas the minimum fruit weights were noted in both the plots of chilli planted in farmers raised bed method and modified raised bed method. The significant differences were found between 1st three bottom removal of flowers in farmers raised bed method and 1st three bottom removal of flowers in modified raised bed method with chilli pruning in farmers raised bed method and chilli pruning in modified raised bed.

The combine association effect of cropping and management techniques on chilli plants on fruit weight was shown in (Table 21 and Figure 17). There was highly significant effect (p=0.00) in combination of cropping and management levels on fruit weight among treatments. The highest fruit weight was figured in TL1.2 *2.3 and TL1.2*2.2 with 30.42 gm and 29.14 gm and the lowest was in Cc*Mc with 19.24. Thus, it declared that the highest fruit weight was under treatment level of chilli planted in modified raised bed method with 1st bottom three removal of flowers in farmers raised bed method and chilli planted in modified raised bed method with 1st bottom three removal of flowers in modified raised bed method and lowest was figured in beans intercropped in modified raised bed method with chilli pruning in farmer's raised bed method.

Table 19 Average value of effect of cropping levels of chilli on fruit weight in gram (gm)

CL	Fruit weight
1.1	23.76^{ab}
1.2	26.87^{a}
1.3	20.92^{bc}
1.4	22.64^{bc}
Cc	19.24^{c}
p value	**

Value followed by the same letter, the same column is significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 20 Average value of effect of management levels of chilli on fruit weight in gram (gm)

ML	Fruit weight
2.1	21.37^{bc}
2.2	22.77^{ab}
2.3	25.61^{a}
2.4	24.44^{ab}
Mc	19.24^{c}
p value	*

Value followed by the same letter, the same column is significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 21 Average value of effect of cropping and management levels of chilli on fruit weight in centimeter (cm)

Treatment	Fruit weight (gm)				
	Cropping level				
Management level	**1.1**	**1.2**	**1.3**	**1.4**	**Cc**
2.1	20.42^{cd}	21.76^{b-d}	22.11^{b-d}	19.98^{d}	
2.2	21.12^{b-d}	29.14^{a}	20.34^{cd}	20.47^{cd}	
2.3	27.06^{ab}	30.42^{a}	20.51^{cd}	24.48^{a-d}	
2.4	26.46^{a-c}	24.95^{a-d}	20.73^{cd}	25.62^{a-d}	
Mc					19.24^{d}
p value	**				

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Cropping levels		**Management level**	
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

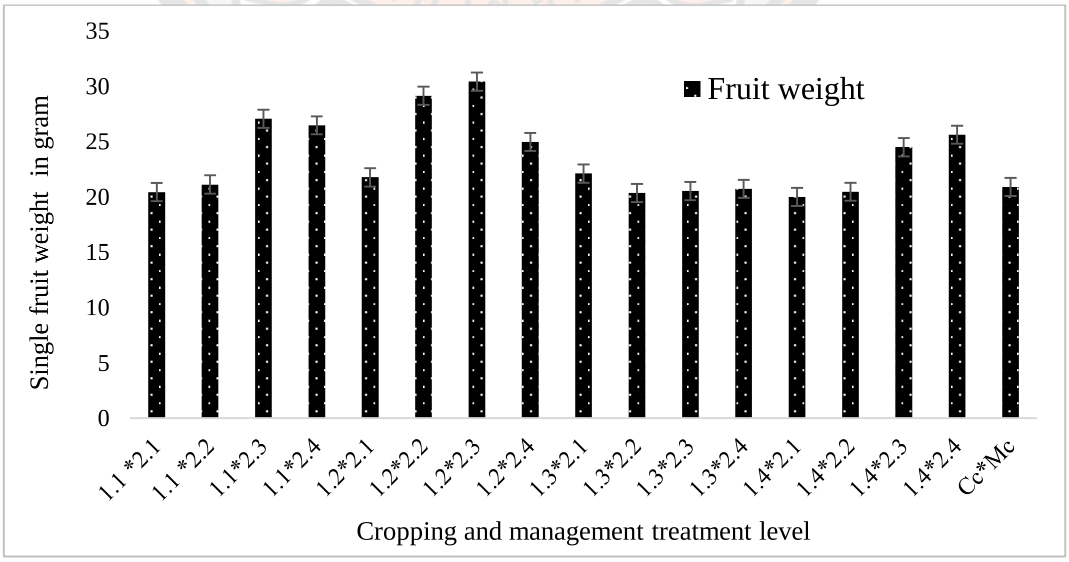

Figure 17 Combination effect of cropping and management level on fruit weight. Error bars denote the standard error of the mean for each treatment.

4.2.2 Number of fruit per plant

The study found that there were highly significance differences on effects of cropping ($p<0.05$) and management levels ($p=0.05$) on number of chilli fruit per plant. Similarly, significant difference was also an interaction between cropping and management levels ($p=0.05$) on number of fruits per plant. Thus, it revealed that there was an influence due to the effects of cropping and management levels on number of fruits per plant as well as there was an interaction between cropping and management levels on number of fruits per plant.

As shown in Table 22, there was significant difference in mean of the effect of different cropping levels to the number of fruits per plant. The maximum number of fruits per plant was figured in CL1.2 with 22 numbers (nos) and the lowest was in Cc with 9 nos. Thus the study confirmed that among different cropping levels, the chilli planted in the modified bed performed best in term of the number of fruit per plant and performed the least in Cc (chilli planted in farmers raised bed method). The result also claimed that there was significant difference on effect of different management levels in terms of number of fruits per plant. The maximum number of fruits per plant was figured in ML2.4 with 18 and the minimum was figured in Mc with 9 number of fruits (Table 23). Therefore, the highest was figured in plot with 1st bottom three removal of chilli flowers in modified raised bed method and the lowest was figured in Mc. Thus, the level of 1st bottom three removal of flowers in modified raised bed method outperformed among the different management levels and the least performed by chilli planted in farmers raised bed method in terms of number of fruits per plant.

There was highly significant different ($p=0.000$) of combination effect of cropping and management levels on number of fruits per plant among treatments levels (Table 24). Among the association effect of cropping and management levels on number of fruits per plant were found under TL1.2*2.4 and TL1.2*2.3 with 98 and 65 and the lowest were in TL1.4*2.1 and TL1.4*2.2 with 24 and 27 numbers per plant respectively (Figure 18). Hence, the treatment level of chilli planted in modified raised bed method and 1st bottom three removal of flower in modified raised bed method outperformed in-terms of number of fruits per plant followed by chilli planted in modified raised bed method and 1st bottom three removal of flower in farmers raised bed method. The least number of fruits per plant was performed by TL1.4*2.1 (chilli intercropped with beans in modified raised bed method and chilli planted in farmers raised bed method).

Table 22 Average value of effect of cropping level of chilli on number of fruits per plant (no)

CL	No of fruits/plant
1.1	15.33^{b}
1.2	22.19^{a}
1.3	11.22^{c}
1.4	10.50^{c}
Cc	9.44^{c}
p value	**

Value followed by the same letter, the same column is significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 23 Average value of effect of management levels of chilli on number of fruits per plant (no)

ML	No of fruits/plant
2.1	11.14^{bc}
2.2	13.42^{b}
2.3	16.58^{a}
2.4	18.11^{a}
Mc	9.44^{c}
p value	**

Value followed by the same letter, the same column is significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 24 Average value of effect of cropping and management levels of chilli on number of fruits per plant

Treatment	Cropping level				
Management level	**1.1**	**1.2**	**1.3**	**1.4**	**Cc**
2.1	12.56^{e-h}	14.22^{d-g}	9.78^{f-h}	8.00^{h}	
2.2	13.44^{d-h}	20.33^{ab}	11.00^{e-h}	8.89^{gh}	
2.3	18.78^{b-d}	21.67^{b}	15.11^{c-f}	10.78^{f-h}	
2.4	16.56^{b-e}	32.55^{a}	9.00^{gh}	14.33^{d-g}	
Mc					10.11^{f-h}
p value	**				

Value followed by the same letter, the same column is not significantly different at Tukey Duncan test (*p*=0.05). * and **, indicate significance level *p* <0.05 and *p* <0.01, respectively. NS, Not significant

	Cropping levels		**Management level**
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

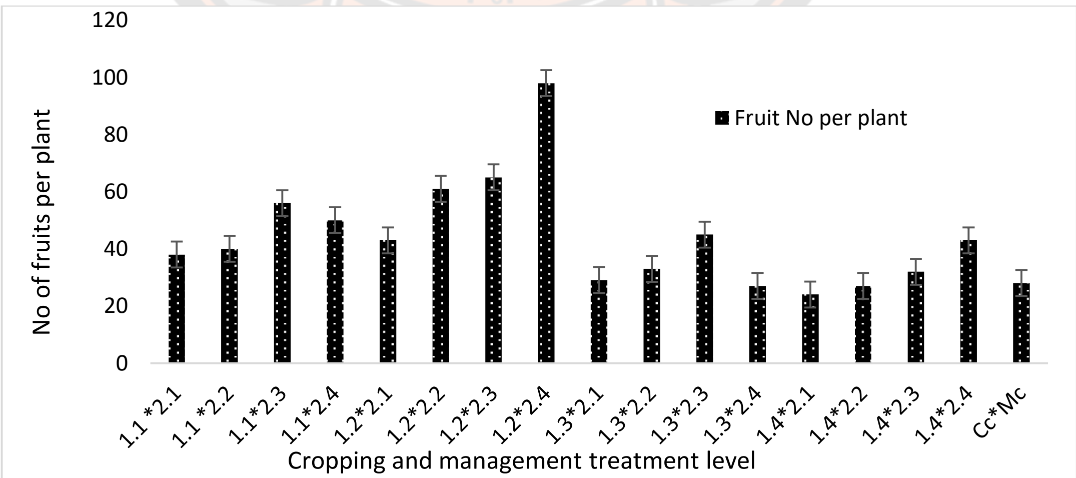

Figure 18 Combination effect of cropping and management levels on number of fruits/plant. Error bars denote the standard error of the mean for each treatment.

4.2.3 Fruit length with or without pedicel

The data showed that the effect of cropping levels had highly significant effects on both chilli lengths with (*p*=0.000) and without pedicel (*p*=0.006). There was significant difference on effect of management on chilli fruit length with pedicel (*p*=0.029) but no significant difference was found in the chilli fruit without pedicel (*p*=0.121). With regard to interaction between the effect of cropping and management levels, there was no significant interaction of cropping and management techniques on chilli with pedicel (*p*=0.110) but there was significant difference on interaction of cropping and management on chilli fruit length without pedicel (*p*=0.037).

The finding stated that there were significant differences among the different cropping levels on fruit length with and without pedicel. The longest fruit length with and without pedicel was confirmed under CL1.2 (21.37, 16.82cm) followed by CL1.4 whereas the shortest length of fruit with and without pedicel was found in Cc (18.56, 14.46 cm) and CL1.3 (19.09, 14.89 cm) (Table 25). The study confirmed that the chilli planted in modified raised bed method outperformed in term of fruit length with and without pedicel followed by chilli intercropped with beans in modified raised bed method. However, Cc (chilli planted in farmers raised bed method) and chilli intercropped with beans in farmers raised bed method performed poorly in case of chilli fruit length with and without pedicel.

In terms of effect of management levels on fruit length, the highest fruit length with and without pedicel was found in ML2.3 (20.97 cm, 16.49 cm) and ML2.4 (20.24 cm and 15.64 cm) (Table 26). Thus, the study specified that among the management techniques, 1st bottom three removal of chilli flowers in both farmers raised bed method and modified raised bed method out performed in terms of fruit length with and without pedicel. The lowest fruit length with and without pedicel was found in Mc with 18.88 cm and 14.46 cm.

There was a significant different of combination effect of cropping and management levels on fruit length and fruit length with pedicel among the treatment levels (Table 27). Among the association effect of cropping and management level on fruit length with and without pedicel was found the maximum under TL1.2*2.3 (22.15, 17.52 cm) and TL1.2*2.2 (22.13,17.82 cm) and the shortest fruit length with and without pedicel was found in TL1.1*2.2 (17.92, 14.19 cm. Thus the results interpreted that the combination of treatment level of chilli planted in modified raised bed method with 1st bottom three removal of flowers in farmers raised bed method outraced amongst other treatment levels followed by chilli planted in modified raised bed method with 1st bottom three removal of flowers in modified raised bed method. The least performed was found in chilli planted in farmers raised bed method with pruning in modified raised bed method (Figure 19).

Table 25 Average value of effect of cropping levels of chilli on fruit length with and without pedicel in centimeter (cm)

CL	Fruit length with pedicel	Fruit length without pedicel
1.1	19.40[bc]	15.27[bc]
1.2	21.36[a]	16.82[a]
1.3	19.09[bc]	14.89[bc]
1.4	20.48[ab]	16.04[ab]
Cc	18.56[c]	14.46[c]
p value	**	**

Value followed by the same letter, the same column is significantly different at Duncen test (*p*=0.05). * and **, indicate significance level *p* <0.05 and *p* <0.01, respectively. NS, Not significant

Table 26 Average value of effect of management levels of chilli on fruit length with and without pedicel in centimeter (cm)

ML	Fruit length with pedicel	Fruit length without pedicel
2.1	19.92[abc]	15.81[ab]
2.2	19.21[bc]	15.09[ab]
2.3	20.97[a]	16.49[a]
2.4	20.24[ab]	15.64[ab]
Mc	18.88[c]	14.46[b]
p value	*	NS

Value followed by the same letter, the same column is significantly different at Duncen test (*p*=0.05). * and **, indicate significance level *p* <0.05 and *p* <0.01, respectively. NS, Not significant

Table 27 Average value of effect of cropping and management levels of chilli on fruit length with and without pedicel in centimeter (cm)

	TRT Cropping level	Management level 2.1	2.2	2.3	2.4	Mc
Fruit length with pedicel (cm)	1.1	15.12[ab]	14.19[ab]	16.26[ab]	15.53[ab]	
	1.2	16.44[ab]	17.82[a]	17.52[ab]	15.20[ab]	
	1.3	15.20[ab]	14.81[ab]	15.35[ab]	14.19[ab]	
	1.4	16.16[ab]	13.55[b]	16.83[ab]	17.63[ab]	
	Cc					14.18[ab]
	p value	*				
Fruit without pedicel (cm)	1.1	19.00[ab]	17.92[b]	20.66[ab]	20.02[ab]	
	1.2	20.79[ab]	22.13[a]	22.15[a]	20.07[ab]	
	1.3	19.06[ab]	18.64[ab]	19.82[ab]	18.84[ab]	
	1.4	20.51[ab]	18.15[ab]	21.23[ab]	22.04[ab]	
	Cc					18.55[ab]
	p value	*				

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Cropping levels		Management level	
1.1	FRBM	2.1	Chilli pruned in FRBM
1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

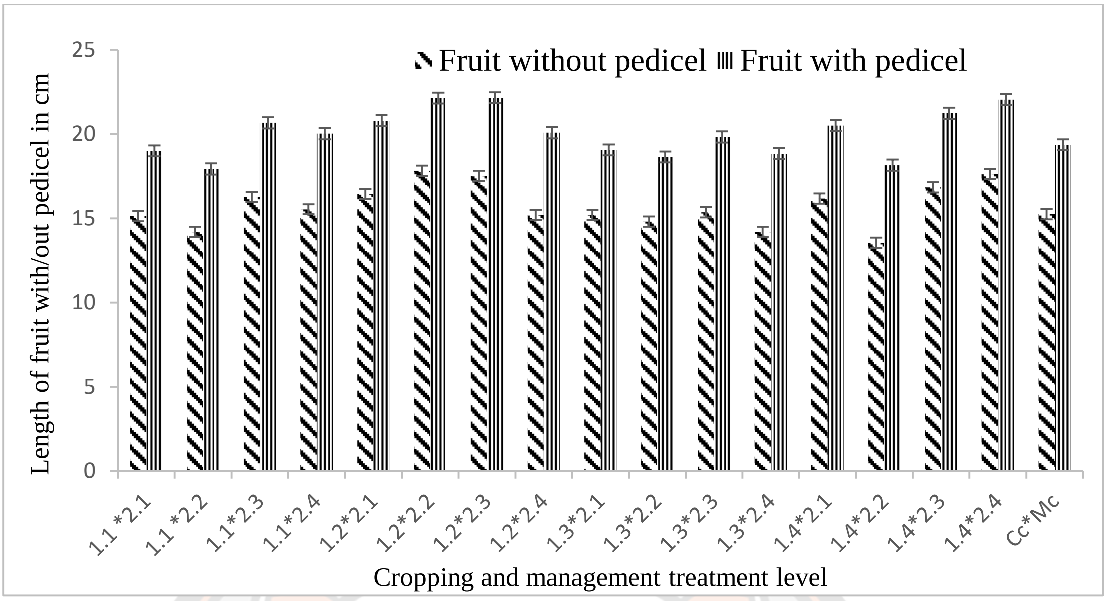

Figure 19 Combination effect of cropping and management level of fruit length with or without pedicel. Error bars signify the standard error of the mean for each treatment.

4.2.4 Fruit girth (fruit girth and fruit girth at apex)

The study showed that there was the significant effect of cropping technique on fruit girth (p= 0.001) but no significant difference was observed on the fruit girth at apex (p=0.297). There was also no significant difference on effect of management techniques on both fruit girth (p=0.915) and fruit girth at the apex (p=0.877). Similarly, there was no interaction between the effect of cropping and management techniques on both fruit girth (p=0.324) and fruit girth at the apex (p=0.495) of chilli.

The widest fruit girth was found in CL1.2 with 26.57 mm followed by CL1.1 with 25.99 mm and CL1.3 and CL1.4 had the narrowest girth of 23.50 and 23.71 mm respectively (Table 28). The finding depicted that the widest fruit girth under the cropping level was found in treatment level of chilli planted in modified raised bed method followed by chilli planted in farmers raised bed method and the narrowest girth was found in chilli intercropped in farmers raised bed method. With regard to the fruit girth at the apex, CL1.1 had 7.08 mm followed by Cc with 6.55 mm and the narrowest fruit girth at the apex was found in CL1.4 with 5.93 and there was no significant difference among the cropping treatment levels. Hence, it revealed that among the chilli girth at the apex, chilli planted in farmers raised bed method had the widest fruit girth and chilli intercropped in modified raised bed method had the narrowest fruit girth.

The effect of different management levels had no significant different on both the fruit girth and fruit girth at the apex (Table 29). The widest girth was noted under ML2.3 and ML2.2 with 25.17 and 25.09 mm and ML2.2 recorded the lowest with 24.55 mm. It interpreted that widest girth was found in plot with the 1st bottom three flowers removal in farmers raised bed method and chilli pruning in modified raised bed method and the narrowest was found in chilli pruned in farmers raised bed method. With regard to the widest fruit girth at the apex of the fruit, ML2.2 had 6.65 mm followed by ML2.4 with 6.37 mm and the narrowest fruit girth at the apex was found in ML2.1. It revealed that management treatment levels of chilli pruned in modified raised bed method had the widest girth at the apex followed by plot having 1st bottom three flowers removal in modified raised bed method. The narrowest fruit girth at the apex was found in chilli pruned in farmers raised bed method.

The combine effect of cropping and management levels on fruit girth showed significant difference but no significant difference on fruit girth at apex, among the treatment levels. The combination effect of cropping and management levels on both widest fruit girth and widest fruit girth at the apex was shown in Table 30. The widest fruit girth was noted under TL1.2*2.3 with 28.25 mm followed by TL1.2*2.2 with 27.30 mm and the narrowest fruit girth was found in TL1.3*2.3 with 21.85 mm. Thus, the result declared that the combination of chilli planted in modified raised bed method with 1st bottom three removal of chilli flowers in farmers raised bed method out performed in terms of widest fruit girth, followed by chilli planted in modified raised bed method with chilli pruned in modified raised bed method and the narrowest fruit girth was performed by chilli intercropped in farmer’s raised bed method with 1st bottom three removal of chilli flowers in farmers raised bed method among treatment levels. The measurement done on the widest girth at the apex was noted in TL1.1*2.2 (7.58 mm) followed by TL1.2*2.3 (7.24 mm) and narrowest was noted in TL1.3*2.3 (4.79 mm) (Table 30). Thus, the finding concludes that widest girth at the apex of chilli was found in combination of chilli planted in farmers raised bed method with pruning in modified raised bed method and chilli plant in modified raised bed method with 1st bottom three removal of chilli flowers in farmers raised bed method and the narrowest chilli girth was found in chilli intercropped beans in farmers raised bed method with 1st bottom three removal in farmers raised bed method.

The result from this study discovered that from the cropping levels, CL1.2 (chilli planted in modified bed) out performed in all the yield parameters such as fruit weight, number of fruits per plant, length of the fruit and girth of the fruit and the least performed was revealed in Cc (farmer's raised bed method (control)) and CL1.3 (chilli intercropped with beans in farmers raised bed method) (Figure 20).

The highest fruit yield in CL1.2 (chilli planting in the modified raised bed method) could be due to water holding capacity by the modified raised bed method throughout the season with 225.83 Mbar on march and 105.33 Mbar on July and also could be the nutrient content is high in CL1.2 especially the major nutrient such such as NPK with nitrogen (N) with 0.05%, Phosphorus (P) with 0.44 Mg/L and Potassium (K) with 1846 kg/ha which are associated with vegetative growth and the fruit formation of the plants as comparing to other treatment levels.

From the management aspect, in-terms of yield parameters, ML2.3, 1st bottom three removal of farmers raised bed method followed by ML2.4 (1st bottom three removal of flowers in modified raised bed method) outperformed fruit weight, fruit length and fruit girth and the least performed by ML2.1 (chilli pruned in farmers raised bed method). The outperforming in yield parameters by ML2.3 and ML2.4 could be due to the chilli plants letting to grow on their own without disturbing the plants which might have provided plants to produce higher number of leaves (141, 135) and fruits (17,18) at the end of vegetative production while ML2.1 and ML2.2 might have disturbed while heading back the stem above 10 cm after one month of transplantation which leads to late vegetative growth letting to fewer number of leaves (97) and fruits (11). The highest yield parameters in ML2.3 and ML2.4 could be due to due to the bottom three removal of flowers which might have provided energy to divert towards upper, receiving the nutrients almost uniformly which could have otherwise diverted easily to the bottom flowers. Though ML2.3 exceeded over ML2.4 in terms of yield parameters, there were no significant differences between the treatment levels.

Therefore, 1st bottom three removal of flowers on both farmers bed raised method and modified raised bed method weightage the same even though the highest nutrients and moisture percentage were found in modified raised bed method. However, the highest number of fruits per plant was recorded in ML2.4. This could be due to more nutrients and water retention capacity along with energy diversion to all parts of plant due to 1st bottom three flower removal in the modified bed. The finding is further supported by Ghebremariam (2007) that the leaves and fruit compete for assimilates and therefore, it is good method to remove the flower buds from the first and second layers, so that fruit development does not check the plants before they build up sufficient foliage to support maximum yields, and fruits then grow to the optimum size. In addition, Kang *et al.* (2008) stated that fruit removal induced significant increases in the concentrations of starch and reducing sugars, but not sucrose, in the flower buds. Assimilates which are normally transferred to developing fruit may be transported, upon fruit removal, to the flower buds which subsequently swell.

The least performed by ML2.1 could be due to heading back of chilli plant after one of transplanting which could have delayed in facilitating the vegetative growth, triggering plants to cause least in all yield parameters

Table 28 Average value of effect of cropping levels of chilli on fruit girth and fruit girth at apex in millimeter (mm)

CL	Fruit girth	Fruit girth at apex
1.1	25.99[ab]	7.08[a]
1.2	26.57[a]	6.18[a]
1.3	23.50[b]	6.25[a]
1.4	23.71[b]	5.93[a]
Cc	23.73[b]	6.55[a]
p value	*	NS

Value followed by the same letter, the same column is significantly different at Duncen test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 29 Average value of effect of management levels of chilli on fruit girth and girth at apex in millimeter (mm)

ML	Fruit girth	Fruit girth at apex
2.1	24.96[a]	6.14[a]
2.2	25.09[a]	6.65[a]
2.3	25.16[a]	6.27[a]
2.4	24.96[a]	6.37[a]
Mc	23.73[a]	6.54[a]
p value	NS	NS

Value followed by the same letter, the same column is significantly different at Duncen test (*p*=0.05). * and **, indicate significance level *p* <0.05 and *p* <0.01, respectively. NS, Not significant

Table 30 Average value of effect of cropping and management levels of chilli on fruit girth and fruit girth at apex

	TRT Cropping level	Management level 2.1	2.2	2.3	2.4	Mc
Fruit girth (mm)	1.1	27.14[a]	25.05[a-c]	26.19[a-c]	25.60[a-c]	
	1.2	24.04[a-c]	27.30[a]	28.25[a]	26.73[ab]	
	1.3	24.75[a-c]	23.65[a]	21.85[c]	23.75[a-c]	
	1.4	22.29[bc]	24.38[a-c]	24.39[a-c]	23.77[a-c]	
	Cc					23.82[a-c]
	p value	**				
Fruit girth at apex (mm)	1.1	6.92[a]	7.58[a]	6.81[a]	7.02[a]	
	1.2	5.06[a]	5.95[a]	7.24[a]	6.27[a]	
	1.3	6.89[a]	6.23[a]	4.79[a]	7.09[a]	
	1.4	5.50[a]	6.84[a]	6.25[a]	5.12[a]	
	Cc					6.54[a]
	p value	NS				

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05). * and **, indicate significance level *p* <0.05 and *p* <0.01, respectively. NS, Not significant.

Cropping levels		Management level	
1.1	FRBM	2.1	Chilli pruned in FRBM

1.2	MRBM	2.2	Chilli pruned in MRBM
1.3	Bean intercropped in FRBM	2.3	1st bottom three FR in FRBM
1.4	Bean intercropped in MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

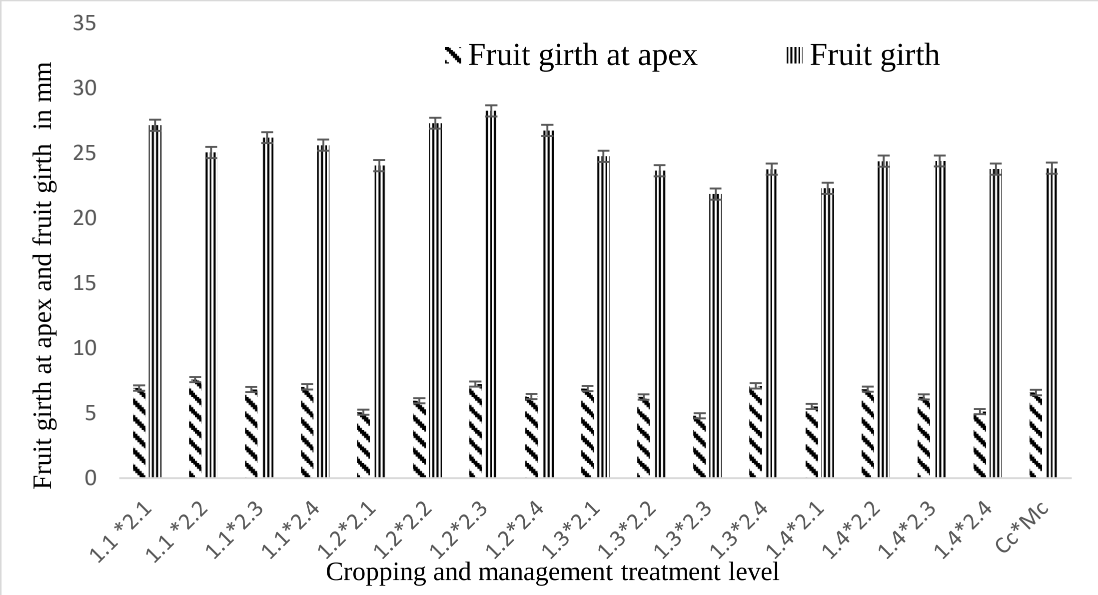

Figure 20 Combination effect of cropping and management levels on fruit girth at apex and fruit girth. Error bars denote the standard error of the mean for each treatment.

4.2.5 Chilli yield and income

The result revealed that the highest yield was obtained by TL1.2 *2.4 with 16669.42 kg/acre followed by TL1.2*2.3 with 13546.50 kg/acre and the lowest yield was obtained by TL1.4*2.1 with 3235.84 kg/acre. Similarly, the income of the farmers for selling chilli at the cost of ngultrum 40 per kg would obtain highest income of Ngultrum 666776.65 from TL1.2 *2.4 and lowest income of Ngultrum 129433.50 from TL1.4*2.1 (Table 31). The reason for keeping chilli price as Nu 40 is during the initial season, chilli price shoots up to Nu 400-500 per kg and during the chilli season it declines to Nu 25- 30 and at the end of the season chilli price goes high upto Nu 100-150. Since the production of chilli coincided with the seasonal production period, the price during that time will be fluctuated between Nu 25- 70. Thus, Nu 40 was kept for the price of chilli.

Table 31 Overall yield (kg/acre) and price of chilli in each treatment level

TL	Fr Wt	FruitNo	10 plnt/2m^2	kg/ acre	Nu.40 /kg/acre	mt/acre
1.1 *2.1	20.42	13	10	5373.39	214935.67	214.94
1.1 *2.2	21.12	13	10	5556.68	222267.06	222.27
1.1*2.3	27.06	19	10	10405.95	416237.89	416.24
1.1*2.4	26.46	17	10	9105.48	364219.07	364.22
1.2*2.1	21.76	14	10	6166.59	246663.67	246.66
1.2*2.2	29.14	20	10	11796.75	471869.85	471.87
1.2*2.3	30.42	22	10	13546.50	541860.10	541.86
1.2*2.4	24.95	33	10	16669.42	666776.65	666.78
1.3*2.1	22.11	10	10	4475.71	179028.34	179.03
1.3*2.2	20.34	11	10	4529.77	181190.73	181.19
1.3*2.3	20.51	15	10	6228.66	249146.42	249.15
1.3*2.4	20.73	9	10	3777.29	151091.77	151.09
1.4*2.1	19.98	8	10	3235.84	129433.50	129.43
1.4*2.2	20.47	9	10	3729.52	149180.84	149.18
1.4*2.3	24.48	11	10	5451.65	218066.05	218.07
1.4*2.4	25.62	14	10	7260.73	290429.15	290.43
Cc*Mc	20.88	10	10	4226.38	169055.33	169.06

4.3 Soil moisture

The Table 32 showed that there were significant effects (p=0.005) of cropping levels of chilli crop on soil moisture on March, May, June and July. Similarly, there were significant effects (p=0.045) was shown on soil moisture to management levels of chilli crops on May till July (Table 33)). Likewise, there was a significant difference (p=0.011) between interaction of cropping and management techniques of chilli crops on soil moisture.

The effect of cropping levels found that there was the significant difference among different cropping levels on soil moisture. Cropping levels of farmers raised bed method (control) and modified raised bed method were compared. The reading indicates that at 200-400 Mbar, there is adequate water and air in the soil for plant growth and at 100-200 Mbar there is plenty of both water and air in the soil for healthy plant growth (Skye Instrument Ltd, nd). Thus, from the above statement explained that even though, all the treatments fulfil the water requirement for the chilli plant growth, chilli planted CL1.2 required less water (225 Mbar) than CL1.1 and Cc during the initial month of March, 2019. Hence, the study resulted that the modified raised bed method retains more water than the farmer's raised bed method. In the same way, during July 2019, the result showed that there was a significant different among the treatments. CL1.2 had 103.33 Mbar whereas CL1.1 and Cc had 133.83 and 163.00 Mbar during July month. The least unit of Mbar of moisture content required less water than more unit. It defined that the modified raised bed method required less moisture than farmers raised bed method. The moisture reading continued to record from March until July, there was no significant different between the management level throughout the vegetative and reproductive period. The figure of ML2.4 and ML2.3 were 240.50 and 252.83 Mbar during March month, which indicated that modified raised bed method having 1st bottom three removal of flowers required less water than farmers raised bed method having 1st bottom three removal of flowers. However, the moisture from April to July kept on fluctuating in ML2.4. It was low with 240.50 Mbar in march then increased to 262.33 Mbar in April and it declined to 201.67 Mbar in May and again increased to 151.67 Mbar which was then decreased to 123.67. Therefore, in July month, ML2.3 required less water than ML2.4.

With regard to association, there was no significant effect of cropping and management levels on soil moisture during April month among treatment levels but there were significant differences on soil moisture during March, May, June and July month among the treatment levels (Table 34). In association of the effect of cropping and management levels, TL1.2*2.4 was the lowest recording with 207.67 Mbar and TL1.1 *2.4 was the highest recording during march which indicated that the modified raised bed method with 1st bottom three removal of flowers in modified raised bed method required the least moisture whereas farmers raised bed method with first bottom three removal of flowers in modified raised bed method required the highest moisture. As the moisture reading continued to record, on July, TL1.2*2.4 recorded 101.33 Mbar and Cc*Mc recorded the highest with 163.00 Mbar (Figure 21). Thus the data indicated that the modified raised bed method with 1st bottom three removal of flowers in modified raised bed method required the least moisture and the farmers bed raised bed method required the highest moisture.

Table 32 Average value of effect of cropping levels of chilli on soil moisture in millibar (Mbar) recorded every month with effect from March until July, 2019

CL	March	April	May	June	July
1.1	267.50[b]	259.17[a]	219.00[b]	173.00[b]	133.83[ab]
1.2	225.83[a]	227.83[a]	188.00[a]	133.00[a]	105.33[a]
Cc	261.67[ab]	236.67[a]	225.00[b]	205.00[c]	163.00[b]
p value	*	NS	**	**	*

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 33 Average value of effect of management levels of chilli on soil moisture in millibar (Mbar) recorded every month with effect from March until July, 2019

Mngt	March	April	May	June	July
2.3	252.83[a]	224.67[a]	205.33[a]	154.67[a]	115.50[a]
2.4	240.50[a]	262.33[a]	201.67[a]	151.67[a]	123.67[a]
Mc	261.67[a]	236.67[a]	225.00[b]	205.00[b]	163.00[b]
p value	NS	NS	*	*	*

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Table 34 Average value of effect of cropping and management levels of on soil moisture in millibar (Mbar) from March until July, 2019

Month	TRT Cropping level (cm)	Management level (cm) 2.3	2.4	Mc
March	1.1	261.66^{b}	273.33^{b}	
	1.2	244.00^{ab}	207.67^{a}	
	Cc			261.661^{b}
	p value	*		
April	1.1	237.00^{a}	281.33^{b}	
	1.2	212.33^{a}	215.00^{a}	
	Cc			236.67^{a}
	p value	NS		
May	1.1	210.67^{bc}	227.33^{c}	
	1.2	200.00^{b}	176.00^{a}	
	Cc			225.00^{c}
	p value	*		
June	1.1	154.67^{b}	191.33^{c}	
	1.2	154.67^{b}	112.00^{a}	
				205.00^{c}
	p value	**		
July	1.1	121.67^{ab}	146.00^{bc}	
	1.2	109.33^{ab}	101.33^{a}	
	Cc			163.00^{c}
	p value	*		

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05). * and **, indicate significance level p <0.05 and p <0.01, respectively. NS, Not significant

Cropping levels		Management level	
1.1	FRBM	2.3	1st bottom three FR in FRBM
1.2	MRBM	2.4	1st bottom three FR in MRBM
Cc	FRBM (Control)	Mc	FRBM (Control)

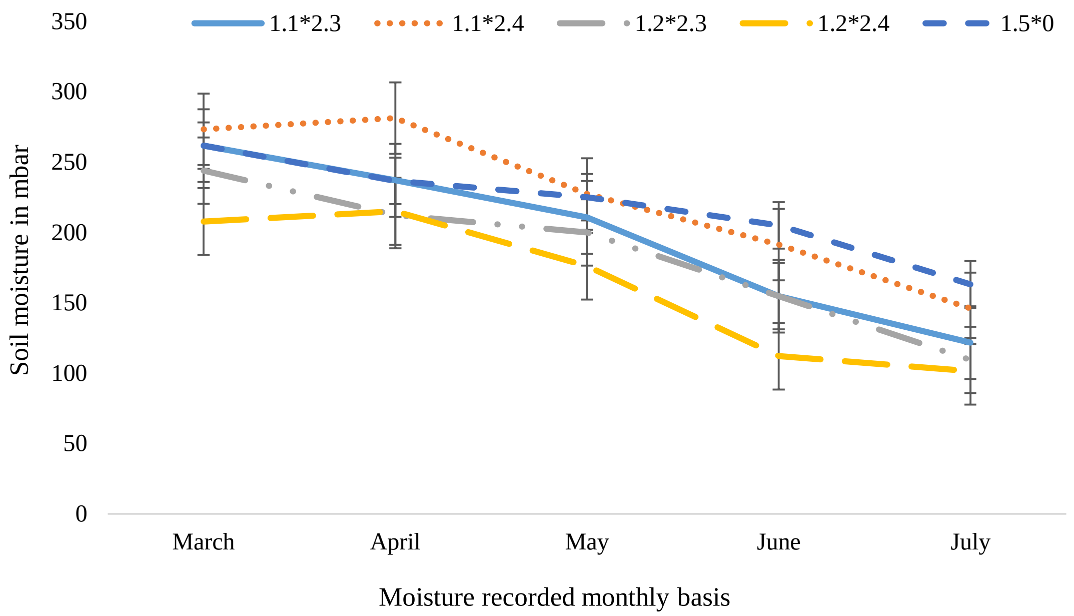

Figure 21 Combination effect of cropping and management level on soil moisture. Error bars denote the standard error of the mean for each treatment.

4.4 Soil data

The finding of soil data disclosed that there was no significant effect of overall cropping and management techniques of chilli crops on pH, Nitrogen (N) and phosphorus (P) whereas there was significant different on Organic carbon (OC) % and potassium (K) while comparing among cropping and management levels (Table 35 and 36)). Similarly, there was no significant different of soil parameters such as pH, before planting chilli plants (pre-test soil) and after harvesting chilli plants (post-test soil) but there were significant differences of effect of cropping and management level on OC%, N, P and K before and after harvesting of chilli. There was also no significant interaction between cropping and management techniques of chilli crops on soil organic carbon (OC), pH, Nitrogen (N), phosphorus (P) and potassium (K). Thus, the study depicted that there were no effects on cropping and management levels on pH, N and P and no interaction between cropping and management on all soil parameters. However, there were effects of cropping and management levels on OC%, N%, P and K before transplanting chilli (pre-test soil) and after harvesting chilli (post-test soil). The result showed that the OC% was noted the highest in CL1.2 (0.64%) followed by CL1.4 (0.59%) and lowest was in Cc. The highest pH was in CL1.4 and CL1.1 but found lowest in CL1.3 (6.13). The highest N% was observed in CL1.4 with 0.06% and Cl 1.2 with 0.06% and lowest was in control. The highest P was recorded in CL1.4 with 0.58 Mg/L and lowest was recorded in CL1.3 with 0.11 Mg/L. Likewise, the highest K was recorded in CL1.2 with 1846 Kg/ha and lowest was recorded in CL1.3 with 1150 Kg/ha. While comparing the soil test before transplanting and after harvesting, the effect of cropping levels outraced before transplanting of chilli on OC%, pH, N and K than soil tested after harvesting chilli . Only K content was the highest obtained after harvesting of chilli in CL1.2 (Table 35).

Regarding the management effect of chilli on soil content, the chilli in 1st bottom three removal of chilli flowers on both farmers raised bed method and modified raised bed method and control were compared. There were no significant differences on management levels on, soil pH, N and P but there were significant differences on soil OC and K content. The highest OC was found in ML2.4 with 0.61% and lowest in Mc with o.45%, highest pH in ML2.4 with 6.34 and lowest in Mc with 6.14, highest N in ML2.4 with 0.05 and ML2.3 with 0.05%, highest P in ML2.4 with 0.76 Mg/L and lowest in ML2.3 and highest K in ML1.4 with 1670 Kg/ha and lowest in Mc. The soil before planting and after harvesting on the effects of management on soil content was compared. Before planting the soil content of OC, pH and NPK were 1.65%, 6.63, 0.18%, 1.99 Mg/L and 500 Kg/ha whereas after harvesting of chilli, the soil content of moist percentage, OC percentage, NPK were highest in ML2.4 with 13.43%, .61%, 0.05%, 0.76 Mg/L and 1670 Kg/ha (Table 36).

The combination effect of cropping and management levels on pH and K showed no significant different among treatment levels as well as before transplanting and after harvesting of chilli. However, significant different was observed on OC%. N%, P, among treatment levels and before and after harvesting, as given in Table 37, 39, & 40. Among the different cropping and management treatment levels, the highest OC was found in TL1.2*2.4 with 0.63% and lowest was found in Cc*Mc with 0.45 (Table 37 and Figure 22), the highest pH was found in TL1.4*2.4 and TL1.2*2.4 with 6.47 and 6.47 and lowest was found in TL1.3*2.3 with 6.13 (Table 38 and Figure 23), the highest N was found in TL1.2*2.4, 1.3*2.3, TL1.4*2.4 with 0.05, 0.05 and 0.05% and lowest was found in TL1.1*2.3 and Cc*Mc with 0.04 and 0.04% (Table 39 and Figure 24), the highest phosphorous was found in TL1.4*2.4 with 1.08 Mg/L and lowest was found in TL1.3*2.3 Mg/L with 0.11 (Table 40 & Figure 25) and the highest K was found in TL1.2*2.4 with 1846 Kg/ha and lowest was found in TL1.3 *2.3 with 1150 Kg/ha (Table 41 & Figure 26). The soil contents of OC percentage, pH, Nitrogen percentage, Phosphorous and Potassium before planting chilli plant were recorded as 11.36%, 1.65%, 6.63, 0.18%, 1.99 Mg/L and 500 Kg/ha respectively.

Table 35 Average value on effect of cropping levels of chilli on soil content

CL	OC%	PH	N %	P Mg/L	K Kg/Ha
1.1	0.52^{ab}	6.47^{a}	0.05^{ab}	0.34^{a}	1314.00^{ab}
1.2	0.63^{b}	$6,22^{a}$	0.06^{b}	0.44^{a}	1846.00^{b}
1.3	0.51^{ab}	6.13^{a}	0.05^{ab}	0.11^{a}	1150.00^{ab}
1.4	0.58^{ab}	6.47^{a}	0.06^{b}	0.58^{a}	1494.00^{b}
Cc	0.45^{a}	6.14^{a}	0.04^{a}	0.31^{a}	1165.00^{b}
Pretest	1.65^{c}	6.63^{a}	0.18^{c}	1.99^{b}	500.00^{a}
p value	NS	NS	NS	*	*

Value followed by the same letter, the same column is not significantly different at Duncan test (p<0.05)

Table 36 Average value on effect of management technique of chilli on soil content

ML	OC %	pH	N %	P Mg/L	K Kg/Ha
Mc	0.45^{c}	6.14^{b}	0.04^{c}	0.31^{b}	1165.00^{ab}
pretest	1.65^{a}	6.63^{a}	0.18^{a}	1.99^{a}	500.00^{b}
2.3	0.51^{c}	6.30^{ab}	0.05^{b}	0.22^{b}	1232.00^{ab}
2.4	0.61^{b}	6.34^{ab}	0.05^{b}	0.76^{b}	1670.00^{a}

Value followed by the same letter, the same column is not significantly different at Duncan test (p<0.05)

Table 37 Average value of effect of cropping and management levels of chilli on organic carbon in percentage (%)

TRT	OC%					
	Cropping level					
Mngt	**1.1**	**1.2**	**1.3**	**1.4**	**Cc**	**Pretest**
2.3	0.52[cd]		0.50[cd]			
2.4		0.63[b]		0.59[bc]		
Mc					0.45[d]	
Pretest						1.65[a]

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05)

Cropping levels		Management level	
1.1	FRBM	2.3	1st bottom three FR in FRBM
1.2	MRBM	2.4	1st bottom three FR in MRBM
1.3	Bean intercropped in FRBM	Mc	FRBM (Control)
1.4	Bean intercropped in MRBM		
Cc	FRBM (Control)		

Table 38 Effect of cropping and management of chilli on soil pH

TRT	pH					
	Cropping level					
Mngt	**1.1**	**1.2**	**1.3**	**1.4**	**Cc**	**Pretest**
2.3	6.47[a]		6.13[a]			
2.4		6.22[a]		6.47[a]		
Mc					6.13[a]	
Pretest						6.63[a]

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05)

Cropping levels		Management level	
1.1	FRBM	2.3	1st bottom three FR in FRBM
1.2	MRBM	2.4	1st bottom three FR in MRBM
1.3	Bean intercropped in FRBM	Mc	FRBM (Control)

1.4 Bean intercropped in MRBM

Cc FRBM (Control)

Table 39 Average value of effect of cropping and management levels of chilli on nitrogen content in percentage (%)

TRt	N%					
	Cropping level					
Mngt	1.1	1.2	1.3	1.4	Cc	pretest
2.3	0.045[bc]		0.050[bc]			
2.4		0.055[b]		0.055[b]		
Mc					0.040[c]	
Pretest						0.18[a]

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05)

Cropping levels		Management level	
1.1	FRBM	2.3	1st bottom three FR in FRBM
1.2	MRBM	2.4	1st bottom three FR in MRBM
1.3	Bean intercropped in FRBM	Mc	FRBM (Control)
1.4	Bean intercropped in MRBM		
Cc	FRBM (Control)		

Table 40 Average value of effect of cropping and management levels of chilli on Phosphorous in Mg/L

Treatment	P Mg/L					
	Cropping level					
Mngt	1.1	1.2	1.3	1.4	Cc	Pretest
2.3	0.34[b]		0.11[b]			
2.4		0.44[b]		0.59[b]		
Mc					0.31[b]	
Pretest						1.99[a]

Value followed by the same letter, the same column is not significantly different at Duncan test (*p*=0.05)

Cropping levels		**Management level**	
1.1	FRBM	2.3	1st bottom three FR in FRBM
1.2	MRBM	2.4	1st bottom three FR in MRBM
1.3	Bean intercropped in FRBM	Mc	FRBM (Control)
1.4	Bean intercropped in MRBM		
Cc	FRBM (Control)		

Table 41 Average value of effect of cropping and management levels of chilli on potassium in kilogram per hectare (Kg/ha)

Treatment	**K Kg/ha**					
	Cropping level					
Mngt level	**1.1**	**1.2**	**1.3**	**1.4**	**Cc**	**pretest**
2.3	1314[ab]		1150[ab]			
2.4		1846[a]		1494[a]		
Mc					1165[ab]	
Pretest						500[b]

Value followed by the same letter, the same column is not significantly different at Duncan test (p=0.05)

Cropping levels		**Management level**	
1.1	FRBM	2.3	1st bottom three FR in FRBM
1.2	MRBM	2.4	1st bottom three FR in MRBM
1.3	Bean intercropped in FRBM	Mc	FRBM (Control)
1.4	Bean intercropped in MRBM		
Cc	FRBM (Control)		

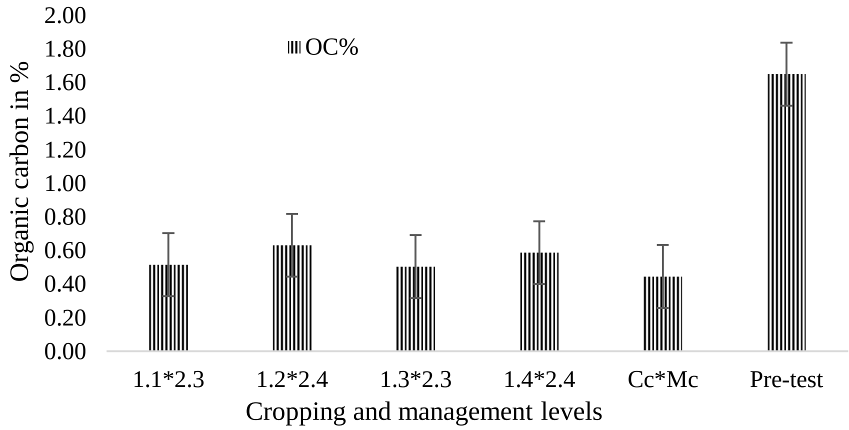

Figure 22 Effect of cropping and mngt level of chilli on organic carbon. Error bars denote the standard error of the mean for each treatment.

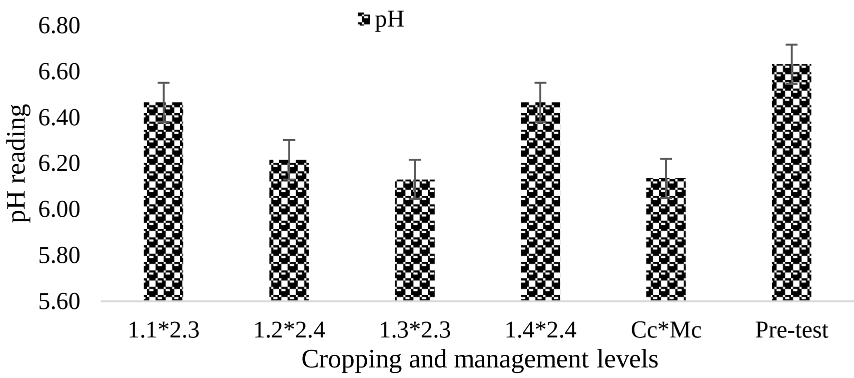

Figure 23 Effect of cropping and mngt level of chilli on soil pH. Error bars denote the standard error of the mean for each treatment.

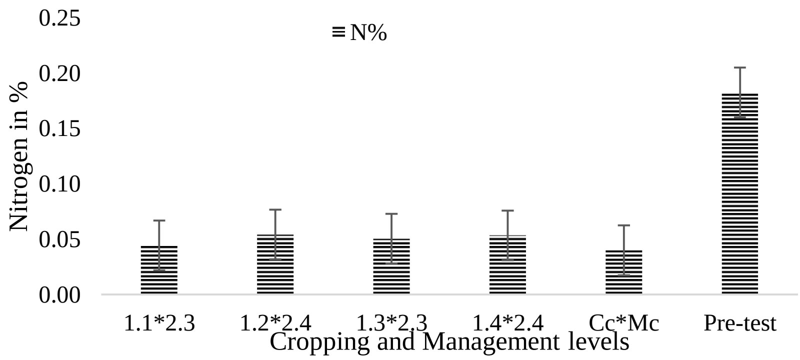

Figure 24 Effect of cropping and mngt levels on chilli on nitrogen. Error bars denote the standard error of the mean for each treatment.

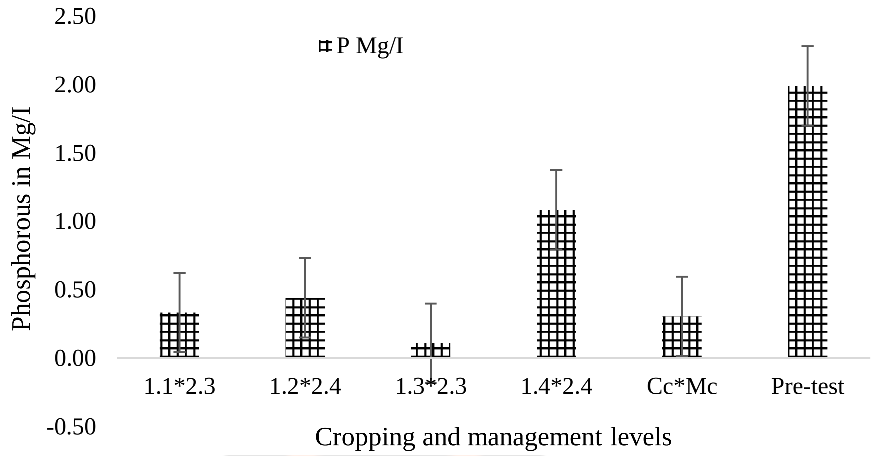

Figure 25 Effect of cropping and mngt levels of chilli on phosphorous. Error bars denote the standard error of the mean for each treatment.

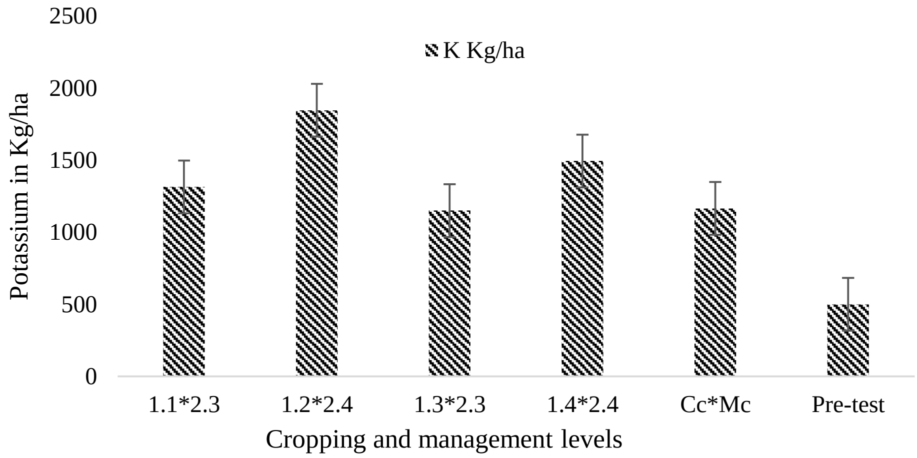

Figure 26 Effect of cropping and management levels of chilli on potassium. Error bars denote the standard error of the mean for each treatment.

4.5 Farmers adoption on technology

4.5.1 Gender group of the respondents

Out of 27 households of Wokhuna village, Kabisa block under Punakha district, 25 households were randomly selected according to the Krejcie and Morgan's sample size for the pre-test interview using semi-structure questionnaire. However, 20 farmers were interviewed since five of them were missing during the interview, out of which 75% were female and 25% were male as shown in table 42. Same farmers were interviewed for the post-test interview to get the view on the same topic.

Table 42 Gender participated in the pre-test and post-test interview

Total	Gender			
Interviewed	Female No	Female %	Male no	Male %
20 (Pre & Post-test)	15	75	5	25

4.5.2 Age group of the respondents

The minimum age participated in pre-test and post-test interview was 26 years and maximum age was 70 years old. The highest percentage of farmers of 30% were from the six age range between 31-40 followed by 25% of participating farmers between 41-50. The lowest age range was between 61-70 were 10% (Table 43). During the field day, the farmers were demonstrated about the treatment and provided the detail information through demonstration. The demonstration was done on management practices such as pruning of chilli and 1st bottom three removal of flowers from chilli plants. The farmers were then asked to observe and compare the treatments in-terms of plant growth, yield, health, their adoption and rejection of the technologies.

Table 43 Age group interviewed

Test type	Age group	number	Percent
Pre-test & Post-test	21-30	3	15
	31-40	6	30
	41-50	5	25
	51-60	4	20
	61-70	2	10

4.5.3 Education level

Among the interviewed farmers in pre-test and post-test interview, majority of the farmers are illiterate with 65% while 20% had undergone primary level and 15% were the dropped out of high school level as shown in Table 44.

Therefore, this result showed that most of the participating farmers were illiterate and least from literate group.

Table 44 Education level of farmers interviewed

Test type	Education level	Number	Percent
Pre-test & Post-test	Illiterate	13	65
	Primary	4	20
	high school	3	15

4.5.4 Farm size

The data from the pre-test and post-test interview about the farm size found that 5% of farmers owned the highest total land of 7 acres and 45% owned the land ranges between 2.1-3 acres and the maximum percentage of farmers (50%) owned the land ranges between 0.5-2 acres (Table 45).

Though all the farmers grew chilli, most of the farmers grew either in 1 acre or less than an acre of land, only few farmers used two acres of land under chilli cultivation. Four farmers (18%) grew 2 acres of land, six farmers (30%) grew one acre of land and rest 10 numbers (50%) grew less than 1 acre (Table 46). The study showed that majority cultivated chilli less than one acre of land.

Table 45 Farm size of farmers

Test type	land in acre	Number	Percent
Pre-test& Post-test	0.5-2	10	50
	2.1 -3	9	45
	7	1	5

Table 46 Chilli cultivated area

Test type	E	No	Percent
Pre-test & Post-test	< 1	10	50
	1	6	30
	2	4	20

4.5.5 Subsistence or commercial farming

All the farmers were growing chilli for commercial purpose, the data showed that 6 farmers (30%) had grown for commercial while 14 (70%) for both commercial and subsistence (Table 47). The study declared that all the farmers were growing chilli to generate income through commercial scale.

Most of the farmers (15 farmers or 75%) said that they sell their products to the capital as they fetch higher price while 5 farmers (25%) said that they sell both in the capital and in the local market (Table 47).

The type of land that the participating farmers cultivated chilli was mostly wet land. About 80% (16 farmers) said that they grew chilli in wet land, 15% (3 farmers) had grown both in wet and dry land and 5% (one farmer) grew in dry land (Table 48).

Famers stated that they rotated chilli after paddy. Most of the farmers (16 nos or 80%) rotated chilli after paddy. Only 2 farmers (10%) rotated chilli after potato, one farmer (5%) rotated chilli after cabbage and 1 farmer (5%) with chilli after wheat (Table 48). From the result, it showed that most of the farmers were practicing good rotational practice since paddy and chilli do not belong to same family and rotating chilli after paddy has advantage for not causing damage by different pests.

Table 47 Type of market that the farmers sell chilli

Test type	Farming type	No	Percent	Market	No	Percent
Pre-test & Post-test	Subsistence	0	0	Local	0	0
	Commercial	6	30	Capital	15	75
	Both	14	70	Both	5	25

Table 48 Type of land and type of crop rotation with chilli

Test type	Land type	No	Percent	Rotation basis	No	Percent
Pre-test & Post-test	dry land	1	5	Chilli- paddy	16	80
	wet land	16	80	Chilli -potato	2	10
	both	3	15	Chilli-cabbage	1	5
				Chilli-wheat	1	5

4.6 Nursery raising

All the farmers raised their own seedlings. Most of the farmers started raising nursery from October onward until January. Among the farmers interviewed, two farmers (10%) raised nursery on October, 10 (50%) farmers on November, five (25%) farmers on December and three (15%) farmers on January (Table 49). All the participating farmers raised the nursery in the same method. The farmers raised the beds of 1-2 m breadth depending upon the size of terrace with convenient length. The farmers explained that they raised nursery nearby the field of their houses for easy watering and monitoring. They raised nursery under poly tunnel. They raised the fine bed incorporating farm yard manure and SSP. Before sowing the soaking seeds, they burned the thick layer of mulch with leaf litter. They said that the reasons for burning their nursery was to emerge healthy seedlings by reducing soil-borne diseases. While raising nursery, they irrigated the bed and broadcasted the soaked seeds mixed with soil and again irrigated for the 2nd time and mulched with the rice straw. The poly tunnels were prepared on the seed sown beds. When the seeds from the bed were about to emerge after 10 to 15 DAT, the straws were burned. They expressed that the burning of straw was to subside the weeds. The emerge seedlings were watered and hoed when necessary. They then left for two months until transplanting in the field. Just before transplanting of seedlings, the seedlings beds were watered thoroughly to facilitate uprooting. About 75% farmers said they raised bed for good drainage and 15% farmers said that it was easy for intercultural operation such as weeding and hoeing while 5% of farmers said that it was recommended by extension to raise bed and 5% of farmers said that it provided better yield (Table 50).

Table 49 Percent of farmers respondent on period of nursery raising

Test type	Period of Nursery Raising	No	Percent
Pre-test	October	2	10
	November	10	50
	December	5	25
	January	3	15

Table 50 Percent of Farmers correspondence on reasoning the raised bed

Type of test	Reason for raised bed	No	Percent
Pre-test	Good drainage	15	75
	ease cultural operation	3	15
	Recommended by Extension	1	5
	For high yield	1	5

4.7 Post-test Interview

Participating farmers were provided to rate the grade (very good, good, average and poor) based on the rate of performance in plant growth and yield through their observations. There were nine parameters as given in table 51.

In the plant growth parameters (plant height and leaves), out of 20 farmers, 17 (85%) farmers rated very good in modified raised bed method followed by 1st bottom three flower removal 15 (75%) farmers in modified raised bed method and the lowest score in getting very good is pruning in farmers raised bed method with 2 (10%) whereas, the lowest rated is pruning in farmers raised bed method with 10 (50%) farmer and control in poor and very poor rating.

With regard to the performance of plant health (disease free), 16 (80%) farmers rated very good in modified raised bed method followed by 15% (75%) with good in 1st bottom flower removal in modified raised bed method and 80% rated very poor in farmers raised bed method (control) and 10% of farmers rated very poor in pruning in farmers raised bed method and 10% in intercropping of beans in farmers raised bed method.

In terms of rate of performance in terms of number of fruits, around 17 (85%) farmers rated very good in Flower removing in modified bed followed by modified raised bed method with 15 (75%) numbers of farmers and the lowest rate is given to in farmers raised bed method rated by 10 (50%) people in very poor and poor category by 50% of farmers in intercropping in farmer's raised bed method.

With regard to the fruit size, chilli planted in the modified raised bed method and flower removing in modified raised bed method were rated highest with very good and good performance voted by 16 (80%) farmers. Eight (40%) farmers categorized very poor in intercropping in farmers raised bed method.

In overall yield, the highest numbers of farmers of 17 (85%), rated very good in flower removing in modified raised bed method followed by good performance under chilli planted in modified raised bed method with 15 (75%) farmers. The poor and very poor rating were on intercropping on farmers bed raised method by 8 (40%) of farmers followed by farmers raised bed method by 7 (35%) and intercropping in modified raised bed and pruning in farmers raised bed method by 6 (30%) farmers.

Table 51 Farmers preference on different techniques performances on biometric parameters

Techniques	Growth health		Plant ht		No of fruits/plant		Fruit size		Overall yield	
	No	%	No	%	No	%	No	%	No	%
Farmers bed raised (1.1*2.3)	4	20	5	25	3	15	2	10	4	20
Modified bed raised (1.2* 2.4	17	85	16	80	15	75	16	80	15	75
Intercropping in FBR (1.3* 2.1)	2	10	1	5	3	15	1	5	2	10
Intercropping in MBR (TL1.4 *2.2)	4	20	5	25	7	35	8	40	8	40
Pruning in FBR (TL1.1*2.1)	2	10	3	15	1	5	5	25	3	15
Pruning in MBR (TL1.2*2.2)	4	20	7	35	9	45	8	40	13	65
Flower removing (FR) in FBR (TL1.3*2.3)	5	25	8	40	3	15	6	30	8	40
FR in MBR (TL1.4*2.4)	16	80	16	80	18	90	16	80	17	85
Control (TL1.5*2.5)	2	10	4	20	4	20	3	15	3	15

4.8 Coding the results for analysis

As shown in Table 2, the farmers responses were coded for analysis. The coding included the farmer's level of knowledge of the cropping and plant management techniques being demonstrated to them, and also intention to adopt the methods and technology. The first five coding were for pre-test interview and the last three coding were for post-test interview as given below in Table 52.

4.8.1 K- no knowledge

None of the farmers had any knowledge of the type of raised beds. None had previously seen the pruning and flower removal demonstrated, and 22 % of farmers had no idea about intercropping with beans and their benefits.

4.8.2 KN- Knowledge but not doing

About 56% farmers knew about intercropping of chilli with beans but they did not practice, with 21 % identifying depredation by monkeys as the reason,13 % of the farmers stated that the chilli plants were being covered and flattened by beans plants, 13 % found that staking of semi-beans was time-consuming and 9 % highlighted that since most of the farmers were not practicing intercropping, they followed the majority and did not practice. However, few farmers (21 %) who could not grow beans as an intercrop with chilli due, oddly, to potential depredation by monkeys from nearby forest areas where settlement was located. The similar finding showed that in the field near forested core areas face problem with higher damage from the wild animals (Wang *et al.*, 2006). Sahoo and Mohnot (2004) reported that the distance parameter between farmland and forest also showed the severity of the damages to the field. The field beyond 1000 m distance from the forest caused a small percentage of crop damage by monkeys and field between 300-1000 m vicinity caused serious problems in rural areas. Therefore, an investigation on agricultural crops damaged by wild animals become a main issue (Wang *et al., 2006)*. Thus, this study found that the participating farmers' solutions were to avoid intercropping chilli with beans since bean crops were easily damaged by monkeys affecting the main crops as well.

4.8.3 KD- Knowledge and doing (farmers know some techniques and practicing at least one or two techniques).

All the farmers had knowledge of using raised beds for chilli crops and even since, they have been practicing. Farmers (78 %) had knowledge on intercropping with beans out of which 22 % of farmers were practicing since their fields were located near their houses. They found that harvesting two crops generated more income. The similar result was shown by (Stagnari *et al.*, 2017). They further mentioned that intercropping beans are highly suitable due to atmospheric nitrogen fixing ability providing low input cropping system, mitigating greenhouse gases emissions and breaking the life cycles of pest and diseases, thus reducing pest and disease incidences

4.8.4 NKA- No knowledge but still accepting the technology.

The farmers had no knowledge on pruning and flower removal. After providing knowledge, and information on pruning, flower removing, intercropping of beans and modified raised bed method, during the pre-test interview, farmers accepted these techniques. Majority of the farmers (96 %) accepted about flower removing, about 96 % of farmers accepted pruning, 74 % farmers accepted modified raised bed method and 17 % accepted intercropping with beans to carry out in future if all of them provided healthy plant stand with high yield. The farmers who accepted intercropping were those whose fields were located near their houses.

4.8.5 NKNA- No knowledge and not accepting the technology

About 4 % of the farmers did not accept the pruning techniques even after being provided with information, giving the reason that they had no work-force and no time for pruning. 26 % of farmers did not accept modified raised bed method said that they have not seen the modified raised bed method and cannot justify while some explained that they are comfortable with the existing raised bed system. About 27 % of farmers who did not accept intercropping of beans said that their fields being attacked by monkeys and 4 % of farmers who did not accept 1st bottom three flower removal said that removing flower being one of the hectic tasks requiring more labour force.

4.8.6 KA- Knowledge and accepting the technology

After the field observation and demonstration, 90 % of the farmers accepted the modified raised bed method, and 45 % of them accepted intercropping in modified raised bed method, 70 % of these also accepted the pruning techniques in modified raised bed method, with 60 % accepted 1st bottom three flower removal in modified raised bed method. Of those who accepted the modified raised bed method, 80 % found good plant growth and yield and 10 % found uniform with larger fruit size. Farmers who accepted pruning and intercropping of beans in modified raised bed method are for trial purposes with the stated intention to continue with the practice if they see improved crop performance. The farmers who accepted 1st bottom three removal of flowers found high number of fruits per plant with uniform and larger fruit size. The farmers statement regarding few flower removal could be true since the study conducted by (Maboko *et a*l., 2012) found that the first two flowers removal of chilli enhanced root development which further increased fruit bearing and fruit size.

The majority of the farmers observed excellent growth and yield parameters in the modified raised bed method and 1st bottom first three flower removal in modified raised bed method.

4.8.7 KNA- Knowledge but not accepting the technology

Of the farmers who had knowledge of all the technologies, about 10 % of the farmers did not accept the modified raised bed structure, 55 % did not accept intercropping with beans, 30 % did not accept pruning and 40 % did not accept 1st three flower removal of chilli.

The farmers stressed that preparation of the modified raised bed method needed more labor force (5 %) and was time consuming (5 %). They also stated that intercropping chilli plants was not healthy leading to the low yield (20 %), not uniform (15 %) and more labour requirement (15 %). (Ouma & Jeruto, 2010) also reported that intercropping required more labours and intercropped plants competed for water, light and nutrients resulting in lower yields. They (15 %) explained that pruned plants had no uniform fruits and had low yields, some (9 %) said that plants were weak and diseased, and few (6 %) highlighted pruning required more labor-force and was time consuming. The farmers emphasized that removing flowers required more workforce (10 %) and time consuming (30 %).

4.8.8 AT- Accepting the technology (farmers accept at-least one or more technologies.

Two important techniques, the modified raised bed method and 1st bottom three flower removal in modified raised bed method were prioritized by the farmers based on the plant growth, plant health, number of fruits, fruit size and overall yield. 90 % of farmers wanted to continue with the modified raised bed method and 60 % of farmers wanted to conduct 1st three flower removal of flowers in modified raised bed method. When farmers were probed further for accepting the modified raised bed technology, farmers (48 %) mentioned that the good yield could be due to good of soil moisture content under rain-fed condition, 26 % said that this could be due to mulching with organic manure and the rest claimed that this could be due to nutrients and moisture. According to (Miah *et al*., 2015) raised bed technology has been proved as a water saving technology and required less irrigation water.

Table 52 Coding analysis based on percentage of farmers' respondents on idea of cropping and management techniques in pre/post test

Cropping and management Levels	Pre-test analysis (%) Total 20 farmers			Post-test analysis (%) Total 20 farmers				
	Code for analysis							
	NK	KN	KD	NKA	NKNA	KA	KNA	AT
Raised bed			100					
Modified	100			74	26	90	10	90
Intercrop beans	22	56	22	17	27	45	55	
Pruning	100			96	4	70	30	
Flower removing	100			96	4	60	40	60

4.9 Modified raised bed method versus farmers raised bed method

The followings are the rating based on performances of chilli crops on cropping and management techniques under modified and farmers raised bed method. The result defined that farmers (100 %) preferred modified raised bed method over farmers raised bed method. Participating farmers observed positive benefits of the modified raised bed method and became enthusiastic towards this technology. The similar study conducted by Miah *et al*. (2015) found that 30.8 % of adopting farmers modified their bed size (width of the bed and furrow) with 29.2 % shortened bed width and 8.7% shortened the furrow width were effective in production, originally learnt from scientists

The result showed that all the farmers preferred modified raised bed method and majority (70 %) of farmers preferred 1st bottom three removal of chilli in modified raised bed over farmers raised bed method (Table 53). The reasons for accepting modified raised bed method by the farmers are due to rating performance of good plant growth (80 %), number of fruits per plant (75 %), uniform size fruits (80 %), healthy plant stand (80 %) and overall yield (75 %).

Table 53 Preferences on raised bed types of cropping and management techniques of chilli crops

Modified raised bed Method (MRBM)	**No**	**%**	Farmers raised bed Method (FRBM)	**No**	**%**
MRBM	20	100	FRBM	0	0
Intercropping in MRBM	10	50	Intercropping in FRB	10	20
Pruning in MRB	11	55	Pruning in FRB	9	45
1st three flower removal in MRB	14	70	1st three removal in FRB	9	45

4.10 Common Test Analysis

The common test analysis was based on farmers' preferences on modified raised bed method between pre-test and post-test interview. Table 54 showed that the acceptance on modified raised bed method between pre-test and post-test interview and between male and female were not significantly different. Therefore, there was no significant association between interviews and acceptance and between genders on modified raised bed method. The figure 27 showed that percentage of farmers accepting modified raised bed method were found higher in post- test (90 %) than pre-test (75 %). Increasing the percentage of farmers from pre-test to post-test were about 80 % of farmers found good plant growth, 75 % of farmers said good number of fruits per plant, about 80 % highlighted uniform fruit size, 80 % expressed healthy plant and about 75 % viewed as high yield of chilli under modified raised bed method. A few number (10 %) of farmers were asked for not adopting modified raised bed technology. They (6 %) explained that modified bed consumed more time and required more labour. Some farmers (4 %) replied that they preferred the existing raised bed. The similar result was studied by (Miah *et al*., 2015).

Table 54 Variables associated with genders on decision of acceptance of modified raised bed method (MRBM)

		Female		Male			
Variables	**Total no**	**Yes**	**No**	**Yes**	**No**	**X2 statistics (df)**	***p* value**
Pre-test	20	11 55%	4 20%	4 20%	1 5%	0.089(1)	0.766
Post-test	20	13 65%	2 10%	5 25%	0	0.741 (1)	0.389

[a] Chi-square test for independence

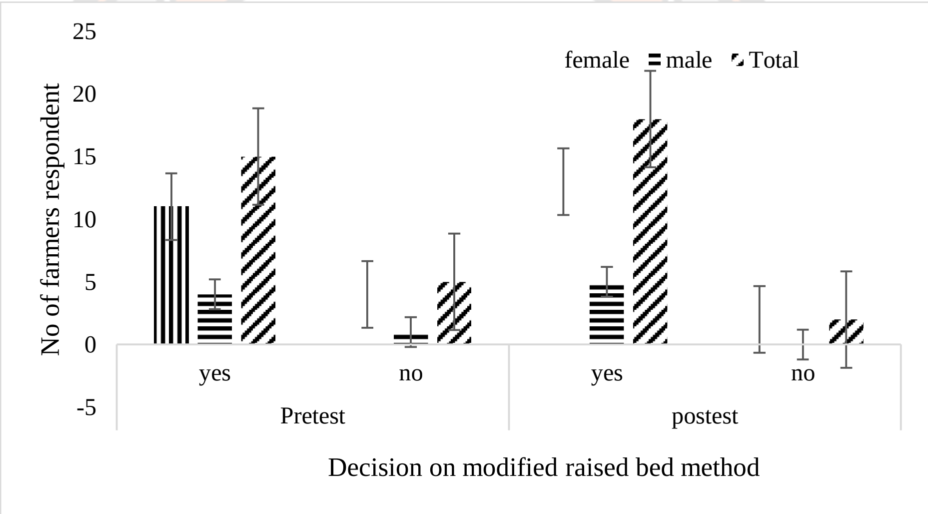

Figure 27 Number of gender participants on decision on modified raised bed method (MRBM). Error bars denote the standard error of the mean for each treatment.

The finding showed that the acceptance intercropping of beans in modified raised bed method between pre-test and post-test interview and between genders were not significantly different. Therefore, there was no significant association between pretest and post-test interviews and between genders on acceptance of intercropping of beans in modified raised bed method (Table 55). The data (Figure 28) revealed that 55 % of the farmers indicated in the post-test that they had made the decision to intercrop with beans in a modified raised bed method. This was significantly higher than the 25% of farmers who had stated this in the pre-test interview. Those farmers who accepted the new techniques indicated that chilli intercropped with beans in the modified raised bed method had a higher yield and more uniform plant stands. The 55 % of farmers who did not accept these techniques emphasized that the main chilli crop intercropped with beans was not healthy (27 % of farmers), not uniform (20 %) and the chilli plants were crushed by the beans plants (8 %).

Table 55 Variables associated with genders on decision of acceptance of intercropping in MRBM.

		Female		Male			
Variables	**Total no**	**Yes**	**No**	**Yes**	**No**	**X2 statistics (df)**	***p* value**
Pre-test	20	12 60%	3 15%	4 20%	1 5%	0.000(1)	1.000
Post-test	20	9 45%	6 30%	2 10%	3 15%	0.606(1)	0.436

[a] Chi-square test for independence

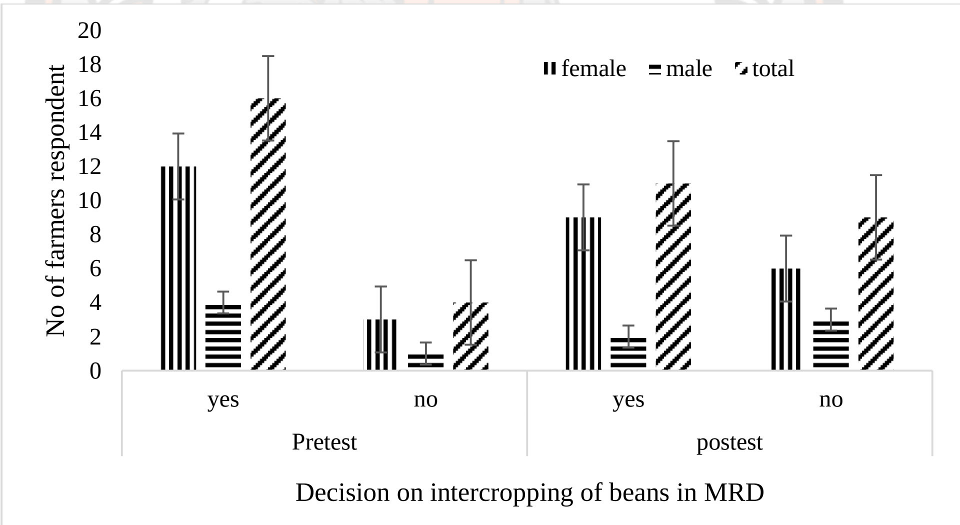

Figure 28 Number of gender participant on decision of intercropping in MRBM. Error bars denote the standard error of the mean for each treatment.

The result showed that the acceptance pruning in modified raised bed method between pre-test and post-test interview was not significantly different. Similarly, there was no significantly different in gender on pruning in modified raised bed method (Table 56). Therefore, there was no significant association between pretest and post-test interviews on acceptance of pruning in modified raised bed method.

Moreover, there was no significantly different on genders in modified raised bed method. The results indicated that, in the post-test, 70 % of the farmers who had accepted the techniques of pruning in the modified raised bed method (Figure 29). This was substantially higher by 15 % identified in the pretest. Some of the reasons for not accepting these techniques were low yield, indicated by 10% of the farmers, the stand was not uniform, (5 %), more farm labor was required and it was more time consuming (10 %), and weak plants resulted (5 %). The farmers accepted pruning in post-test interview mainly for conducting the trial (50 %) and yield (20 %).

Table 56 Variables associated with genders on decision of acceptance of pruning in MRBM

		Female		Male			
Variables	**Total no**	**Yes**	**No**	**Yes**	**No**	**X2 statistics (df)**	***p* value**
Pre-test	20	13 65%	2 10%	4 20%	1 5%	0.131(1)	0.718
Post-test	20	10 50%	5 25%	4 20%	1 5%	0.317(1)	0.573

[a] Chi-square test for independence

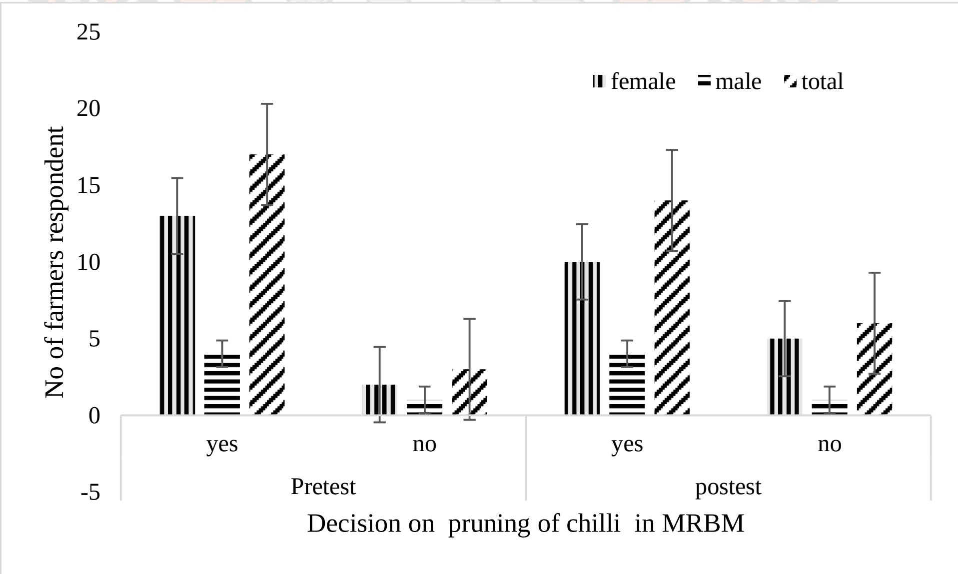

Figure 29 Number of gender participants on decision of chilli pruning in MRBM. Error bars denote the standard error of the mean for each treatment.

The findings found that there was no significantly different (p = 0.305) in acceptance of 1st bottom three flower removal in modified raised bed method (MRBM) between pretest and post-test interviews and no significant different on female and male (Table 57). Thus, there was no relation between interviews and the acceptance of 1st bottom three flower removal in MRBM and between genders. As shown in Figure 30, about 90 % of the farmers accepted decision on 1st bottom three flower removal of chilli in MRBM and 10% did not accept in pretest but after demonstration (post-test) about 60 % of farmers wanted to carry out flower removal. Even though a high percentage of farmers found good performance in plant growth (80 %), number of fruits per plant (90 %), fruit size (80 %), plant health (80 %) and overall yield (85 %) , 30 % farmers found consuming more time and 10 % farmers said no work force for removing flowers. The decrease of percentage of farmers from pretest to post-test who wanted to conduct pruning was because of easily acceptance with theory inputs in pre-test while in posttest farmers found more hectic, time consuming and more work-force requirement.

Table 57 Variables associated with genders on decision of acceptance of 1st bottom three flower removal in MRBM.

		Female		**Male**			
Variables	**Total no**	**Yes**	**No**	**Yes**	**No**	**X2 statistics (df)**	***p* value**
Pre-test	20	13 65%	2 10%	5 25%	0	0.741(1)	0.389
Post-test	20	8 40%	7 35%	2 20%	3 15%	0.267(1)	0.606

[a] Chi-square test for independence

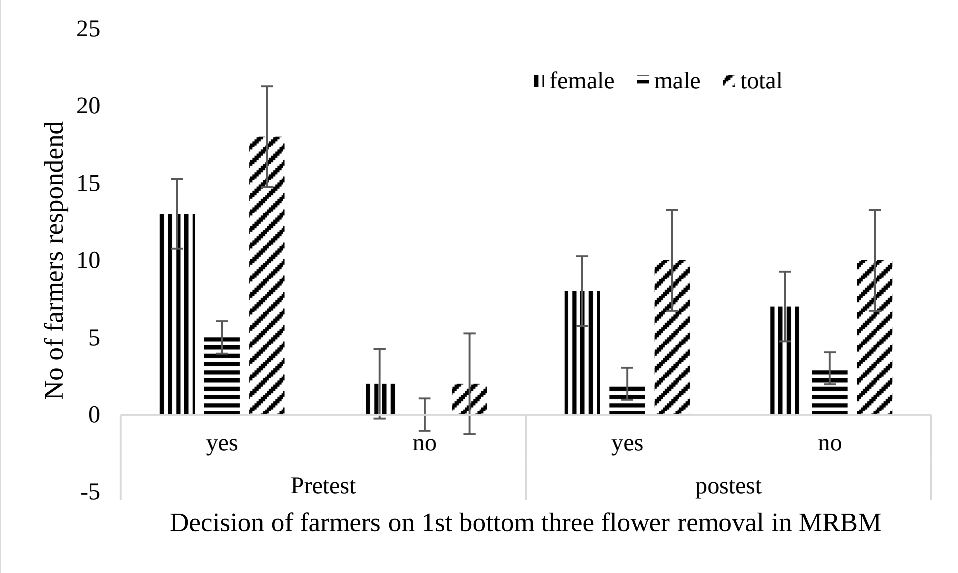

Figure 30 Number of gender participants on decision of 1st bottom three removal in MRBM. Error bars denote the standard error of the mean for each treatment.

The study showed that there was no significant different between female and male in acceptance of at-least one technology. Hence no relation between genders and accepting technology as shown in Table 58. There was also no significant different on acceptance of technology on pre-test and post-test interview. Figure 31 showed that, in the pre-test interview, 95% the farmers accepted to do at-least one of the techniques. However, in the post-test interview, 10 % of farmers indicated that they did not accept any of the techniques. About 5 % of the farmers observed lower yields, 3 % found it to be too time consuming and 2 % were concerned about the higher labor force requirement. From the remaining 90 %, all these farmers wanted to carry out modified raised bed method (MRBM), 50 % wanted to conduct 1st bottom three flower removal in MRBM, giving improved performance of plant growth and yield as the reason. When enquired further about the adoption of the modified raised bed technology, some of the respondent farmers (38 %) reported that healthy plant with the high yield could be due to high moisture in the soil, 36 % mentioned about mulching with compost, 16 % explained cultural operations such as weeding, hoeing and mulching and 10 % said that nutrients with soil moisture. The finding is in line with Miernicki *et al*. (2018) who stated that soil water content increased with increasing rates of landscape bed of raised bed. As per Singh *et al.* (2008) planting crops in the ridge and furrows saved water (20 %–25 %), labour (30 %–40 %) and increase marketable yield (10 %–20 %) since this technique provided plants to grow healthy due to minimum water logging stress. These ridges and furrows functioned as drainage lines for excess water, facilitating modification of ridges and furrow feasible for poor soils with low water holding capacity. Jat *et al*. (2016) viewed that planting potatoes on both sides of a narrow bed increased yields by 25 % and saved 20 % of irrigation water as a comparison to ridge-planting method. Jat *et al.* (2016) further expressed that with adopting of bed planting technology saved 18-50 % irrigation water, about 25 % nitrogen and 25–50 % seed. This finding clearly stated that the participating farmers had understood about the water retention capacity in the modified raised bed for the growth and development of chilli plants under rain-fed farming. Thus, the majority of the participating farmers had accepted to adopt the modified raised bed.

Table 58 Variables associated with genders on decision of acceptance on adoption of technology

		Female		Male			
Variables	**Total no**	**Yes**	**No**	**Yes**	**No**	**X2 statistics (df)**	***p* value**
Pre-test	23	14 70%	1 5%	5 25%	0	0.351 (1)	0.554
Post-test	20	13 65%	2 10%	5 25%	0	0,741(1)	0.389

[a] Chi-square test for independence

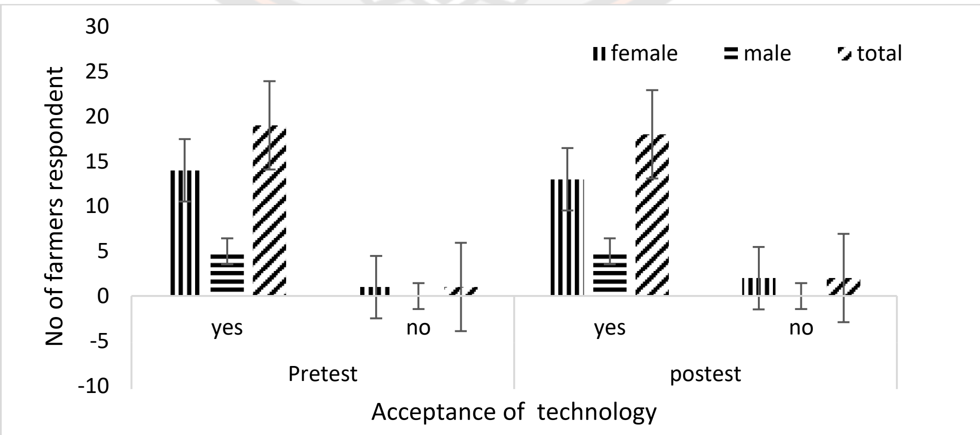

Figure 31 AF- Adoption in future (Adoption of one or two technology in future). Error bars denote the standard error of the mean for each treatment.

CHAPTER V

SUMMARY, RECOMMENDATION AND CONCLUSION

5.1 Summary

A study on effect of cropping and cultural management techniques on chilli production under rain-fed farming was carried out during February 2019 till July 2019 at Wookhana village, Kabisa Block in Punakha District to examine the growth and yield under different cropping techniques and management techniques and to evaluate farmers' acceptance and adoption on technologies of different cropping and management techniques. The experiment was laid out in 4*4+1(control) factorial of randomized complete block design with cropping levels of CL1.1 farmer's raised bed, CL1.2 Modified raised bed, CL1.3 Intercropping in farmer's raised bed CL1.4 Intercropping in modified raised bed Cc Farmer's raised bed (control) and management levels of ML2.1 pruning in farmers raised bed ML2.2 pruning in modified raised bed ML2.3 1st bottom three flower removal in farmers raised bed ML2.4 1st bottom three flower removal in modified raised bed. Mc no pruning and no flower removal in farmers raised bed method (control). There were total of seventeen plots including control in each replication with total of three replications (51 plots). The pre-test interview using semi structure was asked to the randomly selected farmers before conducting an experiment research and post-test interview using questionnaire was asked to the same farmers right after demonstration before harvesting chilli. The biometric parameters, soil moisture and soil properties data were analyzed using General linear model and one way Anova. The pre-test and post-test data were analyzed using code of analysis and Chi-square. The findings of the results were summarized below:

There were significant effects on all plant growth parameters (plant height, stem diameter, length and breadth of leaves and number of leaves) of chili on cropping and management levels throughout the growing period. There were also interactions between cropping and management levels on plant height, leaf length, breadth and number of leaves but no interaction on stem diameter throughout the growing period.

Among the cropping levels, the plant height was found highest (10.63 cm) in CL1.4 (chilli intercropped with beans in modified raised bed), the stem diameter (8.33 mm), leaf length (9.71 cm), leaf breadth (4.44 cm) were highest in chilli planted in modified raised bed and number of leaves per plant was performed maximum in CL1.1 (farmers raised bed) and CL1.2 (modified raised bed) with 126 and 124 numbers at the end of growing season. The plant height (39.69 cm), stem diameter (6.38 mm) leaf breadth (3.47 cm) and number of leaves per plant (73 nos) were observed lowest in control- (chilli planting on farmers bed) and lowest leaf length (8.32 cm) in CL1.1 at the end of growing period. Among the management levels, the plant height (49.35 cm), stem diameter (8.25 mm) , leaf length (9.49 cm), leaf breadth (4.30 cm), number of leaves per plant were recorded highest in ML2.3 farmers raised bed having 1st bottom three flower removal followed by modified raised bed having 1st bottom three flower removal of chilli at the end of growing season. The plant height (35.41 cm) and leaf length (8.50 cm) were noted lowest in ML2.1, stem diameter (6.38 mm), leaf breadth (3.47 cm) and no of leaves per plant (73) in Mc (control) at the end of growing season. Therefore, the combination effect of cropping and management levels was found highest in TL1.2 *2.3 and Cc*Mc in growth parameters.

The yield parameter showed that there were significance differences on effects of cropping and management levels on fruit weight, number of fruits per plant and fruits with pedicel and widest fruit girth. However, there was no effect of cropping on fruit girth at the apex and there were no effects of management levels fruit length with pedicel, widest fruit girth and fruit girth at the apex. On the contrary there was no interaction between cropping and management level on all the yield parameters except number of fruits per plant.

Among the cropping levels, chilli planted in modified bed out performed in fruit weight (26.87 gm), number of fruits per plant (22 nos), length of the fruit (16.82 cm) and fruit girth (26.57 mm) and the least was performed by farmer's raised bed (control). Among the management level, fruit weight, fruit length and fruit diameter was recorded highest in ML2.3 (1st bottom three flower removal of farmers raised bed) followed by ML2.4 (1st bottom three flower removal in modified bed) and number of fruits per plant in Ml2.4 and the least performed by chilli pruned in farmer's raised bed method.

There was a highly significant effect ($p<0.05$) of cropping and management levels of chilli crop on soil moisture. Similarly, there was a significant difference ($p<0.05$) between interaction of cropping and management techniques of chilli crops on soil moisture. The result found that CL1.2 (chilli planted in modified raised bed method) required less water than the chilli planted in farmers raised bed method throughout the growing period. Comparing the management levels, ML2.4 (the modified bed with 1st bottom three removal of flowers in modified bed) required the least moisture whereas farmer's raised bed with first bottom three removal of flowers in modified bed required the highest moisture.

There was no significant effect ($p>0.05$) of overall cropping and management techniques of chilli crops on organic carbon (OC), pH, Nitrogen (N), phosphorus (P) and potassium (K). However, there was significant different ($p>0.05$) of soil properties on before planting chilli plants and after harvesting chilli plants. There was also no significant interaction ($p>0.05$) between cropping and management techniques of chilli crops in all soil properties. The organic carbon, pH and NPK were found maximum in CL 1.4 (chilli intercropped with beans in modified beans) and CL1.2 (chilli planted in modified bed) in the growing period. The OC, N, pH were found lowest in Cc (control) and P and K in CL1.3.

The economic analyses of chilli production was found highest in TL 1.2 *2.4 with 16669.42 kg/acre followed by TL 1.2*2.3 with 13546.50 kg/acre and the lowest yield was obtained from TL1.4*2.1 with 3235.84 kg/acre. Therefore, the income of the farmers for selling chilli at the cost of ngultrum 40 per kg would obtain highest income of Ngultrum 666776.65 from TL 1.2 *2.4 and lowest income of Ngultrum 129433.50 from TL 1.4*2.1.

Thus, from the findings, the null hypothesis was rejected and alternative hypothesis was accepted since there were significant differences on growth and yield of cropping and management techniques on chilli production under rain-fed farming. There were also significant differences in farmers' adoption on cropping and management techniques on chilli production under rain-fed farming

Farmers interview in the post-test found that about 80% of farmers preferred treatment of modified raised bed followed by 75% of farmers who chose treatment of 1st bottom three flower removal in modified raised bed from the rating based on plant growth, health, fruit size, fruit yield and over all yield of chilli crops.

Around 90% of farmers confirmed to carry out modified raised bed and 60% of farmers wanted to conduct 1st bottom three removal of flowers in modified bed in rain-fed condition. Few farmers wanted to conduct pruning of chilli and intercropping with beans for trial basis. However, no follow-up investigation in the next season occurred, so the study cannot, at this point, describe the experience and success or failure of the crops in the next season as a controlled field test.

5.2 Recommendation

Since this is the 1st research on the modified bed method comparing with farmers raised bed method, study on different elevation and soil type need to be done to in the rain-fed region to obtain the precise result. Further study also needs to carry on different varieties of chilli on these two types of methods. The study on different pruning type and different flower removing in Bhutanese context must be carried out for further verification. Intercropping of different type of beans on different bed raised method under rain-fed need to be conducted to assess the growth, yield and soil data.

This study also conducted using farmer method of application farm yard manure (FYM) and organic mulch (compost) but without application of inorganic fertilizers. Thus, through observation, the yield of experiment was low while comparing to the yield of farmers' fields where farmers applied FYM in addition with urea and suphala twice after transplantation as a basal dose (one right after transplanting and another - just before reproduction phase). Therefore, to find the reliable growth and yield parameters, an experiment must be conducted with the least inorganic infected area.

In the pretest, potassium contained in before transplanting of chilli was very low (500 kg/ha). But after chilli harvest, the potassium was found highest with 1846 kg/ha which means the potassium accumulated in the soil was1346 kg/ha. Thus, what causes accumulation of potassium after harvest of chilli need to further investigate for confirmation.

An experiment study declared that the best cropping levels were achieved by CL1.2 and CL1.4 and management levels by ML2.3 and ML2.4 in terms of growth and yield of chilli under rain fed farming. Similarly, the farmers' post-test interview confirmed that majority farmers (90%) accepted CL1.2 and 50% of farmers accepted ML2.4 and wanted to adopt in future. From the findings, both experiment and acceptance of techniques by farmers over-lapped the same result. Therefore, CL1.2 (chilli planted in modified raised bed method) and ML2.3 and ML1.2 (1^{st} bottom three flower removal of chilli in farmers raised bed and 1^{st} bottom three flower removal in modified raised bed method) can be the best recommendation under rain fed farming.

5.3 Conclusion

The following findings were drawn from this research:

Most of the growth parameters were outperformed by TL1.4*2.4 (plant height, leaf length, leaf breadth and leave number) and TL1.2 *2.4 (stem diameter, leaf breadth) thorough out he growing season. The lowest in most plant parameters were found in in TL1.1*2.1 (plant height, stem diameter, leaf length) and leaf breadth found in TL1.3*2.1 and lowest of leaves in Cc*Mc in the later stage of growing period)

Most of the yield parameters were highest in TL1.2*2.3 (fruit weight- fruit length with pedicel and without pedicel (22.15 cm, 17.52 cm), fruit girth (28.25mm) TL1.2*2.4 (no of fruits per plant-98). The lowest was mostly found in TL1.4*2.1 (fruit weight- 19.98 gm, no of fruits per plant (24), shortest fruit length with or without pedicel in TL1.1*2.2 (17.13,14.19 cm), lowest fruit girth in TL1.3*2.3

In terms of soil moisture, TL1.2*2.4 had lowest recording with 207.67 Mbar and lowest in TL1.1*2.4 with 273.33 Mbar and on July, TL1.2*2.4 recorded 101.33 Mbar and Cc*Mc recorded the highest with 163.00 Mbar.

With regard to soil properties, TL1.4*2.4 found highest in soil moist percentage (13.50%), pH 6.47, P (1.08 mg/I) in TL1.2*2.4 highest Oc (0.63%), N

(05%,) and K 1846 Kg/ha. The lowest soil moist % in Cc*Mc with 12.28%, OC with 0.45%, N (0.04%) TL 1.3*2.3 (pH-6.13, P-0.11Mg/L, K (1150 Kg/ha)

Among ten technologies, 16 (80%) farmers out of 20 farmers preferred chilli planted in modified bed (CL1.2) and about 15% (75%) of farmers faovoured 1st bottom three flower removal in modified raised bed (ML2.4) and the least preferred was chilli intercropped with beans in farmers raised bed (CL1.3) with poor rating (50%) and Cc (control) with very poor rating (50% farmers).

With regards to acceptance of technology, 18 (90%) of farmers accepted modified raised bed technology. They preferred the modified bed because of higher yield, and healthy plants and moisture retention capacity. 60% of farmers wanted to conduct trail on 1st bottom three flower removal in modified raised bed since they found promising yield and healthy plant stands. All of the farmers would like to continue in future if the modified bed provides good yield with good moisture retention capacity.

This study presented among cropping techniques, CL1.2 (chilli planted in modified raised bed) and CL1.4 (chilli intercropped with beans in modified bed) and among management level, ML1.3 (1st bottom three flower removal in farmers raised bed) and ML2.4 (1st bottom three flower removal in modified raised bed) outraced other treatment techniques achieved in experiment. Likewise, farmers' interview after demonstration of the techniques found that almost all farmers accepted the chilli planted in modified raised bed and 1st bottom three flower removal of chilli in modified raised bed. Thus the result concluded that in both experiment and farmers interview, chilli planted in modified and both, 1st bottom three flower removal of chilli in farmer's raised bed and in modified raised bed method outperformed other treatments and accepted these techniques under rain fed farming.

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ANNEXURES

Annexure 1

Replication												
Treatment	**Pl no**	**plant parameter**							**Leaf parameters**		
		Pl ht	**pl dia**	**LL**	**Bd**	**No**	**Pl ht**	**pl dia**	**Lh**	**Bd**	**No**
1.2* 2.1	1										
	2										
	3										
1.2* 2.4	1										
	2										
	3										
1.3 * 2.1	1										
	2										
	3										
1.3 * 2.4	1										
	2										
	3										
1.1 * 2.3	1										
	2										
	3										
1.2 * 2.3	1										
	2										
	3										
1.3 * 2.3	1										
	2										
	3										
1.1 * 2.1	1										
	2										
	3										
1.4 * 2.1	1										
	2										
	3										
1.3 *2.2	1										
	2										
	3										

1.1 * 2.2	1										
	2										
	3										
1.4 * 2.2	1										
	2										
	3										
1.4 * 2.4	1										
	2										
	3										
1.4 * 2.3	1										
	2										
	3										
1.2 *2.2	1										
	2										
	3										
1.1 *2.4	1										
	2										
	3										

Note: Pl no- plant number, Pl ht- plant height, Pl dia- plant diameter, number, LL-leaf length, Bd-leaf breadth, No- number of leaves,

Annexure 2:

Fruit parameters

Replication		**Fruit parameters**								
Group	**Pl no**	**Pod no**	**Fr lgt**	**Frlngh Pedi**	**Girth**	**Grirth pex**	**Fruit weight**	**Fruit no 1**	**fr no 2**	**Fr No 3**
1.2* 2.1	1	1								
		2								
		3								
	2	1								
		2								
		3								

	3	1								
		2								
		3								
	1	1								
		2								
		3								
	2	1								
1.2* 2.4		2								
		3								
	3	1								
		2								
		3								
	1	1								
		2								
		3								
	2	1								
1.3 * 2.1		2								
		3								
	3	1								
		2								
		3								

Note: Pod no- pod number, PoL- Pod length, fr length pedi- fruit length with pedicel, frt grith, fruit girsth at apex, Wt- weight of single pod, 1st havest fruit no ,1 no, 2 no, 3 n

Annexure 3

Soil moisture record

Soil moisture	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week
reading								

Annexure 4

Soil parameter

Pre soil test			**Post soil**					
Field preparation			**Without intercrop**			**With intercrop**		
NPK	C:N	pH		NPK	C:N	NPK	C:N	pH

Note: NPK- Nitrogen, Phosphorous and Potassium, C : N - Carbon and Nitrogen, pH- Power of hydrogen ion concentration

Annexure 5

Questionnaire (pre-test) (Tick the appropriate answer in the bracket)

1.Demographic profile

1.1 Code of the farmer …………………………………….

1. 2 Age: …………………Mobile number:……………………………..

1.3 Gender: (Male/Female/others)……………………

1.4 Education level:……………………….

1.5 Mobile no (optional)………………

1.6 Chilli cultivated area: …………………… Acres

1.7 Total land area cultivated: ……………..Acres (□ dry /□ wet / □ kitchen garden /□ others)

1.8 Total household members:……………….. numbers

1.9 Total members working on farm:……………….. numbers

2.0 Type of farm: □ Commercial □ Subsistence □ Both

2.Cropping system

2.1 Where do you grow chilli?

□ Dryland □ Wetland □ Kitchen garden

2.2 Your source of seedling

□ Raise own □ buy □ others

2.3 If raised when do you sow the nursery?

□ Nov □ Dec □ Jan

2.4 How do you raise the nursery?

……………………………………………………………………………………

2.5 How do you prepare fields for chilli transplanting

□ Flat bed □ raised bed □ ridge bed □ furrow bed □ other

2.6 Any idea on bed raising? if yes, go to 1.6.1. if no go to 1.6.2. □ Yes □ No

2.6.1 Why grow on raised/ridge/furrow or other type of raised method?

□ Recommended by extension

□ Good drainage

□ Less disease

□ Less pest

□ Easier intercultural operations

□ Better yield

□ All

2.6.2. if no, why do u prefer flat or traditional method.

□ soil texture (sandy, clay, loamy,)

□ time consumption (less time)

□ Intercultural operation (easy, any others)

□ all

□ Others

2.7. Do you have any idea on chilli intercropping with beans? If yes, go to 2.7.1. □ Yes □ No

2.7.1 Do you practice intercropping of chilli with beans? If yes, go to 2.7.1.1. if no, go to 2.7.1.2

□ Yes □ No

2.7.1.1 Why do you practice intercropping with beans?

□ yield of two crops

□ soil healthy

□ benefit of one crop over other

□ benefits in-terms of money (beans fetch good price/ chillies fetch premium price / both)

□ good combination

□ beans fix nitrogen from atmosphere

□ others

2.7.1.2 why don't you practice intercropping with beans?

□ preference

□ no one is practicing

□ intercultural practices not easy

□ others

2.8 which type of beans do you grow

□ Dwarf □ Climbing □ others

2.9 What do you grow before and after chilli?

□Chilli paddy chilli

□ Chilli wheat chill

□ Chilli legumes chilli

□Chilli oilseeds chill

□ Others

3. Cultural management practices

3.1 Do you have any idea on pruning of chilli plants. If yes, go to 3.1.1 □ Yes

□ No

3.1.1 Did you practice pruning on chilli. If yes go to 3.1.1.1 if no, go to 2.4 □ Yes , if no , go to 3.1.1.2 □ No

3.1.1.1 if yes, since when and what type of pruning?

…………………………………………………………………………………………

3.1.1.2 if no, why didn't you practice pruning?

…………………………………………………………………………………………

3.2 Are you willing to carry out pruning, if it provides high yield ? □ Yes □ No

3.3 Any idea about flower removing from chilli plants? □ If yes, go to 3.3.1 Yes □ No

3.3.1 Did you practice flower removing. If yes, go to 3.3.1.1, if no, go to 3.3.1.2 □ Yes □ No

3.3.1.1 If yes, since how long and what type of flower removing and what is/are the reason/s?

…………………………………………………………………………………………………

3.4. Do you want to practice flower removing if it provides uniform and bigger in size of chilli? If no, go to 3.4.1 ☐ Yes ☐ No

4. Adoption

4.1 Will you adopt these technologies if these technologies ? If yes, go to 4.2, if no, go to 4.3 ☐ Yes ☐ No

4.1.1 what are the reasons for taking up one of the technologies

4.1.2 What is/are the reason/s not for t taking up these technologies?

…………………………………………………………………………………………………

Annexure 6

2. Questionnaire (post-test)

2.0. Code of the farmer:………………………………………………..

Rating of techniques through Observation in field

2.1 Cropping system (bed raising) and intercropping

2.1.1 Rate the performance in plant growth using

Cropping and mngt method	**Performance**			
Farmers raised bed method (control)	Very good	Good	Average	Poor
Farmers raised bed method+ pruning	Very good	Good	Average	Poor
Modified raised bed method + pruning	Very good	Good	Average	Poor
Intercropping in farmers bed + bottom three removal of flowers	Very good	Good	Average	Poor
Intercropping in modified bed + bottom three removal of flowers	Very good	Good	Average	Poor

2.1.2.Rate the performance in terms of number of fruits (through observation)

Cropping and mngt method	**Performance**

Farmers raised bed method (control)	Very good	Good	Average	Poor
Farmers raised bed method+ pruning	Very good	Good	Average	Poor
Modified raised bed method + pruning	Very good	Good	Average	Poor
Intercropping in farmers bed + bottom three removal of flowers	Very good	Good	Average	Poor
Intercropping in modified bed + bottom three removal of flowers	Very good	Good	Average	Poor

2.1.3 Rate the performance in terms of fruit size (through observation)

Cropping and mngt method	**Performance**			
Farmers raised bed method (control)	Very good	Good	Average	Poor
Farmers raised bed method+ pruning	Very good	Good	Average	Poor
Modified raised bed method + pruning	Very good	Good	Average	Poor
Intercropping in farmers bed + bottom three removal of flowers	Very good	Good	Average	Poor
Intercropping in modified bed + bottom three removal of flowers	Very good	Good	Average	Poor

2.1.4 Rate the performance in terms of plant health (pest and disease through observation)

Cropping and mngt method	**Performance**			
Farmers raised bed method (control)	Very good	Good	Average	Poor
Farmers raised bed method+ pruning	Very good	Good	Average	Poor

Modified raised bed method + pruning	Very good	Good	Average	Poor
Intercropping in farmers bed + bottom three removal of flowers	Very good	Good	Average	Poor
Intercropping in modified bed + bottom three removal of flowers	Very good	Good	Average	Poor

2.1.5 Rate the performance in terms of overall yield (observation)

Cropping and mngt method	**Performance**			
Farmers raised bed method (control)	Very good	Good	Average	Poor
Farmers raised bed method+ pruning	Very good	Good	Average	Poor
Modified raised bed method + pruning	Very good	Good	Average	Poor
Intercropping in farmers bed + bottom three removal of flowers	Very good	Good	Average	Poor
Intercropping in modified bed + bottom three removal of flowers	Very good	Good	Average	Poor

2.1.5 Which one do you want to carry out? ☐sole cropping ☐intercropping

and why??

2.1.6 What is your decision on chilli pruning? ☐ Accept ☐ reject

2.1.7. What is/are the reason/s for accepting or rejecting

…………………………………………………………

2.1.8 What is your opinion on first three removal of flowers from plant? ☐ Accept

☐ reject

2.1.9What is/are the reason/s for accepting or rejecting

…………………………………………………………..

2.2. Farmers adoption on technologies

2.2.1 which techniques do you prefer.

☐Farmers raised bed **v** ☐ Improved raised bed,

☐Intercropping in farmers bed **v** ☐ Intercropping in improved raised bed

☐Pruning in farmers raised bed **v** ☐pruning in improved raised bed

☐ Removing of 1st three flowers in farmers raised bed **v** ☐ removing in improved raised bed

2.2.2 Which one do you think is the best among these technologies?

Cropping and mngt method	**Performance**			
Farmers raised bed method (control)	Very good	Good	Average	Poor
Farmers raised bed method+ pruning	Very good	Good	Average	Poor
Modified raised bed method + pruning	Very good	Good	Average	Poor
Intercropping in farmers bed + bottom three removal of flowers	Very good	Good	Average	Poor
Intercropping in modified bed + bottom three removal of flowers	Very good	Good	Average	Poor

2.2.3 What are the reasons for accepting some of the technologies

…………………………………………………………………………………………………

2.2.4 What are the reasons for rejecting some of the technologies?

………………………………………………………………………………………………

2.2.5 Will you continue to use the best techniques in future and why?