YIELD MAXIMIZATION OF FODDER BAJRA AND FODDER SORGHUM IN SUMMER RICE FALLOWS

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(2013-11-188)

THESIS

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By

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THESIS

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2015

DECLARATION

I, **Quwat Ali** hereby declare that this thesis entitled **"Yield maximization of fodder bajra and fodder sorghum in summer rice fallows"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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22. 08.2015 **(2013-11-188)**

CERTIFICATE

Certified that this thesis, entitled **“Yield maximization of fodder bajra and fodder sorghum in summer rice fallows”** is a record of research work done independently by **Mr. Quwat Ali** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of **Mr. Quwat Ali** a candidate for the degree of Master of Science in Agriculture, agree that this thesis entitled **'"Yield maximization of fodder bajra and fodder sorghum in summer rice fallows"** may be submitted by **Quwat Ali** in partial fulfillment of the requirement for the degree.

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ABBREVIATIONS

CP - Crude Protein

CF - Crude Fibre

DAS - Days After Sowing

DM - Dry Matter

LAI - Leaf Area Index

NFE - Nitrogen Free Extract

Introduction

1. INTRODUCTION

Livestock rearing is an integral part of rural living. However, India faces a net deficit of 61.1 per cent green fodder and 21.9 per cent dry crop residues. For feeding the animals, the total area under cultivated fodder is 8.3 million ha on individual crop basis. In India, sorghum among the kharif crops (2.6 million ha) and berseem amongst the rabi crops (1.9 million ha) occupy about 54 per cent of the total cultivated fodder crops area, followed by alfalfa and bajra. Increasing the area under cultivation of fodder crops is difficult because of preferential need for human food, although opportunity exist to improve productivity (ICAR, 2012).

Cultivated fodder has an important role in meeting the requirement of various roughage and nutrients. Animals need feed, which not only meet nutrient requirement and fill the rumen to satisfy the animal, but also provides all the critical elements like highly digestible protein, carbohydrates, fats and minerals. Common fodder crops like maize, sorghum, bajra and oats are rich in energy. Cultivated fodder crops play an important role for feeding ruminants having peculiar digestive system.

Availability of nutritious fodder in the dry period of the year is a limiting factor for the development of livestock in semi-arid regions. Sorghum and pearl millet are two common cereal fodder crops grown in semi - arid regions.

Pearl millet locally known as bajra is a very important dual purpose summer crop grown both for fodder and grain. Tall varieties are cultivated for fodder while dwarf varieties are grown for grain purpose. It is also used for hay, pasture, silage, seed, building material and fuel. Its green forage is a valuable feed for livestock (Alam *et al.,* 2010).

Pearl millet uses less water per unit of forage production, tolerates lower as well as higher soil pH and higher aluminium concentration, and is rich in minerals compared to sorghum. However, sorghum has a wider range of adaptability and is more widely grown.

Fodder sorghum cultivation is emphasized owing to its drought tolerant characteristics and high production potential. Being a heavy feeder of nutrients, soils poor in fertility and low in organic matter content are constraints for its production in arid fringes (Rao *et al.,* 2007).

Compared to fodder maize, which is accepted as a model fodder cereal, the cost of production for sorghum is less primarily because of lower seed and irrigation costs. Water requirements are reported to be 30 - 50 per cent lower than that for maize, which is an important consideration in areas dependent on irrigation. Fodder sorghum will tolerate lower soil fertility than maize and produce reasonable yields.

Certain fodder sorghum varieties with high nutritious values and high fodder production and multicut characters have been recently introduced for which agronomic management is to be formulated. Among the various agronomic factors, proper crop nutrient and appropriate planting geometry are of prime importance in getting higher fodder yield of better quality.

Keeping the above required in view, the present experiment “yield maximization of fodder bajra and fodder sorghum in summer rice fallows” was planned with the following objectives,

- To study the effect of varying plant densities and nitrogen levels on the yield and quality of fodder bajra and fodder sorghum
- To study nutrient removal by these crops

Review of Literature

2. REVIEW OF LITERATURE

Fodder crops have an important role in meeting the requirement of various nutrients and roughages. It is imperative that adequate arrangements are made for the production and supply of fodder and feeds for balanced nutrition of different species of livestock (Meena *et al.,* 2012).

Among various agronomic factors, proper fertilizer application and appropriate planting geometry are of prime importance in getting higher forage yield of better quality. Among different nutrients, nitrogen is considered to be the most important, which improves quality of fodder especially crude protein. Application of nitrogen fertilizer significantly increases plant height because nitrogen promotes plant growth, increases the number and length of the internodes resulting progressive increase in plant height. The number of leaves per plant and leaf area also increases with nitrogen fertilizer, resulting in increased dry matter production of fodder crops. To improve the yield and quality of fodder crops, it is essential to determine the fertilizer requirement of crops.

The literature pertaining to the effect of spacing and nitrogen on growth parameters, nutrient status, forage yield and dry matter of fodder bajra and fodder sorghum are reviewed as follows.

2.1 FODDER BAJRA

Pearl millet (bajra) is a quick-growing and short-duration crop, commonly grown in the arid and semiarid regions for both fodder and grain purposes (Rana and Bana, 2012). It grows mainly under rainfed condition because of its high tillering potential, high dry matter production and drought escaping mechanism.

Ali (2010) reported that pearl millet is particularly adapted to nutrient poor soil and low rainfall conditions. It is erect, leafy and drought resistant plant, widely used in semi arid regions of African and Asian countries (Nithya *et al*., 2006). It has great potential to supply nutritious fodder and is grown in moisture deficient and higher temperature conditions. The chemical analysis showed that it contains 15.2 to 28.5 per cent dry matter, 3.5 to 6 per cent CP, 60.3 to 64.5 per cent neutral detergent fiber, 37.1 to 41 per cent acid detergents fiber, and with 53.9 to 68.7 per cent dry matter in-vitro digestibility (Arora *et al*., 1977).

Due to its good forage quality, farmers of dry areas have shifted its cultivation for fodder rather than grain production. Although pearl millet has adequate nutritional value it is essential to meet the nutritional standards of forage for livestock. The nutritional quality of live stock feed is assessed by its dry matter, crude protein, fat, ash and crude fiber contents. The required concentration of these attributes in dry matter can be achieved with the use of genetically improved cultivars, timely harvesting and application of growth factors such as nitrogen (Cecelia *et al*., 2007).

Almodares *et al*. (2009) implied that dairy farmers consider fodder bajra as superior to any other pastures for milk and beef production because of its lowest hydrocyanic acid potential (HCN-P) values compared with sorghum and sorghum-sudan grass hybrids. The ability to produce it on marginal lands and low rainfall conditions made pearl millet an attractive choice for the sandy and low fertile soils of Egypt (Menezes *et al.,* 1997).

Goswami *et al*. (1970) in a study on 'chemical composition of bajra fodder (African varieties)' conducted in 35 varieties of bajra found that crude protein ranged from 6.81 to 12.80, crude fat 0.89 to 1.75, crude fiber 28.73 to 34.39, nitrogen free extract 41.55 to 51.72, total ash 5.57 to 11.81, Ca 0.29 to 0.69, P 0.47 to 0.84, and oxalic acid 1.19 to 2.16 per cent of dry matter. There was a highly significant negative correlation between N-free extract, protein and ash and Ca. Ash was positively correlated to protein and Ca and oxalic acid. Oxalic acid and Ca were positively correlated.

Sergal and Goswami (1969) reported that the crude fibre and nitrogen free extract increased with plant maturity and crude protein and crude fat content decreased with the advancement of maturity. Total ash, Ca and oxalic acid increased towards dry straw stage.

2.1.1 PLANT POPULATION

Plant spacing between rows and within a row can vary depending on the method of sowing. However, the sowing distance determines the optimum plant stand requirement. In general, if ridges are formed 45 cm apart, then the plants should be 12 to 15 cm apart within a row. If broadbed and furrow method is adopted, the rows should be spaced 60 cm apart on the bed and the distance between plants should be maintained at 10 cm to get the optimum population (Khairwal *et al*., 2007). The plant population per unit area at harvest is one of the most important yield attributing factors. In fodder crops, plant population and growth parameters are differing in different varieties.

2.1.1.1 Plant Height

Plant height is an important component which helps in the determination of growth. Closer spacing hampers intercultural operations and in a densely populated crop, the inter-plant competition for nutrients, air and light is very high, which results in mutual shading, lodging and thus favours more straw yield (Bhowmik *et al.,* 2012). Vegetative development in pearl millet is much influenced by the availability of moisture, soil fertility and the planting density (Mahalakshmi *et al.,* 1987; Azam-Ali *et al.,* 1984; Carberry *et al.,* 1985). Plant population density is a management variable that affects the production and quality of most crops (Shaw *et al.,* 2008).

Podriguez (1973) reported that plant height was significantly correlated with yield and leaf - stem ratio.

2.1.1.2 Leaf Area

Leaf area and canopy structures play important roles on fodder yield. Mohammad *et al*. (1994) reported that varieties having more leaf area produce more fodder yield. Naeem *et al*. (2002) observed wider variation for leaf area while conducting different variety tests of pearl millet. It was observed that leaf area has positive and non significant association with green fodder yield and significant association with dry matter yield.

Tariq *et al*. (2011) reported that the role of nitrogen in improving the leaf to stem proportion was stronger in immature pearl millet plants than mature ones.

Regarding the response of pearl millet to plant density, the results of studies on pearl millet conducted by Almass *et al*. (2007) and Ali (2010) revealed that decreased plant density produced the highest leaf area and leaf area index.

2.1.1.3 Leaf - Stem Ratio

Leaf: stem ratio is a component of canopy architecture and an important factor determining diet selection and forage intake in tropical grasses (Chacon and Stobbs, 1976; Chacon *et al.,* 1978). The decline in forage quality with maturity is directly related to leaf: stem ratio. As plant matures it becomes more “stemmy” (i.e., the leaf: stem ratio decreases). Therefore, a bale of hay that is referred to as “stemmy” is correctly assumed to be of somewhat lower quality. In the same context, tall, coarse or “rank” plants with a low leaf: stem ratio (i.e., more stem than leaf) are of lower quality. The quality of individual plant leaf does not decline to any great extent until it begins to die. However, quality of stems decline with increasing maturity. This process has an important function in plant reproduction and species survival. As the plant matures the stem becomes more fibrous or rigid. The decline in forage quality with maturity is primarily due to increasing lignifications of the stem and increasing proportion of stem compared to leaf (Pinkerton and Cross, 1992).

2.1.1.4 Shoot - Root Ratio

Roots, stems and leaves are functionally interdependent and these three systems maintain a dynamic balance in biomass which reflects relative abundance of above-ground resources (light and CO_2) compared with root-zone resources (water and nutrients) (Poorter, 2012). Whole-plant growth rate and root: shoot ratio, are outcomes of developmental stage and environmental influences.

Pearl millet is known to be deep and profusely rooted, having ability to match its rooting to water availability. Roots appear to play an important role in pearl millet genotypes that differ in the presence or absence of a major terminal drought tolerance (Vadez *et al*., 2012).

Yadav *et al*. (2014) in a study on pearl millet found that the crop had longer root under rainfed than irrigated condition. Root length under rainfed condition was 1.6, 8.6, 8.8 and 7.1 cm more at 20, 40, 60 days after sowing and harvest, respectively compared to irrigated condition. Roots tend to elongate in search of water and nutrients under limited moisture conditions. The increase in the rate of root growth in response to drought depends mostly on the type of plant used, how it is affected by drought and its adaptability to severe conditions (Tyagi *et al.,* 1999; Sanchez *et al*., 2006).

The highest root : shoot ratio maintain greater growth rates giving higher yield under moisture stress conditions (Sashidhar *et al*., 2000).

2.1.1.5 Forage Yield

Fodder yield is a function of the cumulative effect of growth parameters such as plant height and number of tillers per plant. Andreev *et al.* (1984), Abdul *et al.* (1992) and Taran *et al.* (1998) have reported that fodder yield is a varietal character.

In general, pearl millet forage is more succulent and has higher crude protein than sorghum or maize with other chemical constituents being comparable. The dry matter and cell wall digestibility of pearl millet stover are less than that of sorghum (Hanna and Gupta, 1999).

The harvesting management is based on more biomass production in the field with high nutritional value that ultimately affects the animal performance. The differences in feeding quality obtained among the harvesting times surpass the varietals differences (Firdous *et al*., 1996). The most common variations associated with harvesting time are forage yield, dry matter percentage, neutral and acid detergent fiber, water soluble carbohydrates, total digestible nutrients, metabolic energy and crude protein (Gul *et al*., 2008; Khan *et al.,* 2007; Ayub *et al*., 2003). Proper harvest management is crucial for forage yield and quality. Besides deteriorating quality, the late harvesting increases post harvest losses due to rejection of stems by the animals (Man and Wiktorsson, 2003).

Tariq *et al*. (2011) reported that harvesting times have striking effect on plant height, stem diameter, leaf: stem ratio, green forage and dry matter yield. Fresh forage yield showed significant increase with lengthening the harvesting time up to 60 DAS and further delay in harvesting did not account a significant increase.

Cox *et al*. (1998) found that row spacing and population density affects whole plant yield. They also observed a slight yield advantage with narrow row spacing.

2.1.1.6 Dry Matter Production

Dry matter (DM) is the actual amount of feed material leaving water, volatile acids and bases. It is the most important component of animal diet for feeding livestock during lean period.

Different bajra varieties showed significant differences in dry matter yield. Plant height has positive significant association with leaf area and dry matter yield. Dry matter yields of pearl millet forage vary greatly depending on environmental conditions (soil fertility, soil moisture and temperature) and varieties. In semi-arid environments, DM yields can be as low as 0.25-3 t ha^{-1}, while under ideal conditions they can reach 27 t/ha and even more than 40 t/ha. However, yields are often about 20 t ha^{-1} in the tropics, and 8-10 t/ha in the subtropics (Cook *et al*., 2005).

Studies on maize conducted elsewhere reported reduced dry matter in closely spaced plants (Makinde and Alabi, 2002; Ibeawuchi *et al*., 2008; Moosavi *et al*., 2012). Higher dry matter at closer spacing in sorghum was reported by Stickler and Laude (1960); Steiner (1986); and Sneider, *et al*. (2008). Aklilu (2005) recorded significantly higher dry matter content in forage oat harvested at 50 per cent flowering stage.

2.1.2 EFFECT OF NITROGEN

Nitrogen is the nutrient that frequently limits yield and also plays an important role in quality of forage crops. Fertility levels and nitrogen splitting significantly affects fodder yield. Positive response of nitrogen fertilizers has been reported by many workers (Sawi, 1993; Koul, 1997; Omer, 1998; Gasim, 2001). Ismail *et al*. (2001) reported that the improved fodder pearl millet varieties and hybrids responded well to nutrient application. Application of nitrogen at 120 kg ha^{-1} increased stover yields significantly and is considered as optimum rate (Kaushik and Mahendra, 1983;

Dahiya *et al.,* 1986). However, Desale *et al*. (2000) reported maximum green forage, dry matter and CP yields with application of 225 kg N ha^{-1} in four splits.

Increased green fodder and dry matter yields in fodder oats may be attributed to the improvement in the growth attributes due to nitrogen application (Sharma, 2009). A study on fodder oats, showed that digestibility decreased with increased N supply, probably due to higher cellulose, hemicelluloses and greater lignifications of crop at higher N level (Aklilu, 2005). This result was in conformity with the report of Kumar *et al*. (2001). Application of nitrogen up to 120 kg/ ha in pearl millet, significantly enhanced the plant height, dry matter, tillers/ plant, crude protein, green and dry fodder yields net returns (Meena and Jain, 2013). It was supported by the result of (Randhawa *et al*. (1989); Sharma *et al*. (1996). Tariq *et al*. (2011) reported that the significant differences existed among nitrogen levels for crude protein, crude fibre, fat, ash and nitrogen free extract in dry matter.

2.1.2.1 Effect of Nitrogen on Plant Height

Plant height is a significant growth attribute directly linked to the productive prospective of plant in terms of forage yield. The increase in plant height in response to higher levels of nitrogen has been confirmed by the findings of Shehzad *et al*. (2012). Sharma (1973) observed that addition of nitrogen fertilizer increased plant height. Turkhede and Rajendra (1978); Koul (1997); and Gasim (2001) reported increase in plant height with different sources of nitrogen.

The beneficial effect of nitrogen on stem diameter has also been confirmed by Saruhan and Sireli (2005). The higher plant height with surplus nitrogen is mainly reflected by increase in inter nodal distance which results in stem elongation (Hani *et al.,* 2006).

The growth of fodder oats measured as tillers, height, tiller number/ unit area and leaf area index (LAI) revealed that nitrogen levels at 150 kg/ ha maintained significantly higher number of tillers (Sharma, 2009). Increase in growth attributes of fodder oats with increase in N levels was also reported by Singh and Dubey (2007).

2.1.2.2 Effect of Nitrogen on Leaf Area

In forage crops, the number of leaves have huge effect on final yield having better quality considerations as compared to stem. The plant height, plant girth, number of branches, number of tillers and leaf area are the parameters that are directly influencing the fodder yield (Hassan *et al.,* 2014).

The production of abundant quantity of good quality forage is pre-requisite for an efficient and productive livestock industry. The splitting of nitrogenous fertilizer significantly influenced leaf: stem ratio, crude protein and N uptake (Almodares *et al.,* 2009). Applying different source of nitrogen had significant effect at all growth stages (El Noeman *et al.,* 1990; Rageb *et al.,* 1990; Lemocof and Loomis, 1994). Nitrogen significantly increases leaf area through elongation of leaves (Sayed, 1998).

2.1.2.3 Effect of Nitrogen on Crude Protein

Crude protein is an estimate of the level of protein in the feed based on the amount of nitrogen present. Since some, but not all of the nitrogen is in the form of true protein, it is termed “crude” protein. Crude protein is relatively easy to measure and, in general, as crude protein content increases in a forage, livestock will perform better (i.e., gain more weight, produce more milk, etc.). Thus, there is a reasonably good relationship between forage quality and crude protein content (Pinkerton and Cross, 1992).

Crude protein is one of the most important quality determinants of forage crops. Forage with high crude protein contents is considered as the best quality forage. Higher the crude protein content better will be the palatability and digestibility. If feeds contain less than 7 percent crude protein, animals are likely to be deficient in nitrogen; hence become less productive. A minimum protein content of 5 - 6 percent is essential for the maintenance of animals and 9-10 percent for production purpose under sub - tropical conditions (Amodu *et al.,* 2007).

Rao *et al.* (2007) confirmed that crude protein yield and N uptake increased significantly with the increase in nitrogen levels and leads to increased yields. Verma and Singh (1987) and Aklilu (2005) from studies on fodder oats, reported that the significant increase in crude protein yield with increase in N level was due to higher crude protein content and dry matter yield at higher levels of nitrogen. Patel *et al.* (2007) reported that raising nitrogen fertilization level up to 80 kg ha^{-1} in fodder beet resulted a significant increase in CP percentage. The protein would be lower in late harvesting as confirmed by Amodu *et al*. (2001) and Shehu *et al*. (2008). The decrease in CP might be due to the reason that nutrient contents do not match the dry matter production at later growth stage. On the other hand, the lower CP concentration in plant material might be due to the loss of leaves (Buxton, 1996). Crude protein was estimated by multiplying N concentration by 6.25 (Baron *et al.,* 2006).

2.1.2.4 Effect of Nitrogen on Crude Fibre

Crude fibre (CF) is the insoluble carbohydrate remaining in the feed analysis process after the sample is boiled in weak acid and alkali. It is another parameter that influences the quality of forages. The forages with less fibre contents are considered as good quality because lower the crude fibre better will be the intake, palatability and digestibility. Application of nitrogen significantly decreased crude fibre probably due to the increased uptake of nitrogen a major constituent of amino acids and protein and decreased pectin, cellulose and hemicelluloses which are the major constituents of fibre (Babu *et al.,* 1995). Parasad (1979), Gangwar and Kala (1988), Singh *et al.*(1992), and Koul (1997) studied the effect of different nitrogen sources on leaf and stem crude fibre of fodder maize and the lowest crude fibre content was recorded when plants were treated with fertilizer.

Khogali *et al.* (2011) reported that the percentage of crude fiber in fodder beet increased by application of nitrogen. This is in line with those reported by Mustafa (2007). Tariq *et al.* (2011) reported that the effect of lengthening the harvesting time was associated with decrease in CP, ash and fat, accompanying with higher CF concentration in dry matter.

The CF in plant material showed a progressive increase with longer harvesting intervals because of deposition of lignin in cell wall with the passage of time. The harvesting at 75 DAS produced a hard and low quality fodder due to more fiber contents in dry matter Harumoto *et al*. (1986); Ali *et al.*(1999); Ayub *et al*. (2003) and Ayub *et al*. (2007).

2.1.2.5 Effect of Nitrogen on Crude Fat

Ether Extract (EE), also termed crude fat, is the amount of fat and fat-soluble components in a feed. In addition to fats and oils, it includes plant pigments (chlorophyll, xanthophylls, and carotene) and fat-soluble vitamins (A, D, E, and K). Tariq *et al.* (2011) reported that the fat concentration in the plants showed a positive association with nitrogen rates which can be explained by the involvement of nitrogen in photosynthesis which are further used in the synthesis of fatty acid. The improvement in fat contents in dry matter has already been found in a study conducted by Bumane (2010). The absence of nitrogen and height (N x H) effect for fat concentration in millet biomass suggested that adverse effects of maturity on fat cannot be compensated by nitrogen application rates. The significant differences in mean values of fat at various growth stages have been reported by Hussain and Durrani (2009).

2.1.2.6 Effect of Nitrogen on Total Ash

Ash is a measure of the total mineral nutrients viz., calcium, phosphorus, potassium and magnesium in the dry matter. Ash cannot be digested by animals. High ash content of feeds may dilute the amount of nutrients available to the animal. If a plant feed is high in ash content, it may be due to soil contamination during harvest of the plant material. The total ash content is almost higher than 10 per cent or less in few of the fodder species. However, species like *Morusnigra, Tike mimosa,* and *Sorghum bicolor* have exceptionally higher amount of total ash. Higher percentage of acid insoluble ash indicates the poor quality of feed.

Tariq *et al.* (2011) reported that the ash contents in millet were reduced with delayed harvesting due to loss of leaves and translocation of inorganic nutrients from vegetative to reproductive plant parts. The significant differences among the mean values of ash contents at various growth stages have also been reported by Kitaba and Tamir (2007).

Sidak and Miroshnickenko (1993) reported that nitrogen application had no significant effect on ash per cent in fodder beet.

2.1.2.7 Effect of Nitrogen on Nitrogen Free Extract (NFE)

NFE is a calculated value getting after subtraction of sum of weights of water, ether extract, crude protein, crude fibre, and ash. NFE is made up from readily available carbohydrates, such as sugars and starches; this fraction may also contain hemicellulose and lignin. Jakhar *et al.* (2003) found out that application of nitrogen significantly decreased the NFE content of fodder pearl millet. Abdallah and Yassen (2008) reported an increase in total carbohydrates with increasing fertilizer rate in fodder beet.

The inverse relation between nitrogen rates and NFE pearl millet was observed by (Tariq *et al.,* 2011). The lower NFE at higher rate of nitrogen maybe due to positive association of nitrogen with CP, CF, fat and ash contents. The differences in NFE among growth stages were non significant and supported by the studies conducted for grasses, by Hussain and Durrani (2009).

2.1.2.8 Effect of Nitrogen on Nitrate in Plant

Nitrate is the primary nutrient form of nitrogen in soils and is a normal constituent of plants. Occasionally, excessive amounts of nitrate accumulate in plants and result in livestock mortalities. Outbreaks of nitrate toxicity due to consumption of fodder containing high amounts of nitrate have been reported in farm animals throughout the world (Malhi *et al.,* 2004).

In livestock, poisoning due to nitrate ions is influenced by several factors that include plant, environmental, management factors and health status of the animal. The plant factors are the most important amongst these because nitrate toxicity in livestock is caused by consumption of plants rich in nitrates.

The factors that influence the accumulation of nitrate in fodder crops are species, stage of growth, part of plant, pH of soil, use of fertilizers and climatic conditions (Falkengren-Grerup *et al.,* 2004). The amount of nitrate accumulation within the plant depends upon the rate of nitrogen uptake and the rate of its reduction within the plant (Radiositis *et al.,* 2000). Some crops such as sorghum, Sudan grass and oats are known nitrate accumulators and may cause sudden death in animals (Kahn, 2005). Traceable amounts of nitrate can be detected in all plants but it becomes dangerous when it exceeds the safe limit of 2500 ppm NO_3-N. Forages having more than 4500 ppm NO_3-N are considered highly toxic. Increasing N supply up to a certain limit increased the yield. High N depressed yields and resulted in maximum values of 15 mg nitrate-N/g dry matter in ryegrass, 10.7 mg in fodder rye, 25.6 mg in white mustard and 16.1 mg in liho-rape.

Application of P increased yields for each level of N, but affected nitrate-N concentrations only at nitrate-N levels <8-10 mg/g dry matter. NO_3 accumulation was increased by doubling the K supply. Plants grown in shade accumulate more NO_3 than those grown in sunlight, possibly due to NO_3 reduction by photo-chemical reaction (Scharrer and Seibel, 1956). Nitrogen fertilizer applications in excess to maximize growth result in potentially toxic nitrate-nitrogen (NO_3-N) concentrations in grazeable plant tissues (Chakwizira *et al.,* 2015).

2.1.2.9 Effect of Nitrogen on Nutrient Uptake

Nutrient uptake is the mechanism by which plants capture all those elements that are essential for their growth. Nutrient uptake depends on a number of factors, plant species, environmental conditions, nutrient supply and interrelationship among nutrients and between plant and soil, presence of microorganisms (e.g., fungi) in association with plant roots, etc. From a practical perspective, nutrient uptake determines the quantity of nutrients exported from a field via harvest and the requirements for their replenishment (Karamanos, 2013).

Hooda *et al.* (2004) and Tiwana *et al.* (2004) found a significant increase in fodder yield with increased levels of nitrogen and more uptakes of nutrients by application of nitrogen probably favored by better growth and development of crops, resulting into increased fodder yield.

2.1.2.10 Effect of Nitrogen on Forage Yield

Production of good quality forage yield is the ultimate goal, which depends upon the genomic and environmental factors as well as nutrient status of soil and availability of nutrients for the plant. Sharar *et al*. (2003) reported that increased level of N and P significantly increased the green and dry matter yields. Nitrogen application significantly influenced dry forage weight and the differences in dry forage yield may be due the nutrients included in each nitrogen source (El Amin, 2003 and Abdel Gader, 2007). Proper fertilization and harvesting times have been found very effective to improve the quality and quantity of forage pearl millet (Reddy *et al.,* 2003).

Singh*et al.* (2002) confirmed that green forage yield, dry matter yield, plant height, number of leaves/ bunch, leaf area index, dry matter accumulation in leaves and stems increased with increase in cutting interval, except number of tillers/bunch which decreased with increase in cutting interval. Increase in nitrogen application also increased herbage yield and yield attributes of Napier Bajra hybrid.

Increase in green fodder, dry matter and crude protein yields of fodder oats with increased levels of nitrogen were also reported by Singh *et al.* (1997); Sharma and Verma (2005) and Bhilare and Joshi (2007).

2.1.2.11 Effect of Nitrogen on Dry Matter Production

Dry matter and crude protein contents of different fodders showed wide variations. These variations could be a result of agronomic factors such as application of various levels of nitrogen fertilizers, time of harvest, ensiling, field drying and storage (Khan*et al.,* 2014). Similar findings have been reported in Italian rye grass for its dry matter yield, which varied from 18.8 - 75.5 per cent mainly due to different harvesting time (Bittante and Andright, 1982).

2.2 FODDER SORGHUM

Sorghum is highly drought resistant and called 'crop camel' as it grows well under semi-arid conditions and in areas with unreliable rainfall in the tropics. The group of sorghum called 'sorgos' are grown principally for fodder or syrup production. Sorghum is an annual, which can be grown with a rainfall of 300-750 mm. It is cultivated in areas too dry for maize (Thomas, 2008).

Forage sorghum is considered to be a viable alternative to corn silage, particularly when water becomes limited in irrigated system and when input costs associated with seed and fertilizer are an impediment and nutritive value and milk production can be comparable to corn (Marsalis, 2011). Sorghum is one of the most widely adapted forage crops and grown extensively during summer season and has a significant role in livestock production. Many of the forage sorghums have a 'sweet stalk' making them more palatable to livestock when utilized for grazing or for hay. The stalks of forage sorghum tend to be large and succulent, making them less palatable for grazing and sometimes slow in drying down for hay production. The forage sorghums are capable of producing very high amounts of dry matter per unit area (Saini, 2012).

2.2.1 PLANT POPULATION

Among the various agronomic factors, proper manuring and appropriate planting geometry are of prime importance in getting higher forage yield of better quality (Younis and Agabawi, 1967). Manjunath *et al.* (2013) reported that the quality parameters crude fibre, nitrogen free extracts and total carbohydrates were significantly influenced by variation in row spacing. The row spacing of 45 and 60 cm recorded significantly higher yield of crude protein, crude fibre, total ash and ether extract compared to 30 cm row spacing.

Khan *et al.* (1993) in a study on sorghum cv. Giza-3 that was sown by broadcasting, or in 30 cm spaced rows and with a basal dose of 100 kg P_2O_5 and 0, 100, 200, 300 or 400 kg N/ha (50 % as a basal dose and 50 %, 45 days after sowing) reported the greatest green fodder yield with 200 kg N ha^{-1} and 30 cm row spacing (38.44 t ha^{-1}). The number of days to heading increased with increasing N rate. Protein and nitrogen-free extract diminished and fibre increased in crowded plant plots.

2.2.1.1 Plant Height

A study conducted by Manjunatha *et al.* (2013) revealed that the row spacing of 45 cm recorded significantly higher plant height (164.3 cm) and 60 cm row spacing recorded significantly higher number of tillers per meter row.

Sawargaonkar *et al.* (2013) reported that row spacing did not affect plant height and number of leaves per plant, but, significant differences were observed for N level and genotype. A linear increase in these growth attributes with increase in N level was observed up to 90 kg ha^{-1}.

2.2.1.2 Leaf Area

Plant leaf area is a key determinant of the carbon balance of a plant during vegetative development. In early crop development, plant leaf area is the only supplier of as well as the main sink for carbohydrates and can be highly influenced by tillering (Hammer *et al.,* 1987).

The amount of radiation intercepted by a crop is a function of its leaf area index (LAI), its extinction coefficient (*k*) and the incident radiation (Clegg *et al.,* 1974; Muchow *et al.,* 1982; Squire *et al.,* 1984).

Iptas and Acar (2006) observed that row spacing had significant effects on the number of leaves. The number of leaves and leaf area index were higher in the late-maturing than the early-maturing hybrids.

2.2.1.3 Leaf - Stem Ratio

The quality parameters and fodder yield of sorghum can be maximized by enhancing the growth parameters like plant height, stem diameter, L: S ratio and dry matter accumulation irrespective of regional differences (Chandra *et al.,* 2012). Higher leaf: stem ratio has been found to enhance quality characters of forage sorghum (Chaudhary *et al.,* 2007).

2.2.1.4 Shoot - Root Ratio

Shoot to root ratio (S: R) is commonly used to estimate the annual crop residue carbon inputs to the soil from the root biomass left in the soil at harvest (Bolinder *et al*., 2002).

Shoot to root dry weights can be influenced by competition among the standing crop plants, as the individual plants interact with its neighbors in the mixed stands (Sadras and Calderini, 2009) and the competition may be both above- and below-ground (Rubio *et al*., 2001). Crop shoot and root growth requires a limited number of resources, which are light, nutrients and water. Several studies have shown that below-ground competition for water and nutrients is stronger than above-ground competition for light (Casper and Jackson, 1997). The degree of competition among crop plants varies due to differences in genetic makeup (Dubbs, 1971; Hannay *et al*., 1977), root architecture (Rubio *et al*., 2001) and crop nutrition Dahmane and Graham(1981); Eghball and Maranville (1993); Dunbabin *et al*. (2001) and Ma *et al*.(2007). It is generally believed that crop plants do not compete for space (Aldrich, 1984) but Wilson *et al.* (2007) found that competition for space can occur, but the effect is so small that can be ignored in plants communities.

2.2.1.5 Forage Yield

Forage yield of sorghum is about 20 t green matter/ ha but may reach up to 75 t/ ha under optimal growth conditions (FAO, 2009). Since the crop has potential to tiller it could produce more number of tillers per m row and per unit area in 45 and 60 cm row spacing compared to 30 cm which was responsible for getting higher green and dry matter yield (Mishra *et al.,* 1994; Gaurkar and Bharad, 1998; Naganagouda, 2002; and Singh *et al.,* 2008). Grewal *et al.* (2005) also observed that higher number of tillers per plant helped to increase the fodder yield of forage sorghum.

Fodder yield in sorghum is mainly affected by row spacing and seed rate. Yield increases from narrow rows have been attributed to better light interception and more efficient water use (Scott *et al.,* 1999). Greatest yield was obtained from highest seed rate and narrow row spacing (Orak and Kavdr, 1994) and increased row spacing reduced yield (Mokadem *et al.,* 2002).

Orak and Kavdr (1994) and Gonzalez and Graterol (2000) got highest yield from highest seed rate and narrow row spacing. The mean fodder yield at different row spacing and seed rates ranged from 12.39 t ha^{-1} to 77.95 t ha^{-1}. On an average, the highest fodder yield (77.95 t ha^{-1}) was shown by highest seed rate (75 kg ha^{-1}) and narrow spacing (15 cm), while the lowest green fodder yield (12.39 t ha^{-1}) was obtained by the lowest seed rate (50 kg ha^{-1}) and highest row spacing (45 cm). Bishnoi and Mays (2002) indicated that sorghum yield in narrow spacing out yielded in wide rows. Mokadem *et al*. (2002) reported increasing row spacing followed by a reduction in the yield. It was concluded that high seed rate and narrow row spacing proved to be the best combination for getting higher fodder yield of sorghum.

Planting in single rows gave the highest green fodder yields followed by double row and triple-row strips (Nazir *et al.,* 1997). A decrease in plant density in sorghum i.e. increase of within row spacing from 5 to 60 cm decreased dry matter yield while forage digestibility and protein content improved (Caravetta *et al.,* 1990). Significant reduction in dry matter yields occurred as row spacing increased from 15 to 90 cm (Corleto and Cazzato, 1990).

2.2.1.6 Dry Matter Production

Mahmood and Honermeier (2012) reported that row spacing have no clear effect on the dry matter yield whereas double rows of 75 cm and narrow row spacing (37.5 cm) led to significantly higher yield than wide row spacing of 75 cm. when area per plant is decreased, the dry weight per plant declines but total dry matter per acre increased.

2.2.2 EFFECT OF NITROGEN

Of the major nutrient elements, nitrogen is of special significance in increasing green biomass yield and its quality in fodder crops. Nitrogen fertilization has been reported to improve not only the yield but also the crude protein content of the sorghum fodder to a considerable extent (Younis and Agabawi, 1967).

Mishra *et al.* (1994); Gaurkar and Bharad (1998); Naganagouda (2002) and Singh *et al.* (2008) reported that the green and dry matter were increased significantly with successive increase in nitrogen levels up to 300 kg N ha^{-1}. Wilson and Minson (1980) noted that N fertilizer generally has little effect on digestibility.

Application of nitrogen @ 80 kg ha^{-1} significantly increased green forage and dry matter yields of sole cropping and sorghum + legumes intercropping compared with the control and 40 kg N ha^{-1} (Sood and Sharma, 1992).

Quality, especially protein content, and yield can be improved by increased fertilizer application provided that moisture and other factors are adequate. In general, forage sorghum should receive 120 -150 lb N per acre for a yield goal of 20-25 green tons (6 -7.5) dry tons) per acre (Newman *et al.,* 2009).

In sorghum, nitrogen application increased CP, ash and HCN content but decreased CF and non-structural carbohydrate content (Mohamed and Hamd, 1988). Application of N up to 120 kg ha^{-1} increased the green forage, dry matter and CP contents and decreased NDF contents (Bebawi, 1988). While application of N at the rate of 100 -120 kg ha^{-1} was suggested as optimum in sorghum by Gill *et al*. (1988) and El-Hattab and Harb (1991). Bebawi, (1988) and Gill *et al.* (1988) observed that split application has no advantage. Even a marginal application of 50 kg N ha^{-1} improved digestibility (Lourenco *et al.,* 1993).

2.2.2.1 Effect of Nitrogen on Plant Height

The height of plant was increased significantly with the application of nitrogen. Increased plant height in sorghum by increasing the rate of nitrogen was reported by Muldoon (1985).

Ahmad *et al.* (2007) reported that increased nitrogen application has pronounced effect in increasing vegetative growth of crop pants.

Significant increase in plant height with nitrogenous fertilizers has also been observed in maize by (Abbas and Al-Younis, 1980; Desai and Dore, 1980; Abdel-Gawad 1983; Bajwa*et al*., 1983; Safdar, 1997; and Ahmad, 1999).

2.2.2.2 Effect of Nitrogen on Leaf Area

Leaf area is a measure of size of assimilatory system of plant and is a product of leaf length and breath. It is considered to be mainly concerned with the accumulation and partitioning of photosynthates to the economic parts of the plant and plays an important role in the production of green fodder yield in fodder crops and leaves are more nutritious than stems (Afzal *et al.,* 2013).

Application of nitrogen increased the number of leaves per plant significantly and the plant height, stand density, green forage yield and crude protein content increased with increasing N rate (Nazir *et al.,* 1997). Eltelib (2004) reported the significant variation in leaf area with increase in nitrogen levels. Line sowing has better effect on leaf area per plant (Nazir*et al*., 1997). These results are confirmed by the findings of Ayube *et al*. (1999) who reported that application of N fertilizer significantly increased the leaf area plant of maize fodder.

2.2.2.3 Effect of Nitrogen on Crude Protein

The increase in crude protein with increasing N application is due to increased absorption of N. Since N is the main constituent of amino acids; it ultimately increased crude protein contents of plants (Saini, 2012). Nazir *et al.* (1997) reported that the planting geometry had no significant effect on crude protein content.

Mengel and Kirkby (2001) showed that the increased crude protein content due to the fact that P is an important structural component of DNA and RNA. Polat *et al.* (2007) reported that crude protein concentrations were significantly enhanced with increasing levels of P fertilizer applications.

In early stages of growth, protein accounts for 12 to 18 per cent of dry weight, but drops from 5 to 8 per cent as the plant reaches maturity. The decline in protein is most marked in taller leaves and stem. Maximum protein yield does not coincide with maximum forage yield. The crude protein content increased with the increase of nitrogen rate, but decreased when the nitrogen rate exceeded the critical point. The best forage quality was obtained from the treatment 280 kg/ ha nitrogen (Feng *et al*., 2013).

Significant differences in crude protein content among the sorghum cultivar were reported by Lukipudis, 1984; and Neylon *et al.,* 2002. Reddy *et al.* (2003) reported that nitrogen significantly improved the crude protein content.

2.2.2.4 Effect of Nitrogen on Crude Fibre

Application of nitrogen had depressing effect on crude fibre content because it resulted in increased leaf weight and wider leaf-stem ratio which might have decreased the crude fibre content in sorghum. Effect of harvesting stage was quite significant on crude fibre content and crude fibre production of plants (Ayub*et al.,* 2002). Ram and Singh (2001) indicated that the crude fibre content increased from 27.6 to 33.8 per cent with increase in plant age from 50 to 100 DAS. McDonald *et al.* (1991) reported that fibre content was decreased by application of N fertilizer.

2.2.2.5 Effect of Nitrogen on Crude Fat

Crude fat content in sorghum decreased as the plant age advances. Higher fat content (2.31 per cent) was recorded at 50 DAS as compared to 2.18 and 1.63 per cent at 75 and 100 DAS, respectively. The total production of crude fat increased due to increase in dry matter yield (Ayub *et al.,* 2002).

2.2.2.6 Effect of Nitrogen on Total Ash

Total ash, ether extract content and yield increased significantly with increased nitrogen levels. whereas, nitrogen free extract decreased significantly with increase in N level up to 240 kg ha^{-1} (Bhilare *et al.,* 2002). The effect of nitrogen application on ash per cent content showed significant effect on sorghum forage. Nitrogen application at the rate of 100 kg N/acre has maximum (6.3 per cent) ash content. Ash ranges from 8 to 11 per cent in young plants, but after heading decreases to 4 to 5 per cent (Afzal *et al.,* 2012).

2.2.2.7 Effect of Nitrogen on Nitrogen Free Extract (NFE)

Saini (2012) reported that the increase in nitrogen doses decreased the NFE content significantly. With the application of 75 per cent nitrogen of the recommended dose, 52.9 per cent NFE content was obtained as compared to 52.1 and 50.7 per cent obtained with the application of 100 and 125 per cent nitrogen of the recommended dose, respectively. Nitrogen free extract increased with the age of plant up to 75 DAS after which it followed a decreasing trend. NFE content was 51.3 per cent at 50 DAS which increased to 52.8 per cent at 75 DAS and then its value decreased to 51.6 per cent at 100 DAS. Decrease in NFE content at later stage of the crop was due to formation of more fibre content in crop plant.

2.2.2.8 Effect of Nitrogen on Nitrate in Plant

Sorghum is a nitrate accumulator even though nitrates are generally non toxic to ruminants, their transformation into ammonia, within the rumen, produces toxic nitrates. Nitrate levels ranging from 0.5 to 1 per cent in dry matter the plants are considered potentially toxic to ruminants. Nitrate levels higher than 1 per cent in dry matter is considered dangerous (Yaremcio, 1991). Nitrates are more in the stems rather than leaves (Harada *et al.,* 2000).

Several environmental conditions results in nitrate accumulation, notably severe drought, high N fertilization and frost. A well-managed N fertilizer application can reduce nitrate accumulation (Wilmoth *et al.,* 2000).

Sidhu *et al.* (2011) in a study on estimation of nitrate content in commonly used fodder crops, viz., berseem (*Trifoliumalexandrinum*), bajra (*Pennisetumglaucum*), maize (*Zea mays*), oats (*Avena sativa*), sorghum (*Sorghum vulgare*) and tori (*Brassica napus*) observed that the nitrate level was the highest in sorghum on dry matter basis, followed by oats and tori, berseem, maize and bajra. The nitrate content was also determined in fodder samples harvested from young and mature stages and in different parts of plants. The stem part of forage plants had higher content than leaves; however, concentrations were low in mature crops as compared to immature ones.

Nitrate toxicity is not common in fodder sorghum, but it may happen during drought if large amounts of nitrogen fertilizer have been applied (Bernard *et al.,* 2011). To prevent nitrate poisoning, livestock should not be given full access to fodder sorghum (Wilmoth *et al.,* 2000).

2.2.2.9 Effect of Nitrogen on Nutrient Uptake

Nutrient uptake precedes dry matter accumulation because nutrients are required for growth and dry matter accumulation. Akram *et al.* (2007) reported that nitrogen uptake was improved with P and K application. Sharma and Ramna (1993) observed that application of K released the fixed NH_4^+ ion from soil and helped the crop for better uptake of nitrogen. Phosphorus uptake with P+K was highest (29.7 kg ha^{-1}) followed by P alone, and both showed significantly higher P uptake as compared with K alone and control. Application of K did not improve P uptake by sorghum significantly. Dongale and Kadrekar (1992) reported that N, P and K uptake, and apparent recovery of P in sorghum was appreciably higher with significant increases of P application.

2.2.2.10 Effect of Nitrogen on Forage Yield

Nutrient management in forage sorghum significantly improved plant height and leaf area index (LAI) at 60 DAS and green-fodder yield. Singh *et al.* (2013) reported that the forage yield was influenced with increase in nitrogen levels from 0 to 180 kg/ha. The crop produced significantly higher green forage yield (44.86 t/ha) when 120 kg N was applied. The magnitude of increase was 21.44 and 12 per cent over control and 60 kg N/ha compared to 120 kg N/ ha, respectively. However, further increase in N from 120 to 180 kg/ ha had no significant effect on green forage yield. Forage yield is increased due to more accumulation of photosynthates and its distribution on root and shoot. The effective development of different plant parts such as leaf, stem and roots are prerequisites for higher weight (Dhar *et al.*, 2006 and Rao *et al.*, 2007).

Patel *et al.* (1994) and Rao *et al.* (2007) also reported higher fodder yield of sorghum under higher fertilizer dose. The crop receiving 75 per cent N as basal and 25 per cent N at 25 DAS as top dressing significantly increased fodder yield.

Abou-Amer and Kewan (2014) confirmed that fodder yield was increased significantly by increasing levels of N and P fertilizer. Similar results were obtained on fodder maize, by Alias *et al.* (2003) and Rashid and Iqbal (2012).

Yadav *et al.* (2007) reported increase in forage yield due to application of 75 kg N through urea + 25 kg N through FYM.

The total green fodder yield (179.63 t ha^{-1}) was significantly higher at 300 kg N ha^{-1} compared to 38.7, 24.7 and 11.6 per cent more over 120, 180 and 240 kg N ha^{1}, respectively. The total dry matter yield was also significantly increased with increase in nitrogen level and was 40.0, 26.2 and 11.9 per cent higher over 120, 180 and 240 kg N ha^{-1}, respectively. The improvement in both green forage and dry matter yields at higher N levels was attributed to improved growth and yield parameters (Manjunatha *et al.,* 2013).

Nazir *et al.* (1997) confirmed that the single - row planting gave the highest green fodder yield of about 133 t ha^{-1} followed by double-row and triple-row strips with 126 and 121 t ha^{-1}, respectively.

HuaiPing *et al.* (2009) reported that application of mixed NPK fertilizer not only improved biomass but also increased its output per unit area in terms of crude protein, crude fiber and crude fat. Among the factors influencing biomass production, N fertilizer application produced the best effect followed by P and K. Plant height and variability of crude protein, crude fiber and crude fat contents were mainly dependent on varieties.

2.1.2.11 Effect of Nitrogen on Dry Matter Production

Dry matter production in sorghum was more when N and P were applied (Abou-Amer and Kewan, 2014). Das *et al.* (1996) observed that dry matter yield of sorghum increased with the application P at all the stages of crop growth and boot leaf stage.

John *et al.* (2012) observed that dry matter yield in photoperiod-sensitive sorghum was significantly affected by row spacing.

Abdel - Rahman *et al.* (1983) in a study on chemical composition, feeding value and rumen fermentation of commonly cultivated green summer fodders in Egypt, reported that elephant grass (*Pennisetumpurpureum*), Sudan grass (*Sorghum vulgare*) and fodder maize, where harvested at the same stage of growth, contained crude protein 10.9, 7.8 and 7.9, crude fibre 24.6, 23.1 and 23.3, fat 2.9, 2.4 and 2.5, N-free extract 47.3, 56.2 and 55.5 and ash 14.3, 10.6 and 10.9 per cent, respectively, on dry matter basis.

Saini (2012) observed that application of 125 per cent nitrogen of the recommended dose produced highest dry matter yield (126 q/ha) which was 14.3 and 5.1 per cent higher over 75 and 100 per cent of the recommended dose. Verma *et al.* (2005) also reported the similar results. Green fodder and dry matter yield increased with the delay in harvesting. Dry matter yield at 100 DAS was 186 q/ ha which was 52.4 and 274.4 per cent higher at 75 and 50 DAS, respectively. Dry weight of plant depends on the green biomass of plant (Singh *et al.,* 2007).

2.5 UTILIZATION OF RICE FALLOWS FOR FODDER CULTIVATION

Continuous adoption of rice-rice cropping system has led to deterioration of soil quality resulting in a serious threat to its sustainability in high rainfall areas. Therefore crop diversification with wider choice in the production of a variety of crop is being promoted to restore soil quality.

Continuous cultivation of rice for longer periods with low system productivity, and often with poor crop management practices, results in loss of soil fertility due to emergence of multiple nutrient deficiency (Fujisaka *et al.,* 1994; Dwivedi *et al.,* 2001) deterioration of soil physical properties (Tripathi, 1992), and decline in factor productivity and crop yields in high productivity areas (Yadav, 1998). When rice is grown, soil undergoes drastic changes, i.e. aerobic to anaerobic environment, leading to several physical and electro-chemical transformations. Puddling breaks capillary pores, reduces void ratio, destroys soil aggregates, disperses fine clay particles, and lowers soil strength in the puddled layer (Sharma and Datta, 1986). In systems that are frequently wet and dry, there is potential for significant loss of N by leaching and denitrification. Further, since nitrite is intermediate in both the reduction of nitrate and the oxidation of ammonia, aerobic denitrification via nitrate may be more substantial and widespread than previously realized, especially on soils that are alternately wet and dry (Ponnamperuma, 1972).

Cassman *et al.* (1995) proposed that the now commonly observed, smaller than previous response to N fertilizer in continuously flooded rice systems, is associated with sequestration of N in resistant lignin compounds formed from the large amounts of retained crop residues. If this is the case, then perhaps there is an important role for rice rotations that include other crops to break this sequestration of nitrogen.

Diversification and intensification of rice-based system to increase productivity per unit resource is very pertinent. Crop diversification shows lot of promises in alleviating these problems besides fulfilling basic needs and regulating farm income, withstanding weather aberrations, controlling price fluctuctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, ensuring environmental safety and creating employment opportunity (Gill and Ahlawat, 2006). Crop diversification has been recognized as an effective strategy for judicious use of land and water resources, sustainable agricultural development and environmental improvement (Hedge *et al.,* 2003). The crop diversification may enhance profitability, reduce pests, spread out labour more uniformly, reduce risks from aberrant weather by different planting and harvesting times and source of high value products from new crops (Reddy and Suresh, 2009). In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the suitability of a cropping system (Yadav, 2002). Hence, selection of component crops needs to be suitably planned to harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Anderson, 2005).

Introduction of a legume crop in rice-based cropping system may have advantages well beyond the N addition through biological nitrogen fixation including nutrient recycling from deeper soil layers, minimizing soil compaction, increase in soil organic matter, breaking of weed and pest cycles and minimizing harmful allelopathic effects (Sanford and Hairston, 1984; Wani *et al*., 1995).

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 (Suneethevi *et al.,* 2004).

Materials and Methods

3. MATERIALS AND METHODS

The research project entitled “Yield maximization of fodder bajra and fodder sorghum in summer rice fallows’’ was conducted in Department of Agronomy, College of Horticulture of Kerala Agricultural University during 2014. 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 2). Geographically, the area is situated at 10° 31’ N latitude and 76° 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. The details of the meteorological data recorded at Vellanikkara during the crop period are presented in the Appendix 1 Fig. 1 and 2.

3.3 SOIL CHARACTERISTICS

Soil of the experimental site based on soil texture is classified as sandy loam. The soil is acidic in reaction with pH of 5.11

Table 3.1 Soil chemical properties before experiment

Parameter	Value	Method used
a) Mechanical composition (%)		
Sand	68.83	Robinson's International Pipette method, 1992
Silt	16.27	
Clay	14.90	
Textural class	Sandy loam	
b) Chemical properties		
Organic carbon (%)	0.77	Walkley and Black, 1934
Available nitrogen (kg ha)	98.7	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg/ ha)	9.02	Bray extractant - Ascorbic acid reductant method (Watanabe and Olsen, 1965)
Available Potassium (kg/ ha)	93.25	Neutral normal ammonium acetate extractant Flame Photometry (Jackson, 1958)
Available calcium (kg/ ha)	73.47	Neutral normal ammonium acetate extract using Atomic Absorption Spectrophotometer
Available magnesium (kg/ ha)	17.56	Neutral normal ammonium acetate extract using Atomic Absorption Spectrophotometer
pH	5.11	Soil water suspension of 1: 2.5 and read in pH meter (Jackson, 1958)

Fig 3.1. Weather data during the crop period (April - June 2014)

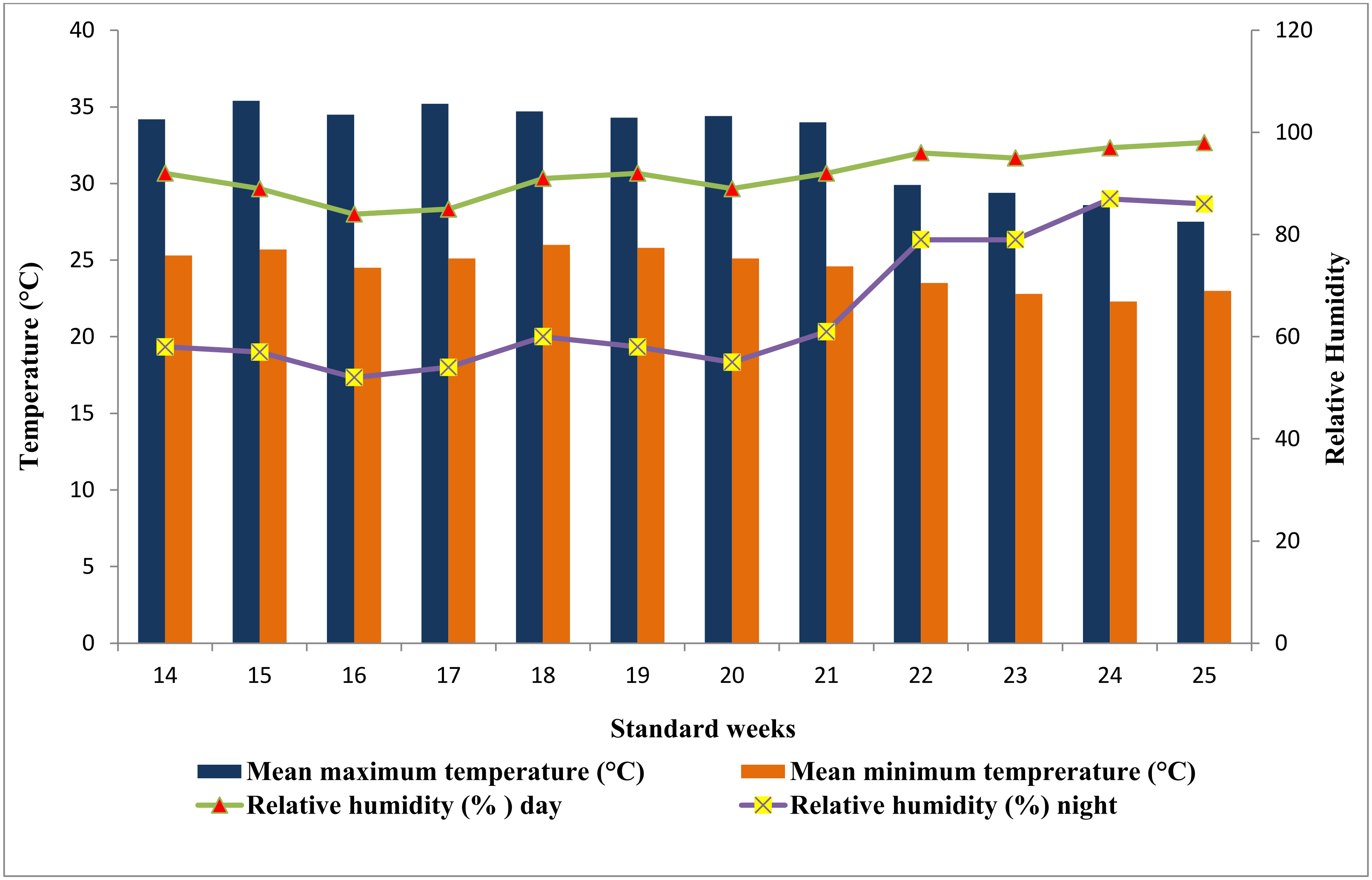
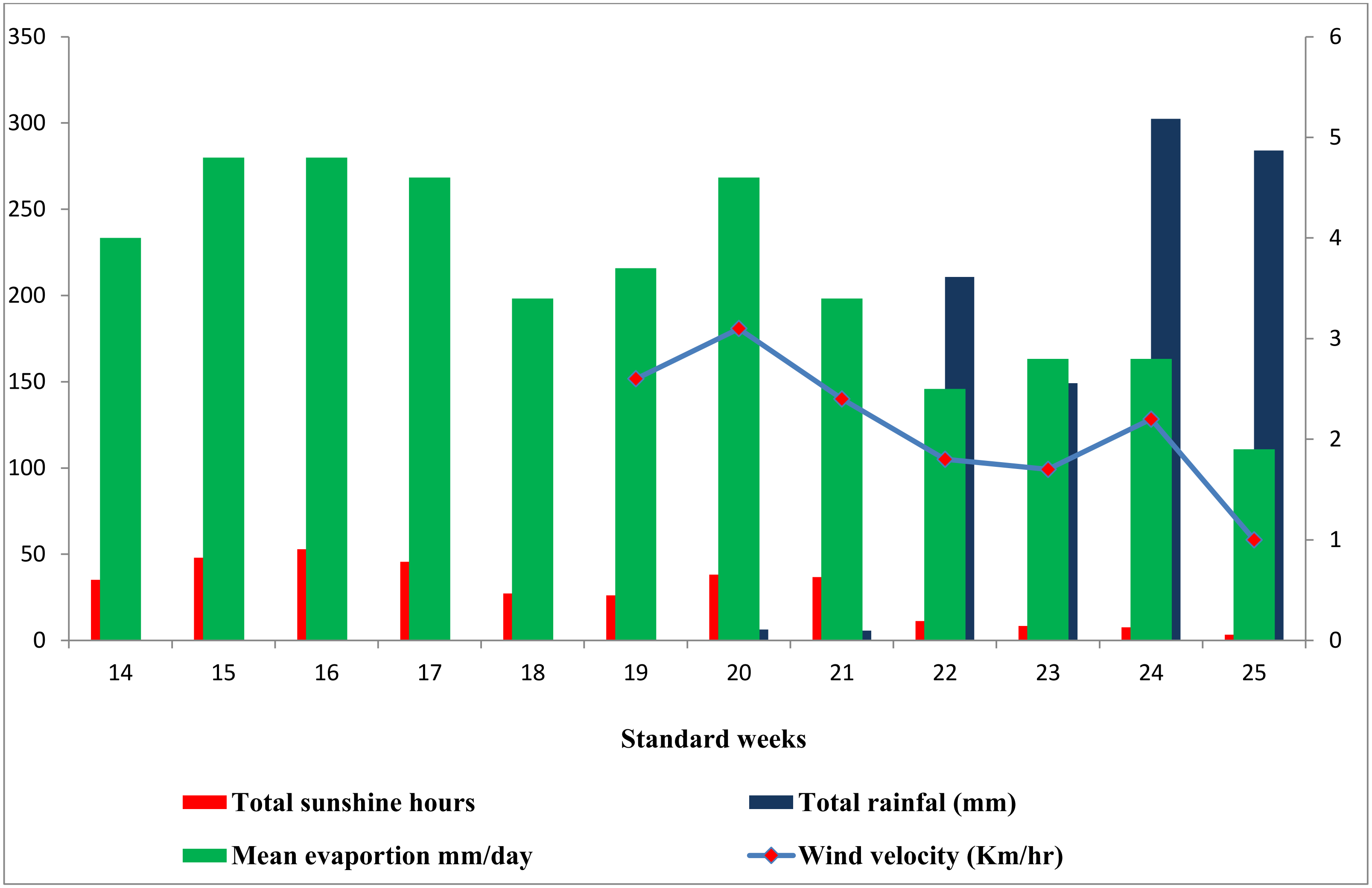


Fig 3.2. Weather parameters during the crop period (April - June 2014)



3.4 DETAILS OF THE EXPERIMENT

3.4.1 Design of the layout

The design was randomized block design with 12 treatments replicated thrice. The plot size was 4 m x 4.5 m. The treatment details are given below.

Treatment details			
Treatment combinations: 12			
1.	Crops	2 crops	F_1 - Fodder Bajra
			F_2 - Fodder Sorghum
2.	N fertilizer dose	2 doses	N_1 - 60 kg/ ha
			N_2 - 90 kg/ ha
3.	Spacing	3 spacing	S_1 - 30 x15 cm
			S_2 - 25 x15 cm
			S_3 - 20 x15 cm

Details of cultural operations

1.	Sowing	Fodder bajra	03-04/04/14
		Fodder sorghum	
2.	Weed control	Spraying 2, 4 - D	1kg ai/ ha on 25/04/14
		Spraying Carfentrazone	20 g ai/ ha on 01/05/14
3.	Harvesting	Fodder bajra	12/06/14
		Fodder sorghum	18/06/14

Duration: Fodder bajra 69 days and Fodder sorghum 75 days

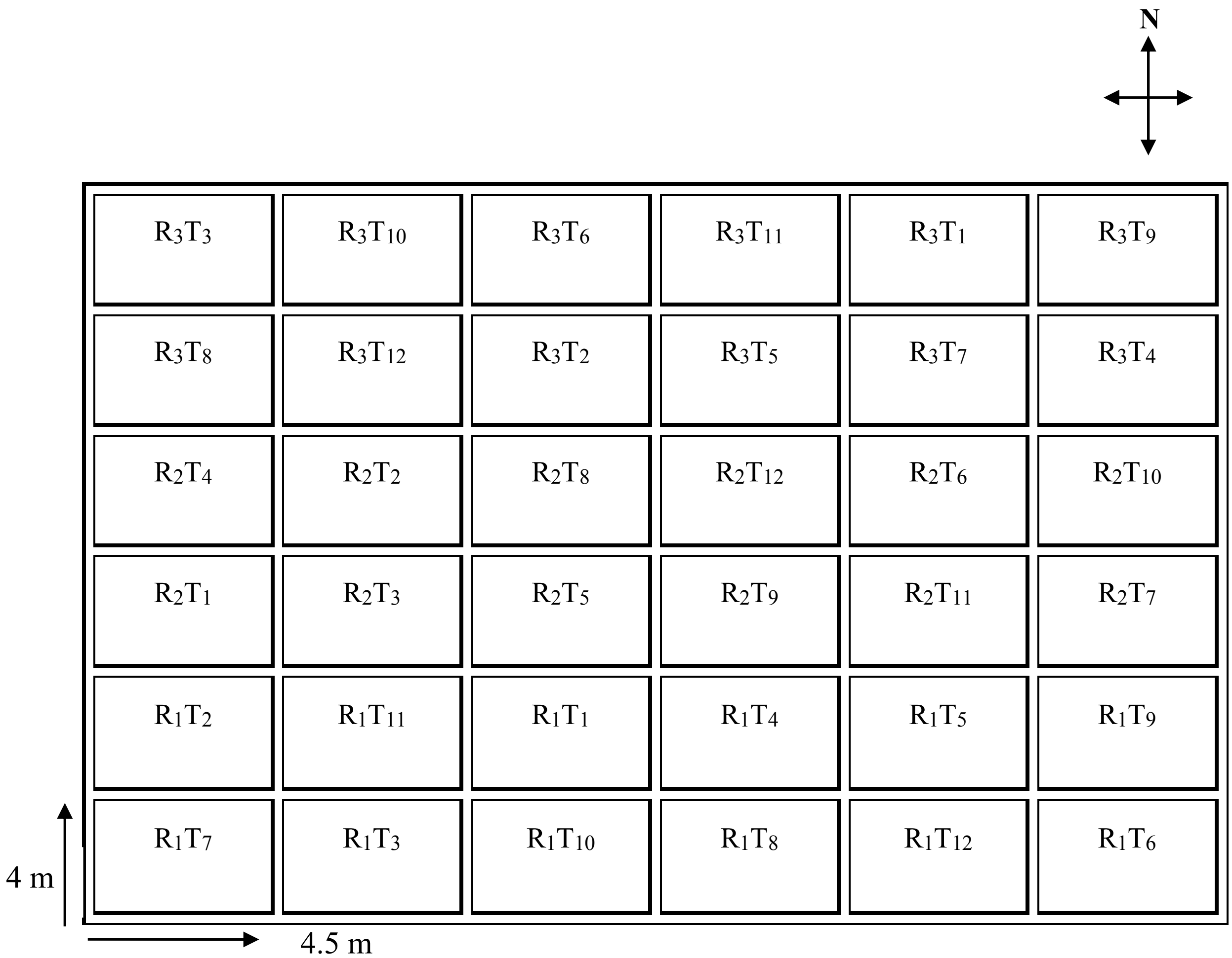


Fig 3.3 Layout of the field experiment

T_1 – $F_1S_1N_1$	T_7 – $F_2\,S_1N_1$	F_1 – Fodder bajra
T_2 – $F_1S_1N_2$	T_8 – $F_2\,S_1N_2$	F_2 – Fodder sorghum
T_3 – $F_1S_2\,N_1$	T_9 – $F_2\,S_2\,N_1$	S_1 – 30 x 15 cm
T_4 – $F_1S_2\,N_2$	T_{10} – $F_2\,S_2\,N_2$	S_2 – 25 x 15 cm
T_5 – $F_1S_3N_1$	T_{11} – $F_2\,S_3N_1$	S_3 – 20 x 15 cm
T_6 – $F_1S_3N_2$	T_{12} – $F_2\,S_3N_2$	N_1 – 60 kg/ ha
		N_2 – 90 kg/ ha

Plate 1. Field view at initial stage

Plate 2. Hand weeding of the plots

3.4.2 Fodder crops

The details of the crops, varieties used

Crop	**Variety**
Fodder bajra (F_1)	Avikabajra (AVKB - 19)
Fodder sorghum (F_2)	CoFS - 29

3.5 CROP HUSBANDRY

(i) **Land preparation**

The land was prepared according to treatments. Both the crops were dibbled at spacings of 30 cm x 15 cm, 25 cm x 15 cm and 20 cm x 15 cm.

(ii) **Fertilizers**

Urea (46% N), Rajphos (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. Fertilizer doses of 60, 90: 40: 20 kg N, P_2O_5 and K_2O/ ha were applied respectively.

The entire quantity of P and half of the recommend doses of N and K were applied as basal and the remaining quantities of N and K_2O applied at knee high stage.

(iii) **After cultivation**

Thinning was done at 20 DAS to maintain the required plant population.

(iv) **Harvesting**

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

3.6 OBSERVATIONS ON GROWTH CHARACTERS

Three 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 and 60 DAS. From each plot, three plants along with all their tillers were selected and the height was measured in cm from ground level to the tip of the 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. LAI was measured using leaf area meter and was measured at 30 DAS and at 60 DAS.

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf area}}{\text{Land area}}$$

(iii) Leaf - Stem Ratio

Leaf: stem ratio was determined at 60 DAS. The plants were cut at the base and then the leaves and stems were carefully separated and weighed. The ratio was calculated on fresh weight basis.

$$\text{Leaf: stem ratio} = \frac{\text{Dry weight of leaf}}{\text{Dry weight of stem}}$$

(iv) Shoot - Root Ratio

Three plants from each plot were randomly pulled out and their root and shoot portions were separated. The shoot: root ratio was calculated at 60 DAS.

$$\text{Shoot: root ratio} = \frac{\text{Dry weight of shoot}}{\text{Dry weight of root}}$$

(v) Forage yield

At harvest, the fresh weight 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°C. 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 0.25 m^2 of three areas in each plot was taken and recorded. The observation was taken at 30 DAS. The total number of grasses 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° C and the weed dry weight was recorded and expressed in kg/ m^2 at 30 DAS and at harvest.

3.8 NUTRIENT CONTENT AND UPTAKE OF FODDER CROPS

Nutrients		Method used
(i)	**Nitrogen**	The nitrogen content was estimated by Microkjeldahl digestion and distillation method (Jackson, 1973) and expressed as percentage.
(ii)	**Phosphorus**	The phosphorus content 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 calcium and magnesium content was estimated using diacid mixture and read by atomic absorption spectrophotometer (Jackson, 1958) and expressed as percentage.
(v)	**Uptake of nutrients**	The total 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 harvest were sun dried and then dried to constant weight. The ground samples of stem and leaf both together were 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 the crude protein.

(ii) Crude Fibre

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

(iii) **Crude Fat (Ether Extract)**

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 °C 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, crude fat and ash content values expressed in percentage from hundred.

(vi) Nitrate Content

Nitrate content of plants was estimated by using the method described by Bhargava and Raghupathi, 1993.

3.10 SOIL ANALYSIS

Composite soil samples were taken randomly from six areas of the field, prior to the sowing of fodder bajra and fodder sorghum and from each plot after harvest. The soil samples were then air dried, powdered and passed through 0.5 mm sieve for organic carbon and through 2 mm sieve for analysis of other parameters and are recorded as the following.

(i) Organic Carbon

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

(ii) Available Nitrogen

Alkaline permanganate method (Subbiah and Asija, 1956) was used for determination of available N in soil.

(iii) Available Phosphorus

Available phosphorus content of soil was determined using Bray no.1 extractant and molybdophosphoric acid method in hydrochloric acid system (Watanabe and Olsen, 1965).

(iv) Available Potassium

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

(v) Soil pH

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

3.11 STATISTICAL ANALYSIS

Data generated on 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).

Results

4. RESULTS

Observations on plant and soil characters as well as quality parameters were recorded and were statistically analyzed. The data for different parameters were initially analyzed as three factors RBD to verify whether any significant two factor and three factor interactive effects existed, the three factors ANOVA for most of the characters resulted as non significant interactive effects. Further the very objective of the study was yield maximization of fodder bajra and fodder sorghum. Both grasses are very similar in growth habit. Hence the data were analyzed only as single RBD with 12 treatments and 3 replications. Post hoc test namely DMRT was carried out wherever any significant F value was noticed. The results are given below.

4.1 EFFECT OF SPACE AND NITROGEN LEVELS ON BIOMETRIC CHARACTERS

As the experiment was conducted to study the effect of varying plant densities and nitrogen levels on the yield of fodder bajra and fodder sorghum, the results obtained to meet these two objectives are given as follows:

4.1.1 Plant height (cm)

The effect of spacing and N levels on plant height is presented in Table 4.1. It varied with different spacings and levels of nitrogen fertilizer application at 30 DAS and 60 DAS. At both stages the maximum plant height was obtained from the treatments with narrower spacing (20 cm x 15 cm) and higher level (90 kg/ ha) of nitrogen applied, followed by (25 cm x 15 cm) and (30 cm x 15 cm) spacing.

At 30 DAS, the highest plant height ranged from 68.2 to 75.8 cm in fodder bajra and in fodder sorghum ranged from 55.8 cm to 71.7 cm. At 60 DAS the highest plant height in fodder bajra was 152.3 cm and in fodder sorghum it was 155.8 cm.

The treatments with narrow spacing and higher dose of nitrogen had better performance in terms of plant height compared to those treatments with wider spacing and lower dose of N.

4.1.2 Leaf Area Index

The leaf area index estimated at 30 DAS and 60 DAS is presented in Table 4.2. LAI was significantly different among treatments regarding spacing at both 30 DAS and 60 DAS. The plants in narrow spacing plots with higher levels of nitrogen recorded significantly higher LAI value than those in wider spacing and lower dose of N.

At 30 DAS, LAI value ranged from T_6 (3.53) followed by T_4 (3.27) and T_2 (2.26). The lowest value was recorded in T_7 (1.07). At 60 DAS, the highest value was (7.13) in T_6 followed by (7.00) in T_{12}. T_4 was at par with T_5 and all others were at par. The lowest LAI value was recorded in T_7 (4.5).

The effect of nitrogen fertilizer application also recorded significantly different LAI from higher dose (90kg/ ha) to lower dose (60kg/ ha) LAI values at both 30 DAS and 60 DAS were significantly higher in treatments with higher dose of nitrogen compared to those with lower dose of N.

Table 4.1 Plant height as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (cm)	At 60 DAS (cm)
T_1	71.65 [abc]	120.2 [c]
T_2	71.33 [a]	137.5 [abc]
T_3	68.20 [ab]	127.7 [bc]
T_4	75.36 [a]	137.9 [abc]
T_5	68.53 [ab]	143.3 [a]
T_6	75.80 [a]	152.3 [a]
T_7	56.26 [cd]	147.5 [ab]
T_8	70.96 [a]	147.9 [a]
T_9	55.83 [d]	148.7 [a]
T_{10}	71.70 [a]	149.7 [a]
T_{11}	60.06 [bcd]	146.9 [ab]
T_{12}	71.13 [a]	155.8 [a]
	CD (0.05) - 10.747	**CD (0.05) - 20.934**

Table 4.2 Leaf area index as influenced by fodder type, spacing and N level

Treatments	At 30 DAS	At 60 DAS
T_1	2.24^{bc}	4.86^{b}
T_2	2.26^{bcd}	4.90^{b}
T_3	2.80^{ab}	4.86^{b}
T_4	3.27^{a}	5.56^{ab}
T_5	2.90^{ab}	5.56^{ab}
T_6	3.53^{a}	7.13^{a}
T_7	1.07^{d}	4.50^{b}
T_8	1.46^{cd}	4.73^{b}
T_9	1.49^{cd}	5.05^{b}
T_{10}	1.53^{cd}	5.20^{b}
T_{11}	1.53^{cd}	5.06^{b}
T_{12}	1.61^{cd}	7.00^{a}

CD (0.05) - 0.980 **CD (0.05) - 1.733**

Plate 3. A field of fodder bajra at 50 % flowering stage

Plate 4. Fodder sorghum after harvest of fodder bajra

4.1.3 Leaf - Stem Ratio

Leaf : stem ratio was recorded based on fresh weight of leaves and stems of three sample plants at 60 DAS. The data pertaining to leaf: stem ratio are presented in Table 4.3. Highest leaf: stem ratio (0.56) was recorded from T_1 and the lowest ratio (0.28) was recorded from T_8. The effect of nitrogen on the leaf: stem ration on fodder bajra, was clearly showed that the highest ratio recorded from the treatments with higher dose of nitrogen fertilizer. But in case of fodder sorghum all treatments were at par.

4.1.4 Shoot - Root Ratio

Shoot : root ratio was recorded at 60 DAS. The data of shoot: root ratio is presented in Table 4.3.There was no significant variation between treatments.

Shoot: root ratio of different treatments ranged from 2.6 in (T_7) to 3.9 in (T_2). The highest ratio was recorded from the plot which utilized higher dose of nitrogen (90 kg ha^{-1}). The lowest ratio was recorded from plots of wider spacing and lower dose (60 kg ha^{-1}) of nitrogen fertilizer.

Treatments	Leaf to stem ratio (harvest)	Shoot to root ratio (harvest)
T_1	0.56 [ab]	3.06
T_2	0.52 [ab]	3.06
T_3	0.49 [b]	3.4
T_4	0.52 [a]	3.6
T_5	0.48 [b]	3.0
T_6	0.51 [a]	2.8
T_7	0.30 [c]	2.6
T_8	0.28 [c]	2.9
T_9	0.34 [c]	3.3
T_{10}	0.28 [c]	3.5
T_{11}	0.32 [c]	2.8
T_{12}	0.28 [c]	2.8

Table 4.3 Leaf - stem ratio and shoot - root ratio as influenced by fodder type, spacing and N level

CD (0.05) - 0.12 **NS**

4.1.5 Green fodder Yield

Green fodder yield of leaf and stem and also the total fodder yield were recorded separately (Table 4.4). There was no significant variation in forage yield of stem due to various treatments. However, fodder yield of leaf and total fodder yield were significantly different. Higher fodder yield (9.25 t ha^{-1}) of leaf was recorded in T_6, followed by T_4 (9.13 t h^{-1}) which had narrow spacing and higher dose of nitrogen. The lowest fodder yield of leaf was recorded in T_9 (4.66 t ha^{-1}).

Due to the plant densities and nitrogen application, different plots showed different results in fodder yield of stem. Highest fodder yield of stem was recorded in T_{12} (18.67 t ha^{-1}) followed by T_{10} (18.3 t ha^{-1}).

Regarding the total fodder yield, due to the effect of plant density and nitrogen level, in different treatment there were different fodder yield. Among the treatments T_6 (27 t ha^{-1}) had the highest fodder yield which was followed by T_4 (26.39 t ha^{-1}). The lowest fodder yield was recorded from T_9 (19.43 t ha^{-1}). The treatments with higher dose of nitrogen and narrower spacing had good performance and produced higher fodder yield.

4.1.6 Dry Matter Production

There was significant difference in dry matter production at 30 DAS and at harvest (Table 4.5). At 30 DAS, the highest dry matter (2.03 t ha^{-1}) was obtained from T_6. At harvest T_{12} recorded the highest dry matter (7.7 t ha^{-1}) followed by T_8 and T_{10}. Among all treatments, T_1 had the lowest dry matter production. Dry matter production was more in fodder bajra at young stage compared to fodder sorghum, but at harvest stage fodder sorghum produced more dry matter. In fodder bajra the dry matter produced was maximum with lesser spacing whereas it was reverse in fodder sorghum.

Table 4.4 Fresh fodder yield (t/ ha) as influenced by fodder type, spacing and N level

Treatments	Leaf	Stem	Total forage yield
T_1	8.22[ab]	14.56	22.78[ab]
T_2	8.39[ab]	16.11	24.50[ab]
T_3	7.40 [b]	14.82	22.20[ab]
T_4	9.13 [a]	17.26	26.39[ab]
T_5	7.37 [b]	15.24	22.61[ab]
T_6	9.25 [a]	17.82	27.00 [a]
T_7	5.16 [c]	16.74	21.90[bc]
T_8	5.18 [c]	17.93	23.11[bc]
T_9	4.66 [c]	13.50	18.16[c]
T_{10}	5.24 [c]	18.30	23.54[bc]
T_{11}	4.80 [c]	14.63	19.43[bc]
T_{12}	5.33 [c]	18.67	24.00[ab]
	CD (0.05) - 1.37	**NS**	**CD (0.05) - 4.938**

Table 4.5 Dry fodder yield (t/ ha) as influenced by fodder type, spacing and N level

Treatments	At 30 DAS	At harvest
T_1	1.54^{b}	4.30^{de}
T_2	1.56^{b}	4.87^{cde}
T_3	1.73^{ab}	4.33^{de}
T_4	1.93^{ab}	4.86^{cde}
T_5	1.88^{ab}	4.40^{e}
T_6	2.03^{a}	4.93^{bcde}
T_7	0.92^{c}	7.00^{abc}
T_8	0.92^{c}	7.20^{ab}
T_9	0.74^{c}	5.30^{bcde}
T_{10}	1.03^{c}	7.10^{abcd}
T_{11}	1.01^{c}	5.80^{bcde}
T_{12}	1.07^{c}	7.70^{a}

CD (0.05) - 0.414 **CD (0.05) - 2.354**

4.2. OBSERVATIONS ON WEED GROWTH

4.2.1 Species wise weed count/ m^2 as influenced by fodder type, spacing and nitrogen level

Weed count was done at 30 DAS. The data on weed count is presented in Table 4.6. All grass weeds and broadleaved weeds which existed in the field were counted separately and the total weed count was also taken. Between treatments, variation was not found to be significant with respect to the weed count. However, variation was shown among treatments in number of weeds. The number of grass weeds per m^2 ranged from148 in (T_1) to 401.3 in (T_2). In case of broadleaved weeds, it was least in T_3 (44) and the maximum in T_{10} (113.3).

There was no significant variation in number of grass and broadleaved weeds in different treatments with respect to the spacing and nitrogen levels in fodder bajra and fodder sorghum.

Among the weeds, only grass and broadleaved weeds were present in the cropped field. The population of grass weeds was dominant compared to broadleaved weeds. Sedges were not present in the cropped field. Among grass weeds, *Isachne miliacea*, *Brachiaria mutica, Oryza sativa* and *Echinochloa crusgalli* were found dominant which might be due to the effect of rice fallows. Regarding broadleaved weeds, *Aeschynomene americana*, *Phyllanthus* sp*., Melochia corchorifolia*, *Cyanotis axillaris, Heliotropium indicum* and *Ludwigia parviflora* were present.

4.2.2 Weed dry weight

Weed dry weight was recorded at 30 DAS and at harvest. The data pertaining weed dry weight at 30 DAS and harvest are presented in Table 4.7. There was no significant variation with respect to the weed dry matter at both observations. High dry weight of weeds was observed in sorghum than bajra and it was as high as 518 kg/ ha in early stage and 591.1 kg/ ha at harvest.

4.2.3 Nutrient content and uptake by weeds

Weeds were analyzed for nutrient content at 30 DAS and at harvest. The data pertaining to nutrient content of weeds is presented in Table 4.8. The nitrogen content in weeds at 30 DAS and at harvest was not significantly different. The higher N content was recorded in T_6 (2.50) followed by T_{12} (2.39) on 30 DAS. The lowest N content of weeds was recorded in T_9 (1.92). At harvest stage also N content of weeds were not significantly different and it remained almost the same as that of the early stage. Regarding N removal by weeds at harvest there was significant difference among the treatments. The N removal ranged from 4.03 kg/ ha in (T_2) to 11.15 kg/ ha in (T_8). In general fodder sorghum showed more N removal than fodder bajra (Table 4.9).

Regarding P content there was no significant difference. The highest P content was recorded in T_7 (0.55) followed by T_5 (0.47). P content in weeds at harvest was found to be slightly less than the early stage. P removal by weeds was not found to be significantly different. It ranged from 0.61 kg/ ha in T_2 to 1.97 kg/ ha in T_7. P removal was also higher by fodder sorghum.

K content of weeds at 30 DAS and at harvest was not found to be significantly different. The highest K content at 30 DAS, recorded from T_2 (3.0 %) followed by T_1 (2.9 %) and the lowest content was obtained from T_9 (2.2 %) and at harvest highest was in T_2 (3.2 %) which was followed by T_1 (3.1 %). The lowest content of K was in T_4 (2.0 %). There was very high K content compared to N content. K removal by weeds was not significantly different. It ranged from 5.06 kg/ ha in (T_6) to16.38 kg/ ha in (T_8).

Ca content in weeds was not found to be significantly different at 30 DAS and at harvest. The Ca content at 30 DAS ranged from 0.34 % in (T_8) to 0.64% in (T_6). At harvest the highest content was in T_3 (0.67 %) and the lowest content was recorded in T_9 (0.42 %). Regarding Ca removal by weeds there was no significant variation among the treatments. Ca removal ranged from 0.87 kg/ ha in (T_2) to 2.91 kg/ ha in (T_{12}).

Regarding Mg content also there was not much difference between stages and treatment levels. The Mg content was around 0.1 % in weeds. Mg removal by weeds was also not found to be significantly different. Mg removal by weeds recorded from 0.21 kg/ ha in (T_2) to 0.69 kg/ ha in (T_8). Generally nutrient removal by fodder sorghum was more than fodder bajra.

Table 4.6 Weed count as influenced by fodder type, spacing and N level

Treatments	Grass weed (m^2)	Broadleaved weed (m^2)	Total weed count (m^2)
T_1	148.0	81.3	229.3
T_2	401.3	108	426.0
T_3	210.6	44.0	256.0
T_4	341.3	45.3	341.3
T_5	226.6	64.0	336.0
T_6	197.3	79.0	281.3
T_7	181.3	50.6	232.0
T_8	320.0	66.6	340.0
T_9	177.3	54.6	217.3
T_{10}	338.6	113.3	386.6
T_{11}	236.3	92.0	255.0
T_{12}	230.6	92.0	321.7
	NS	**NS**	**NS**

Table 4.7 Dry weight of weeds as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (kg/ ha)	At harvest (kg/ ha)
T_1	115.7	217.9
T_2	256.3	186.2
T_3	115.7	334.7
T_4	275.8	405
T_5	341.6	323.8
T_6	252.0	255.2
T_7	323.8	591.1
T_8	500.5	576.8
T_9	308.0	493.1
T_{10}	492.8	481.6
T_{11}	518.0	486.5
T_{12}	507.7	564.2
	NS	**NS**

Table 4.8 Nutrient content of weeds as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (%)					At harvest (%)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
T_1	1.98	0.37	2.9	0.58	0.099	2.15	0.35	3.1	0.46	0.109
T_2	2.21	0.43	3.0	0.48	0.111	2.15	0.32	3.2	0.48	0.111
T_3	2.04	0.34	2.8	0.45	0.118	1.80	0.33	3.1	0.67	0.113
T_4	2.15	0.38	2.6	0.48	0.102	1.98	0.32	2.0	0.45	0.099
T_5	2.03	0.47	2.3	0.53	0.099	1.98	0.29	2.1	0.61	0.118
T_6	2.50	0.49	2.6	0.64	0.106	2.49	0.34	2.0	0.58	0.101
T_7	1.98	0.55	3.0	0.41	0.098	1.98	0.33	2.0	0.59	0.094
T_8	2.33	0.38	2.7	0.34	0.098	2.15	0.29	2.7	0.48	0.12
T_9	1.92	0.39	2.2	0.49	0.099	1.86	0.26	2.4	0.42	0.105
T_{10}	2.15	0.30	2.3	0.47	0.104	2.21	0.36	2.5	0.55	0.109
T_{11}	1.98	0.23	2.3	0.41	0.096	2.21	0.30	2.7	0.44	0.111
T_{12}	2.39	0.28	2.3	0.43	0.100	2.33	0.25	2.8	0.57	0.105
	NS	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4.9 Nutrient removal by weeds as influenced by fodder type, spacing and N level

Treatments	N (kg/ ha)	P (kg/ ha)	K (kg/ ha)	Ca (kg/ ha)	Mg (kg/ ha)
T_1	4.69^{cd}	0.77	6.84	1.00	0.23
T_2	4.03^{d}	0.61	5.58	0.87	0.21
T_3	5.85^{cd}	1.11	8.77	1.64	0.35
T_4	8.28^{abcd}	1.29	8.07	1.34	0.40
T_5	6.37^{bcd}	0.94	6.66	2.09	0.38
T_6	6.40^{bcd}	0.90	5.06	1.35	0.25
T_7	10.64^{ab}	1.97	11.11	2.66	0.55
T_8	11.15^{a}	1.72	16.38	2.41	0.69
T_9	8.96^{abc}	1.29	12.82	2.27	0.52
T_{10}	10.46^{ab}	1.73	10.70	2.87	0.51
T_{11}	10.63^{ab}	1.45	13.35	2.08	0.53
T_{12}	8.52^{abc}	1.35	16.19	2.91	0.56
	CD (0.05) - 4.34	**NS**	**NS**	**NS**	**NS**

4.3 NUTRIENT CONTENT AND UPTAKE BY FODDER CROPS

4.3.1 Nitrogen

Analysis was done for nutrient content of plant samples which were collected at 30 DAS, 60 DAS and at harvest. The data of nitrogen content of plants in different treatments are presented in Table 4.10. At 60 DAS and at harvest the nutrient content of leaf and stem was analyzed separately. Nitrogen content of leaf at both 60 DAS and at harvest was recorded higher compared to content of N in stem.

At 30 DAS, the nitrogen content in plant ranged from 1.39 per cent in (T_3) to 2.13 per cent in (T_6) in fodder bajra whereas in fodder sorghum it ranged from 1.25 per cent in (T_7) to 2.09 per cent in (T_{12}).

The nitrogen content in leaf was significantly different at 60 DAS with the highest nitrogen content of leaf recorded from T_{12} (2.04 %) which was followed by T_6 (2.03 %). Nitrogen content in stem was also significantly different. The highest nitrogen content was obtained from T_{10} (1.69 %) followed by T_{12} (1.57 %). The lowest nitrogen content was observed fromT_3 (1.04 %).

The data of N content of fodder crops at harvest are given in Table 4.11. In leaf all the treatments which applied with higher dose of nitrogen, had higher content of nitrogen. The nitrogen content was varied significantly at harvest stage also in fodder bajra and fodder sorghum.

The highest nitrogen content in stem at harvest was recorded from T_{12} (1.80 %) followed by T_4 and T_6 and the lowest N content was recorded in T_7 (1.22 %).

Table 4.10 Nitrogen content of fodder crops as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (%)	At 60 DAS leaf (%)	At 60 DAS stem (%)
T_1	1.55 ^{bcd}	1.45^{bc}	1.22^{def}
T_2	1.93 ^{abc}	1.51^{bc}	1.16^{ef}
T_3	1.39 ^{d}	1.39^{bc}	1.04 ^{f}
T_4	1.73 ^{abcd}	1.8^{ab}	1.34^{bcde}
T_5	1.72 ^{abcd}	1.51^{bc}	1.16^{ef}
T_6	2.13 ^{a}	2.03 ^{a}	1.51^{abc}
T_7	1.25 ^{d}	1.39^{bc}	1.28^{cdef}
T_8	1.98 ^{ab}	1.63^{abc}	1.45^{abcd}
T_9	1.64 ^{abcd}	1.28 ^{c}	1.22^{def}
T_{10}	1.71 ^{abcd}	1.86^{ab}	1.69 ^{a}
T_{11}	1.46 ^{cd}	1.22 ^{c}	1.28^{cdef}
T_{12}	2.09 ^{a}	2.04 ^{a}	1.57^{ab}
	CD (0.05) - 0.494	**CD (0.05) - 0.490**	**CD (0.05) - 0.270**

Table 4.11 Nitrogen content of fodder crops at harvest as influenced by fodder type, spacing and N level

Treatments	Leaf (%)	Stem (%)
T_1	1.57 ^{bcd}	1.40^{bc}
T_2	1.63 ^{abcd}	1.51^{abc}
T_3	1.68 ^{abcd}	1.34^{bc}
T_4	1.9 ^{ab}	1.57^{ab}
T_5	1.45 ^{bcd}	1.28^{bc}
T_6	1.81 ^{abc}	1.57^{ab}
T_7	1.28 ^{d}	1.22 ^{c}
T_8	2.13 ^{a}	1.39^{bc}
T_9	1.45 ^{bcd}	1.51^{abc}
T_{10}	1.63 ^{abcd}	1.39^{bc}
T_{11}	1.34 ^{cd}	1.28^{bc}
T_{12}	2.09 ^{a}	1.80 ^{a}

CD (0.05) - 0.517 **CD (0.05) - 0.2**

Regarding N uptake there was no significant variation (Table 4.16). Among all treatments, T_{12} noticed highest (150.8 kg/ ha) N uptake which was followed by T_{10} (109.0 kg/ ha), T_8 (96.72 kg/ ha) and T_6 (89.06 kg/ ha).

4.3.2 Phosphorus

The data on phosphorus content of plants in treatments are presented in Table 4.12. The variation in phosphorus content at 30 DAS was not found to be significant. However, at 60 DAS, P content of stem was significantly different it ranged from 0.19 to 0.31 percent. Phosphorus content of leaf at 60 DAS was not significantly different.

At harvest, the phosphorus content of leaf and stem was significantly different. Highest phosphorus content of leaves was observed from T_4 (0.308 %). And the highest phosphorus content of stems at harvest was shown from T_2 (0.306 %) and the lowest content was from T_7 (0.188 %).

P uptake was not found to be statistically significant. However, it was different in various treatments (Table 4.16). P uptake was higher in T_{12} (18.03 kg/ ha) followed by T_6 (16.73 kg/ ha).

4.3.3 Potassium

Potassium content of plant at 30 DAS, 60 DAS and at harvest was not found significantly different (Table 4.13). The highest K content 3.4 per cent at 30 DAS was shown by T_4 and at 60 DAS T_3 with 3.1 per cent had the highest K content in leaves. At 60 DAS, T_6 and T_7 stems had highest K content (2.5 %).

With respect to K content of leaves and stems at harvest, T_2 recorded the highest value in leaves (2.6 %) and stems (3.1 %) even though there was no significant difference between treatments.

Regarding K uptake variation was not found to be significant (Table 4.16). However, the highest K uptake was noticed from T_{12} (152.8 kg/ ha) followed by T_8 (146.8 kg/ha).

4.3.4 Calcium

The data on Ca content are presented in (Table 4. 14). There was no significant difference in Ca content at any stage of growth of the fodder crops. Ca content in different treatments recorded at 30 DAS ranged from 0.34 to 0.54 percent. At 60 DAS, the percentage Ca content of leaves, ranged from 0.293 % in (T_6) to 0.503 % in (T_8). In stems it ranged from 0.306 to 0.423 per cent.

At harvest the Ca content of leaves, ranged from 0.326 % to 0.453 % in fodder bajra and 0.33 % to 0.45 % in fodder sorghum and the lowest Ca content of stems was recorded from T_{10} (0.30 %) and higher range in T_5 (0.44 %). A comparison of the Ca content of leaves and stems showed that the Ca content of leaves at both 60 DAS and at harvest was higher than that of stems.

With respect to the Ca uptake, the data are presented in Table 4.16. The Ca uptake was not found to be significantly different. However, it ranged from 160.46 to 366.43 kg/ ha.

4.3.5 Magnesium

Magnesium content of plants in different treatments is presented in Table 4.15. Though there was no significant difference in Mg content of plants. Mg content at 30 DAS ranged from 0.09 to 0.16 per cent. At 60 DAS, the Mg content of leaves varied from 0.08 to 0.15 per cent. And Mg content in stems was 0.08 to 0.10 per cent. At harvest the highest Mg content of leaves ranged from 0.06 to 0.16 per cent and stem ranged from 0.05 to 0.12 per cent. Mg content of leaves was recorded higher compared to stems at both 60 DAS and harvest.

Table 4.12 Phosphorus content of fodder crops as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (%)	At 60 DAS		At harvest	
		Leaf (%)	Stem (%)	Leaf (%)	Stem (%)
T_1	0.179	0.287	0.281^{abc}	0.304^{ab}	0.298^{ab}
T_2	0.198	0.274	0.291^{ab}	0.249^{abcd}	0.306^{a}
T_3	0.194	0.216	0.310^{a}	0.224^{d}	0.280^{abc}
T_4	0.211	0.228	0.271^{bcd}	0.308^{a}	0.274^{abcde}
T_5	0.258	0.212	0.240^{abc}	0.241^{bcd}	0.271^{abcde}
T_6	0.228	0.283	0.261^{abc}	0.301^{abc}	0.255^{bcde}
T_7	0.280	0.229	0.230^{cd}	0.237^{bcd}	0.188^{f}
T_8	0.257	0.184	0.240^{bcd}	0.212^{d}	0.228^{ef}
T_9	0.258	0.241	0.240^{bcd}	0.208^{d}	0.237^{de}
T_{10}	0.208	0.200	0.230^{cd}	0.237^{bcd}	0.278^{abcd}
T_{11}	0.260	0.195	0.190^{d}	0.220^{d}	0.241^{cde}
T_{12}	0.145	0.216	0.231^{cd}	0.234^{cd}	0.277^{abcd}
	NS	**NS**	**CD (0.05) - 0.057**	**CD (0.05) - 0.067**	**CD (0.05) - 0.047**

Table 4.13 Potassium content of fodder crops as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (%)	At 60 DAS		At harvest	
		Leaf (%)	Stem (%)	Leaf (%)	Stem (%)
T_1	2.6	2.3	2.3	2.1	2.7
T_2	2.4	3	2.5	2.6	3.1
T_3	2.9	3.1	1.9	2.3	3.1
T_4	3.4	2.4	2.0	2.3	2.2
T_5	2.3	2.2	2.4	1.9	1.9
T_6	2.4	2.2	2.5	2.2	2.1
T_7	2.5	2.3	2.5	2.3	2.3
T_8	2.1	1.9	2.2	2.4	2.6
T_9	1.8	1.6	1.5	1.8	0.9
T_{10}	2.3	1.3	1.8	2.1	2.6
T_{11}	1.9	1.6	2.5	1.9	2.1
T_{12}	2.0	1.2	2.0	1.9	2.0
	NS	**NS**	**NS**	**NS**	**NS**

Table 4.14 Calcium content of fodder crops as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (%)	At 60 DAS		At harvest	
		Leaf (%)	Stem (%)	Leaf (%)	Stem (%)
T_1	0.34	0.403	0.306	0.326	0.330
T_2	0.42	0.406	0.390	0.356	0.396
T_3	0.42	0.373	0.350	0.430	0.343
T_4	0.44	0.383	0.336	0.366	0.373
T_5	0.52	0.343	0.326	0.396	0.446
T_6	0.47	0.293	0.423	0.453	0.330
T_7	0.44	0.426	0.390	0.450	0.406
T_8	0.40	0.503	0.376	0.406	0.333
T_9	0.45	0.436	0.400	0.330	0.433
T_{10}	0.54	0.436	0.316	0.420	0.300
T_{11}	0.49	0.313	0.326	0.376	0.380
T_{12}	0.46	0.436	0.360	0.463	0.320
	NS	**NS**	**NS**	**NS**	**NS**

Table 4.15 Magnesium content of fodder crops as influenced by fodder type, spacing and N level

Treatments	At 30 DAS (%)	At 60 DAS		At harvest	
		Leaf (%)	Stem (%)	Leaf (%)	Stem (%)
T_1	0.122	0.084	0.094	0.094	0.088
T_2	0.103	0.106	0.109	0.166	0.081
T_3	0.099	0.092	0.097	0.067	0.059
T_4	0.120	0.105	0.100	0.079	0.119
T_5	0.130	0.127	0.103	0.130	0.077
T_6	0.108	0.105	0.093	0.127	0.129
T_7	0.105	0.105	0.096	0.089	0.080
T_8	0.104	0.102	0.088	0.089	0.089
T_9	0.099	0.104	0.101	0.080	0.077
T_{10}	0.163	0.103	0.097	0.074	0.127
T_{11}	0.139	0.100	0.098	0.103	0.092
T_{12}	0.100	0.150	0.085	0.122	0.095
	NS	**NS**	**NS**	**NS**	**NS**

Table 4.16 Nutrient uptake as influenced by fodder type, spacing and N level

Treatments	N (kg/ ha)	P (kg/ ha)	K (kg/ ha)	Ca (kg/ ha)	Mg (kg/ ha)
T_1	75.22	13.75	100.70	16.17	4.25
T_2	79.13	12.86	126.00	17.20	3.83
T_3	70.96	9.73	96.56	18.36	2.92
T_4	88.20	14.88	108.20	17.94	5.71
T_5	63.13	14.10	82.52	16.04	3.19
T_6	89.06	16.73	108.66	20.48	6.27
T_7	79.96	16.53	165.80	33.03	5.89
T_8	96.72	15.26	146.80	35.67	6.54
T_9	77.86	11.91	109.10	24.01	4.24
T_{10}	109.00	15.53	140.93	26.90	7.42
T_{11}	78.98	13.75	110.06	23.78	5.07
T_{12}	150.80	18.03	152.83	36.64	7.40
	NS	**NS**	**NS**	**NS**	**NS**

Regarding Mg uptake the data are given in Table 4.16. The Mg uptake was not significantly different. The values ranged from 29.2 to 74.24 kg/ ha.

4.4 NUTRITIVE VALUE OF FODDER CROPS

A mixture of leaves and stems from the harvested samples were analyzed for determining the contents of crude protein, crude fibre, crude fat, total ash, nitrogen free extract and nitrate content of fodder crops.

The data pertaining to proximate analysis are presented in Table 4.17. Crude protein, total ash content and nitrate content varied significantly. There was no significant difference with respect to crude fibre, crude fat, NFE and Ca: Mg ratio.

The highest amount of crude protein was recorded from T_6 and T_{12} (12.23 %) followed by T_{10} (11.63 %). T_4 (10.26 %) and T_8 (10.16 %) were at par and the lowest content was recorded in T_9 (8.61 %). The effect of nitrogen in crude protein content of plants was clearly noticed. The treatments which got higher dose (90 kg/ ha) of nitrogen fertilizer recorded higher percentage of crude protein content compared to those that received lower dose (60 kg/ ha) of N fertilizer.

Crude fibre content of crops was not significantly different. But due to the effect of N levels applied, the crude fibre was varying between treatments. It was recorded from 31.5 to 37.03 percent in T_3 and T_5 respectively. The treatments receiving higher dose of nitrogen recorded lower content of crude fibre compared to those applied with lower dose of nitrogen.

Crude fat content of crops was not significantly different. It varied from1.56 to 1.86 percent. Due to the effect of nitrogen fertilizer the treatments applied with higher dose of nitrogen recorded comparatively higher crude fat content.

The percentage of total ash in fodder crops was significantly different. The highest ash content was recorded from T_6 (7.9 %) which was at par with T_5 (7.5 %)

and the lowest content recorded in T_7 (4.8 %). The effect of nitrogen was significantly clear. The treatment which got higher dose of N recorded higher percentage of total ash.

Nitrogen free extract was not found to be significantly different. But the effect of nitrogen levels applied was certainly noticed. The treatments applied with higher dose of nitrogen recorded lower nitrogen free extract compared to those applied with lower dose. NFE ranged from 53.06 % in (T_1) to 44.16 % in (T_{12}).

Nitrate content in fodder crops varied significantly. The nitrate content varied from 547 ppm in (T_5) to 1362 ppm in (T_8). It was observed that sorghum had the higher amount of nitrate than that in bajra.

With respect to Ca: Mg ratio, the variation between treatments was not found to be significant. However, the highest ratio was recorded in T_{10} (5.0) which was followed by T_7 (4.82) and the lowest ratio was noticed in T_2 (2.59).

4.5 SOIL ANALYSIS

Soil analysis was done before and after the experiment. The details of available nutrient status, organic carbon and soil pH are given below:

4.5.1 Organic carbon

The data pertaining to organic carbon in soil after the experiment are presented in Table 4.18. Organic carbon content after the experiment increased slightly compared to before experiment.

Table 4.17 Nutritive value of fodder crops as influenced by fodder type, spacing and N level

Treatments	Crude protein (%)	Crude fibre (%)	Crude fat (%)	Total ash (%)	NFE (%)	Nitrate (ppm)	Ca: Mg ratio
T_1	9.06^{c}	32.2	1.66	5.7^{bc}	53.06	581^{de}	3.29
T_2	9.42^{bc}	32.1	1.67	5.9^{bc}	51.65	718^{d}	2.59
T_3	9.06^{c}	31.5	1.66	5.1^{c}	52.47	552^{e}	4.42
T_4	10.26^{abc}	33.2	1.70	5.4^{bc}	50.45	563^{de}	4.29
T_5	9.40^{bc}	37.0	1.83	7.5^{a}	47.66	547^{e}	3.40
T_6	12.23^{a}	33.9	1.86	7.9^{a}	47.25	630^{de}	3.91
T_7	9.06^{c}	33.6	1.63	4.8^{c}	51.55	1015^{c}	4.82
T_8	10.16^{abc}	32.9	1.73	5.1^{c}	48.08	1362^{a}	4.47
T_9	8.61^{c}	36.3	1.56	5.1^{c}	49.73	993^{c}	4.79
T_{10}	11.63^{ab}	33.0	1.63	6.7^{ab}	48.13	1139^{bc}	5.00
T_{11}	8.73^{c}	35.3	1.63	5.5^{bc}	50.23	1116^{bc}	3.59
T_{12}	12.23^{a}	35.2	1.76	5.6^{bc}	44.16	1200^{b}	3.84
	CD (0.05) - 2.523	**NS**	**NS**	**CD (0.05) - 1.566**	**NS**	**CD (0.05) - 157.012**	**NS**

Before experiment it was 0.75 % and after experiment recorded 0.77 %. The variation was found to be non significant between the treatments.

4.5.2 Available N

The data pertaining to available nitrogen in soil is presented in Table 4.18. Available N in soil before experiment was 163.8 kg/ ha but it was decreased to 158.2 kg/ ha after experiment. The variation was not found to be significant between the treatments.

4.5.3 Available P

Available P in soil after experiment decreased from 18.78 kg/ ha to 15.55 kg/ ha. The difference between treatments was not found to be significant (Table 4.18).

4.5.4 Available K

Available K in soil also decreased after the experiment. Before experiment it was recorded as 102.28 kg/ ha and after experiment was 101.10 kg/ ha. There was no significant difference between treatments.

4.5.5 Available Ca

Available Ca in soil increased after experiment. Before experiment it was 73.47 ppm and after experiment it was 81.50 ppm. The variation between treatments was not found significant.

4.5.6 Available Mg

Available Mg in soil also increased. Available Mg before the experiment was 17.56 ppm and after experiment it was increased to 29.59 ppm in soil. The variation between treatments was not found to be significant.

Table 4.18 Soil analysis after the experiment

Treatments	pH	OC (%)	Available N (kg/ ha)	Available P (kg/ ha)	Available K (kg/ ha)	Available Ca (ppm)	Available Mg (ppm)
T_1	4.82	0.72	151.2	18.06	114.26	89.70	30.49
T_2	4.90	0.83	159.6	15.26	97.93	70.87	29.88
T_3	5.00	0.80	151.2	17.19	100.3	94.24	31.34
T_4	4.84	0.83	172.2	17.36	96.10	81.26	31.33
T_5	4.80	0.70	155.4	17.28	103.16	75.87	30.40
T_6	4.82	0.72	184.8	17.19	97.00	89.52	30.28
T_7	4.99	0.72	147.0	13.54	100.22	67.31	28.64
T_8	4.98	0.82	159.6	12.47	105.72	77.22	28.50
T_9	4.97	0.75	138.6	12.89	103.52	87.44	30.37
T_{10}	4.97	0.82	155.4	16.55	97.76	77.03	30.09
T_{11}	5.07	0.77	155.4	12.57	98.16	97.62	30.02
T_{12}	4.97	0.76	168	16.3	99.11	73.95	23.79
	NS	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4.5.7 Soil pH

Soil pH decreased after the harvest of both fodder crops. Before the experiment it was 5.11 and after the experiment it decreased to 4.92. With respect to the treatments the variation was no significant but, there was an increase in soil acidity.

Discussion

5. DISCUSSION

A field experiment to study the effect of varying plant densities and nitrogen levels on the yield and quality of fodder bajra and fodder sorghum and to study nutrient removal by these crops was conducted during 2014. The results obtained from the experiment reported in the previous chapter are discussed based on available literature.

5.1 GROWTH ANALYSIS

Sowing was done on 3rd and 4th April, 2014. Both fodder bajra and fodder sorghum established well and showed good growth. It took 69 days for fodder bajra and 75 days for fodder sorghum for harvesting the crops were harvested at 50 per cent flowering. Analysis of data on growth parameters showed that spacing and proper nitrogen fertilizer application was the key to increase plant growth and produce higher yield in fodder crops.

Plant height is considered as a varietal character which is an important component that helps in the determination of growth and it is a significant growth attribute directly linked with the productivity of plant in terms of forage yield.

Plant height in the present study was influenced by spacing and nitrogen level. Among the 12 treatments under study with 3 spacings (30 cm, 25 cm and 20 cm between the plants and 15 cm among the rows), the best performance of plant with respect to the plant height at 30 DAS and 60 DAS was recorded from the treatments which had narrow space (20 cm x 15 cm) compared to the two other spacing. It could be seen from Table 4.1 and Fig.4; that at 30 DAS the tallest plant (75.80 cm) was observed from T_6 and at 60 DAS the tallest plant (155.83 cm) was obtained from T_{12} which were sown in closer spacing. This finding is in agreement with those reported by Bhowmik *et al.* (2012) that closer spacing hampers intercultural operations and in a densely populated crop, the inter-plant competition for nutrients, air and light is very high, which results in mutual shading, lodging and thus favours more straw yield. Azam-Ali *et al.* (1984), Carberry *et al.* (1985) and Mahalakshmi *et al.* (1987) reported that vegetative development in pearl millet is much influenced by the availability of moisture, soil fertility and the planting density. Manjunatha *et al.* (2013) noticed that the row spacing of 45 cm recorded significantly higher plant height (164.3 cm) and 60 cm row spacing recorded significantly higher number of tillers per meter row.

The effect of nitrogen level was also studied in the present study. The treatments which were applied with higher dose (90 kg/ ha) of nitrogen were comparable with those applied with lower dose (60 kg/ ha) of nitrogen fertilizer. However, among all twelve treatments, six of them which were applied with higher dose were having the highest plants. The increase in plant height in response to higher levels of nitrogen has been confirmed by Shehzad *et al*. (2012). Sharma (1973) observed that addition of nitrogen fertilizer increased plant height. Turkhede and Rajendra (1978), Koul (1997), and Gasim (2001) reported increase in plant height with different sources of nitrogen. The height of plant increased significantly with the application of nitrogen. Increase in plant height in sorghum by increasing the rate of nitrogen was reported by Muldoon (1985).

Leaf is considered as very important factor for proper growth of plant because it is a platform for light catching. Leaf area is the measure of the size of assimilatory system of the plant and is the product of leaf length and breadth. In forage crops, the number of leaves have huge effect on final yield having better quality considerations as compared to stem.

The highest values of LAI in this study at 30 DAS and 60 DAS were found from treatments with narrow spacing (20 cm x 15 cm). At 30 DAS, the LAI value was highest (3.53) in T_6 followed by T_4 (3.27) and at 60 DAS T_6 and T_{12} had higher value of LAI which were (7.13) and (7.00) respectively. It was against the finding of Almass *et al*. (2007) and Ali (2010) who noticed the response of pearl millet to the plant density that decreased plant density produced the highest leaf area and leaf area index.

Application of nitrogen also influenced LAI value. Increasing level of nitrogen showed an increase in LAI at 30 DAS and 60 DAS. The treatments applied with higher level of N, had higher value viz., T_6 (3.53) and T_4 (3.27) at 30 DAS. At 60 DAS in T_6 the value was 7.13 and T_{12} was 7.00 in T_{12} which were the highest values among all treatments. It was also reported by Nazir *et al.* (1997) that application of nitrogen increased the number of leaves per plant significantly and the plant height, stand density, green forage yield and crude protein content increased with increasing N rate. Eltelib (2004) reported significant variation in leaf area with increase in nitrogen levels. Line sowing has better effect on leaf area per plant (Nazir *et al*., 1997).

Almodares *et al.* (2009) had observed that split application of nitrogenous fertilizer significantly influenced leaf: stem ratio, crude protein and N uptake. Tariq *et al*. (2011) had reported that the role of nitrogen in improving the leaf to stem proportion was stronger in immature pearl millet plants than mature ones. This could be found in the Table 4.2 and Fig.5; that the treatments applied with higher dose of nitrogen at both 30 DAS and 60 DAS observations, gave good results and recorded higher values of LAI.

Leaf to stem ratio is a component of canopy architecture and an important factor determining diet selection and forage intake in tropical grasses (Chacon and Stobbs, 1976; Chacon *et al.,* 1978).

Fig.4. Plant height (cm) as influenced by fodder type, spacing and N level

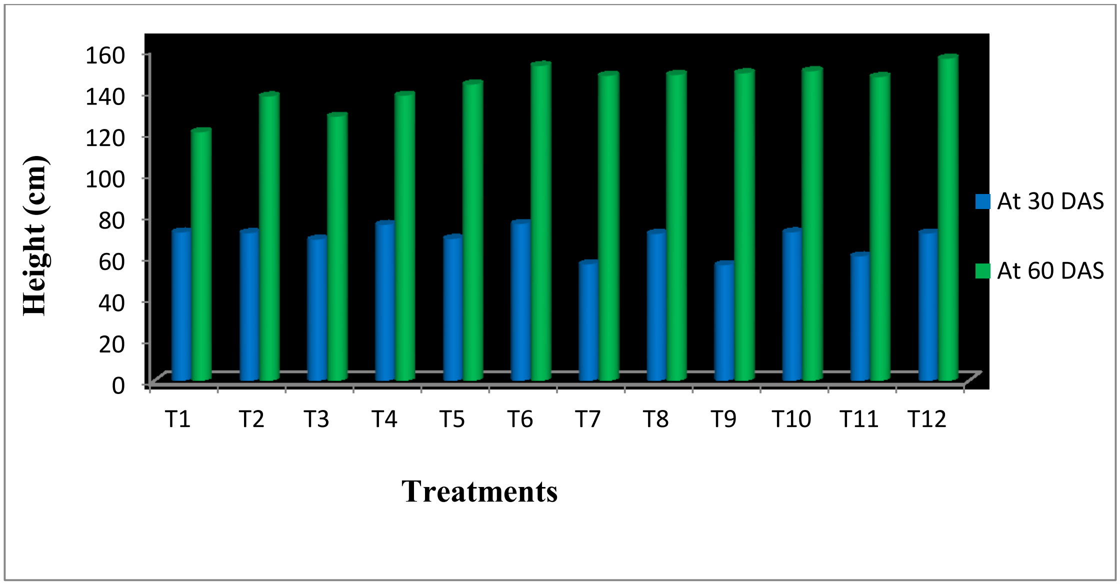
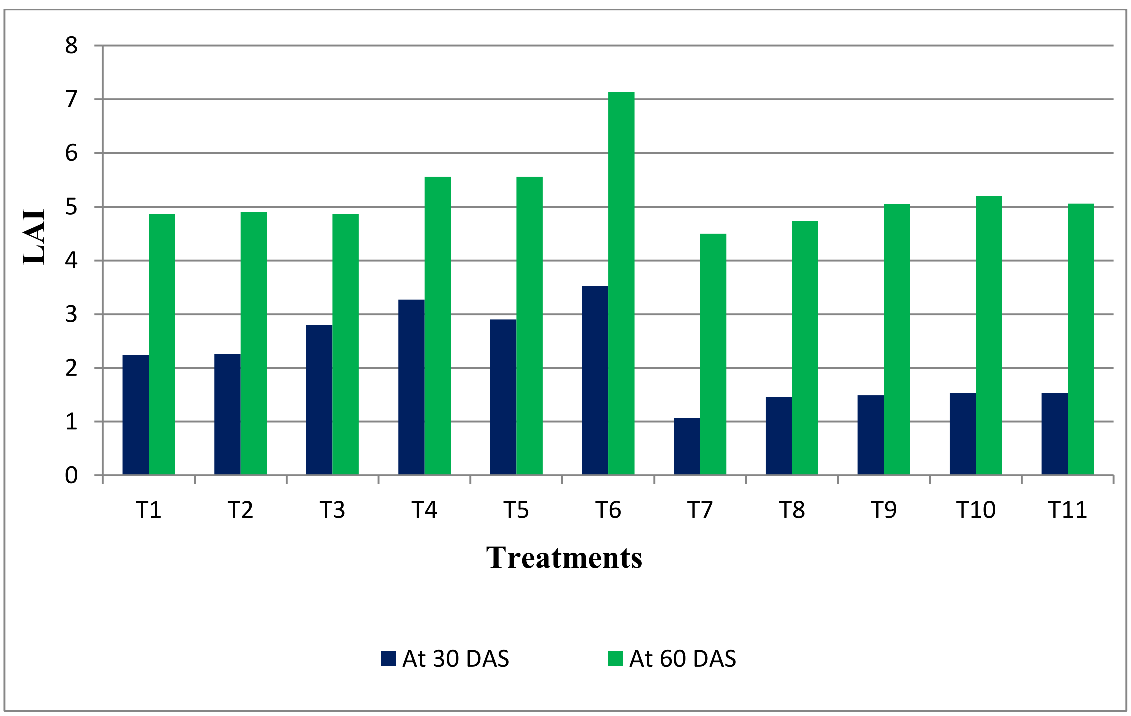


Fig.5. Leaf area index as influenced by fodder type, spacing and N level



The leaf: stem ratio was high at 60 DAS. At this stage, the plants were not matured and it could be seen that the crops had high quality at this stage. As fodder bajra is erect and leafy plant, it showed higher ratio of leaf to stem. The effect of nitrogen was also noticed (i.e., the treatments applied with higher dose, had higher ratio compared to those with lower dose). It can be seen in Table 4.3 and Fig.6. This finding could be supported by the observation done by Chandra *et al.* (2012) who stated that the decline in forage quality with maturity is directly related to the leaf: stem ratio. As plant matures it becomes more 'stemmy' (i.e., the leaf: stem ratio decreases) therefore, a bale of hay that is referred to as "stemmy" is correctly assumed to be of somewhat lower quality. In the same context, tall, coarse or "rank" plants with a low leaf: stem ratio (i.e., more stem than leaf) are of lower quality. The quality parameters and fodder yield of sorghum can be maximized by enhancing the growth parameters like plant height, stem diameter, L: S ratio and dry matter accumulation. Higher leaf : stem ratio enhance quality characters of forage sorghum (Yadav *et al.,* 2003; Chaudhary *et al.,* 2007).

Roots, stems and leaves are functionally interdependent and these three systems maintain a dynamic balance in biomass which reflects relative abundance of above-ground resources (light and CO_2) compared with root-zone resources (Poorter, 2012). Whole-plant growth rate and shoot: root ratio, are outcomes of developmental stage and environmental influences.

The data pertaining to shoot to root ratio are given in Table 4.3 and Fig.7. The variation of shoot to root ratio was not found to be significant. The highest shoot: root ratio (3.9) was recorded from T_2 which was with wide spacing and higher dose of nitrogen applied and the lowest ratio (2.6) was observed from T_7 which was also with wider spacing but lower dose of nitrogen. It might be due to the effect of above and underground competition between the plants for utilizing resources specially competition for nutrients that nitrogen could have helped the treatments to utilize

Fig.6. Leaf to stem ratio as influenced by fodder type, spacing and N level

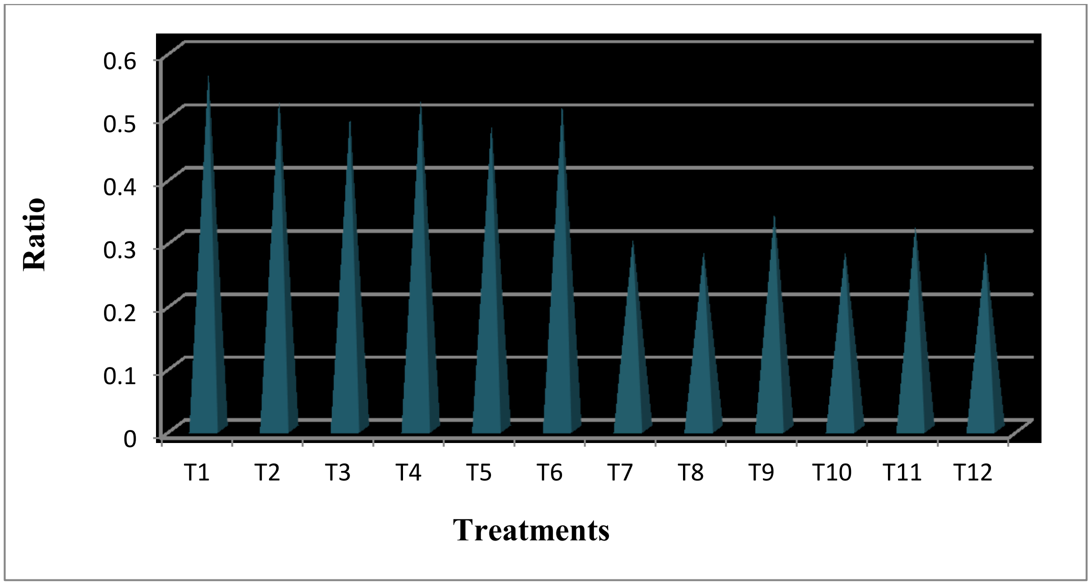
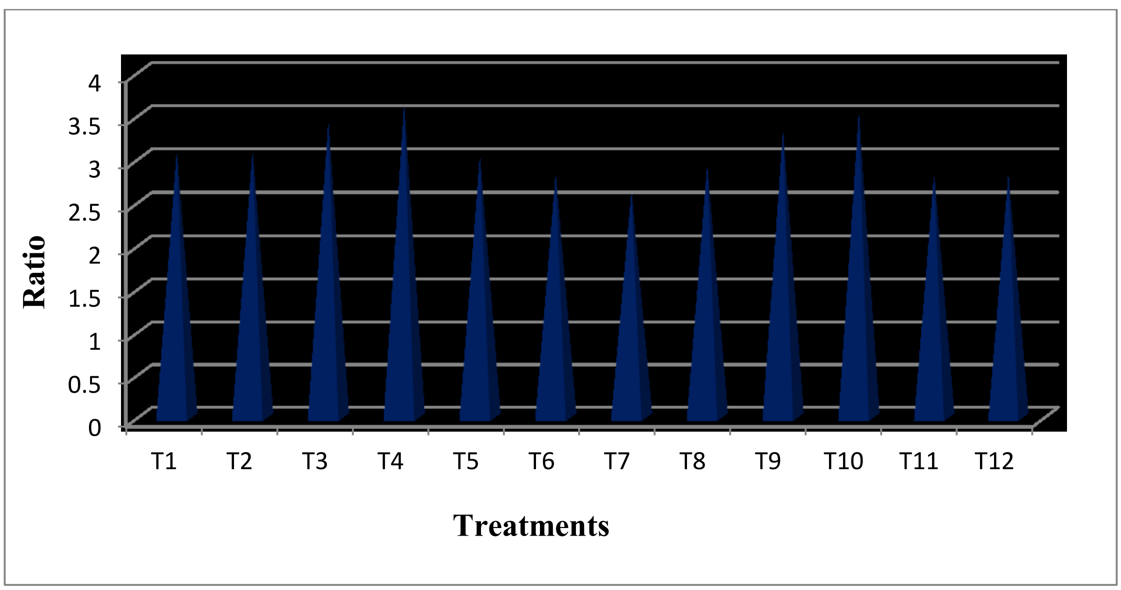


Fig.7. Shoot to root ratio as influenced by fodder type, spacing and N level



higher level of N fertilizer to result in highest S: R ratio. This finding is in good line with those reported by Vadez *et al*. (2012) that pearl millet is known to be deep and profusely rooted, having an ability to match its rooting to water availability. Roots appear to play an important role in pearl millet genotypes that differ in the presence or absence of a major terminal drought tolerance. Shoot to root dry weights can be influenced by competition among the standing crop plants, as the individual plants interact with its neighbours in the mixed stands (Sadras and Calderini, 2009) and the competition may be both above and below ground (Rubio *et al*., 2001). Crop shoot and root growth requires a number of resources, which are light, nutrients and water. Several studies have shown that below-ground competition for water and nutrients is stronger than above-ground competition for light (Casper and Jackson, 1997).

5.2 GREEN FODDER YIELD

Fodder yield is a function of the cumulative effect of growth parameters such as plant height and number of tillers per plant and is the ultimate goal, which depends upon the genomic and environmental factors as well as nutrient status of soil and availability of nutrients for the plant. The data on forage yields are given in Table 4.4and Fig.8. The harvesting was done at 50 percent flowering, hence the dates were different for fodder bajra and fodder sorghum. The yields of leaves, stems and also the total forage yield were recorded separately.

Green fodder yield was more in bajra than sorghum. The leaf yield was around 35 percent in fodder bajra where as it was only around 22 percent in fodder sorghum compared to the total yield. The highest fodder yield was 27 t/ ha and 24 t/ ha in fodder bajra and sorghum respectively among the various treatments.

Firdous *et al*. (1996) indicated that the harvesting management is based on more biomass production in the field with high nutritional value that ultimately affects the animal performance. The differences in feeding quality obtained among the harvesting times surpass the varietals differences. Tariq *et al*. (2011) reported that the plant height and fresh fodder yield showed significant increase with lengthening the harvesting time up to 60 DAS and further delay in harvesting did not account a significant increase.

The effect of plant density and nitrogen levels on fodder yield were two main objectives for the present study. It was observed that spacing influenced fodder yield. Among treatments under study, T_6 with yield of 27 t/ ha showed the best performance with better leaf production and stem yield in fodder bajra. In the case of sorghum, T_{12} with 24 t/ ha gave the highest fodder yield. Both treatments were in narrow spacing. Scott *et al.* (1999) reported that forage yield was mainly affected by row spacing. Orak and Kavdr (1994) also observed that yield increase from narrow rows have been attributed to better light interception and more efficient water use. Gonzalez and Graterol (2000) also reported high yield from high seed rates and narrow row spacing.

Total green yield is contributed by the leaves and stems. Stems gave higher fodder yield than leaves. Likewise the highest (27 t/ ha) total fodder yield was obtained from T_6 i. e., fodder bajra grown with 20 x 15 cm spacing and supplied with 90 kg N/ ha. In this regard Hanna and Gupta (1999) indicated that pearl millet fodder is more succulent and has higher crude protein (CP) than sorghum or maize with other chemical constituents being comparable. It is clear that with increase in nitrogen levels the fodder yields of both stems and leaves considerably increased.

By the effect of nitrogen level on growth parameters, higher fodder yields were obtained from the treatments applied with higher dose of N which could be supported by the findings of Reddy *et al.* (2003). According to them proper fertilization and harvesting times have been found very effective to improve the quality and quantity of fodder pearl millet. In the present study both dose of nitrogen fertilizer and K was applied as split that half of N and K and full P was applied as basal top dressing and half of N with half K was applied at knee high stage. It supported the crops to produce higher yield and response better to fertilizer. Rao *et al.* (2007) had reported higher fodder yield of sorghum under higher fertilizer dose. The crop receiving 75% N as basal and 25% N at 25 DAS as top dressing significantly increased fodder yield. Abou-Amer and Kewan (2014) confirmed that fodder yield was increased significantly by increasing levels of N and P fertilizer.

5.3 DRY MATTER PRODUCTION

Dry Matter is the actual amount of feed material leaving water, volatile acids and bases. It is the most important component of animal diet for feeding livestock during lean period. The data of dry matter production at 30 DAS and harvest are presented in the Table 4.5 and Fig.9. Dry matter production of the crops in the present study was varying from treatment to treatment. At 30 DAS the highest dry matter (2.03 t/ ha) was obtained from T_6 but at harvest the highest dry matter (7.70 t/ ha) was observed from T_{12}. It showed that fodder bajra has better growth initially than fodder sorghum. The highest dry matter yield obtained in fodder bajra was in the plot which was sown at closer spacing of 20 x 15 cm and supplied with higher dose of N fertilizer (90 kg/ ha) both in the early stage and towards harvest. Fodder sorghum also followed the same trend. But the dry matter production was around 70 percent higher than that of fodder bajra at harvest. Fodder sorghum takes more time for its 50 % flowering stage but produced more dry matter and more ash content. But the fresh forage yield was more from fodder bajra than fodder sorghum because of the reason that fodder bajra produced more leaves and had less leaf stem ratio. Comparatively better shoot to root ratio was also shown by fodder bajra. It was in line with findings of Tyagi *et al.* (1999); Sashidhar *et al.* (2000); Sanchez *et al.* (2006); Vadez *et al.* (2012); and Khan *et al.* (2014). Leaves are more succulent and less weight than stems while drying.

Fig.8. Green fodder yield (t/ ha) as influenced by fodder type, spacing and N level

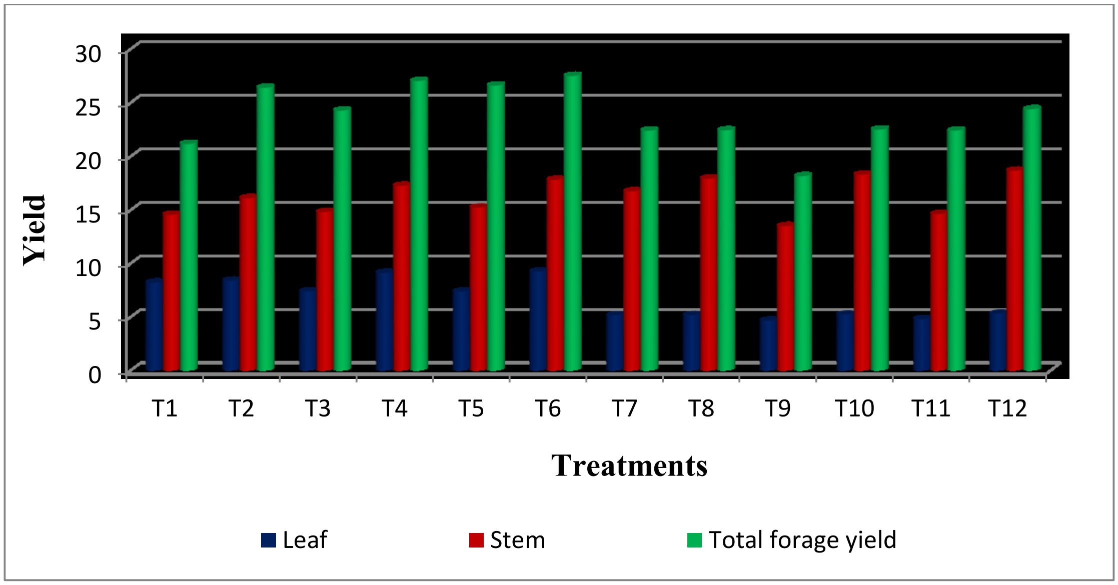
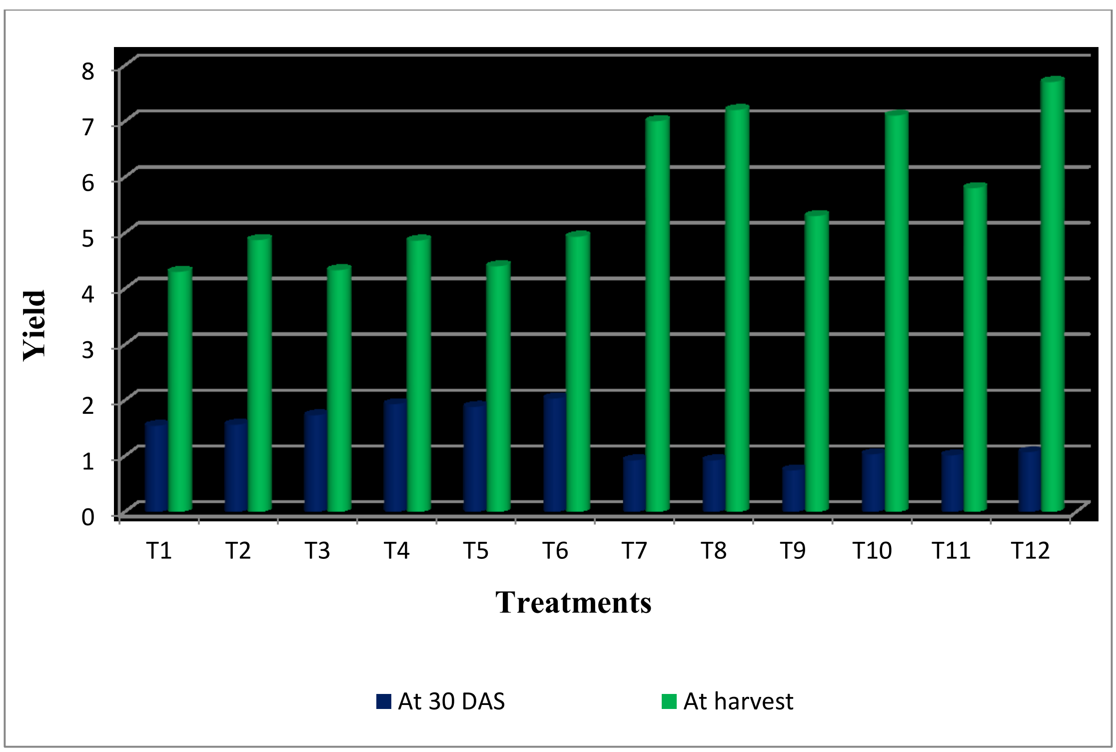


Fig.9. Dry matter production (t/ ha) as influenced by fodder type, spacing and N level



5.4 WEED POPULATION AND WEED DRY WEIGHT

Population of weeds was taken at 30 DAS and the dry matter of weeds at 30 DAS and at harvest was recorded. The data pertaining to weed population, weed dry weight and nutrient content of weeds are given in Tables 4.6 to 4.9 and Figurs.10 and 11. Grass weeds were dominant over broadleaved weeds. Among grass weeds, *Isachne miliacea*, *Brachiaria mutica, Oryza sativa* and *Echinochloa crusgalli* were found dominant. Regarding broadleaved weeds, *Aeschynomene americana*, *Phyllanthus* sp., *Melochia corchorifolia*, *Cyanotis axillaris, Heliotropium indicum* and *Ludwigia parviflora* were present. Sedge weeds were absent. Along with hand weeding, herbicide application was done two times to control the weeds from the field. 2, 4 -D was used at the dose of 1kg ai/ ha sprayed after thinning and gap filling. Second herbicide Carfentrazone was sprayed at the rate 20 g ai/ ha. Khairwal *et al.* (2007) recommended that low rates of 2, 4-D at 0.5 to 1.0 kg/ ha may be applied when the plants are about 10 to 30 cm tall.

Weed dry weight at 30 DAS was the highest (507.7 kg/ ha) in T_{12} and at harvest the highest (591.1 kg/ ha) weed dry weight was observed from T_7 because of more spacing and hence more light infiltration. The grassy weeds have similar nutrient requirement and they also absorbed the applied and native nutrients and due to their less biomass than crops showed better percentage nutrient content. Dry weight of weeds at harvest was comparatively more in fodder sorghum than fodder bajra due to more light interception in sorghum leading to higher dry matter production of weeds. Nutrient content in weeds at 30 DAS and at harvest, recorded higher than the nutrient content of main plant. Regarding nutrient removal weeds in fodder sorghum showed more nutrient removal than fodder bajra. N removal was significantly different but in case of P, K, Ca and Mg there was no marked variation.

Fig.10. Weed count / m^2 as influenced by fodder type, spacing and N level

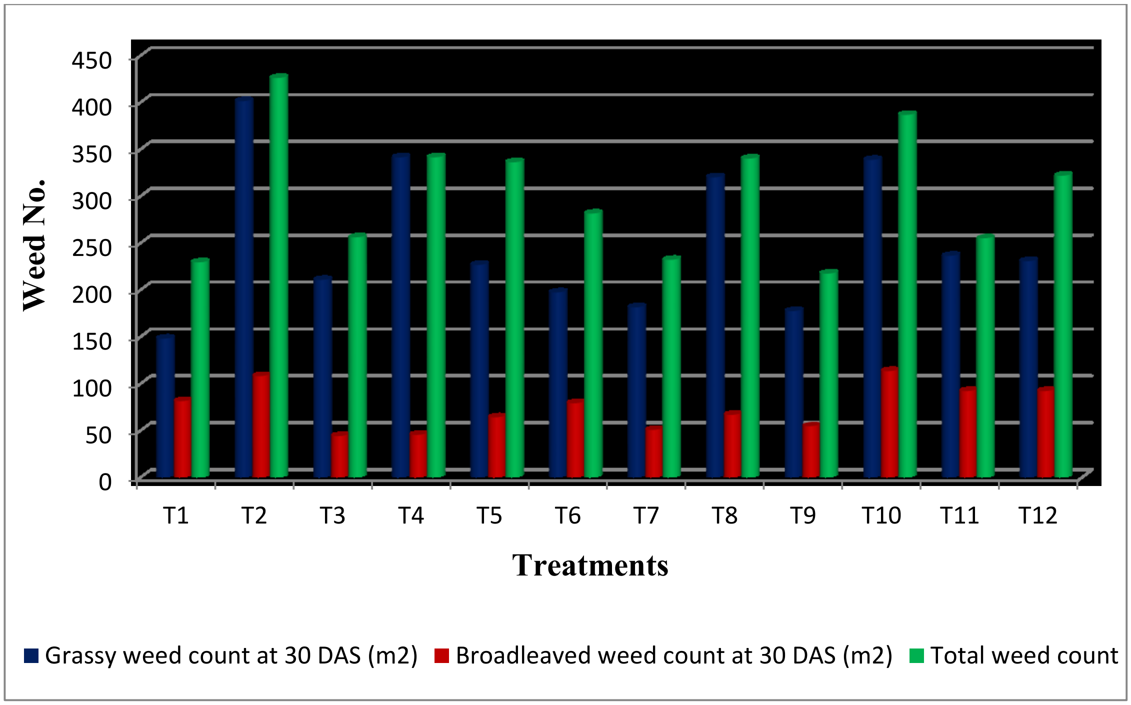
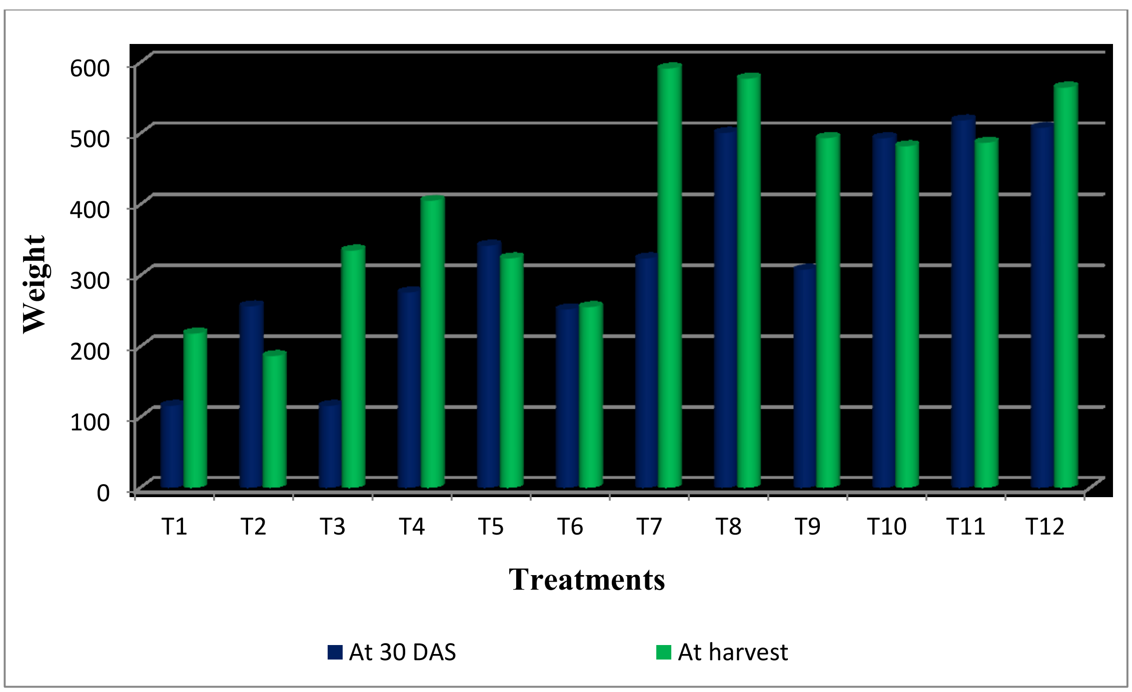


Fig.11. Dry weight (kg/ ha) of weeds as influenced by fodder type, spacing and N level



5.5 NUTRIENT CONTENT AND UPTAKE BY FODDER CROPS

Analysis for nutrient content of NPK Ca and Mg in the plants was done at 30 DAS, 60 DAS and at harvest. At 30 DAS a mixed sample of whole plant was analyzed but at 60 DAS and harvest analysis was done for leaves and stems separately. At 30 DAS the nitrogen content was more compared to the later stages probably because the stem was not much developed at that stage. Later on the nutrient in leaves got reduction and the stem also was having good N content even though it was less than the leaves.

The data of N content are presented in Table 4.10, 4.11 and Fig.12. In general N content of the leaves was higher than those in the stems. At 30 DAS the highest N content (2.13 %) was observed from T_6 which was followed by T_{12} (2.09 %). These two treatments were applied with higher dose of nitrogen fertilizer with a closer spacing. At 60 DAS the highest N content (2.04 %) of leaves was recorded from T_{12} followed by T_6 (2.03) and the variation of nitrogen content of leaves were significant. In fodder bajra the N content in leaves at 60 DAS varied from 1.39 to 2.03 percent whereas in fodder sorghum it varied from 1.22 to 2.04 per cent. In all the cases a higher dose of N fertilizer gave a higher N content. In the case of nitrogen content of stem there was significant variation from 1.04 to 1.51 per cent in fodder bajra. The N content varied from 1.22 to 1.57 per cent in stems at 60 DAS. At the harvest stage the N content in leaves in fodder bajra ranged from (1.45 %) in T_5 to (1.90 %) in T_4. whereas in fodder sorghum it ranged from (1.28 %) in T_7 to (2.13 %) in T_8. The N content in the stems at harvest stage also varied significantly in both crops, according to the spacing and fertilizer level (Fig 12). However, the collective average N content in fodder bajra and fodder sorghum did not show much variation, it was 1.44 and 1.45 respectively. Due to these reasons there was no significant difference in N uptake by the crops.

Nutrient uptake is the mechanism by which plants capture all those elements that are essential for their growth. Nutrient uptake depends on a number of factors viz., plant species, environmental conditions, nutrient supply and interrelationship among nutrients and between plant and soil, presence of microorganisms (e.g., fungi) in association with plant roots, etc. From a practical perspective, nutrient uptake determines the quantity of nutrients exported from a field via harvest and the requirements for their replenishment (Karamanos, 2013).

Regarding N uptake, there was no significant variation. The data of nutrient uptake of all nutrients under study is given in Table 4.16 and Fig.17. The highest uptake (150.8 kg/ ha) was observed from T_{12} which is in good agreement with those found by Akram *et al.* (2007) that nitrogen uptake was improved with P and K application. Sharma and Ramna (1993) observed that application of K released the fixed NH_4 + ion from soil and helped the crop for better uptake of nitrogen.

The data of P content is given in Table 4.12 and Fig. 13. P content of leaves recorded higher (0.308 %) from T_4 at 60 DAS. P uptake was higher (18.03 kg/ ha) in T_{12}. It was previously mentioned that higher dose of N fertilizer was applied in this treatment so had better performance compared to other treatments.

The highest K content was observed at 30 DAS from T_4 (3.4 %) and at harvest (3.1 %) in T_2. K uptake was higher (152.83 kg/ ha) in T_{12} followed by T_8 and T_{10}. All these treatments were supplied with higher dose 90 kg N/ ha. In general K uptake was more in widely spaced crops (Table 4.14, Fig.17).

The highest Ca content at 30 DAS was recorded from T_{10} (0.54 %). The highest Ca content in leaves was in T_8 (0.50 %) at 60 DAS. Ca uptake was 366.43 kg/ ha in T_{12} (Table 4.17).

Mg at 30 DAS was high in T_{10} (0.163 %) and with respect to the Mg content in leaves at harvest the highest was recorded (0.166 %) in T_2 (Table 4.15).

Fig.12. Nitrogen content (%) of fodder crops as influenced by fodder type, spacing and N level

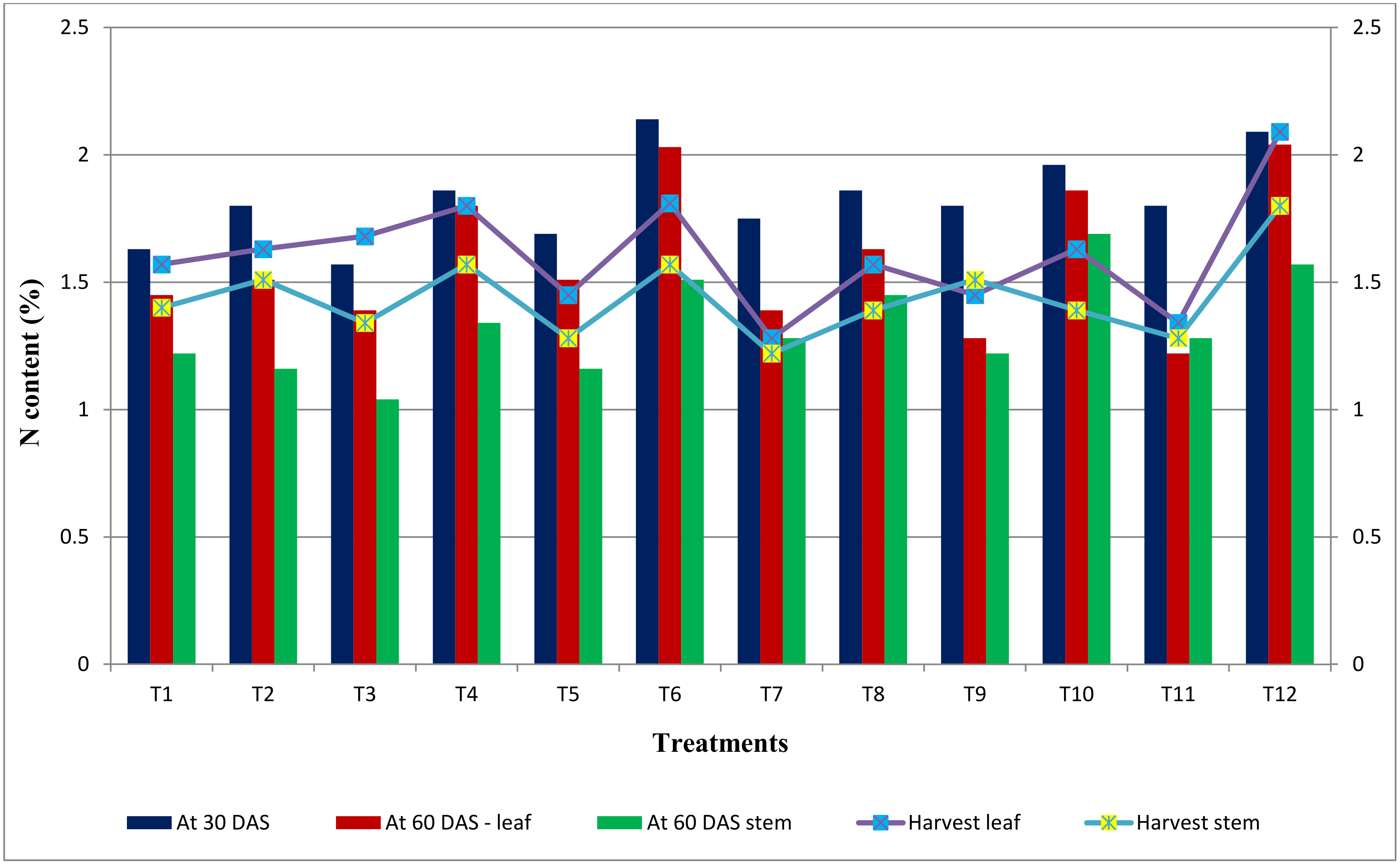


Fig.13. P content (%) of fodder crops as influenced by fodder type, spacing and N level

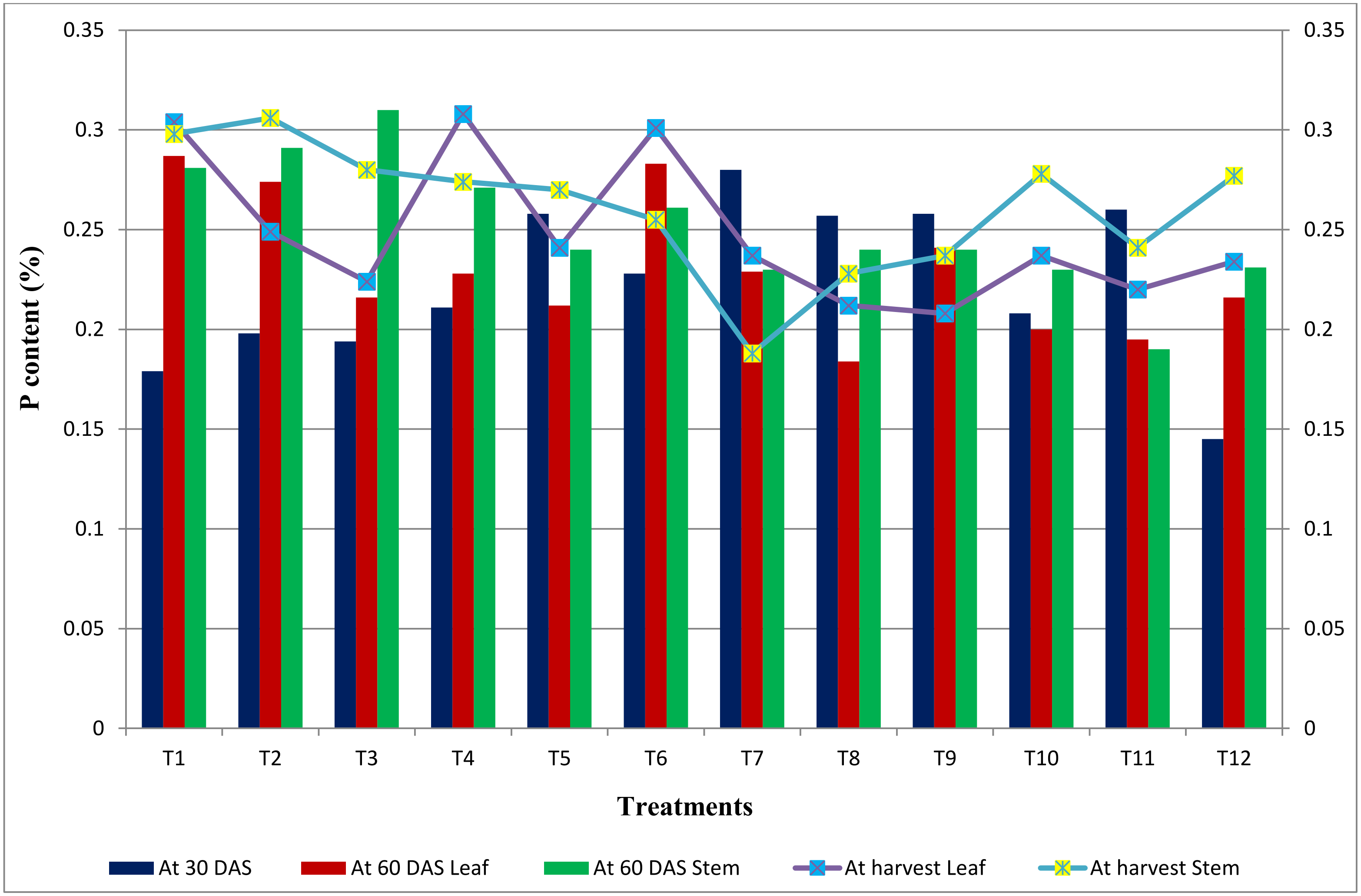


Fig.14. K content (%) of fodder crops as influenced by fodder type, spacing and N level

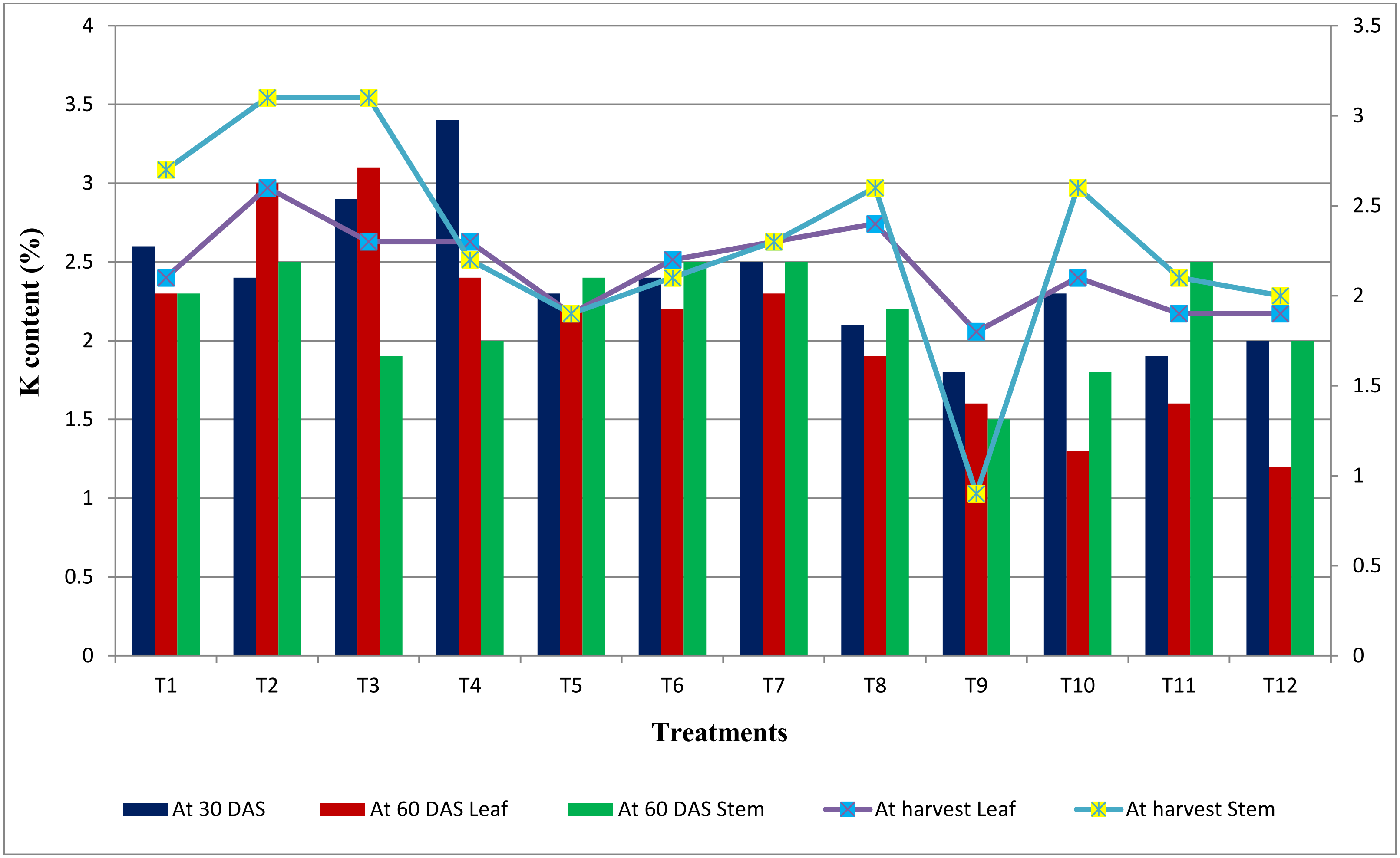


Fig.15. Ca content (%) of fodder crops as influenced by fodder type, spacing and N level

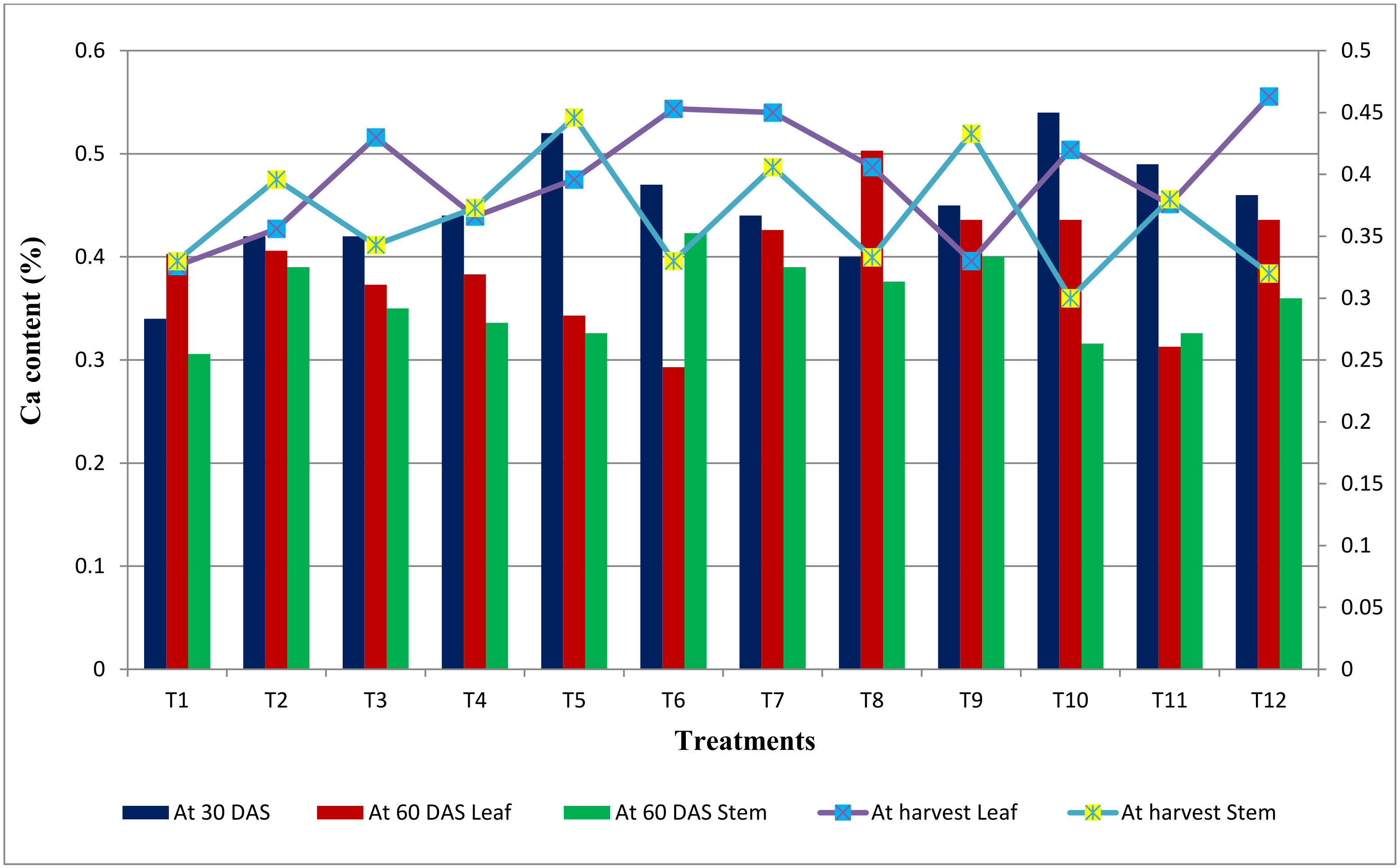


Fig.16. Mg content (%) of fodder crops as influenced by fodder type, spacing and N level

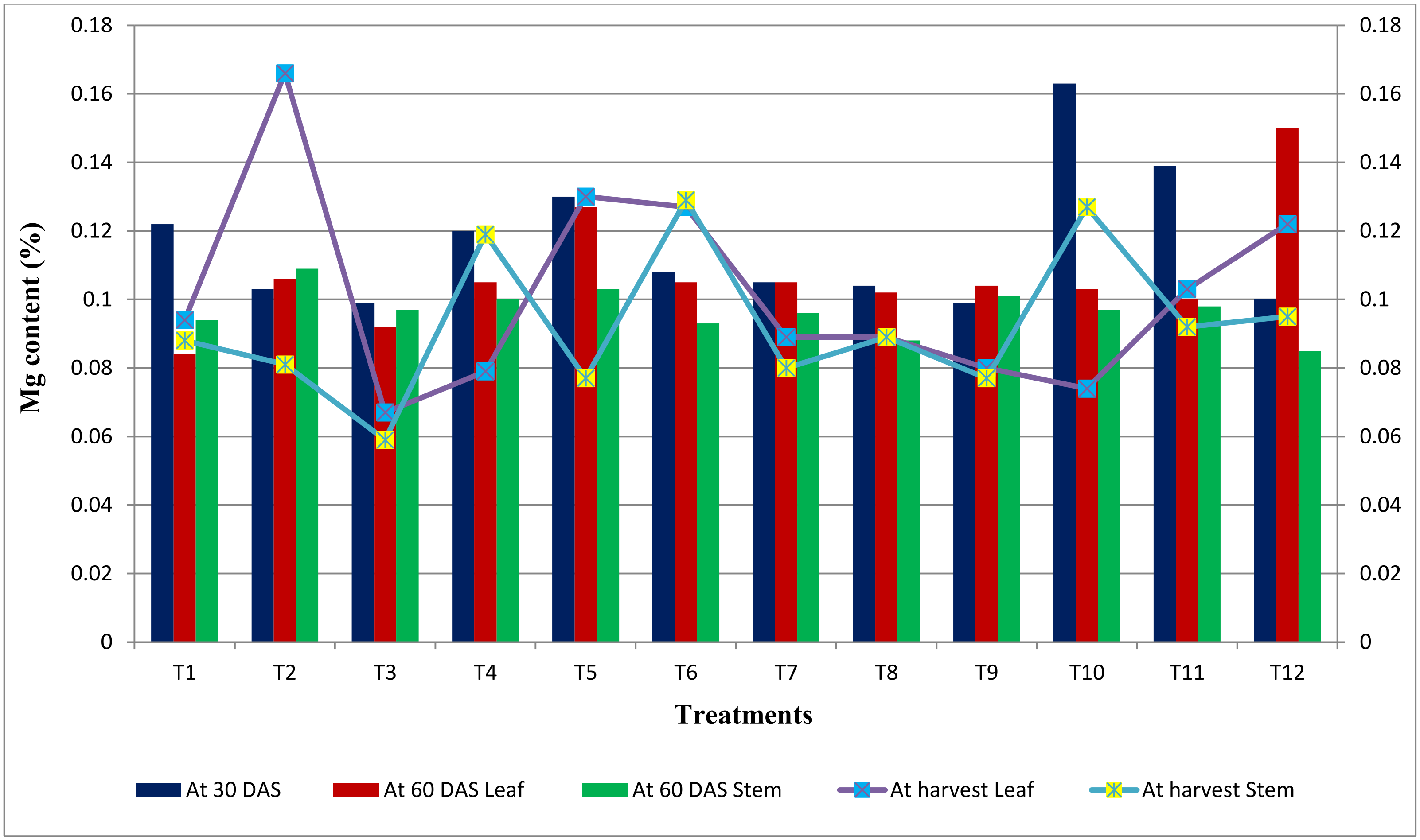
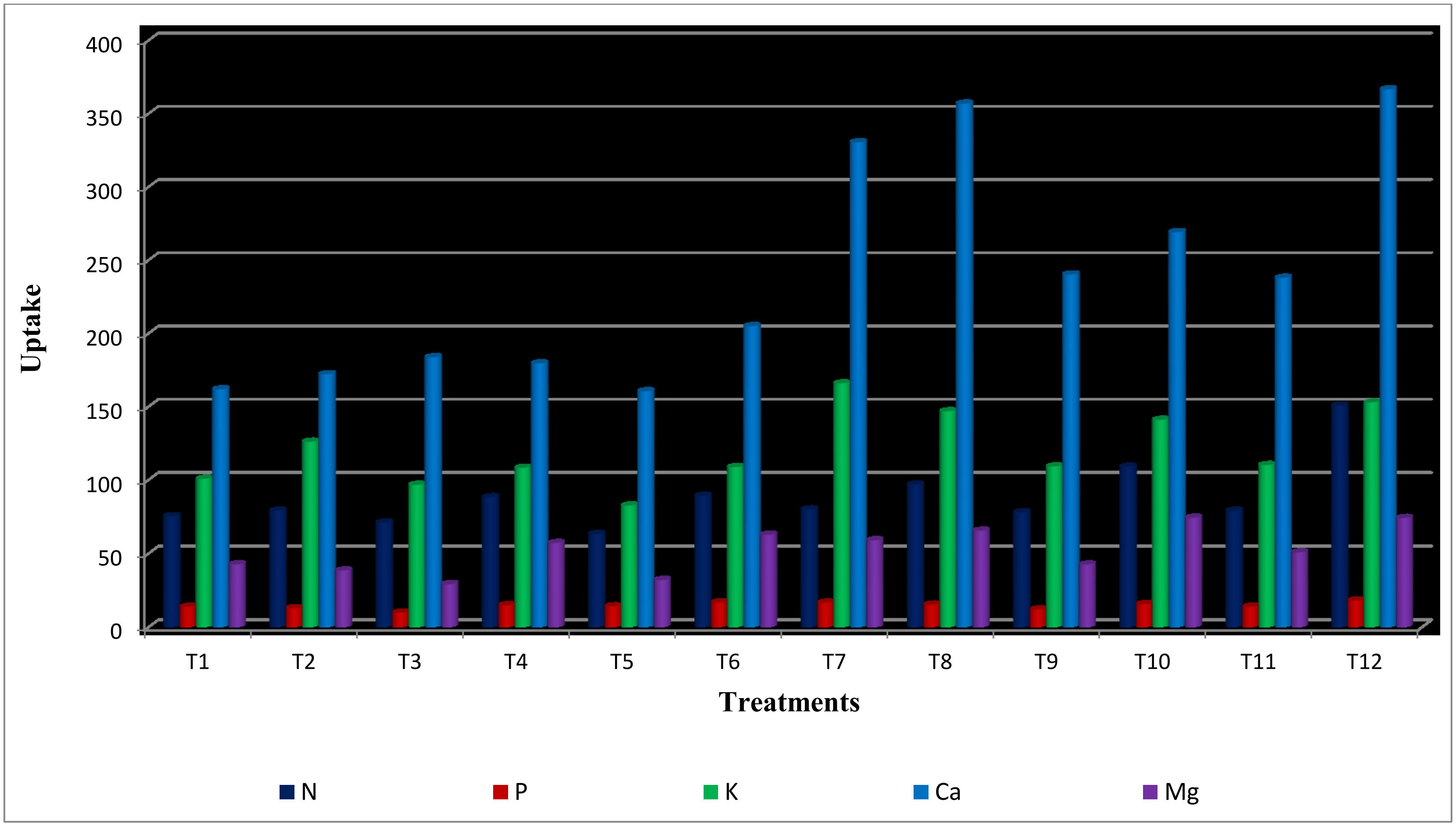


Fig.17. Nutrient uptake by fodder crops as influenced by fodder type, spacing and N level



Mg uptake was found highest (74.24 kg/ ha) in T_{10} which was followed by T_{12} (74.06). These treatments were applied with higher dose of nitrogen. The effect of nitrogen fertilizer on nutrient uptake was reported by Tiwana *et al.* (2004) and Hooda *et al.* (2004) that significant increase in fodder yield with increased levels of nitrogen and more uptake of nutrients by application of nitrogen probably favored by better growth and development of crops, resulting in increased fodder yield (Fig. 20 and 21 and 22).

5.5 NUTRITIVE VALUE AND QUALITY

Nutritive values of crops included in the study were assessed based on proximate analysis. The important quality parameter such as crude protein, crude fibre, crude fat, total ash, NFE, nitrate content and Ca and Mg ratio were done at harvest as mixed samples of leaves and stems. The data of the proximate analysis of fodder crops are given in Table 4.17 and Fig.18.

Crude protein is one of the most important quality determinants of forage crops. Forage with high crude protein contents is considered as the best quality forage. Higher the crude protein content better will be the palatability and digestibility. The variation of crude protein of the study was significant. The crude protein percentage ranged from 8.61 per cent in T_9 to 12.23 per cent in T_{12} and T_6 which were at par. It showed that irrespective of the crop higher dose of N with closer spacing gave good quality fodder from bajra and sorghum. It has been found that a minimum protein content of 5 - 6 percent is essential for the maintenance of animals and 9-10 percent for production purpose under sub - tropical conditions. Amodu *et al.* (2007) and Afzal *et al.* (2012) reported that in early stages of growth, protein accounts for 12 to 18 per cent of dry weight, but drops from 5 to 8 per cent as the plant reaches maturity. The decline in protein is most marked in taller leaves and stem. Maximum protein yield does not coincide with maximum fodder yield.

The findings of the study from T_6 and T_{12} proved that the crude protein content in the plant is directly linked to the amount of nitrogen fertilizer application that along with significant variation in crude protein content, the highest content were found from all those treatments applied with higher dose of nitrogen. It has already been found by Saini (2012) that increase in crude protein with increasing N application is due to increased absorption of N. Since N is the main constituent of amino acids, it ultimately increased crude protein contents of plants. Petal *et al.* (1994) and Rao *et al.* (2007) also confirmed that crude protein yield and N uptake increased significantly with the increase in nitrogen levels and leads to increased yields.

Crude fibre is another parameter that influences the quality of forages. The forages with less fibre contents are considered as good quality because lower the crude fibre better will be the intake, palatability and digestibility.

Crude fibre of the crops in the present study was not found significantly different but difference in data recorded might be due to the effect of nitrogen fertilizer application. Crude fibre has ranged from 31.5 per cent in (T_3) to 37.03 per cent in (T_5) in the case of fodder bajra and 32.9 per cent in (T_8) to 36.3 % in (T_9) in the case of fodder sorghum.

Regarding the relation between crude fibre and harvesting stage, Ayub *et al.* (2002) indicated that effect of harvesting stage was quite significant on crude fiber content and crude fibre production of plants. It has confirmed by Ram and Singh (2001) that the crude fibre content increased from 27.6 to 33.8 % with increase in plant age from 50 to 100 DAS.

Comparatively the treatments which received higher dose of nitrogen, resulted in lower content of crude fibre than those applied with lower dose of nitrogen where the effect of nitrogen could be seen. Regarding its importance, Babu *et al.* (1995) have mentioned that application of nitrogen significantly decreased the crude fibre which might be due to the increased uptake of nitrogen which is the constituent of amino acids and protein and decreased the pectin, cellulose and hemicelluloses which are the major constituents of fibre.

Ether extract is the amount of fat and fat-soluble components in a feed. In the present study, the percentage of crude fat was not shown significant variation. The highest fat percentage (1.86) was found from T_6 and the lowest percentage (1.56) was recorded from T_9. This finding can be supported by Tariq *et al.* (2011) who reported that the fat concentration in the plants showed a positive association with nitrogen rates which could be explained by the involvement of nitrogen in photosynthesis which are further used in the synthesis of fatty acid.

The results have shown that the fat content range is low, but in this case Ayub *et al.* (2002) indicated that crude fat content decreased as the plant age advances. Higher fat content (2.31 %) was recorded at 50 DAS as compared to 2.18 and 1.63 per cent at 75 and 100 DAS, respectively. The total production of crude fat increased due to increase in dry matter yield.

Ash is a measure of the total mineral nutrients viz., calcium, phosphorus, potassium and magnesium in the dry matter. In this study the total ash content showed significant variation from treatments applied with higher dose of nitrogen to those applied with lower dose. The maximum ash content (7.9 %) was recorded from T_6 and the minimum content (4.8 %) was observed from T_7. The difference in ash content might have been due to the effect of nitrogen that is reported by Bhilare *et al.* (2002) that total ash, ether extract content and yield increased significantly with increased nitrogen levels. Nitrogen free extract decreased significantly with increase in N level up to 240 kg ha^{-1}. Afzal *et al.* (2012) reported that nitrogen application at the rate of 100 kg N/acre have maximum (6.3 %) ash content and the effect of nitrogen application on ash content showed significant effect on sorghum forage.

Ash content was affected by stage of harvest also. Tariq *et al.* (2011) reported that the ash contents in millet was reduced with delayed harvesting due to loss of leaves and translocation of inorganic nutrients from vegetative to reproductive plant parts and Afzal *et al.* (2012) implied that, ash ranges from 8 to 11 % in young plants, but after heading decreases to 4 to 5 per cent.

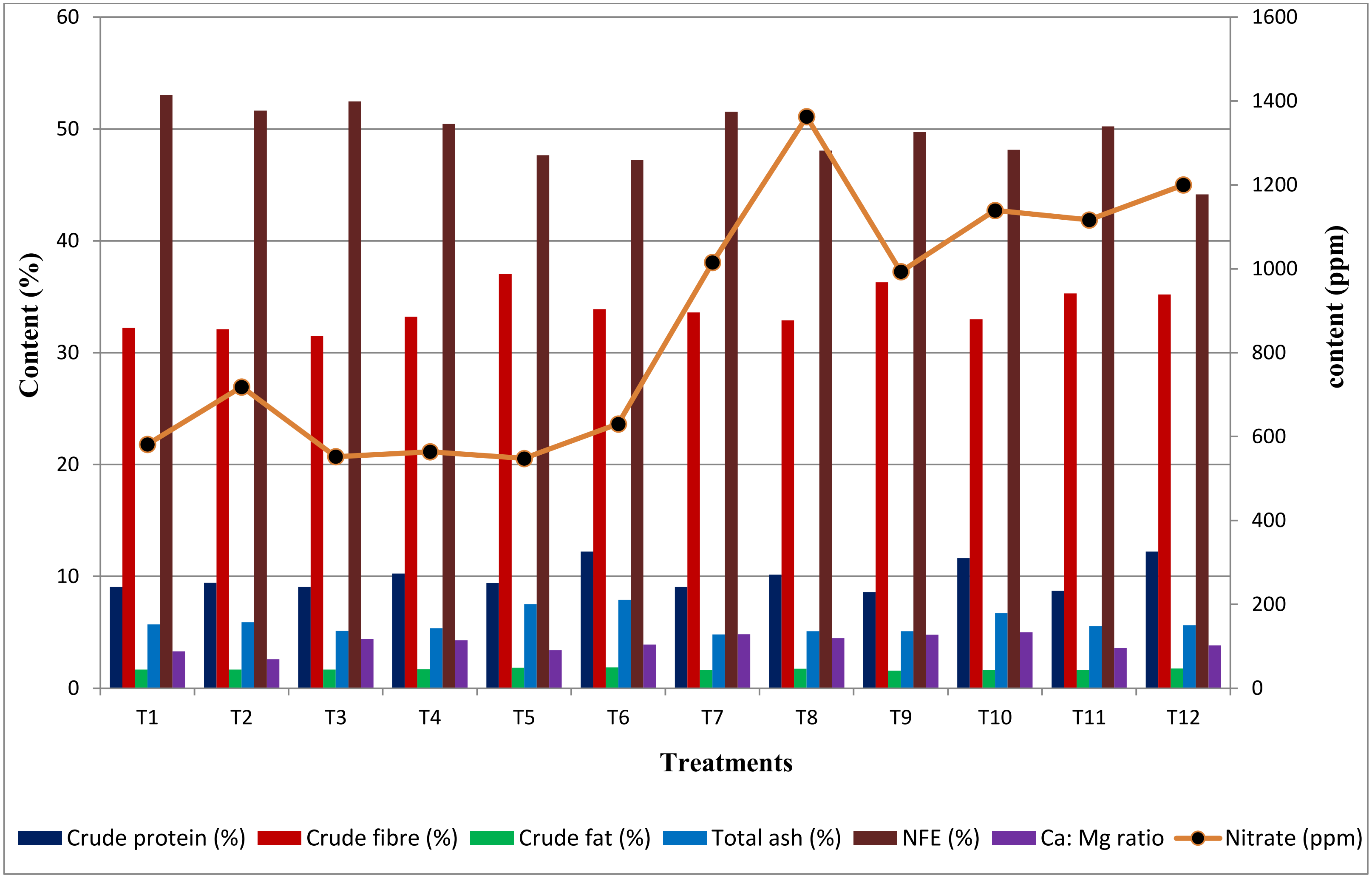
NFE is a calculated value getting after subtraction of sum of weights of water, ether extract, crude protein, crude fiber, and ash. NFE is made up primarily of readily available carbohydrates, such as sugars and starches; this fraction may also contain hemicellulose and lignin.

In the present study the percentage of NFE was not found to be significantly different. It ranged from maximum (53.06 %) in T_1 to the minimum (44.16 %) in T_{12}. All treatments with lower level of nitrogen application had higher content of NFE than those applied with higher dose. It was found out by Jakhar *et al.* (2003) that application of nitrogen significantly decreased the NFE content of fodder pearl millet. And it can also be supported by Saini (2012) who reported that the increase in nitrogen doses decreased the NFE content significantly.

Nitrate is the primary nutrient form of the nitrogen in soils and is a normal constituent of plants. Outbreaks of nitrate toxicity due to consumption of fodder containing high amounts of nitrate have been reported in farm animals throughout the world (Malhi *et al.,* 2004).

The factors that influence the accumulation of nitrate in fodder crops are species, stage of growth, part of plant, pH of soil, use of fertilizers and climatic conditions (Falkengren-Grerup *et al.,* 2004). Nitrate content in the present study was significantly different among the treatments.

Fig.18. Nutritive value and quality of fodder crops as influenced by fodder type, spacing and N level



The highest nitrate content (1362.6 ppm) recorded from T_8 followed by (1200) ppm in T_{12} and the lowest nitrate content (547.8 ppm) was recorded from T_5. Nitrate content was more in fodder sorghum compared to fodder bajra.

Radiositis *et al.* (2000) reported that the amount of nitrate accumulation within the plant depends upon the rate of nitrogen uptake and the rate of its reduction within the plant. And also it can be due to the stage of growth.

The Ca to Mg ratio is the relative proportions of Calcium and Magnesium. Ca to Mg ratio was not found to be significantly different. The highest ratio (5.0) was found in T_{10} and the lowest (2.59) in T_{12}.

5.6 SOIL ANALYSIS AFTER EXPERIMENT

Analysis for soil after experiment was done to estimate the available NPK Ca and Mg. The data pertaining to soil analysis is presented in Table 4.18 and Fig.19 and 20. All the available nutrients under study were not found to be significantly different.

Organic carbon percentage of the soil showed slight increase from 0.75 % before experiment to 0.77 % after experiment. Available nitrogen in soil showed decrease from 163.8 kg/ ha to 158.2 kg/ ha. Available P also decreased from 18.78 kg/ ha to 15.55 kg/ ha after experiment. In case of K it decreased from 102.28 kg/ ha to 101.10 kg/ ha. Regarding Ca and Mg both were increased, Ca increased from 73.47 ppm before experiment to 81.50 ppm after experiment and Mg increased from 17.56 ppm to 29.59 ppm.

pH of the soil also decreased from 5.11 to 4.93. It might be due to the inherent acidity of the soil and high rate of absorption of Ca + Mg from the soil by the fodder crops. Menon (1987) also reported that pH of the soil decreased after raising fodder crops.

Fig.19. Available NPK (kg/ ha) in soil

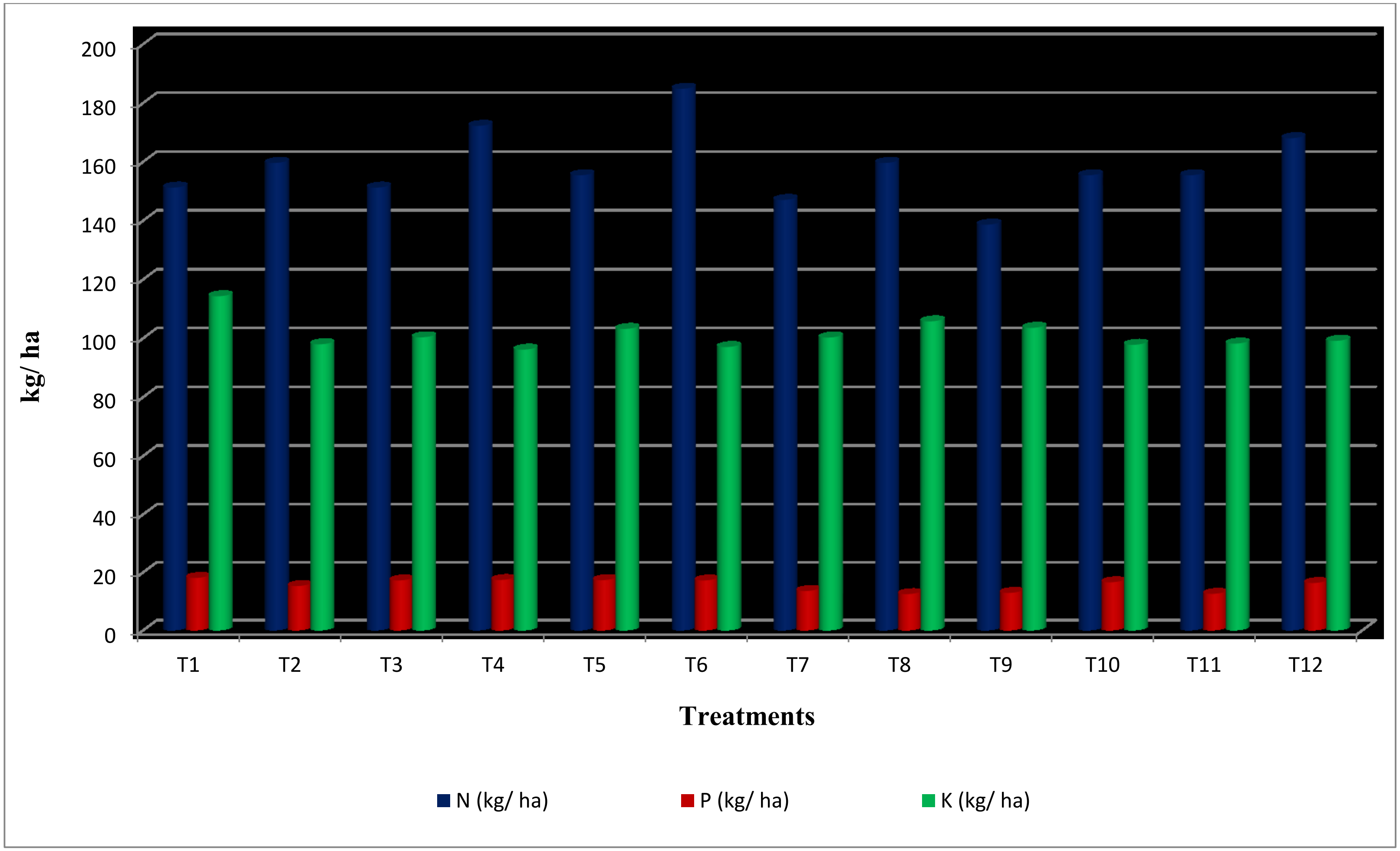
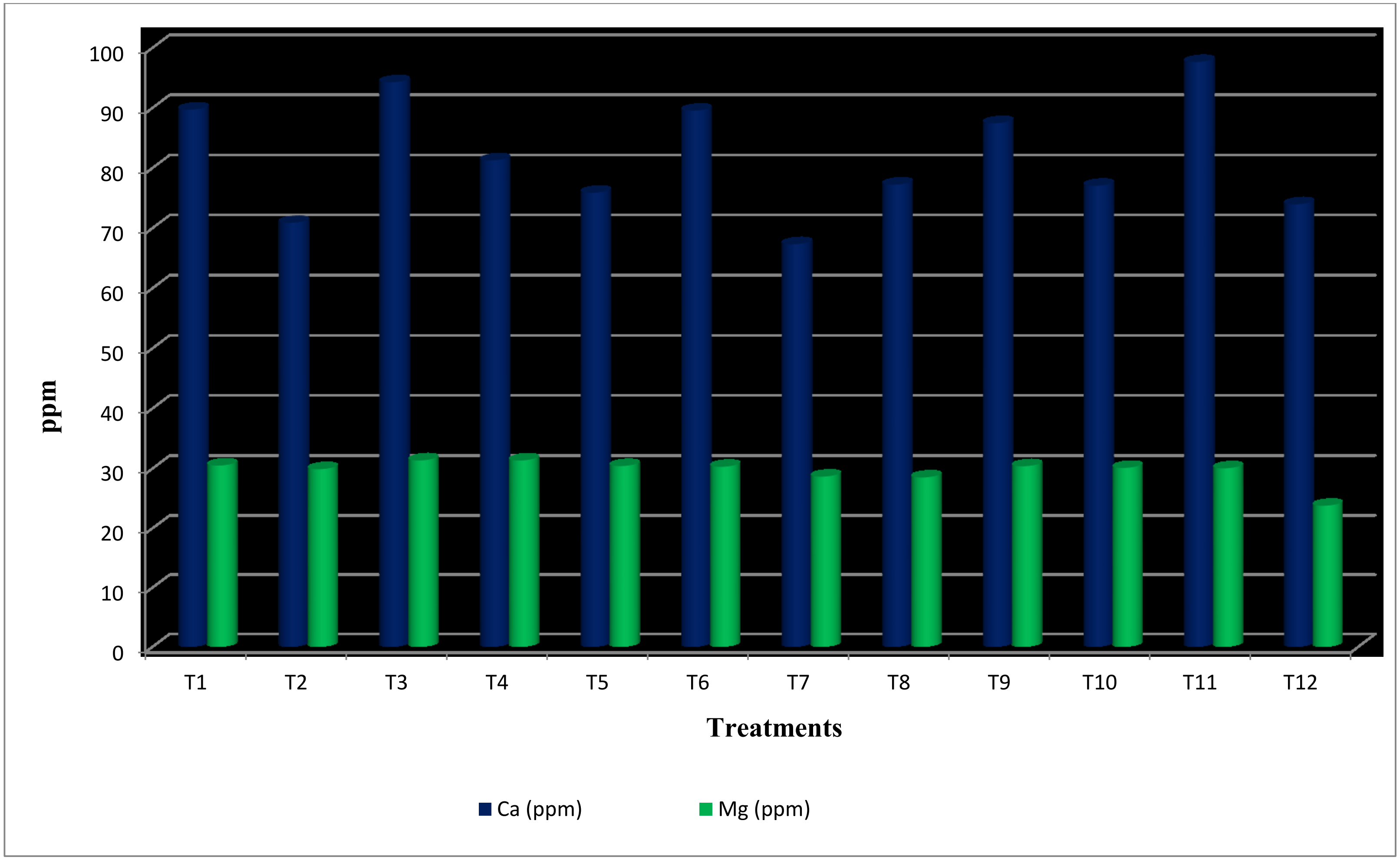


Fig.20. Available Ca and Mg (ppm) in soil



Summary

6. SUMMARY

The research project entitled "Yield maximization of fodder bajra and fodder sorghum in summer rice fallows'' to study the effect of varying plant densities and nitrogen levels on the yield and quality of fodder bajra and fodder sorghum, and the nutrient removal by these crops was conducted in the Department of Agronomy, College of Horticulture of Kerala Agricultural University during 2014.

The experiment was laid out in randomized block design with twelve treatments and three replications. The treatments comprised factorial combination two fodder crops (fodder bajra and fodder sorghum), three spacings (30 x 15 cm, 25 x 15 cm and 20 x 15 cm) and two levels of nitrogen (90 kg/ ha and 60 kg/ ha). The plant population in three spacings were 222222, 266666 and 333333 plants/ ha respectively for 30 x 15 cm, 25 x 15 cm and 20 x 15 cm spacings.

Observations on growth parameters were taken at 30 days after sowing (DAS) and 60 days after sowing (DAS). Main observations recorded were plant height, leaf area index, shoot : root ratio and leaf : stem ratio. Harvest was done at 50 per cent flowering. The yield of stem, leaves, total fodder yield and dry fodder yield were recorded. Analysis of variance was done for data collected using the statistical package, 'WASP'. Duncan's multiple range test (DMRT) was used to compare means.

Plant height was influenced by spacing and nitrogen level. The best performance of plant with respect to the plant height at 30 DAS and 60 DAS was recorded from the treatments in which plants were sown with narrow spacing and applied with higher dose of nitrogen.

The highest values of leaf area index at 30 DAS and 60 DAS were found in treatments with narrow spacing. High rate of N fertilizer resulted in high LAI.

The effect of nitrogen was also noticed in the case of leaf : stem ratio treatments applied with higher dose, resulted in higher leaf stem ratio

The highest shoot: root ratio was recorded in the treatments with wider spacing and applied with higher dose of nitrogen.

Green fodder yield

The yield of leaf, stem and total fodder were recorded separately. Stem contributed more towards leaf. The leaf yield was around 35 percent in fodder bajra whereas it was only around 22 percent in fodder sorghum. Higher fodder yield was obtained from the treatments applied with higher dose of N.

Fodder bajra had better growth initially than fodder sorghum. The highest dry matter yield obtained in fodder bajra was in the treatment which was sown at closer spacing of 20 x 15 cm and supplied with higher dose of N fertilizer (90 kg/ ha) both in the early and harvest stages. Fodder sorghum also followed the same trend. Towards the dry matter production at harvest was around 70 percent higher than that of fodder bajra.

Weed population and weed dry weight

Grass weeds were dominant over broadleaved weeds in the field. Sedge weeds were absent.

Weed dry weight at 30 DAS was highest in the treatment which was with close spacing and higher level of N. At harvest the highest weed dry weight was observed from treatment with wider spacing. At both stage the highest dry weight was recorded in fodder sorghum than that in fodder bajra. Nutrient content of weeds at 30 DAS and at harvest were found to be higher than the nutrient content of fodder crops.

Nutrient content and uptake by fodder crops

At 30 DAS the nitrogen content was more compared to the later stages probably because the stem was not much developed at that stage. At 30 DAS, N content ranged from 1.39 per cent in (T_3) to 2.13 per cent in (T_6) in fodder bajra whereas in fodder sorghum it ranged from 1.25 per cent in (T_7) to 2.09 per cent in (T_{12}). Lowest N content was found in treatments which was given lower dose of nitrogen and the highest N content was in treatments which were given higher dose of nitrogen, in both the fodder crops.

Regarding N uptake, there was no significant variation. The highest uptake (150.8 kg/ ha) was in treatment which was given higher level of nitrogen.

P content of leaves recorded higher with 0.308 per cent in T_4 which was given higher dose of nitrogen and sown at moderate spacing (25 x 15 cm). P uptake was higher with 18.03 kg/ ha in the treatment with higher level of nitrogen and narrow spacing (20 x 15 cm).

Highest K content of 3.4 per cent was observed at 30 DAS in T_4 with higher dose of nitrogen and moderate spacing (25 x 15 cm). K uptake was higher (152.83 kg/ ha) in T_{12} where fodder sorghum grown at higher level of nitrogen and sown with narrow spacing.

Highest Ca content of 0.54 per cent at 30 DAS was recorded in T_{10} which was sown at moderate spacing and given higher dose of N. At 60 DAS the highest Ca content in leaves was in T_8 (0.50 %) where fodder sorghum was sown with higher dose of N and wider spacing (30 x 15 cm). Highest Ca uptake (366.43 kg/ ha) was also in sorghum crop in T_{12} which was given higher level of nitrogen and sown with narrow spacing.

Mg at 30 DAS was high in T_{10} (0.163 %) which was given higher dose of nitrogen and grown at moderate spacing (25 x 15 cm). Highest Mg uptake 74.24 kg/ ha was also found in T_{10}.

Nutritive value and quality of fodder crops

The crude protein percentage ranged from 8.61 per cent in T_9 where fodder sorghum was grown at wider spacing and giving lower dose of N, to 12.23 per cent in T_6 and T_{12} where fodder bajra and fodder sorghum were grown with higher dose of N and closer spacing.

Crude fibre ranged from 31.5 per cent in (T_3) in which fodder bajra was giving lower level of N and wider spacing, to 37.0 per cent in (T_5) where fodder bajra was grown with lower level of nitrogen and close spacing.

The highest fat percentage (1.86) was found in T_6 where fodder bajra was grown with higher dose of N and the lowest percentage (1.56) was recorded in T_9 where fodder sorghum was grown with lower dose of N.

The highest ash content of 7.9 per cent was recorded in T_6 (fodder bajra with higher dose of N and close spacing) and the lowest content of 4.8 per cent was observed from T_7 (fodder sorghum with lower dose of N and wider spacing).

Nitrogen free extract ranged from 53.06 per cent in T_1 (fodder bajra with lower dose of N and wider spacing) to the 44.16 per cent in T_{12} (fodder sorghum with higher level of N and closer spacing). All treatments with lower level of nitrogen application had higher content of NFE than those applied with higher dose.

The highest nitrate content 1362.6 ppm was in T_8 (fodder sorghum with higher level of N and wider spacing) followed by 1200 ppm in T_{12} (fodder sorghum with higher level of N and closer spacing) and the lowest nitrate content 547.8 ppm was recorded from T_5 (fodder bajra with lover level of N and closer spacing). Nitrate content was more in fodder sorghum compared to fodder bajra.

Regarding to Ca - Mg ratio, the highest ratio (5.0) was found in T_{10} (fodder sorghum with higher dose of N and moderate spacing) and the lowest ratio was (2.59) that found in T_2 (fodder bajra with higher level of N and wider spacing).

Soil analysis after experiment

Organic carbon percentage of the soil showed slight increase from 0.75 per cent before experiment to 0.77 per cent after experiment. Available N, P and K were decreased. Regarding to Ca and Mg both were increased. Soil pH was decreased.

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Appendix

Appendix 1. Meteorological data for the experimental period (April - June 2 014)

Standard weeks	Period	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Relative humidity (%)		Wind velocity (Km/hr)	Total sunshine hours	Mean evaporation mm/day	Total rainfall (mm)
				Day	Night				
14	April	34.2	25.3	92	58	*	35.2	4	0
15		35.4	25.7	89	57	*	48	4.8	0
16		34.5	24.5	84	52	*	52.9	4.8	0
17		35.2	25.1	85	54	*	45.6	4.6	0
18		34.7	26.0	91	60	*	27.3	3.4	0
19	May	34.3	25.8	92	58	2.6	26.2	3.7	0
20		34.4	25.1	89	55	3.1	38.2	4.6	6.4
21		34.0	24.6	92	61	2.4	36.8	3.4	5.7
22		29.9	23.5	96	79	1.8	11.3	2.5	210.8
23	June	29.4	22.8	95	79	1.7	8.4	2.8	149.2
24		28.6	22.3	97	87	2.2	7.6	2.8	302.5
25		27.5	23.0	98	86	1	3.4	1.9	284.1

Abstract

YIELD MAXIMIZATION OF FODDER BAJRA AND FODDER SORGHUM IN SUMMER RICE FALLOWS

by

QUWAT ALI

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ABSTRACT OF THE THESIS

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ABSTRACT

Fodder crops have an important role in meeting the feed requirement of animals which provide roughages as well as nutrients to them. Green fodder is an essential component of feeding high yielding animals to obtain optimum level of production. Among various agronomic factors, proper fertilizer application and appropriate planting geometry are of prime importance in getting higher forage yield of better quality. Among different nutrients, nitrogen is considered to be the most important, which improves quality of fodder especially crude protein.

A field experiment to study the effect of varying plant densities and nitrogen levels on yield and quality of fodder bajra and fodder sorghum, and the nutrient removal by these crops was conducted during 2014. Factorial combinations of two fodder crops (F_1 - Fodder bajra and F_2 - fodder sorghum), three spacings (S_1 - 30 x 15 cm, S_2 - 25 x 15 cm and S_3 - 20 x 15 cm) and two N levels (N_1 - 60 kg ha^{-1} and N_2 - 90 kg ha^{-1}) were the treatments. Observations on growth and yield of fodder crops, nutrient contents, fodder quality parameters, soil characters and weed incidence were recorded.

Analysis of data on growth parameters showed that spacing and proper nitrogen fertilizer application are the key factors to increase the plant growth and produce higher yield in fodder crops. Fodder yield was more in fodder bajra than fodder sorghum. The highest fodder yield was 27 t ha^{-1} and 24 t ha^{-1} for fodder bajra and fodder sorghum, respectively. Higher fodder yields were obtained from the treatments which were given higher dose of N. The highest dry matter yield for fodder bajra was in the treatment which was sown at closer spacing and given higher dose of N fertilizer, both in the early stage and towards harvest. Fodder sorghum also followed the same trend. But the dry matter production at harvest was around 70 percent higher than that of fodder bajra. Regarding weed population, grass weeds

were dominant over broadleaved weeds, and sedge weeds were absent. Dry weight of weeds at harvest was comparatively more in fodder sorghum than fodder bajra due to more light interception in sorghum leading to higher dry matter production of weeds. In case of nutrient removal by weeds it was more in fodder sorghum than fodder bajra.

N content of the leaves was higher than that in the stems. Application of higher dose of N fertilizer always resulted in higher N content. The average N content in fodder bajra and fodder sorghum did not show much variation. N, P, K, Ca and Mg uptakes were recorded higher in fodder sorghum with closer spacing and higher dose of nitrogen. Irrespective of the crops, higher dose of N with closer spacing gave good quality fodder from both bajra and sorghum. Higher crude fibre and nitrogen free extract were recorded from the treatments applied with lower dose of nitrogen, but ash content, crude fat and nitrate content of the fodder crops were higher in treatments applied with higher dose of nitrogen.

Organic carbon percentage of the soil showed slight increase. Available N, P and K in soil showed reduction. However, Ca and Mg contents were increased. pH of soil also showed decrease.

The study revealed that spacing and application of nitrogen fertilizer influenced growth, fodder yield, dry matter production and quality of both fodder bajra and fodder sorghum. As the spacing decreased and level of nitrogen fertilizer increased, fodder bajra and fodder sorghum performed better and produced higher yield.