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TILLAGE AND WATER SAVING TECHNIQUES FOR BLACK GRAM IN RICE FALLOWS

By

AISHA MOL P. B.

(2015-11-034)

THESIS

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DECLARATION

I, Aisha mol P. B. (2015-11-034) hereby declare that the thesis entitled **"Tillage and water saving techniques for black gram in rice fallows"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other university or society.

Vellanikkara

Date: 3/11/17

Aisha mol P. B.

(2015-11-034)

CERTIFICATE

Certified that the thesis entitled **"Tillage and water saving techniques for black gram in rice fallows"** is a bonafide record of research work done independently by **Miss. Aisha mol P. B.** (2015-11-034) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associate ship or fellowship to her.

Vellanikkara

Date: 3/11/17

Dr. Latha A.
Chairperson
Advisory Committee

CERTIFICATE

We the undersigned members of the advisory committee of **Miss. Aisha mol P. B.** (2015-11-034) a candidate for the degree of Master of Science in Agriculture, with major field in Agronomy, agree that this thesis entitled "Tillage and water saving techniques for black gram in rice fallows" may be submitted by **Miss. Aisha mol P. B.** (2015- 11- 034) in partial fulfillment of the requirement for the degree.

Dr. A. Latha
Professor (Agronomy) & Head
Agricultural Research Station
Mannuthy
(Chairperson)

Dr. C. George Thomas
Professor & Head
Department of Agronomy
COH, Vellanikkara
(Member, Advisory committee)

Dr. P. Prameela
Professor (Agronomy)
College of Horticulture,
Vellanikkara
(Member, Advisory Committee)

20/10/17

Dr.P. Sureshkumar
Professor & Head and
Radiological Safety Officer
Radio Tracer Laboratory
COH,Vellanikkara
(Member, Advisory committee)

Dr. A. Velayutham
Professor & Head
Dept. of farm management
Agricultural College and Research Institute
Killikulam, Vellanadu, Tamil Nadu

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Aisha Mol P. B.

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LIST OF ABBREVIATIONS

%	-	Per cent
@	-	At the rate of
^0C	-	Degree Celcius
B: C	-	Benefit Cost ratio
Ca	-	Calcium
cm	-	Centi metre
Cu	-	Copper
DAS	-	Days after sowing
dSm^{-1}	-	Deci Siemens per meter
EC	-	Electrical conductivity
et al	-	And others
Fe	-	Iron
FYM	-	Farm yard manure
g	-	Gram
i.e	-	That is
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare
L	-	Litres
M	-	Metre
Mg	-	Magnesium
Mg ha^{-1}	-	Mega gram per hectare
mm	-	Milli Metre
Mn	-	Manganese
MOP	-	Muraite of potash
MSL	-	Mean Sea Level
N	-	Nitrogen
OC	-	Organic Carbon
P	-	Phosphorus
ppm	-	Parts per million
RBD	-	Randomized Block Design
S	-	Sulphur
Zn	-	Zinc

Introduction

I. INTRODUCTION

Black gram (*Vigna mungo*) or urad is one of the major pulse crop grown throughout India and India contributes 70% of the black gram production of the world. It is considered as an important source of protein in developing countries like India. Leguminous crops like black gram also can enhance the available nitrogen content in soil which will benefit subsequent crops. Besides, the cultivation of black gram has become more remunerative due to high price and changing domestic economy in rural areas resulting in increased demand for the commodity.

In India black gram is cultivated in an area of 3.5 m. ha and the production is 2.1 m.t (NCAER, 2016). The average productivity is low and the production is not sufficient to meet the per capita requirement. During 2016-2017, 4.68 lakh t of black gram was imported to India to meet the domestic demand. It is mainly grown under rainfed condition with poor management practices and low inputs. In Kerala, the cultivation of black gram is very limited or negligible. The summer rice fallows of traditional rice growing tracts are the potential areas for pulse cultivation in Kerala. Inclusion of short duration low water requiring legumes like black gram offers excellent opportunity to utilize residual soil moisture and nutrients in rice fallows. These areas can be effectively utilized for short duration pulses like black gram and green gram during summer season.

Conservation agriculture is gaining momentum now-a-days. It ensures minimum soil disturbance by reducing the disruption of soil structure, composition and biodiversity. It provides increased profit, sustainable production, conservation of environment, less energy input, less labour requirement, soil moisture conservation and reduced erosion. The adoption of conservation tillage can improve soil porosity and available water holding capacity which enhance edaphic environment and regulate aeration. Mulching and drip irrigation are water saving technologies in crop production.

Mulching is the application of materials like plant residues, green leaves, straw or polythene sheet over the surface of soil to prevent evaporation from the soil surface, to have desired soil temperature and to reduce weed growth. In agriculture, 45% yield loss is through weeds and by the use of mulches crop-weed competition can be reduced which ensure weed management at a very low cost. Increased hydrothermal conditions under the mulch increases the microbial activity and the carbon and nitrogen transformations in soil with enhanced soil nutrient status.

The drip irrigation systems have proved their superiority over other conventional methods owing to its precise and direct application of water in the root zone with a considerable saving in fertilizer and water. Mulching contributed to the crop production by influencing soil productivity, weed control and moisture conservation.

The proposed project will help to develop technologies to enhance the productivity and tap the maximum yield potential of black gram especially in summer rice fallows. Hence, this experiment was undertaken with the objectives of studying the effect of reduced tillage practices on yield of black gram in rice fallows and testing the feasibility of mulch cum drip irrigation practices under conservation tillage in rice fallows.

Review of Literature

II. REVIEW OF LITERATURE

Pulses act as a major source of protein in human nutrition. The combination of cereals and pulses form a balanced diet which provides most of the essential nutrients to human body. But the production and supply of pulses is not enough to meet the domestic demand which leads to the hike in price of pulses. Hence, by improving the productivity of pulses the supply of pulses can meet the demand.

2.1. Rice fallows for pulse production

In India about 11.695 m ha area of rice kept fallow during third crop season. These are potential areas for pulse production. Mutnal *et al.* (1995) compared the performance of 16 crops in rice fallows using only residual moisture and reported that cereals like maize, wheat and sorghum gave poor performance, while field pea and cow pea provided maximum grain yield and cowpea and black gram with highest net income to farmers in wetland rice fallows. Similarly, Kar and Kumar (2009) grew green gram, black gram, lathyrus and pea in the rice fallows of north east India using residual soil moisture and every crop performed well with limited input supply. This proves that rice fallows are potential areas for pulse production.

Singh *et al.* (2016a) concluded that different management practices like selection of appropriate varieties of pulses, residue retention, conservation agriculture, mulching, zero tillage, lifesaving irrigation, foliar nutrition, relay cropping etc. help to enhance the productivity of pulses and rice when pulses are growing in rice fallows.

Amarasingha *et al.* (2017) also reported that, growing a short duration crop like mung bean during third season in rice fallows without using any inorganic fertilizers and irrigation boosted the overall productivity of the system with the exploitation of residual soil moisture in the fallows.

2.1.1. Effect of pulses on soil nutrient status

Sharma *et al.* (2000) explained that the cultivation of mung bean in rice fallows and incorporation of its residues in field increased the organic carbon and available nitrogen and phosphorus in soil. Zhao *et al.* (2015) experimented similar things in south east china and found that growing legumes after two rice crop in a year can reduce the annual nitrogen input by 55%. The incorporation of legume residues in the rice fields substitute 25% of the chemical nitrogen by leguminous nitrogen.

Similarly, Xing *et al.* (2017) conducted an experiment by including a grain legume in a cereal based cropping system and observed that field pea provided 25-60 kg N/ha to the following wheat production. The study also indicated that residues of legumes get decayed only within two years since the legume fixed nitrogen had been available for the following two years of crop production.

Rice-rice-legume rotation ensure beneficial returns to farmers due to improved yield, less expenditure on fertilizers, reduced loss of nitrogen from soil and significant decline in nitrogen pollution (Zhao *et al.,* 2015).

2.2. Conventional tillage VS Conservation tillage

Tillage practices can influence the physical, chemical and biological properties of soil. With the growth of agriculture different types of tillage practices also developed in the world. In modern agriculture we always prefer tillage with minimum soil disturbance (conservation tillage) for crop production. Even though, conventional tillage is the most adopted tillage practice in agriculture. According to Singh *et al.* (2016b) conservation agriculture based management practices such as minimum tillage, zero tillage and residue retention may hold potential to increase soil health, yield and profits.

2.2.1. Effect of tillage on growth and yield

Both of these tillage systems can make different types of effects on growth and yield of crops. Many studies had taken place comparing the effects of conventional and conservation tillage.

In the case of growth rate of crops under different tillage practices, Peter, (2008) conducted tillage experiments in cassava and reported that the growth rate of cassava was always higher in the tilled fields than zero tilled fields. Leaf Area Index is an important growth character of pulse crops. So the effect of tillage and mulching in Leaf Area Index was studied by Henry and Chinedu (2014). They reported that the Leaf area index of cow pea exhibited maximum value from tilled and mulched fields (2.82–4.05) than tilled un-mulched, untilled mulched and untilled un-mulched fields of cow pea. They also compared the dry matter production of cow pea from tilled and untilled plots and found that the dry matter production from tilled plots was higher than untilled plots. The better distribution and retention of soil water after tillage and mulching improved this yield of cow pea in that fields.

The response of crops to fertilizer application can vary with tillage systems adopted. Kang *et al.* (1982) described that the yield of maize from tilled fields was almost double than that of non-tilled plots under limited supply of nitrogen. When adequate nitrogen is supplied the yields from tilled and non-tilled plots were almost same.

In sorghum, Guzha (2004) reported higher yield from tilled plots than untilled plots due to high water retention in the tilled plots. The yield advantage from no tilled plots will be obtained only after few years of no tillage practice. But, Kar and Kumar (2009) studied the yield of lathyrus, black gram, pea and green gram in rice fallows during summer with reduced tillage and conventional tillage practices. They found that all the 4 crops gave 34-44% increase in yield under reduced tillage than other. Similarly, Reza *et al.* (2015) compared the yield of cowpea- millet intercropping system under 3 different tillage practices like no tillage, reduced tillage and conventional tillage. The result showed that the yield of cow pea was highest under no-tillage treatment. Yunhui *et al.* (2016) also said that Eight years of continuous conservation tillage improved the yield of wheat and maize by 10% and 17% respectively in rainfed regions of China.

2.2.2. Effect of tillage on soil moisture content

In rainfed agriculture, tillage practices has got an important role in controlling soil moisture content. Bescansa *et al.* (2006) explained that the available water holding capacity of soil with no tillage was higher than that of conventional tillage. Alvarez and Steinbach (2009) also found that fields with reduced tillage or no tillage had a higher level of soil water content than that of conventionally tilled fields of Argentine Pampas. In a study comparing conventional tillage with minimum tillage lasted for 12 years revealed that the minimum tillage had increased plant available water content and water holding capacity than conventional tillage in top 10cm soil layer (Kaurin *et al.*, 2015). Similarly, TerAvest *et al.* (2015) reported that the soil water content in the top 20cm layer of soil was 34% higher in conservation agriculture fields than conventionally tilled fields of maize, cowpea and pigeon pea. But, Abu-Hamdeh,(2004) had a different opinion that conventional tillage practices in soil increased the proportion of macro and micro pores in soil which leads to an increase in the water holding capacity of soil.

The tillage systems had an effect on saturated hydraulic conductivity of soil in the top 10 cm soil layer and it increased from 1.78 to 3.37, 1.57 to 2.95 and 1.37 to 2.28 (X 10^{-2} cm h^{-1}) under no tillage, reduced tillage and traditional tillage respectively (Kahlon *et al.,* 2013). Canqui *et al.* (2017) concluded that tillage treatments show significant difference in infiltration. Conventional tillage practices had higher rate of infiltration than no tillage under ponded water conditions. Sixty minutes of infiltration in both tillage systems showed 74% higher infiltration rate in fields with conventional tillage than that of fields with no tillage. This is due to the presence of more voids in conventionally tilled soil. But the plant available water content and water retention at any soil depth were same in conventional and no tillage fields.

The water use efficiency differ among crops and tillage practices. Moroke *et al.* (2011) compared the water use efficiency of sorghum, cow pea and sunflower under no tillage and they suggested that the WUE was greatest for sorghum (1.03 kg m^{-3}) followed by cow pea (0.52 kg m^{-3}) and sunflower (0.32 kg m^{-3}). Mishra *et al.* (2012a) compared the WUE of chick pea under three tillage practices like zero tillage, ploughing followed by planking and deep ploughing, and found that the WUE of deep tillage was higher than that of zero tillage since the absorption and retention of moisture in soil profile was higher in deep tillage than in zero tillage. Likewise, an experiment comparing different moisture conservation practices in black gram by Jat *et al.* (2013) in semi-arid tropics revealed that summer deep ploughing increased the WUE of T-9 variety of black gram from 8.8 % to 15% and seed yield by 16% to 21% over shallow tillage due to more infiltration and soil moisture availability in deeply ploughed fields. Contradicting all this results, Yunhui *et al.* (2016) reported that eight years of continuous conservation tillage improved the water use efficiency of wheat by 24% and maize by 15% in rainfed regions of China.

2.2.3. Effect of tillage on soil properties

When studying the effect of two different tillage practices on soil physical properties, comparisons on bulk density is important. Bescansa *et al.* (2006) reported that soil bulk density in the upper 15 cm layer was higher under no tillage than reduced tillage and conventional tillage. In the deeper layers also it was greater under reduced tillage than others. Kar and Kumar (2009) had sown black gram and green gram under three tillage treatments like zero tillage, reduced tillage and conventional tillage in the summer rice fallows of eastern India, and reported that the bulk density of zero- tilled fields (1.54 Mg/m3) was higher than that of others. Alvarez and Steinbach (2009) observed that the bulk density and aggregate stability of soil with reduced and no tillage was higher than that of conventionally tilled soil. The infiltration rate was doubled under no tillage compared to conventional tillage.

Conventional tillage and no tillage fields exhibited no significant difference in the bulk density of soil in the 0-60 cm layer (Angers *et al.*, 1997). Similarly, Canqui *et al.* (2017) reported that there is no difference in bulk density of fields with conventional tillage and reduced tillage. The porosity and saturated hydraulic conductivity were also same under the two tillage systems.

Kaurin *et al.* (2015) conducted a comparison of minimum tillage and conventional tillage for 12 years and the results revealed that the bulk density, porosity and infiltration rate of top soil had no remarkable variation between tillage treatments. But, Singh *et al.* (2016b) conducted a study to compare the physical properties of soil with zero tillage and conventional tillage practices in a rice- maize system. According to their results, the amount of water stable aggregates (>0.2 mm), bulk density and infiltration rate of soil gave a significant improvement under zero tilled direct sown rice- zero tilled maize system than transplanted rice- conventionally tilled maize system. The root mass density was also higher under zero tillage by 20-50% in the top 60 cm layer of soil.

Yadav *et al.* (2015) reported higher soil pH in conventionally tilled plots than no tillage plots under maize- maize- field pea cropping systems. Kibet *et al.* (2016) narrated that in the top 10 cm layer of soil, different tillage systems had no effect on pH of soil. But in the 10-40 cm layer of soil, the pH is increased by 1.9 units in plough tillage and 0.9 units in no tillage. More mixing of lime in soil by tillage is the reason for more pH increase in the plough tilled fields.

The soil temperature may vary with tillage practices. Fabrizzi *et al.* (2005) reported that the mean soil temperature was lower under no tillage than minimum tillage in corn and wheat fields, but maximum soil temperature was higher for minimum tillage.

Kahlon *et al.* (2013) said that, the soil with no tillage had a better structural stability than traditionally ploughed soil. So, long term use of no tillage along with mulch application enhances soil quality. Kurothe *et al.* (2014) compared the effect of no- tillage and conventional tillage on soil erosion and they found that the average soil loss in no- tillage was 37% lesser than that of conventional tillage, and the bulk density of soil was also higher under no-tillage fields. Since soil erosion was found to be less in no tillage, more quality soil can be assured in no tillage field.

Microorganisms are an important part of soil which contributes to soil quality. A rice- rice- pulse based conservation agriculture system with zero tillage throughout the year, showed a significantly higher microbial population in the rhizosphere. The combination of zero tillage with residue retention gave better soil conditions for micro flora (Govindan and Chinnusamy, 2014). An experiment conducted by Singh *et al.* (2015) revealed that zero tilled plots with wheat and soya bean residues showed more bacterial and fungal populations than the plots with conventional tillage. Hence the microbial activity was higher under zero tillage which contributes to improved soil health in zero tilled plots.

2.2.4. Effect of tillage on soil nutrient status

Different tillage practices have significant effect on the nutrient availability in soil. Bescansa *et al.* (2006) said that the soil organic matter content in the top 15 cm layer is higher under no tillage and reduced tillage systems than under conventional tillage in semi- arid climate. Capelle *et al.* (2012) suggested that conservation tillage systems like no tillage and reduced tillage, would effectively resolve the disadvantages of conventional tillage in depleting C stock by increasing the abundance and activity of soil biota. According to Bhattacharyya *et al.* (2015) in the top soil layers zero tilled plots had 24% more labile c pools than conventionally tilled plots and soil compaction was also less in zero tilled plots. Ten years of minimum tillage improved the soil organic carbon by 11% in the top 20 cm soil layer in semi-arid rainfed systems of southern India. (Prasad *et al.,* 2016).

But, according to Angers *et al.* (1997) the content of carbon and nitrogen in the 0-60 cm layer of conventional and no tillage fields showed no significant difference. However, Kibet *et al.* (2016) revealed that the organic matter content in the 10-20 cm depth of soil was higher in the ploughed fields than zero tilled fields of maize- soybean cropping system due to the mixing of crop residues to deeper layers by ploughing. But in the 0-10 cm layer the organic matter was 5 times higher in the non-tilled fields than ploughed fields.

Alvarez and Steinbach (2009) reported that the nitrate nitrogen levels were higher in conventionally tilled plots than no tillage plots. Although, Yadav *et al.* (2015) concluded that the available nitrogen, phosphorus and potassium content was higher under no tillage fields than conventional tillage fields under maize- maize- field pea cropping systems. Samant and Patra (2016) conducted an experiment to find the effect of tillage on nutrient content of soil and they confirmed that maximum available nitrogen, phosphorus and potassium were obtained from zero tilled plots and they yield better than conventionally tilled plots of rice- green gram cropping system under rainfed conditions of Odisha. Zhiqiang *et al.* (2016) also observed 25% increase in total nitrogen content in the top 15 cm layer of soil under no tillage with straw cover than traditional tillage with straw removal.

Phosphorus is an essential element for plant growth. Changes in the phosphorus content in soil significantly affects crop performance. Many experiments dealt with the relation between tillage and phosphorus content in soil. Mullins *et al.*

(1980) reported that the concentration of soil phosphorus was higher in the conventionally tilled fields than in the no tillage plots at top 15 cm layer of soil. The soil potassium levels also reported high in the conventional tillage fields. But, according to Henry and Chinedu (2014) highest phosphorus use efficiency was observed from fields of cowpea with tillage and mulch (72.4 kg/kg P) than from fields without tillage and mulch (36.4 kg/kg P). The conclusions of Yunhui *et al.* (2016) was opposite to this. They reported that eight years of continuous no tillage improved the available phosphorus in top soil by 4% and soil available potassium by 13%. But soil total nitrogen was decreased by 2.3%. Margenot *et al.* (2017) explained that reduced tillage improved the total labile phosphorus in the top 15 cm soil layer. But at 30 cm depth the total phosphorus get reduced due to stratification of soil phosphorus under reduced tillage.

Lavado *et al.* (1999) conducted an experiment in corn, soybean and wheat about the effect of tillage in micronutrients. The concentrations of iron, manganese, nickel and copper were more in conventional tillage plots than zero tilled plots. But zinc, cobalt, lead concentrations were higher in zero tilled fields and selenium, molybdenum and boron exhibited no significant difference between tillage treatments.

2.2.5. Effect of tillage on nutrient content and uptake by plants

Sharp *et al.* (1986) reported lower uptake of nitrogen and higher uptake of phosphorus by maize plants under minimum tillage system than conventional tillage systems. Min *et al.* (2016) compared the effect of conventional tillage and no tillage on the uptake of nitrogen, phosphorus and potassium by rice plants and they found 17-43% less uptake of nitrogen, phosphorus and potassium from the no tillage fields. Martinez *et al.* (2017) analysed the mineralization and uptake of nitrogen from the conventionally tilled and no tillage fields of wheat and revealed that the mineralisation of nitrogen and content of nitrogen was found to be higher from the no tillage fields. But it did not resulted in the higher uptake of nitrogen.

2.3. Mulching

Mulches are defined as materials that are applied to soil surface, as opposed to materials that are incorporated into the soil profile (Chalker-Scott, 2007). Since 2000, the use of plastic mulches had increased in the field of agriculture. It is called plasti-culture (Kyrikou and Briassoulis, 2007)

2.3.1. Effect of mulching on plant growth

Plastic mulching helped to make a micro climate suitable for crop growth (Otsuki *et al.,* 2000). Mulching of cropped area reduced the cost for weed management and pest management (Jabran *et al*., 2015). In green gram, wheat straw mulch produced more number of branches per plant than polythene mulch and non-mulch treatments. The number of pods per plant and 100 grain weight were similar in straw and polythene mulched fields. But the number of grains per pod was higher in straw mulching (Chavan *et al.,* 2014).

Xie *et al*. (2005) conducted an experiment to find the effect of various mulches on crop growth and reported that, leaf area and leaf area index increased which resulted in high rate of evapotranspiration from mulched fields after tillering. The mulched plots acquired maximum leaf area index 10 days earlier than non-mulched plots and it was clearly due to early germination of seeds in plastic mulched plots than others.

Gupta and Gupta (1983) reported increased root growth, nodulation, shoot growth and plant water status from mulched fields of green gram and cluster bean. Samui and Ambhore (2000) found that the shoot and root dry weight of ground nut was higher in mulched plots than non-mulched plots at 30 and 60 days after sowing.

2.3.2. Effect of mulching on yield

The grain and straw yield of maize and green gram where higher from mulched plots than non-mulched plots (Gaur and Mukherjee, 1980). Xie *et al.* (2005) reported that the yield of wheat from plastic mulched plots was higher than from others due to extraction of more soil water from mulched fields. Chick pea showed 10.6% increase in seed yield from mulched plots (Singh *et al.,* 2010). Malekar and Atakare (2011) found that the yield of ground nut from polythene mulched plots show 10-25% increase in yield than non-mulched plots. Chavan *et al.* (2014) reported similar trend in yield of green gram from straw mulched and polythene mulched fields. According to an experiment conducted at IISR, Kozhikode maximum yield of ginger was obtained when white or ash coloured mulches were used (Thankamani *et al.,* 2016).

2.3.3. Effect of mulching on soil physical properties

Different rates of organic mulching raised the total porosity by 35–46%. Bulk density was not affected by mulch (Mulumba and Lal, 2008). Jordan *et al.* (2010) reported that mulching improves soil structure, soil aeration and organic matter content in soil. Seven years of continuous plastic film mulching increased the proportion of water stable macro aggregates (>.25 mm) of soil by 16% in the top 15 cm layer. Gradual increase in the root mass and microbial activity in soil holds the reason behind it (Wang *et al.*, 2017).

There are so many other effects for mulching in soil. Mulching improved the growth of fungi, bacteria, actinomycetes and azotobacter in mulched fields of maize and green gram (Gaur and Mukherjee, 1980). Organic mulching materials like hay, straw etc. always leads to weed problems in the field. (Chalker-Scott, 2007). Plastic mulching in both ridges and furrows increased the temperature of the upper soil layers (Li-Min *et al.*, 2015).

2.3.4. Effect of mulching on soil nutrient status

Gaur and Mukherjee (1980) described that the mulching of fallow and cropped fields of maize and green gram had improved the amount of organic carbon, humin and humus carbon in soil. The content of nitrate and ammoniacal nitrogen and available phosphorus was also higher in the mulched fields.

Mulching the field for 30-60 DAS is beneficial to improve microbial biomass and nutrients. Mulching the field throughout the crop duration will increase the accumulation of total mineral nitrogen in soil at the time of harvest (Li *et al.*, 2004a). Seven years of continuous plastic mulching decreased the soil pH by 0.19 to 0.54 units because of the buildup of soil nitrate in soil due to stimulated nitrogen mineralization (Wang *et al.*, 2017).

Plastic film mulching helped to cut back salt accumulation in rhizosphere (Dong *et al.*, 2009). Polythene mulching declines the soil organic matter content and increases greenhouse gas emission (Cuello *et al.*, 2015). Organic materials used as mulch get decomposed and add nutrients to soil. This is an advantage of organic mulch over plastic mulch (Kader *et al.*, 2017).

Jat and Gautam (2000) reported higher amount of nutrient absorption by crop plants in mulched fields. Idhani and Gautam (2008) revealed that more amount of nutrients from non- mulched plots are removed by weeds in green gram fields.

2.3.5. Effect of mulching on soil moisture status

Mulching of cropped area had an effect on soil moisture depletion. Different rates of organic mulching raised the available water content of soil by 18–35% (Mulumba and Lal, 2008). The mulched plots showed a significantly higher water use efficiency than plots without mulching. (Li *et al.,* 2004b). Soil water retention in the upper soil layers was higher for mulched plots compared to no mulch (Cook *et al.*, 2006). Cultural mulching in chick pea reduced the capillary movement of water to upper soil layers and thereby reduced the loss of water through evaporation (Mishra *et al.*, 2012b). Li-Min *et al.* (2015) discovered that soil moisture content in the 20-40 cm soil layer of mulched plots was 6-32% higher than the non-mulched plots.

When different organic and inorganic materials are available for mulching, Jenni *et al.* (2004) found that plastic mulching is most suitable for moisture conservation than paper mulch. Straw mulching presented higher grain yield and WUE than soil dust mulch and unmulched condition (Sarkar and Singh, 2007). And, plastic film mulching throughout the season increased the water supply capacity of the soil in the semi-arid areas of China (Wu *et al.*, 2017).

Planting of crops on ridges mulched with plastic films allow rain water to flow through furrows and thus it reduced soil runoff (Gan *et al.*, 2013). Plastic mulching had get the capacity to increase crop water use efficiency (Almeida *et al.*, 2015).

2.3.6. Effect of mulching on content and uptake of nutrients by plants

Liu *et al.* (2003) compared the uptake of nutrients by rice from the traditional flooding, plastic mulching and straw mulching soil conditions. The uptake of nitrogen, phosphorus and potassium was higher from the plots with plastic mulching than the traditionally flooded plots. And the addition of nutrients to soil was higher from the straw mulched plots.

Kumar and Dey (2011) reported that, there were 179% increase in the uptake of nutrients under polythene mulched fields with drip irrigation. Adekiya *et al.* (2017) found that the content of nitrogen, phosphorus, potassium, calcium and magnesium in the leaves of okra was higher from the mulched fields compared to the unmulched fields.

Masvaya *et al.* (2017) analysed the uptake of nitrogen from mulched and unmulched fields of maize plants. They discovered a 5-19 % reduction in the uptake of nitrogen from the mulched fields due to less mineralization of nitrogen in soil.

2.4. Drip irrigation

The scarcity of water is increasing day by day in all parts of the world and various sectors are competing for the limited supply of water. In this situation, researchers are trying to find alternate technologies to reduce water use or to minimize the wastage of water. Agriculture industry is the one which uses water at a very high quantity. About 70% of global fresh water is used in agriculture. Traditional irrigation practices like basin irrigation, border irrigation, hose irrigation, flooding etc. contributes to wastage of valuable water. In this context researchers introduced micro irrigation systems as an innovative approach. Traditional irrigation practices were labour intensive and less costly. But micro irrigation requires high initial investment but less labour. In drip irrigation, less amount of water is applied per plot without causing any reduction in yield (Kooij *et al.,* 2013). Fertilizers also can be applied through this micro irrigation systems.

2.4.1. Effect of drip irrigation on plant growth

Howell *et al.* (1997) compared the effect of surface and sub-surface drip irrigation systems and stated that the crop performance and yield of maize was not much differed among the two irrigation methods. Patel *et al.* (2009) conducted a study to find the effect of drip irrigation on okra and reported that, when 80% of evaporation from the field was supplemented through drip irrigation, the length and girth of pod, number of pods per plant and pod weight per plant showed a significant improvement.

Singh *et al.* (2009) reported that the plant height, leaf area index and dry matter production from drip irrigated fields was significantly higher than that from surface irrigated fields. According to Patel *et al.* (2009) the emergence and growth of weeds was very less in drip irrigated plots than surface irrigated plots of okra.

Quin *et al.* (2016) compared the leaf area index of maize leaves in drip irrigated and border irrigated fields and reported that the LAI of drip irrigated plots was higher than that of border irrigated plots during initial growth period. Colak *et al.* (2017) concluded that in egg plants highest leaf area index was obtained when water was supplied through surface drip irrigation at three days interval compared to other treatments.

2.4.2. Effect of drip irrigation on yield

Patel *et al.* (2009) found that maximum pod yield of okra was obtained from the plots where 80% of Epan was supplemented through drip irrigation. It was 46% higher than the yield from surface irrigation. Similarly, Rekha *et al.* (2009) reported 50% higher yield of okra from drip irrigated fields than furrow irrigated fields. Drip irrigation always maintained an optimum moisture in rhizosphere and energy required to extract nutrients from the soil was less which led to maximum utilization of nutrients in soil and higher yield.

Mukherjee *et al.* (2010) irrigated the tomato field at 25mm and 50 mm cumulative pan evaporation by drip system and compared them with rainfed condition. The field irrigated at 25mm of cumulative pan evaporation recorded 7-30% higher fruit yield than fields irrigated at 50mm cumulative pan evaporation and rainfed condition. This helped for effective nutrient use, high rate of photosynthesis and better performance of plant translocation system which contributed to higher fruit yield.

Quin *et al.* (2016) reported higher yield and biomass of maize under drip irrigation than border irrigation. According to Colak *et al.* (2017), the level of irrigation, interval of irrigation and method of irrigation influenced the yield of eggplant. The yield and quality of eggplant was higher when water was supplied through subsurface drip system at 3 days interval compared to other methods of irrigation.

The rate and interval of irrigation also had a crucial role in crop performance. Irrigation at 12.5mm cumulated pan evaporation gave higher yield of potato than that at 25 mm cumulated pan evaporation (Stylianou and Orphanos, 1981). Ertek *et al.* (2006) compared the yield of cucumber where it is irrigated at 4 days and 8 days interval. The quantity of water used is determined by Class A pan evaporimeter with three plant-pan coefficients 0.5, 0.75 and 1. The highest fruit yield of cucumber was obtained from fields irrigated at 8 days interval with a Kcp value of 1. Similarly, Rekha *et al.* (2009) experimented various irrigation levels in okra. Highest pod yield of okra was obtained from fields with drip irrigation at 1.00 Epan than fields with drip irrigation at 0.75 Epan and 0.5 Epan.

Irrigation of crops according to the pan evaporation rates helps to reduce wastage of water. Singh *et al.* (2009) conducted an experiment on tomato with different irrigation levels like drip irrigation at 100% pan evaporation, 80% pan evaporation, 60% pan evaporation, and surface irrigation. The results revealed that the fruit yield from the fields with drip irrigation at 80% of pan evaporation was higher than that from other treatments. Liu *et al.* (2013) scheduled irrigation of wheat using pan evaporation with different coefficients from 0.5 to 1.5 and the results showed that the yield of wheat was highest from fields with coefficient 1.25.

2.4.3. Effect of drip irrigation on soil physical properties

Guo-hua *et al.* (2015) conducted an irrigation experiment in wheat and found that the bulk density of soil at harvest of wheat was higher in border irrigated fields (1.35 g/cm3) than sprinkler irrigated (1.26 g/cm3) and surface drip irrigated fields (1.22 g/cm3), where the initial bulk density of the field was 1.10 g/cm3. Higher water ponding depth in border irrigation resulted in higher bulk density.

2.4.4. Effect of drip irrigation on soil moisture status

The soil water content at 100cm depth of soil showed greater variability in border irrigated plots whereas the soil water content in drip irrigated plots showed low variability because only small amount of water was applied through drip irrigation in maize. The leakage of water under border irrigation was much higher than that under drip irrigation (Quin *et al.,* 2016). According to Colak *et al.* (2017), compared to surface drip irrigation, the water applied through sub-surface drip irrigation is less because, the rate of evapotranspiration is less in sub-surface drip irrigation.

Patel *et al.* (2009) reported that the water use efficiency was higher in drip irrigated plots than surface irrigated plots. Singh *et al.* (2009) reported higher water use efficiency in fields with drip irrigation at 80% of pan evaporation of tomato than other surface irrigated fields. Mukherjee *et al.* (2010) compared the water use efficiency of tomato fields irrigated at 25mm cumulative pan evaporation by drip system, 50mm cumulative pan evaporation by drip system and rainfed condition. The results showed that the water use efficiency from fields irrigated by drip system at 50mm CPE gave highest water use efficiency than rainfed condition and irrigation at

25mm CPE. Similarly, Cabrera *et al.* (2016) reported higher irrigation water use efficiency in surface drip irrigated fields (7 kg/m^3) of potato than sub surface drip irrigated (6 kg/m^3) and seepage irrigated (4 kg/m^3) fields. The reason for this was higher water use under seepage irrigation for plant growth.

2.4.5. Effect of drip irrigation on soil and plant nutrient status

Under traditional methods of irrigation, deep percolation and surface run off of water causes a substantial loss of nutrients from plant root zone and fertilization causes the pollution of water in surface and ground water sources of the region, which is a threat to human life. So by the use of drip irrigation the availability of nutrients increases in soil which will reduce the quantity of fertilizer to be applied during crop growth.

Praharaj *et al.* (2017) conducted drip irrigation studies on pigeon pea and reported that the uptake of nutrients like nitrogen, phosphorus and potassium by plants higher under drip irrigated plots with improved nutrient availability. Patel *et al.* (2012) also reported higher uptake of nitrogen, phosphorus and potassium from drip irrigated fields than furrow irrigated fields. They explained that, the higher values of nitrogen uptake with drip irrigation methods might be due to increase in solubility of nutrients with increasing water content in soil. The conductivity of the soil increases when soil moisture content is high and under such condition, mass flow transport of nutrients increases which leads to higher uptake. Ya-dan *et al.* (2017) conducted a study on tomato using drip irrigation and they found that the nitrogen use efficiency increased with increase in the amount of water applied through drip irrigation. Similarly, Aujla *et al.* (2007) reported that compared to furrow irrigation, drip irrigation not only reduced the nitrogen supplies, but also increased the nitrogen use efficiency (NUE).

Materials and Methods

III. MATERIALS AND METHODS

The research work on the topic "Tillage and water saving techniques for black gram in rice fallows" was undertaken at the Department of Agronomy, College of Horticulture, Kerala Agricultural University, Vellanikkara during 2015-2017. The details of materials used and methods adopted for the experiment are narrated in this chapter.

3.1 LOCATION

The location of the experiment was at Agricultural Research Station, Mannuthy. Geographically the area is situated at a latitude 10°31'12.9" N, longitude 76°13'14.4" E and altitude of 40.29 m above Mean Sea Level. The experiment was conducted in rice fallows after the harvest of mundakan crop during the period from December 2016 to March 2017.

3.2 SEASON AND WEATHER CONDITIONS

The experimental site enjoys typical humid tropical climate with mean annual rainfall of 198.3 mm during 2016. Mean maximum and minimum temperature during the year were 32.5^0C and 23.9^0 C respectively. Important meteorological parameters recorded during the cropping period are given in appendix I.

3.3 SOIL CHARACTERISTICS

The soil texture of the experimental site is sandy clay loam and belongs to the taxonomical order Oxisol. The soil is acidic with a pH of 5.43. The basic physicochemical properties of the soil are presented in Table 3.1.

Table 3.1. Soil physical and chemical properties before the experiment

Parameters	Value	Method used
a) Mechanical composition		
Coarse sand (%)	27.20	Robinson international pipette method (Piper, 1942)
Fine sand (%)	23.90	
Silt (%)	22.70	
Clay (%)	26.20	
Texture	Sandy clay loam	
b) Chemical properties		
pH	5.43	1: 2.5 soil water ratio and read in pH meter (Jackson, 1958)
EC (micro S)	136.30	Supernatant of 1: 2.5 soil water ratio and read in conductivity meter (Jackson, 1958)
Available nitrogen (kg/ha)	313.60	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg/ha)	25.60	Bray extractant- Ascorbic acid reductant method (Watanabe and Olsen, 1965)
Available potassium (kg/ha)	341.00	Neutral normal ammonium acetate extractant Flame photometry (Jackson,1958)
Organic carbon (%)	0.54	Walkely and Black method, 1934
c) Physical properties		
Bulk density (g/cm^3)	1.24	Keen and Raczksowski, 1921
Maximum Water holding capacity (%)	31.57	Keen and Raczksowski, 1921
Field capacity (%)	15.00	Field method
Permanent wilting point (%)	7.50	Field method
d) Moisture content by weight (%)		
At 5 cm depth	6.90	Thermogravimetric method
At 10 cm depth	8.70	Thermogravimetric method
At 15 cm depth	9.80	Thermogravimetric method

3.4 DETAILS OF THE EXPERIMENT

3.4.1. Design and layout

The experiment was laid out as RBD in split plot replicated thrice. There were 4 main plot treatments with tillage and mulching and 3 subplot treatments with different levels of drip irrigation. The plot size was 20 m^2 and total area under experiment was 0.088 ha. The treatment details are given below.

Table 3.2 Treatment details

Main plots	**Tillage with mulching**
T_1	Conventional tillage with mulching
T_2	Conventional tillage without mulching
T_3	Reduced tillage with mulching
T_4	Reduced tillage without mulching
Sub plots	**Drip irrigation**
I_1	80% EP
I_2	40% EP
I_3	Life saving irrigation

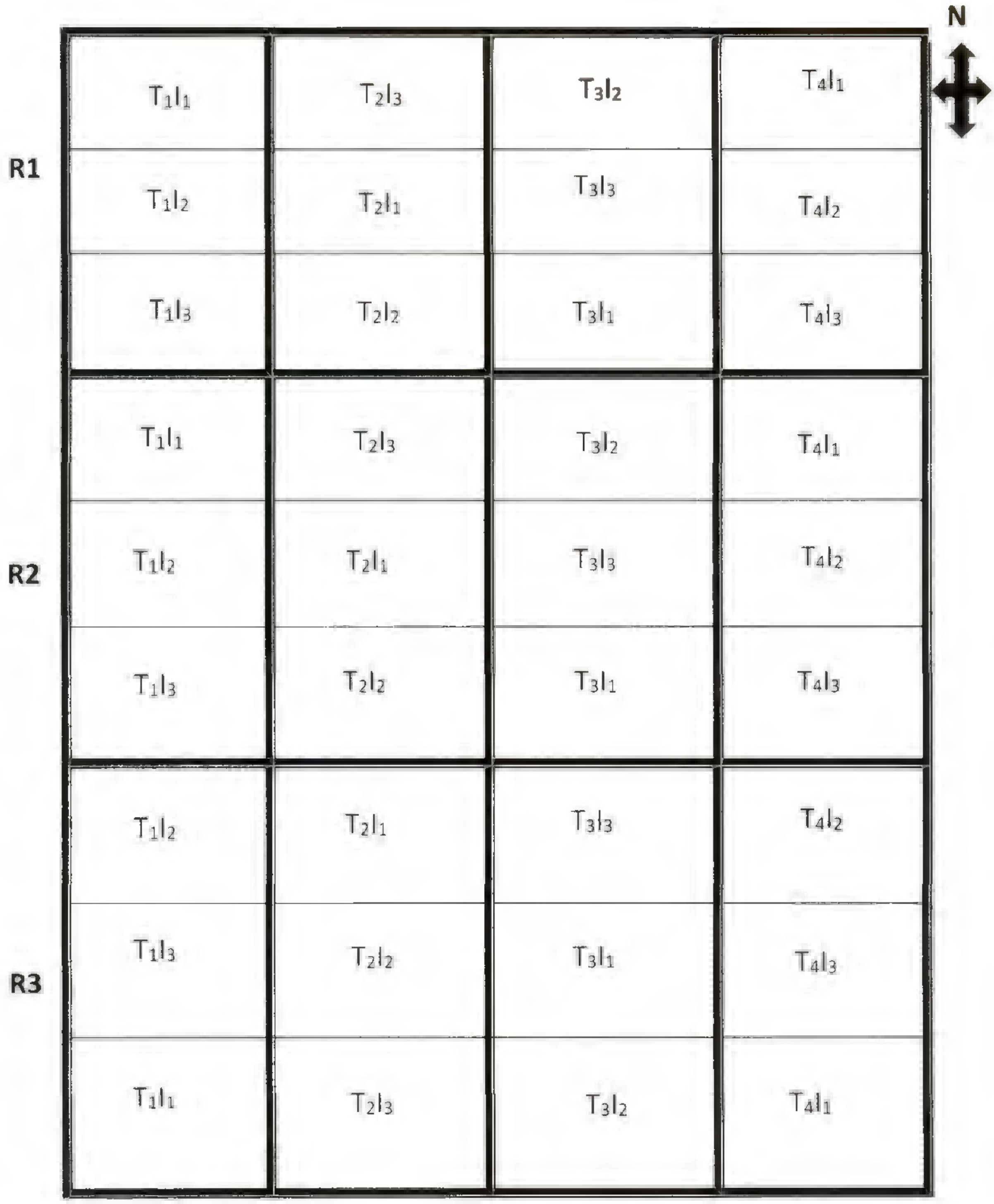
3.4.2 Crop

Crop	: Black gram
Variety	: T-9
Spacing	: 25 X 15 cm
Seed rate	: 20 kg/ha
Date of sowing	: 24-12-2016
Date of 1st harvest	: 18-02-2017
Date of 2nd harvest	: 24-02-2017
Date of 3rd harvest	: 01-03-2017
Duration of the crop	: 70 days

In conventional tillage the field was ploughed three times thoroughly using tractor, pulverized using rotovator and beds were taken. In reduced tillage the field was ploughed only once and beds were taken with minimum soil disturbance. Mulching was done with black polyethylene sheet of 30 micron thickness.

In I_1, irrigation was given at 80% of the daily pan evaporation through drip on alternate days. In I_2, 40 % of the daily pan evaporation was given on alternate days. In I_3, irrigation was given during flowering stage (at 36 DAS) of the crop as life saving irrigation.

Fig 3.1. LAY OUT OF FIELD EXPERIMENT



T_1 : Conventional tillage with mulching
T_2 : Conventional tillage without mulching
T_3 : Reduced tillage with mulching
T_4 : Reduced tillage without mulching

I_1 : 80% EP
I_2 : 40% EP
I_3 : Life saving irrigation

3.5 CROP HUSBANDARY

i) Land preparation and sowing

The land was prepared as per tillage treatments. Beds were prepared and the treatments of mulching and drip were imposed. The seeds of black gram were dibbled at a spacing of 25 X 15 cm.

ii) ***Manures and fertilizers***

Lime was applied at the time of first ploughing at the rate of 250 kg/ha. Before sowing farm yard manure at the rate of 10 t/ha was applied uniformly and incorporated. Urea (46% N), Mussorie Rock Phosphate (20% P_2O_5) and Muriate of potash (60% K_2O) were applied as fertilizers for the nutrient requirement as per POP (20:30:30 kg of N: P_2O_5: K_2O per hectare) of KAU (Crops, 2016).

Half quantity of nitrogen, whole of phosphorus and potash were applied at the time of final ploughing. The remaining nitrogen was applied as foliar spray as urea solution at 2% in two equal split doses on 15th and 30th day after sowing.

iii) After cultivation

Irrigation was given on alternate days as per the treatment.

iv) Pest and disease management

There were the attack of mites and infection of collar rot in the experimental field and control measures were adopted.

v) Harvesting

Harvesting was done at three stages. First harvest was done at 57 days after sowing. 2nd after 63 days and final harvest at 70 days after sowing.

3.6 OBSERVATIONS

3.6.1. Growth characters

Ten plants were randomly selected from each plot and observations on growth was recorded. The following observations were recorded at different growth stages of crop.

i) Plant height

Height of ten plants was measured in cm from ground level to the tip of the longest leaf at 15, 30, 45 and 60 DAS.

ii) No. of branches per plant

The number of branches per plant was counted at 15, 30, 45 and 60 DAS. Ten plants were selected from each plot and number of branches was counted.

iii) Leaf Area Index

Leaf area index is the ratio of leaf area of plant to land area (Watson, 1947). The leaf area of randomly selected plants were measured at 35 DAS and leaf area index was calculated using the formula

$$\text{Leaf Area Index} = \text{Leaf area of plant/ land area}$$

iv) Biomass production

The fresh weight of the uprooted 10 plants from each plot was weighed and recorded immediately after harvest and expressed as g/plant.

v) Dry matter production

Ten plants were uprooted, cleaned and oven dried at 70° C and the dry weight was recorded and expressed as g/plant.

3.6.2. Yield attributes and yield

Ten plants were randomly selected from each plot and observations were recorded.

i) Time for 50% flowering

The number of days taken for 50% flowering was recorded.

ii) Pod length

The length of pods was measured from ten selected plants from each plot after harvest and expressed in cm.

iii) No. of pods per plant

Ten plants were harvested separately from each plot and the total number of pods from each plant were counted.

iv) Number of seeds per pod

Ten plants were selected from each plot. The number of seeds per pod was counted from each plant.

v) 1000 seed weight

From each plot 1000 grains were randomly selected, weighed and recorded as 1000 grain weight.

vi) Yield

The seed yield from each plot was recorded separately and expressed as kg/ha.

3.6.3. *Soil moisture content*

The soil moisture content was determined by thermo gravimetric method. Soil samples were collected from 5, 10 and 15cm depth at 15 days interval using soil auger and fresh weight was recorded. The samples were dried in oven and oven dry weight was recorded. Soil moisture content was determined before planting, 15, 30, 45 and 60 DAS using the following formula.

$$Pw = \frac{Wm - Wd}{Wd} \times 100$$

Pw = percentage of soil moisture by weight

Wm = weight of moist sample

Wd = weight of oven dry sample

3.6.4. *Water Use Efficiency (kg/ha mm)*

Field water use efficiency is the yield of marketable crop produced per unit of water used in the field.

$$WUE = Y/WR$$

Where WUE = Field water use efficiency in (kg/ha mm)

Y = Marketable crop yield in (kg/ha)

CU = Water requirement of the crop in depth (mm)

3.6.5. *Physicochemical properties of soil*

i) **Maximum Water holding capacity**

The water holding capacity is measured using Keen raczkowski box method. The soil samples collected before and after the crop was used to measure water holding capacity using the equation.

Maximum Water holding capacity (%)=

$$\frac{\text{(Weight of keen box with saturated soil} - \text{weight of keen box with air dried soil)} \times 100}{\text{Weight of keen box with air dried soil} - \text{weight of keen box}}$$

ii) Bulk density

Bulk density is an indicator of soil compaction. It is measured using Keen raczkowski box method. The bulk density of soil of each plot before and after the experiment was determined using the equation.

$$B_d \ (g/cm^3) = \frac{\text{weight of keen box with air dried soil} - \text{weight of keen box}}{\text{Volume of keen box}}$$

iii) pH

The pH of the soil before and after the crop was determined in 1: 2.5 soil-water suspension using a pH meter.

iv) EC

The electrical conductivity of soil is measured before and after the crop using EC meter.

v) Organic carbon

Soil samples of each plot were collected, air dried under shade and sieved through 0.5 mm mesh sieve and the organic carbon content (%) of soil was determined using Walkley and Black method (1934).

vi) Available nitrogen content

Soil samples were collected from each plot, air dried and sieved using 2mm mesh sieve before and after the experiment. The available nitrogen content of soil was determined using Alkaline permanganate method (Subbiah and Asija, 1956) and expressed as kg/ha.

vii) Available phosphorus content

Soil samples were collected from each plot, air dried and sieved using 2mm mesh sieve before and after the experiment. The available phosphorus content of soil was determined using Spectrophotometer and expressed as kg/ha.

viii) Available potassium content

Soil samples were collected from each plot, air dried and sieved using 2mm mesh sieve before and after the experiment. The available potassium content of soil was determined using Flame photometer (Jackson, 1958) and expressed as kg/ha.

3.6.6. ***Plant analysis***

Five plants were collected from each plot, oven dried and powdered. The nitrogen, phosphorus and potassium content of the plant samples were determined using standard procedures. The uptake of N, P and K were obtained by multiplying the content of these nutrients with the dry weight of plants and expressed in kg/ha

i) Nitrogen content

The total nitrogen content of the plant was analyzed using Microkjeldhal digestion and distillation method (Jackson, 1958) and expressed as kg/ha.

ii) Phosphorus content

The powdered plant samples were digested using diacid digestion and the phosphorus content was determined by Vanadomolybdo phosphoric yellow color method (Bray and Kurtz, 1945; Watanabe and Olsen, 1965) and expressed as kg/ha.

iii) Potassium content

The powdered plant samples were digested using diacid digestion and the potassium content (kg/ha) was determined using Flame photometer (Jackson, 1958)

3.7. STATISTICAL ANALYSIS

Data generated on various parameters were analyzed using the statistical package MSTAT (Freed, 1986) for analysis of variance. Multiple comparisons among the treatment means were done using critical difference at 5% level of probability.

3.8. ECONOMIC ANALYSIS

Cost of production of black gram under various tillage practices were calculated based on the labour charges of the locality, cost of inputs and treatment costs. The net return per hectare and B:C ratios were also calculated. Initial investment cost of drip irrigation was 2.5 lakhs/ha which is not fully included in B:C ratio since it is a fixed cost. Only the interest on fixed investment and depreciation were included as the cost of laying out drip.

Plate 1. Land preparation

Plate 2. Lime application

Plate 3. Basal application of fertilizers

Plate 4. Layout of drip irrigation system

Plate 5. General view of experimental plot at 15 DAS

Plate 6. General view of the experimental plot at 30DAS

Plate 8. Manual harvesting of black gram

Results

IV. RESULT

The results of the research work on "Tillage and water saving techniques for black gram in rice fallows" conducted in the Dept. of Agronomy, College of Horticulture, Vellanikkara during the year 2016- 2017 are recorded below.

4.1 GROWTH CHARACTERS

4.1.1 Plant height

The height of plants differed significantly among tillage treatments at 15, 30, 45 DAS and at harvest (Table 4.1). At 15 DAS the tallest plants were observed in the treatment of reduced tillage with mulching (T_3) followed by conventional tillage with mulching (T_1) and shortest plants were present in the treatment conventional tillage without mulching (T_2). At 30, 45 and 60 DAS mulched plots of both conventional tillage (T_1) and reduced tillage (T_3) exhibited tallest plants with statistically comparable values at each stage.

The effect of drip irrigation on plant height followed similar trend at all stages of growth. At 15, 30, 45 and 60 DAS, the tallest plants were present in the drip irrigation treatments of 80% (I_1) and 40% EP (I_2) which were on par. Life saving irrigation (I_3) always produced the shortest plants.

The tillage with mulching X drip irrigation interaction was also significant (Table 4.2). At 15 DAS, tallest plants were on mulched plots with reduced tillage and drip irrigation of 80% (T_3I_1) and 40% EP (T_3I_2) and they had statistically comparable values. At 30 and 45 DAS, higher values of plant height was observed for treatment combinations of conventional tillage with mulching and reduced tillage with mulching with drip irrigation at 80% EP and 40% EP were statistically on par. At 60 DAS, all the above treatment combinations except reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2) exhibited tallest plants with statistically comparable values. Shortest plants were produced from unmulched plots with conventional tillage and life saving irrigation (T_2I_3) at all stages of growth.

4.1.2. Number of branches per plant

The data on number of branches per plant are given in Table 4.3. Tillage treatments had significant effect on number of branches per plant at all stages of growth. The number of branches per plant followed almost similar trend at fortnightly interval. At 15, 45 and 60 DAS, the treatments viz. reduced tillage with mulching (T_3) and conventional tillage with mulching (T_1) exhibited highest number of branches per plant with statistically comparable values. At 30 DAS, best treatment was reduced tillage with mulching (T_3). Number of branches varied significantly with levels of drip irrigation. AT 15 DAS, best treatments were Drip irrigation at 40% (I_2) and 80% EP (I_1) which were on par and continued to be the same trend at 30, 45 and 60 DAS.

Tillage with mulching X drip irrigation interaction effect was also found to be significant (Table 4.4). At 15 DAS, best treatment combination was reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1). However, it was on par with conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1), reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2) and conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2). At 30 and 45 DAS, higher number of branches were observed in the treatment of reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2) and conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) which were on par. At 60 DAS, best treatment combination was conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) which was comparable with reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1). Conventional tillage without mulching and life saving irrigation (T_2I_3) treatment recorded the lowest number of branches at 15 and 30 DAS and reduced tillage with mulching and life saving irrigation (T_3I_3) was the lowest at 45 and 60 DAS.

4.1.3. Leaf Area Index

The data pertaining to Leaf Area Index are presented in Table 4.5. Leaf Area Index differed significantly among tillage treatments. The plants receiving conventional tillage with mulching (T_1) exhibited significantly higher Leaf Area Index than all other treatments. The next best treatments were reduced tillage with mulching (T_3) and conventional tillage without mulching (T_2) which were statistically on par.

The three drip irrigation levels also exhibited significant difference of LAI. Drip irrigation at 80% EP (I_1) was recorded maximum LAI of 3.29 followed by drip irrigation at 40% EP (I_2) and life saving irrigation (I_3) with LAI of 2.08 and 0.68 respectively.

The interaction between tillage with mulching treatments and drip irrigation was also significant with respect to LAI (Table 4.6). Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) exhibited significantly higher value of LAI (3.22) than all other treatments, while conventional tillage without mulching and life saving irrigation (T_2I_3) had the lowest LAI (0.5).

4.1.4 Biomass production per plant

The tillage treatments differed significantly with respect to biomass production per plant. From Table 4.5, it is clear that conventional tillage with mulching (T_1) recorded maximum biomass production followed by reduced tillage with mulching (T_3). Least biomass production was from plots of reduced tillage without mulching (T_4).

Biomass production differed significantly among drip irrigation levels. Drip irrigation at 80% EP (I_1) recorded the highest biomass production and it was on par with drip irrigation at 40% EP (I_2). Least biomass production was from life saving irrigation (I_3).

Tillage with mulching X drip irrigation interaction was also significantly different with respect to biomass production (Table 4.6). Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) had the highest biomass production and it was on par with reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1). Lowest biomass production was obtained from the treatment combination of conventional tillage without mulching and life saving irrigation (T_2I_3).

4.1.5 Dry matter production per plant

Dry matter production per plant varied significantly among tillage treatments. From Table 4.5 it is clear that conventional tillage with mulching (T_1) recorded the highest dry matter production per plant followed by reduced tillage with mulching (T_3). Least dry matter production was observed in reduced tillage without mulching (T_4).

Drip irrigation levels also exhibited significant difference with respect to dry matter production per plant. Drip irrigation at 80% EP (I_1) and drip irrigation at 40% EP (I_2) were on par with higher dry matter production. Lowest dry matter production was from life saving irrigation (I_3) treatments.

The interaction effect was significantly differed (Table 4.6). Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) recorded the highest and treatment combination of reduced tillage without mulching and life saving irrigation (T_4I_3) recorded the lowest dry matter production among the treatment combinations.

Table 4.1 Effect of tillage with mulching and drip irrigation levels on plant height (cm) of black gram at different stages of growth

Treatment	15 DAS	30 DAS	45 DAS	60 DAS
Main plots - Tillage with mulching				
Conventional tillage with mulching (T_1)	12.51	22.70	27.86	29.16
Conventional tillage without mulching (T_2)	10.97	19.46	22.94	23.50
Reduced tillage with mulching (T_3)	13.79	22.60	26.90	27.82
Reduced tillage without mulching (T_4)	11.78	19.93	23.34	23.84
CD (P=0.05)	**0.65**	**1.92**	**3.00**	**3.36**
Sub plots - Drip irrigation				
Drip irrigation at 80% EP (I_1)	12.71	23.53	28.68	29.96
Drip irrigation at 40% EP (I_2)	12.48	22.40	26.99	27.95
Life saving irrigation (I_3)	11.59	17.58	20.12	20.33
CD (P=0.05)	**0.48**	**1.24**	**1.90**	**2.08**

Table 4.2 Interaction effect of tillage with mulching and drip irrigation levels on plant height (cm) of black gram at different growth stages

Treatment combinations	15 DAS	30 DAS	45 DAS	60 DAS
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	12.63	25.57	30.20	31.43
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	12.60	24.43	32.47	34.87
Conventional tillage with mulching and life saving irrigation (T_1I_3)	12.30	18.20	20.90	21.17
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	11.33	21.03	25.37	26.13
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	11.47	21.20	25.10	25.80
Conventional tillage without mulching and life saving irrigation (T_2I_3)	10.10	16.13	18.37	18.57
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	14.50	25.20	30.37	31.50
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	13.77	23.77	28.80	30.23
Reduced tillage with mulching and life saving irrigation (T_3I_3)	13.10	18.83	21.53	21.73
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	12.37	22.33	26.50	27.33
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	12.10	20.30	23.87	24.33
Reduced tillage without mulching and life saving irrigation (T_4I_3)	10.87	17.17	19.67	19.87
CD (P=0.05)	**0.96**	**2.49**	**3.80**	**4.16**

Table 4.3 Effect of tillage with mulching and drip irrigation levels on number of branches per plant of black gram at different stages of growth

Treatment	15 DAS	30 DAS	45 DAS	60 DAS
Main plots - Tillage with mulching				
Conventional tillage with mulching (T_1)	1.50	7.11	9.60	9.91
Conventional tillage without mulching (T_2)	1.16	6.30	8.26	8.38
Reduced tillage with mulching (T_3)	1.63	7.53	9.92	10.01
Reduced tillage without mulching (T_4)	1.20	6.87	8.76	8.77
CD (P=0.05)	**0.21**	**0.39**	**0.81**	**0.90**
Sub plots - Drip irrigation				
Drip irrigation at 80% EP (I_1)	1.47	7.69	10.32	10.58
Drip irrigation at 40% EP (I_2)	1.48	7.61	10.03	10.12
Life saving irrigation (I_3)	1.17	5.56	7.06	7.12
CD (P=0.05)	**0.12**	**0.33**	**0.47**	**0.46**

Table 4.4 Interaction effect of tillage with mulching and drip irrigation levels on no. of branches per plant of black gram at different stages of growth

Treatment combinations	15 DAS	30 DAS	45 DAS	60 DAS
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	1.70	8.73	12.07	12.73
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	1.57	7.23	9.80	9.97
Conventional tillage with mulching and life saving irrigation (T_1I_3)	1.23	5.37	6.93	7.03
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	1.20	6.93	9.27	9.57
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	1.37	6.67	8.60	8.60
Conventional tillage without mulching and life saving irrigation (T_2I_3)	0.90	5.30	6.90	6.97
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	1.77	8.13	10.90	10.97
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	1.70	9.00	12.10	12.30
Reduced tillage with mulching and life saving irrigation (T_3I_3)	1.43	5.47	6.77	6.77
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	1.20	6.97	9.03	9.03
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	1.30	7.53	9.60	9.60
Reduced tillage without mulching and life saving irrigation (T_4I_3)	1.10	6.10	7.63	7.67
CD (P=0.05)	**0.24**	**0.66**	**0.94**	**0.92**

Table 4.5 Effect of tillage with mulching and drip irrigation levels on Leaf Area Index, biomass (g/plant) and dry matter production (g/plant) of black gram

Treatments	**Leaf Area Index**	**Biomass production**	**Dry matter production**
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	3.26	24.18	12.65
Conventional tillage without mulching (T_2)	1.65	12.57	6.16
Reduced tillage with mulching (T_3)	1.75	20.16	10.35
Reduced tillage without mulching (T_4)	1.41	10.30	4.70
CD (P=0.05)	**0.15**	**2.17**	**0.90**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	3.29	18.95	10.69
Drip irrigation at 40% EP (I_2)	2.08	18.61	9.95
Life saving irrigation (I_3)	0.68	12.84	4.75
CD (P=0.05)	**0.08**	**1.53**	**0.81**

Table 4.6 Interaction effect of tillage with mulching and drip irrigation levels on Leaf area index, biomass (g/plant) and dry matter production (g/plant)

Treatment combinations	**LAI**	**Biomass production**	**Dry matter production**
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	3.22	27.62	16.40
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	2.56	23.77	14.12
Conventional tillage with mulching and life saving irrigation (T_1I_3)	1.00	21.15	7.43
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	3.01	15.60	7.60
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	1.43	13.37	7.23
Conventional tillage without mulching and life saving irrigation (T_2I_3)	0.50	8.73	3.65
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	2.55	26.25	13.82
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	2.12	21.90	12.37
Reduced tillage with mulching and life saving irrigation (T_3I_3)	0.60	12.33	4.87
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	1.82	11.57	4.93
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	1.80	10.18	6.10
Reduced tillage without mulching and life saving irrigation (T_4I_3)	0.60	9.15	3.07
CD (P=0.05)	**0.17**	**3.05**	**1.61**

4.2. YIELD ATTRIBUTES AND YIELD

4.2.1. Time for 50% flowering

The time taken to complete 50% flowering is arranged in Table 4.7. All of the tillage treatments were statistically comparable with respect to time for 50% flowering. Even so, reduced tillage with mulching (T_3) completed 50% flowering earlier than all others followed by conventional tillage with mulching (T_1).

Time for 50% flowering differed significantly among drip irrigation levels. Life saving irrigation (I_3) attained 50% flowering earlier than the other two treatments. Drip irrigation at 80% EP (I_1) and 40 % EP (I_2) had comparable values and completed 50% flowering at 35 DAS.

The interaction effect was also significantly different (Table 4.8). Reduced tillage with mulching and life saving irrigation (T_3I_3) and conventional tillage with mulching and life saving irrigation (T_1I_3) completed 50% flowering at 30 DAS which were earlier than all other treatment combinations.

4.2.2. Pod length

The length of pods differed significantly among tillage treatments. From Table 4.7 it is clear that the longest pods were produced in mulched plots under reduced tillage (T_3) (4.26 cm) and the shortest pods by conventional tillage without mulching (T_2) which was comparable with reduced tillage without mulching (T_4) with pod length of 3.82 and 3.75 cm respectively. Among drip irrigation levels, drip irrigation at 80% EP (I_1) and 40% EP (I_2) were on par and produced the longest pods of 4.15 cm and 4.06 cm length.

The tillage with mulching and drip irrigation interaction was also significant (Table 4.8). Longest pods were present in the treatment combination of reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1). However it was on par with reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2) and treatment combination of conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1). Shortest pods were observed from the combination of reduced tillage without mulching and life saving irrigation (T_4I_3).

4.2.3. Number of pods per plant

Total number of pods produced per plant is depicted in Table 4.7. Tillage treatments had significant effect on the number of pods produced per plant per plot with maximum number of pods (14.02) by the plants in the mulched plots under conventional tillage (T_1). Lowest number of pods per plant (7.00) was obtained from unmulched plots with reduced tillage (T_4). Number of pods per plant differed significantly among drip irrigation levels also. Drip irrigation at 80% EP (I_1) gave maximum number of pods (13.48) and minimum (5.16) from life saving irrigation (I_3).

The interaction effect was also found to be significant (Table 4.8). Among the twelve treatment combinations conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) had the highest number of pods. The least number of pods was from unmulched plots with reduced tillage and life saving irrigation (T_4I_3).

4.2.4. Number of seeds per pod

The tillage treatments varied significantly with respect to the number of seeds per pod (Table 4.9). The number of seeds per pod from mulched plots under reduced tillage (T_3) was comparable with that of mulched plots under conventional tillage (T_1) (6 and 5.87 respectively). The number of seeds per pod from conventional tillage without mulching (T_2) and reduced tillage without mulching (T_4) was on par.

Among the drip irrigation levels, drip irrigation at 80% EP (I_1) and drip irrigation at 40% EP (I_2) were on par. Life saving irrigation (I_3) produced the least number of seeds per pod among irrigation levels.

The tillage with mulching X drip irrigation interaction was significant (Table 4.10). The maximum number of seeds per pod was produced by reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2). And, it was on par with treatment combinations of conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1), reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1) and reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1).

4.2.5. 1000 seed weight

All of the tillage treatments were statistically comparable with respect to 1000 seed weight. However, reduced tillage without mulching (T_4) recorded the highest 1000 seed weight of 61.62 g (Table 4.9). In the case of drip irrigation levels also, all the treatments were on par and drip irrigation at 40% EP (I_2) recorded the highest.

The tillage with mulching X drip irrigation interaction was also on par with respect to 1000 seed weight (Table 4.10). However, the highest 1000 seed weight was exhibited by the treatment combination of reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2) with a weight of 64.4 g.

4.2.6. Yield per hectare

The data regarding the yield per hectare is depicted in Table 4.9. Yield of black gram differed significantly among tillage treatments. Conventional tillage with mulching (T_1) recorded the highest yield of black gram (1339 kg/ha) followed by reduced tillage with mulching (T_3). Lowest yield was obtained from reduced tillage without mulching (T_4) with yield of 729 kg/ha .

Drip irrigation levels also had significant effect on yield produced. Highest yield was recorded from drip irrigation at 80% EP (I_1) followed by drip irrigation at 40% EP (I_2) and life saving irrigation (I_3).

The tillage with mulching X drip irrigation interaction also differed significantly with respect to the yield produced per hectare (Table 4.10). Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) recorded the highest yield of

1908 kg/ha and reduced tillage without mulching and life saving irrigation (T_4I_3) recorded the lowest yield of 540 kg/ha.

Table 4.7 Effect of tillage with mulching and drip irrigation levels on yield attributes of black gram

Treatments	Time for 50% flowering (DAS)	Pod length (cm)	Number of pods per plant
Main plots – Tillage with mulching			
Conventional tillage with mulching (T_1)	33	4.04	14.02
Conventional tillage without mulching (T_2)	34	3.82	7.94
Reduced tillage with mulching (T_3)	32	4.26	10.44
Reduced tillage without mulching (T_4)	34	3.75	7.00
CD (P=0.05)	**NS**	**0.39**	**0.78**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	35	4.15	13.48
Drip irrigation at 40% EP (I_2)	35	4.06	10.92
Life saving irrigation (I_3)	31	3.69	5.16
CD (P=0.05)	**1.25**	**0.21**	**0.73**

Table 4.8 Interaction effect of tillage with mulching and drip irrigation levels on yield attributes of black gram

Treatment combinations	Time for 50% flowering (DAS)	Pod length (cm)	No. of pods per plant
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	35	4.28	22.33
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	35	4.00	14.20
Conventional tillage with mulching and life saving irrigation (T_1I_3)	30	3.92	5.53
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	35	4.00	10.50
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	35	3.90	7.83
Conventional tillage without mulching and life saving irrigation (T_2I_3)	33	3.55	5.50
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	33	4.48	11.93
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	33	4.47	14.00
Reduced tillage with mulching and life saving irrigation (T_3I_3)	30	3.82	5.40
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	35	3.88	9.13
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	35	3.88	7.67
Reduced tillage without mulching and life saving irrigation (T_4I_3)	32	3.48	4.20
CD (P=0.05)	**2.5**	**0.42**	**1.45**

Table 4.9 Effect of tillage with mulching and drip irrigation levels on yield attributes and yield of black gram

Treatments	Number of seeds per pod	1000 seed weight (g)	Yield (kg/ha)
Main plots – Tillage with mulching			
Conventional tillage with mulching (T_1)	5.87	57.45	1339
Conventional tillage without mulching (T_2)	5.27	60.92	838
Reduced tillage with mulching (T_3)	6.00	59.79	1067
Reduced tillage without mulching (T_4)	5.27	61.62	729
CD (P=0.05)	**0.36**	**NS**	**97.08**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	5.93	59.61	1258
Drip irrigation at 40% EP (I_2)	5.78	61.89	1090
Life saving irrigation (I_3)	5.09	58.33	633
CD (P=0.05)	**0.38**	**NS**	**66.80**

Table 4.10 Interaction effect of tillage with mulching and drip irrigation levels on yield attributes and yield of black gram

Treatment combinations	No. of seeds per pod	1000 seed weight (g)	Yield (kg/ha)
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	6.10	54.71	1908
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	5.80	61.99	1398
Conventional tillage with mulching and life saving irrigation (T_1I_3)	5.70	55.67	711
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	5.47	62.64	1047
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	5.33	60.11	797
Conventional tillage without mulching and life saving irrigation (T_2I_3)	5.00	60.01	671
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	6.07	58.76	1438
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	6.60	61.08	1155
Reduced tillage with mulching and life saving irrigation (T_3I_3)	5.33	59.52	609
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	6.10	62.32	921
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	5.37	64.40	727
Reduced tillage without mulching and life saving irrigation (T_4I_3)	4.33	58.13	540
CD (P=0.05)	**0.77**	**NS**	**134**

4.3 SOIL MOISTURE CONTENT

4.3.1 Soil moisture content by weight (%) at 15 DAS

The data regarding the soil moisture content at 15 DAS from different depths of soil are furnished in Table 4.11. Soil moisture content at 15 DAS vary significantly among tillage treatments. At depths of 5, 10 and 15 cm, the moisture content was higher in the treatments of reduced tillage with mulching (T_3) and reduced tillage without mulching (T_4) which had comparable values.

Drip irrigation definitely had significant effect on soil moisture content at different depths. At 10 and 15 cm soil depth, highest moisture content was with drip irrigation at 80% EP (I_1) followed by drip irrigation at 40% EP (I_2) and life saving irrigation (I_3). But, at 5 cm soil depth, drip irrigation at 80% EP (I_1) and 40% EP (I_2) had comparable values for soil moisture content.

The tillage with mulching X drip irrigation interaction also had significant effect on soil moisture content at different depths (Table 4.12). At 5cm depth, moisture content was higher with treatment combinations of reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2), reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1), reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1), reduced tillage with mulching and life saving irrigation (T_3I_3) and conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1) which were on par. At 10 cm depth, highest moisture content was from the plots with reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1) and least with reduced tillage without mulching and life saving irrigation (T_4I_3). At 15 cm depth, treatment combinations of reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2), conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1), reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1), reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1) and reduced tillage with mulching and life saving irrigation (T_3I_3) were on par.

4.3.2. Soil moisture content by weight (%) at 30 DAS

From Table 4.13., it is clear that, the moisture content at 5cm depth was maximum with reduced tillage without mulching (T_4). At 10cm and 15 cm depth best treatments were reduced tillage with mulching (T_3) and without mulching (T_4) which were on par. Soil moisture content significantly differ among drip irrigation levels also. At 5 and 10 cm depth the highest moisture content was observed in the treatment of drip irrigation at 80% EP (I_1) followed by drip irrigation at 40% EP (I_2) and life saving irrigation (I_3). At 15 cm depth, the moisture content at drip irrigation at 80% EP (I1) and 40% EP (I_2) were on par with higher values.

The interaction effect was also significantly different (Table 4.14). At 5cm depth, higher moisture content was with treatment combinations, reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1), conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2), reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1) and conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1). At 10 cm depth, highest moisture content was in plots of reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2). At 15 cm depth, best treatment combinations were reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1) and reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1) which were statistically on par.

4.3.3. Soil moisture content by weight (%) at 45 DAS

At 45 DAS, the moisture content at different depths of soil differed significantly among tillage treatments (Table 4.15). At 5 and 10 cm depth, higher moisture content was in plots of reduced tillage without mulching (T_4) and with mulching (T_3) which were on par. At 15 cm depth, reduced tillage with mulching (T_3) had the highest soil moisture content and it was comparable with moisture content from the unmulched plots under reduced tillage (T_4). At various levels of drip irrigation also moisture content varied significantly. At 5, 10 and 15 cm depth, higher soil moisture content was in life saving irrigation (I_3) followed by drip irrigation at 80% EP (I_1) and drip irrigation at 40% EP (I_2).

At 45 DAS also the tillage with mulching X drip irrigation interaction was significantly differed (Table 4.16). At 5cm depth, higher moisture content was observed from treatment combinations of reduced tillage without mulching and life saving irrigation (T_4I_3), conventional tillage with mulching and life saving irrigation (T_1I_3), conventional tillage without mulching and life saving irrigation (T_2I_3) and reduced tillage with mulching and life saving irrigation (T_3I_3). At 10 cm depth, treatment combinations of reduced tillage with mulching and life saving irrigation (T_3I_3) and reduced tillage without mulching and life saving irrigation (T_4I_3) were on par. And at 15 cm depth also reduced tillage with mulching and life saving irrigation (T_3I_3) recorded highest moisture content. The lower moisture content at 10 and 15 cm depth was observed from plots of conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2).

4.3.4. Soil moisture content by weight (%) at 60 DAS

Among tillage treatments, the soil moisture content at 5 and 10 cm depth were maximum in plots of reduced tillage with mulching (T_3) and without mulching (T_4) which were statistically comparable (Table 4.17). But, at 15 cm depth all the treatments showed highest comparable values for moisture content. Soil moisture content differed significantly among drip irrigation treatments. At 5, 10 and 15 cm depth of soil highest moisture content was observed from drip irrigation at 80% EP (I_1).

The interaction effect was also significantly differed (Table 4.18). At 5cm depth, best treatment combinations were reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1), reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2) and reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1). At 10 cm depth, reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1), conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) and reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1) had higher soil moisture content. At 15 cm depth, reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) and reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1) had statistically comparable values for moisture content .

Table 4.11 Effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 15 DAS

Treatment	Depth		
	5 cm	10 cm	15 cm
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	9.60	11.00	12.06
Conventional tillage without mulching (T_2)	9.18	10.72	11.48
Reduced tillage with mulching (T_3)	10.61	12.38	13.07
Reduced tillage without mulching (T_4)	10.30	10.88	12.26
CD (P=0.05)	**0.44**	**0.61**	**0.99**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	10.51	12.21	13.16
Drip irrigation at 40% EP (I_2)	10.15	11.19	12.39
Life saving irrigation (I_3)	9.11	10.33	11.09
CD (P=0.05)	**0.62**	**0.43**	**0.76**

Table 4.12 Interaction effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 15 DAS

Treatment combinations	**Depth**		
	5 cm	**10 cm**	**15 cm**
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	10.43	12.47	13.63
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	9.40	10.07	11.60
Conventional tillage with mulching and life saving irrigation (T_1I_3)	8.97	10.47	10.93
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	9.90	11.43	12.47
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	9.30	10.90	11.63
Conventional tillage without mulching and life saving irrigation (T_2I_3)	8.33	9.83	10.33
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	10.77	13.40	13.00
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	11.13	11.47	13.83
Reduced tillage with mulching and life saving irrigation (T_3I_3)	9.93	12.27	12.37
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	10.93	11.53	13.53
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	10.77	12.33	12.50
Reduced tillage without mulching and life saving irrigation (T_4I_3)	9.20	8.77	10.73
CD (P=0.05)	**1.25**	**0.85**	**1.51**

Table 4.13 Effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 30 DAS

Treatment	Depth		
	5 cm	**10 cm**	**15 cm**
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	8.71	9.49	10.39
Conventional tillage without mulching (T_2)	8.13	9.32	10.06
Reduced tillage with mulching (T_3)	8.86	10.56	11.69
Reduced tillage without mulching (T_4)	9.54	10.31	11.31
CD (P=0.05)	**0.60**	**0.66**	**0.72**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	9.87	10.94	11.93
Drip irrigation at 40% EP (I_2)	9.15	10.43	11.61
Life saving irrigation (I_3)	7.42	8.38	9.04
CD (P=0.05)	**0.35**	**0.30**	**0.40**

Table 4.14 Interaction effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 30 DAS

Treatment combinations	**Depth**		
	5 cm	**10 cm**	**15 cm**
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	10.07	11.07	11.77
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	8.40	9.23	10.63
Conventional tillage with mulching and life saving irrigation (T_1I_3)	7.67	8.17	8.77
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	9.07	10.90	11.47
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	8.23	9.67	10.17
Conventional tillage without mulching and life saving irrigation (T_2I_3)	7.10	7.40	8.53
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	9.83	11.27	12.23
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	9.93	10.83	13.00
Reduced tillage with mulching and life saving irrigation (T_3I_3)	6.80	9.57	9.83
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	10.50	10.53	12.27
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	10.03	12.00	12.63
Reduced tillage without mulching and life saving irrigation (T_4I_3)	8.10	8.40	9.03
CD (P=0.05)	**0.70**	**0.60**	**0.79**

Table 4.15 Effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 45 DAS

Treatment	Depth		
	5 cm	**10 cm**	**15 cm**
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	9.21	10.54	11.12
Conventional tillage without mulching (T_2)	8.82	10.29	10.61
Reduced tillage with mulching (T_3)	9.61	11.59	12.42
Reduced tillage without mulching (T_4)	9.69	11.62	12.01
CD (P=0.05)	**0.47**	**0.78**	**0.83**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	9.07	10.75	11.23
Drip irrigation at 40% EP (I_2)	8.72	9.88	10.46
Life saving irrigation (I_3)	10.22	12.41	12.94
CD (P=0.05)	**0.32**	**0.66**	**0.69**

Table 4.16 Interaction effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 45 DAS

Treatment combinations	Depth		
	5 cm	10 cm	15 cm
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	9.20	10.97	11.63
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	8.07	8.60	9.13
Conventional tillage with mulching and life saving irrigation (T_1I_3)	10.37	12.07	12.60
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	8.50	10.03	10.33
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	7.87	9.03	9.20
Conventional tillage without mulching and life saving irrigation (T_2I_3)	10.10	11.80	12.30
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	9.23	10.93	11.67
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	9.67	10.43	11.40
Reduced tillage with mulching and life saving irrigation (T_3I_3)	9.93	13.40	14.20
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	9.33	11.07	11.27
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	9.27	11.43	12.10
Reduced tillage without mulching and life saving irrigation (T_4I_3)	10.47	12.37	12.67
CD (P=0.05)	**0.63**	**1.32**	**1.38**

Table 4.17 Effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 60 DAS

Treatment	Depth		
	5 cm	10 cm	15 cm
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	8.10	9.01	9.94
Conventional tillage without mulching (T_2)	7.91	8.84	9.54
Reduced tillage with mulching (T_3)	8.76	9.70	10.31
Reduced tillage without mulching (T_4)	8.80	9.88	10.46
CD (P=0.05)	**0.49**	**0.77**	**0.59**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	8.68	10.10	10.77
Drip irrigation at 40% EP (I_2)	8.28	9.16	9.66
Life saving irrigation (I_3)	8.22	8.82	9.77
CD (P=0.05)	**0.31**	**0.43**	**0.38**

Table 4.18 Interaction effect of tillage with mulching and drip irrigation levels on soil moisture content (%) from different depths at 60 DAS

Treatment combinations	**Depth**		
	5 cm	**10 cm**	**15 cm**
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	8.60	10.23	11.07
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	7.50	7.93	8.37
Conventional tillage with mulching and life saving irrigation (T_1I_3)	8.20	8.87	10.40
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	8.06	9.67	10.07
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	7.70	8.20	8.73
Conventional tillage without mulching and life saving irrigation (T_2I_3)	7.97	8.67	9.83
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	8.73	10.40	11.33
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	9.00	9.77	10.23
Reduced tillage with mulching and life saving irrigation (T_3I_3)	8.53	8.93	9.37
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	9.33	10.10	10.60
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	8.90	10.73	11.30
Reduced tillage without mulching and life saving irrigation (T_4I_3)	8.17	8.80	9.47
CD (P=0.05)	**0.61**	**0.86**	**0.75**

4.4 WATER USE EFFICIENCY

The data pertaining to the effect of treatments on WUE of crop is given in Table 4.19. Among the tillage treatments highest water use efficiency of 2.92 kg/ha mm was exhibited by conventional tillage with mulching (T_1). Lowest WUE of 2.08 kg/ha mm was recorded from the treatment of reduced tillage without mulching (T_4).

WUE of black gram varied significantly among drip irrigation levels. Life saving irrigation (I_3) exhibited the highest WUE of 6.32 kg/ha mm followed by the treatment of drip irrigation at 40% EP (0.77 kg/ha mm) and drip irrigation at 80% EP (0.44 kg/ha mm). In the case of tillage with mulching X drip irrigation interaction (Table 4.20), conventional tillage with mulching and life saving irrigation (T_1I_3) had highest value of 7.11 kg/ha mm.

Table 4.19 Effect of tillage with mulching and drip irrigation levels on Water Use Efficiency (kg/ha mm) of black gram

Treatments	Water Use Efficiency
Main plots - Tillage with mulching	
Conventional tillage with mulching (T_1)	2.92
Conventional tillage without mulching (T_2)	2.55
Reduced tillage with mulching (T_3)	2.50
Reduced tillage without mulching (T_4)	2.08
CD (P=0.05)	**0.34**
Sub plots - Drip irrigation	
Drip irrigation at 80% EP (I_1)	0.44
Drip irrigation at 40% EP (I_2)	0.77
Life saving irrigation (I_3)	6.32
CD (P=0.05)	**0.25**

Table 4.20 Interaction effect of tillage with mulching and drip irrigation levels on Water Use Efficiency (kg/ha mm) of black gram

Treatment combinations	WUE
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	0.67
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	0.98
Conventional tillage with mulching and life saving irrigation (T_1I_3)	7.11
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	0.37
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	0.56
Conventional tillage without mulching and life saving irrigation (T_2I_3)	6.71
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	0.41
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	1.01
Reduced tillage with mulching and life saving irrigation (T_3I_3)	6.09
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	0.32
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	0.51
Reduced tillage without mulching and life saving irrigation (T_4I_3)	5.39
CD (P=0.05)	**0.50**

4.5 PHYSICOCHEMICAL PROPERTIES OF SOIL

4.5.1. Maximum Water holding capacity of soil

Maximum Water holding capacity of soil had no significant difference among tillage treatments (Table 4.21). All the drip irrigation levels exhibited statistically comparable values for maximum water holding capacity.

The tillage with mulching X drip irrigation interaction was also on par (Table 4.22). However, higher water holding capacity was obtained from the treatment combinations of reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2).

4.5.2. Bulk density of soil

The tillage treatments differed significantly with respect to bulk density (Table 4.21). Lowest bulk density of 1.12 g/cm^3 was observed in the treatment of conventional tillage with mulching (T_1) and the highest bulk density of 1.23 g/cm^3 was from the treatment of reduced tillage without mulching (T_4). Among the irrigation levels, lower bulk density was with drip irrigation at 40% EP (I_2). It was on par with drip irrigation at 80% EP (I_1) with 1.21 g/cm^3 bulk density.

The interaction effect was also significantly differed (Table 4.22). Best treatment combination was conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2) followed by conventional tillage with mulching and life saving irrigation (T_1I_3) with values of 1.06 and 1.11 g/cm^3 respectively.

4.5.3. Soil pH

Tillage treatments had significant effect on soil pH (Table 4.23). The highest soil pH (5.88) was observed in the unmulched plots under reduced tillage (T_4). More acidic soil was observed in mulched plots under conventional tillage (T_1) with a pH of 5.20. Unmulched plots of conventional tillage (T_2) and mulched plots under reduced tillage (T_3) had statistically comparable values of soil pH. In the case of drip irrigation levels, soil pH exhibited on par values at all the three levels of drip irrigation (I_1, I_2 & I_3).

The tillage and drip irrigation interaction was significantly differed (Table 4.24). Reduced tillage without mulching and life saving irrigation (T_4I_3) showed the highest soil pH and it was on par with the treatment combinations viz. conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2), conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2) and reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1). Acidity was more with mulched plots under conventional tillage and drip irrigation at 40% EP (T_1I_2).

4.5.4. EC of soil

The data pertaining to electrical conductivity of soil are presented in Table 4.23. Unmulched plots under conventional tillage (T_2) and reduced tillage (T_4) exhibited highest EC of soil with statistically comparable values of 0.99 and 0.92 dS/m respectively. Mulched plots under conventional tillage (T_1) and reduced tillage (T_3) had comparable values with lowest EC among tillage treatments. The EC of soil differed significantly among drip irrigation levels. EC from plots with drip irrigation at 40% EP (I_2) and life saving irrigation (I_3) were higher and on par.

The interaction effect was also significantly differed (Table 4.24). Highest EC was observed from the unmulched plot under conventional tillage and drip irrigation at 40% EP (T_2I_2) and lowest from mulched plot under conventional tillage with drip irrigation at 80% EP (T_1I_1).

4.5.5 Organic carbon content of soil

From the data presented in Table 4.23, it is clear that organic carbon content of soil recorded a high value of 0.66% from plots of reduced tillage without mulching (T_4) and lowest value of 0.57% from conventional tillage with mulching (T_1). Organic carbon content of soil did not exhibit significant difference among drip irrigation levels.

In the case of tillage with mulching and drip irrigation interaction (Table 4.24), reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1) recorded the highest organic carbon content which was on par with the treatment combinations, conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2) and conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1). Lowest organic carbon content was from the unmulched plot under reduced tillage with drip irrigation at 40% EP (T_4I_2).

4.5.6 Available nitrogen content of soil

Significantly different available nitrogen content was observed among tillage treatments (Table 4.25). The available N content was highest in plots of reduced tillage without mulching (T_4) followed by reduced tillage with mulching (T_3) which were on par. The treatments conventional tillage with mulching (T_1) and without mulching (T_2) were on par with lowest available nitrogen content. In the case of drip irrigation levels, all the three treatments were on par. However, the highest value was observed from the drip irrigation at 80% EP (I_1).

The interaction effect was also significantly different (Table 4.26). The higher available N content was from treatment combination of reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1). It was comparable with the treatment combinations of reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2), reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1), reduced tillage without mulching and life saving irrigation (T_4I_3), reduced tillage with mulching and life saving irrigation (T_3I_3), conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1), conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1), and conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2).

4.5.7 Available phosphorus content of soil

Among the tillage treatments, all the treatments except conventional tillage with mulching (T_1) had statistically comparable values with higher phosphorus content of soil (Table 4.25). All the drip irrigation levels were also on par with respect to soil phosphorus content. In the case of interaction effect of tillage with mulching and drip irrigation (Table 4.26), reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1) had the highest available P content of soil and it was statistically comparable with treatment combinations of reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), reduced tillage with mulching and life saving irrigation (T_3I_3) and conventional tillage without mulching and life saving irrigation (T_2I_3).

4.5.8 Available potassium content of soil

The effect of tillage on available potassium content of soil differed significantly among tillage treatments (Table 4.25). The tillage treatment of reduced tillage without mulching (T_4) had highest available K content, followed by conventional tillage without mulching (T_2) and reduced tillage with mulching (T_3) which were on par. All the drip irrigation levels had statistically comparable values of potassium content in soil.

The tillage with mulching X drip irrigation interaction was also significantly differed (Table 4.26). The treatment combinations of reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1) followed by conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2), reduced tillage without mulching and life saving irrigation (T_4I_3) and reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2) recorded higher available K content.

Table 4.21 Effect of tillage with mulching and drip irrigation levels on physical properties of soil.

Treatments	**Max. Water holding capacity (%)**	**Bulk density (g/cm^3)**
Main plots - Tillage with mulching		
Conventional tillage with mulching (T_1)	33.75	1.12
Conventional tillage without mulching (T_2)	35.68	1.16
Reduced tillage with mulching (T_3)	34.05	1.21
Reduced tillage without mulching (T_4)	37.28	1.23
CD (P=0.05)	**NS**	**0.02**
Sub plots - Drip irrigation		
Drip irrigation at 80% EP (I_1)	35.19	1.21
Drip irrigation at 40% EP (I_2)	35.22	1.19
Life saving irrigation (I_3)	35.17	1.38
CD (P=0.05)	**NS**	**0.02**

Table 4.22 Interaction effect of tillage with mulching and drip irrigation levels on physical properties of soil.

Treatment combinations	Max. Water holding capacity (%)	Bulk density (g/cm³)
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	33.82	1.17
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	33.55	1.06
Conventional tillage with mulching and life saving irrigation (T_1I_3)	33.88	1.11
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	35.91	1.16
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	35.83	1.16
Conventional tillage without mulching and life saving irrigation (T_2I_3)	35.32	1.15
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	33.67	1.25
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	33.85	1.22
Reduced tillage with mulching and life saving irrigation (T_3I_3)	34.62	1.15
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	37.35	1.23
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	37.65	1.31
Reduced tillage without mulching and life saving irrigation (T_4I_3)	36.85	1.13
CD (P=0.05)	**NS**	**0.04**

Table 4.23 Effect of tillage with mulching and drip irrigation levels on chemical properties of soil.

Treatments	pH	EC (dS/m)	Organic carbon (%)
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	5.20	0.63	0.57
Conventional tillage without mulching (T_2)	5.65	0.99	0.65
Reduced tillage with mulching (T_3)	5.47	0.58	0.61
Reduced tillage without mulching (T_4)	5.88	0.92	0.66
CD (P=0.05)	**0.64**	**0.10**	**0.09**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	5.49	0.56	0.66
Drip irrigation at 40% EP (I_2)	5.61	0.91	0.61
Life saving irrigation (I_3)	5.55	0.86	0.59
CD (P=0.05)	**NS**	**0.06**	**NS**

Table 4.24 Interaction effect of tillage with mulching and drip irrigation levels on chemical properties of soil.

Treatment combinations	pH	EC (dS/m)	Organic carbon (%)
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	5.29	0.36	0.53
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	5.04	0.46	0.55
Conventional tillage with mulching and life saving irrigation (T_1I_3)	5.27	1.08	0.63
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	5.70	0.73	0.68
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	6.10	1.43	0.73
Conventional tillage without mulching and life saving irrigation (T_2I_3)	5.16	0.81	0.54
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	5.31	0.45	0.63
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	5.65	0.81	0.65
Reduced tillage with mulching and life saving irrigation (T_3I_3)	5.44	0.46	0.56
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	5.64	0.70	0.82
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	5.65	0.95	0.53
Reduced tillage without mulching and life saving irrigation (T_4I_3)	6.34	1.09	0.63
CD (P=0.05)	**0.87**	**1.43**	**0.14**

Table 4.25 Effect of tillage with mulching and drip irrigation levels on available nutrient status (kg/ha) of soil

Treatments	Available N	Available P	Available K
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	152.70	15.46	396.11
Conventional tillage without mulching (T_2)	158.74	18.27	498.56
Reduced tillage with mulching (T_3)	174.23	18.95	484.00
Reduced tillage without mulching (T_4)	182.58	20.06	567.33
CD (P=0.05)	**14.86**	**2.30**	**47.04**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	174.66	18.09	480.42
Drip irrigation at 40% EP (I_2)	167.18	18.13	503.33
Life saving irrigation (I_3)	159.36	18.33	475.75
CD (P=0.05)	**NS**	**NS**	**NS**

Table 4.26 Interaction effect of tillage with mulching and drip irrigation levels on available nutrient status (kg/ha) of soil

Treatment combinations	**Available N**	**Available P**	**Available K**
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	161.56	15.07	363.00
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	154.17	15.78	389.00
Conventional tillage with mulching and life saving irrigation (T_1I_3)	142.38	15.52	436.33
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	169.13	17.53	498.33
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	159.10	17.79	568.33
Conventional tillage without mulching and life saving irrigation (T_2I_3)	147.99	19.49	429.00
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	175.62	18.61	462.00
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	175.65	18.58	513.33
Reduced tillage with mulching and life saving irrigation (T_3I_3)	171.44	19.65	477.00
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	192.34	21.15	598.33
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	179.80	20.36	542.67
Reduced tillage without mulching and life saving irrigation (T_4I_3)	175.62	18.67	561.00
CD (P=0.05)	**35.94**	**1.83**	**57.81**

4.6 NUTRIENT CONTENT AND UPTAKE BY PLANTS

4.6.1 Content of nitrogen in plants

The data pertaining to the content of nitrogen in plants are presented in Table 4.27. Among the tillage treatments, reduced tillage without mulching (T_4) recorded the highest content which was on par with plots of conventional tillage without mulching (T_2). The drip irrigation levels varied significantly with respect to content of N in plants. Highest N content was recorded from the treatments of life saving irrigation (I_3) and drip irrigation at 40% EP (I_2) with on par values.

The tillage with mulching X drip irrigation interaction was also significantly differed (Table 4.28). The content of N from treatment combinations of reduced tillage without mulching and life saving irrigation (T_4I_3), conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2), reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2), reduced tillage with mulching and life saving irrigation (T_3I_3) and conventional tillage with mulching and life saving irrigation (T_1I_3) were higher and on par.

4.6.2 Content of phosphorus in plants

The content of P among tillage treatments did not differ significantly (Table 4.27). They were on par among drip irrigation levels also. The interaction effect was also on par (Table 4.28).

4.6.3 Content of potassium in plants

The data related to the content of potassium in plants is depicted in Table 4.27. The content of K differed significantly among tillage treatments. The highest content was recorded from the plots of reduced tillage with mulching (T_3) and lowest from conventional tillage with mulching (T_1). Among the drip irrigation levels, the content of K in plants exhibited statistically comparable values.

The interaction effect was significantly differed with respect to the content of K in plants (Table 4.28). The plots of reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2), reduced tillage without mulching and life saving irrigation (T_4I_3), conventional tillage without mulching and life saving irrigation (T_2I_3), reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1), conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2) and reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2) recorded higher content of potassium in plants with on par values.

4.6.4 Uptake of nitrogen by plants

The data pertaining to the uptake of nitrogen by plants are presented in Table 4.29. The tillage treatment of conventional tillage with mulching (T_1) recorded the highest N uptake of 25.77 kg/ha compared to other treatments followed by reduced tillage with mulching (T_3) and conventional tillage without mulching (T_2).

Drip irrigation levels differed significantly with respect to uptake of nitrogen by plants. Among the drip irrigation levels, drip irrigation at 80% EP (I_1) and 40% EP (I_2) recorded higher uptake with on par values. Life saving irrigation (I_3) showed lowest uptake for nitrogen.

In the case of tillage with mulching X drip irrigation interaction (Table 4.30), conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) had higher N uptake which was comparable with the uptake from reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1). Conventional tillage without mulching and life saving irrigation (T_2I_3) recorded the lowest uptake of nitrogen by plants.

4.6.5 Uptake of phosphorus by plants

The uptake of phosphorus by plants differed significantly among tillage treatments (Table 4.29). Uptake of phosphorus from mulched plots under conventional tillage (T_1) and reduced tillage (T_3) were statistically comparable with higher values.

Uptake of phosphorus from unmulched plots under conventional tillage (T_2) and reduced tillage (T_4) recorded lower uptake of P with comparable values.

Among the irrigation levels, drip irrigation at 80% EP (I_1) recorded the highest P uptake and it was comparable with uptake from plots of drip irrigation at 40% EP (I_2). Life saving irrigation (I_3) recorded the lowest uptake of phosphorus by plants.

The interaction effect was also significantly differed (Table 4.30). Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1) recorded highest phosphorus uptake which was comparable with the treatment combination of conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1).

4.6.6 Uptake of potassium by plants

The data related to the uptake of potassium by plants are depicted in Table 4.29. Uptake of potassium by plants differed significantly among tillage treatments. Mulched plot under conventional tillage (T_1) and reduced tillage (T_3) were statistically on par with higher uptake of potassium by plants. It was followed by conventional tillage without mulching (T_2). Among the irrigation levels, drip irrigation at 80% EP (I_1) and 40% EP (I_2) were on par and had higher uptake of potassium by plants. Life saving irrigation (I_3) exhibited the lowest potassium uptake by plants.

The tillage with mulching X drip irrigation interaction was also significantly differed with respect to the uptake of potassium by plants (Table 4.30). Conventional tillage with mulching and drip irrigation at 80%EP (T_1I_1) was highest with uptake of 25.8 kg/ha. It was on par with reduced tillage with mulching and drip irrigation at 40%EP (T_3I_2) and reduced tillage with mulching and drip irrigation at 80%EP (T_3I_1) with an uptake of 24.04 and 23.98 kg/ha respectively. The lowest potassium uptake was recorded from the treatment combination of reduced tillage without mulching and life saving irrigation (T_4I_3).

Table 4.27 Effect of tillage with mulching and drip irrigation levels on nutrient content (%) of plant

Treatments	N	P	K
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	2.11	0.10	1.37
Conventional tillage without mulching (T_2)	2.46	0.10	1.54
Reduced tillage with mulching (T_3)	2.29	0.11	1.62
Reduced tillage without mulching (T_4)	2.50	0.11	1.58
CD (P=0.05)	**0.21**	**NS**	**0.22**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	2.15	0.10	1.58
Drip irrigation at 40% EP (I_2)	2.39	0.10	1.58
Life saving irrigation (I_3)	2.49	0.11	1.43
CD (P=0.05)	**0.24**	**NS**	**NS**

Table 4.28 Interaction effect of tillage with mulching and drip irrigation levels on nutrient content (%) of plant

Treatment combinations	N	P	K
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	2.00	0.09	1.59
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	1.86	0.09	1.48
Conventional tillage with mulching and life saving irrigation (T_1I_3)	2.48	0.10	1.04
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	2.45	0.10	1.55
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	2.91	0.10	1.32
Conventional tillage without mulching and life saving irrigation (T_2I_3)	2.03	0.10	1.74
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	2.16	0.11	1.73
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	2.21	0.10	1.96
Reduced tillage with mulching and life saving irrigation (T_3I_3)	2.51	0.11	1.17
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	1.99	0.10	1.43
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	2.57	0.11	1.58
Reduced tillage without mulching and life saving irrigation (T_4I_3)	2.95	0.11	1.75
CD (P=0.05)	**0.47**	NS	**0.38**

Table 4.29 Effect of tillage with mulching and drip irrigation levels on nutrient uptake (kg/ha) by plants

Treatments	N	P	K
Main plots - Tillage with mulching			
Conventional tillage with mulching (T_1)	25.77	1.18	18.11
Conventional tillage without mulching (T_2)	15.65	0.61	9.19
Reduced tillage with mulching (T_3)	23.07	1.11	17.9
Reduced tillage without mulching (T_4)	11.46	0.50	7.18
CD (P=0.05)	**1.52**	**0.11**	**1.58**
Sub plots - Drip irrigation			
Drip irrigation at 80% EP (I_1)	22.73	1.07	17.05
Drip irrigation at 40% EP (I_2)	22.56	0.99	16.02
Life saving irrigation (I_3)	11.67	0.50	6.23
CD (P=0.05)	**1.82**	**0.14**	**1.14**

Table 4.30 Interaction effect of tillage with mulching and drip irrigation levels on nutrient uptake (kg/ha) by plants

Treatment combinations	N	P	K
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	32.73	1.50	25.80
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	26.32	1.29	20.86
Conventional tillage with mulching and life saving irrigation (T_1I_3)	18.24	0.75	7.69
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	18.63	0.74	11.79
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	21.06	0.73	9.57
Conventional tillage without mulching and life saving irrigation (T_2I_3)	7.26	0.36	6.21
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	29.81	1.52	23.98
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	27.22	1.26	24.04
Reduced tillage with mulching and life saving irrigation (T_3I_3)	12.16	0.54	5.67
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	9.73	0.50	6.62
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	15.62	0.66	9.60
Reduced tillage without mulching and life saving irrigation (T_4I_3)	9.01	0.33	5.34
CD (P=0.05)	**3.64**	**0.28**	**2.28**

4.7 ECONOMICS OF CULTIVATION

The data regarding B:C ratio is presented in Table.4.31. The B:C ratio differed significantly with the tillage treatments. Conventional tillage with mulching (T_1) and without mulching (T_2) recorded the highest B:C ratios with on par values of 1.16 and 1.09 respectively. Among the drip irrigation levels also the B:C ratio varied significantly. Drip irrigation at 80% EP (I_1) recorded the highest B:C ratio followed by the treatment drip irrigation at 40% EP (I_2).

The interaction effect was also differed significantly (Table 4.32). Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1) recorded the highest B:C ratio of 1.65. Lowest B:C ratio was from the treatment combination of reduced tillage with mulching and life saving irrigation (T_3I_3).

Table 4.31 Effect of tillage with mulching and drip irrigation levels on benefit: cost ratio of black gram

Treatments	Benefit: Cost ratio
Main plots - Tillage with mulching	
Conventional tillage with mulching (T_1)	1.16
Conventional tillage without mulching (T_2)	1.09
Reduced tillage with mulching (T_3)	0.94
Reduced tillage without mulching (T_4)	0.98
CD (P=0.05)	**0.10**
Sub plots - Drip irrigation	
Drip irrigation at 80% EP (I_1)	1.32
Drip irrigation at 40% EP (I_2)	1.12
Life saving irrigation (I_3)	0.69
CD (P=0.05)	**0.18**

Table 4.32 Interaction effect of tillage with mulching and drip irrigation levels on benefit: cost ratio of black gram

Treatment combinations	B:C ratio
Conventional tillage with mulching and drip irrigation at 80% EP (T_1I_1)	1.65
Conventional tillage with mulching and drip irrigation at 40% EP (T_1I_2)	1.21
Conventional tillage with mulching and life saving irrigation (T_1I_3)	0.62
Conventional tillage without mulching and drip irrigation at 80% EP (T_2I_1)	1.36
Conventional tillage without mulching and drip irrigation at 40% EP (T_2I_2)	1.04
Conventional tillage without mulching and life saving irrigation (T_2I_3)	0.87
Reduced tillage with mulching and drip irrigation at 80% EP (T_3I_1)	1.02
Reduced tillage with mulching and drip irrigation at 40% EP (T_3I_2)	1.27
Reduced tillage with mulching and life saving irrigation (T_3I_3)	0.54
Reduced tillage without mulching and drip irrigation at 80% EP (T_4I_1)	1.23
Reduced tillage without mulching and drip irrigation at 40% EP (T_4I_2)	0.98
Reduced tillage without mulching and life saving irrigation (T_4I_3)	0.72
CD (P=0.05)	**0.16**

Discussion

V. DISCUSSION

The experiment on the topic "Tillage and water saving techniques for black gram in rice fallows" was conducted at Agricultural research station, Mannuthy during 2016-2017 and the results obtained are discussed below.

5.1. Effect of tillage with mulching and drip irrigation levels on growth of black gram

The growth and yield characters obtained at different growth phases clearly have shown the influence of conventional tillage and reduced tillage on its growth. The plant height recorded at 30, 45 and 60 DAS from different tillage treatments revealed that the mulched plots under conventional tillage had the tallest plants followed by mulched plots under reduced tillage during different stages of plant growth. The conventional tillage with mulching also recorded higher number of branches at different growth phases of black gram (fig.2). Peter (2008) and Sunil *et al.* (2008) also reported higher growth rate in the tilled and mulched plots than zero tillage and no mulch treatments.

The conventional tillage with mulching achieved maximum biomass and the least from reduced tillage without mulching (fig.3). The dry matter production also followed similar trend of biomass production with highest dry matter from conventional tillage with mulching. Henry and Chinedu (2014) found similar results with mulching. The better soil condition due to tillage and wetter moisture regime due to mulching might have contributed favourable soil physical condition for better growth resulting in higher biomass and dry matter production in this treatment. Least dry matter production was obtained from treatment of reduced tillage without mulching.

The levels of drip irrigation also produced significant effect on growth of black gram. Among the three levels, the growth was maximum from plots with drip irrigation at 80% EP followed by 40% EP. This results complies with the results recorded by Patel *et al.* (2009). Better distribution of water under drip irrigation have contributed to better utilization of water in different growth phases of the crop which resulted in increased growth parameters and economized the quantity of water required for the crop. The results also clearly revealed that the drip irrigation levels had more influence on plant growth than tillage variations. The significant interaction between tillage with mulching and drip irrigation levels showed that the tallest plants were observed from plots with conventional tillage or reduced tillage and drip irrigation at 80% EP at all stages of plant growth.

The shortest plants were always observed in the unmulched plots under conventional tillage with life saving irrigation. The absence of mulching and proper irrigation affected the proper soil physical condition and reduced moisture availability of soil which led to reduced plant growth. Pramanik (1999) observed that the height and growth rate of maize plants were lower under no mulch treatments.

The leaf area index of the treatment, conventional tillage with mulching was significantly superior to all other tillage treatments. The results are in conformity with the work of Henry and Chinedu (2014). Xie *et al.* (2005) reported that, the mulched plots acquired maximum leaf area index 10 days earlier than non-mulched plots. The same situation was also created in this experiment also. LAI was higher in tilled and mulched fields due to the better growing environment created by improvement in physical condition of soil by tillage and better water utilization and uptake of nutrients under mulching. In the case of drip irrigation levels, drip irrigation at 80% EP showed the largest LAI and the life saving irrigation showed the lowest.

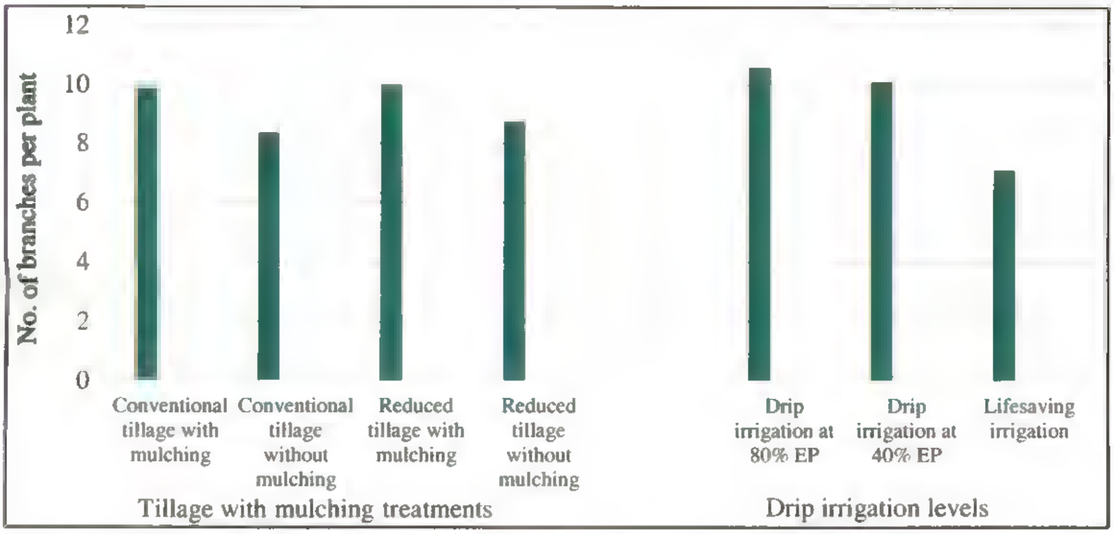


Fig. 2. Effect of tillage with mulching and drip irrigation levels on number of branches per plant at 60 DAS

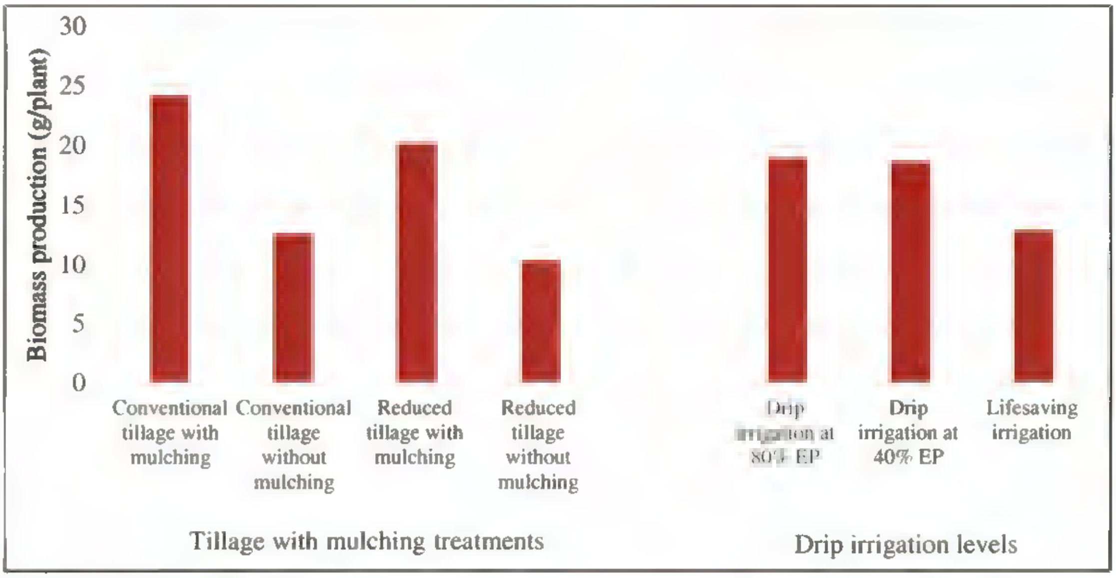


Fig. 3. Effect of tillage with mulching and drip irrigation levels on biomass production of black gram

5.2. Effect of tillage with mulching and drip irrigation levels on yield attributes of black gram

Though tillage or mulching failed to produce significant effect on early flowering, levels of irrigation was found to produce variation in earliness of flowering. Life saving irrigation completed 50% flowering earlier than all other treatments. The water stress faced by these plants during growth phase imposed earliness in flowering. But growth characters were not favourable for higher yield in these treatments.

Number of pods produced per plant is an important yield attribute of pulses. Tillage treatments had significant effect on the number of pods produced per plant (fig.4). Maximum number of pods were produced by the plants in the mulched fields under conventional tillage and minimum number of pods per plant from unmulched fields of reduced tillage. Chavan *et al.* (2014) also revealed that the fields with mulching of either wheat straw or plastic produced more number of pods per plant than unmulched fields in green gram. However significantly longer pods were observed in plots of reduced tillage with mulching and it was on par with the treatment conventional tillage with mulching. It is clear that the mulching had significant influence on the elongation of pods though tillage had no obvious effect.

Plots with drip irrigation at 80% EP gave maximum number of pods and pod length, and minimum was from life saving irrigation. It is proven fact that the increased availability of water improved the growth and thereby yield attributes of the crop. The interaction effects were also significant. Among the twelve treatment combinations, conventional tillage with mulching and drip irrigation at 80% EP was the best treatment combination.

The mulched fields under reduced tillage and conventional tillage produced higher number of seeds per pod (fig.4). The effect of mulching is evident

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from the result obtained. Chavan *et al.* (2014) also observed higher number of grains per pod from the polythene mulched fields than unmulched fields in green gram.

The drip irrigation at 80% EP and 40% EP produced comparable number of seeds per pod due to uniform availability of water in required amounts. Patel *et al*. (2009) reported that, when 80% of evaporation from the field was supplemented through drip irrigation, the length and girth of pod, number of pods per plant and pod weight per plant showed a significant improvement. The tillage with mulching treatments or levels of drip irrigation did not produce variation in 1000 seed weight of black gram.

5.3. Effect of tillage with mulching and drip irrigation levels on yield of black gram

Among the tillage with mulching treatments, mulched plots under conventional tillage recorded the highest yield (1339 kg/ha) and it was 25, 60 and 80% higher than that of reduced tillage with mulching (1067 kg/ha), conventional tillage with mulching (838 kg/ha) and reduced tillage without mulching (729 kg/ha) respectively. Kang *et al*. (1982) reported that the yield of maize from tilled fields was almost double that of no tillage plots under limited supply of nitrogen. Guzha (2004) reported higher yield of sorghum from tilled plots than untilled plots due to high water retention in the tilled plots. It is clearly evident that maximum yield was obtained at conventional tillage with mulching due to higher number of pods per plant and seeds per pod. Better aeration, good soil physical condition and better utilization of water without loss due to conventional tillage and mulching might have resulted in proper root growth, in turn better growth and higher yield.

Chick pea showed 10.6% increase in seed yield from mulched plots (Singh *et al.,* 2010). Similar results of increased yield was also reported by Xie *et al.* (2005) in wheat, Gaur and Mukherjee (1980) and Chavan *et al*. (2014) in green gram.

The higher yield under mulching was due to better water extraction and utilization by plants being mulching combined with tillage.

Drip irrigation levels also had significant effect on yield per plant. Highest yield was recorded from drip irrigation at 80% EP and it was 15% higher than the yield of drip irrigation at 40% EP. Here, the level of drip irrigation with highest quantity of water recorded the highest yield due to the higher yield attributes attained by the crop due to increased water for crop growth in that treatment. Patel *et al.* (2009) found that 46% increase in pod yield of okra from the plots where 80% of Epan was supplemented through drip irrigation. The results are also in agreement with Singh *et al.* (2009). Among the interaction effects, it was found that conventional tillage with mulching and drip irrigation at 80% EP recorded 30% higher yield than reduced tillage with mulching and drip irrigation at 80% EP.

The tillage, mulching and drip irrigation are the three favourable situations in the experiment for better growth of plants. Seed yield is the resultant product of co-ordinated interplay of all the growth and yield contributing characters. The improved soil physical condition and increased root growth due to tillage, increased availability of moisture, reduced moisture loss from soil surface, improved micro environment of crops due to mulching and uniform and optimum availability of water due to drip irrigation had favoured the growth factors resulting in higher pod yield. The adequate availability of moisture positively influenced the dry matter production and indirectly by increasing the utilization of moisture by the crop. All these have contributed to higher yield in the best interaction treatment of conventional tillage with mulching and drip irrigation at 80% EP.

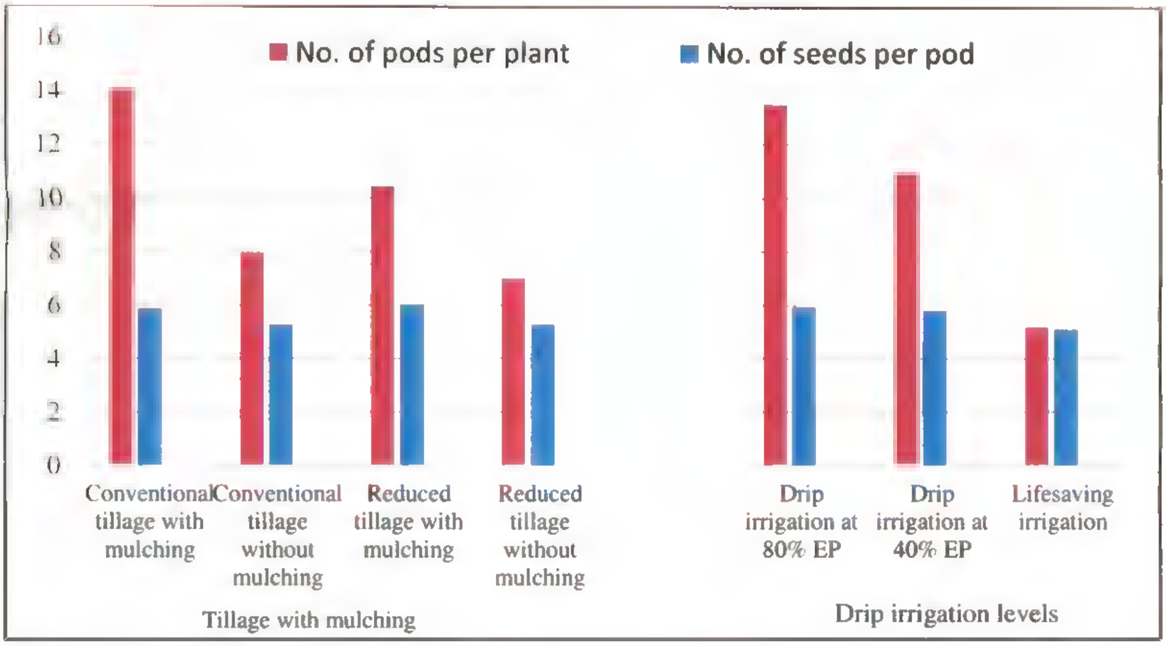

Fig. 4. Effect of tillage with mulching and drip irrigation levels on yield attributes of black gram

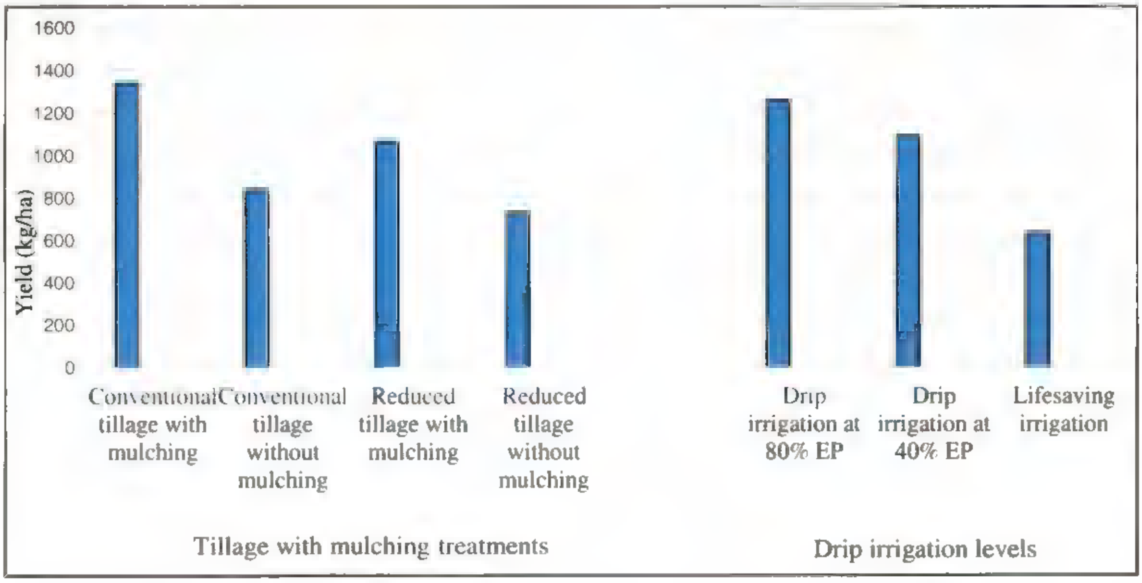

Fig. 5. Effect of tillage with mulching and drip irrigation levels on yield of black gram

5.4. Effect of tillage with mulching and drip irrigation levels on soil moisture content at different growth phases of black gram

Soil moisture depletion in the profile is normally influenced by tillage and mulching, fertilizer application and rooting pattern of crop. In black gram, being a short duration crop, the roots are confined to top layers of soil and the moisture content up to 45 cm depth can reflect on the growth of crop. The reduced tillage decreases soil erosion, run off and improved soil moisture content as reported by Palm *et al.* (2014). Due to reduced tillage, the soil had minimum soil disturbance. In this study also soil moisture content was higher in the treatment of reduced tillage with mulching at 5, 10 and 15 cm of soil depth and also at different growth phases of the crop (15, 30, 45 and 60 DAS) (fig. 6&7). Reduced tillage and mulching are water conservation technologies for storing higher moisture content in soil through improvement in water holding capacity. Increased plant available water content and water holding capacity was also noticed with minimum tillage compared to conservation tillage by Kaurin *et al*. (2015). Teravest *et al*. (2015) also reported that the soil water content of fields with conservation tillage was higher than that of conventional tillage by an average of 20 mm in the top 60 cm soil layer. While mulch might have disrupted capillary water movement to surface layers thereby reducing water loss through evaporation leading to reduced moisture depletion in the soil profile.

Among the drip irrigation levels, drip irrigation at 80% EP and 40% EP recorded the highest soil moisture content at different growth stages and depths. It is quite evident that the higher moisture content was due to higher availability of water. At 45 DAS, the soil moisture content at 5, 10 and 15 cm depth was maximum at life saving irrigation. Life saving irrigation was given at that time when the plant showed the symptoms of wilting due to moisture stress and this resulted in higher soil moisture content in that treatment.

In the case of tillage and drip irrigation interactions, higher moisture content was observed with reduced tillage with mulching and drip irrigation at 80% EP. The combined effect of different treatments created favourable situation for conservation of moisture resulting in higher moisture content up to 15 cm depth of soil at different growth phases of the crop. The experiment being conducted in rice fallows during summer the soil moisture content at deeper layers was not determined. Moreover, the extreme drought situation created during the experiment period (Appendix 1.) resulted in very low soil moisture content and this also affected the yield of crop.

5.5. Effect of tillage with mulching and drip irrigation levels on Water Use Efficiency of black gram

Being the division of economic yield to water used in the field, water use efficiency reflects the efficacy of a given treatment in transforming the water used into economic produce ie, seed yield per unit water use. Among the tillage treatments conventional tillage with mulching exhibited a 15, 18 and 40% higher WUE than conventional tillage without mulching, reduced tillage with mulching and reduced tillage without mulching respectively. Jat *et al.* (2013) revealed that summer deep ploughing increased the WUE of T-9 variety of black gram from 8.8 % to 15% and seed yield by 16% to 21% over shallow tillage due to more infiltration and soil moisture availability in deeply ploughed fields.

The deep tillage might have favoured the penetration of water to deeper layers of soil. The results are in conformity with the works of Biswas *et al.* (2015) and Mishra *et al.* (2012b). The mulches might have lowered the evaporation loss and consequent consumptive use compared to non mulches which resulted in increasing WUE in mulched plots.

Water Use Efficiency of black gram varied significantly among drip irrigation levels also. Life saving irrigation was the best treatment among them. The general trend of WUE for various drip treatments showed that lower the amount of water use, higher the WUE. Low irrigation regime reduced deep percolation and increased water use from root zone soil (Patel *et al.*, 2009). In the case of tillage X drip irrigation interactions, conventional tillage with mulching and life saving irrigation was the best treatment combination.

5.6. Effect of tillage with mulching and drip irrigation levels on physico-chemical properties of soil.

Lowest bulk density was observed in the treatment of conventional tillage with mulching and the highest from the treatment of reduced tillage without mulching. Bescansa *et al.* (2006) reported that soil bulk density in the upper 15 cm layer was lower under conventional tillage than no tillage. It is reported that decrease of soil bulk density was noticed under ploughed soil when it was contrasted with no tillage (Alvarez and Steinbach 2009). Among the irrigation levels, best treatments were drip irrigation at 80% EP and 40% EP. Tillage improves the aeration of soil resulting in increased porosity and decreased bulk density. In reduced tillage soil compaction is more leading to reduced porosity and high bulk density.

The soil was found to be near neutral under reduced tillage without mulching. More acidic soil was observed in mulched plots under conventional tillage. In the case of drip irrigation levels, soil pH exhibited on par values at all the three levels of drip irrigation. Among interactions, reduced tillage without mulching and life saving irrigation showed towards neutral soil pH.

EC of soil was low at higher levels of drip irrigation due to washing of salts to lower layers of soil with increased level of irrigation. Highest EC was observed from the unmulched plot under conventional tillage and drip irrigation at 40% EP.

Organic carbon content in soil recorded high value from plots of reduced tillage without mulching and lowest value from conventional tillage with mulching. Ten years of minimum tillage improved the soil organic carbon by 11% in the top 20 cm soil layer in semi-arid rainfed systems of southern India. (Prasad *et al.*, 2016). According to Bhattacharyya *et al.* (2015) the top soil layers of zero tilled plots had 24% more labile c pools than conventionally tilled plots. The increased organic carbon content under reduced tillage may be due to the fact that reduced tillage helped the soil to restore more organic matter content and prevent the exposure to external factors which led to the accumulation of organic carbon in soil and increased nutrient content of soil. Highest organic carbon content in soil was achieved from drip irrigation at 80% EP and lowest from life saving irrigation.

In the case of available nitrogen content in soil, the best treatments were reduced tillage with and without mulching. Samant and Patra (2016) also reported that maximum available nitrogen, phosphorus and potassium were obtained from zero tilled plots and they yielded better than conventionally tilled plots. In the case of drip irrigation levels, all of the three treatments were on par. The best treatment combination was reduced tillage without mulching and drip irrigation at 80% EP.

Among the tillage treatments, the best treatment with respect to available phosphorus and potassium contents of soil was reduced tillage without mulching. Yadav *et al.* (2015) reported that the available nitrogen, phosphorus and potassium contents were higher under no tillage fields than conventional tillage fields under maize- maize- field pea cropping systems. Reduced tillage treatments, due to the minimum disturbance to soil, provided habitats and substrates for soil biota, especially microorganisms, which are responsible for mineralization of soil nutrients. Hence, the availability of nutrients was found to be higher under reduced tillage without mulching. The drip irrigation levels did not produce any difference with respect to available phosphorus and potassium content.

5.7. Effect of tillage with mulching and drip irrigation levels on nutrient content and uptake by plants.

Among the tillage with mulching treatments, the highest content of nitrogen and potassium in plants were recorded from the plots of reduced tillage without mulching. The content of phosphorus in plants did not differ significantly among tillage with mulching treatments. The available nitrogen, phosphorus and potassium contents in soil were also high under the treatment reduced tillage without mulching. Since the availability of nutrients in soil was high in this treatment, the plant nutrient content was also found to be high in the same. Among the drip irrigation levels, the content of phosphorus and potassium in plants exhibited statistically comparable values.

But, the uptake of nitrogen, phosphorus and potassium exhibited highest values from the plots of conventional tillage with mulching. The increased uptake of nitrogen with tillage (Al-Kaisi and Kwaw-Mensah, 2007) and mulching (Kumar and Dey, 2011 and Liu *et al.*, 2003) was reported by many workers. The uptake being a product of nutrient content of plant and dry matter production, the higher values for dry matter production under conventional tillage with mulching had resulted in increased uptake values also under conventional tillage with mulching. Among the irrigation levels, drip irrigation at 80% EP had higher uptake of nitrogen, phosphorus and potassium by plants. More soil moisture content in this treatment enhanced the availability of nutrients in soil and absorption of nutrients by plants which leads to increased uptake of nutrients from the plots with drip irrigation at 80% EP. Patel *et al.*, (2012) reported the same ie. Increased uptake of nitrogen, phosphorus and potassium with higher levels of drip irrigation. Among the treatment combinations, conventional tillage with mulching and drip irrigation at 80% EP recorded highest nitrogen, phosphorus and potassium uptake by plants.

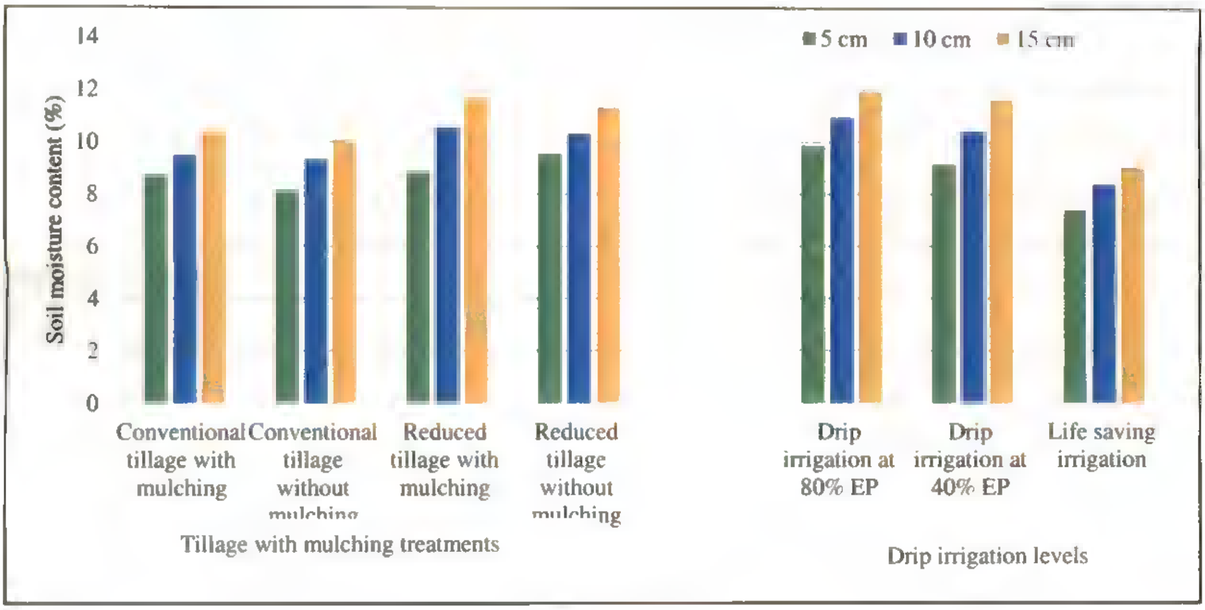

Fig. 6. Effect of tillage with mulching and drip irrigation levels on soil moisture content by weight (%) at 5, 10, 15 cm depth at 30 DAS

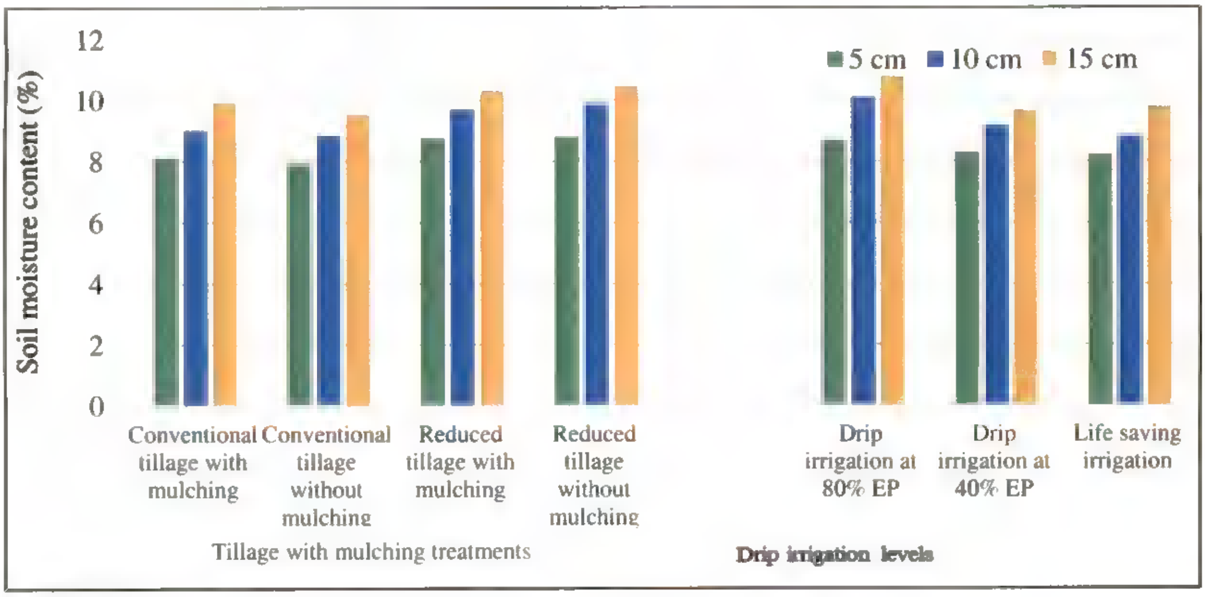

Fig. 7. Effect of tillage with mulching and drip irrigation levels on soil moisture content by weight (%) at 5, 10, 15 cm depth at 60 DAS

5.8. Effect of tillage with mulching and drip irrigation levels on benefit : cost ratio of black gram

Conventional tillage with mulching and drip irrigation at 80% EP recorded the highest B:C ratio of 1.65 (fig.8). Lowest B:C ratio was from the treatment combination of reduced tillage with mulching and life saving irrigation. Higher yield obtained from the treatment combination of conventional tillage with mulching and drip irrigation at 80% EP made it the most profitable one.

In rice fields, the ploughing during summer season for interception of water is a common practice. The farmers are following the practice of ploughing the field even without pulse cultivation. So the cost for ploughing once is not required to be taken in to consideration for cultivation of pulses. Besides, the investment for laying out drip is costly and the cost can be met through 2-3 years of cultivation only.

Black gram being premium price crop and a crop with increased domestic demand, the cultivation especially in summer rice fallows with mulching and drip irrigation will be viable and profitable to farmers. This in turn will be helpful for utilization of summer rice fallows and capturing the residual soil moisture. The pulse cultivation can also be considered as an added monetary advantage to farmers and also to meet the internal demand of pulses by decreasing the import. The drip irrigation is a water saving technique but initial investment is high. So the economic aspects should also be taken in to consideration during the choice of irrigated systems for low productive crops like pulses in summer rice fallows. Conventional tillage with mulching and drip irrigation at 80% EP was found to be better option in terms of yield and net returns in black gram for cultivation in summer rice fallows.

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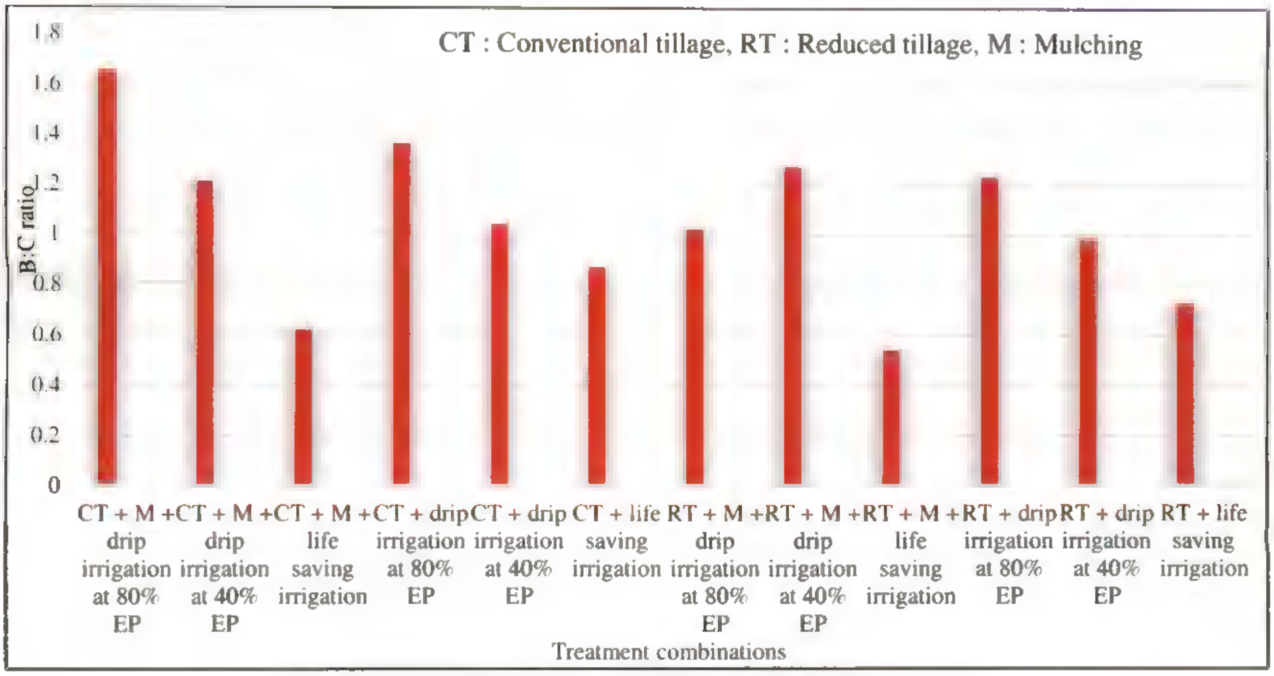

Fig. 8. Interaction effect of tillage with mulching and drip irrigation levels on B:C ratio

Summary

VI. SUMMARY

A study entitled "**Tillage and water saving techniques for black gram in rice fallows**" was conducted during the year 2016-2017 at Agricultural Research Station, Mannuthy. The project was aimed to study the effect of reduced tillage practices on yield of black gram in rice fallows and to test the feasibility of mulch cum drip irrigation practices under conservation tillage in rice fallows. The study resulted in the following findings.

- The plant height recorded at 30, 45 and 60 DAS from different tillage treatments revealed that the mulched plots under conventional tillage had the tallest plants.
- The conventional tillage with mulching also recorded higher number of branches at different growth phases of black gram.
- Drip irrigation at 80% EP produced tallest plants and highest number of branches per plant at all stages of growth.
- The leaf area index of the treatment conventional tillage with mulching was significantly superior to all other tillage treatments.
- Drip irrigation at 80% EP showed the largest LAI and the life saving irrigation showed the lowest.
- The conventional tillage with mulching achieved maximum biomass and dry matter production and among drip irrigation levels, drip irrigation at 80% EP recorded the highest biomass and dry matter production.

- Tillage or mulching failed to produce significant effect on early flowering. But, plots with life saving irrigation completed 50% flowering earlier than other treatments.
- Maximum number of pods per plant and seeds per pod were produced by the plants in the mulched plots with conventional tillage.
- Significantly longer pods were observed in plots of reduced tillage with mulching which was on par with conventional tillage with mulching.
- Plots with drip irrigation at 80% EP recorded maximum number of pods per plant, seeds per pod and pod length.
- The tillage with mulching or levels of drip irrigation did not produce variation in 1000 seed weight.
- Mulched plots under conventional tillage recorded the highest yield.
- Among the drip irrigation levels, highest yield was recorded from plots with drip irrigation at 80% EP.
- The maximum soil moisture content was recorded under reduced tillage with or without mulching at 5, 10 and 15 cm depth during different growth phases of the crop.
- The maximum soil moisture content was recorded from drip irrigation at 80% EP at 15, 30 and 60 DAS.
- Conventional tillage with mulching exhibited the highest WUE compared to other treatments.
- Among drip irrigation levels, highest water use efficiency was exhibited by life saving irrigation.
- Lowest bulk density of soil was observed in the treatment of conventional tillage with mulch.
- The available nitrogen, phosphorus, potassium and organic carbon contents of soil was highest from reduced tillage without mulching.

- The contents of nitrogen, phosphorus and potassium in plants were also recorded highest values from the treatment of reduced tillage without mulching.
- The uptake of nitrogen, phosphorus and potassium were higher from the mulched plots under conventional tillage.
- Drip irrigation at 80% EP recorded the highest uptake of N, P and K.
- Conventional tillage with mulching and drip irrigation at 80% EP had the highest net returns resulting in higher B:C ratio.

Conventional tillage with mulching and drip irrigation at 80% EP was found to be better option in terms of yield and net returns in black gram for cultivation in summer rice fallows.

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Appendix

APPENDIX-I

Weekly weather data during experiment at ARS, Mannuthy from December 2016 to March 2017

Std. week	Date	Temperature (^0C)		Relative humidity (%) day			Wind speed (km/hr)	Mean sunshine hours	Mean evap.(mm)	Rain fall (mm)
		Max.	Min.	Morning	Evening	Mean				
52	24/12/16- 31/12/16	32.9	22.6	79	46	62	4.3	7.8	4.0	0.0
1	1/1/17-7/1/17	33.9	21.9	73	37	55	3.4	8.7	4.0	0.0
2	8/1/17-14/1/17	34.2	20.9	75	37	56	2.9	8.2	3.6	0.0
3	15/1/17-21/1/17	34.2	22.3	64	34	49	6.8	9.0	5.1	0.0
4	22/1/17-28/1/17	33.9	25.5	63	40	51	7.8	4.6	5.9	0.0
5	29/1/17-4/2/17	35.1	23.5	67	35	51	5.6	8.5	5.2	0.0
6	5/2/17-11/2/17	35.7	23.0	68	25	46	4.2	9.2	5.1	0.0
7	12/2/17-18/2/17	35.4	23.0	59	26	43	9.1	10.1	7.8	0.0
8	19/2/17-25/2/17	36.3	22.9	89	38	63	2.3	6.7	4.4	0.0
9	26/2/17-4/3/17	37.4	24.5	64	36	50	4.3	7.0	6.3	0.0

APPENDIX-II

Details of cost of cultivation

Sl. No.	Particulars	Men/ha (Rs.550/day)	Women/ha (Rs.450/day)	Amount (Rs./ha)
1	Ploughing (machine)	-	-	12000/-
2	Bed preparation	23	-	12650/-
3	Organic manure application	23	-	12650/-
4	Lime application	23	-	12650/-
5	Lay out of mulching sheet	-	50	22500/-
6	Lay out of drip irrigation system	9	-	4950/-
7	Sowing	-	50	22500/-
8	Fertilizer application	-	22	9900/-
9	Topdressing	-	10	4500/-
10	Plant protection chemical spraying	-	10	4500/-
11	Harvesting threshing	-	20	9000/-

APPENDIX-III

Details of cost of inputs

Sl. No.	Particulars	Amount (Rs./kg)
1	Seed	320.00
2	Organic manure	2.70
3	Lime	13.00
4	Mulching sheet	6.50 /m^2
5	Urea	7.00
6	Rajphos	7.00
7	MOP	20.00

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TILLAGE AND WATER SAVING TECHNIQUES FOR BLACK GRAM IN RICE FALLOWS

By

AISHA MOL P. B.

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ABSTRACT OF THE THESIS

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Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Agronomy

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR – 680656, KERALA, INDIA

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Abstract

Black gram is one of the major pulse crop grown throughout India. It is cultivated in an area of 3.5 m. ha with a production of 2.1 m. tones (NCAER, 2016). However, the production is not sufficient to meet the domestic demand. In Kerala, black gram cultivation is very limited or negligible. The summer rice fallows are the potential areas for pulse cultivation in Kerala. It is mainly grown under rainfed condition with poor management practices and so the productivity is found to be very low. Hence, measures are to be taken to enhance the productivity of pulses with advancements in technology. Conservation agriculture is gaining momentum now-a-days and mulching and drip irrigation are water saving technologies for enhanced crop production.

The research work on the topic "Tillage and water saving techniques for black gram in rice fallows" was undertaken in the Department of Agronomy, College of Horticulture, Vellanikkara during 2015-2017. The project was aimed to study the effect of reduced tillage practices on yield of black gram in rice fallows and to test the feasibility of mulch cum drip irrigation practices under conservation tillage in rice fallows. The experiment was laid out as RBD in split plot replicated thrice. There were 4 main plot treatments with tillage and mulching (conventional tillage with mulching, conventional tillage without mulching, reduced tillage with mulching, reduced tillage without mulching) and 3 subplot treatments with levels of drip irrigation (at 80% EP, 40% EP and life saving irrigation). Observations on growth, yield attributes and yield were recorded and soil moisture status, nutrient contents of plant and soil were determined.

The conventional tillage with mulching produced taller plants with higher number of branches and LAI at different growth phases of black gram. Maximum biomass and dry matter production were also achieved under

conventional tillage with mulching. Among the levels of drip irrigation, drip irrigation at 80% EP had the tallest and vigorous plants compared to other levels.

Maximum number of pods per plant, longer pods and highest number of seeds per pod were produced by the plants in mulched plots with conventional tillage. Conventional tillage with mulching recorded the highest yield (1339 kg/ha) and it was 25, 60 and 80% higher than that of reduced tillage with mulching, conventional tillage without mulching and reduced tillage without mulching respectively. Among the drip irrigation levels, highest yield attributes and yield were recorded from plots with drip irrigation at 80% EP.

Conventional tillage with mulching exhibited a 15, 18 and 40% higher WUE than conventional tillage without mulching, reduced tillage with mulching and reduced tillage without mulching respectively Among drip irrigation levels, highest water use efficiency was recorded from plots with life saving irrigation. Higher soil moisture content was recorded by reduced tillage with or without mulching and drip irrigation at 80% EP at different depths as well as at different growth phases.

Bulk density was found to be lower in the treatment of conventional tillage with mulching. Reduced tillage without mulching recorded the highest nutrient content of plants and available nutrient contents of soil. B:C ratio was found to be maximum under conventional tillage with mulching and drip irrigation at 80% EP.

Conventional tillage with mulching and drip irrigation at 80% EP was found to be better option in terms of yield and net returns in black gram for cultivation in summer rice fallows.

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