Production potential of cereal fodder crops under various tillage practices in rice fallows

by

GINTU GEORGE

(2009 - 11 - 141)

THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2011

DECLARATION

I hereby declare that the thesis entitled "**Production potential of cereal fodder crops under various tillage practices in rice fallows**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellanikkara

Date: 25-08-2011

Gintu George

(2009 - 11 - 141)

Dr. P. Prameela
Assistant Professor (SS)
Department of Agronomy
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur, Kerala

Date: 25.08.2011

CERTIFICATE

Certified that the thesis entitled **"Production potential of cereal fodder crops under various tillage practices in rice fallows"** is a record of research work done independently by Miss. Gintu George (2009-11-141) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

Vellanikkara

Dr. P. Prameela
Chairperson
Advisory Committee

CERTIFICATE

We the undersigned members of the advisory committee of **Miss. Gintu George (2009-11-141)** a candidate for the degree of **Master of Science in Agriculture**, with major field in Agronomy, agree that this thesis entitled **"Production potential of cereal fodder crops under various tillage practices in rice fallows"** may be submitted by **Miss. Gintu George (2009-11-141)** in partial fulfillment of the requirement for the degree.

Dr. P. Prameela
Assistant Professor (SS)
Department of Agronomy
College of Horticulture
Vellanikkara
(Chairperson)

Dr. C.T. Abraham
Professor and Head
Department of Agronomy
College of Horticulture
Vellanikkara
(Member)

Dr. Meera V. Menon
Associate Professor
Department of Agronomy
College of Horticulture
Vellanikkara
(Member)

Dr. Shyama K.
Assistant Professor
Department of Animal Nutrition
College of Veterinary and Animal Sciences
Mannuthy
(Member)

External Examiner who evaluated the thesis:

Dr. C. Jayanthi
Professor (Dept. of Agron)
TNAU, Coimbatore

Acknowledgement

Words cannot express my deep sense of gratitude and indebtedness to Dr. P. Prameela, Assistant Professor (SS), Department of Agronomy and chairperson of my Advisory Committee. I wish to place my heartfelt thanks to madam for her inspiring guidance, untiring help, patience, encouragement, constructive criticism and valuable suggestions during the period of the investigation and preparation of the thesis. My sincere and heartfelt gratitude ever remains with her.

I express my sincere gratitude to Dr. C.T. Abraham, Professor and Head, Department of Agronomy and member of my advisory committee for his valuable suggestions and guidance rendered to me for the completion of the research programme and preparation of the thesis.

I am ever grateful to Dr. Meera V. Menon, Associate Professor, Department of Agronomy, and member of my advisory committee for her valuable help, guidance and critical assessment throughout the period of the work. I thank her for all the help and cooperation she has extended to me.

I am deeply obliged to Dr.Shyama K., Assistant Professor, Department of Animal Nutrition, College of Veterinary and Animal Sciences, Mannuthy and member of my advisory committee for her unfailing support and relevant suggestions.

I wish to extend my whole hearted gratitude to Dr. C. George Thomas, Professor, Department of Agronomy, for his unstinted support, critical comments and valuable suggestions during my entire study and research work.

I am extremely thankful to Dr. P. S. John, Professor, Department of Agronomy, for his constant encouragement and constructive criticisms during the course of this study.

It is my pleasant privilege to acknowledge Dr. Mercy George, Professor, Department of Agronomy, for her unwavering encouragement and valuable advice during the course of investigation.

I also extend my sincere gratitude to Dr. K.E.Usha and Dr. P.A.Joseph, Professors, Department of Agronomy, for their valuable suggestions and encouragement throughout my work period.

I consider it is a privilege to express my heartfelt thanks to Sri. S. Krishnan, Associate Professor, Department of Agricultural Statistics, for his relentless support in resolving the statistical analysis of data.

My sincere thanks are also due to Dr. P. Suresh Kumar, Professor and Head, (Radio Tracer Laboratory), for his well timed support and help during the thesis work.

I also avail this opportunity to pay my sincere and heartfelt thanks to Sri. A. G. Rajendrababu, Farm Manager, Department of Agronomy, for his timely assistance in field works.

I am extremely delightful to place on record my profound sense of gratitude to labourers, Department of Agronomy for their sincere help and cooperation during the conduct of this research work.

I sincerely acknowledge the whole hearted cooperation of Mr.Nandakumar, Mrs.Priya Lakshmi, Mr.Rajesh and Mr.Joshy.

I wish to express my sincere thanks to Ms. Lakshmi, Ms. Jini, Ms. Moni, Ms. Soubhagyavathy, Ms. Saritha, Ms. Sheena and Ms. Sreela, Research Assistants of Department of Agronomy for their whole hearted cooperation and timely assistance.

Special thanks go to Mr. Aravindh, Students Computer Club, COH, for rendering necessary help whenever needed.

Words fall short as I place on record my indebtedness to my seniors, classmates, Juniors and friends, Ms. Sreevidhya, Ms. Sneha, Brindha Devi, Keerthi, Fasila, Ance, Swafah, Soumya, Rajees, Varun, Athul, Shyama, Savitha, Ms. Kavitha and Roshin for their prompt help and cooperation for the entire period of study.

Special thanks are also due to **Sri. Sachu Zachariah John** and **Sri. M. T. Thomas** for their timely and sincere help at critical junctures.

With gratitude and affection, I recall the boundless affection, constant encouragement, warm blessings and motivation from pappa, mummy, sister and grand parents without which this endeavour would never have become a reality.

Above all, I bow my head before the Great Truth, the Almighty, for enlightening and making me confident and optimistic throughout my life.

Gintu George

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

11.	Effect of tillage on weed dry matter production at harvest (kg/ha)	75
12.	Effect of tillage on nutrient uptake by fodder cereals (kg/ha)	78
13.	B - C ratio of fodder crops in various tillage practices	83

LIST OF PLATES

Introduction

1. INTRODUCTION

Fodder crops have an important role in meeting the requirement of various nutrients and roughage in milk production. Adequate availability of feed and fodder for livestock is vital for economizing milk production, as they constitute a major share of cost of livestock rearing. The average annual growth rate in the production of milk in our country in recent years has been close to four per cent (GOI, 2010). As per an assessment made by the Planning Commission, the domestic demand for milk by 2021-22 is expected to be 172.20 Mt and hence the milk production in India has to be increased to 180 Mt. The domestic demand for milk is growing at about 6 Mt per year, whereas annual incremental production over the last ten years has been about 3.5 Mt per year (GOI, 2010).

Though livestock rearing is an important subsidiary activity and an integral part of homestead farming systems as well as integrated farming systems, fodder cultivation did not receive much attention earlier due to availability of straw, herbage and other crop residues to meet the limited demands of local breeds. The population of crossbred cattle is increasing year by year and they have high productivity together with high feed demand. So lack of quality straw and herbage is a major problem faced even by small dairy farmers. However, cultivation of fodder crops has not gained momentum.

This is due to many reasons of which the important one, especially under Kerala situation, is the scarcity of land and high cost of cultivation. The decline in rice cultivation has also resulted in the unavailability of sufficient quantity of paddy straw. The area under rice in Kerala has been declining considerably over the past 2-3 decades with 40 per cent conversion from 1970 to 2008 (KSLUB, 2008). Introduction of short duration fodder crops in the existing cropping systems is a viable option to overcome this. The rice fallow offer a potential site for fodder production in Kerala, especially in the dry summer months, using the residual moisture and summer showers.

Green fodder crops are the cheaper source of nutrients as compared to concentrates and are useful in bringing down the cost of feeding. Fodder cereals provide all the critical elements in animal nutrition like highly digestible protein, carbohydrates, fats and minerals. They also are very good sources of beta carotene.

Cereal fodder crops like maize, sorghum and bajra are rich in energy and produce large quantities of quality herbage. These crops produce reasonably good herbage yield within a short growing period of 60-80 days. Hence after the first or second crop of rice, a cereal fodder crop can be introduced in the cropping system by utilizing the residual moisture of the rice field or by providing irrigation wherever possible.

Maize is the most nutritious and palatable *kharif* fodder for milch animals. Moreover it is free from anti-nutritional constituents and can be fed safely at all stages of growth, and it also makes good silage. Sorghum is also an ideal forage crop growing in areas where moisture is a limiting factor for crop growth, while bajra is an important source of food, feed and fodder. Though maize, sorghum and bajra are tropical crops, they are not traditionally cultivated in Kerala, and hence the major objective of the study was to find out the production potential of these fodder cereals and their suitability to rice fallow.

Cost of labour is the major factor contributing to the cost of cultivation of any crop. The cost for land preparation can be saved if minimum or zero tillage practices are followed. Minimum tillage is aimed at reducing tillage to the minimum necessary for ensuring a good seed bed, rapid germination and favourable growing conditions. This is a major component of conservation agriculture which plays an important role in sustainable agricultural production. Also, as these crops are to be introduced in rice fallows, tillage practices to be adopted assume significance as the soil is puddled previously.

So, the experiment aims at testing the suitability of zero and minimum tillage for raising cereal fodders in rice fallows and to work out the economics of various tillage practices so that a viable package can be developed for the benefit of dairy farmers.

As the total herbage produced is to be harvested in a single cut, excess quantity has to be preserved for future use. The study also aims to assess the suitability of preservation of these herbages as silage.

Under these circumstances, the present investigation was taken up with the following objectives

- To assess the production potential of fodder maize, fodder sorghum and fodder bajra under different tillage practices in rice fallow
- To evaluate the quality of forage and suitability for preservation as silage
- To study the effect of tillage on incidence of weeds
- To study the changes in soil physical and chemical properties due to introduction of cereal fodder in rice based cropping system

Review of Literature

2. REVIEW OF LITERATURE

Cereal fodder crops are considered as excellent feed for animals. With the increase in cattle population, the gap between the demand and supply of fodder is also increasing which can be reduced through the intensification of forage production. Food-forage based systems provide a support to the farmers when they adjust a part of their land and or season exclusively for fodder production.

Tillage is aimed at achieving successful establishment and better growth of crops but with minimum environmental cost. Tillage improves infiltration and percolation, soil aeration, porosity and workability of soil. Zero tillage and minimum tillage practices are now gaining importance and have proved to be successful in many crops. As opposed to conventional tillage, these practices, apart from their role in soil and moisture conservation, helps to minimize cost of cultivation.

The literature pertaining to the use of cereal fodders, effect of tillage on soil properties, crop growth and yield, weed population, nutrient absorption, economics of minimum tillage practices, utilization of rice fallow for fodder cultivation and fodder preservation are reviewed under this chapter.

2.1 CEREAL CROPS AS FODDER

Maize is considered an ideal forage crop and can be raised throughout the year in areas where irrigation facilities are available. Fodder maize can be fed safely at any stage of growth and there is no risk of prussic or oxalic acid poisoning or ergot disease (Chatterjee and Das, 1989).

Sorghum is a promising forage crop, capable of producing high yield (Singh *et al.*, 1971), and continues to be the major source of dry fodder and more so in the lean months of summer (Murthy, 1992).

Bajra or pearl millet is an important cereal crop that provides food, feed, stover and fuel to the farming community. Stover constitutes a major component of ruminant rations in marginal production environments, particularly during the dry season when green fodder or grazing is limited (Khairwal *et al.*, 2009).

2.2 EFFECT OF TILLAGE PRACTICES ON CEREAL CROPS

Effect of tillage on soil physical properties, moisture conservation, weed population and crop growth are well documented. However, studies on fodder crops, especially fodder cereals are few. The available literature pertaining to cereal crops is reviewed here.

Sarma and Gautham (2010) reported that conventional tillage gave higher grain yield of maize (0.11 – 0.17 t/ha) than minimum tillage. Chemical weeding with herbicide (Alachlor) resulted in 7.8 per cent higher yield of maize over mechanical weeding. There was significant increase in grain yield with conventional tillage (23.5%) due to reduced population and dry weight of weeds when compared with zero till (3.69 t/ha). They also reported that conventional tillage, higher seed rate (24 kg/ha) and hand weeding at 25 and 45 DAS appeared to be the best in reducing weed growth, producing maximum yield and net return in maize.

Sathyamoorthi *et al.* (2001) reported that higher maize grain yield with better economic returns could be achieved by land preparation with tractor drawn disc plough followed by cultivator tillage combined with integrated weed management (pre-emergence application of atrazine at the rate of 0.25 kg/ha followed by one hand weeding). According to Ram *et al.* (2010) yield attributing characters and grain yield of maize did not differ significantly among various tillage and crop establishment practices.

Disturbing the soil too much through tillage is not actually required to obtain good crop yields (Prasad *et al.*, 2006) and also a major portion of energy (25-30 %) in agriculture is utilized for either field preparation or crop establishment (Tomar *et al.*, 2006), where conventional tillage is mostly followed.

The green fodder yield of sorghum was significantly higher in conventional tillage based rotations than minimum tillage based rotations but it was at a par with zero tillage based rotations (Dixit *et al.*, 2010). It was also recorded that tillage methods and summer ploughing significantly influenced the green fodder yield of sorghum.

Better performance of cereal fodder crops under zero tillage has been reported by many scientists. Minimum tillage was more effective in conserving soil moisture and resulted in the same yield of maize as conventional tillage (Bhatt *et al.*, 2004). Govaerts *et al.* (2005) could obtain stable high yield with zero tillage in wheat-maize rotation.

Yield attributing characters and grain yield of maize did not differ significantly among various tillage practices and crop establishment practices (Kaputsa *et al.*, 1996). Raised seed bed and conventional tillage increased grain yield of maize by 13.74 and 16.90 per cent over zero tillage (Chopra and Angiras, 2008). Similar findings of increased maize yield under conventional tillage with residue incorporation compared to zero tillage was reported by Saha *et al.* (2010). Potter *et al.* (1996) reported that the biomass production of sorghum was less sensitive to tillage intensity than maize.

An experiment was conducted at the Regional Agricultural Research Station, Pattambi during rabi 1998-'99 to study the feasibility of minimum tillage system in rice cultivation (Mathew and Johnkutty, 2003). The highest yield was observed in treatment of local tillage system with two hand weedings (3687 kg/ha), which was closely followed by minimum tillage system (3333 kg/ha). Minimum tillage system with pre-plant spray of glyphosate followed by butachlor spray gave an yield on par with that of local tillage system with hand weeding. There was no serious weed problem in plots of minimum tillage system. The results of the study indicated the possibility of raising a rice crop with minimum tillage operations and controlling the weed growth both by pre and post-planting herbicide application.

In red soil, tillage to a depth of 20 cm coupled with *in situ* surface mulching was found helpful for enhancing rain water conservation as well as its utilization for achieving higher yield of sorghum under rainfed conditions in semi arid conditions of Madhya Pradesh (Narayan and Lal, 2010).

Deep tillage improved the soil moisture storage, water use efficiency and grain yield of pearl millet while consumptive use of water was higher with minimum tillage. Total dry matter yield with deep tillage and conventional tillage were 23.2 and 10.2 per cent higher than minimum tillage in the first season trial, and the corresponding values for the second season were 30.7 and 13.3 per cent (Saxena *et al.*, 1997).

2.3 EFFECT OF TILLAGE PRACTICES ON WEED POPULATION AND CROP YIELD

Among the annual agricultural losses in India, weeds account for 45 per cent. So adoption of proper weed control measures is very important. Weed control measures include physical, cultural, biological and chemical methods. Tillage practices come under physical methods of weed control. Nowadays, zero tillage and minimum tillage practices are gaining importance in conservation agriculture due to their role in soil and moisture conservation and reduced cost of cultivation.

It is widely recognized that primary tillage influences distribution of weed seeds in different soil layers (Fray and Olson 1978; Froud-Williams *et al.*, 1983). They also observed that inversion tillage such as mould board ploughing resulted in burial of large proportion of weed seeds. Non-inversion tillage methods such as chisel ploughing left a greater proportion of weed seeds near the surface. Boll and Miller

(1990) reported that secondary tillage practices such as hand hoeing and harrowing had lesser influence on the seed bank than primary tillage.

Chopra and Angiras (2008) studied the influence of various tillage methods on the productivity and weed control in maize. Raised seed bed resulted in significantly lower density and dry matter of weeds at 60 days after sowing and at harvest of the crop, followed by conventional tillage.

Chauhan and Johnson (2009) reported that agronomic practices such as tillage have implications for weed competition and weed management strategies. The effect of different tillage systems, including conventional tillage, minimum tillage and zero-tillage, on the emergence pattern of different weed species was evaluated in a field experiment in the kharif seasons of 2007 and 2008. In both years, seedling emergence of *Digitaria ciliaris, Echinochloa colona, Eleusine indica, Ageratum conyzoides, Eclipta prostrata* and *Portulaca oleracea* were greater in zero-tillage compared with either conventional or minimum tillage where the seedling emergence was similar.

Mishra and Singh (2009) observed that rotational tillage systems significantly reduced the seed density of *E. colona* as compared to continuous zero or conventional tillage systems. Weed seed number decreased considerably in plots receiving effective weed control (herbicide + one hand weeding).

In a 20 year tillage experiment Cardina *et al.* (1991) found that the greatest weed seed density was in no tillage plots and the lowest in conventional tillage plots. Similarly, Tisdale *et al.* (1995) found that total weed density was the greatest after one year in no tillage and two years in conventional tillage. Sathyamoorthi *et al.* (2001) reported that primary tillage with country plough resulted in lower densities of grasses and sedges, whereas broad leaved weed population was reduced by tractor drawn disc or mould board plough followed by cultivator tillage in maize fields raised in black clay and red sandy loam soils.

The depressing effect of weeds on crop yields varies with types of weeds, intensity and duration of weed infestation. Young *et al.* (1984) stated that *Agropyron repens* at a density of 745 shoots/m^2 reduced maize grain yield by 37 per cent. *Echinochloa crusgalli* at a density of 100 plants /m^2 reduced the yield of maize by 18 per cent (Kropft *et al.*, 1984). Maize yield was reduced by 80 per cent when the fields were infested with *Rottboellia exaltata* (Sharma and Zelaya, 1986).

According to Tiwari *et al.* (1987), maize grain yield was reduced by 100 per cent due to uncontrolled weed competition under maize-cowpea intercropping system. However, Rola and Rola (1992) reported that the presence of *Amaranthus retroflexus* in maize fields reduced grain yield by 20 and 30 per cent with 20 and 30 weeds/m^2. Whereas, Vargessel *et al.* (1994) opined that the weed distribution in corn fields was not a critical consideration in determining yield loss. However, Amador-Ramirez (2002) registered higher grain yield in maize with an increase in the weed free period.

2.4 WEED SHIFT DUE TO CROP ROTATION

The crop rotation that included one to three year of forage production resulted in higher densities of annual broad leaved and perennial weeds in the succeeding potato crop (Liebman *et al.*, 1996). Similarly, Stevenson *et al.* (1997) reported that the total weed density in the barley-forage rotation was about three times that in the barley monoculture. Subsequently, Pandey *et al.* (2001) recorded reduced density of broad leaved and grass weeds with repeated weedings or herbicidal management with atrazine and pendimethalin in maize-wheat rotation.

New tillage practices such as reduced, minimum or no-tillage commonly caused changes in the composition and abundance of weed species present in the cropping system (Froud-Williams *et al.*, 1983; Gebhardt *et al.*, 1985; Boll and Miller, 1990). However, in some cases tillage had no selective influence on weed flora

(Swanton *et al.,* 1993). Zero tillage with effective weed control was found more remunerative in soybean-wheat system (Mishra and Singh, 2009).

Weed population shifts towards annual weeds were observed when conventional tillage systems were changed to zero-tillage systems in maize (Boll and Miller, 1993). Tuesca *et al.* (2001) reported that the weed spectrum changed rapidly in no-tillage systems with increase of annual grassy weed population in maize-soybean as against wind dispersed weeds in wheat-soybean cropping system and inconsistent behaviour of perennial weeds in relation to tillage systems.

2.5 EFFECT OF TILLAGE ON NUTRIENT ABSORPTION

Tillage and fertility management influence both nutrient and soil moisture dynamics in the soil– plant system, which in turn affect nutrient use efficiency in cropping systems. Some of the tillage functions are to incorporate fertilizer and crop residues in the soil, improve soil aeration, and subsequently promote organic N and P mineralization (House *et al.*, 1984; Huntington *et al.*, 1985; Carter and Rennie, 1987; Groffman *et al.*, 1987; Rice *et al.*, 1987; Varco *et al.*, 1993; McCarthy *et al.*, 1995; Yoong *et al.*, 2001; Dinnes *et al.,* 2002).

Tillage along with N fertilizer application had a significant effect on plant uptake of N and P, especially at early growth stages of maize. But the N rate and seasonal variability have more influence on plant N and P uptake than do the tillage system (Al-Kaisi and Kwaw-Mensah, 2007).

Nitrogen uptake of maize increased significantly with chemical weeding and legume mulching and it was lower under minimum tillage (Sharp *et al.*, 1986). They also reported that the P uptake of maize was more efficient under no tillage than under conventional tillage.

Tillage treatments affected the distribution of roots and extractable P in the top soil layer (Anderson *et al.*, 1987). Phosphorus absorption and dry matter production in conventional tillage were less than that in a hand planted no till plot but greater than that with severe soil disturbance (Mc Gonigle *et al.*, 1990). Greater rates of P fertilizer were not required in reduced tillage systems compared with systems that cause a greater degree of soil disturbance (Miller *et al.*, 1995).

Compared with zero tillage, the conventional tillage system significantly changed the mineralizable C and N pools (Woods and Schuman, 1988). However, a long-term zero-till system has potentially greater mineralizable C and N pools compared with conventional tillage (Doran, 1980). The tillage system can influence soil N availability due to its impact on soil organic C and N mineralization and subsequent plant N use or accumulation (Gilliam and Hoyt, 1987; Mehdi *et al.*, 1999; Sanju and Singh, 2001; Dinnes *et al.*, 2002; Al-Kaisi and Licht, 2004; Licht and Al-Kaisi, 2005a).

The plant N use can be altered by the different management practices and interactions between tillage system, N rate, and N application timing. The interactive effects of different tillage systems such as zero tillage, conventional tillage, or minimum tillage and N rate on grain N uptake was significant in increasing N removal with increasing N rate (Halvorson *et al.*, 2001).

Just as the N availability is affected by the tillage system, P availability can also be affected, leading to P deficiency in many cropping systems. Plant P uptake varies with soil P and moisture availability, and the concentration of P in plant tissue decreases with plant age and water stress (Payne *et al.*, 1995). It was found that banded P (deep or shallow) increased early corn growth and P uptake compared with broadcasting or placement with no tillage (Mallarino *et al.*, 1999).

2.6 EFFECT OF TILLAGE ON SOIL PROPERTIES

Sharma and Acharya (2000) reported no significant change in soil organic carbon, but opined that the effect of conservation tillage may be significant when practiced over a long period of time.

The role of tillage and mulching practices in conserving soil moisture, with subsequent beneficial effect on crop productivity has long been recognized (Sharma *et al.*, 1990; Sharma and Acharya, 2000). Tillage and weed control practices had no effect on organic carbon and total nitrogen status of soil and increased infiltration rate (Sharma *et al.*, 2010a). They also reported that conventional tillage along with legume mulching and chemical weeding was beneficial for improving moisture and nutrient conservation and achieving higher productivity and profitability of maize.

Soil bulk density recorded in no–tillage was significantly higher than conventional tillage, fresh beds and permanent beds (Kumar *et al.*, 2002). Aggarwal and Goswami (2003) also found less bulk density in beds. The results were in accordance with that obtained by Ram *et al.* (2010).

The increase in infiltration rate under improved tillage was attributed to improved porosity, reduced run off and bulk density and favourable tilled conditions (Bharadwaj and Sindhwal, 1998). This is in agreement with the findings of Pandey *et al.* (2005); Gurumurthy and Rao (2006); Narayan and Lal (2010).

2.7 TILLAGE AND WATER USE EFFICIENCY

No-till increased soil water storage capacity and improved water use efficiency compared to conventional tillage. Mulch is a good option for rice residue management under upland condition, especially with reduced or no tillage. Goswami and Saha (2006) reported beneficial effect of rice straw mulching in regulating soil temperature

Water use efficiency of maize without tillage was 18.3, 17.5, 57.8 and 100% greater than with tillage at irrigation (12 mm) frequencies of 2, 4, 8 and 12 days respectively. The leaf water potential of maize was generally higher for no-tillage compared with conventional ploughing (Lal *et al.*, 1978). Higher water use efficiency was also reported in no-tillage by Chauhan *et al.*, (2000).

2.8 ECONOMICS OF MINIMUM TILLAGE PRACTICES

Cost of labour is the major factor influencing net profit from the cultivation of any crop. Zero tillage has many economic and environmental benefits over conventional tillage such as lower labour and fuel needs, reduced soil erosion, reduced run off, increased soil organic carbon contents and increased soil biological activity (West and Post, 2002). Jain *et al.* (2007) also reported similar findings.

The highest net returns and B: C ratio was observed in maize under no tillage due to low cost of cultivation (Landers *et al.*, 2001). Similar results of higher net income in no tillage were reported by Ram *et al.* (2010).

2.9 UTILIZATION OF RICE FALLOWS FOR FODDER CULTIVATION

The rice fallows offer a potential site for fodder production especially in the dry summer months using the residual moisture and summer showers. Short duration crops like fodder cereals or legumes can be fitted into the existing cropping systems so that fallow period can be made use of.

Food-fodder based crop rotations have been evaluated for their profitability and were found more remunerative than others in many agro-climatic and management situations (Suneethadevi *et al.*, 2004).

According to Kumar *et al.* (1997), sorghum after rice gave the highest output energy of $59.1x10^3$ MJ/ha as compared to rice (*Oryza sativa*)-pigeonpea (*Cajanus cajan*) and rice-safflower (*Carthamus tinctorius*).

Combination of cereals and legumes were compared with sole cereal crops for evaluating the fodder production potential. The green fodder yield was highest for maize + cowpea combination (19.8 t/ha) followed by sole crop of maize (19.5 t/ha). Bajra + cowpea was the second best treatment (12 t/ha) followed by sorghum + cowpea combination (11.7 t/ha) (AICRP, 2001).

2.10 FODDER PRESERVATION AS SILAGE

The best way to regulate the supply of palatable and nutritious fodder during the lean period is to conserve the surplus fodder in the form of hay and silage (Patil and Singh, 1980). Sorghum is a promising forage crop and is capable of producing high yields and continues to be the major source of dry fodder, especially in the lean months of summer (Murthy, 1992).

Narayanan and Dabadghao (1972) reported that maize is the most common crop for silage making and the right time of silage making is between flowering and milk stage. Although the production of fodder maize and fodder sorghum may not be distributed evenly over the growing season, forage maize and sorghum can readily be ensiled to produce high quality stored feed (Mansfield *et al.*, 1990).

Chatterjee and Maiti (1981) reported that silage made from sorghum registered 3.1, 4.5, 34.8 and 47.9 per cent crude protein, ether extract, crude fibre and NFE respectively and the values were less than green forage. Singh and Srivastava (1990) stated the dry matter content of the material should be between 30-45 per cent at the time of ensiling and ensiling of chopped material gave quality silage. Further, the authors have opined that one per cent urea can be added at the time of ensiling which increased the crude protein from 1.1 to 6.3 per cent in silage made from grass. Hansen *et al.* (1992) observed reduced nitrate content by ensiling maize.

Chauhan and Dahiya (1993) concluded that addition of urea at one per cent and 1.5 per cent increased the crude protein content from 8.14 per cent in untreated silage to 11.10 and 13.05 per cent respectively. Thakur and Sharma (1993) observed an increase in silage quality by adding one per cent common salt and 0.25 per cent urea. Chauhan (1995) reported that the apparent digestibility was higher in silage than in hay. He also observed that addition of 1.5 per cent molasses, one per cent each of common salt and urea enhanced the quality of silage.

Materials and Methods

3. MATERIALS AND METHODS

The research project entitled "Production potential of cereal fodder crops under various tillage practices in rice fallows" was undertaken at the Department of Agronomy, College of Horticulture of Kerala Agricultural University during 2009-2010. The details of materials used and methods adopted in the conduct of the experiment are presented in this chapter.

3.1 LOCATION

The experiment was conducted in the Kotteppadam field under the Department of Agronomy, College of Horticulture, Vellanikkara (Plate 1). Geographically, the area is situated at $10^0$31'N latitude and $76^0$13'E longitude and an altitude of 40.3 m above mean sea level.

3.2 SEASON AND WEATHER CONDITIONS

The experiment was conducted in rice fallow after the harvest of first season rice crop (date of harvest: 04-11-09) during the period from November 2009 to February 2010. The details of the meteorological data recorded at Vellanikkara during the crop period are presented in the Appendix 1 and Fig. 1 and 2.

3.3 SOIL CHARACTERISTICS

Soil of the experimental site is texturally classified as sandy loam. The soil is acidic in reaction with a pH of 5.4. The field capacity of the soil was 14.6 per cent and permanent wilting point was 4.6 per cent. The basic physico-chemical properties of the soil are presented in Table 3.1.

Table 3.1. Soil physico chemical properties before the experiment

Parameters	**Value**	**Method used**
a) Mechanical composition (%)		Robinson's International Pipette method, 1992
Sand	68.83	
Silt	16.27	
Clay	14.90	
Textural class	Sandy loam	
b) Physical characteristics		
Bulk density (g/cc)	1.43	Core method (Piper, 1966)
Particle density (g/cc)	2.60	
Porosity (%)	45.00	
Field capacity (%)	14.60	
c) Chemical properties		
Organic carbon (%)	0.64	Walkley and Black method, 1934
Available phosphorus (kg/ha)	20.34	Bray extractant-Ascorbic acid reductant method (Watnabe and Olsen, 1965)
Available potassium (kg/ha)	103.00	Neutral normal ammonium acetate extractant Flame Photometry (Jackson, 1958)
pH	5.4	

Fig. 1. Weather data during the crop period (November 2009 to February 2010)

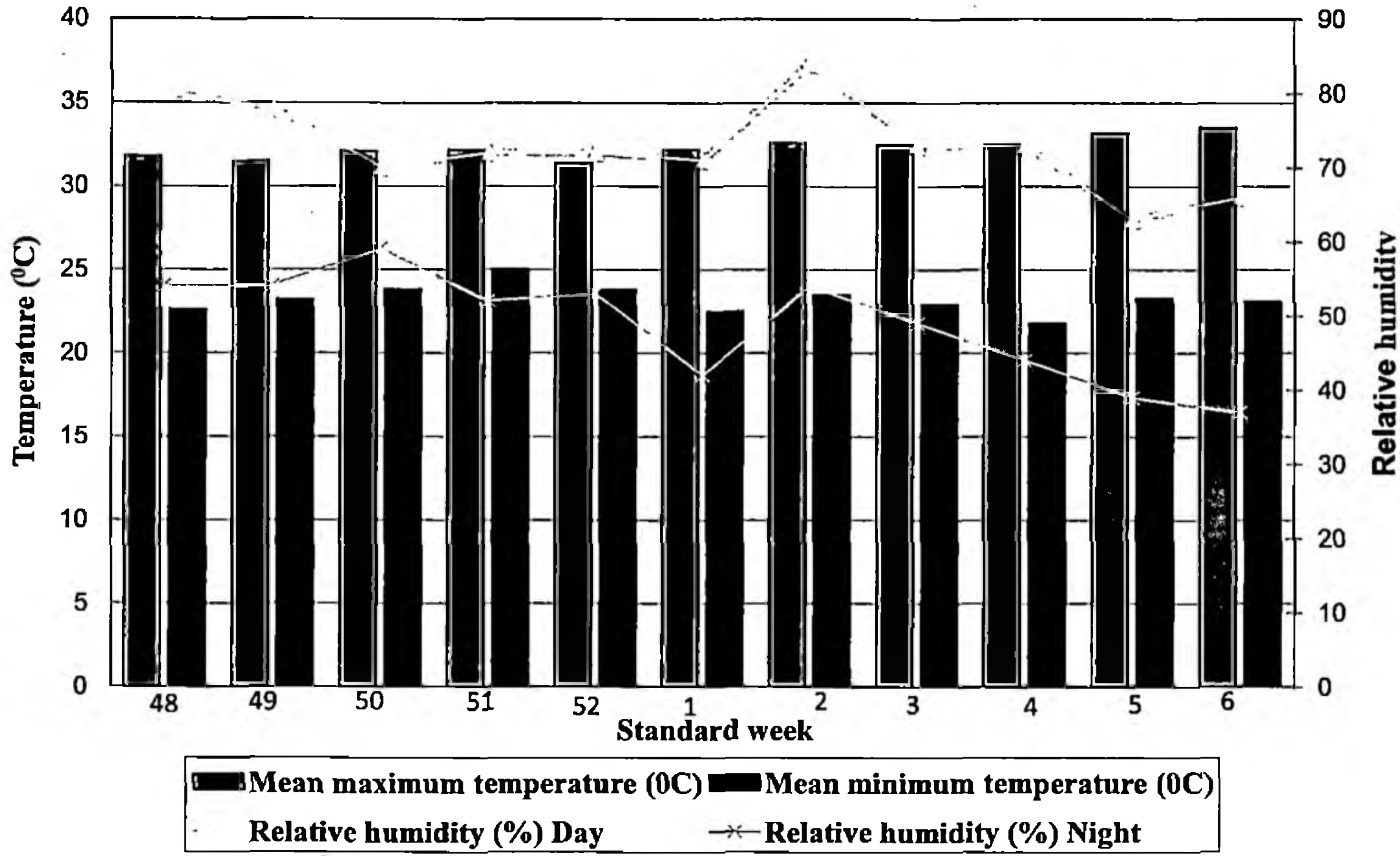
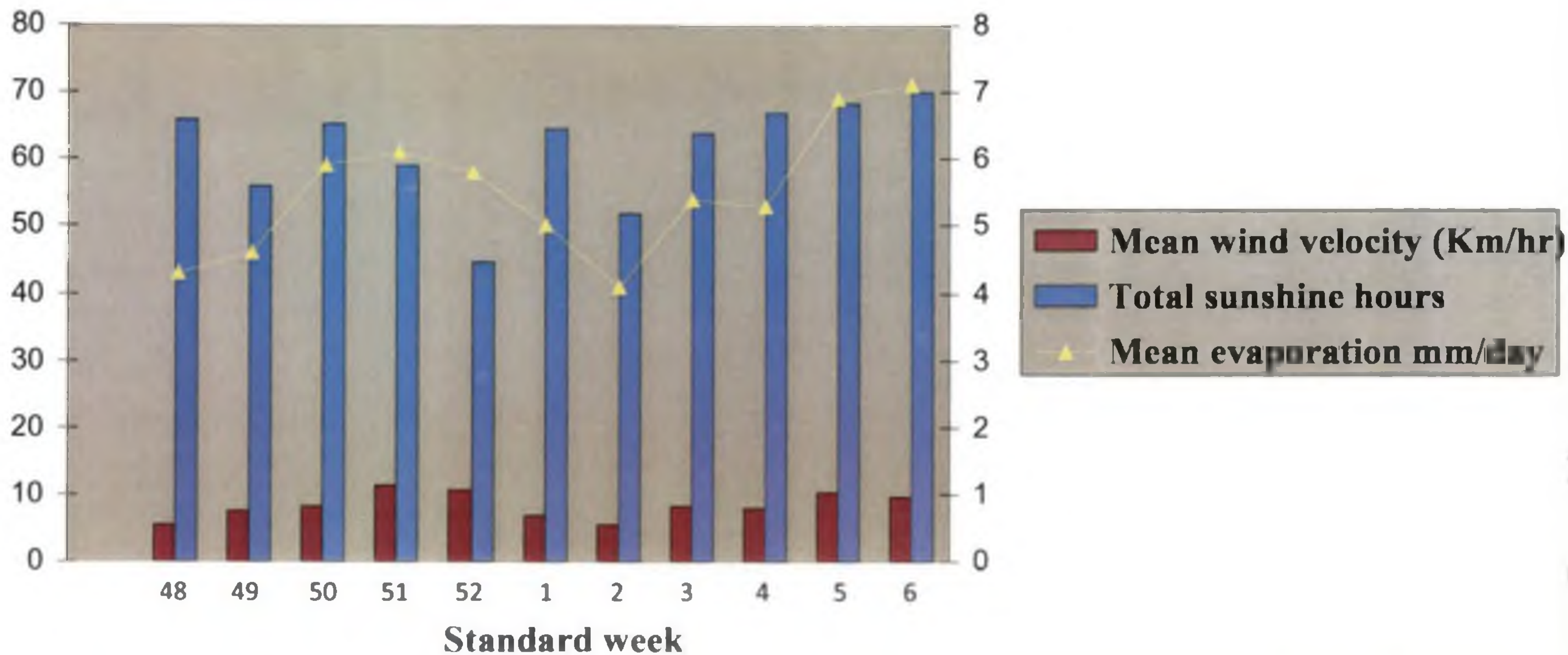


Fig. 2. Weather parameters during the crop period (November 2009 to February 2010)



3.4 DETAILS OF THE EXPERIMENT

3.4.1 Design and Layout

The design was split plot with four main plot treatments and three sub plot treatments replicated four times (Plate 2). The plot size was 20m^2. The layout of the field is given in Fig.3 and the treatment details are given below.

Main plots	**Tillage treatments**
M_1	Zero tillage without herbicide application
M_2	Zero tillage with herbicide (glyphosate) application
M_3	Minimum tillage
M_4	Normal tillage
Sub plots	**Fodder cereals**
S_1	Fodder Maize
S_2	Fodder Sorghum
S_3	Fodder Bajra

Date of sowing: 30-11-2009

Date of harvest: 29-01-2010

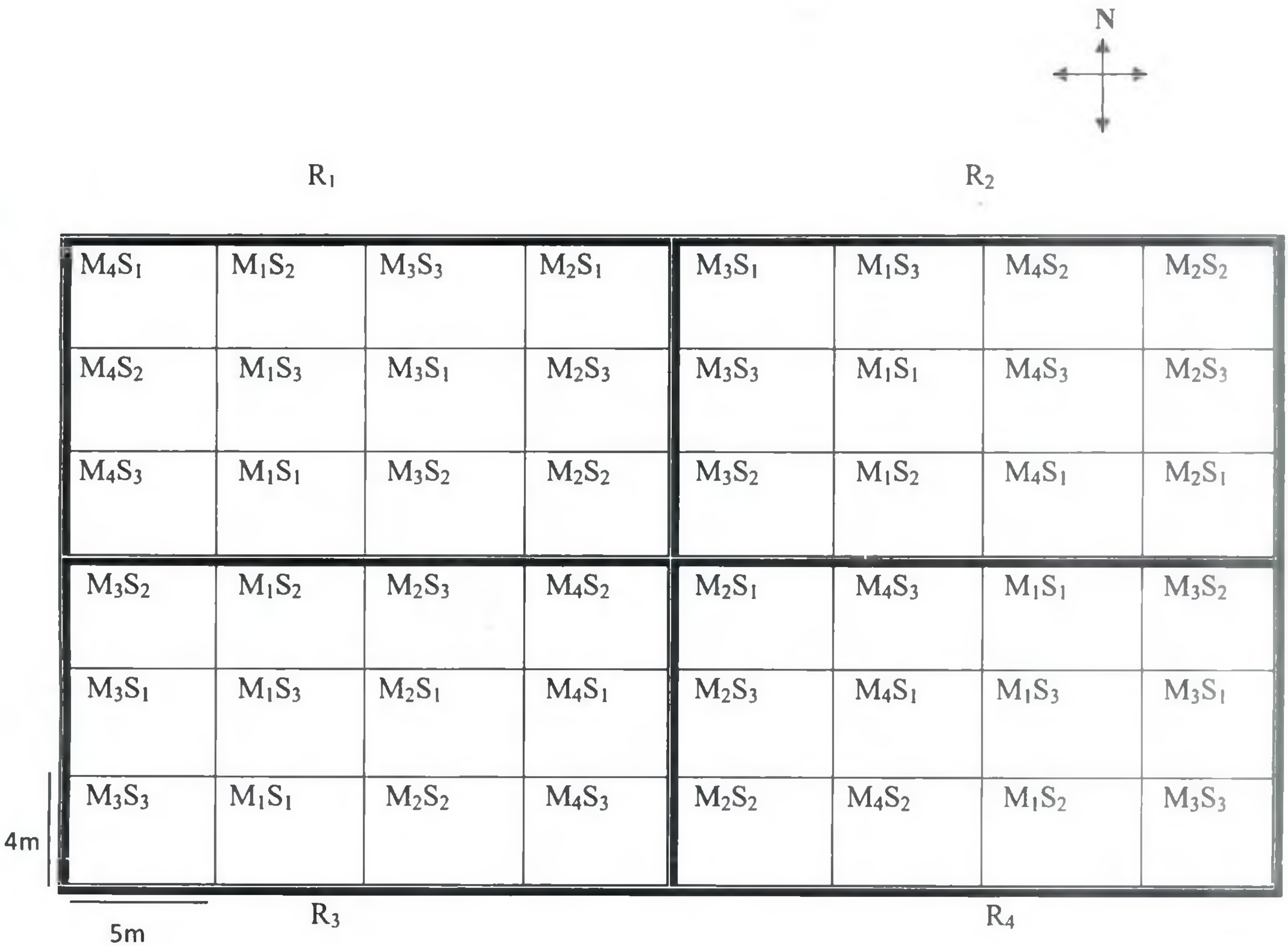
Duration of the crops: 60 days

In zero tillage without herbicide application (M_1), the land was kept undisturbed (Plate 3). For M_2, glyphosate was applied at the rate of 0.8 kg /ha and there was no soil disturbance (Plate 5). For M_3 soil was dug in strips (width about 15cm) at a spacing of 30 cm (Plate 4). In the case of M_4, the land was ploughed thoroughly twice and then ridges and furrows were taken (Plate 6).

Plate 1. Rice fallow before layout of the experiment

Plate 2. General view of the field after layout

Fig. 3 Layout of field experiment



M_1: Zero tillage without herbicide application

M_2: Zero tillage with herbicide application

M_3: Minimum tillage

M_4: Normal tillage

S_1: Fodder Maize

S_2: Fodder Sorghum

S_3: Fodder Bajra

Plate 3. Zero tillage without herbicide application (M_1)

Plate 4. Minimum tillage (tilling along the rows only, M_3)

a. **Spraying glyphosate**

b. **One week after Glyphosate spray**

Plate 5. Zero tillage with herbicide application (M_2)

a. Tilling the land using a cultivator

b. Well prepared land with ridges and furrows

Plate 6. Normal tillage (M_4)

3.4.2 Fodder Crops

The details of the crops, varieties used, seed rate and spacing followed are listed below.

Crops	**Variety**	**Seed rate (kg/ha)**	**Spacing (cm x cm)**
Fodder Maize	African Tall	50	30 x 15
Fodder Sorghum	CO - 27	40	30 x 15
Fodder Bajra	CO - 8	10	30 x 15

3.5 CROP HUSBANDARY

(i) Land Preparation and Sowing

The land was prepared according to the treatment. All the crops were dibbled at a spacing of 30 cm x 15 cm.

(ii) Manures and Fertilizers

Before sowing farm yard manure(FYM) at the rate of 10 t/ha was applied uniformly to the plots and incorporated. Urea (46% N), Mussorie Rock Phosphate (20% P_2O_5) and Muriate of Potash (60% K_2O) were the fertilizers used for the experiment. Fertilizers were applied as per the recommendation for the respective crops. Fertilizer doses of 120:60:40, 60:40:20 and 40:20:20 kg N, P_2O_5 and K_2O/ ha were applied for fodder maize, fodder sorghum and fodder bajra, respectively.

The entire quantity of P and half the recommended doses of N and K were applied as basal and the remaining quantity of N and K were top dressed at 30 days after sowing to all the three crops.

(iii) After Cultivation

Thinning was done 15 DAS to maintain the required plant population. The crops were given 5cm irrigation once in 4 to 5 days.

(iv) Harvesting

Harvesting was done at 50 per cent flowering stage. Two border rows all around the plots were left for silage making. The remaining plants were harvested and forage yield recorded.

3.6 OBSERVATIONS ON GROWTH CHARACTERS

Five plants were randomly selected from each plot for recording observations on plant height, leaf area index, leaf-stem ratio, shoot-root ratio and dry matter production. The following observations were recorded at different growth stages.

(i) Plant Height

Plant height was recorded at 30 DAS, 50 DAS and at harvest. From each plot, ten plants were selected and the height was measured in cm from ground level to the tip of leaves. The average height per plant was worked out.

(ii) Leaf Area Index

It refers to the ratio of leaf area to the land area. The leaf area of the uprooted plants was measured using leaf area meter. LAI was measured at 30 DAS and at harvest.

(iii) Leaf - Stem Ratio

Leaf: stem ratio was determined at 30 DAS and at harvest. The plants were cut at the base and then the leaves and stems were carefully separated and weighed.

(iv) Shoot - Root Ratio

Five plants from each plot were randomly pulled out and their root and shoot portions were separated. The shoot-root ratio was calculated at 30 DAS and at harvest.

(v) Forage Yield

At harvest, the fresh weight of the fodder cereals was recorded in kg/plot and expressed as t/ha.

(vi) Dry Matter Production

The uprooted plants were chopped, first air dried and then oven dried at 70^0C. The dry weight was recorded and expressed as t/ha.

3.7 OBSERVATIONS ON WEED GROWTH

(i) Weed Count

Species wise weed count randomly chosen from $1m^2$ area in each plot was taken and recorded. The observations were taken at 30 DAS and at harvest. The total number of grasses, sedges and broad leaved weeds were recorded.

(ii) Weed Dry weight

The weeds from the sampling area in each plot were uprooted, dried initially in shade and then in a hot air oven at 70^0C and the weed dry weight was recorded and expressed in g/m^2 at 30 DAS and at harvest.

3.8 NUTRIENT CONTENT AND UPTAKE

(i) Nitrogen

The nitrogen content in leaf and stem was estimated by Microkjeldahl digestion and distillation method (Jackson, 1950) and expressed as percentage.

(ii) Phosphorus

The phosphorus content in leaf and stem was estimated colorimetrically by the vanadomolybdate method (Jackson, 1958) and expressed as percentage.

(iii) Potassium

The potassium content was estimated in a flame photometer (Jackson, 1958) and expressed as percentage.

(iv) Calcium and Magnesium

The Ca and Mg content was estimated using diacid mixture and read by atomic absorption spectrophotometer (Jackson, 1958) and expressed as percentage.

(v) Uptake of Nutrients

The total uptake of NPK was worked out by multiplying nutrient content and dry matter production and expressed as kg/ha.

3.9 PROXIMATE ANALYSIS

Sample plants collected from each plot at 30 DAS and at harvest were sun dried and then oven dried to constant weight. The stem and leaf were separated, ground, digested and nutrient content estimated.

(i) Crude Protein

Plant nitrogen content was estimated by Microkjeldhal digestion and distillation method (Jackson, 1958). This content was multiplied by 6.25 to obtain crude protein content of the sample.

(ii) Crude Fibre

The crude fibre content was estimated using the acid – alkali digestion method (Sadasivam and Manickam, 1992).

(iii) Ether Extract (Crude fat)

Crude fat was estimated by extracting the plant material with the fat solvent, petroleum benzene (A.O.A.C., 1975).

(iv) Total Ash

Ash content was determined by igniting a known quantity of plant sample at 600^0C for three hours (A.O.A.C., 1975).

(v) Nitrogen Free Extract (NFE)

Nitrogen Free Extract of the plant sample was obtained by subtracting crude protein, crude fibre, ether extract and ash content values expressed in percentage from hundred.

(vi) Tetany Ratio

The quality of herbage was also assessed with respect to the tetany ratio, which was calculated as (% DM of K /39) / (% DM of Ca/20) + (% DM of Mg/12.1). A ratio above 2.2 indicates proneness to grass tetany (Klingerman, 2007).

3.10 SOIL STUDIES

3.10.1 Physical Constants of Soil

(i) Bulk density

The conventional core method (Piper, 1966) was used for determining the bulk density of soil of each plot both prior to as well as after the experiment.

(ii) Particle density

Particle density was determined from the mass of soil solids and their volume. The volume was calculated from the mass and density of the water displaced by the sample with the help of a pycnometer.

(iii) Soil moisture status

Soil moisture content at the end of crop period was determined by gravimetric method and expressed as percentage on dry weight basis.

3.10.2 Chemical Analysis

Composite soil samples were taken from each plot prior to the sowing of fodder cereals as well as after the harvest of the crops. The soil samples were then air dried, powdered and passed through 2mm sieve and the following parameters recorded.

(i) Organic carbon

Walkley and Black method (1934) was used for the determination of total organic carbon content of soil.

(ii) Available phosphorus

Available phosphorus content of soil was determined using Bray 1 extractant and molybdophosphoric acid method in hydrochloric acid system (Watnabe and Olsen, 1965).

(iii) Available potassium

The available potassium content of soil was determined flame photometrically using the neutral normal ammonium acetate extractant (Jackson, 1958).

(iv) pH

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

3.11 FODDER PRESERVATION

The experiment on silage preservation with and without the addition of molasses was done as per the method described by Otieno *et al.*, (1990) and replicated thrice. The three fodder cereals were harvested at soft dough stage and chopped into small pieces of about 2 cm length. Silage was made in plastic bags (60 cm x 35 cm) of 150 gauge thickness. In molasses treatments, molasses was added at the rate of 30-35 kg/ tone wet weight. To 3.5 kg material, 125 ml of molasses mixed with equal quantity of water was added and thoroughly mixed with hand before filling in plastic bags (Plate 11).

Each bag was filled with 3.5 kg chopped material, pressed thoroughly to expel air and tightly tied using jute twine and stacked one above the other on racks. After three months the bags were opened and the quality parameters like pH, colour and odour were assessed.

For pH determination, 10g silage was taken in a beaker to which 100 ml hot distilled water was added and stirred intermittently for 30 minutes and the pH of the suspension was recorded. Based on pH, odour and colour the silage was graded as very good, good or fair. A good silage will have greenish to yellowish colour and pleasant odour. The pH ranges of very good, good and fair silage were taken as 3.8 to 4.2, 4.2 to 4.5 and > 4.5 respectively (Thomas, 2008).

3.12 STATISTICAL ANALYSIS

Data generated on the various parameters were analyzed statistically by using the analysis of variance. In case the effects were found to be significant Duncan's Multiple Range Test was done for making logical comparisons between treatment means (Panse and Sukhatme, 1978).

3.13 ECONOMICS

Cost of production of cereal fodders 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.

Results

4. RESULTS

Observations on plant and soil characters as well as quality parameters were recorded and were statistically analyzed and the results are given below.

4.1 BIOMETRIC OBSERVATIONS

4.1.1 Plant Height

Plant height differed significantly among tillage methods at 30 DAS, 50 DAS and at harvest (Table 4.1). At 30 DAS, the tallest plants were observed in minimum tillage followed by herbicide based zero tillage and normal tillage which were on par. At 50 DAS and at harvest, though the tallest plants were observed in herbicide based zero tillage the trend was the same with all the tillage treatments except zero tillage recording statistically comparable values. The lowest plant height was recorded in zero tillage at all the stages of observation.

Among three cereal fodders, maize recorded the highest plant height at 30 DAS and at harvest followed by bajra and sorghum. However, at 50 DAS bajra recorded the highest plant height followed by maize and sorghum. Tillage x crop interaction was not significant at any stage.

4.1.2 Leaf Area Index (LAI)

Leaf area index differed significantly among tillage treatments both at 30 DAS and at harvest (Table 4.2 and 4.3). The plants in the herbicide based zero tillage plots recorded significantly higher LAI values than all other treatments. The next best treatments were normal and minimum tillage which were statistically on par.

The three fodder crops also differed significantly with respect to LAI. Fodder maize recorded the highest LAI (2.65 at 30 DAS and 5.12 at harvest) which was significantly different from sorghum and bajra. The LAI of these two crops were comparable.

The interaction between tillage methods and fodder crops were also significant at both the stages of observation. In the case of fodder maize, herbicide based zero tillage (5.98) and minimum tillage (5.08) treatments were superior whereas in bajra, herbicide based zero tillage (3.12) and normal tillage (3.04) were superior. However in bajra, LAI in normal tillage was comparable to that of minimum tillage (2.62). In sorghum, except zero tillage (2.58) all tillage methods recorded statistically comparable LAIs.

In general the zero tillage practices resulted in significantly inferior values of LAI till harvest stage of the crop.

4.1.3 Leaf - Stem Ratio

Leaf stem ratio was recorded based on fresh weight of leaves and stems of five sample plants. There was no significant difference between tillage methods with respect to leaf stem ratio at both the stages (Table 4.4). Highest leaf stem ratio was recorded by plants in minimum tillage at 30 DAS and in zero tillage at harvest. The ratio remained more or less constant.

There was significant difference among crops at both the stages. At 30 DAS and at harvest, highest leaf stem ratio was recorded by sorghum plants followed by maize, the values being statistically on par. The lowest ratio was recorded by bajra plants at both the stages. The interaction between main plots and sub plots was not significant both at 30 DAS and at harvest.

4.1.4 Shoot - Root Ratio

There was no significant difference between tillage methods with respect to shoot root ratio at 30 DAS and at harvest (Table 4.5). However, crops differed significantly at 30 DAS with fodder bajra and sorghum recording higher values than maize. At harvest, there was no significant difference between the three cereal fodder crops. In all the crops, the ratio recorded at harvest stage was lower than that at 30 DAS. Main plot x sub plot interaction was also found to be non significant at 30 DAS and at harvest.

4.1.5 Forage Yield

Tillage treatments had significant influence on forage yield of fodder cereals. The highest yield of 20.72 t/ha was recorded in herbicide based zero tillage which was statistically superior to others (Table 4.6). The next best treatments were minimum and normal tillage which recorded comparable yields. Zero tilled plots recorded the lowest herbage yield.

Significant variation was noticed among the cereal fodder crops also. Fodder maize gave the highest herbage yield (20.19 t/ha) followed by fodder sorghum and fodder bajra. However, yield of sorghum (15.91 t/ha) and bajra (15.81 t/ha) were comparable.

Significant interaction was noticed between tillage methods and cereal fodders. Fodder maize recorded the highest yield in herbicide based zero tillage (22.94 t/ha) followed by minimum tillage (22.31 t/ha), both values being statistically on par (Plate 7 and 8). Fodder sorghum recorded the highest yield in normal tillage (Plate 9) which was on par with herbicide based zero tillage and minimum tillage (18.56, 18.39 and 17.69 t/ha). Fodder bajra (Plate 10) recorded the highest and statistically superior yield in herbicide based zero tillage (20.84 t/ha). The next best yield was recorded in normal tillage (16.68 t/ha) which was on par with minimum tillage (16.16 t/ha). All the three fodder crops recorded the lowest yield in zero tilled plots which was statistically inferior to other tillage methods. Comparing the performance of three crops in zero tillage, maize had the highest yield of 16.5 t/ha which was about 43 per cent higher than that of fodder sorghum and fodder bajra.

Table 4.1 Effect of tillage on height of fodder cereals (cm)

Treatment	30DAS	50DAS	Harvest
Tillage methods			
Zero tillage	48.19	74.42	150.68
Herbicide based zero tillage	57.63	87.61	176.01
Minimum tillage	59.94	82.72	165.41
Normal tillage	53.93	84.47	168.61
CD (0.05)	**6.58**	**6.07**	**12.32**
Fodder cereals			
Maize	66.60	78.63	186.23
Sorghum	50.15	74.23	150.87
Bajra	64.03	94.05	170.93
CD (p= 0.05)	**8.57**	**5.95**	**14.69**

Table 4.2 Effect of tillage methods on leaf area index of fodder cereals at 30 DAS

Subplot / **Main plot**	Maize	Sorghum	Bajra	**Main plot mean**
Zero tillage	2.33	1.40	1.22	**1.65**
Herbicide based zero tillage	3.09	1.82	2.21	**2.37**
Minimum tillage	2.73	1.71	1.71	**2.05**
Normal tillage	2.47	1.82	2.01	**2.10**
Sub plot mean	**2.65**	**1.68**	**1.78**	

CD (p=0.05) - Main plot = 0.25 **CD (p=0.05)** - Sub plot = 0.16

CD (p=0.05) - Main plot x sub plot interaction = 0.32

Table 4.3 Effect of tillage methods on leaf area index of fodder cereals at harvest

Subplot / Main plot	Maize	Sorghum	Bajra	Main plot mean
Zero tillage	4.44	2.58	2.45	**3.16**
Herbicide based zero tillage	5.98	3.05	3.12	**4.05**
Minimum tillage	5.08	2.77	2.62	**3.49**
Normal tillage	4.93	2.89	3.04	**3.62**
Sub plot mean	**5.12**	**2.82**	**2.81**	

CD (p=0.05) - Main plot = 0.20 **CD (p=0.05)** - Sub plot = 0.21

CD (p=0.05) - Main plot x sub plot interaction = 0.42

Table 4.4 Effect of tillage methods on leaf: stem ratio of fodder cereals

Treatment	**30DAS**	**Harvest**
Tillage methods		
Zero tillage	0.84	0.75
Herbicide based zero tillage	0.71	0.65
Minimum tillage	0.86	0.65
Normal tillage	0.82	0.60
CD (p=0.05)	**NS**	**NS**
Fodder cereals		
Maize	0.83	0.75
Sorghum	0.94	0.76
Bajra	0.66	0.48
CD (p=0.05)	**0.14**	**0.05**

Table 4.5 Effect of tillage methods on shoot - root ratio of fodder cereals

Treatment	30DAS	Harvest
Tillage methods		
Zero tillage	4.37	4.15
Herbicide based zero tillage	4.34	4.01
Minimum tillage	4.55	3.89
Normal tillage	4.90	4.43
CD (p=0.05)	**NS**	**NS**
Fodder cereals		
Maize	4.31	4.11
Sorghum	5.40	4.19
Bajra	5.50	4.06
CD (p=0.05)	**0.44**	**NS**

Table 4.6 Effect of tillage methods on herbage yield of fodder crops (t/ha)

Subplot / **Main plot**	Maize	Sorghum	Bajra	**Main plot mean**
Zero tillage	16.50	9.00	9.56	**11.69**
Herbicide based zero tillage	22.94	18.39	20.84	**20.72**
Minimum tillage	22.31	17.69	16.16	**18.72**
Normal tillage	19.00	18.56	16.68	**18.08**
Sub plot mean	**20.19**	**15.91**	**15.81**	

CD (p=0.05) - Main plot = 2.49 **CD (p=0.05)** - Sub plot = 1.10

CD (p=0.05) - Main plot x sub plot interaction = 2.20

Plate 7. Fodder maize in herbicide based zero tillage

Plate 8. Fodder maize in minimum tillage

Plate 9. Fodder sorghum in normal tillage

Plate 10. Fodder bajra in herbicide based zero tillage

It can also be seen that the difference between the crops were not very conspicuous in herbicide based zero tillage and normal tillage methods.

4.1.6 Moisture Content in Forage

Tillage practices did not influence the moisture content of forage. There was no significant variation between tillage methods with respect to moisture content of the crops at 30 DAS and at harvest (Table 4.7). However, significant difference was noticed between crops. The highest moisture content was recorded by fodder sorghum and the lowest by fodder bajra at both stages. At 30 DAS, moisture content of fodder maize was comparable to that of fodder sorghum while at harvest it was on par with fodder bajra. There was no significant interaction between main plots and sub plots at 30 DAS and at harvest.

4.1.7 Dry Matter Production

Significant variation was noticed among tillage methods with respect to dry matter production at 30 DAS and at harvest (Table 4.8 and 4.9). At both stages, dry matter production was highest in herbicide based zero tillage followed by minimum tillage. Though the tillage treatments differed significantly from each other at 30 DAS, by harvest stage, minimum and normal tillage recorded statistically comparable values of dry matter accumulation (5.92 and 5.74 t/ha, respectively). The lowest value was recorded in zero tillage (3.71 t/ha).

Among cereal fodders, fodder maize had the highest dry matter production (6.46 t/ha) followed by fodder bajra (5.26 t/ha). Significant interaction between tillage methods and cereal fodders was noticed with respect to dry matter production at both stages. All the three fodder crops recorded the highest values in herbicide based zero tillage. But the dry matter production of sorghum in herbicide based zero tillage was comparable to that of normal tillage at 30 DAS, while at harvest all the tillage methods except zero tillage were statistically on par. At harvest, maize had comparable dry matter in herbicide based zero tillage and minimum tillage whereas for bajra, minimum and normal tillage were comparable. The same trend was observed in the case of herbage yield also.

4.2 OBSERVATIONS ON WEED GROWTH

4.2.1 Species Wise Weed Count

Between tillage methods, significant variation in the population of grass weeds could be noticed only at the initial stage (Table 4.10). The highest number of grass weeds was observed in zero tillage followed by minimum and herbicide based zero tillage, the latter two being statistically on par. The lowest number of grassy weeds was observed in normal tillage.

There was no significant variation among fodder crops with respect to population of grass weeds at 30 DAS and at harvest. The interaction between tillage methods and fodder crops was also found to be non significant.

Among the weeds present in the cropped field, the population of sedges was the lowest and the variation between main plots, sub plots as well as their interaction was found to be non significant at both the stages of observation.

The dominant weeds in the experimental field were the dicot weeds and there was significant difference in the number of dicot weeds according to the tillage practices (Table 4.11). However, there was no significant variation in dicot population between the three fodder cereals. The population of dicot weeds showed a decreasing trend in zero and minimum tillage from 30 DAS to harvest stage. But the population of dicots in normal tillage showed a considerable increase of 4.15 no./m^2 from 30 DAS to harvest stage of the fodder crops. The population was 6.93 no./m^2 at 30 DAS and 11.08 no./m^2 at harvest. However, the population showed a marginal increase from 10.83 no./m^2 to 11.52 no./m^2 in herbicide based zero tillage.

Significant main plot x sub plot interaction was observed at 30 DAS. It was found that though the weed population in different tillage practices followed a similar trend in the case of three fodder crops, there was difference with respect to response of crops to same tillage practice. For example, in zero tillage, population of dicots in maize and sorghum was significantly high and comparable compared to that of bajra. In herbicide applied and minimum tilled plots population of dicots were on par in maize, sorghum and bajra. The number of weeds in normal tillage was comparable in sorghum and bajra, whereas, it was significantly low in normal tilled maize.

At harvest stage also, significant interaction could be seen between tillage treatments and fodder cereals (Table 4.12). Though the weed density was the highest in zero tilled plots of all the three fodder cereals, variation in population was seen with respect to herbicide based zero tillage and normal tillage. In maize and bajra, herbicide based zero tillage and normal tillage resulted in significant lower population of dicots whereas in sorghum herbicide based zero tillage resulted in the lowest density of dicot weeds.

4.2.2 Weed Dry Weight

Weed dry weight varied with tillage as well as with fodder crops at 30 DAS and at harvest also, as in the case of weed count (Table 4.13 and 4.14). The treatments with highest weed count resulted in highest weed dry matter production. The highest weed dry matter production of 1545 kg/ha was in zero tilled plots compared to the minimum value of 193 kg/ha in normal tillage plots at 30 DAS. The normal as well as herbicide based zero tillage recorded statistically comparable values, whereas minimum tillage recorded intermediary values of weed dry matter production. A similar trend was there at harvest stage also. However the weed dry matter in herbicide based zero tillage was almost doubled, whereas it showed about three times increase in normal tillage.

Table 4.7 Effect of tillage methods on moisture content of fodder cereals (%)

Treatment	30DAS	Harvest
Tillage methods		
Zero tillage	78.91	67.68
Herbicide based zero tillage	81.01	70.61
Minimum tillage	81.43	69.92
Normal tillage	80.57	68.84
CD (p=0.05)	**NS**	**NS**
Fodder cereals		
Maize	80.75	67.91
Sorghum	81.62	70.17
Bajra	78.97	67.37
CD (p=0.05)	**2.10**	**2.18**

Table 4.8 Effect of tillage methods on dry matter production of fodder crops at 30 DAS (t/ha)

Subplot / Main plot	Maize	Sorghum	Bajra	Main plot mean
Zero tillage	3.74	1.24	1.88	**2.27**
Herbicide based zero tillage	5.82	3.20	4.03	**4.35**
Minimum tillage	5.40	2.96	3.66	**4.01**
Normal tillage	4.70	3.13	3.26	**3.69**
Sub plot mean	**4.90**	**2.63**	**3.21**	

CD (p=0.05) - Main plot = 0.08 **CD (p=0.05)** - Sub plot = 0.05

CD (p=0.05) - Main plot x sub plot interaction = 0.10

Table 4.9 Effect of tillage methods on dry matter production of fodder crops at harvest (t/ha)

Subplot / Main plot	Maize	Sorghum	Bajra	Main plot mean
Zero tillage	5.28	2.70	3.16	**3.71**
Herbicide based zero tillage	7.34	5.52	6.88	**6.58**
Minimum tillage	7.14	5.31	5.33	**5.92**
Normal tillage	6.08	5.46	5.68	**5.74**
Sub plot mean	**6.46**	**4.75**	**5.26**	

CD (p=0.05) - Main plot = 0.73 **CD (p=0.05)** - Sub plot = 0.37

CD (p=0.05) - Main plot x sub plot interaction = 0.74

Table 4.10 Population of grasses and sedges as influenced by tillage methods (No. /m^2)

Treatment	**Grasses**		***Sedges**	
	30DAS	**Harvest**	**30DAS**	**Harvest**
Tillage methods				
Zero tillage	11.08	9.32	2.37 (5.12)	1.90 (3.12)
Herbicide based zero tillage	7.56	8.20	1.35 (1.33)	1.12 (0.75)
Minimum tillage	8.24	7.88	2.02 (3.58)	1.89 (3.08)
Normal tillage	5.44	6.88	0.71 (0.00)	0.71 (0.00)
CD (p=0.05)	**1.96**	**NS**	**NS**	**NS**
Fodder cereals				
Maize	7.36	7.04	1.66 (2.25)	1.39 (1.44)
Sorghum	8.92	8.40	1.58 (2.00)	1.41 (1.50)
Bajra	8.48	8.24	1.95 (3.31)	1.67 (2.30)
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**

*values given in parenthesis are before the $\sqrt{x+0.5}$

Table 4.11 Population of broad leaved weeds (No./m²) as influenced by tillage methods at 30 DAS

Subplot / Main plot	Maize	Sorghum	Bajra	Main plot mean
Zero tillage	24.80	23.92	20.92	**23.21**
Herbicide based zero tillage	11.20	11.28	10.00	**10.83**
Minimum tillage	16.68	16.44	16.72	**16.61**
Normal tillage	5.44	8.76	6.60	**6.93**
Sub plot mean	**14.53**	**15.10**	**13.56**	

CD (p=0.05) - Main plot = 0.73 **CD (p=0.05)** - Sub plot = NS

CD (p=0.05) - Main plot x sub plot interaction = 2.28

Table 4.12 Population of broad leaved weeds (No./m²) as influenced by tillage methods at harvest

Subplot / Main plot	Maize	Sorghum	Bajra	Main plot mean
Zero tillage	18.88	15.44	15.28	**16.52**
Herbicide based zero tillage	9.52	10.80	14.28	**11.52**
Minimum tillage	15.52	12.40	15.24	**14.36**
Normal tillage	8.88	12.76	11.60	**11.08**
Sub plot mean	**13.20**	**12.84**	**14.12**	

CD (p=0.05) - Main plot = 0.43 **CD (p=0.05)** - Sub plot = NS

CD (p=0.05) - Main plot x sub plot interaction = 2.88

Table 4.13 **Effect of tillage on weed dry weight at 30 DAS (kg/ha)**

Subplot / Main plot	Maize	Sorghum	Bajra	Main plot mean
Zero tillage	1570	1625	1440	**1545**
Herbicide based zero tillage	307	357	327	**330**
Minimum tillage	525	601	545	**557**
Normal tillage	190	200	190	**193**
Sub plot mean	**648**	**696**	**626**	

CD (p=0.05) - Main plot = 48.52 **CD (p=0.05)** - Sub plot = 33.52

CD (p=0.05) - Main plot x sub plot interaction = 67.04

Table 4.14 **Effect of tillage on weed dry weight at harvest (kg/ha)**

Subplot / Main plot	Maize	Sorghum	Bajra	Main plot mean
Zero tillage	1690	1745	1563	**1666**
Herbicide based zero tillage	539	682	650	**624**
Minimum tillage	1047	1116	1070	**1078**
Normal tillage	620	650	490	**587**
Sub plot mean	**974**	**1048**	**943**	

CD (p=0.05) - Main plot = 42.56 **CD (p=0.05)** - Sub plot = 33.88

CD (p=0.05) - Main plot x sub plot interaction = 67.80

Maize and bajra recorded significantly lower population compared to sorghum at both the stages of observation. The response of all the crops to different tillage methods was the same at 30 DAS and at harvest. The highest weed dry matter of all crops was recorded at zero tillage and lowest in normal tillage at 30 DAS whereas, by harvest the lowest weed dry matter was observed in maize in herbicide based zero tillage and bajra in normal tillage. In sorghum, both herbicide based zero tillage and normal tillage were comparable with respect to weed dry matter at this stage.

4.3 NUTRIENTS CONTENT AND UPTAKE

Maize plants had the highest content of all the three primary nutrients in leaf and stem compared to sorghum and bajra (Table 4.15 and 4.16). In general, uptake of nutrients was higher in herbicide based zero tillage (Table 4.17).

(i) Nitrogen

There was significant difference between tillage treatments with respect to nitrogen content in plant parts as well as its uptake. The nitrogen content in leaf and stem was found to be significantly higher in normal tillage whereas it was comparable in all other treatments.

Though the highest nitrogen uptake was recorded in herbicide based zero tillage (98.66 kg/ha), this was comparable to that of normal and minimum tillage. The uptake was significantly lower in zero tillage plots (53.85 kg/ha).

Significant variation was also found among crops with respect to content and uptake for nitrogen. The leaf and stem nitrogen contents in maize and sorghum was comparable whereas it was significantly lower in bajra. However, a different trend could be observed in the case of nitrogen uptake with maize recording the highest nitrogen uptake of 99.4 kg/ha which was significantly higher than that of sorghum and bajra, both of which recorded comparable uptakes (71.21 and 79.59 kg/ha).

(ii) Phosphorus

The phosphorus content in leaf and stem as well as the uptake of phosphorus showed significant variation between tillage treatments (Table 4.15 and 4.16). The leaf and stem phosphorus content as well as its uptake were found significantly higher in herbicide based zero tillage and normal tillage which were on par. The P uptake was the lowest in zero tillage (5.07 kg/ha) (Table 4.17).

As in the case of nitrogen, maize and sorghum recorded statistically higher values of phosphorus content in leaf and stem compared to bajra. However, with respect to uptake of this nutrient, all the crops differed significantly from each other with fodder maize recording the highest value (10.35 kg/ha) followed by fodder sorghum (8.06 kg/ha) and fodder bajra (6.77 kg/ha).

(iii) Potassium

There was significant difference between tillage methods with respect to potassium content and uptake. The potassium content in leaf was higher in herbicide based zero tillage (1.68%) as well as in normal tillage (1.61%) which were comparable statistically. The potassium content of normal tillage was comparable to that in minimum tillage (1.5%) which in turn was on par with zero tillage (1.35%) indicating that the difference between treatments was not very drastic (Table 4.15).

With respect to K content in stem all the three tillage treatments except zero tillage recorded superior and statistically comparable values (Table 4.16). However, the uptake of K was found to be significantly higher and comparable in herbicide based zero tillage as well as normal tillage (105.32 and 97.34 kg/ha respectively). The uptake in zero tillage was only about half that of normal tillage.

Significant variation was noticed among fodder crops with respect to potassium content and uptake. Potassium content in leaf was significantly higher in fodder maize followed by fodder bajra and fodder sorghum. But the potassium content in stem was comparable in fodder maize and fodder bajra. All the three fodder crops differed significantly from each other with respect to K uptake. The uptake of potassium by fodder maize was found to be significantly higher than that of fodder bajra and fodder sorghum. Fodder sorghum recorded the lowest potassium uptake (Table 4.17).

(iv) Calcium

There was significant difference between tillage treatments with respect to calcium content and uptake. The calcium content in leaf and stem in all the treatments except zero tillage was found to be comparable and was significantly higher than that in zero tillage (Table 4.15 and 4.16).

The trend was different in the case of uptake of calcium. Higher and statistically comparable values of Ca uptake was recorded in herbicide based zero tillage and normal tillage (26.6 and 24.26 kg/ha) while in minimum tillage the uptake was low (22.64 kg/ha). The lowest uptake was observed in plants from zero tilled plots (Table 4.17).

Among fodder crops maize and bajra had higher and comparable contents of Ca in leaf as well as stem. However, Ca uptake differed in all the fodder cereals tried. The highest uptake was registered by maize followed by bajra and sorghum.

(v) Magnesium

Unlike other nutrients, there was no significant variation between tillage methods on magnesium content in plant parts (Table 4.15 and 4.16). But significant variation was found in its uptake. The highest Mg uptake was recorded by plants in herbicide based zero tillage which was on par with normal and minimum tillage. Zero tillage registered significantly lower values of Mg uptake (Table 4.17).

Table 4.15 Nutrient content in leaf of fodder crops as influenced by tillage methods (%)

Treatment	N	P	K	Ca	Mg
Tillage methods					
Zero tillage	1.93	0.18	1.35	0.44	0.27
Herbicide based zero tillage	2.06	0.21	1.68	0.49	0.28
Minimum tillage	1.97	0.19	1.50	0.47	0.30
Normal tillage	2.25	0.23	1.61	0.51	0.33
CD (p=0.05)	**0.14**	**0.02**	**0.17**	**0.04**	**NS**
Fodder cereals					
Maize	2.05	0.22	1.84	0.50	0.30
Sorghum	2.16	0.22	1.36	0.42	0.28
Bajra	1.94	0.16	1.59	0.52	0.30
CD (p=0.05)	**0.15**	**0.02**	**0.11**	**0.03**	**NS**

Main plot x sub plot interaction - NS

Table 4.16 Nutrient content in stem of fodder crops as influenced by tillage methods (%)

Treatment	N	P	K	Ca	Mg
Tillage methods					
Zero tillage	0.90	0.09	1.18	0.23	0.28
Herbicide based zero tillage	0.97	0.11	1.49	0.32	0.30
Minimum tillage	0.92	0.09	1.39	0.30	0.27
Normal tillage	1.06	0.12	1.53	0.34	0.32
CD (p=0.05)	**0.06**	**0.01**	**0.08**	**0.06**	**NS**
Fodder cereals					
Maize	1.05	0.10	1.41	0.32	0.31
Sorghum	1.02	0.11	1.35	0.30	0.28
Bajra	0.80	0.09	1.43	0.27	0.29
CD (p=0.05)	**0.13**	**0.01**	**0.05**	**0.04**	**NS**

Main plot x sub plot interaction - NS

Table 4.17 Nutrient uptake by fodder crops as influenced by tillage methods (kg/ha)

Treatment	N	P	K	Ca	Mg
Tillage methods					
Zero tillage	53.85	5.07	47.43	12.50	10.16
Herbicide based zero tillage	98.66	10.34	105.32	26.60	19.01
Minimum tillage	85.06	8.16	85.42	22.64	16.72
Normal tillage	96.03	9.97	97.34	24.26	18.55
CD (p=0.05)	**15.21**	**1.40**	**9.37**	**3.68**	**2.40**
Fodder cereals					
Maize	99.40	10.35	105.32	26.49	19.54
Sorghum	71.21	8.06	65.38	17.34	13.21
Bajra	79.59	6.77	80.93	20.68	15.59
CD (p=0.05)	**10.13**	**0.86**	**7.04**	**1.77**	**2.09**

Main plot x sub plot interaction - NS

Variation in magnesium content in plant parts of fodder cereals was statistically negligible. However, they differed significantly from each other with respect to uptake, which were 19.54, 15.59 and 13.21 kg/ha for fodder maize, fodder bajra and fodder sorghum respectively.

4.4 NUTRITIVE VALUE OF FODDER CROPS

Leaves and stems of the three fodder cereals were analyzed separately for contents of crude protein, crude fibre, ether extract, total ash and nitrogen free extract.

Significant variation was found between tillage methods with respect to crude protein content of leaves of fodder crops (Table 4.18 and 4.19). The crude protein content of leaves of fodder crops in herbicide based zero tillage as well as in normal tillage was comparable and significantly higher than minimum and zero tillage, both of which were statistically on par.

Variation in protein content was noticed between crops also. Fodder sorghum leaves recorded the highest crude protein content which was on par with fodder maize which in turn was comparable to fodder bajra.

Tillage methods did not influence the crude fibre, ether extract, total ash and nitrogen free extract of leaves of fodder crops. The variation was found to be non significant among fodder crops also. Interaction between main plot and sub plot was also absent.

No significant variation was noticed between tillage methods with respect to nutritive value of stem except crude protein content. Among crops, variation was found to be significant in the case of crude protein, crude fibre and nitrogen free extract. The crude protein content of stem of fodder sorghum and fodder maize was comparable and significantly higher than fodder bajra.

Table 4.18 Nutritive value of leaf of fodder crops as influenced by tillage methods (%)

Treatment	Crude protein	Crude fibre	Ether extract	Total ash	Nitrogen Free Extract
Tillage methods					
Zero tillage	12.20	25.73	2.13	6.91	53.03
Herbicide based zero tillage	13.27	26.72	2.34	7.08	50.59
Minimum tillage	12.32	26.57	2.23	6.76	52.12
Normal tillage	13.75	25.48	2.12	6.96	51.68
CD (p=0.05)	**0.88**	**NS**	**NS**	**NS**	**NS**
Fodder cereals					
Maize	12.82	26.71	2.19	7.23	51.03
Sorghum	13.11	25.68	2.14	6.66	52.41
Bajra	12.12	25.99	2.29	6.87	52.14
CD (p=0.05)	**0.94**	**NS**	**NS**	**NS**	**NS**

Main plot x sub plot interaction - NS

Table 4.19 Nutritive value of stem of fodder crops as influenced by tillage methods (%)

Treatment	Crude protein	Crude fibre	Ether extract	Total ash	Nitrogen Free Extract
Tillage methods					
Zero tillage	5.63	36.78	1.05	5.26	51.07
Herbicide based zero tillage	6.06	38.30	1.19	5.88	48.86
Minimum tillage	5.75	38.10	1.15	5.26	49.79
Normal tillage	6.63	36.73	1.04	5.24	50.70
CD (p=0.05)	**0.38**	**NS**	**NS**	**NS**	**NS**
Fodder cereals					
Maize	6.55	41.17	1.16	5.11	46.02
Sorghum	6.38	35.82	1.09	5.43	51.21
Bajra	5.03	35.37	1.09	5.68	52.84
CD (p=0.05)	**0.81**	**3.68**	**NS**	**NS**	**4.24**

Main plot x sub plot interaction - NS

In the case of crude fibre, the highest content was recorded by maize stem which was significantly higher than that in fodder sorghum and fodder bajra which were on par. For NFE, a reverse pattern compared to crude fibre content was observed with fodder sorghum and fodder bajra recording higher values than fodder maize both of which were comparable.

Tetany ratio was calculated as (% DM of K /39) / (% DM of Ca/20) + (% DM of Mg/12.1). It was found that the ratio fell within a narrow range of 1.92 to 2.04 for various tillage methods (Fig. 4). The plants in the normal tillage registering the lowest value of 1.92 and the plants in herbicide based zero tillage with the highest ratio of 2.04. Among fodder cereals, sorghum had the lowest tetany ratio of 1.95 followed by bajra (1.98) and maize (2.06).

4.5 SOIL PROPERTIES

4.5.1 Bulk Density

Bulk density was found to be slightly decreased (1.43 to 1.37g/cm^3) after the experiment (Table 4.20). But there was no significant variation between tillage methods and fodder crops.

4.5.2 Organic Carbon

Organic carbon content was found to be slightly increased after the experiment (0.64 to 0.78 %). The variation was found to be non significant between tillage methods and among fodder crops.

4.5.3 Available P and K

Neither tillage nor crops significantly influenced the status of available P and K in soil after the experiment. However, there was an increase from 20.34 to 23.32 kg/ha in the available P content after raising the fodder crops. But the available K status of soil remained almost constant.

Table 4.20 Soil physico chemical properties as influenced by tillage methods and fodder crops

Treatment	Bulk density (g/cm^3)	pH	Organic carbon (%)	Available P (kg/ha)	Available K (kg/ha)
Tillage methods					
Zero tillage	1.40	5.0	0.69	22.50	98.34
Herbicide based zero tillage	1.39	5.0	0.78	23.32	101.42
Minimum tillage	1.38	5.0	0.75	23.07	105.43
Normal tillage	1.37	5.2	0.71	22.97	103.65
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**
Fodder cereals					
Maize	1.38	5.1	0.76	23.16	104.65
Sorghum	1.39	5.0	0.71	22.61	102.59
Bajra	1.39	5.1	0.72	22.12	98.76
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**

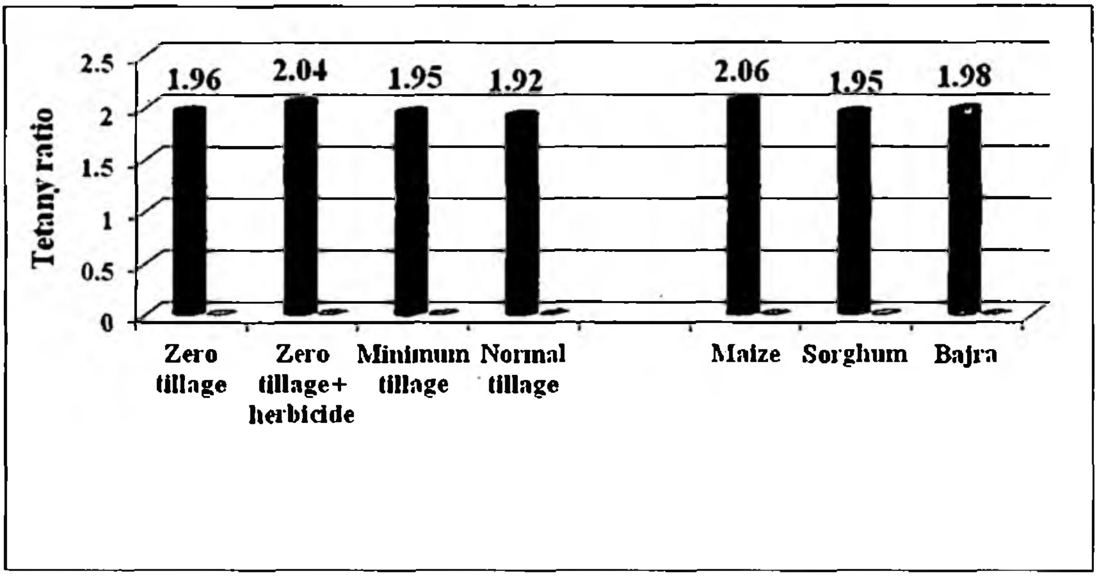


Fig. 4. Tetany ratio of fodder cereals as influenced by various tillage practices

Table 4. 21 Quality parameters of silage with and without molasses as additive

	With molasses			Without molasses		
	pH	Colour	Odour	pH	Colour	Odour
Fodder maize	3.9	Golden yellow	Pleasant	4.1	Golden yellow	Pleasant
Fodder sorghum	3.8	Golden yellow	Pleasant	4.2	Golden yellow	Pleasant
Fodder bajra	3.8	Golden yellow	Pleasant	4.1	Golden yellow	Pleasant

Table 4.22 Economics of cereal fodder crops in various tillage practices

Fodder cereals / Tillage methods	Maize				Sorghum				Bajra			
	Total cost (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	**B : C ratio**	Total cost (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	**B : C ratio**	Total cost (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	**B : C ratio**
Zero tillage	10543	28050	17507	**2.66**	10543	15300	4757	**1.45**	10543	16252	5709	**1.54**
Herbicide based zero tillage	11790	38998	27208	**3.31**	11790	31263	19473	**2.65**	11790	35428	23638	**3.00**
Minimum tillage	11689	37927	26238	**3.24**	11689	30073	18384	**2.57**	11689	27472	15783	**2.35**
Normal tillage	15752	32300	16548	**2.05**	15752	31552	15800	**2.00**	15752	28356	12604	**1.80**

4.5.4 Soil pH

Soil pH was not significantly altered by tillage methods or fodder crops. However, a decrease in pH (from 5.4 to 5.0) following cereal fodder cropping was noticed.

4.6 FODDER PRESERVATION

The silage made from fodder maize, fodder sorghum and fodder bajra were found to be good in quality with golden yellow colour, pleasant smell and a pH ranging from 3.8 to 4.2 (Table 4.21). In silage prepared without the addition of molasses, pH was slightly higher compared with silage prepared with molasses.

4.7 ECONOMICS

Cost of production as well as the net return was the least in case of zero tillage. The highest gross returns of Rs. 38,998 per hectare was observed for maize grown under herbicide based tillage and resulted in the highest B:C ratio of 3.31. Maize crop also resulted in a B:C ratio of 3.24 under minimum tillage. However, sorghum and bajra resulted in a relatively lower B: C ratio obviously due to the low forage yield. Bajra resulted in a higher B: C ratio of 3 compared to sorghum when grown under herbicide based zero tillage. B: C ratios observed with normal tillage were higher for sorghum and bajra, when compared with zero tillage, but in the case of maize it was reverse (Table 4.22).

Comparing crops as well as tillage methods, the highest B: C ratio of 3.31 was realised when maize was grown under herbicide based zero tillage. The next best B: C ratio of 3.24 was for maize under minimum tillage. When bajra was raised with herbicide based zero tillage a B: C ratio of 3.00 was realized. Maize under zero tillage registered a B: C ratio of 2.66 which was higher than B: C ratio of sorghum and bajra under all tillage treatments except bajra under herbicide based zero tillage. In sorghum highest B: C ratio of 2.65 was achieved with herbicide based zero tillage followed by 2.57 for minimum tillage. Normal tillage in maize and sorghum recorded almost the same B: C ratio of 2.05 and 2.00 whereas for bajra it was only 1.80.

Discussion

5. DISCUSSION

5.1 FORAGE YIELD AND TILLAGE

Analysis of data on average herbage yield of three cereal fodders under different tillage practices showed that the herbicide based zero tillage, minimum tillage and normal tillage practices gave comparable yields (20.72, 18.72 and 18.08 t/ha). Zero tillage practices resulted in significantly lower yields (11.69 t/ha). The yield increase over zero tillage was to the tune of 77 per cent and 60 per cent in herbicide based zero tillage and minimum tillage and 55 per cent in normal tillage (Fig. 5). This indicated the possibility of reduction in cost and energy for tillage practices in rice fallow cereal production. Carter *et al.* (2002) reported that normal tillage may not be required for getting good crop yield. Lal (1989) also opined that no till farming systems are successful for production of row crops in the tropics.

The forage yield of fodder maize, sorghum and bajra also varied. Fodder maize recorded significantly higher yield of 20.19 t/ha followed by 15.91 t/ha for fodder sorghum and 15.81t/ha for fodder bajra. So it can be inferred that fodder maize is a better choice compared to other two crops. In maize, a number of varieties including African tall were found to perform well in Kerala with a fodder yield of 30-47 t/ha within a brief growing period of 55- 60 days. Fodder sorghum as well as bajra are also palatable and nutritious fodder crops which can give a fresh herbage yield of about 25-30 t/ha under Kerala condition (KAU, 1998).

The interaction between tillage methods and fodder cereals indicated that crops do differ with respect to tillage requirements when raised in rice fallows. Fodder maize performed better in herbicide based zero tillage as well as in minimum tillage. Many workers have previously reported better performance of maize under minimum tillage practices than under conventional tillage.

Shenk and Saunders (1981) observed that no till and reduced tillage systems produced more maize grain yield than ploughed treatments. Sharma *et al.* (2010b) reported that chemical weeding with herbicides resulted in 7.8 per cent higher yield of maize over mechanical weeding. In the present study, yield increase of about 20 per cent could be achieved by herbicide based zero tillage or minimum tillage over normal tillage. In the case of bajra, herbicide based zero tillage was the best treatment (20.84 t/ha) and the yield advantage by herbicide based zero tillage compared to minimum or normal tillage was 4.42 t/ha (26% higher). The response of fodder bajra to minimum and normal tillage was comparable, whereas in the case of fodder sorghum minimum, normal and herbicide based zero tillage had similar effects on herbage yield. In the case of sorghum, the yield could be doubled by herbicide based zero tillage, minimum or normal tillage compared to no tillage. Hence the study reveals that for the three fodder crops there is no need for intensive tillage operations, though the crops require a weed free condition for their initial growth and development. The cost of cultivation can be reduced considerably if herbicide based zero tillage or minimum tillage is resorted to instead of normal tillage.

Though herbicide application is not advocated in the context of environmental safety and residual toxicity, here, seems to be harmless. The chance of herbicide residue problem and the resultant toxicity in livestock fed with fodder raised in a field treated with glyphosate is minimal. Glyphosate is a post emergence broad spectrum herbicide which normally enters the plants through the green aerial parts, mainly the foliage. It was sprayed prior to sowing of the crop on the emerged weeds and the crop was harvested 60 to 65 days after sowing. A characteristic of glyphosate is that its herbicidal activity through soil is low. This has been ascribed to its easy adsorption to the soil constituents. It has been also found to be fairly immobile in soil and in soil its degradation is brought about by micro flora (Grossbard and Atkinson, 1985).

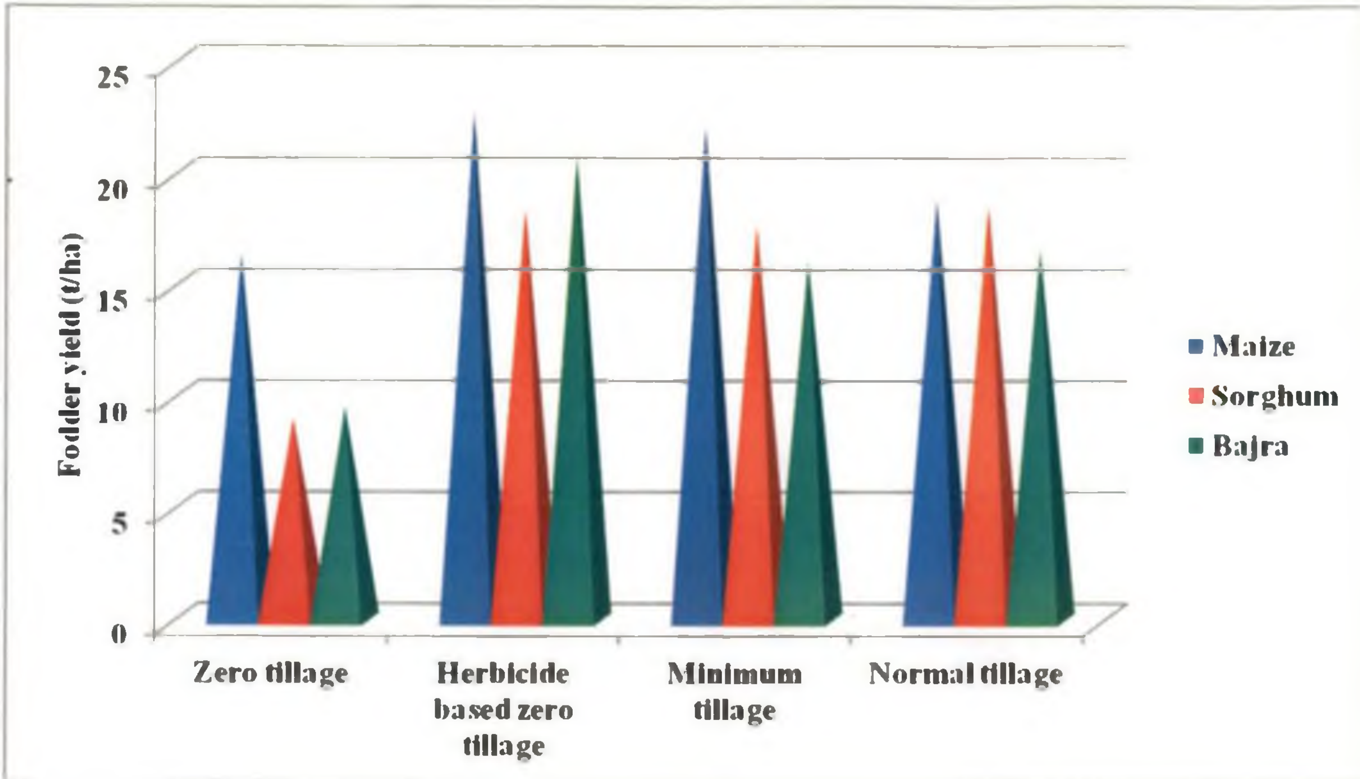


Fig.5. Effect of tillage methods on forage yield of fodder cereals (t/ha)

The better performance of crops in herbicide based zero tillage and minimum tillage can be attributed to many reasons. In general, conservation tillage practices like minimum tillage and herbicide based zero tillage help in soil and water conservation and for maintaining favourable soil temperature regime due to the mulching effect of stubbles of previous crop. Bhatt *et al.* (2004) reported that minimum tillage was more effective in conserving soil moisture and resulted in the same yield of maize as in conventional tillage. According to Sharma *et al.* (2010) conventional tillage along with legume mulching and chemical weeding in maize was beneficial for improving moisture and nutrient conservation and achieving higher productivity.

In the present study also, the soil moisture content during germination period was high in minimum tillage plots (11%) compared to normal tillage (6.5%). This might be probably due to more evaporation loss of moisture from tilled surface soil layer. The soil moisture content recorded three weeks after sowing followed a similar trend with conventional tillage recording the lowest moisture percentage (Fig. 6). This is in conformity with the findings of Lal (1989), who reported that conservation tillage has a moderating effect on soil moisture and temperature regimes and regulate the rates of evaporation. Favourable moisture regime by the use of no till system is also reported by many workers. However it was found that the tillage practices did not influence the moisture content in herbage at 30DAS and at harvest.

The crop's response to tillage practices can also be explained in terms of weed competition. A close look at the weed weight and weed count indicated that tillage practices influenced the weed population and nature of weed flora. It can be seen that the weed weight at 30 DAS in zero tillage plots was significantly higher (1545 kg/ha). The corresponding value of minimum tillage and herbicide based zero tillage was 557 kg/ha and 330 kg/ha respectively. Hence, it can be inferred that the weed competition during the initial period of growth might have resulted in poor growth of the fodder cereals in zero tillage.

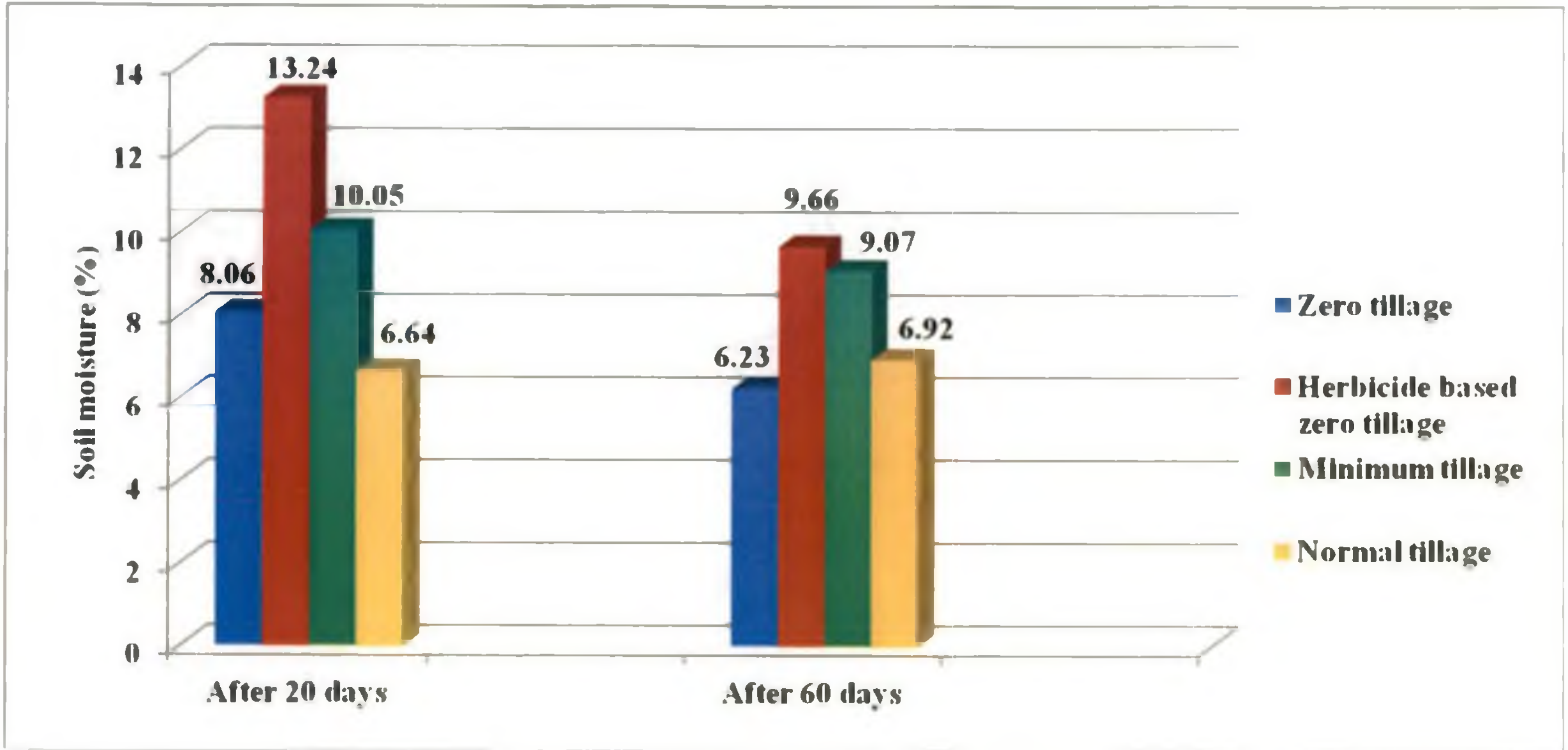


Fig. 6. Soil moisture content (%) as influenced by tillage practices

Sarma and Gautam (2010), observed a significant increase in grain yield of maize with conventional tillage due to reduced population and dry weight of weeds when compared with no tillage.

In herbicide based zero tillage, almost complete weed control was achieved at the time of sowing due to herbicide application. Hence the weed dry matter production till harvest was low compared to zero or minimum tillage. Lakshmi *et al.* (2009) and Tripathi *et al.* (1998) reported that herbicides integrated with hand weeding treatments recorded significantly higher grain yields than other weed management practices in rice. In minimum tillage, weeds along the rows, where seeds were sown, were controlled due to the tillage along the rows. So weed competition was not high during the initial growth phase, which resulted in low weed dry weight in this treatment compared to zero tillage.

The negative effects of weeds on crop growth due to competition for water, nutrients and sunlight is well documented. Escasinas and Escalada (1980) observed that most severe weed competition in dry land sorghum occurred during the first 30 DAS and weeds that germinate later had little effect. Panchal and Krishnasastry (1974) observed that increased duration of weed free condition from 10 to 20 and 30 days after sowing was accompanied by linear increases in grain yield of sorghum. Kondap and Reddy (1978) and Shetty (1978) reported that the critical period of weed competition in sorghum was 15 to 30 DAS.

The number of weeds as well as weed dry weight were significantly higher in zero tillage followed by minimum tillage. The lowest weed dry weight and population of grass, sedge and broad leaved weeds in conventional tillage can be attributed to almost complete weed control achieved through this method. Lower population of *Phalaris minor* and higher population of broad leaf weeds under zero tillage as compared to conventional tillage was also reported by Yadav *et al.* (2005). Mishra *et al.* (2005) also reported lesser dry weight of broadleaf weeds in conventional tillage as compared to zero tillage. Aslam *et al.* (1993) and Dixit *et al.* (2003) also reported lower dry matter of *Phalaris minor* under zero tillage as compared to conventional tillage.

5.2 PLANT GROWTH PARAMETERS AND TILLAGE

5.2.1 Plant Height

The growth parameters recorded at various growth stages also showed favourable influence of minimum and herbicide based zero tillage on plant growth. The plant height at 30 DAS, 50 DAS and at harvest was significantly lower in zero tillage treatments. Agbede *et al.* (2008) reported that growth parameters like plant height, leaf area, stem girth, dry matter and grain yield of sorghum were higher in herbicide based zero tillage compared to other tillage practices.

It was found that during all the growth phases there was no significant variation in plant height among herbicide based zero tillage, minimum tillage and normal tillage. It can be seen that the herbage yield was also comparable in these treatments indicating a strong positive correlation between plant height and herbage yield.

Among the three cereal fodders, maize plants were the tallest followed by bajra and sorghum. The difference in plant height among the fodder crops is a varietal character. There are reports which show that the plant height of fodder maize, fodder sorghum and fodder bajra are 302 cm, 262 cm and 270 cm respectively (TNAU, 2010). As the response of all the crops to different tillage methods were the same, there was no interaction. The better growth of plants under conservation tillage practices can also be due to favourable conditions like better soil moisture and temperature regimes due to the mulching effect of residues of previous crop. Sharma *et al.* (2010) reported that conventional tillage along with legume mulching and chemical weeding was beneficial for improving moisture and nutrient conservation and achieving higher productivity and profitability of maize.

5.2.2 Leaf Area Index

In the case of leaf area index, the plants in the herbicide based zero tillage recorded the highest value both at 30 DAS (2.37) and at harvest (4.05) which was significantly superior to other tillage methods (Fig. 7 and 8). This indicated that the plants experienced favourable growth conditions in this treatment. The least LAI values were recorded in zero tillage treatment due to severe weed competition and resultant poor growth. The plants in other two treatments i.e. minimum and normal tillage recorded intermediate values both at 30 DAS and at harvest.

Maize plants recorded the highest LAI at 30 DAS and at harvest followed by sorghum and bajra. The LAI of maize at harvest was 5.12, which was considerably higher than sorghum (2.82) and bajra (2.81). This indicated that maize plants had more vigorous growth with more number of leaves which ultimately led to the highest yield. Towards harvest, LAI values of all crops increased, as the crops attained maximum vegetative growth by this time (60 DAS). The increase in LAI values by harvest time resulted from more number of leaves and leaf expansion towards later phases of growth. This is in accordance with the findings of Raj (1987). He observed that leaf expansion was slow during at the initial stages of crop growth and maximum leaf area was attained at 50 per cent flowering by which time majority of tillers also developed maximum leaf area. Gardner et al. (1988) reported that LAI of 3 to 5 is usually necessary for maximum dry matter production of most cultivated plants.

A similar trend as that of herbage yield was found in LAI also, with significant interaction between tillage methods and crops. Fodder maize recorded highest LAI in herbicide based zero tillage (5.98) which was significantly higher than the next best treatment, i.e. minimum tillage (5.08). However, LAI of maize in

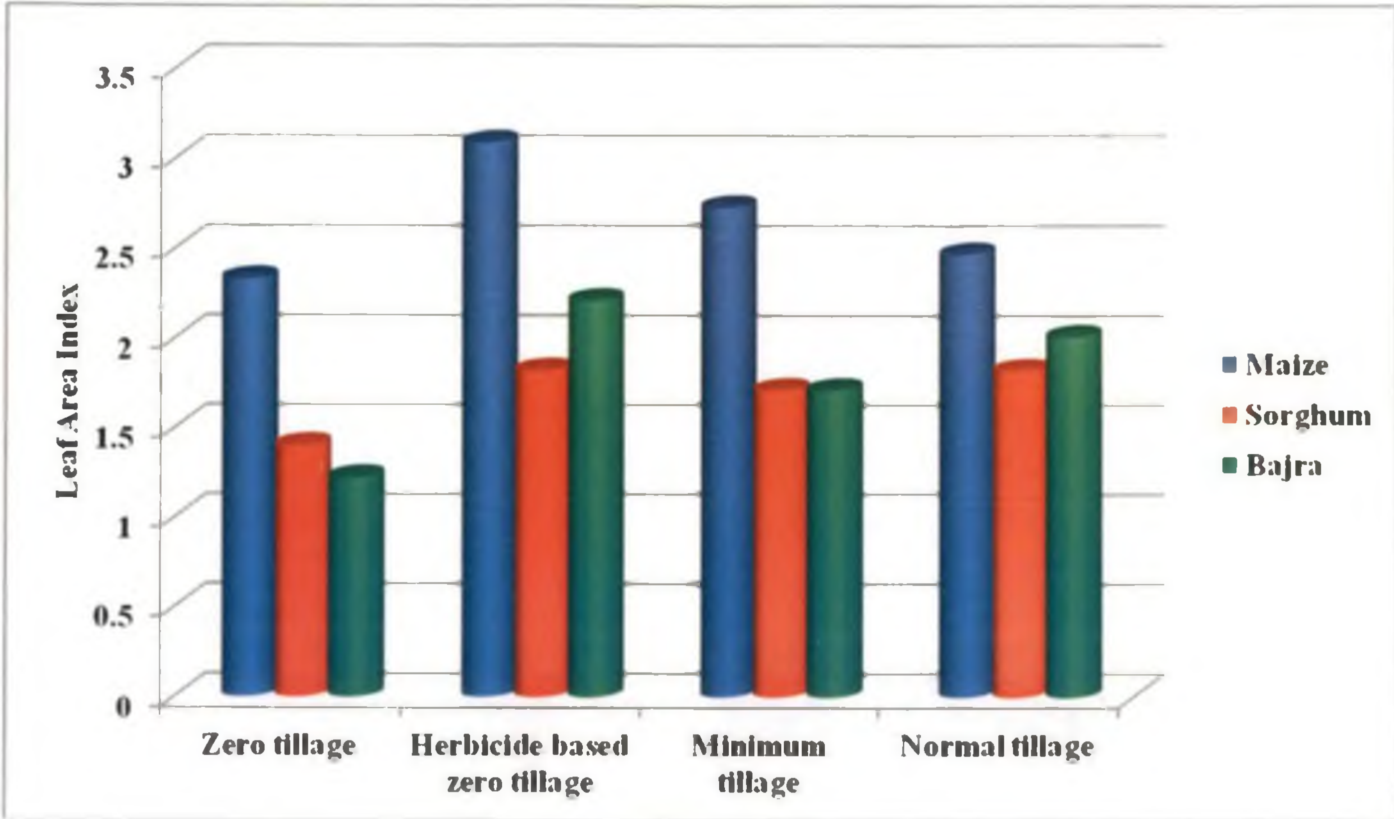


Fig. 7. Effect of tillage methods on LAI of fodder cereals at 30 DAS

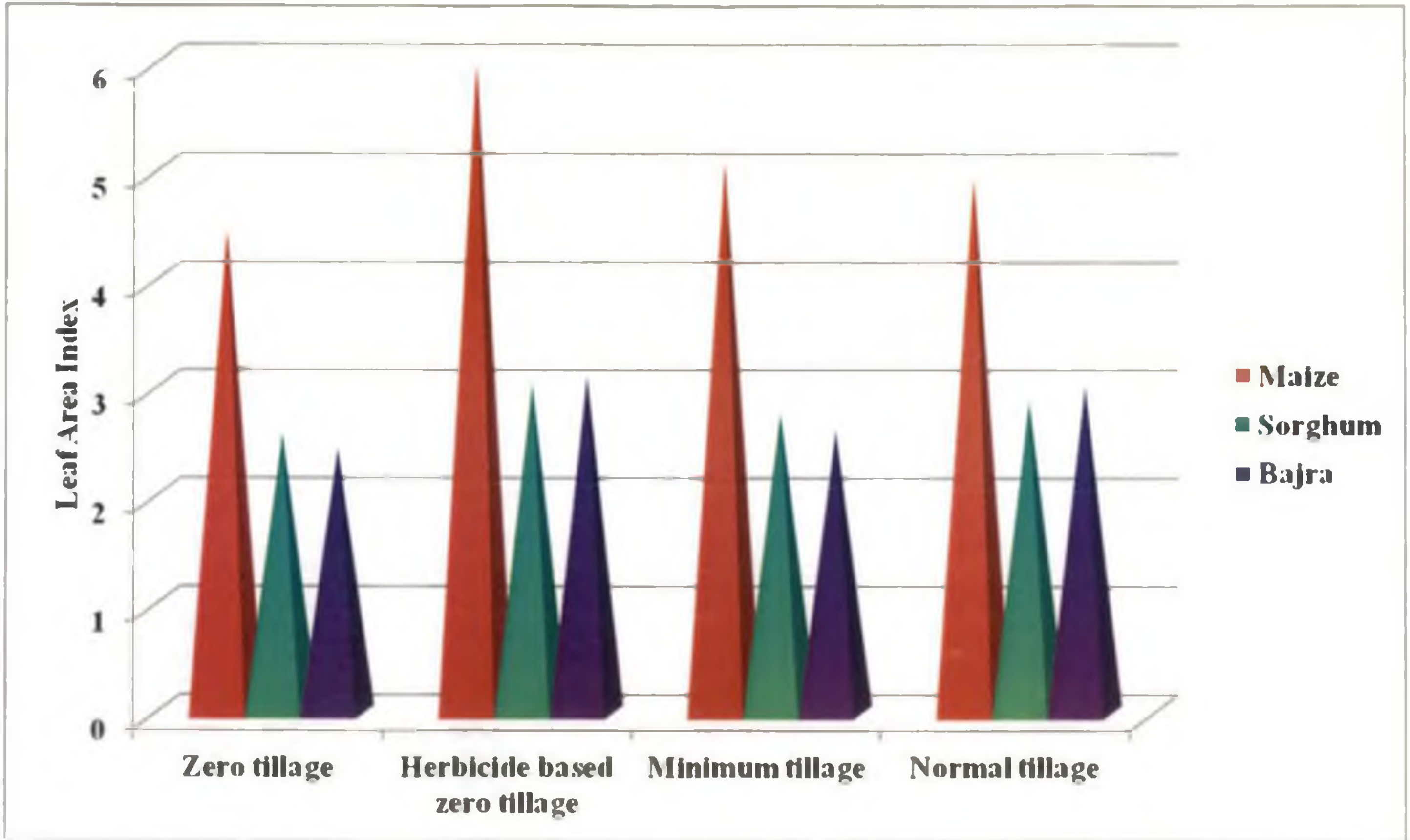


Fig. 8. Effect of tillage methods on LAI of fodder cereals at harvest (60 DAS)

minimum and normal tillage were comparable. LAI values of sorghum in herbicide based zero tillage, minimum and normal tillage was statistically comparable whereas, in bajra, herbicide based zero tillage (3.12) and normal tillage were superior. However, LAI in normal tillage (3.04) was comparable to that of minimum tillage (2.62).

5.2.3 Leaf - Stem Ratio

Leaf stem ratio is an important quality parameter of fodder crops. If the harvested produce contains more of stems, it will be more fibrous, difficult to chew and the herbage will be wasted by the livestock. Hence leafiness of the crop or high leaf stem ratio is a desirable character in cut and carry system of livestock feeding.

The observations indicated that leaf stem ratio cannot be altered by tillage, probably because it is a genetic character of a particular species. The significantly different values of leaf stem ratio of the three crops under study also points to this fact. The highest leaf stem ratio at harvest was found in maize and sorghum. These two crops, because of having almost similar growth habit, resulted in comparable values whereas, in bajra the ratio was low (0.48) because the leaves of the plants are narrow and has more of stem because of tillering nature.

5.2.4 Shoot - Root Ratio

It was found that tillage practices had no influence on shoot root ratio. Almost the same values were recorded both at initial and at final growth stages. Between crops a slight variation in values of shoot root ratio was observed only at 30 DAS. Higher values of sorghum and bajra might have resulted from their poor root weight compared to maize (Fig. 9). It was found that root weight of maize was higher compared to sorghum and bajra at both 30 DAS and at harvest. Many workers have reported the influence of tillage practices on root growth or root distribution pattern. In the present study, root distribution pattern was not studied. It can be inferred that,

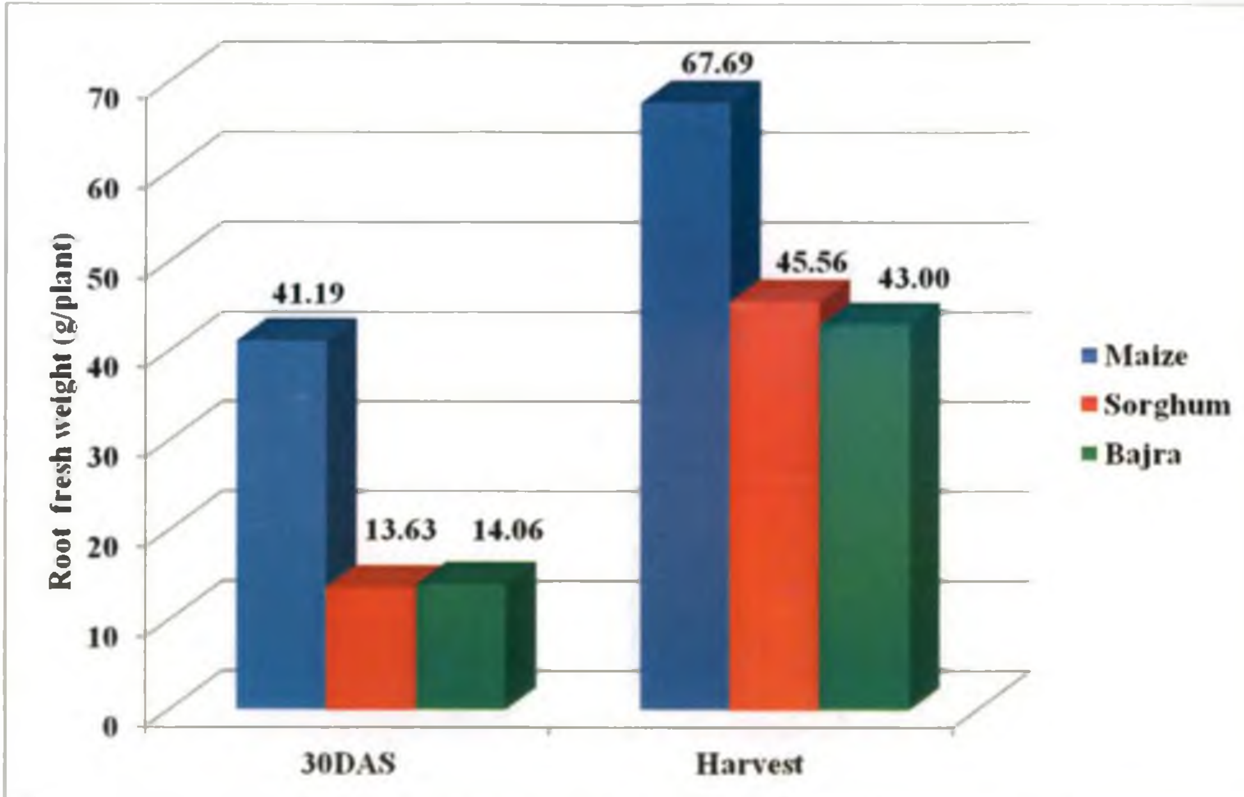


Fig. 9. Root fresh weight of fodder cereals at 30 DAS and at harvest (g/plant)

as all the three crops are having shallow root system, tillage had no effect on root growth. According to Lal (1989), in general, conservation and reduced tillage systems favour more root growth in the surface soil layer beneath the residues and the total weight of root system is reduced compared to that seen in a ploughed system. However, Chopart (1984) reported restricted root growth in an untilled soil.

It was noticed that the ratio was not affected, because if plant growth is poor, the root growth as well as shoot growth are also affected leading to a constant ratio. Hence, the effect of tillage though it was marked on plant growth, shoot root ratio remained unaltered. In all the crops, the ratio recorded at harvest stage was lower than that at 30 DAS. At harvest, there was no significant difference between the three fodder cereals because in sorghum and bajra the ratio decreased from 5.4 to 4.2 and 5.5 to 4.1 from 30 DAS to harvest.

5.2.5 Moisture Content

Significant difference between tillage methods could not be observed with respect to moisture content of herbage both at 30 DAS and at harvest. This is because of the fact that the crops were given irrigation for 30 DAS due to death of soil moisture as there was no intermittent rain. It can also be assumed that tillage might have some influence under dry land condition. The variation between crops with respect to moisture content is understandable due to the difference between crops in phenology, leafiness, leaf stem ratio etc. Fodder sorghum recorded higher moisture content probably due to the moisture conservation mechanism of this drought tolerant crop. Thangavelu (1967) concluded from a study with several varieties of sorghum that high moisture content in leaf is a characteristic favouring drought resistance.

Moisture content of fodder crops is an important parameter which decides their succulence and palatability. Further, as these crops are suitable for silage making, moisture content of herbage at harvest time decides whether wilting is needed before ensilage or not. Hence observation on moisture content was made.

5.2.6 Dry Matter Production

The variation in dry matter production with respect to tillage practices can be explained in terms of the plant growth parameters recorded in herbicide based zero tillage and minimum tillage. It can be seen that plant height and LAI were the highest in herbicide based zero tillage followed by minimum tillage or normal tillage which resulted in higher dry matter yield also (Fig. 10). Variation in dry matter with tillage practices has also been reported by Agbede *et al.* (2008). Higher dry matter in herbicide based zero tillage and minimum tillage can also be due to less weed competition and favourable effect due to mulching effect of crop residues of the rice crop. Sharma and Acharya (2000) also reported that crop residues of previous crop can favourably influence the succeeding crop due to their mulching effect. Sharma *et al.* (1990) observed the role of tillage and mulching practices in conserving soil moisture, with subsequent beneficial effect on crop productivity.

Dry matter production of the three fodder cereals followed a slightly different trend compared to their herbage yield. This is due to the difference in moisture content of cereals. Though the fresh herbage yield of sorghum and bajra were comparable statistically, their dry matter production differed significantly with bajra having higher dry matter yield of 3.21 t/ha compared to 2.63 t/ha in sorghum. As in the case of herbage yield, maize recorded the highest value, due to the good growth of plant.

5.3 EFFECT OF TILLAGE ON WEED GROWTH

5.3.1 Weed Population and Tillage

Population of grasses, sedges and dicot weeds were taken and a perusal of data showed that there was a change in weed population with tillage treatments.

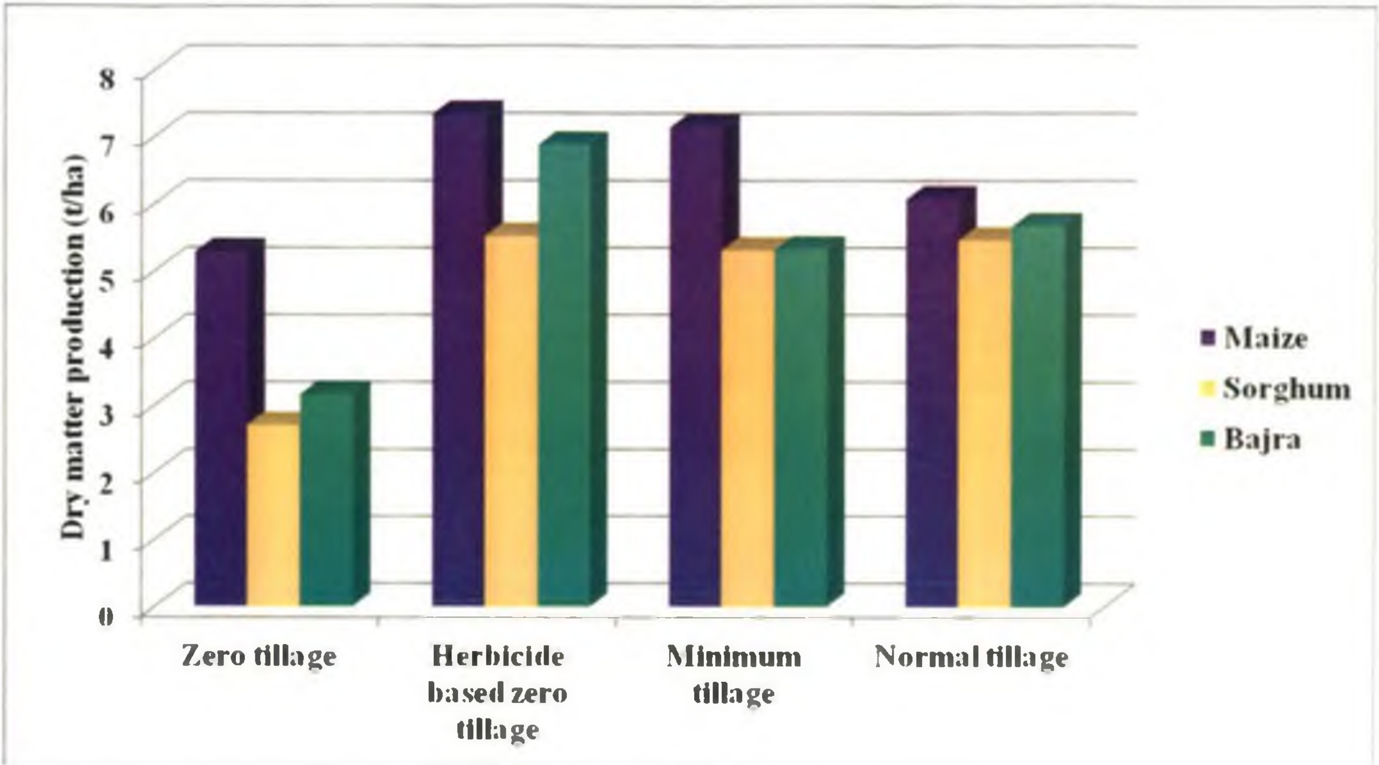


Fig. 10. Effect of tillage methods on dry matter production of fodder cereals at harvest (t/ha)

Broad leaved weeds were the major weed flora of the experimental field followed by grasses and sedges. The grassy weed population consisted mainly *Digitaria ciliaris, Ischaemum indicum, Isachne miliacea* and *Echinochloa* sp. The major sedges were *Fimbristylis miliacea* and *Cyperus haspan* and the dicots included mainly *Ludwigia parviflora, Melochia corchorifolia, Mollugo pentaphylla* and *Sphaeranthus indicus*.

In zero tillage plots as there was no disturbance of soil, the weed population was high during all stages of growth. This is in accordance with the findings of Singh *et al.* (2009) and Bisen and Singh (2008). According to them, the highest weed population and weed dry weight was observed in zero tillage and the lowest weed dry weight and population of all grassy, sedges and broad leaved weeds in conventional tillage.

In herbicide based zero tillage and normal tillage complete weed control was achieved at the time of sowing. However, by 30 DAS weed population increased in herbicide applied plot and was on par with minimum tillage. The increase in population of weeds in herbicide applied plots was due to subsequent germination and growth of weeds.

At harvest significant variation could not be observed between tillage methods because of increase in weed population in some treatments and decrease in population in some others. The population in zero tilled plots showed a decline, probably due to smothering of weeds by crops and also due to drying up of some weeds. In minimum tillage a slight reduction in number of grassy weeds was noticed from 8.22 to 7.88. However, in herbicide based zero tillage and normal tillage, a slight increase in population was seen due to subsequent growth of weeds.

The population of sedges was very low and hence significant variation with respect to tillage practices or fodder crops could not be observed. Population of broad leaved weeds showed a considerable increase of 4.15 no./m^2 from 30 DAS to harvest in normal tillage. This might have resulted from the favourable soil conditions for emergence of weed seedlings from the soil seed bank.

There was no variation in population of grasses, sedges and broad leaved weeds with respect to fodder cereals. This might be due to the similarity in growth habit of the three cereal crops and absence of crop bound or crop associated weeds with respect to these crops.

5.3.2 Weed Dry Weight and Tillage

Compared to weed population, the dry matter production of weeds per unit area can give an indication about the weed competition. Hence, weed dry matter production was also recorded to get an idea about the effect of tillage levels on weed management (Fig. 11). It was found that in normal tilled plots, due to complete weed removal, weed population was the lowest at 30 DAS. In herbicide based zero tillage, due to application of the broad spectrum herbicide glyphosate complete weed control was achieved by the time of sowing. But due to subsequent germination and growth of weeds in this treatment, weed dry matter production showed an increase at harvest stage.

In minimum tillage, as strip tillage was practiced some weeds present in interrow spaces were left undisturbed, which led to higher values of weed dry matter compared to normal tillage or herbicide based zero tillage. It could also be seen that though weed count decreased in zero tilled plots from 30 DAS to harvest, weed dry matter showed an increase. This is due to more vegetative growth of the weeds present especially the weeds like *Digitaria ciliaris* which produced a number of tillers with a spreading growth habit. Increase in weed dry matter production with decrease in weed count is also reported by Channappagoudar and Biradar (2007).

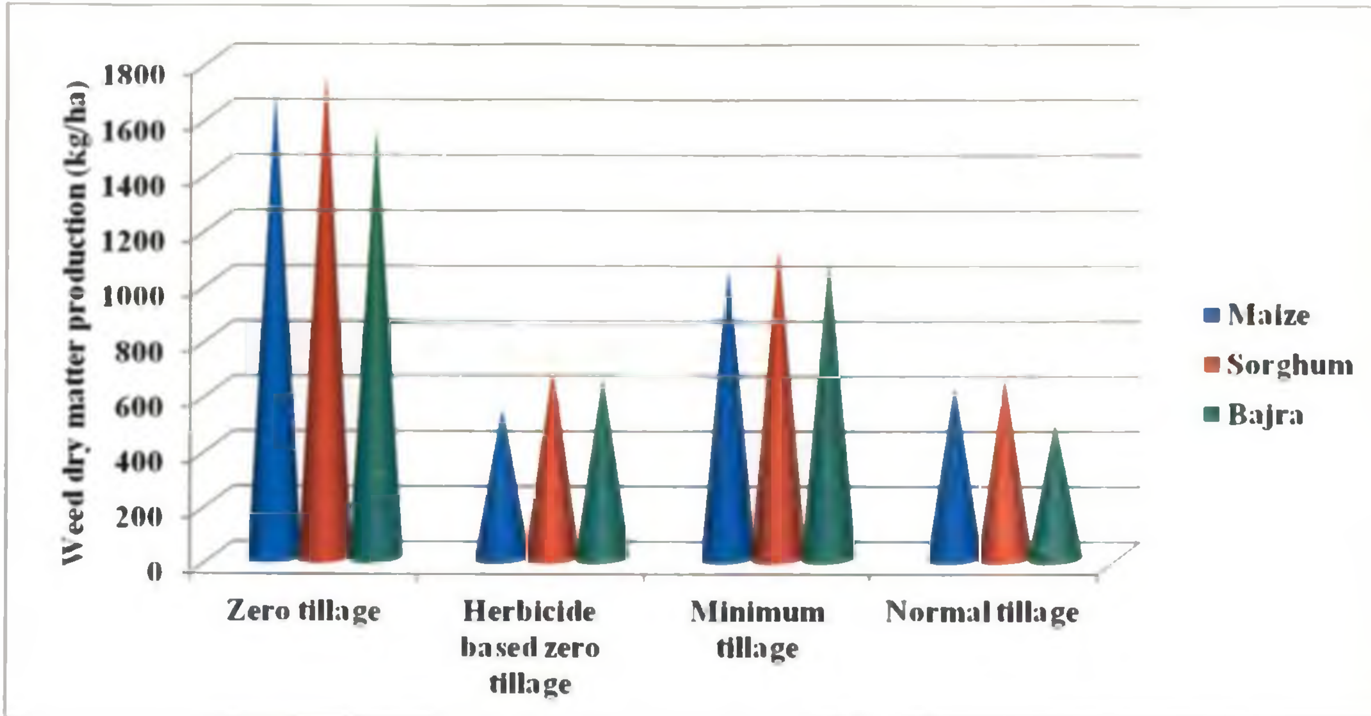


Fig. 11. Effect of tillage on weed dry weight at harvest (kg/ha)

5.4 NUTRIENT CONTENT AND UPTAKE

In general, the contents of N, P and K were more in leaf compared to stem. The N and P contents of leaf and stem showed considerable variation. N and P contents of leaf was almost double that of stem. Analysis of the data showed that different tillage operations can influence nutrient contents of plant parts. The plants in normal tillage as well as herbicide based zero tillage always recorded higher values of primary nutrients in leaf. This is probably due to less weed competition which resulted in better nutrient availability.

Ojeniyi (1993) reported that the availability of N, P and K in the soil and the grain yield were increased by tillage. The higher content of nutrients in herbicide based zero tillage, minimum and normal tillage compared to zero tillage would be due to better nutrient availability. Verma *et al.* (2007) reported that herbicide application brought about significant reduction in N, P and K uptake by weeds and enhanced nutrient uptake by wheat crop. Pandey *et al.* (2001) and Jat *et al.* (2004) also reported less nutrient removal by weeds in herbicidal treatments leading to more nutrient uptake by crop.

In the case of K, the variations between different tillage methods were not very conspicuous, and the difference in nutrient contents in leaf as well as in stem was also not very high. On an average the leaf content was 1.53 per cent whereas stem content was 1.39 per cent.

A comparison between the three fodder cereals indicated that maize and sorghum had higher contents of N and P compared to bajra but K content of sorghum leaf and stem was lower than that of maize and bajra.

Apart from the variation between crops, the difference in the quantity of fertilizers applied to these crops also might have resulted in difference in nutrient contents. The fertilizer recommendation for fodder maize is 120:60:40 and for fodder sorghum 60:40:20 compared to 40:20:20 for fodder bajra (N: P_2O_5: K_20 kg/ha).

As the fertilizer recommendation is based on crop requirement and its removal, it can be inferred that bajra requires less nutrients than maize or sorghum.

The nutrient removal was less in zero tilled plots compared to other tillage practices with respect to all the nutrients (Fig. 12). On an average the N uptake in herbicide based zero tillage, minimum and normal tillage were higher by almost 40 per cent compared to zero tillage. Sharma *et al.* (2010) reported that the N uptake of maize increased significantly with chemical weeding and legume mulching and it was lower under minimum tillage.

The P uptake and K uptake were high and comparable in herbicide based zero tillage and normal tillage. Sharp *et al.* (1986) reported that the plant uptake of P was more efficient under no tillage than under conventional tillage. Anderson *et al.* (1987) reported that tillage treatments affected the distribution of roots and extractable P in the top soil layer.

The P uptake varied from 5.07 kg/ha in zero tillage to 10.34 kg/ha in herbicide based zero tillage whereas, K uptake was in the range of 47.43 (zero tillage) to 105.32 kg/ha (herbicide based zero tillage). The drastic decline in uptake values in zero tilled plots resulted from the least dry matter production in this treatment together with lesser contents of nutrients. Singh *et al.* (2009), reported that the nutrient uptake (N, P and K) in conventional, reduced and rotary tillage practices were significantly higher than that in zero tillage.

The comparison between nutrient uptakes by fodder cereals revealed that maize is a soil depleting crop compared to bajra or sorghum. The N, P and K uptake by maize was 99.4, 10.35 and 105.32 kg/ha compared to 71.21, 8.06 and 65.38 kg/ha

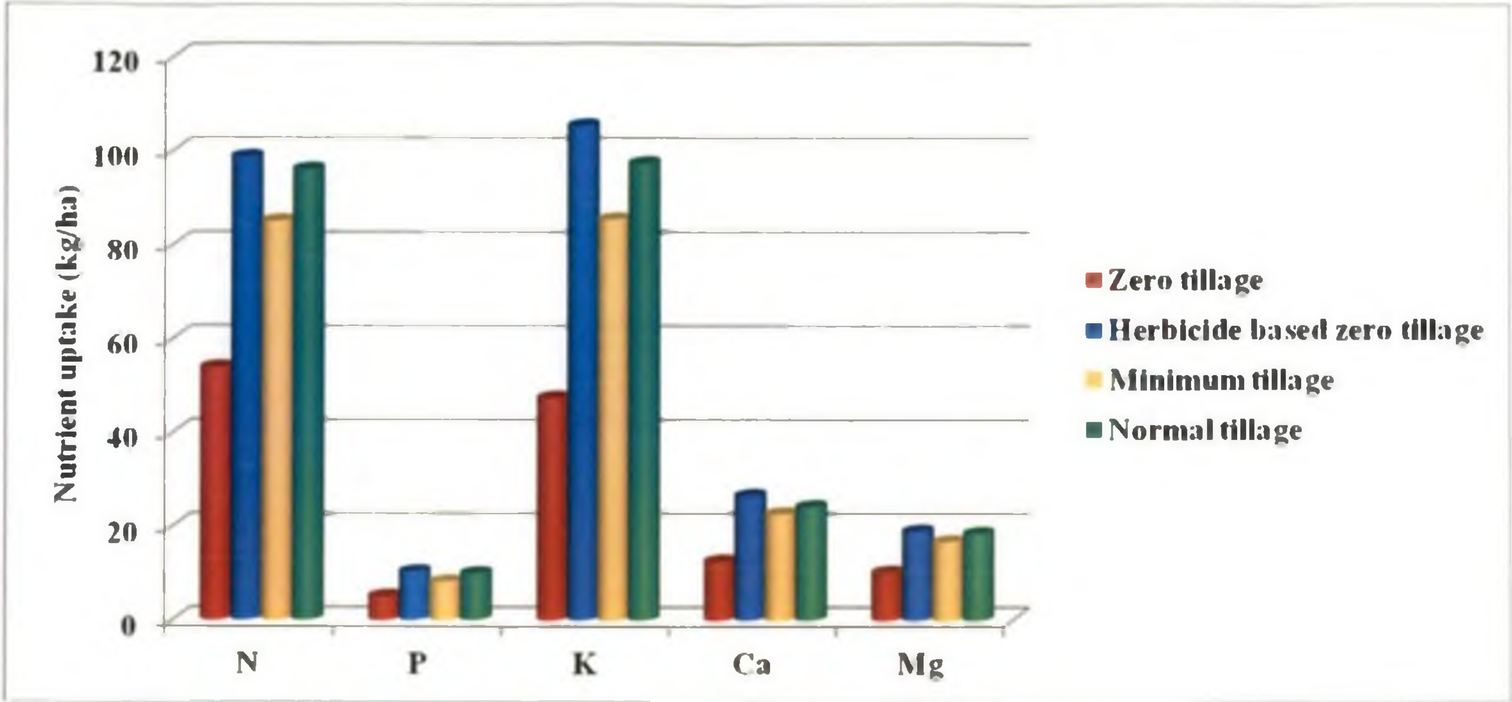


Fig. 12. Effect of tillage on nutrient uptake by fodder cereals (kg/ha)

for sorghum. The difference in uptake resulted from higher content of nutrients in maize as well as high dry matter production.

The Ca content in the stem and leaf as well as its uptake varied with tillage practices. However, in the case of Mg the difference could be observed only with its uptake. It was found that the Ca content of plants in zero tillage was low compared to all other treatments, probably due to low availability of this nutrient in the zero tilled plots due to weed competition. The uptake of Ca and Mg in this treatment was also significantly low compared to all others which were on par due to the same reasons. Competition of weeds for nutrients is well documented. Pandya and Purohit (1976) concluded that the competition for nutrients between sorghum crop and weeds occur between 41 to 80 days and they also noticed higher mineral content in the weeds than the crop. The removal of 25.55 kg N, 6.94 kg P_2O_5 and 41.63 kg K_2O/ha by weeds within 40 days from the emergence of sorghum crop has been estimated by Badhe and Nalamwar (1981).

The significant variation in uptake of Ca and Mg by maize, sorghum and bajra can be explained in the terms of dry matter production by these crops.

5.5 NUTRITIVE VALUE

The important quality parameters of fodder crops are crude protein, crude fibre, ether extract, total ash and NFE. The leaves and stems were analyzed separately to assess the nutritive value of fodder crops.

Though a change in crude protein was observed with tillage methods and with the crops, no changes in the crude fibre, ether extract, total ash and NFE were recorded. The crude protein content in leaves and stems was high in herbicide based zero tillage and normal tillage as the nitrogen contents in these treatments were high. The crude protein content in the leaf was in the range of 12.2 to 13.75 and in stem it was 5.63 to 6.64 per cent. The respective nitrogen contents were 1.93 to 2.25 and 0.90 to 1.06 per cent.

As the nitrogen content in maize and sorghum were high, their crude protein content was also higher than that of bajra. The other quality parameters were not altered because of inherent characteristics of the crops which cannot be altered by management practices. The values are within the limits reported by other workers.

Cows require a constant supply of magnesium in their diet. In some cases cattle fed on magnesium deficient forage crops develop grass tetany or hypomagnesemia, indicated by very low levels of blood Mg. Normal level of Mg in blood is about 2mg/100ml plasma. In an animal with grass tetany, the level of Mg will likely be below 1mg/100ml plasma.

The tetany ratio of fodder cereals raised under different tillage methods was below 2.2, the threshold level causing hypomagnesimia. Hence it can be concluded that when cattle are fed with fodder cereals raised under varying tillage levels, there is no chance of grass tetany. Filley (2005) cited by Klingerman (2007) reported that this ratio should be below 2.2 in herbage to avoid chances of grass tetany in cattle.

5.6 SOIL PROPERTIES AFTER CEREAL FODDER

The bulk density of soil was found to be slightly lower than previous experimental data (Tables 3.1 and 4.2.6). The decrease in bulk density might have resulted from loosening of soil by crop root growth and organic matter addition by the crop. This result corroborates with the findings of Sharma *et al.* (2010).

The organic carbon content also showed an increase from 0.64 to 0.78 % which indicates organic matter addition due to raising of fodder cereals. The available P status of soil also showed a slight increase whereas, K status remained more or less constant.

The pH of soil though not drastically changed, a trend towards acidity (5.4 to 5.1) was noticed. Similar findings were reported by Menon (1987) and Rani (2001). They observed a decrease in soil pH after raising fodder crops (both legumes and cereals) in rice fallows.

5.7 FODDER PRESERVATION

In the case of cereal fodder crops, preservation is very important as the entire crop has to be harvested in a single cut and the surplus quantity needs to be preserved for future use. Ensilage and hay making are the two popular methods of fodder preservation. All the three fodder crops are ideal for silage making. In this method, the green forage is fermented under anaerobic condition without appreciable loss of nutritive value.

Bag method of ensiling suited to small farmers was tried. Silage in plastic bags makes it easier to ration the silage at the time of feeding as it is in small batches of known quantity (Plate 11). As the entire quantity in the bag is used for feeding, there is no spoilage due to aerobic deterioration (Otieno *et al.*, 1990) which leads to loss of considerable quantity of silage in big silos once it is opened for feeding.

Ensiling of cereal fodders without adding molasses as additive was tried. All the cereal fodder crops are rich in soluble carbohydrates and low to medium in protein with a moisture content of about 70 per cent and are well suited for silage making. Molasses is added as a source of water soluble carbohydrates as primary substrate for lactic acid bacteria. Actually molasses is needed if the material for ensiling is low in soluble carbohydrates. Cereal crops are reported to be rich in soluble carbohydrates, the study shows the possibility of ensiling fodder maize, sorghum and bajra without addition of molasses. According to Thomas (2008), maize silage does not need additives that improve fermentation, as it ferments quite readily.

a. Chopped herbage

b. Mixing with molasses

d. Packed herbage

c. Filling in plastic bags

Plate 11. Various steps in ensiling

5.8 ECONOMICS

The feasibility of a crop production or management practice can be judged only by cost benefit analysis. In the case of rice fallow cultivation, this is very important as most often the land is left fallow due to economic constraints. In dairying, in order to reduce the cost of production, the cost of fresh fodder production has to be minimized. Hence the cost benefit analysis was carried out.

The analysis indicated that for rice fallow cereal fodder production, maize cultivation with herbicide based zero tillage was the best option as it resulted in the highest B: C ratio of 3.31 (Fig. 13). This was due to the high gross and net returns. If the farmer follows a herbicide free production system, he can raise maize with minimum tillage as the B: C ratio for this treatment was found to be the next best (3.24). Gopinath *et al.* (2007) reported higher B: C ratio (1.79) in zero tillage compared to conventional tillage (1.75) in wheat.

Of the other two crops, bajra was found to be more profitable than sorghum. Here also herbicide based zero tillage realized the highest B: C ratio (3.0) than other tillage treatments. Even simply dibbling the maize seed in rice fallow was found to be profitable with B: C ratio of 2.66 and this is a better option than leaving the land fallow as the soil properties were also improved by fodder cultivation.

In terms of B: C ratio normal tillage method could not perform better than herbicide based zero tillage or minimum tillage due to high labour cost. The cost of cultivation for this treatment was Rs. 15,752/ha compared to Rs. 11,790/ha for herbicide based zero tillage and Rs. 11,689/ha for minimum tillage.

The highest net profit of Rs 27,208/ha was realized in maize under herbicide based zero tillage whereas, the least profit of Rs 4757/ha was observed when sorghum was raised in zero tillage (control). According to Ram *et al.* (2010) the highest net return and B: C ratio were observed in no tillage due to low cost of

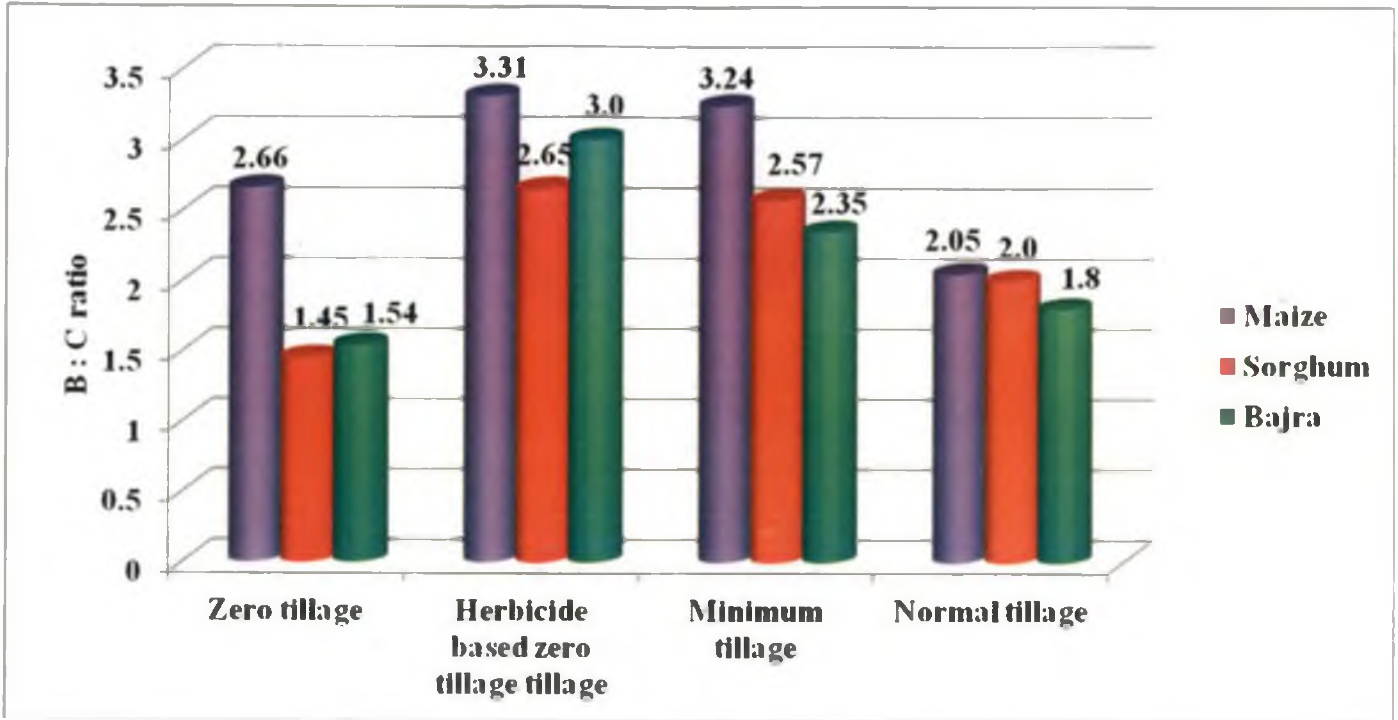


Fig. 13. B - C ratio of fodder crops in various tillage practices

cultivation. Similar results of higher net income from maize in no tillage were reported by Landerson *et al*. (2001). Chopra and Chopra (2010) suggested that a crop of wheat can be taken up at low cost by adopting zero and reduced tillage with sequential application of herbicides for control of complex weed flora.

Summary

6. SUMMARY

A study entitled **"Production potential of cereal fodder crops under various tillage practices in rice fallows"** was conducted at the Department of Agronomy, College of Horticulture, Vellanikkara during the period from November 2009 to February 2010, to study the effect of tillage practices on herbage yield, growth parameters, content and uptake of nutrients, quality parameters as well as the economics of production of fodder crops in rice fallows. The study resulted in the following findings.

- Average forage yield of three cereal fodders (maize, sorghum and bajra) under different tillage practices showed that the herbicide based zero tillage, minimum tillage and normal tillage practices gave comparable yields.

- Fodder maize recorded significantly higher yield of 20.19 t/ha followed by 15.91 t/ha for fodder sorghum and 15.81t/ha for fodder bajra.

- Fodder maize under herbicide based zero tillage was the best with regard to yield and B:C ratio.

- For a herbicide free production system, fodder maize under minimum tillage is the best choice.

- Tillage practices influenced the weed population and nature of weed flora. Normal tillage plots had the lowest population and dry weight of weeds.

- The number of weeds as well as weed dry weight was significantly higher in zero tillage plots followed by minimum tillage plots

- The lowest weed dry weight and population of grass, sedge and broad leaved weeds were observed in conventional tillage.

- The growth parameters recorded at various growth stages also showed favourable influence of minimum and herbicide based zero tillage on plant growth.

- The plants in the herbicide based zero tillage recorded the highest value of LAI both at 30 DAS (2.37) and at harvest (4.05) which was significantly superior to other tillage methods.

- Tillage practices had no significant influence on leaf stem ratio, shoot root ratio and moisture content of herbage at harvest.

- Maize plants recorded the highest LAI at 30 DAS and at harvest followed by sorghum and bajra. The highest leaf stem ratio at harvest was found in maize and sorghum.

- Tillage treatments influenced the nutrient contents of plant parts. The plants in normal tillage as well as herbicide based zero tillage always recorded higher contents of primary nutrients.

- A comparison between three fodder cereals indicated that maize and sorghum had higher contents of N and P compared to bajra, but K content of sorghum leaf and stem was lower than that of maize and bajra.

- The nutrient removal was less in zero tilled plots compared to other tillage practices for the nutrients studied. The drastic decline in uptake values in zero tilled plots resulted from the least dry matter production in this treatment.

- The crude protein content in leaves and stems of fodder cereals was high in herbicide based zero tillage and normal tillage, as the nitrogen content in these treatments were high.

- Tillage methods did not influence the crude fibre, ether extract, total ash and nitrogen free extract of leaves of fodder crops.

- Preservation of fodder as silage was suitable to all the three fodder crops and quality silage can be made even without the addition of molasses.

- The soil physical and chemical properties were improved by fodder production.

- Though the cost of production was the least for zero tillage (Rs. 31,630), it resulted in significantly lower yields and hence, a lower B:C ratio.

It can be concluded that for rice fallow cereal fodder production herbicide based zero tillage or minimum tillage can be resorted to instead of going for normal tillage. Fodder maize under herbicide based zero tillage can be recommended for maximum forage yield as well as net profit. In situations where herbicide application is not advocated, maize can be grown under minimum tillage. Zero tillage without herbicide application cannot be recommended due to high weed competition and resultant poor yields. The study revealed the influence of tillage practices on weed population and the nature of weed flora. The conventional tillage resulted in the lowest weed dry weight and population. Tillage practices influence the nutrient content of plant parts as well as the nutrient removal. Of the various quality parameters crude protein content was high in plants raised under herbicide based zero tillage whereas, tillage methods did not influence the crude fibre, crude fat or the carbohydrate content of fodder cereals. Silage of good quality can be made from fodder maize, fodder bajra and fodder sorghum even without addition of molasses. The soil, physical and chemical properties were improved by fodder production.

References

REFERENCES

A.O.A.C. [Association of Official Analytical Chemists] 1975. *Official and Tentative Methods of Analysis*, (12th Ed.). Association of Official Analytical Chemists, Washington, D. C., 1094p.

Agbede, T. M., Ojeniyi, S. O. and Awodun, M. A. 2008. Effect of tillage method on growth, yield and nutrient content of sorghum (*Sorghum bicolor L.*) in forest savanna transition zone of Nigeria. *Int. J. Sustain. Crop Prod.* 3(5): 35-39.

Aggarwal, P. and Goswami, B. 2003. Bed planting system for increasing water use efficiency of wheat (*Triticum aestivum*) grown in Inceptisol (Typic Ustochrept). *Indian J. Agric. Sci.* 73(7): 422-425.

Al-Kaisi, M. and Kwaw- Mensah, D. 2007. Effect of tillage and nitrogen uptake rate on corn yield and nitrogen and phosphorus uptake in a corn – soybean rotation. *Agron. J.* 99: 1548-1558.

Al-Kaisi, M. and Licht, M. A. 2004. Effect of strip tillage on corn nitrogen uptake and residual soil nitrate accumulation compared with no-tillage and chisel plow. *Agron. J.* 96: 1164–1171.

Al-Kaisi, M. M. and Waskom, R. M. 2002. Utilizing swine effluent for sprinkler-irrigated corn production. *J. Soil Water Conserv.* 57: 111–120.

Amador- Ramirez, M. D. 2002. Critical period of weed control in transplanted chilli pepper. *Weed Res.* 42: 203-209.

Anderson, E. L., Millner, P. D. and Kunishi, H. M. 1987. Maize root length density and mycorrhizal infection as influenced by tillage and soil phosphorus. *J. Plant Nutr.* 10(9-16): 1349-1356.

Aslam, M., Majid, A., Hashmi, N. I. and Hobbs, P. R. 1993. Improving wheat yield in the rice – wheat cropping system of the Punjab through zero tillage. *Pak. J. Agric. Res.* 4: 8-11.

Badhe, S. B. and Nalamwar. 1981. A critical study of crop-weed competition in hybrid sorghum. In: *Abstracts of Papers, Annual Conference of Indian Society Weed Science*; Nov.25, 1981, p. 28.

Ball, D. A. and Miller, S.D. 1993. Cropping history, tillage and herbicide effects on weed flora composition in irrigated corn. *Agron. J.* 85: 817-821.

Ball, D.A. and Miller, S.D. 1990. Weed seed population response to tillage and herbicide use in three irrigated cropping sequences. *Weed Sci.* 38: 511-517.

Bharadwaj, S. P. and Sindhwal, N. S. 1998. Zero tillage and weed mulch for erosion control on sloping farm land in Doon valley. *Indian J. Soil Conserv.* 26: 81-85.

Bhatt, R., Khera, K. L. and Arora, S. 2004. Effect of tillage and mulching on yield of corn in the submontaneous rainfed region of Punjab, India. *Int. J. Agric. Biol.* 6(1): 126-128.

Bisen, P. K. and Singh, R. 2008. Effect of tillage and weeed control practices on weed growth and yield of wheat (*Triticum aestivum*) in rice (*Oryza sativa*) – wheat system. *Indian J. Agric. Sci.* 78(4): 347-350.

Buhler, D. D. 1991. Influence of tillage systems on weed population dynamics and control in northern corn belt of the United States. *Adv. Agron.* 1: 55-60.

Cardina, J., Regnier, E. and Harrison, K. 1991. Long-term tillage effects on seed banks in three Ohio soils. *Weed Sci.* 39: 186-194.

Carter, M. R. and Rennie, D. A. 1987. Effects of tillage and deposition and utilization of ^{15}N residual fertilizer. *Soil Tillage Res.* 9: 33–43.

Carter, M. R., Sanderson, J. A., Ivany, J. A. and White, R. P. 2002. Influence of rotation and tillage on forage maize productivity, weed species and soil quality of a fine sandy loam in the cool humid climate of Atlantic Canada. *Soil Tillage Res.* 67(1): 85-98.

Channappagoudar, B. B. and Biradar, N. R. 2007. Physiological studies on weed control efficiency in direct sown onion. *Karnataka J. Agric. Sci.* 20(2): 375-376.

Chatterjee, B. M. and Das, P. K. 1989. *Forage Crop Production, Principles and Practices.* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 484p.

Chatterjee, B. N. and Maiti. 1981. *Silage and Hay making.* ICAR, New Delhi, 360p.

Chauhan, B. S. and Johnson, D. E. 2009. Influence of tillage systems on weed seedling emergence pattern in rainfed rice. *Soil Tillage Res.* 106(1): 15-21.

Chauhan, D. S., Sharma, P. K. and Chhonkar, R. S. 2003. Comparative performance of tillage options in wheat (*Triticum aestivum*) productivity and weed management. *Indian J. Agric. Sci.* 73(7): 402-406.

Chauhan, D. S., Sharma, R. K., Tripathi, S. C., Kharub, A. S. and Chokkar, R. S. 2000. Wheat cultivation after rice – a paradigm shift in tillage technology. *Indian Fmg.* 50(6): 21-23.

Chauhan, T. R. 1995. Comparative performance of urea enriched maize / maize stover silage in growing baffaloes bull calves. *Buffalo J.* 11(2): 149-159.

Chauhan, T. R. and Dahiya, S. S. 1993. Comparative nutritive value of urea enriched maize silage to adult buffaloes. *Indian J. Anim. Sci.* 63(1): 1216-1218.

Chopra, N. K. and Chopra, N. 2010. Evaluation of tillage system and herbicides on wheat (*Triticum aestivum*) performance under rice (*Oryza sativa*)-wheat cropping system. *Indian J. Agron.* 55(4): 304-307.

Chopra, P. and Angiras, N. N. 2008. Influence of tillage and weed control methods on weeds, yield and yield attributes of maize (*Zea mays* L.). *Indian J. Weed Sci.* 40(1&2): 28-32.

deMooy, C. J., Young, J. L. and Kaap, J. D. 1973. Comparative response of soybeans and corn to phosphorus and potassium. *Agron. J.* 65: 851–855.

Dinnes, D. L., Karlen, D. L., Jaynes, D. B., Kasper, T. C., Hatfield, J. L., Colvin, T. S. and Cambardella, C. A. 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. *Agron. J.* 94:153–171.

Dixit, A. K., Agarwal, R. K., Das, S. K., Raj, A. K. and Sahai, C. S. 2010. Influence of tillage management practices on productivity of sorghum + cowpea - wheat cropping systems under limited irrigation conditions. In: *Range Management and Agroforestry Symposium Issue* (A). Indian Grassland and Fodder Research Institute, Jhansi, pp.19-20.

Dixit, J., Gupta, R. S. K. and Yadav, R. L. 2003. No tillage and conventional tillage system evaluation for production of wheat – An analysis. Indian *J. Agric. Res.* 37: 199-203.

Doran, J. W. 1980. Soil microbial and biochemical changes associated with reduced tillage. *Soil Sci. Soc. Am. J.* 44:765–771.

Escasinas, A. B. and Escalada, R. G. 1980. Effect of different methods and timings of weed control on the yield and yield components of grain sorghum. *Ann. Trop. Res. (Philipp)* 2(3): 156-164.

Fray, P.K. and Olson, W.A. 1978. Techniques for seperating weed seed from soil. *Weed Sci.* 26; 530-533.

Froud-Williams, R. J., Chancellor, R. J. and Drennon, D. S. H. 1983. Potential changes in weed flora associated with reduced cultivation systems in cereal production in temperate regions. *Weed Res.* 21: 99-109.

Gardner, F. P., Pearce, R. B. and Mitchell, R. L. 1985. *Physiology of Crop Plants* (Reprint, 1988). Scientific Publishers, Jodhpur, 327p.

Gebhardt, M. R., Daniel, T. C., Scheveiger, E. E. and Allmaras, R. R. 1985. Conservation tillage. *Science* 230: 625-630.

Gilliam, J. W. and Hoyt, G. D. 1987. Effect of conservation tillage on fate and transport of nitrogen. In: Logan, T. J. (ed.), *Effects of Conservation Tillage on Ground Water Quality: Nitrates and Pesticides.* Lewis Publications, Chelsea, pp 217–240.

GOI [Government of India]. 2010. *Economic Survey* [on line]. Available: http://indiabudget.nic.in/index.asp. [16 Mar. 2011].

Gopinath, K. A., Kumar, N., Pande, H. and Bisht, J. K. 2007. Bio-efficacy of herbicides in wheat under zero and conventional tillage systems. *Indian J. Weed Sci.* 39(3 & 4): 201-204.

Goswami, S. B. and Saha, S. 2006. Effect of organic and inorganic mulches on soil moisture conservation, weed suppression and yield of elephant foot yam (*Amorphophallus paeoniifolius*). *Indian J. Agron.* 51(2): 154-156.

Govaerts, B., Sayre, K. D. and Deckers, J. 2005. Stable high yields with zero tillage and permanent bed planting. *Field Crop Res.* 94(1): 33-42.

Groffman, P.M., Hendrix, P.F. and Crossley, D.A. Jr. 1987. Nitrogen dynamics in conventional and no-tillage agrosystems with inorganic fertilizer legume inputs. *Plant Soil* 7:315–322.

Grossbard, E. and Atkinson, D. 1985. *The Herbicide Glyphosate.* Butterworth and Co. (Publishers) Ltd, London, 490p.

Gurumurthy, P. and Rao, M. S. 2006. Effect of tillage and irrigation regimes on soil physical properties and performance of sunflower in rice fallows II. Water use and crop yield. *J. Indian Soc. Soil Sci.* 54(1): 18-23.

Halvorson, A. D., Wienhold, B. J. and Black, A. L. 2001. Tillage and nitrogen fertilization influence and soil nitrogen in an annual cropping system. *Agron. J.* 93:836–841.

Hansen, W. P. Otterby, D. E. Linn, J. G. and Kuchn, C. S. 1992. Effect of additives on fermentation of corn silage containing different amounts of added nitrte nitrogen. *J. Dairy Sci.* 75(6): 1555-1561.

House, G. J., Stinner, B.R., Crossley, D. A. Jr., Odum, E. P. and Langdale, G. W. 1984. Nitrogen cycling in conventional and no-tillage agrosystems in the southern Piedmont. *J. Soil Water Conserv.* 39: 194–200.

Huntington, T. G., Grove, J. H. and Frye, W.W. 1985. Release and recovery of nitrogen from winter annual crops in no-till corn production. *Commun. Soil Sci. Plant Anal.* 16:193–211.

Jackson, M. L. 1958. *Soil Chemical Analysis* (Indian Reprint, 1967). Prentice Hall of India (Pvt.) Ltd., New Delhi, 498p.

Jain, N., Miahra, J. S., Kewat, M. L. and Jain, V. 2007. Effect of tillage and herbicides on grain yield and nutrient uptake by wheat (*Triticum aestivum*) and weeds. *Indian J. Agron.* 52(2): 131-134.

Jat, R. S., Nepalia, V., Shivran, D. R. and Chalka, M. 2004. Relative NPK uptake by wheat and associated weeds as affected by weed control and sowing methods. *Haryana J. Agron.* 20: 13-15.

Kaputsa, G., Krausz, R. F. and Mattnews, J. L. 1996. Corn yield is equal in conventional, reduced tillage and no tillage after 20 years. *Agron. J.* 88: 812-817.

KAU [Kerala Agricultural University]. 1998. *Status Paper on Fodder Research in Kerala Agricultural University*. College of Agriculture, Vellayani, 33p.

Khairwal, I. S., Rajpurohit, B. S. and Kumari, S. 2009. Pearl millet: a potential forage and fodder crop [abtract]. In: *'Abstracts, Forage Symposium on Emerging Trends in Forage Research and Livestock Production*; 16-17, February, 2009. CAZRI RRS, Jaisalmer (Rajasthan), India, p.7. Abstract No. 5.

Klingerman, C. M. 2007. *Grass Tetany in Cattle- an Examination of its Causes, Clinical Signs and Cures* [on line]. Dairy Research, Teaching and Extension, University of Delaware. Available: http://ag.udel.edu/anfs/faculty/kung/documents/GrassTetanyinCattle.pdf. [12 Jan. 2011].

Kondap, S. M. and Reddy, J. 1978. Crop weed competition studies in jowar (*Sorghum bicolor* L.). Paper presented at the All India Weed Science Conference held at Tamil Nadu Agricultural University, Coimbatore, 3-4 Feb., 1978.

Kropft, M. J., Vossen, F. J. H., Spitters, C. T. T. and De Groot, W. 1984. Competition between maize and a natural population of Echinochloa *crusgalli*. *Neth. J. Agric. Sci.* 32(4): 324-327.

KSLUB [Kerala State Land Use Board] 2008. *Vibhava Keralam* 1(5):1-4.

Kumar, M. R., Murthy, G. R. K. and Subbaiah, S. V. 1997. Energy dynamics of rice – based cropping systems under different methods of rice cultivation. *J. Agric. Engng.* 34(2): 17-25.

Kumar, V., Singh, S., Yadav, A., Malik, R. K. and Hobbs, P. R. 2002. Studies on the effect of zero tillage in wheat on physico - chemical properties of soil in comparison to conventional tillage. In: *Herbicide Resistance Management and Zero Tillage in Rice-Wheat Cropping System.* Proceedings of International Symposium, Hisar, India. CCS Haryana Agricultural University, India, pp 110-112.

Lakshmi, N. V., Rao, Y. H., Sekhar, K. C. and Lakshmi, G. V. 2009. Performance of dry sown rice under lowland to different weed management practices. *Andhra Agric. J.* 56(2): 144-146.

Lal, R. 1989. Conservation tillage for sustainable agriculture: tropics versus temperate environments. *Adv. Agron.* 42: 86-185.

Lal, R., Wilson, G. F. and Okigbo, B. N. 1978. Conservation tillage and sustainable agriculture. *Adv. Agron.* 42: 92-94.

Landers, J. N., Saturnino, H. M. and De Freitas, P. L. 2001. Organizational and policy consideration in zero tillage. In: Saturnino, H. M. and Landerson, J. N. (eds.). *The Environment and Zero Tillage.* APDC, Brasmlia, Brazil, pp 13-14.

Licht, M. A. and Al-Kaisi, M. 2005a. Corn response, nitrogen uptake and water use in strip-tillage compared with no-tillage and chisel plow. *Agron. J.* 97:705–710.

Liebhardt, W. C. 1976. Soil characteristics and corn yield as affected by previous applications of poultry manure. *J. Environ. Qual.*, 5: 459-462.

Liebman, M., Drummond, F.A., Carson, S. and Zhang, J. 1996. Tillage and rotation crop effects on weed dynamics in potato production systems. *Agron. J.* 88: 18-26.

Mallarino, A. P., Bordoli, J. M. and Borges, R. 1999. Phosphorus and potassium placement effects on early growth and nutrient uptake of no-tillage corn in relationships with grain yield. *Agron. J.* 91:37–45.

Mansfield, C. W., Mislevy, P. and Hammona, L. C. 1990. Yield and nutritive value of forages grown under irrigated and non irrigated condition. *Trop. Grassl.* 24: 55-60.

Mathew, G. and Johnkutty, I. 2003. Effect of minimum tillage system on productivity of rice. *J. Trop. Agirc.* 41: 50-51.

Mc Gonigle, T. P., Evans, D. G. and Miller, M. H. 1990. Effect of degree of soil disturbance on mycorrhizal colonisation and phophorus absorption by maize in growth chamber and field experiments. *New Phytol.* 116(4): 624-636.

McCarthy, G. W., Meisinger, J. J. and Jenninskiens, F. M. 1995. Relationship between total-N, biomass-N and active - N under different tillage systems and N fertilizer treatments. *Soil Biol. Biochem.* 27: 1245–1250.

Mehdi, B. B., Madramootoo, C. A. and Mehuys, G. R. 1999. Yield and nitrogen content of corn under different tillage practices. *Agron. J.* 91:631–636.

Menon, M. V. 1987. Potential and prospects of fodder legumes in rice fallows. MSc (Ag) thesis, Kerala Agricultural University, Thrissur, 82p.

Miller, M. H., Mc Gonigle, T. P. and Addy, H. D. 1995. Functional ecology of vesicular arbuscular mycorrhizae as influenced by phosphate fertilization and tillage in an agricultural ecosystem. *Crit. Rev. Biotechnol.* 15: 3-4, 241-255.

Mishra, J. S. and Singh, V. P. 2009. Weed dynamics and productivity of soybean (Glycine max) – based cropping systems as influenced by tillage and weed management. *Indian J. Agron.* 54(1): 73-75.

Mishra, J. S., Singh, V. P. and Yaduraju, N. T. 2005. Effect of tillage practices and herbicides on weed dynamics and yield of wheat (*Triticum aestivum*) under different transplanted rice (*Oryza sativa*) – wheat system in vertisols. *Indian J. Agron.* 50: 106-109.

Murthy, U. R. 1992. Sorghum production and utilization in India - the present and the future. *Agric. Situ. India* 47(6): 497-506.

Narayan, D. and Lal, B. 2010. Rainwater conservation and yield of sorghum (*Sorghum bicolor*) as influenced by tillage and cover management practices in red soils. *Indian J. Agron.* 54(4): 438-443.

Narayanan, T. R. and Dabadghao, P. M. 1972. *Forage Crops of India*. ICAR, New Delhi, 373p.

Obreza, T. A. and Rhoads, F. M. 1988. Irrigated corn response to soil test indices and fertilizer nitrogen, phosphorus, potassium and magnesium. *Soil Sci. Soc. Am. J.* 52:701–706.

Ojeniyi, S. O. 1993. Nutrient availability and maize yield under reduced tillage practices. *Soil Tillage Res.* 26(1): 89-92.

Otieno, K.., Onim, J. F. M. and Mathuva, M. N. 1990. A gunny –bag ensilinh technique for small scale farmers in Western Kenya. In: Dzowela, B. H. and Said, A. N., Wendem – Agenehu, A. and Kategile, T. A. (eds.), *Utilization of Research Results on Forage and Agricultural By-product Materials as Animal Feed Resources in Africa.* Proceedings of the first joint workshop held in Lilongwe, Malawi; 5-9 Dec. 1988.

Panchal, Y. C. and Krishnasastry, K. S. 1974. Cereal crop fields should be weed free for the first 4-6 weeks after sowing to ensure good yields. *Curr. Res.* 3: 51-52.

Pandey, A. K., Prakash, V., Singh, R. D., Singh, P. and Chauhan, V. S. 1999. Direct and residual effect of weed control measures in maize and wheat cropping system under mid-hill conditions of North Western Himalayas. *Indian J. Weed Sci.* 31(3):204-209.

Pandey, I. B., Sharma, S. L., Tiwari, S. and Bharati, V. 2001. Effect of tillage and weed management on grain yield and nutrients removal by wheat (*Triticum aestivum*) and weeds. *Indian J. Weed Sci.* 33: 107-111.

Pandey, I. B., Sharma, S. L., Tiwari, S. and Misra, S. S. 2005. Economics of tillage and weed management system for wheat (*Triticum aestivum*) after lowland rice (*Oryza sativa*). *Indian J. Agron.* 50(1): 44-47.

Pandya, S. M. and Purohit, J. P. 1976. Ecological studies of crop-weed association of jowar (*Sorghum vulgare* Pers.) crop fields in Rajkot. *J. Indian Bot. Soc.* 55(1): 14-22.

Panse, V. G. and Sukhatme, P. V. 1978. Statistical Methods for Agricultural Workers. ICAR, New Delhi, 347p.

Patil, B.D. and Singh, S.A. 1980. Forage crops and grasses. In: *Handbook of Agriculture*, ICAR, New Delhi, pp. 1128-1165.

Payne, W. A., Hossner, L. R., Onken, A. B. and Wendt, C. W. 1995. Nitrogen and phosphorus uptake in pearl millet and its relation to nutrient and transpiration efficiency. *Agron. J.* 87:425–431.

Piper, C. S. 1966. *Soil and Plant Analysis*. Hans Publishers, Bombay, 368p.

Potter, K. N., Morrison, J. E. and Torbert, H. A. 1996. Tillage intensity effects on corn and grain sorghum growth and productivity on a vertisol. *J. Prod. Agric.* 9(3): 385-390.

Prasad, R., Dinesh, K. and Shivay, Y. S. 2006. Strategies for sustained soil fertility. *Indian Fmg.* 56: 4-8.

Raj, A. S. 1987. *An Introduction to Physiology of Cereal Crops.* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 225p.

Ram, H., Kler, D. S., Singh, Y. and Kumar, K. 2010. Productivity of maize (*Zea mays*) – wheat (*Triticum aestivum*) system under different tillage and crop establishment practices. *Indian J. Agron.* 55(3): 185-190.

Rice, C. W., Grove, J. H. and Smith, M. S. 1987. Estimating soil net nitrogen mineralization as affected by tillage and soil drainage due to topographic position. *Can. J. Soil Sci.* 67:513–520.

Robinson, G. W. 1992. A new method for the mechanical analysis of soils and other dispersions. *J. Agric. Sci.* 12: 306-321.

Rola, H. and Rola, J. 1992. Effect of competition from *Amaranthus retioflexus L.* on sugarbeed and maize crop and possibilities for its chemical control in south west Poland. In: *16th German Conference on Weed Biology and Control,* Germany (10-12 Mar.), 1992, pp. 215-220.

Sadasivam, S. and Manickam, A. 1992. *Biochemical Methods for Agricultural Sciences.* Wiley Eastern Ltd., New Delhi, 246p.

Saha, S., Chakraborty, D., Sharma, A. R., Tomar, R. K., Bhadraray, S., Sen, U., Behera, U. K., Purakayastha, T. J., Garg, R. N. and Kalra, N. 2010. Effect of tillage and residue management on soil physical properties and crop productivity in maize (*Zea mays*) – Indian mustard (*Brassica juncea*) system. *Indian J. Agric. Sci.* 80(8):679-685.

Sanju, U. M. and Singh, B. P. 2001. Tillage, cover crop and kill-planting date effects on corn yield and soil nitrogen. *Agron. J.* 93:878–886.

Sarma, C. K. and Gautam, R. C. 2010. Weed growth, yield and nutrient uptake in maize (*Zea mays*) as influenced by tillage, seed rate and weed control method. *Indian J. Agron.* 55(4): 299-303.

Sathyamurthi, R., Chinnusamy, C., Kandasamy, O. S. and Sankaran, N. 2001. Weedseed dynamics under cultivated field as influenced by preparatory tillage. In: *Abstracts, First Biennial Conference in the New Millennium on Eco-friendly Weed Management Options for Sustainable Agriculture;* 23-24 May, 2001. Indian Society of Weed Science and University of Agricultural Science, Bangalore.

Saxena, A., Singh, D. V. and Joshi, N. L. 1997. Effect of tillage and cropping systems on soil moisture balance and pearl millet yield. *J. Agron. Crop Sci.* 178(4): 251-257.

Sharma, A. R., Singh, R., Dhyani, S. K. and Dube, R. K. 2010a. Moisture conservation and nutrient recycling through legume mulching in rainfed maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping system. *Nutrient Cycling in Agroecosystems* 87(2): 187-197.

Sharma, A. R., Singh, R., Dhyani, S. K. and Dube, R. K. 2010b. Tillage and legume mulching effects on moisture conservation and productivity of rainfed maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping system. *Indian J. Agron.* 55(4): 245-252.

Sharma, D. and Zelaya, O. 1986. Competition and control of itch grass (*Rottobelella exaltata*) in maize (*Zea mays*). *Trop. Pest Manag.* 32(2): 101-104.

Sharma, P. K. and Acharya, C. L. 2000. Carry-over residual soil moisture and conservation tillage practices for sowing of rainfed wheat (*Triticum aestivum L.*) in North Western India. *Soil Tillage Res.* 57: 43-52.

Sharma, P. K., Kharwara, P. C. and Tewatia, R. K. 1990. Residual soil moisture and wheat yield inrelation to mulching and tillage during preceeding rainfed crop. *Soil Tillage Res.* 15: 279-284.

Sharp, R. R., Boswell, F. C. and Hargrove, W. L. 1986. Phosphorus fertilization and tillage effect on dinitrogen fixation in soybeans. *Plant Soil* 96(1): 31-44.

Shenk, M. D. and Saunders, J. L. 1981. Environmental pollution and conservation tillage. In: Akobundu, I. O. and Deutsch, A. E. (eds.), *No-Tillage Crop Production in the Tropics*. International Plant Protection Centre, Oregon State University, Corvallis, pp. 73-85.

Shetty, S. V. R. 1978. Weed control in sorghum in the tropics. Paper presented at the *10th Annual Meeting of Weed Science Society Philippines,* Manila, 3 to 6 May, 1978. 14p.

Simpson, J. E., Adiar, C. R., Kobler, G. O., Dawson, E. H., Dabald, H. A., Kester, E. B. and Klick, J. T. 1965. *Quality Evaluation Studies of Foreign and Domestic Rices*. Tech. Bull. No. 1331, U. S. D. A. Service. 186p.

Singh, P. and Srivastava, A. K. 1990. Biofertilizer for augumenting forage production. *Forage Production Technology*, IGFRI, Jhansi, pp. 9-10.

Singh, S.D., Mishra, D.K., Vyas, D.L. and Daulay, H.S. 1971. Fodder production of sorghum in association with different legumes under different levels of nitrogen. *Indian J. Agric. Sci.* 41(2): 172-176.

TNAU [Tamil Nadu Agricultural University]. 2010. TNAU Agritech Portal [on line]. Available: http://agritech.tnau.ac.in/agriculture/foragecrops_foddermaize.html [16 Aug. 2010].

Tomar, R. K., Garg, R. N. and Gupta, V.K. 2006. Optimum tillage and resource conserving technologies for cropping systems. *Indian Fmg*. 56: 27-32.

Tripathi, H. P., Singh, V. K., Verma, D. K. and Jiswal, L. M. 1998. Chemical weed control in direct seeded rice under rainfed upland conditions. *Oryza* 35(3): 288-289.

Tuesca, D., Puricelli, E. and Papa, J. C. 2001. A long term study of weed flora shifts in different tillage systems. *Weed Res*. 41: 369-382.

Varco, J. J., Frye, W. W., Smith, M. S. and MacKown, C. T. 1993. Tillage effects on legume decomposition and transformation of legume and fertilizer nitrogen-15. *Soil Sci. Soc. Am. J.* 57:750–756.

Vargessel, M. J., Scheweizer, E. E., Garrett, K. A. and Westia, P. 1994. Influence of weed density and distribution on corn (*Zea mays*) yield. *Weed Sci.* 43: 215-218.

Verma, S. K., Singh, R. P. and Singh, R. K. 2007. Effect of application time on efficiency of herbicides in wheat (*Triticum aestivum*) under zero tillage. *Indian J. Weed Sci.* 39(3 & 4): 197-200.

Walkley, A. and Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 37: 29-38.

Watnabe, P. S. and Olsen, S. R. 1965. Test of an ascorbic acid method for determining phosphate in water and NH_4HCO_3 extracts from soil. *Proc. Soil Sci. Am.* 29: 677-678.

Singh, U., Saad, A. A., Singh, S. R. and Sharma, L. K. 2009. Yield and weed flora of wheat as influenced by tillage options and fertility levels under rainfed temperature conditions. *Ann. Agric. Res.* 30(1 & 2): 67-70.

Stevenson, F. C., Legere, A., Simard, R. R. and Laford, D. P. J. 1997. Weed species diversity in spring barley varies with crop rotation and tillage, but not with natural source. *Weed Sci.* 45: 798-806.

Sueethadevi, K. B., Reddy, D., Madhusudhan and Sultan, M. A. 2004. Comparison of food and fodder based cropping systems for sustained productivity under irrigated condition. *Forage Res.* 30(1): 49-53.

Swanton, C. J., Clements, D. R. and Derkson, D. A. 1993. Weed succession under conservation tillage: a herbicidal frame work for research and management. *Weed Technol.* 7: 286-297.

Thakur, S. S. and Sharma, D. D. 1993. Nutrient utilization and rumen fermentation in crossbred calves fed maize fodder preserved with urea plus common salt treatment. *Indian J. Anim. Sci.* 63(4): 456-460.

Thangavelu, S. 1967. Studies on drought resistance in sorghum - leaf and panicle characters. *Madras Agric J.* 54: 224-227.

Thomas, C. G. 2008. *Forage Crop Production in the Tropics* (2nd Ed.). Kalyani Publishers, New Delhi, 333p.

Tisdale, S. L., Nelson, W. L., Beaton, J. D. and Havlin, J. L. 1995. *Soil Fertility and Fertilizers* (5th Ed.). Prentice Hall of India Pvt. Ltd., New Delhi, 735p.

Tiwari, A. N., Rathi, K. S. and Yadav, A. N. 1987. Effect of intercrop and herbicides on weed control in maize. *Indian J. Agron.* 32(1): 97-98.

TNAU [Tamil Nadu Agricultural University]. 2010. TNAU Agritech Portal [on line]. Available: http://agritech.tnau.ac.in/agriculture/foragecrops_foddermaize.html [16 Aug. 2010].

Tomar, R. K., Garg, R. N. and Gupta, V.K. 2006. Optimum tillage and resource conserving technologies for cropping systems. *Indian Fmg*. 56: 27-32.

Tripathi, H. P., Singh, V. K., Verma, D. K. and Jiswal, L. M. 1998. Chemical weed control in direct seeded rice under rainfed upland conditions. *Oryza* 35(3): 288-289.

Tuesca, D., Puricelli, E. and Papa, J. C. 2001. A long term study of weed flora shifts in different tillage systems. *Weed Res*. 41: 369-382.

Varco, J. J., Frye, W. W., Smith, M. S. and MacKown, C. T. 1993. Tillage effects on legume decomposition and transformation of legume and fertilizer nitrogen-15. *Soil Sci. Soc. Am. J.* 57:750–756.

Vargessel, M. J., Scheweizer, E. E., Garrett, K. A. and Westia, P. 1994. Influence of weed density and distribution on corn (*Zea mays*) yield. *Weed Sci.* 43: 215-218.

Verma, S. K., Singh, R. P. and Singh, R. K. 2007. Effect of application time on efficiency of herbicides in wheat (*Triticum aestivum*) under zero tillage. *Indian J. Weed Sci.* 39(3 & 4): 197-200.

Walkley, A. and Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 37: 29-38.

Watnabe, P. S. and Olsen, S. R. 1965. Test of an ascorbic acid method for determining phosphate in water and NH_4HCO_3 extracts from soil. *Proc. Soil Sci. Am.* 29: 677-678.

West, T. O. and Post, W. M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation : A global data analysis. *Soil Sci. Soc. Am. J.* 66: 1930-1946.

Woods, L. E. and Schuman, G. E. 1988. Cultivation and slope position effects on soil organic matter. *Soil Sci. Soc. Am. J.* 52:1371–1376.

Yadav, D. S., Shukla, R. P., Sushant and Kumar, B. 2005. Effect of zero tillage and nitrogen level on wheat (*Triticum aestivum*) after rice (*Oryza sativa*). *Indian J. Agron.* 50: 52-53.

Yoong, K. S., Clayton, G. W. and Rice, W.A. 2001. Tillage and previous crop effects on dynamics of nitrogen in a wheat-soil system. *Agron. J.* 93:842–849.

Young, F. L., Wyse, D. L. and Jones, R. J. 1984. Quack grass interference on corn. *Weed Sci.* 32(2): 226-234.

Appendix

Appendix 1. Meterological data for the experimental period (November 2009 to February 2010)

Standard week	Period	Total rainfall (mm)	Mean maximum temperature (^0C)	Mean minimum temperature (^0C)	Relative humidity (%)		Mean wind velocity (Km/hr)	Total sunshine hours	Mean evaporation mm/day
					Day	Night			
48	November 26 - 02	-	31.8	22.6	80	54	5.6	66	4.3
49	December 03 - 09	-	31.5	23.2	78	54	7.5	55.9	4.6
50	10 - 16	-	32.1	23.8	70	59	8.3	65.4	5.9
51	17 - 23	-	32.2	25.0	72	52	11.3	58.9	6.1
52	24 - 31	42.7	31.4	23.8	72	53	10.7	44.8	5.8
1	January 01 - 07	-	32.2	22.5	71	42	6.9	64.4	5.0
2	08 - 14	-	32.6	23.5	84	54	5.6	51.7	4.1
3	15 - 21	-	32.5	22.9	73	49	8.3	63.8	5.4
4	22 - 28	-	32.5	21.8	73	44	7.9	67.1	5.3
5	29 - 04	-	33.2	23.3	63	39	10.2	68.2	6.9
6	February 05 - 11	-	33.5	23.1	66	37	9.5	70.1	7.1

Abstract

Production potential of cereal fodder crops under various tillage practices in rice fallows

by

GINTU GEORGE

(2009 – 11 - 141)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the

requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2011

ABSTRACT

In order to test the feasibility of raising cereal fodders in rice fallows under various tillage systems an experiment entitled "Production potential of cereal fodder crops under various tillage practices in rice fallows" was conducted at the Department of Agronomy, College of Horticulture, Vellanikkara, Thrissur, Kerala. The experiment was laid out in split plot design with four replications during the period from November 2009 to February 2010. The main plots had tillage practices as treatments which included zero tillage with and without herbicide application (M_1 and M_2), minimum tillage (M_3) and normal tillage (M_4). The subplots had three treatments, viz., fodder cereals; maize (S_1), sorghum (S_2) and bajra (S_3).

Analysis of data on herbage yield of the three fodders under different tillage practices showed that the herbicide based zero tillage, minimum tillage and normal tillage practices resulted in comparable yields (20.72, 18.72 and 18.08 t/ha). Zero tillage without herbicide application resulted in significantly lower yield (11.69 t/ha). Growth parameters like plant height, leaf area index, leaf stem ratio, shoot root ratio etc. recorded at various growth stages also showed the favourable influence of minimum and herbicide based zero tillage on plant growth. Among the cereal fodders, maize recorded significantly higher yield of 20.19 t/ha followed by sorghum with 15.91 t/ha and bajra with 15.81 t/ha.

Considering tillage practices and crops together, the highest B: C ratio of 3.31 was realized when maize was grown under herbicide based zero tillage closely followed by maize under minimum tillage with a B: C ratio of 3.24. Of the other two crops, bajra was found to be more profitable than sorghum. Like maize, herbicide based zero tillage resulted in a higher B: C ratio (3.0) for bajra than other tillage treatments.

The yield reduction in zero tillage without herbicide application was mainly due to weeds. A study of weed spectrum showed that dicots were the major weed flora followed by grasses and sedges. The weed population and weed dry matter production were the highest in zero tillage without herbicide application followed by minimum and herbicide based tillage and the least was in normal tillage. Weed dry matter production in zero tilled without herbicide plot was 1545 kg/ha compared to a much lower dry matter accumulation of 193 kg/ha in normal tillage plot.

The silage made from all the three cereal fodders was found to be of good quality with golden yellow colour, pleasant smell and a pH ranging from 3.8 to 4.2. In silage prepared without the addition of molasses, pH was found to be slightly higher (4.2) compared to silage prepared with molasses as additive (3.9).

The study revealed that fodder maize under herbicide based zero tillage was the best with regard to yield and B: C ratio. However, for a herbicide free production system, maize grown under minimum tillage is preferred due to its equally good performance.