FODDER PRODUCTION POTENTIAL OF MAIZE (*Zea mays* L.) + COWPEA (*Vigna unguiculata* L.) INTERCROPPING UNDER DIFFERENT NITROGEN LEVELS

A

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DECLARATION

I, Hannah Krujia Asangla, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

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C E R T I F I C A T E

This is to certify that the thesis entitled, **'Fodder production potential of maize (*Zea mays* L.) + cowpea (*Vigna unguiculata* L.) intercropping under different nitrogen levels'**, submitted for fulfilment of the requirements for the award of DOCTOR OF PHILOSOPHY (Agriculture) in Agronomy under Nagaland University, Medziphema is a record of bonifide research work carried out by Mrs. Hannah Krujia Asangla, Reg. No. 613/2014 under my guidance and supervision.

The candidate has fulfilled all the requirements under the Ph. D. regulations of Nagaland University and the thesis or part of it has not been submitted to any other University for any degree or distinction.

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LIST OF ABBREVIATION

ANOVA	–	Analysis of Variance
Anon.	–	Anonymous
@	–	At the rate of
C.D.	–	Critical Difference
cm	–	centimeter
DAS	–	days after sowing
DMD	–	Dry matter digestibility
°C	–	Degree centigrade
DF	–	Degree of Freedom
et al.	–	*et alia* (and others)
Fig.	–	Figure
FYM	–	Farm Yard Manure
g	–	gram
ha	–	hectare
ICAR	–	Indian Council of Agricultural Research
i.e.,	–	that is
IVOMD	–	*In vitro* organic matter digestibility
IVDMD	–	*In vitro* dry mater digestibility
kg	–	kilogram
K_2O	–	potassium
m	–	meter
Max	–	Maximum
Min	–	Minimum
MOP	–	Muriate of Potash
MSS	–	Mean Sum of Square
NDF	–	Neutral Detergent Fibre
NRC	–	National Research Centre
NS	–	Non Significant
P_2O_5	–	phosphorus
q	–	Quintal
SEm	–	Standard Error Mean
SS	–	Sum of Square
Viz.,	–	Namely

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CHAPTER-I

INTRODUCTION

Indian agriculture is basically a mixed farming enterprise, where crop production and livestock are the major functional components. The cropping programme is supported by livestock production as a complimentary source of income, employment of family and ultimately the livelihood improvement of about 70 per cent population of the country. However, the low productivity of livestock is attributed to poor fodder and feed resources. At present, the country faces a net deficit of 61.1 per cent green fodder, 21.9 per cent dry crop residues and 64 per cent feeds. According to Kumar (2012) it was estimated that the average cultivated area devoted to fodder production was around 4 to 5 per cent of the total cultivated area. To meet the current level of livestock production and its annual growth in population, the deficit in all components of fodder, dry crop residues and feed has to be met either from increasing productivity or by utilizing untapped feed resources (Raju, 2013). The green fodder crops are known to be cheaper source of nutrients as compared to concentrates and hence useful in bringing down the cost of feeding and reduce the need for purchase of feeds, concentrates from the market. The adequate supply of nutritive fodder and feed is a crucial factor impacting the productivity and performance of the animals.

Fodders as a group of crops differ from food and commercial crops as they are primarily grown for the fresh green vegetative biomass. The plant species are cultivated and harvested for feeding the animals in the form of forage mostly at its vegetative stage of growth. There is therefore, emphasis on increasing per day productivity for obtaining higher biomass yield in single as well as multicut forage species. Feed and fodder production and its utilization depend on the cropping pattern, climate, socio economic condition and livestock type. Cereal fodders and grasses are characteristically determinate in growth habit and their herbage quality deteriorates after flowering. They have wider adaptability and variability in terms of growth, regeneration potential, yield and quality of herbage. Cereal forages such as maize, sorghum, oat, barley and millets give higher forage yield but are deficient in protein contents. Forage legumes such as soybean, cowpea, cluster bean etc. are rich sources of protein but their forage yield only half in comparison with cereal forages (Iqbal *et al*., 2015). Legumes by and large are indeterminate in growth habit and thus maintain quality traits over longer periods. In fodder production, legumes have special significance because of high herbage quality protein and partial independence from soil for their nitrogen needs. They also fix and add atmospheric nitrogen through their root nodules in the soil (Agrawal *et al.*, 2008).

Maize (*Zea mays* L.) is one of the most important cereal crops of the world used both as food and feed. When grown as fodder, the crop gives huge quantities of green herbage in a short time. It is the most nutritious, succulent, palatable and considered most ideal crop because of its quick growth and high yield and therefore, aptly called the 'king of cereals'. Maize being an exhaustive crop has very high nutrient requirement and its productivity is closely linked with proper and adequate nutrient management (Rajeshwari *et al*., 2007). Maize is almost free from antinutritional factor and is most preferred grain for feed. A total of 59 per cent of total maize grain produced in the country is utilized in manufacture of concentrate feed for livestock (Raju, 2013). Maize is an important dual purpose crop used in human diet and animal feed. It has the potential to supply large amount of energy rich forage for animal diets, and its fodder can safely be fed at all stages of growth without any danger of oxalic acid, prussic acid as in case of sorghum causing harm to animals (Dahmardeh *et al*., 2009). Although maize provides high yield in terms of dry matter, it produces forage with low protein content. Protein is also needed by rumen bacteria which digests much of the feed for ruminant animals (Ghanbari, 2000) which becomes necessary to provide livestock with protein supplements when forage quality is low. Cowpea an annual legume with high level of protein can be mixed with maize to improve forage protein content in diets and thus cost of high quality forage production can be lowered (Eskandari and Ghanbari, 2009).

Protein rich forage legumes provide cheaper source of quality feed and enhance animal productivity when grown with grasses in the tropics (Thomas *et al*., 1997). Forage legumes are important as they enrich the nitrogen content of the soil and have a high nutritive value (Dev, 2001). Cowpea (*Vigna unguiculata* L. Walp) is an important pulse crop of high protein content which can be grown as a fodder crop. In India it occupies 0.3 million hectare out of 0.65 million hectare area under different pulse and vegetable cowpea (Raju, 2013). It is a quick growing crop, which produces remarkable quantity of bulk in a short span of time and therefore is esteemed as a valuable catch crop as fodder, green manure, grains or vegetable crop (Thomas, 2003). Cowpea fits well in intercropping with maize, bajra and sorghum and have potential of dual type varietal development of forage and vegetable.

Cultivation of two or more crops simultaneously on the same field for higher yield and increased economic returns is important in the present context of agricultural scenario. The per capita availability of cultivable land has been shrinking due to increasing demographic pressures. The concept of intercropping is to get increased total productivity per unit area and time besides equitable and judicious utilization of land resources and farming inputs (Marer *et al*., 2007) in other words, it is crop intensification in both time and space dimension. Thus intercropping system can provide many benefits through increased efficiency of land use, enhancing the capture and use of light, water and nutrients, controlling weeds, insects, diseases and increasing the length of production cycle (Alla *et al*., 2014). Intercropping was originally practiced as an insurance against crop failure under rainfed condition. The current trend in global agriculture is to search for highly productive, sustainable and environmentally friendly cropping systems (Crew and Peoples, 2004). Intercropping legumes contribute to increased productivity of other crops when incorporated into cropping systems as intercrops (Giller and Wilson, 1991). Maize-legume intercropping is currently receiving global attention because of its prime importance in world agriculture. According to Sullivan (2003), intercropping offers farmers the opportunity to engage nature’s principle of diversity on their farms. It is a system of cultivation of cereal as the primary food crop but on a legume base. The growing of fodder crops in mixture with legumes enhanced fodder palatability and digestibility (Chaudhary and Husain, 1985). Patel *et al*. (1987) reported that intercropping can provide substantial yield advantage as compared to sole cropping. Other studies carried out by Malakar *et al.* (2009) and Polthanee and Treloges (2003) also showed that intercropping have more yield advantages over sole cropping as a result of complementary use of growth resources. There were also some contrary reports that the dry matter yields of maize sown alone were greater than with soybean intercropping however, such intercropping gave higher crude protein yields than maize alone (Khandaker, 1994). Thus, it is justified that, intercropping has been recognised as a beneficial system for crop production.

Introduction of high yielding varieties coupled with irrigation facilities and increased use of fertilizers and other agro chemicals have brought about spectacular increases in the yield of crop. According to Acharya and Sharma (2008) about half of the total increase in food grain production in the post green revolution era had been attributed to the use of fertilizers and more than one third of the increase is due to nitrogen fertilizers alone. Bindhani *et al.* (2007) emphasized that the acidic rainfed upland soils are generally low in organic matter, where application of nitrogen fertilizers is highly necessary to meet the nitrogen requirement. According to Iqbal *et al.* (2014) plant nutrition has a significant effect on forage maize yield, particularly nitrogen supplied either through inorganic or organic means. Response of a crop to added nitrogen fertilizers is largely dependent on nutrient supplying capacity of the soil and crop requirement is influenced by several management practices. The requirement of fodder crops for nutrients particularly nitrogen is comparatively higher. This is due to the fact that fodder crops are grown to produce luxuriant and succulent vegetative growth in a short period (Agrawal *et al*., 2008). The supply of recommended dose of fertilizer to both component crops could increase the yield in an intercropping system. In addition the fertilizer needs of a component crop in cereal-legume intercropping systems are likely to be very different from the requirements of respective sole crop, which is logical as two crops grown in association may or may not exploit the growth resource fully (Roy and Barun, 1983). In cereal-legume intercropping system, recommended amount of chemical fertilizer for main crop being applied; the assumption is that the legume component can fulfill its own requirement (Sharma and Gupta, 2001).

Agriculture as a whole in Nagaland is totally rainfed due to the agro-ecological condition and the undulating topography of the land. Livestock management in the state is indeed a great challenge faced by the local farmers. The need to create awareness in modern management techniques especially of growing fodder crops as feed for livestock becomes a necessity in order to encourage farmers to rear livestock under intensive system. There are very few works done under hilly ecosystem and in view of the above points, it was felt pertinent to conduct this experiment under the agroecological conditions of Nagaland entitled "**Fodder production potential of maize (*Zea mays* L.) + cowpea (*Vigna unguiculata* L.) intercropping under different nitrogen levels**". This investigation was undertaken with the following objectives:-

1. To evaluate the suitable planting geometry of maize + cowpea intercropping.
2. To determine the optimum dose of nitrogen for maize + cowpea intercropping.
3. To estimate the economics of various treatments

CHAPTER-II

REVIEW OF LITERATURE

Agriculture and animal husbandry in India are interwoven with the intricate fabric of the society in cultural, religious and economical ways as mixed farming and livestock rearing forms an integral part of rural living and has been a source of employment in rural areas for centuries. There is tremendous pressure of livestock rearing and availability of feed and fodder, as land available for fodder production has been decreasing. The livestock population is expected to grow at the rate of 0.55 per cent in the coming years and the population is likely to be around 781 million by 2050. Further, India is among the leading producers of milk, meat and eggs. The productivity of our animals is 20 to 60 per cent lower than the global average due to improper nutrition, inadequate health care and management. Half of the total losses in livestock productivity are contributed by the inadequacy in supply of feed and fodder (Anon., 2013). At present the country faces a net deficit of 61.1 per cent of green fodder, 21.9 per cent of dry crop residues and 64 per cent of concentrate feed ingredients (Raju, 2013). India has nearly 4.9 per cent of the total cropped area under cultivated forages. Intricate technologies have been developed for increasing fodder production in different situations with stability and sustainability of cultivated and non cultivated fodder crops (Anon., 2013). Feed and fodder production and its utilization depend on the cropping pattern, climate, socio economic condition and livestock type. Without ensuring an adequate supply of quality feed and fodder, the achievement of targeted growth of livestock sector in the coming years looks almost impossible (Kumar, 2012).

Literatures published in this regard more so with regard to fodder maize and cowpea intercropping under different nitrogen levels are reviewed and presented in this chapter.

2.1 Intercropping as a practice

Intercropping system improves cropping intensity as two or more crops occupy the land simultaneously. Intercropping of forage legumes with forage maize not only improves the nutritive value of fodder but also help in maintaining the soil fertility (Berg, 1990). Ibrar *et al*. (2002) reported beneficial effects of legumes intercropped in maize on soils with low fertility as legumes fix atmospheric nitrogen besides meeting their own nitrogen requirements. This eventually helps in partially meeting the nitrogen needs of cereals.

Grossman and Quarles (1993) divided intercropping two or more crops simultaneously on the same piece of land into four basic different spatial arrangements:

i) Row intercropping – planting two or more crops simultaneously with both crops planted in distinctive row.
ii) Strip intercropping – planting of two or more crops together in strips wide enough to permit separate crop production practices using machines, but close enough for the crops to interact.
iii) Mix intercropping – planting of two or more crops together without any distinct row arrangement.
iv) Relay intercropping – planting of a second crop into an already standing crop which is at its reproductive stage or has completed its reproductive development, but before harvesting.

The principal reasons for farmers to intercrop are flexibility, profit maximization, risk minimization against crop failure, soil conservation and maintenance, weed control and balanced nutrition. Cereal and legumes which has become a popular combination among farmers was probably due to legumes ability to combat soil erosion and raise its fertility levels (Matusso *et al*., 2012). Moreover, they have the potentials to give higher yield than sole crops, greater yield stability and efficient use of nutrients (Seran and Brintha, 2010). Similarly, better weeds control, improvement of quality by diverse crops while cereal crops require larger area to produce same yield as cereals in an intercrop system (Ijoyah, 2012). Reduction in yield of component crop may occur due to intense competition, the situation in which two or more plants share the same growth factors each far below their combined demands and in the same environment is known as competition (Thole, 2007). The basic morpho-physiological changes and agronomic features such as fertilizer application, sowing time, and proportion of crop mixture are basic determinants of competition between component crops. Where constituent crops are arranged in certain rows, the degree of competition is determined by the comparative growth rates, growth duration and proximity of roots of the diverse crops. The cereal component in a cereal + legume intercrop has advanced growth rate, height advantage, and a more widespread rooting system which gives it upper hand in competition with associated legumes. Among the various combinations of cereals and legumes, maize and cowpea is most widely used by small scale farmers (Mpangane *et al*., 2004). Filho (2000) reported that intercropped maize is more competitive than cowpea in terms of use of available resources mainly soil water. The major disadvantage is that intercropping is not well adapted to very dry, poorly drained and heavy clay soils and also implies difficulty in harvesting, using machinery.

2.2 Effect of intercropping on growth, yield and quality attributes

2.2.1 Growth attributes

Meena *et al*. (2007) reported that all the growth parameters of *cenchrus* and cowpea viz., plant height, number of tillers per plant in *cenchrus* and branches per plant in cowpea and dry matter production per plant of both the crops were affected significantly by different inter row ratios. The highest increase in growth parameters were recorded at 1:2 row ratios followed by 1:1 and 2:1 row ratios which might be due to fixation of atmospheric nitrogen into soil by root nodules of cowpea and reduced inter row specific competition of solar radiation and plant nutrient.

Alhaji (2008) in his study on the yield performance of some cowpea varieties under sole and intercropping with maize at Bauchi, Nigeria found that intercropping of different varieties of cowpea with maize significantly affected the plant height, leaf area and leaf indices of maize. Nadeem *et al*. (2009) reported that maize sown alone produced significantly taller plants and higher number of leaves per plant than sown in mixture with legumes, however it was statistically similar to mixed sowing of maize + *sesbania.* The reason of shorter plants can be attributed to more competition due to having more number of plants per square metre in case of maize + legumes cropping. Increase in plant height under sole maize sowing was also observed by Hugar and Palled (2008). According to Eskandari and Ghanbari (2009), the cereal component maize is usually taller than the legume cowpea and has a faster growing or more extensive root system, particularly a larger mass of fine roots and is competitive for soil nitrogen. This enables the legume component cowpea to fix nitrogen from the atmosphere which is expressed as a facilitative effect of intercrop components that maize and cowpea have complimentary effect in assimilating nitrogen. Studies conducted by Undie *et al*. (2012) in the first year of study (2007) on maize+soybean intercropping and crop arrangement had no significant effect on plant height of maize at all the sampling intervals while in 2008, intercropping and crop arrangement significantly influenced plant height at all the sampling periods. At 4 weeks after sowing, the plant height of sole maize was statistically similar to plant height of 1:1 and 2:2 arrangements. At 10 weeks after sowing, difference in plant height between the sole maize and 1:1 crop arrangement was statistically the same but significantly higher than those at 2:2 or 1:2 arrangements. Their study also revealed that in both the years sole maize consistently produced the highest number of leaves than any of the intercropping arrangements at four sampling intervals. In soybean, intercropping and crop arrangement significantly affected the number of leaves at all the sampling intervals. At 4 weeks after sowing in 2007 and 6, 8, 10 and 12 weeks after sowing in both years, the sole crop produced significantly higher number of leaves per plant than either 1:1, 1:2 or 2:2 intercropping arrangements, while the 1:1 arrangement produced significantly the lowest. Studies conducted by Choudhary *et al.* (2012) on production potential, soil moisture and temperature as influenced by maize + legume intercropping revealed that significantly taller plants, LA, LAI and DMP were observed with sole maize. The lowest plant height was recorded on 1: 5 maize + black gram intercropping followed by 1:5 maize + french bean intercropping. Increase in plant height under maize sole treatment was due to the fact that the wider space available in sole maize reduced the competition of light and nutrients, which probably provided favourable physical environment and helped the plant to grow taller. Lemlem (2013) also found that intercropping maize with cowpea reduced maize plant height. Nyasasi and Kisetu (2014) assessed the response of maize and cowpea under sole and intercropping system at the Sokoine University of Agriculture Farm, Tanzania and reported that the height of maize plant was relatively smaller in intercrop than in sole maize. In another study, intercropping cowpea with maize resulted in an increase in maize plant height especially when the intercropped crops were planted at the same of maize planting date (Keriasha *et al*., 2010). The vegetative growth of component crop in a mixture was affected by intercropping (Mangasini *et al*., 2012). Similarly, Refay *et al*. (2013) observed that sorghum intercropped with cowpea exhibited greater potentiality and recorded higher values of plant height and grain yield per plant. Alla *et al*. (2014) observed that the height of maize plant under intercropping system was more than that in the sole maize may be due to competition of associated crops for interception of light intensity. Mobasser *et al*. (2014) found that intercropping cereal and grain legume crops helps maintain and improve soil fertility because crops like cowpea, mung bean and soybean accumulate from 80 to 350 kg N/ha.

2.2.2 Yield and yield attributes

Intercropping corn and soybean under different planting pattern and nitrogen fertilizer revealed that seed yield of soybean was the highest compared with intercropped patterns in which the competition for resources highly affected yield and yield components (Panhwar *et al*., 2004). Similarly, Abera *et al*. (2005) reported that intercropping gave significantly higher combined yield than from the monoculture which might be probably due to marked morphological difference of the two crops which facilitates better utilization of more light and other environmental resources. There was highest green fodder and dry matter production when *Cenchrus* and cowpea were sown in 1:2 row ratio which might be due to beneficial effect of cowpea on *Cenchrus* in cereal legume intercropping system through fixation of atmospheric nitrogen into root system of associated *Cenchrus* (Meena *et al*., 2007).

According to Surve *et al*. (2012), intercropping system of maize and cowpea in 2: 1 row ratio showed higher green fodder yield than sole maize whereas in 1:1 and 1:2 row ratio system the green fodder yield was decreased over sole maize and sole cowpea. Under cereal legume intercropping system better utilization of crop production resources might have increased the yield. The highest green forage yield of 12.22 tonnes per hectare and dry matter yield of 2.039 tonnes per hectare were recorded for cowpea sown in alternate rows with forage maize (Iqbal *et al*., 2012). Studies reported by Mukhtar (2014) revealed that cowpea intercropped with maize at 1:1 row arrangement recorded the highest grain yield per plant and per hectare, which was significantly different from sole crops.

According to Prasanthi and Venkateswaralu (2014), legume fodders intercropped within the pairs of maize performed better with lower reduction in dry matter indicating better utilization of environmental resources and the availability of ample space between paired rows. The highest total dry matter was recorded in treatments, maize pairs + cowpea. Studies carried out by Pal *et al*. (2014) reported that sole sorghum produced significantly higher dry forage yield that was statistically at par with sorghum + cowpea (25 %) intercropping system.

Intercropping offered more plants per unit area and efficient utilization of environmental and soil resources. Nutrient contribution of legume fodders may have also played a positive role. Intercropping tend to ameliorate some of the fertility constraint of poor farmlands. Adeleke and Haruna (2012) mentioned that pulses are usually intercropped with cereals and advance land productivity over soil amelioration. In a study, Vesterager *et al*. (2008) found maize and cowpea intercropping as beneficial on nitrogen poor soil. Maize /cowpea intercropping increases the amount of nitrogen, phosphorus, and potassium contents associated to monocrop of maize (Dahmardeh *et al*., 2010).

Maize + legume intercrop could considerably increase forage quantity and quality and lessening condition for protein supplement (Ali and Mohammad, 2012). Intercropping cereals and legumes is important due to some potential benefits including the enhancement of forage quality through the complimentary outcome of two or more crops grown instantaneously on the same part of land (Hamdollah, 2012). Study conducted by Choudhary *et al*. (2012) revealed that the maize grain yield was significantly higher in sole maize followed by 1:1 maize + cowpea. However 1:5 maize + blackgram recorded with the tune of 87.3 per cent lower grain yield followed by 1:5 maize + frenchbean and 1:5 maize + cowpea (86.6 and 83.5 per cent respectively). An important measure in grass land resource is the yield of forage; this defines the volume of dry matter obtainable to livestock, thus legume + cereal configuration is considered as a management approach in producing both quality and quantity forage (Shi *et al*., 2013).

2.2.3 Quality attributes

Row proportion of intercropping components inevitably affects the crude protein content of forage. Comparing different planting patterns in intercropping maize fodder and cowpea revealed that row proportion affected the content of crude protein in various ratios in which increasing cowpea in proportion resulted to the increase of protein content (Ibrahim *et al.*, 2006). According to Meena *et al*. (2007), the intercrop row ratio of 1:2 between *Cenchrus* and cowpea resulted in highest crude protein content during both the years, which may be due to higher proportion of leguminous fodder cowpea than cereal *Cenchrus*. Crude protein content of maize in intercrop was significantly greater than in maize sole crop. Crude protein of maize showed no significant differences between different intercrop planting patterns, therefore forge quality of maize was higher in intercrops compared with its sole crop (Eskandari and Ghanbari, 2009). Observations made in maize + cowpea intercropping systems by Dahmardeh *et al*. (2009) and Ibrahim *et al*. (2012) showed that the quality traits like crude protein, crude fibre and total ash of maize were significantly improved by sowing it in mixture with legumes and all these parameters increased with increasing the seeding rate of legumes in the mixtures. This might be due to the transfer of fixed nitrogen by component legumes to the maize sown in mixture. Sebetha *et al*. (2010) reported that cowpea in sole plots had higher crude protein content than in the intercropped plots.

Prasanthi and Venkateswaralu (2014), also reported that the highest crude protein of maize in maize pairs + cowpea intercropping, which might possibly be the result of fixation of higher amount of nitrogen and its release, either by direct excretion from legume root system with nodules or by decomposition of nodule and root debris.

Ram (2008) reported that under wider row spacing, legume intercrops were able to grow better, fixing greater amount of atmospheric nitrogen, some part of which might become available to cereal crop. The increase in crude fibre content with increase in age could be ascribed to the accumulation of structural material such as hemicelluloses, cellulose, lignin, silica etc (Hussain and Durrani, 2009). Crude fibre content of maize was significantly influenced by different crop combinations. Intercropping and combination of intercropping and fertilizer improved forage quality by decreasing crude fiber of grass (Muhammad, 2010). Ibrahim *et al*. (2012) observed negative correlation between nitrogen and crude fibre content in maize and legume intercropping. Similarly, Reza *et al*. (2012) from their study observed that row proportions had significant effect on crude fibre while nitrogen fertilizer did not affect crude fibre significantly and the highest amount of obtained in the pure stand of forage sorghum with 41.22 per cent and the lowest amount achieved in the proportion of 25 per cent Sorghum: 75 per cent Limabean with 35.77 per cent. However, in another study, the highest crude fibre content was observed in sole fodder maize while maize grown along with legumes might have availed better nitrogen nutrition making it more succulent (Prasanthi and Venkateswaralu, 2014).

Reza *et al*. (2012) also observed that the ash content was affected by different planting patterns at $p<0.01$. The replacement series produced the lowest amount of ash content and the highest percentage of it obtained in pure stand of sorghum followed by additive series. Traits like crude protein and ash content of forage maize increased when intercropped with legumes compared to its sole-cropping (Javanmard *et al*, 2009).

Ibrahim *et al*. (2012) conducted an experiment at the University of Agriculture Faisalabad, Pakistan in order to study the forage quality of maize and legumes grown in pure stand and in mixture showed that the total ash percentage of mixed forage differed significantly by seed ratios of different maize legume mixtures. Cowpea alone gave significantly higher ash percentage in contrast, the lower ash percentage was observed in maize alone.

According to Firdous and Gilani (1999), the highest dry matter digestibility coefficients were recorded in case of leaf fraction (68.21 ± 0.39 to 77.04 ± 0.33). The dry matter digestibility of whole plant ranged from 65.69 ± 0.40 to 75.82 ± 0.39, being higher than the of stem fraction of the plant (58.52 ± 0.24 to 69.35 ± 0.27). Azim *et al.* (1989) also reported a decline in dry matter digestibility of whole maize plant and its fractions at two vegetative stages. They further reported that maximum dry matter digestibility was found in leaves followed by whole mixed plant, middle and bottom portions of the stem. A field experiment conducted by Dahmardeh *et al*. (2009) reported that dry matter digestibility of intercrops (100 % maize + 50 % cowpea) produced the highest dry matter digestibility of 70.9 per cent and the intercrop 25 % maize + 75 % cowpea produced the lowest dry matter digestibility. The dry matter digestibility of the intercrop was between the sole maize and higher than that for sole cowpea. Cereal legume inter-cropping systems improved both quantity and quality of the fodder and supported by Verma *et al*. (1997) by concluding that digestible dry matter yield increased significantly in sorghum + cowpea paired row intercropping. Javanmard *et al*. (2009) reported that intercropping of legumes with *Zea mays* significantly increased digestibility of the forages. Study conducted by Amasaib *et al*. (2012) at the University of Khartoum, demonstration farm at Sudan, revealed that inter seeding grasses with legumes has a significant effect on dry matter digestibility of *Zea mays* ranging from 55.01 per cent for sole seeding to 64.70 per cent for mixed seeding. The positive effect of intercropping on dry matter digestibility may be attributed to the higher protein concentration for *Zea mays* when sown in the mixture with *Lablab purpureus*. Pal *et al.* (2014) also reported that sole sorghum had significantly highest digestible dry matter production. The digestible dry matter yield of cowpea was recorded significantly highest under sorghum + cowpea (100%) followed by sole cowpea. Similarly sorghum + rice bean (100%) had significantly higher value that was statistically at par with sole rice bean. Among the intercropping systems, sorghum + cowpea (25%), gave significantly higher digestible dry matter yield that remained significantly equal to all other intercropping systems.

Field experiments were conducted over 2 years (1998-1999 and 1999-2000) at the Universidad National del Sur research facility in Bahia Blanca (38° 48'S, 62° 13'W), Argentina by Alfredo *et al*. (2003) on nitrogen and row spacing on *Digitaria eriantha* production and digestibility and revealed that nitrogen fertilization rates and row spacing interacted significantly ($P < 0.05$) within each method of fertilization for mean annual IVDMD. As verified for spring and summer sampling, IVDMD increased as nitrogen fertilization rates increased. Under split fertilization, erratic responses were obtained when comparing row spacings. When fertilizer was applied at one time, however, IVDMD was greater ($P < 0.05$) at 0.5 than at 0.3 m row spacing only in the 0 and 100 kg per ha nitrogen treatments. Study conducted by Datt *et al*. (2009) on nutritional evaluation of cultivated fodder crops grown under agro climate of Tripura revealed that among graminaceous fodders, the IVDMD and IVOMD values were the highest in maize and the lowest in broom grass while in case of leguminous fodders, rice bean showed the minimum digestibility level and berseem the maximum.

2.3 Effect of nitrogen on growth, yield and quality attributes in intercropping system

2.3.1 Growth attributes

Zhao *et al*. (2005) reported that different levels of nitrogen fertilizer affected the height and the leaf area resulting in significant difference between treatments. In forage sorghum and millet the number of tillers and the leaf area of plants increases with increasing nitrogen levels and this ultimately lead to a rise in dry matter. According to Chaudhari *et al*. (2006) application of 120 kg nitrogen per ha supplemented through organic manures in maize may be attributed to increased plant height and more leaf area production per plant. An experiment conducted at the Students Research Farm, Punjab Agricultural University, Ludhiana by Chaudhary *et al*. (2007) reported that growth and yield attributes of maize was significantly influenced by nitrogen application and planting geometry. Plant height, leaf area index and dry matter accumulation increased with every increment in nitrogen dose and the increase in all the growth attributes was significant up to 150 kg N per ha. . Nadeem *et al*. (2009) also reported that nitrogen application significantly affected the plant height and number of leaves per plant of maize. Zubair (2009) has also reported a significant effect of nitrogen application on plant height of cluster bean cultivars when sown alone. Thayamini and Brintha (2010) noted that the average maize plant height increased significantly with the presence of cowpea coupled with different fertilizer rate. Rehman *et al.* (2010) studied the impact of nitrogen application on growth and yield of maize + cowpea intercropping and reported that the plant height of maize increased with increase in nitrogen application rate. The maximum was in sole maize with full dose of N (250 kg/ha), followed by maize intercropped with cowpea and N at 225 kg per ha and the minimum was in sole maize with no nitrogen.

Undie *et al.* (2012) from two years experiment on the effect of nitrogen application on yield and yield components of late season maize soybean intercropping reported that application of nitrogen up to 100 kg per hectare significantly raised plant height of maize at all samplings dates over when no nitrogen was used. The number of leaves per plant in maize also significantly increased at 100 kg nitrogen per hectare over when no nitrogen was applied in both the years of study. The number of leaves at 12 weeks after sowing increased by 0.68 and 2.84 in 2007 and 2008 respectively over no nitrogen application. The effect of nitrogen on number of leaves per plant in soybean was significant at each of the sampling intervals in both the years of study. At 4 and 6 weeks after sowing in each year, the number of leaves in soybean significantly increased at all nitrogen rates from 0 to 100 kg per hectare.

Increase in the growth of maize was reported by Adesoji *et al*. (2013) as a result nitrogen effects that lead to increase cell division, cell expansion and increase in size of all its morphological parts. Amujoyegbe and Elemo (2013) while evaluating the productivity of maize and cowpea intercrop as influenced by different time of introducing cowpea and nitrogen fertilizer observed that nitrogen levels consistently increased the plant height of maize at 6 and 9 weeks after sowing and significantly taller maize plants were recorded with the application of 90 and 135 kg N per ha. Safari *et al.* (2014) conducted an experiment on yield and quality of forage corn in response to N fertilization and plant density in Kermanshah province, Iran where nitrogen was applied in four rates (0, 75, 150 and 225 kg/ha) and reported that plant height of corn was significantly affected by N treatment. The tallest plants were recorded with 225 kg per ha N, followed by 150 kg per ha N. A study conducted at fodder production area of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana by Kumar *et al*. (2014) on fodder maize and cowpea that were sown in 1:1 ratio at 30 cm apart reported that the growth parameters like plant height, stem girth, leaves per plant, fresh weight per plant and leaf stem ratio were significantly influenced by different nitrogen and phosphorous levels. Maximum plant height of maize was recorded with 90 kg nitrogen + 30 kg phosphorous.

2.3.2 Yield and yield attributes

There are various reports considering the positive effects of nitrogen fertilizer on yield increase. The majority of the surveys reported yield increase proper to increasing nitrogen even though the best possible treatment or nitrogen level is highly dependent on the characteristics of soil, climate and the site of experimental.

Oad *et al*. (2004) also reported that significantly higher forage maize yield was obtained when 120 kg per ha nitrogen as urea was applied in combination with 3000 kg per ha farm yard manure. Chaudhari *et al*. (2006) also reported that the grain and dry fodder yields of maize were significantly increased with increased levels of fertilizers owing significant increase in leaf area, dry matter and yield attributes with higher fertilizer levels. Ibrahim *et al*. (2006) reported that forage maize yield was increased when it was intercropped with forage legumes and it was mainly due to more nitrogen availability for maize forage. Almodares *et al*. (2008) reported that nitrogen was effective in increasing maize and sorghum yield as well as quality parameters such as protein content as compared to control treatment. They concluded that nitrogen applied in the form of urea was instrumental in increasing the forage maize yield and protein content. Nadeem *et al*. (2009) reported that maize sown with *Sesbania* produced significantly higher dry matter yield than maize alone and in mixture with cowpea. The dry matter yield showed an increasing trend with increased fertilizer rates and maximum dry matter yield was obtained when nitrogen was applied @ 150 kg per ha. Rehman *et al.* (2010) also reported maximum biological yield of maize in sole maize with full dose of N (250 kg/ha) which was statistically at par with maize intercropped with cowpea and N at 225 kg/ha and maize intercropped with cowpea and N at 200 kg/ha. The minimum biological yield was observed in maize alone without nitrogen. Reza *et al*. (2012) reported that increasing nitrogen to the level of 160 kg per hectare resulted to the increase in yield for forage dry weight of sorghum although there was no significant difference between the two treatments of 160 and 240 kg nitrogen per hectare.

Safari *et al*. (2014) also reported that dry matter content and forage yield of corn increased with increase in the amount of N application and the highest dry matter content and forage yield was obtained in 150 and 225 kg/ha nitrogen application. Iqbal *et al*. (2014) conducted a field trial on forage maize and results revealed that the maximum green forage and dry matter yield was achieved when recommended dose of nitrogen was supplied through inorganic means in the form of urea fertilizer. They concluded that combining organic and inorganic sources have similar potential to increase the fresh forage yield of maize.

2.3.3 Quality attributes

Chaudhary *et al*. (2007) reported that the graded nitrogen levels and crop geometry showed significant effect on crude protein yield where application of 150 kg N per ha being at par with 120 kg N per ha resulted in higher crude protein. The increased protein content was observed with increasing nitrogen dose since it is one of the components of protein. According to Nadeem *et al*. (2009), the effect of nitrogen application on crude protein content was significant at each increase in nitrogen levels while the nitrogen application significantly decreased the crude fibre contents and the decrease was significant at each increase in nitrogen level and maximum crude fibre was obtained where no nitrogen was applied. Safari *et al*. (2014) reported that among different rates of N application (0, 75,150 and 225 kg/ha N), 225 kg/ha N application obtained the highest crude protein content in corn.

Ayub *et al.* (2004) reported that maize grown in mixture either with cowpea or *Sesbania* produced significantly higher ash percentage than maze grown alone. The ash contents were also significantly influenced by nitrogen application which was found maximum at nitrogen level of 150 kg/ha.

Kumar *et al*. (2014) conducted an experiment on fodder maize and cowpea which were sown in 1:1 ratio of 30 cm apart under different levels of nitrogen and phosphorous at fodder production area of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana. They reported that *in vitro* dry matter digestibility and crude protein yield of maize, cowpea and mixture was influenced significantly with different nitrogen and phosphorus levels where the highest crude protein content, *in vitro* dry matter digestibility and crude protein yield of maize, cowpea and total mixture was recorded with 67.5 kg N + 60 kg P_2O_5 per hectare and was at par with recommended dose of fertilizer of maize, 67.5 kg N + 30 kg P_2O_5 per hectare, 67.5 kg N + 45 kg P_2O_5 per hectare. Iqbal *et al*. (2015) stated that forage maize provides more crude protein than forage legumes because of the fact that forage maize gives a fairly high forage yield as compared to forage legumes on per hectare basis.

According to Snyman and Joubert (2002) the mean IVDMD of maize residues predicts that it may supply in at least the maintenance energy needs of ruminants while the mean IVDMD of grain sorghum residue points to a sub maintenance energy level. The high IVDMD and low NDF value of sunflower- cob residues suggest that it could be used in diet intended for production. The nutritional quality of both grain sorghum and maize residues was remarkably improved by means of ammoniation to produce forages with maintenance and production potential respectively. The ammoniation response at the various IVDMD values may help in predicting the economical justification of ammoniation. A perusal of study conducted by Kalra and Sharma (2015) revealed that IVDMD of fodder maize was significantly affected by FYM and nitrogen levels. Application of nitrogen levels significantly affected the IVDMD per cent of fodder maize. Increase in nitrogen levels produced significantly higher IVDMD than lower level. The magnitude of increase with application of 120 kg N per ha was 9.6 per cent over control. With nitrogen application, the increase in IVDMD content might be due to increase in leaf: stem ratio, LAI, etc. as the leaves contained more protein and soluble carbohydrates than stem than lower levels. Increase in nitrogen application increased the IVDMD over control as was reported by Sindhu *et al*. (2006).

2.4 Plant population and spatial arrangement

In intercropping system, plant population and spatial arrangement play a pivotal role affecting the total yield of intercrop combinations over the sole crops. The response of intercrops to plant population and spatial arrangement had also been advocated by Willey (1979). Results of some of the investigations carried out in this respect are enlisted here.

Morgado and Willey (2003) established a field experiment at John Innes Institute farm, in Norwich, East Anglia region of the United Kingdom to study the effect of plant population on yield and yield efficiency of maize-bean. Three bean plant population *viz.,* 25% (60,000 plants/ha), 50% (120,000 plants/ha) and 75% (180,000 plants/ha) and interplanted with maize in an additive model, resulting in three row arrangements: one row of maize for one row of beans (1:1), one row of maize for two rows of beans (1:2) and one row of maize for three rows of beans (1:3). The result revealed that dry matter yield accumulation of individual maize plant decreases with increases in bean plant population and competitive effect is biggest at the highest level in an arrangement of one row of maize for three rows of beans. Chaudhary *et al*. (2007) reported that plant height and plant population was increased with decrease in plant spacing and significantly taller plants were produced under 30 cm x 20 cm. According to Marer *et al*. (2007), maize with 100 per cent pigeon pea population recorded significantly higher grain yield over other systems but was on par with same row ratio at 50 per cent pigeon pea population and 1:1 row ratio at 100 per cent pigeon pea population. Nadeem *et al*. (2009) reported that plant population of maize + legumes was significantly higher in treatments where maize was sown with legumes being maximum where maize was sown with *Sesbania*. A higher plant population in mixed cropping can be attributed to more number of seed in mixed crop treatments than maize alone due to difference in seed size and test weight of mixed treatments. An experiment conducted at Botswana college of Agriculture garden by Legwaila *et al.* (2012) to study the effects of intercropping maize and cowpea on the performance of maize and cowpea showed that sole plots of maize produced more dry matter weight than maize intercropped with cowpea. This could be attributed to high plant density and lack of competition for resources in sole cropping.

2.5 Economics of cultivation

The studies conducted by Meena *et al.* (2007) on response of Dhaman grass (*Cenchrus setigerus*) and cowpea (*Vigna unguiculata*) to intercropping ratios and integrated plant nutrient management in semi arid region, intercropping ratios 1:2 (*Cenchrus* : cowpea) gave significantly higher net returns followed by 1:1 intercrop ratio. While the minimum net return was obtained with 2:1 row ratio of *Cenchrus* and cowpea. Higher net profit in 1:2 intercropping system might be due to higher fodder production and lowest cost of cultivation than other intercropping row ratios. In respect of benefit cost ratio, the highest value was obtained with 1:2 row ratios of *Cenchrus*: cowpea as compared to other intercropping row ratios. This might be due to higher share of cowpea in total dry mater production than *cenchrus* under different row ratios.

At Jhansi, a study was conducted by Agrawal *et al*. (2008) to compare the agro economics of perennial grasses based round the year fodder production systems. The results revealed that guar – oat – cowpea grown in perennial based guinea grass system produced the highest green fodder per hectare and net income. The gross income from Guinea + (guar – oat – cowpea) was higher over setaria based + cowpea – berseem + mustard – cowpea and napier bajra hybrid based berseem + mustard – cowpea systems respectively. Among the fodder based cropping systems, multicut sorghum +*S. sphaecelata* – berseem + mustard yielded the maximum forage and net income per hectare. The gross income was also greater in this system as compared to sorghum – berseem + mustard and berseem + mustard – multicut sorghum system.

A study by Sheoran *et al*. (2010) to assess the production potential, biological and economic feasibility of intercropping maize with black gram in different row proportions under rainfed conditions, reported that, irrespective of the planting pattern all the intercropping systems showed their superiority in terms of economic viability and sustainability over monoculture cropping of maize. The highest B: C ratio (1.64) was recorded with intercropping black gram with maize (50 cm) in 1:1 row ratio. The increase in the number of intercrop rows in between maize rows (maize + blackgram in 1:2 row ratio) or higher the number of maize rows neighbouring blackgram row (maize paired + blackgram in 2:1 row ratio) caused a decline in economic returns.

Studies conducted by Bindhani *et al*. (2007) on nitrogen management in baby corn reported that, the net return and benefit cost ratio were the highest with 120 kg N/ha, which resulted in significant increase in net return and benefit cost ratio compared to that of no nitrogen and 40 and 80 kg N per ha respectively. Parlawar *et al*. (2003) also recorded the highest gross monetary return (GMR) when crop was fertilized with 120 kg N per ha in their study on performance of maize and sorghum varieties to different levels of nitrogen. Similar results were also reported by Sutaria *et al*. (1999) and Sharma *et al*. (2000).

Rehman *et al.* (2010) reported maximum net farm income (` 128802) and higher benefit cost ratio (2.02) from maize intercropped with cowpea and N at 225 kg per ha. While the minimum values was with sole maize without nitrogen (` 24925 and 0.75 respectively).

CHAPTER-III

MATERIALS AND METHODS

The investigation entitled “**Fodder production potential of maize (*Zea mays* L.) + cowpea (*Vigna unguiculata* L.) intercropping under different nitrogen levels”** was conducted during *kharif* season of 2011 and 2012 at the demonstration block at Krishi Vigyan Kendra, Phek district, Porba, Nagaland. The details of materials used and procedures followed during the course of investigation are presented in this chapter.

3.1 General information

3.1.1 Location

The farm area lies in sub alpine temperate zone and is situated at an elevation of 1842 metres above mean sea level with the geographical location at $25^{o}62'$ North latitude and $95^{o} 33'$ East longitude.

3.1.2 Climatic condition

The climate broadly represents sub-alpine tropical climate zone with high relative humidity, moderate temperature with medium to high rainfall. The mean temperature ranged from 9°C to 31°C during summer and rarely goes below 8°C in winter due to high atmospheric pressure. The rainfall from March to August ranged between 1641 and 836 mm while the total number of rainy days was 135 and 113 days during 2011 and 2012 respectively. The meteorological data recorded during the period of investigation were presented in Table 1.

3.1.3 Soil condition and its analysis

The soil of the experimental plot was categorised as clay loam and well drained. Soil samples were collected before sowing and after harvest of crop from each plot and were air dried, ground, and sieved through 2 mm diameter sieve and were used for estimation of available N, P, K, and organic carbon. The soil was acidic in nature with high organic carbon content. The details of physico-chemical status of the soil at the experimental site before sowing and after harvest of crop is presented in Table 2.

3.1.3.1 pH

The pH of soil sample was determined in 1:2 soil water suspension using Glass electrode pH meter developed by Jackson (1973).

3.1.3.2 Organic carbon

Orgaic carbon was determined by Walkley and Black (1934) rapid titration method described by Piper (1966) and the results were presented in terms of percentage.

3.1.3.3 Available nitrogen

The available soil nitrogen (N) was estimated by Alkaline potassium permanganate method as suggested by Subbiah and Asija (1956) and the data were calculated in terms of kilogram per hectare.

3.1.3.4 Available phosphorous

Available phosphorus (P) was extracted with 0.03 N, NH_4F in 0.025 N HCl solution. The procedure is primarily meant for soil, which are moderate to strongly acidic acid with pH around 5.5 or less (Brays and Kurtz, 1945).

3.1.2.5 Available potassium

The available soil potassium (K) was extracted from 5 g of soil by shaking with 25ml of neutral ammonium acetate (pH 7) solution for half an hour and the extract was filtered immediately through a dry filter paper (Whatman No. 1) and then potassium concentration in the extract was determined by flame photometer (Jackson, 1973).

Table 1. Meteorological data during the period of investigation (2011-2012) at Porba, Phek district

Month	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)	No of rainy days
2011	**Max**	**Min**	**Max**	**Min**		
March	22.5	12.7	72	54	72	9
April	23.1	14.0	85	69	56	12
May	23.5	16.7	94	80	243	25
June	24.1	18.9	97	88	400	30
July	24.1	19.2	97	88	438	29
August	24.2	18.8	96	87	432	30
2012						
March	26.0	9.0	80	30	4	0
April	28.0	14.0	85	42	98	15
May	30.9	16.4	85	45	85	15
June	28.0	19.0	94	72	221	27
July	28.0	19.0	96	77	222	28
August	28.5	19.6	97	80	206	28

Source: ICAR Regional Research Centre, Jharnapani, Nagaland

Table 2. Physico-chemical soil properties of the experimental field at Porba, Phek district

Soil parameters	Fertility status				Rating
	Before sowing		After harvest		
	2011	2012	2011	2012	
pH	5.04	5.09	5.11	5.15	Acidic
Organic carbon (%)	0.53	0.59	0.59	0.62	Medium
Available N (kg/ha)	236.84	239.43	239.61	242.28	Low
Available P (kg/ha)	8.19	8.63	9.26	9.75	Low
Available K (kg/ha)	118.52	120.49	124.17	123.14	Low- medium

3.1.4 Experimental details

Experimental design	: Randomised Block Design	
Cropping system	: Maize sole	C_1
	Cowpea sole	C_2
	Maize + cowpea (1:1)	C_3
	Maize + cowpea (2:1)	C_4
	Maize + cowpea (3:1)	C_5
Nitrogen levels	: 0 kg / ha	N_1
	40 kg / ha	N_2
	80 kg / ha	N_3
	120 kg / ha	N_4
Number of treatment combinations	: 20	
Number of replications	: 3	
Total number of plots	: 60	
Plot size	: 5 m x 4 m	
Block border	: 1 m	
Plot border	: 0.5 m	
Varieties	Maize – Vijay composite	
	Cowpea – UPC – 1956	

3.2 Field preparation and sowing

The field was thoroughly ploughed in the month of February – March and the layout prepared according to the various cropping systems. The seed materials were procured from Dimapur. Maize (cv. Vijay Composite) at seed rate of 50 kg/ha and cowpea (cv. UPC- 1956) at seed rate of 20 kg/ha were sown on 8th April 2011 and 9th April 2012. The plant to plant and row to row spacing for both maize and cowpea was 30 cm x 10 cm respectively. All the plots were given uniform intercultural operations during the entire growth period in both years of study. The crops were harvested for fodder purpose on 17th June 2011 and 20th June 2012.

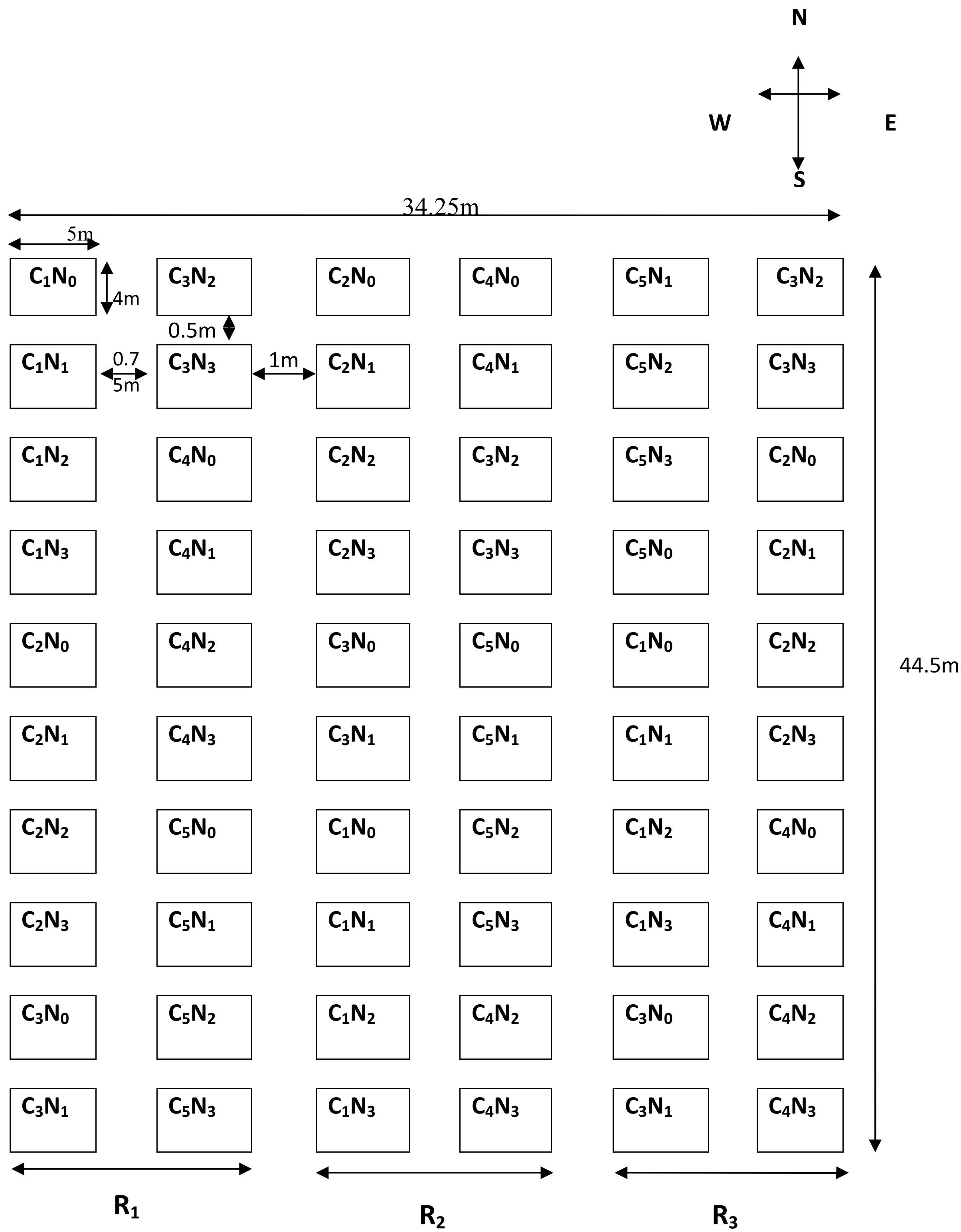

Fig. 1: Experimental layout

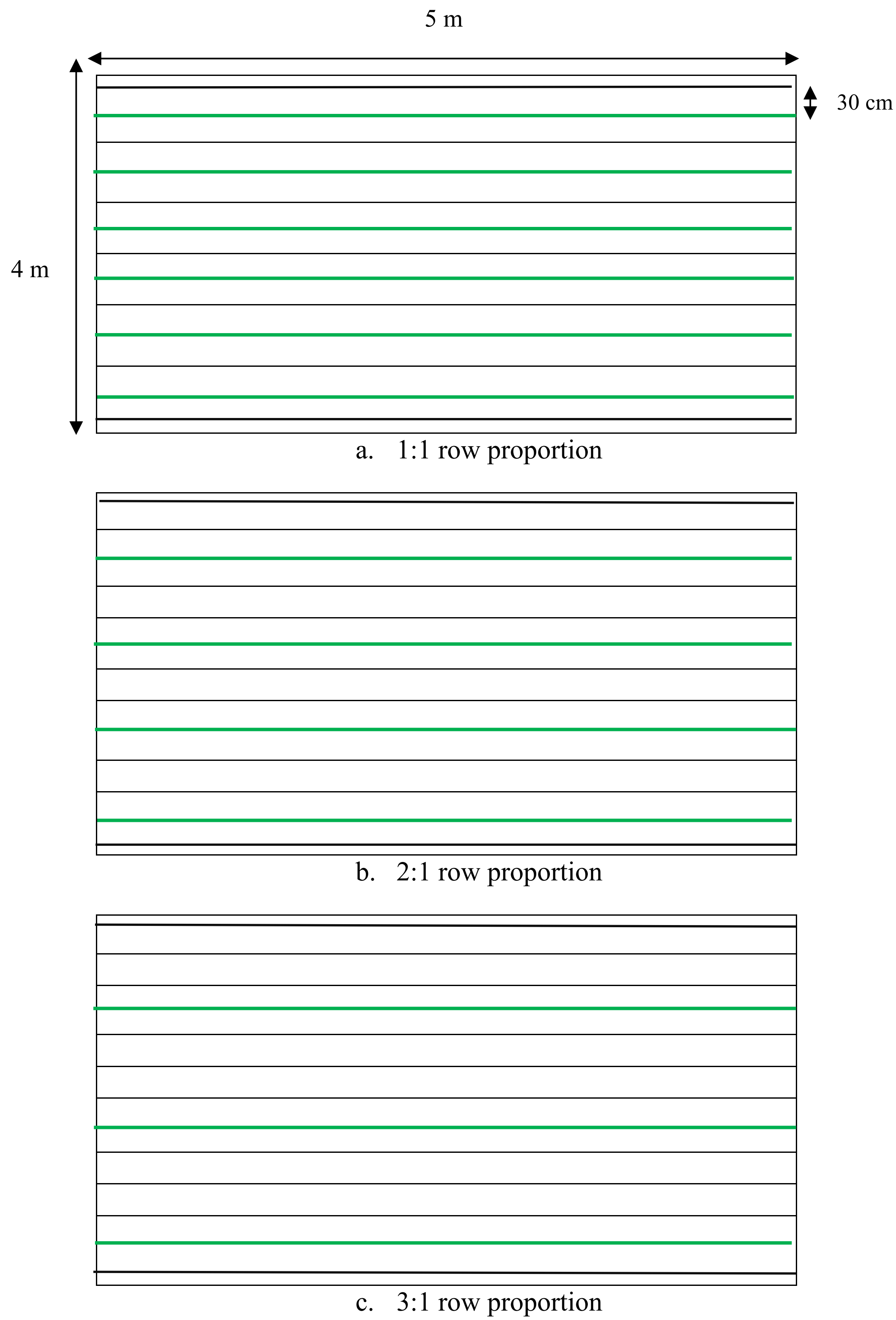

Fig. 2: Individual plot layout as per row proportion

Main crop
Intercrop

3.3 Fertilizer application

Uniform recommended dose of 40 kg P_2O_5 and 20 kg K_2O per hectare was applied as basal application in all plots after sowing. Nitrogen was applied in two split doses, first dose was applied as basal and remaining half of N was applied after 30 days after sowing (DAS) as per treatment. Only soil raking was done in control plots during the time of nitrogen application.

3.4 Growth parameters

3.4.1 Plant height (cm)

Plant height and number of leaves per plant of maize and cowpea were recorded at 7 days interval from 14 days after sowing (DAS) up to harvest (70 DAS) as green forage before the crops entered reproductive stage. Five numbers of plants were randomly selected for taking the growth parameters in maize and cowpea. At the base of the maize stem 10 cm above the soil, a small mark (with white paint) was given from which the height of plant to the apical tip was measured which was later taken into account. The cowpea was measured from the second node upto the apical tip as its height in cm.

3.4.2 Number of leaves per plant

Total number of physiologically active green leaves per plant were counted from the five randomly selected tagged plants from each plot and the average were calculated in numbers.

3.4.3 Plant population

Plant population of the main crop (maize) and the intercrop (cowpea) were recorded before harvest from three randomly selected areas in all the treatments per square meter. The results thus obtained were recorded as plants per m^2.

3.4.4 Fresh forage yield

The green forage consisting of the whole plant were harvested and weighed of each plot to record the forage yield of maize and of cowpea separately. The samples were kept for sometime to evaporate the adhering water, if any, and weighed to record the fresh weight then calculated on hectare basis. The results thus obtained were recorded as t/ha.

3.4.5 Total fresh forage yield

The fresh forage yield in t/ha of both maize and cowpea was added up treatment wise and then analysed statistically.

3.4.6 Per cent dry matter content

It was calculated by using the following formula and dry matter yield per hectare was calculated:

$$\text{Per cent dry matter content} = \frac{\text{Dry weight of sample (g)}}{\text{Fresh weight of sample (g)}} \text{ X } 100$$

3.4.7 Dry matter yield

The harvested green forage were chopped into 20 cm lengths with the help of a manual chaff cutter and air dried for 3 – 4 days and then dried in the oven at 60 ±5 ºC for 48 hours. To ensure that samples were dried properly, they were weighed three times at hourly interval till a constant weight was obtained. The dry matter yield of individual plot was calculated by multiplying the fresh forage yield (t/ha) with conversion factor (dry weight of the sample/fresh weight of the sample) of each plot. The weight was recorded and calculated on hectare basis and recoded as t/ha.

3.4.8 Total dry matter yield

The dry matter yield in t/ha of both maize and cowpea was added up treatment wise and then analysed statistically.

3.4.9 Crude protein

The crude protein of leaf samples of maize and cowpea were analysed by Kjeldahl nitrogen method (A.O.A.C. 1990) and the results obtained were presented in percentage. The percentage of crude protein was calculated by multiplying the per cent total nitrogen value by 6.25.

The crude protein of maize and cowpea was calculated by using the formula:

$$\text{Crude protein (\%)} = 100 \text{ x } \frac{\text{Y x (B – B1) x 0.02 x 6.25}}{\text{X x W}}$$

Where,

Y = volume (ml) made out of digested sample

X = volume (ml) of aliquot taken for distillation

B = volume (ml) of N/7 H_2SO_4 consumed for titration of blank distillate

W = weight (g) of oven dried sample taken for digestion

(1 ml of N/7 H_2SO_4 = 0.02 g N)

6.25 factor for converting nitrogen into protein

3.4.10 Crude fibre

The crude fibre of leaf samples of maize and cowpea were estimated by using the standard procedures as recommended by A.O.A.C. (1990). Crude fibre is determined as that fraction remaining after digestion with standard solutions of sulphuric acid and sodium hydroxide under controlled conditions. The crude fibre of maize and cowpea was calculated by using the formula:

$$\text{Crude fibre (\%)} = \frac{\text{(a – b)}}{\text{w}} \text{ x 100}$$

Where,

a = weight (g) of silica basin plus oven dried residue left after acid and alkali digestion

b = weight (g) of silica basin and ash

w = weight (g) of oven dried sample

3.4.11 Total ash content

Total ash content of maize and cowpea were analysed by using the standard procedures as recommended by A.O.A.C. (1990). The total ash of maize and cowpea was calculated by using the formula:

$$\text{Total ash (\%)} = \frac{(c - a)}{w} \times 100$$

Where,

a = empty weight (g) of silica basin

c = weight (g) of silica basin with ash

w = weight of moisture free sample

3.4.12 *In vitro* dry matter digestibility

IVDMD of maize and cowpea were analysed by using the technique given by Tilley and Terry (1963). Samples of dry forage weighing 0.5 gram were subjected to 48 hour digestion period with rumen liquor. Rumen liquor was collected from 3 rumen cannulated adult cattle, strained through a muslin cloth and pooled together which was used as innoculum source. The donor animals were fed according to their requirements (NRC, 2001). All the determinations were carried in triplicate and data were statistically analysed for both maize and cowpea. The IVDMD was calculated by using the formula:

$$\text{IVDMD (\%)} = \frac{\text{Dry matter input} - \text{Dry matter remaining undigested}}{\text{Dry matter input}} X\ 100$$

Digestible dry matter yield (kg/ha) = Dry matter yield x IVDMD

3.5 Economics of cultivation

3.5.1 Cost of cultivation (`/ha)

It was calculated on per hectare basis for each treatment by taking into account the prevailing input, labour and operational cost. The result was expressed in `/ha.

3.5.2 Gross income (`/ha)

Gross return was the value of the economic yield calculated at prevailing market price. The result was expressed in `/ha.

3.5.3 Net income (`/ha)

Net return was calculated by subtracting the cost of cultivation from the gross return on per hectare basis. The result was expressed in `/ha.

3.5.4 Benefit cost ratio

Benefit cost ratio was computed by dividing the net return by total cost of cultivation.

$$\text{Benefit cost ratio} = \frac{\text{Net return (`/ha)}}{\text{Total cost of cultivation (`/ha)}}$$

3.6 Statistical analysis

All data pertaining to the present investigation were subjected to statistical analyses by the methods described by Cochran and Cox (1963) and Sukhatme and Amble (1978). The statistical significance of various effects was tested at 5 per cent probability level. The analysis of variance tables (ANOVA) are given in the appendices.

CHAPTER-IV

EXPERIMENTAL FINDINGS

In this chapter, an attempt has been made to present the results of the experiment carried out during the *kharif* season of 2011 and 2012 with the help of appropriate data tables and figures, wherever necessary, for each parameter. The analysis of variance tables have been given in appendix.

4.1 Growth attributes

4.1.1 *Maize plant height*

Data on plant height (cm) of maize as influenced by cropping system and N levels recorded at different growth stages *viz*., 14, 21, 28, 35, 42, 49, 56, 63 DAS (days after sowing) and at harvest are presented in Table 3a, 3b and Fig. 3 for 2011 and 4a, 4b and Fig. 4 for 2012 respectively.

During 2011, the plant height of maize was found to be significantly different only at 21 and 56 DAS where the different row proportions were found to be significantly superior over the sole treatment. At 21 DAS, maize in 3:1 (C_5) row ratio recorded the tallest plant height value of 22.33 cm and it was statistically at par with 2:1 (C_4) and 1:1 (C_3) row ratio (22.32 and 22.16 cm respectively). However, at 56 DAS, 1:1 row ratio recorded the tallest plant height (80.91 cm) which was statistically at par with 3:1 and 2:1 row ratio (80.70 and 80.17 cm respectively). The lowest plant height values (20.75 and 79.47 cm) were recorded with sole maize (C_1) cropping on both these two days of observation in 2011. In general, the plant height of maize was found greatest with the intercropping system of 1:1 ratio on 28, 35, 42, 49 DAS and at harvest barring 14 and 63 DAS. During the second year (2012) none of the growth stages showed any significant effect on the plant height of maize. However, the tallest plant heights were recorded in 1:1 ratio intercropping on all days of observation except at 28 and 63 DAS while the lowest was in sole maize in all the days of observation (Table 4a and 4b).

Table 3a. Effect of different cropping system and N levels on the plant height (cm) of maize from 14 to 35 DAS of 2011

Treatments	Days after sowing			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	12.49	20.75	31.41	40.88
C_2: Sole cowpea	--	--	--	--
C_3: Maize + cowpea (1:1)	12.48	22.16	32.32	41.49
C_4: Maize + cowpea (2:1)	12.44	22.32	31.93	41.31
C_5: Maize + cowpea (3:1)	12.15	22.33	31.59	41.05
SEm±	0.19	0.18	0.29	0.39
CD (P=0.05)	NS	0.53	NS	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	12.05	21.23	31.62	40.36
N_2: 40	12.32	21.79	31.85	41.34
N_3: 80	12.63	22.05	31.69	41.42
N_4: 120	12.57	22.49	32.09	41.60
SEm±	0.19	0.18	0.29	0.39
CD (P=0.05)	NS	0.53	NS	NS
C x N				
SEm±	0.38	0.36	0.59	0.78
CD (P-0.05)	NS	NS	NS	NS

Table 3b. Effect of different cropping system and N levels on the plant height (cm) of maize from 42 DAS to harvest of 2011

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	53.51	68.99	79.47	91.25	105.88
C_2: Sole cowpea	--	--	--	--	--
C_3: Maize + cowpea (1:1)	54.40	70.14	80.91	91.72	107.36
C_4: Maize + cowpea (2:1)	54.10	69.64	80.17	91.83	106.12
C_5: Maize + cowpea (3:1)	54.23	69.62	80.70	91.20	107.36
SEm±	0.46	0.38	0.30	0.40	0.67
CD (P=0.05)	NS	NS	0.87	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	53.87	68.98	80.06	91.15	106.22
N_2: 40	54.42	69.69	80.24	91.19	106.39
N_3: 80	54.04	69.80	80.20	91.41	106.93
N_4: 120	53.91	69.92	80.76	92.25	106.64
SEm±	0.46	0.38	0.30	0.40	0.67
CD (P=0.05)	NS	NS	NS	NS	NS
C x N					
SEm±	0.91	0.76	0.61	0.81	1.34
CD (P-0.05)	NS	NS	NS	NS	NS

Table 4a. Effect of different cropping system and N levels on the plant height (cm) of maize from 14 to 35 DAS of 2012

Treatments	Days after sowing			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	11.27	19.27	31.37	41.17
C_2: Sole cowpea	--	--	--	--
C_3: Maize + cowpea (1:1)	11.32	19.50	31.52	41.49
C_4: Maize + cowpea (2:1)	11.27	19.47	31.54	41.33
C_5: Maize + cowpea (3:1)	11.28	19.41	31.40	41.33
SEm$\pm$	0.08	0.25	0.13	0.16
CD (P=0.05)	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	10.93	18.57	30.90	40.43
N_2: 40	11.28	18.96	31.49	40.72
N_3: 80	11.38	19.75	31.61	41.22
N_4: 120	11.54	20.36	31.84	42.95
SEm$\pm$	0.08	0.25	0.13	0.16
CD (P=0.05)	0.23	0.73	0.39	0.46
C x N				
SEm$\pm$	0.16	0.51	0.27	0.32
CD (P-0.05)	NS	NS	NS	NS

Table 4b. Effect of different cropping system and N levels on the plant height (cm) of maize from 42 DAS to harvest of 2012

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	53.43	68.89	73.00	87.58	105.70
C_2: Sole cowpea	--	--	--	--	--
C_3: Maize + cowpea (1:1)	54.57	69.63	74.13	87.82	107.05
C_4: Maize + cowpea (2:1)	54.27	69.28	74.21	87.98	106.07
C_5: Maize + cowpea (3:1)	54.50	69.33	74.20	88.12	106.47
SEm±	0.42	0.30	0.35	0.29	0.62
CD (P=0.05)	NS	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	52.26	67.79	72.87	87.78	104.34
N_2: 40	53.77	69.01	73.35	87.68	105.85
N_3: 80	55.23	69.80	74.12	87.75	106.68
N_4: 120	55.52	70.33	75.20	88.29	108.41
SEm±	0.42	0.30	0.35	0.29	0.62
CD (P=0.05)	1.21	0.86	1.00	NS	1.78
C x N					
SEm±	0.84	0.59	0.69	0.59	1.23
CD (P-0.05)	NS	NS	NS	NS	NS

During 2011, the effect of nitrogen on the plant height of maize was found to be significant only at 21 DAS where it was observed that all the treatments with nitrogen application (N_2, N_3 and N_4) recorded significantly superior values than the treatment where nitrogen was not applied at all (N_1). The greatest height (22.49 cm) was observed with application of nitrogen at the rate of 120 kg/ha (N_4) and it was at par with N application @ 80 kg/ha (N_3) (22.05). The plant height in N_2 treatment was at par with N_3. Although there was no difference statistically at the other days of observation greater values of plant height was associated with those treatments where nitrogen was applied at different rates and the lowest with no nitrogen at all. During 2012 all the days of observation except 63 DAS showed remarkable significance in plant height. From the table it is clear that at all the days of observation the greatest value was recorded in N_4 where nitrogen was applied at 120 kg/ha and statistically greater than the rest of the treatments at 35, 56 DAS and at harvest. This was followed by the N_3 treatment where N was applied @ 80 kg/ha and it was at par with N_4 at 14, 21, 28, 42 and 49 DAS and statistically greater than N_1 and N_2 at 35 and 56 DAS. N_1 treatment recorded significantly the lowest value compared to other treatments at all days of observation except at 21, 35, 56 DAS and at harvest where it was statistically the same with N_2 treatment. The effect of different levels of nitrogen was not recorded to be significant at 63 DAS; however the plant height more or less increased with the increase in level of nitrogen application.

4.1.2 *Cowpea plant height*

The data on plant height of cowpea recorded at different days of observation at harvest during 2011 have been presented in Table 5a, 5b and Fig. 5 during 2012 have been presented in Table 6a, 6b and Fig. 6 respectively.

The effect of different row proportions on plant height of cowpea was significant over it sole treatment only at 21 DAS during 2011 (Table 5a). The highest value was in C_4 (2: 1 row ratio with 12.64 cm) followed by C_5 (3:1 row ratio with 12.57 cm) and C_3 (1: 1 row ratio with 12.43 cm). The lowest value was in C_2 (sole with 12.06 cm). No significant difference on the plant height of cowpea was recorded during the other days of observation *viz.,* 14, 28, 35, 42, 49, 56, 63 DAS and at harvest (Table 5a and 5b) however, in general, cowpea in 1:1 row ratio recorded the highest plant height

Table 5a. Effect of different cropping system and N levels on the plant height (cm) of cowpea from 14 to 35 DAS of 2011

Treatments	Days after sowing			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	--	--	--	--
C_2: Sole cowpea	7.71	12.06	16.24	21.04
C_3: Maize + cowpea (1:1)	7.77	12.43	16.47	21.19
C_4: Maize + cowpea (2:1)	7.74	12.64	16.26	21.14
C_5: Maize + cowpea (3:1)	7.71	12.57	16.39	21.10
SEm$\pm$	0.10	0.10	0.11	0.17
CD (P=0.05)	NS	0.28	NS	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	7.54	11.81	15.50	20.47
N_2: 40	7.63	12.14	15.62	20.97
N_3: 80	7.82	12.53	16.99	21.34
N_4: 120	7.94	13.23	17.27	21.69
SEm$\pm$	0.10	0.10	0.11	0.17
CD (P=0.05)	0.30	0.28	0.32	0.48
C x N				
SEm$\pm$	0.21	0.19	0.22	0.34
CD (P-0.05)	NS	0.56	NS	NS

Table 5b.Effect of different cropping system and N levels on the plant height (cm) of cowpea from 42 DAS to harvest of 2011

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	--	--	--	--	--
C_2: Sole cowpea	24.85	29.73	36.29	38.12	40.40
C_3: Maize + cowpea (1:1)	24.89	29.94	36.54	38.63	41.53
C_4: Maize + cowpea (2:1)	24.72	29.92	36.50	38.43	41.32
C_5: Maize + cowpea (3:1)	24.80	27.68	36.27	38.63	41.40
SEm±	0.09	1.12	0.12	0.22	0.82
CD (P=0.05)	NS	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	24.10	28.33	35.01	37.90	38.77
N_2: 40	24.52	29.45	36.05	38.08	41.35
N_3: 80	25.14	29.36	36.65	38.60	42.07
N_4: 120	25.51	30.13	37.88	39.12	43.77
SEm±	0.09	1.12	0.12	0.22	0.82
CD (P=0.05)	0.25	NS	0.36	0.63	2.35
C x N					
SEm±	0.17	2.24	0.25	0.44	1.63
CD (P-0.05)	NS	NS	NS	NS	NS

Table 5c. Interaction effect of different cropping system and N levels on plant height (cm) of cowpea during 21 DAS of 2011

Cropping system (C)	N-levels (kg/ha)			
	N_1 0	N_2 40	N_3 80	N_4 120
C_2 Sole cowpea	11.37	11.38	12.52	12.97
C_3 Maize + cowpea (1:1)	12.25	11.96	12.21	13.31
C_4 Maize + cowpea (2:1)	12.05	12.56	12.63	13.32
C_5 Maize + cowpea (3:1)	11.56	12.64	12.76	13.32
SEm±	0.19			
CD (P = 0.05)	0.56			

Table 6a. Effect of different cropping system and N levels on the plant height (cm) of cowpea from 14 to 35 DAS of 2012

Treatments	**Days after sowing**			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	--	--	--	--
C_2: Sole cowpea	8.02	11.43	16.33	23.11
C_3: Maize + cowpea (1:1)	8.34	11.98	16.08	22.96
C_4: Maize + cowpea (2:1)	8.32	11.88	16.57	22.85
C_5: Maize + cowpea (3:1)	8.27	11.97	16.06	22.78
SEm$\pm$	0.09	0.14	0.22	0.21
CD (P=0.05)	NS	0.40	NS	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	7.95	11.18	15.29	21.54
N_2: 40	8.32	11.68	15.74	21.32
N_3: 80	8.26	11.88	16.25	24.35
N_4: 120	8.41	12.52	17.75	24.49
SEm$\pm$	0.09	0.14	0.22	0.21
CD (P=0.05)	0.27	0.40	0.63	0.62
C x N				
SEm$\pm$	0.19	0.28	0.43	0.43
CD (P=0.05)	NS	NS	NS	NS

Table 6b. Effect of different cropping system and N levels on the plant height (cm) of cowpea from 42 DAS to harvest of 2012

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	--	--	--	--	--
C_2: Sole cowpea	24.20	28.82	33.65	38.32	40.97
C_3: Maize + cowpea (1:1)	24.20	29.07	33.48	38.38	41.34
C_4: Maize + cowpea (2:1)	23.95	28.98	33.63	38.65	41.02
C_5: Maize + cowpea (3:1)	24.02	29.15	33.38	38.88	41.07
SEm±	0.12	0.18	0.16	0.16	0.16
CD (P=0.05)	NS	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	22.90	28.25	32.80	38.23	40.22
N_2: 40	23.57	28.18	33.50	38.68	40.78
N_3: 80	24.70	29.78	33.77	38.52	41.72
N_4: 120	25.20	29.80	34.03	38.80	41.68
SEm±	0.12	0.18	0.16	0.16	0.16
CD (P=0.05)	0.34	0.51	0.46	NS	0.46
C x N					
SEm±	0.24	0.36	0.32	0.31	0.32
CD (P-0.05)	NS	NS	NS	NS	NS

in all the days of observation while C_2 (sole) recorded the lowest at 14, 21, 28, 35, 63 DAS and at harvest. In 2012 also, the effect of different row proportions on plant height of cowpea was found to be significant over the sole treatment only at 21 DAS (Table 6a). The tallest plant of cowpea (11.98 cm) was recorded in C_3 (1:1 row ratio) and it was found to be statistically at par with both C_5 (3:1 row ratio with 11.97 cm) and C_4 (2:1 row ratio with 11.88 cm).

A general observation of the data on plant height as influenced by different nitrogen levels revealed that plant height increased with the increase in N levels in all the growth stage in both the years of experimentation. During 2011 (Table 5b) all the growth stages except at 49 DAS, the different nitrogen levels recorded significant results on the plant height. N_4 treatment was significantly superior to N_1 and N_2 in all the stages and at par with N_3 at 14, 28, 63 DAS and at harvest. The lowest value was in N_1 treatment followed by N_2 in each observation. An analysis of the data for 2012 (Table 6a and 6b) also showed a similar trend on plant height of cowpea. All the days of observation except 63 DAS showed significant difference. The highest and the lowest plant heights were recorded in N_4 and N_1 treatments respectively in all the observation.

Table 5c presents the interaction effect of C×N on the plant height of cowpea at 21 DAS during 2011. The data revealed that application of 120 kg/ha N (N_4) recorded the highest plant height at 2:1 and 3:1 row ratio (13.32 cm) and was statistically at par with 1:1 row ratio with the same N dose. The lowest value was in sole cowpea (11.37 cm) with no application of N (N_0) followed by sole cowpea (11.38 cm) and maize + cowpea in 1:1 row ratio (11.96 cm) with N @ 40 kg/ha.

4.1.3 *Maize leaves per plant*

Table 7a and 7b for 2011 and 8a and 8b for 2012 depicts the number of leaves per plant in maize as affected by intercropping ratio and different levels of nitrogen application. From the data an increasing trend in the number of leaves can be seen in both the years. In 2011 year of experimentation the effect of different cropping systems recorded significant difference in the number of leaves per plant at 21, 28 (Table 7a) and 42 DAS (Table 7b). In all these stages, 1:1 row ratio (C_3) recorded significantly more number of leaves per plant while the lowest was in sole treatment

Table 7a. Effect of different cropping system and N levels on the number of leaves of maize from 14 to 35 DAS of 2011

Treatments	Days after sowing			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	2.35	3.99	6.60	10.40
C_2: Sole cowpea	--	--	--	--
C_3: Maize + cowpea (1:1)	2.53	4.42	6.90	10.55
C_4: Maize + cowpea (2:1)	2.50	4.30	6.75	10.70
C_5: Maize + cowpea (3:1)	2.41	4.18	6.87	10.87
SEm$\pm$	0.05	0.09	0.06	0.15
CD (P=0.05)	NS	0.27	0.18	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	2.42	4.08	6.60	10.22
N_2: 40	2.42	4.15	6.62	10.37
N_3: 80	2.47	4.40	6.75	10.70
N_4: 120	2.49	4.27	7.15	11.23
SEm$\pm$	0.05	0.09	0.06	0.15
CD (P=0.05)	NS	NS	0.18	0.43
C x N				
SEm$\pm$	0.10	0.19	0.13	0.29
CD (P-0.05)	NS	NS	NS	NS

Table 7b. Effect of different cropping system and N levels on the number of leaves of maize from 42 DAS to harvest of 2011

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	12.30	12.07	12.70	12.07	12.10
C_2: Sole cowpea	--	--	--	--	--
C_3: Maize + cowpea (1:1)	12.75	12.32	12.73	12.22	12.70
C_4: Maize + cowpea (2:1)	12.36	12.17	12.80	12.20	12.40
C_5: Maize + cowpea (3:1)	12.32	12.10	12.73	12.22	12.44
SEm±	0.12	0.09	0.09	0.10	0.15
CD (P=0.05)	0.35	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	12.17	12.00	12.53	11.95	12.15
N_2: 40	12.43	11.85	12.73	12.05	12.56
N_3: 80	12.40	12.02	12.70	11.95	12.18
N_4: 120	13.00	12.78	13.00	12.75	12.75
SEm±	0.12	0.09	0.09	0.10	0.15
CD (P=0.05)	0.35	0.27	0.25	0.28	0.43
C x N					
SEm±	0.24	0.19	0.17	0.19	0.30
CD (P-0.05)	NS	NS	0.50	NS	NS

Table 7c. Interaction effect of different cropping system and N levels on number of leaves of maize during 56 DAS of 2011

Cropping system (C)	N-levels (kg/ha)			
	N_1 0	N_2 40	N_3 80	N_4 120
C_1 Sole maize	12.60	12.60	12.40	13.20
C_3 Maize + cowpea (1:1)	12.60	12.53	12.60	13.20
C_4 Maize + cowpea (2:1)	12.53	13.20	12.73	12.73
C_5 Maize + cowpea (3:1)	12.40	12.60	13.07	12.87
SEm±	0.17			
CD (P = 0.05)	0.50			

(C_1). In the 2nd year of experimentation (2012), none of the observations was found to be significant on the number of leaves of maize (Table 8a and 8b). However, higher values were associated with maize sown in different row ratios and lower ones in sole maize.

Like plant height, the number of leaves per plant also showed an increasing trend with every increase in N level. Among the different levels of nitrogen, N application @120kg/ha recorded the highest number of leaves per plant at all the growth stages in both years of experimentation. In the 1st year, observations at 28, 35, 42, 49, 56, 63 DAS and at harvest recorded significant differences in the number of leaves per plant in maize with 7.15, 11.23, 13.00, 12.78, 13.00, 12.75 and 12.75 respectively as the highest values (Table 7a and 7b). At 28, 42, 49, 56, and 63 DAS, N_0 was statistically similar with N_1 and N_2; however it recorded the least value in all the stages of observation. In the second year only 49, 56 and 63 DAS showed significant variations in the number of leaves with 12.75, 12.77 and 15.12 respectively as the highest values in 120 kg/ha N (Table 8b) and they were all at par with N_3. N_0 recorded the least number of leaves per plant and was at par with N_2 at 49 and 56 DAS.

The interaction effect of C×N was found to be significant only at 56 DAS during 2011 (Table 7c). Sole maize (C_1) and maize in 1:1 row ratio (C_3) where N was applied @ 120 kg/ha and maize in 2:1 row ratio (C_4) with N @ 40 kg/ha recorded the same and significantly the highest value (13.20) than the rest of the treatments and was at par with C_5 (13.07). The lowest value of 12.40 was in 3:1 row ratio with N @ 0 kg/ha and sole maize with N @ 80 kg/ha.

4.1.4 *Cowpea leaves per plant*

The number of leaves per plant of cowpea presented in Table 9a and 9b for 2011 and 10a and 10b for 2012 revealed that the effect of different cropping system did not show significant variations at all growth stages. However the highest values were seen in intercropping system than the sole system.

The influence of nitrogen levels on the number of leaves of cowpea during 2011 had significant effect at 21, 28, 35, 42, 49, 56, 63 DAS and at harvest (Table 9a and 9b). At all these days of observations the highest number of leaves per plant was

Table 8a. Effect of different cropping system and N levels on the number of leaves of maize from 14 to 35 DAS of 2012

Treatments	Days after sowing			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	2.15	4.82	6.55	12.23
C_2: Sole cowpea	--	--	--	--
C_3: Maize + cowpea (1:1)	2.15	4.73	6.78	12.38
C_4: Maize + cowpea (2:1)	2.17	4.60	6.63	12.33
C_5: Maize + cowpea (3:1)	2.17	4.73	6.67	12.40
SEm$\pm$	0.04	0.16	0.07	0.13
CD (P=0.05)	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	2.15	4.52	6.65	12.35
N_2: 40	2.15	4.85	6.58	12.33
N_3: 80	2.13	4.63	6.68	12.28
N_4: 120	2.20	4.88	6.72	12.38
SEm$\pm$	0.04	0.16	0.07	0.13
CD (P=0.05)	NS	NS	NS	NS
C x N				
SEm$\pm$	0.09	0.31	0.14	0.26
CD (P-0.05)	NS	NS	NS	NS

Table 8b. Effect of different cropping system and N levels on the number of leaves of maize from 42 DAS to harvest of 2012

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	12.35	12.22	12.33	14.67	14.53
C_2: Sole cowpea	--	--	--	--	--
C_3: Maize + cowpea (1:1)	12.44	12.42	12.67	14.80	14.68
C_4: Maize + cowpea (2:1)	12.42	12.43	12.63	14.80	14.58
C_5: Maize + cowpea (3:1)	12.37	12.38	12.57	14.77	14.67
SEm$\pm$	0.13	0.08	0.12	0.07	0.18
CD (P=0.05)	NS	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	12.12	11.93	12.32	14.00	14.48
N_2: 40	12.48	12.06	12.40	14.90	14.57
N_3: 80	12.43	12.70	12.72	15.02	14.64
N_4: 120	12.54	12.7	12.77	15.12	14.77
SEm$\pm$	0.13	0.08	0.12	0.07	0.18
CD (P=0.05)	NS	0.22	0.35	0.20	NS
C x N	0.26	0.15	0.24	0.14	0.36
SEm$\pm$	NS	NS	NS	NS	NS
CD (P-0.05)					

Table 9a. Effect of different cropping system and N levels on the number of leaves of cowpea from 14 to 35 DAS of 2011

Treatments	**Days after sowing**			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	--	--	--	--
C_2: Sole cowpea	4.56	7.27	11.63	16.03
C_3: Maize + cowpea (1:1)	4.25	7.47	11.68	16.35
C_4: Maize + cowpea (2:1)	4.38	7.63	11.73	16.27
C_5: Maize + cowpea (3:1)	4.57	7.37	11.73	16.35
SEm±	0.12	0.14	0.17	0.15
CD (P=0.05)	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	4.32	6.73	11.10	15.81
N_2: 40	4.38	7.08	11.47	15.53
N_3: 80	4.57	7.72	11.95	16.52
N_4: 120	4.49	8.20	12.26	17.13
SEm±	0.12	0.14	0.17	0.15
CD (P=0.05)	NS	0.39	0.50	0.43
C x N				
SEm±	0.24	0.27	0.35	0.30
CD (P-0.05)	NS	NS	NS	NS

Table 9b. Effect of different cropping system and N levels on the number of leaves of cowpea from 42 DAS to harvest of 2011

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	--	--	--	--	--
C_2: Sole cowpea	20.03	26.03	33.05	37.88	40.55
C_3: Maize + cowpea (1:1)	20.23	26.35	33.27	38.02	40.76
C_4: Maize + cowpea (2:1)	20.15	26.50	33.27	37.71	40.64
C_5: Maize + cowpea (3:1)	20.10	26.40	33.23	38.00	40.42
SEm±	0.13	0.22	0.17	0.19	0.12
CD (P=0.05)	NS	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	19.45	24.73	31.85	35.82	38.61
N_2: 40	19.78	25.87	32.93	38.22	40.62
N_3: 80	20.42	26.47	33.27	38.44	41.58
N_4: 120	20.87	28.22	34.77	39.13	41.57
SEm±	0.13	0.22	0.17	0.19	0.12
CD (P=0.05)	0.38	0.63	0.48	0.54	0.36
C x N					
SEm±	0.26	0.43	0.33	0.37	0.25
CD (P=0.05)	NS	NS	NS	NS	NS

Table 10a. Effect of different cropping system and N levels on the number of leaves of cowpea from 14 to 35 DAS of 2012

Treatments	**Days after sowing**			
	14	21	28	35
Cropping system (C)				
C_1: Sole maize	--	--	--	--
C_2: Sole cowpea	4.70	6.50	11.23	19.33
C_3: Maize + cowpea (1:1)	5.02	6.70	11.52	20.33
C_4: Maize + cowpea (2:1)	4.92	6.58	11.50	20.58
C_5: Maize + cowpea (3:1)	5.03	6.67	11.47	20.43
SEm$\pm$	0.09	0.08	0.16	0.41
CD (P=0.05)	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)				
N_1: 0	4.87	6.58	11.03	19.20
N_2: 40	5.00	6.67	11.62	20.55
N_3: 80	4.83	6.57	11.50	20.35
N_4: 120	4.97	6.63	11.57	20.58
SEm$\pm$	0.09	0.08	0.16	0.41
CD (P=0.05)	NS	NS	NS	NS
C x N				
SEm$\pm$	0.18	0.16	0.32	0.82
CD (P-0.05)	NS	NS	NS	NS

Table 10b. Effect of different cropping system and N levels on the number of leaves of cowpea from 42 DAS to harvest of 2012

Treatments	Days after sowing				
	42	49	56	63	At harvest
Cropping system (C)					
C_1: Sole maize	--	--	--	--	--
C_2: Sole cowpea	19.73	25.40	31.58	37.98	38.28
C_3: Maize + cowpea (1:1)	19.82	25.60	32.00	38.48	40.18
C_4: Maize + cowpea (2:1)	19.58	25.57	31.75	37.96	39.35
C_5: Maize + cowpea (3:1)	19.72	25.55	31.90	38.22	39.28
SEm±	0.22	0.24	0.25	0.32	0.48
CD (P=0.05)	NS	NS	NS	NS	NS
Nitrogen levels (N-kg/ha)					
N_1: 0	19.27	24.52	31.55	37.73	39.22
N_2: 40	19.55	24.92	32.25	37.86	39.72
N_3: 80	19.73	25.48	31.82	38.65	38.93
N_4: 120	20.30	27.20	31.62	38.40	39.23
SEm±	0.22	0.24	0.25	0.32	0.48
CD (P=0.05)	0.63	0.69	NS	NS	NS
C x N					
SEm±	0.43	0.48	0.50	0.65	0.96
CD (P-0.05)	NS	NS	NS	NS	NS

recorded in N_4 treatments and was statistically at par with N_3 at only 28 DAS and at harvest. The N_1 treatment recorded the lowest in 21, 28, 42, 49, 56, 63 DAS and at harvest and it was at par with N_2 treatment at 28 and 42 DAS. At 35 DAS, though N_1 did not achieve the lowest value it was at par with N_2 value which was recorded to be the lowest. In 2012, the effect of nitrogen levels on the number of leaves per plant of cowpea showed significance only at 42 and 49 DAS where the N_4 treatment recorded significantly the highest number of leaves of cowpea with 20.30 and 27.20 respectively (Table 10b). The N_1 treatment with 19.27 at 42 DAS and 24.52 at 49 DAS recorded the lowest number of leaves per plant and was at par statistically with N_3 treatment (19.55 at 42 DAS and 24.92 at 49 DAS).

4.1.5 *Plant population per m^2*

The data pertaining to plant population per m^2 of maize and cowpea as influenced by different cropping system and different N levels recorded during 2011 and 2012 is presented in Table 11 and Fig. 7 (maize) and Fig. 8 (cowpea)

Maize – In both the years of experimentation and also their pooled data, plant population per m^2 between sole and intercropping treatments did not differ significantly. However the sole cropping (C_1) of maize recorded the highest value (30.33, 30.58 and 30.46 per m^2 during 2011, 2012 and pool of two years respectively) while the lowest value was in 2:1 row ratio (C_4) during 2011 (26.78 per m^2) and in 3:1 row ratio (C_5) during 2012 (27.83 per m^2) and pooled (27.50 per m^2).

Different nitrogen levels also did not show any significant effect on plant population during both the years and also in their pooled data. However, N_4 recorded the highest plant population of 29.58, 30.17 and 29.88 per m^2 in 2011, 2012 and pooled data respectively. The lowest was recorded with N_1 in both years of experimentation and also their pooled data.

Cowpea – Different row proportions showed significant effect on plant population per m^2 in cowpea during both the years and also their pooled analysis. The data revealed that the values in each treatment differed significantly from each other in both the years of study and also their pooled analyses. Further, sole crop of cowpea (C_2) obtained the maximum plant population (27.83, 27.25 and 27.54 per m^2 during 2011, 2012 and pool respectively) and all of the row ratios failed to be statistically

Table 11. Effect of different cropping system and N levels on plant population per m^2 of maize and cowpea

Treatments	Maize			Cowpea		
	2011	2012	Pooled	2011	2012	Pooled
Cropping system (C)						
C_1: Sole maize	30.33	30.58	30.46	--	--	--
C_2: Sole cowpea	--	--	--	27.83	27.25	27.54
C_3: Maize + cowpea (1:1)	29.00	29.67	29.33	25.83	25.08	25.46
C_4: Maize + cowpea (2:1)	26.78	29.25	28.01	23.17	22.25	22.71
C_5: Maize + cowpea (3:1)	27.17	27.83	27.50	16.92	16.00	16.46
SEm±	1.51	0.84	0.89	0.35	0.57	0.38
CD (P=0.05)	NS	NS	NS	1.00	1.66	1.10
Nitrogen levels (N-kg/ha)						
N_1: 0	26.03	28.67	27.35	24.25	21.83	22.50
N_2: 40	28.58	29.07	28.83	23.00	22.33	22.67
N_3: 80	29.08	29.42	29.25	23.33	22.17	22.75
N_4: 120	29.58	30.17	29.88	23.17	24.25	24.25
SEm±	1.51	0.84	0.89	0.35	0.57	0.38
CD (P=0.05)	NS	NS	NS	NS	NS	NS
C x N						
SEm±	3.01	1.69	1.77	0.69	1.15	0.76
CD (P=0.05)	NS	NS	NS	NS	NS	NS

similar to it. Among the row ratios, cowpea in 1:1 row ratio (C_3) recorded the highest (25.83, 25.08 and 25.46 per m^2 in 2011, 2012 and pooled respectively) which was followed by 2:1 row ratio (C_4) – 23.17, 22.25 and 22.71 per m^2 in 2011, 2012 and pooled respectively. The minimum plant population was obtained in 3:1 row ratio (C_5) (16.92, 16.00 and 16.46 per m^2 during 2011, 2012 and pooled respectively).

The effect of nitrogen levels on the plant population of cowpea did not reach significant levels in both 2011 and 2012 and also pooled data. However, the data from pool of two years showed N application @ 120 kg/ha (N_4) to have the maximum population (24.25 per/m^2) and the minimum (22.50 per/m^2) where there was no application of N (N_1).

4.2 Yield and yield attributes

4.2.1 *Fresh forage yield (t/ha)*

Maize - It is evident from the data (Table 12a) that the fresh forage yield of maize in sole treatment (C_1) was significantly higher than the fresh forage yield of maize in different row proportions for both the years of experimentation and pooled data (56.93, 57.38 and 57.15 t/ha respectively). This was followed by the yield in 3:1 row ratio (C_5) – 39.04, 38.93 and 38.99 t/ha during 2011, 2012 and pooled respectively and it was statistically comparable with the yield in 2:1 row ratio (C_4) – 39.03, 38.61 and 38.82 t/ha during 2011, 2012 and pooled respectively. Further, yield in 1:1 row ratio recorded significantly the lower fresh forage yield values of 28.93, 33.61 and 31.27 t/ha in 2011, 2012 and pool respectively.

Significant variations in the fresh forage yield of maize was also observed for different nitrogen levels in both the years and also their pooled analysis. The maximum fresh forage yield of 48.08 t/ha and 48.32 t/ha were recorded in N_4 treatments in 2011 and 2012 respectively. N_3 treatment (43.03 and 44.88 t/ha respectively) and N_2 treatment (41.50 and 42.34 t/ha respectively) produced statistically comparable yields and N_1 treatment (31.34 and 32.98 t/ha respectively) recorded significantly the lowest yield than all the other nitrogen levels for both the years. A similar effect was also seen on the pooled data of both years.

Table 12a. Effect of different cropping system and N levels on fresh forage yield (t/ha) of maize

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	56.93	57.38	57.15
C_2: Sole cowpea	--	--	--
C_3: Maize + cowpea (1:1)	28.93	33.61	31.27
C_4: Maize + cowpea (2:1)	39.03	38.61	38.82
C_5: Maize + cowpea (3:1)	39.04	38.93	38.99
SEm±	1.65	1.36	1.18
CD (P=0.05)	4.78	3.94	3.40
Nitrogen levels (N-kg/ha)			
N_1: 0	31.34	32.98	32.16
N_2: 40	41.50	42.34	41.92
N_3: 80	43.03	44.88	43.95
N_4: 120	48.08	48.32	48.20
SEm±	1.65	1.36	1.18
CD (P=0.05)	4.78	3.94	3.40
C x N			
SEm±	3.31	2.73	2.35
CD (P=0.05)	NS	NS	NS

Table 12b. Effect of different cropping system and N levels on dry matter yield (t/ha) of maize

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	15.99	16.53	16.26
C_2: Sole cowpea	--	--	--
C_3: Maize + cowpea (1:1)	8.50	8.82	8.66
C_4: Maize + cowpea (2:1)	11.58	10.76	11.17
C_5: Maize + cowpea (3:1)	11.57	11.48	11.53
SEm$\pm$	0.47	0.43	0.33
CD (P=0.05)	1.35	1.25	0.96
Nitrogen levels (N-kg/ha)			
N_1: 0	8.78	8.89	8.84
N_2: 40	12.33	11.46	11.89
N_3: 80	12.63	13.30	12.97
N_4: 120	13.91	13.94	13.93
SEm$\pm$	0.47	0.43	0.33
CD (P=0.05)	1.35	1.25	0.96
C x N			
SEm$\pm$	0.94	0.86	0.66
CD (P=0.05)	NS	NS	NS

4.2.2 *Dry matter yield (t/ha)*

From the Table 12b it was also evident that the data on the dry matter yield (t/ha) of maize followed the same trend as its fresh forage yield for both 2011, 2012 and pool data. Sole maize recorded significantly highest dry matter yield compared to the different row proportions for both the years, and also when two years data were pooled (15.99, 16.53 and 16.26 t/ha respectively). The lowest dry matter yield was recorded in 1:1 row ratio in both the years and also their pooled data (8.50, 8.82 and 8.66 t/ha respectively). Yield in C_4 and C_5 were statistically at par with one another other.

The nitrogen levels also had significant effect on dry matter yield of maize during 2011, 2012 and pooled data. Similar to its fresh forage yield result, the dry matter yield of maize was significantly the lowest in N_1 treatment where there was no application of nitrogen during both 2011 and 2012 and pool data (8.78, 8.89 and 8.84 t/ha respectively). At both 2011 and 2012, the highest dry matter yield was in N_4 treatment (13.91 and 13.94 t/ha respectively) which was found to be at par with N_3 (12.63 and 13.30 t/ha respectively) and statistically the same in the analysis of their pooled data (13.93 t/ha in N_4 and 12.97 t/ha in N_3)

4.2.3 *Fresh forage yield (t/ha)*

Cowpea - From Table 13a it was evident that there was significant variations among the different cropping systems on the fresh forage yield of cowpea. A perusal of the data showed that all the treatments differed significantly from each other and the sole treatment - C_2 (31.76, 31.98 and 31.87 t/ha in 2011, 2012 and pooled respectively) recorded significantly highest compared to their intercropping with different row proportions. Among the different row proportions, cowpea in 1:1 row ratio – C_3 (16.38, 17.48 and 16.93 t/ha in 2011, 2012 and pooled respectively) recorded the highest, followed by 2:1 - C_4 (10.17, 8.45 and 9.31 t/ha in 2011, 2012 and pooled respectively). The lowest fresh forage yield of 4.98, 3.98 and 4.48 t/ha were recorded in 3:1 row ratio – C_5 in both the years and their pool.

Different nitrogen levels also had significant effect on fresh forage yield of cowpea in both 2011 and 2012 and also in their pooled. In all the observations, the N_4 level of treatment produced significantly higher fresh forage yield of 18.75, 19.01 and

Table 13a. Effect of different cropping system and N levels on fresh forage yield (t/ha) of cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	--	--	--
C_2: Sole cowpea	31.76	31.98	31.87
C_3: Maize + cowpea (1:1)	16.38	17.48	16.93
C_4: Maize + cowpea (2:1)	10.17	8.45	9.31
C_5: Maize + cowpea (3:1)	4.98	3.98	4.48
SEm±	0.39	0.62	0.38
CD (P=0.05)	1.12	1.79	1.10
Nitrogen levels (N-kg/ha)			
N_1: 0	11.96	10.62	11.29
N_2: 40	15.48	15.43	15.45
N_3: 80	17.08	16.83	16.96
N_4: 120	18.75	19.01	18.88
SEm±	0.39	0.62	0.38
CD (P=0.05)	1.12	1.79	1.10
C x N			
SEm±	0.77	1.24	0.76
CD (P=0.05)	NS	NS	NS

Table 13b. Effect of different cropping system and N levels on dry matter yield (t/ha) of cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	--	--	--
C_2: Sole cowpea	8.93	9.13	9.04
C_3: Maize + cowpea (1:1)	4.99	5.25	5.12
C_4: Maize + cowpea (2:1)	3.36	2.88	3.12
C_5: Maize + cowpea (3:1)	1.99	1.73	1.86
SEm±	0.11	0.18	0.10
CD (P=0.05)	0.32	0.52	0.30
Nitrogen levels (N-kg/ha)			
N_1: 0	3.71	3.38	3.54
N_2: 40	4.64	4.70	4.67
N_3: 80	5.21	5.27	5.24
N_4: 120	5.71	5.35	5.68
SEm±	0.11	0.18	0.10
CD (P=0.05)	0.32	0.52	0.30
C x N			
SEm±	0.22	0.36	0.21
CD (P=0.05)	NS	NS	NS

18.88 t/ha respectively than the other treatments. It was followed by N_3 (17.08, 16.83 and 16.96 t/ha) and N_2 (15.48, 15.43 and 15.45 t/ha) respectively. In the 1st year of experiment and pooled data of two years, N_3 produced statistically higher yield than N_2 however in the 2nd year, both of these treatments were statistically at par with each other. The lowest fresh forage yield of 11.96, 10.62 and 11.29 t/ha in 2011, 2012 and their pooled analysis respectively were recorded in N_1 level.

4.2.4 *Dry matter yield (t/ha)*

It is also evident from Table 13b that during both the years and their pooled data, the sole crop of cowpea produced significantly the higher dry matter yield (8.93, 9.13 and 9.04 t/ha respectively) as compared to different row proportions. Dry matter yield in all the intercropping systems were significantly lower with the C_5 (1.99, 1.73 and 1.86 t/ha in 2011, 2012 and pool respectively) producing the lowest yield and C_3 (4.99, 5.25 and 5.12 t/ha in 2011, 2012 and pool respectively) the highest among them followed by C_4 (3.36, 2.88 and 3.12 t/ha in 2011, 2012 and pooled respectively).

A significant increase in the dry matter yield of cowpea with increase in nitrogen levels were observed in both the years and also in their pooled data. The effect was highly significant at N_4 (N @ 120 kg/ha) treatment where it was found to be statistically at par with N_3 treatment in the 2nd year of experiment. The lowest dry matter yield was obtained from N_1 treatment (3.71, 3.38 and 3.54 t/ha in 2011, 2012 and pooled respectively)

4.2.5 Total fresh forage yield (t/ha)

Table 14a, 14b and Fig. 9, 10 depicts the total fresh forage and total dry matter yield respectively of the maize and cowpea taken under study. From the data it was evident that the various nitrogen levels showed significant differences in the total fresh forage yield and total dry matter yield of the intercrops in both years of study. There was significant effect of cropping systems on the fresh forage yield during 2012 pooled analysis and during 2011 on the total dry matter yield and pooled analysis.

In general, the highest total fresh forage yield in 2011 (49.20 t/ha) was observed in C_4 row ratio followed by C_3 row ratio in 2012 (45.31 t/ha). In 2012, C_3 row ratio

Table 14a. Effect of different cropping system and N levels on total fresh forage yield (t/ha) maize and cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
$C_1 + C_2$	44.35	44.68	44.51
C_3: Maize + cowpea (1:1)	45.31	51.09	48.20
C_4: Maize + cowpea (2:1)	49.20	47.06	48.13
C_5: Maize + cowpea (3:1)	44.02	42.91	43.46
SEm$\pm$	1.46	1.40	1.12
CD (P=0.05)	NS	4.04	3.23
Nitrogen levels (N-kg/ha)			
N_1: 0	34.13	34.56	34.35
N_2: 40	46.05	46.51	46.28
N_3: 80	48.36	49.91	49.94
N_4: 120	54.33	54.75	54.54
SEm$\pm$	1.46	1.40	1.12
CD (P=0.05)	4.22	4.04	3.23
C x N			
SEm$\pm$	2.92	2.80	2.24
CD (P=0.05)	NS	NS	NS

Table 14b. Effect of different cropping system and N levels on total dry matter yield (t/ha) maize and cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
$C_1 + C_2$	12.46	12.83	12.65
C_3: Maize + cowpea (1:1)	13.46	14.07	13.78
C_4: Maize + cowpea (2:1)	14.94	13.64	14.29
C_5: Maize + cowpea (3:1)	13.56	13.21	13.39
SEm$\pm$	0.42	0.43	0.31
CD (P=0.05)	1.21	NS	0.90
Nitrogen levels (N-kg/ha)			
N_1: 0	10.00	9.61	9.81
N_2: 40	13.90	12.95	13.42
N_3: 80	14.45	15.18	14.82
N_4: 120	16.11	16.01	16.07
SEm$\pm$	0.42	0.43	0.31
CD (P=0.05)	1.21	1.24	0.90
C x N			
SEm$\pm$	0.83	0.86	0.63
CD (P=0.05)	NS	NS	NS

produced significantly highest total fresh forage yield (51.09 t/ha) closely followed by C_4 row ratio treatment (47.06 t/ha) which were statistically at par with one another. The pooled data was also found to be significantly high with C_3 row ratio (48.20 t/ha) which was at par with C_4 row ratio treatment (48.13 t/ha). The lowest total fresh forage yield (44.02, 42.91 and 43.46 t/ha) was obtained with C_5 cropping system in both the years and pooled analysis.

The total fresh forage yield increased with the progressive increase in nitrogen levels in both years of study. The greatest total fresh forage yield (54.33, 54.75 and 54.54 t/ha) was recorded with N_4 treatment which was found to be significantly high in both years of study and pooled analysis. This was closely followed by N_3 treatment (48.36, 49.91 and 49.94 t/ha). The least total fresh forage yield (34.13, 34.56 and 34.35 t/ ha) was obtained in treatments N_1 where no nitrogen was applied in the two years of study and their pooled analysis.

The cropping systems and nitrogen levels did not show any significance on the total fresh forage yield in both years of experimentation.

4.2.6 Total dry matter yield (t/ha)

A perusal of the data in Table 14a and Table 14b shows that the different nitrogen levels significantly influenced the total fresh and dry matter content of forage crops under study.

The total dry matter yield of crops significantly higher (14.94 t/ha) with C_4 row ratio as compared to other cropping systems under study in 2011, while in 2012, C_3 row ratio was observed to produce greater dry matter content (14.07 t/ha) although non-significant with other treatments. The pooled data resulted with significantly greater dry matter content (14.29 t/ha) with C_4 row ratio followed by C_3 treatment (3.78 t/ha). The lowest dry matter content (12.46, 12.83 and 12.65 t/ha) of crops were obtained with C_1+C_2 (sole maize + sole cowpea) cropping in 2011, 2012 and pooled data.

On close analysis of the data it was evident that the total dry matter content of intercrops increased with every increase in the nitrogen doses applied and recorded significantly highest values (16.11, 16.01 and 16.07 t/ha) with N_4 treatment in both years of study and pooled data. This was closely followed by N_3 treatment which was found to be statistically at par only in 2012 (14.45, 15.18 and 14.82 t/ha). The least values of total dry matter yield (10.00, 9.61 and 9.81 t/ha) were recorded with N1 treatment in both years of study and pooled data.

The total dry matter yield of intercrops was not influenced by the different cropping systems and nitrogen levels under study in both the years.

4.3 Quality attributes

4.3.1 *Crude protein (%)*

Maize - Table 15a represents the significant effect of different cropping systems and N levels on per cent crude protein content of maize. In maize, among the cropping systems under study, the highest per cent crude protein content of 12.55, 12.76 and 12.66 % during 2011, 2012 and pool respectively was obtained from C_3 (1:1) and it was statistically superior than all other treatments. Both C_4 and C_5 row ratio was found to be statistically at par with each other and markedly higher than C_5 in 2011 but in 2012 both of them were at par with C_5. The lowest amount of crude protein was recorded in C_1 row ratio (10.36 and 10.95 % during 2011 and 2012 respectively). Data on pooled analysis was similar with that of 2011.

The maximum crude protein was recorded with N_4 treatment in 2011, 2012 and pooled with 12.39, 12.78 and 12.59 % respectively. It was statistically superior to all other treatments during 2011 and pool but was at par with N_3 (12.30 %) during 2012. Between N_2 and N_3 there was no difference at all the observations. During 2011, N_1 treatment (10.60 %) obtained the lowest value but was at par with N_2 (11.19 %) and N_3 (11.38%). Similarly during both 2012 and also pool of two years, N_1 treatment (9.97 and 10.29 % respectively) produced the lowest but it was not at par with N_2 and N_3.

The interaction effect of C × N on the per cent crude protein of maize was recorded to have significant variation among the various treatments in 2011, 2012 and their pooled data (Table 15c). Higher values were with maize in sole plots with N @ 40, 80 and 120 kg/ha of N in all these observations. While all the cropping systems with 0 kg N/ha and the intercropping systems with N @ 40, 80 and 120 kg/ha of N associated with the lower values.

Table 15a. Effect of different cropping system and N levels on per cent crude protein content of maize

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	10.36	10.95	10.66
C_2: Sole cowpea	--	--	--
C_3: Maize + cowpea (1:1)	12.55	12.76	12.66
C_4: Maize + cowpea (2:1)	11.51	11.57	11.54
C_5: Maize + cowpea (3:1)	11.12	11.26	11.19
SEm±	0.34	0.34	0.25
CD (P=0.05)	0.98	0.99	0.72
Nitrogen levels (N-kg/ha)			
N_1: 0	10.60	9.97	10.29
N_2: 40	11.19	11.47	11.33
N_3: 80	11.38	12.30	11.84
N_4: 120	12.39	12.78	12.59
SEm±	0.34	0.34	0.25
CD (P=0.05)	0.98	0.99	0.72
C x N			
SEm±	0.68	0.69	0.50
CD (P=0.05)	1.96	1.99	1.44

Table 15b. Effect of different cropping system and N levels on per cent crude protein content of cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	--	--	--
C_2: Sole cowpea	17.21	18.13	17.68
C_3: Maize + cowpea (1:1)	16.80	17.71	17.26
C_4: Maize + cowpea (2:1)	16.40	17.32	16.86
C_5: Maize + cowpea (3:1)	16.15	16.98	16.57
SEm$\pm$	0.08	0.10	0.07
CD (P=0.05)	0.24	0.29	0.19
Nitrogen levels (N-kg/ha)			
N_1: 0	16.32	17.24	16.86
N_2: 40	16.61	17.48	16.98
N_3: 80	16.81	17.63	17.18
N_4: 120	16.90	17.78	17.34
SEm$\pm$	0.08	0.10	0.07
CD (P=0.05)	0.24	0.29	0.19
C x N			
SEm$\pm$	0.17	0.20	0.13
CD (P=0.05)	NS	NS	NS

Table 15c. Interaction effect of different cropping system and N levels on the per cent crude protein of maize during 2012 and pool of two years

Cropping system (C)	N-levels (kg/ha)			
	N_1 0	N_2 40	N_3 80	N_4 120
2011				
C_1 Sole Maize	11.49	13.10	13.05	13.48
C_3 Maize + cowpea (1:1)	11.60	11.69	11.88	12.04
C_4 Maize + cowpea (2:1)	12.07	12.18	12.30	12.50
C_5 Maize + cowpea (3:1)	11.22	11.46	11.61	11.85
SEm±	0.17			
CD (P = 0.05)	0.45			
2012				
C_1 Sole maize	11.43	13.24	12.48	12.96
C_3 Maize + cowpea (1:1)	11.56	11.64	11.83	12.00
C_4 Maize + cowpea (2:1)	12.06	12.24	12.33	11.96
C_5 Maize + cowpea (3:1)	11.17	11.43	11.56	11.86
SEm±	0.22			
CD (P = 0.05)	0.64			
Pooled (2011 - 2012)				
C_1 Sole maize	11.46	13.17	12.77	13.22
C_3 Maize + cowpea (1:1)	11.58	11.67	11.86	12.02
C_4 Maize + cowpea (2:1)	12.07	12.21	12.32	12.23
C_5 Maize + cowpea (3:1)	11.20	11.45	11.59	11.86
SEm±	0.12			
CD (P = 0.05)	0.36			

Cowpea - The highest per cent crude protein in cowpea cropping system was obtained from sole cowpea (C_2) compared to different row proportions in both the years and their pooled (17.21, 18.13 and 17.68 % respectively) (Table 15b). In 2011, it was at par with C_3 (16.80 %) and both of them were markedly higher than C_4 (16.40 %) and C_5 (16.15 %). During 2012 and in pooled data the per cent crude protein content of all the cropping systems differed significantly from each other and C_5 recorded the lowest (16.98 and 16.57 % in 2012 and pooled data respectively). In 2011, 2012 and pooled, among the different nitrogen levels the maximum per cent crude protein content was obtained from N_4 treatments (16.90, 17.78 and 17.34 % respectively) and it was at par with N_3 (16.81, 17.63 and 17.18 % respectively). The lowest was recorded in N_1 treatment with 16.32, 17.24 and 16.86 % in 2011, 2012 and pooled respectively.

4.3.2 *Crude Fibre (%)*

Maize - Different cropping systems showed significant variation on the per cent crude fibre content of maize during 2011 and pool of two years (Table 16a). In both these observations, the sole crop of maize (24.67 and 24.18 % respectively) recorded significantly higher value than any of the intercropping treatments. It was also observed that there was no statistical difference among the intercropping treatments. However, 1:1 recorded the highest value (22.62 and 21.90 % in 2011 and pool of two years) and both 2:1 (21.53 %) and 3:1 (21.53 %) in 2011 and 3:1 (20.58 %) in pooled data recorded the lowest. Similar result was also seen for 2012 though there was no significant variation.

The effect of nitrogen levels on the per cent crude fibre content of maize did not show significant effect during 2011 and 2012, however, analysis of their pooled data showed significant difference (Table 16). N_1 (24.28 %) treatment recorded significantly higher value than all the other treatment. The lowest was in N_4 (20.51 %) and it was at par with N_2 (22.00 %) and N_3 (20.98 %).

Cowpea – Data on the per cent crude fibre content of cowpea depicted in Table 16b revealed that different cropping systems showed significant difference among themselves in the per cent crude fibre content of cowpea in 2011, 2012 and pooled data. Sole cowpea - C_2 (22.79, 22.73 and 22.76 %) recorded the highest per cent crude fibre

Table 16a. Effect of different cropping system and N levels on per cent crude fibre content of maize

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	24.67	23.69	24.18
C_2: Sole cowpea	--	--	--
C_3: Maize + cowpea (1:1)	22.62	21.18	21.90
C_4: Maize + cowpea (2:1)	21.53	20.66	21.09
C_5: Maize + cowpea (3:1)	21.35	19.81	20.58
SEm$\pm$	0.65	1.36	0.69
CD (P=0.05)	1.87	NS	1.99
Nitrogen levels (N-kg/ha)			
N_1: 0	24.14	24.41	24.28
N_2: 40	22.31	21.69	22.00
N_3: 80	21.90	20.05	20.98
N_4: 120	21.81	19.21	20.51
SEm$\pm$	0.65	1.36	0.69
CD (P=0.05)	NS	NS	1.99
C x N			
SEm$\pm$	1.30	2.73	1.38
CD (P=0.05)	NS	NS	NS

Table 16b. Effect of different cropping system and N levels on per cent crude fibre content of cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	--	--	--
C_2: Sole cowpea	22.79	22.73	22.76
C_3: Maize + cowpea (1:1)	22.14	22.09	22.12
C_4: Maize + cowpea (2:1)	20.41	20.49	20.45
C_5: Maize + cowpea (3:1)	20.17	20.16	20.17
SEm$\pm$	0.07	0.11	0.05
CD (P=0.05)	0.21	0.31	0.16
Nitrogen levels (N-kg/ha)			
N_1: 0	21.48	21.50	21.49
N_2: 40	21.44	21.41	21.43
N_3: 80	21.38	21.31	21.35
N_4: 120	21.21	21.25	21.23
SEm$\pm$	0.07	0.11	0.05
CD (P=0.05)	NS	NS	0.16
C x N			
SEm$\pm$	0.15	0.21	0.11
CD (P=0.05)	NS	NS	NS

followed by C_3 (22.14, 22.09 and 22.12 %). The lowest was in C_5 treatment (20.17, 20.16 and 20.17 %). For cowpea also the effect of different levels of nitrogen did not show any significant on crude fibre content during 2011 and 2012; however their pooled analysis was found to be significant. All the treatments were found to be at par with each other and N_1 recorded the highest values while N_4 recorded the lowest.

4.3.3 *Total ash content (%)*

Maize – The per cent total ash content was significant with different cropping system only during 2012 and pool of two years data (Table 17a). In both these observations, all the intercropping systems where maize was intercropped with cowpea in different row proportions recorded higher values than its sole treatment. Maize in 1:1 row ratio (C_3) recorded the highest value in both 2012 (7.78 %) and pooled data (7.67%) and it was statistically at par with 3:1 (C_4) in 2012 and significantly higher than all other treatments in the pool of two years. The lowest amount of total ash content was recorded in C_1 row ratio with 7.18 per cent and 7.33 per cent during 2011 and 2012 respectively. This might be due to the increase in seed rate or proportion of legume in C_3 row ratio as compared to other cropping systems.

The different nitrogen levels affected per cent total ash content significantly in both years of study and in the pooled data. There was progressive increase in the per cent total ash content with increase in the N levels. The highest total ash content (7.65, 7.92 and 7.79 %) which was significantly highest was recorded with N_4 treatment during 2011, 2012 and pooled data of both years respectively. The lowest total ash content was recorded with control treatment in both years and pooled data (7.14, 7.16 and 7.15 % respectively)

Cowpea – The different cropping systems significantly influenced the per cent total ash content in forage in both years of study and the pooled data (Table 17b). The maximum total ash was obtained in sole crop of cowpea (C_2) in both the years. In 2011 and 2012, the highest total ash was 9.04 per cent and 7.88 per cent respectively and 8.96 per cent in pooled data of both years which were significantly greater than all other

Table 17a. Effect of different cropping system and N levels on per cent total ash content of maize

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	7.18	7.33	7.26
C_2: Sole cowpea	--	--	--
C_3: Maize + cowpea (1:1)	7.56	7.78	7.67
C_4: Maize + cowpea (2:1)	7.32	7.58	7.45
C_5: Maize + cowpea (3:1)	7.30	7.45	7.38
SEm±	0.10	0.08	0.06
CD (P=0.05)	NS	0.22	0.18
Nitrogen levels (N-kg/ha)			
N_1: 0	7.14	7.16	7.15
N_2: 40	7.21	7.38	7.30
N_3: 80	7.36	7.68	7.52
N_4: 120	7.65	7.92	7.79
SEm±	0.10	0.08	0.06
CD (P=0.05)	0.28	0.22	0.18
C x N			
SEm±	0.19	0.15	0.12
CD (P=0.05)	NS	NS	NS

Table 17b. Effect of different cropping system and N levels on per cent total ash content of cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	--	--	--
C_2: Sole cowpea	9.04	8.88	8.96
C_3: Maize + cowpea (1:1)	8.63	8.40	8.51
C_4: Maize + cowpea (2:1)	8.49	8.24	8.37
C_5: Maize + cowpea (3:1)	8.18	7.98	8.08
SEm±	0.06	0.05	0.04
CD (P=0.05)	0.18	0.15	0.12
Nitrogen levels (N-kg/ha)			
N_1: 0	8.28	8.11	8.20
N_2: 40	8.50	8.27	8.38
N_3: 80	8.68	8.44	8.56
N_4: 120	8.88	8.68	8.78
SEm±	0.06	0.05	0.04
CD (P=0.05)	0.18	0.15	0.12
C x N			
SEm±	0.12	0.10	0.08
CD (P-0.05)	NS	NS	NS

treatments. The lowest per cent total ash of 8.18 and 7.98 were recorded in C_5 row ratio in both the years respectively and pooled data (8.08 %).

A close scrutiny of the data shows that the various nitrogen treatments significantly influenced per cent total ash content in cowpea. There was progressive increase in per cent ash content in with increase in nitrogen levels where N_4 treatment recorded 8.88, 8.68 and 8.78 per cent in 2011, 2012 and pooled data respectively. N_4 treatment was found to be statistically at par with N_3 treatment in 2012 and pooled analysis. The lowest ash content was obtained with N1 treatment in both years and pooled data (8.38, 8.11 and 8.20 per cent respectively).

The interaction between cropping system and nitrogen levels on the ash content in intercropping maize and cowpea as forage plants failed to reach the level of significance.

4.3.4 *In vitro dry matter digestibility (IVDMD %)*

The influence of various intercropping systems and nitrogen levels on *in vitro* dry matter digestibility is depicted in Table 18a and 18b for maize and cowpea respectively.

Maize - The effect of different cropping system on maize *in vitro* dry matter digestibility did not show any significant variations due to cropping systems. However, in general, the highest IVDMD was recorded in C_3 row ratio with 64.14 and 64.00 per cent in 2011 and 2012 respectively. This was followed by C_4 treatment (63.64 per cent) in 2011 and C_5 (63.90 per cent) in 2012. The pooled data also showed similar trend where the greatest value (64.07 per cent) was obtained with C_3 row ratio followed by C_5 (63.76 per cent) The lowest amount of IVDMD with 62.99 and 63.58 per cent was recorded in both the years respectively.

The different levels of nitrogen treatment did not show any significant differences among the N treatments on the IVDMD. In general, N_4 recorded the maximum IVDMD with 63.92 and 64.25 per cent in 2011 and 2012 respectively. Which was closely followed by N_3 treatment with 63.80 and 63.82 per cent and the lowest was recorded in N_1 with 62.98 and 63.55 per cent respectively in the two years of study. The pooled analysis also recorded greatest IVDMD values (64.04 per cent) with N_4 treatment while the least was observed with N_1 treatment (63.27 per cent).

Table 18a. Effect of different cropping system and N levels on *in vitro* dry matter digestibility content of maize

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	62.99	63.58	63.29.
C_2: Sole cowpea	--	--	--
C_3: Maize + cowpea (1:1)	64.14	64.00	64.07
C_4: Maize + cowpea (2:1)	63.64	63.75	63.69
C_5: Maize + cowpea (3:1)	63.62	63.90	63.76
SEm±	0.38	0.25	0.25
CD (P=0.05)	NS	NS	NS
Nitrogen levels (N-kg/ha)			
N_1: 0	62.98	63.55	63.27
N_2: 40	63.69	63.62	63.65
N_3: 80	63.80	63.82	63.81
N_4: 120	63.92	64.25	64.08
SEm±	0.38	0.25	0.25
CD (P=0.05)	NS	NS	NS
C x N			
SEm±	0.76	0.50	0.49
CD (P=0.05)	NS	NS	NS

Table 18b. Effect of different cropping system and N levels on *in vitro* dry matter digestibility content of cowpea

Treatments	2011	2012	Pooled
Cropping system (C)			
C_1: Sole maize	--	--	--
C_2: Sole cowpea	61.41	60.28	60.85
C_3: Maize + cowpea (1:1)	62.63	62.18	62.41
C_4: Maize + cowpea (2:1)	62.28	61.35	61.82
C_5: Maize + cowpea (3:1)	62.33	61.28	61.81
SEm$\pm$	0.33	0.48	0.30
CD (P=0.05)	NS	NS	NS
Nitrogen levels (N-kg/ha)			
N_1: 0	60.99	60.93	60.96
N_2: 40	61.53	61.22	61.37
N_3: 80	62.80	61.23	61.55
N_4: 120	63.33	61.72	62.52
SEm$\pm$	0.33	0.48	0.30
CD (P=0.05)	0.96	NS	0.87
C x N			
SEm$\pm$	0.66	0.96	0.60
CD (P=0.05)	NS	NS	NS

Cowpea – The different cropping system did not show any significant effect on per cent IVDMD in cowpea during 2011 and 2012. In general, the maximum IVDMD (62.63 per cent and 62.18 per cent) was obtained in C_3 in both the years which was followed by C_5 row ratio in 2011 (62.33 per cent) and C_4 row ratio with (61.35 per cent) in 2012. The lowest per cent IVDMD of 61.41 and 60.28 were recorded in C_2 treatment in 2011 and 2012 respectively.

The different nitrogen treatments showed significant variations only in 2011 and pooled data. N_4 treatment recorded the highest IVDMD (63.33 per cent) which was significantly highest over all the other treatments. In the second year N_4 treatment showed 61.72 per cent content of IVDMD and pooled analysis was found to contain 62.52 per cent in cowpea. The lowest per cent IVDMD was obtained from N_1 treatment which was 60.99 per cent and 60.93 per cent respectively in both the years. The interaction between cropping systems and nitrogen levels on the per cent IVDMD content did not show any significant variations in both years of study.

4.4 Studies on economics

4.4.1 *Cost of cultivation (`/ha)*

The data (Table 19a) revealed that among intercropping systems of maize with cowpea row proportion, the highest cost of cultivation (` 25742.09) was recorded in $C_5$ row ratio. The least was recorded with sole cowpea, $C_2$ (` 24332.09).

Among the different nitrogen levels, N_4 treatment recorded the highest cost of cultivation (` 28552.39). The least was recorded in $N_1$ treatment (` 21181.39).

4.4.2 *Gross return (`/ha)*

Between sole and intercropping treatments, gross return (Table 19a) was higher with C_2 treatment amounting to ` 63515.00 in 2011 in and ` 68580.00 in 2012 in C_3 row ratio and the least gross return was obtained in C_5 row ratio for both the years with ` 46885.00 and ` 23247.91 respectively.

Among the different nitrogen levels, N_4 treatment recorded the highest gross return (` 68456.00) and (` 69068.00) and the least was recorded in N_1 treatment (` 44204.00) and (` 43376.00) in both the years.

Table 19a. Economics of different cropping systems with maize and cowpea and nitrogen levels

Treatments	Cost of cultivation (`/ha)	Gross return (`/ha)	
		2011	2012
Cropping system (C)			
C_1: Sole maize	24532.09	56935.00	57375.00
C_2: Sole cowpea	24332.09	63515 .00	63950.00
C_3: Maize + cowpea (1:1)	24792.09	61680 .00	68580.00
C_4: Maize + cowpea (2:1)	25386.09	59362.50	55507.50
C_5: Maize + cowpea (3:1)	25742.09	48990.00	46885.00
Nitrogen levels (N-kg/ha)			
N_1: 0	21181.39	44204.00	43376.00
N_2: 40	23938.39	57972 .00	58554.00
N_3: 80	26155.39	61754 .00	62840.00
N_4: 120	28552.39	68456 .00	69068.00

4.4.3 *Net return (`/ha)*

Net return (Table 19b) was found to be highest in sole cropping of cowpea as compared to different row proportion where sole cowpea recorded the highest net return of ` 39182.91 in 2011, while in the 2$^{nd}$ year, $C_3$ row ratio of 1: 1 obtained maximum net returns of ` 43787.91. The lowest net return was obtained in C_5 (3:1 row ratio) with ` 23247.91 and ` 21142.91 respectively for both the years.

Under different nitrogen levels the highest net return of ` 39903.61 and ` 40515.61 respectively were obtained from N_4 treatment in 2011 and 2012. While N_1 recorded the lowest net return of ` 23022.61 and ` 22194.61 respectively in both the years.

4.4.4 *Benefit-cost ratio*

Sole cropping of cowpea showed the highest B:C ratio (1.62) followed by C_3 1:1 row ratio (1.48) in 2011 (Table 19b). During 2012, row ratio of C_3 obtained the highest B:C ratio of 1.75 compared to all the other cropping systems. The least B:C ratio of 0.89 and 0.81 was found in C_5 (3:1 row ratio) in the two years respectively.

Among the different nitrogen levels, N_2 treatment recorded the highest B:C ratio of 1.42 and 1.45 respectively in both the years. The least B:C ratio of 1.10 and 1.06 was recorded in N_1 treatment in the two years of study.

Table 19b. Economics of different cropping systems with maize and cowpea and nitrogen levels

Treatments	Net return (`/ha)		B:C	
	2011	2012	2011	2012
Cropping system (C)				
C_1: Sole maize	32402.91	32842.91	1.32	1.35
C_2: Sole cowpea	39182.91	39617.91	1.62	1.62
C_3: Maize + cowpea (1:1)	36887.91	43787.91	1.48	1.75
C_4: Maize + cowpea (2:1)	33976.41	30121.41	1.31	1.16
C_5: Maize + cowpea (3:1)	23247.91	21142.91	0.89	0.81
Nitrogen levels (N-kg/ha)				
N_1: 0	23022.61	22194.61	1.10	1.06
N_2: 40	34033.61	34615.61	1.42	1.45
N_3: 80	35598.61	36684.61	1.37	1.41
N_4: 120	39903.61	40515.61	1.40	1.42

CHAPTER-V

DISCUSSION

Maize (*Zea mays* L.) is a versatile crop which finds a place in the human food, animal feed, fodder and industrial raw material. India being an agricultural country, about 70% of the population lives in the villages whose livelihood depends mainly on agriculture and animal husbandry. India has huge livestock population of 512.05 million (Anon, 2012) and ranks first in milk production in the world (Anon, 2015). Agriculture in Nagaland depends entirely on monsoon and therefore growing of crops especially fodder crops are mainly grown during the *kharif* season. Intercropping is a cultivation practice to increase the variety of crops grown in the same piece of land. Further when legume crops are intercropped with non-leguminous crops, there is added benefit of compensating the nitrogen requirements of plants in the field. This chapter presents the results of the present investigation and discussed with relevant reports to support the findings.

5.1 Growth parameters

5.1.1 Effect of intercropping

5.1.1.1 Maize

Data presented in Table 3a and Table 3b showed that the plant height of maize was significantly higher under intercropping system over sole cropping at 21 and 56 DAS during 2011. From Table 4a and 4b also it was observed that during 2012 maize height in all the row proportions was taller than sole treatment though it did not reach a significant level. This might be due to fixation of atmospheric nitrogen into soil by root nodules of cowpea, nodules decomposition and reduced inter row specific competition for solar radiation because of smaller plant stature of cowpea as compared to maize plants and as a result maize grew erect and taller than the cowpea plants in intercropping system. Similar results were given by Eskandari and Ghanbari (2009) who stated that the cereal component maize was usually taller than the legume cowpea because of its faster growing or more extensive root system for extracting the nutrient resources from the soil. Alla *et al*. (2014) also stated that the height of maize plant under intercropping system was more than that in the sole maize due to competition of associated crops for intercepting light intensity which leads to increase in maize plant height

The number of leaves per plant in maize was also observed to be more in the intercropping system in both the years of experimentation and 1:1 row ratio recorded significantly more number of leaves as compared to sole treatment where the least was observed at 21, 28 and 42 DAS only during 2011 (Table 7a and 7b). The reason might be due to the complimentary effect of accompanying legume crop in the intercropping system and also since the legume population was more in 1:1 ratio as compared to other cropping ratios. The present findings corroborates with the works carried out by Mobasser *et al*. (2014) who observed that intercropping cereal and grain legume crops maintain and improve soil fertility because crops like cowpea, mung bean and soybean accumulate from 80 to 350 kg N/ha. This could be attributed to vigorous vegetative growth of maize crops in the present investigation.

Plant population per m^2 of maize between sole and intercropping treatments was observed to be non significant in both the years and also their pooled data (Table 11). However the sole cropping (C_1) of maize recorded the highest value compared to any of the intercropping system which obviously was due to the presence of greater proportion of maize plant under sole cropping as compared to intercropped plots. Similar results were reported by Pattanashetti (2000) in maize + soybean cropping system.

5.1.1.2 Cowpea

The data presented in Table 5a, 5b and Table 6a, 6b showed that among the various stages of observation, the plant height in sole treatment was markedly lower than the heights in all the row proportions only at 21 DAS. This finding is logical, since there is light competition in the inter-and intra-plants of cowpea and maize cropping system. Alla *et al*. (2014) also found similar conclusion in intercropping cowpea + maize and stated that the competition between the two associated crops in an intercropping system is further amplified by maize elongation and consequently its large shading on cowpea.

At any of the growth stages of 2011 (Table 9a, 9b) and 2012 (Table 10a, 10b), the number of leaves per plant of cowpea was not influenced due to different cropping system, however the highest values were seen in the intercropping systems than the sole system. The reason might be due to lack of competition for resources such as light, water and nutrients in sole cowpea crop and as a result the sole cowpea grew and matured faster and thus caused sole cowpea plants to lose some leaves before harvesting.

The data on plant population per m^2 (Table 11) revealed that the values in each treatment differed significantly from one another and the sole crop of cowpea (C_2) produced maximum plant population, followed by cowpea in 1:1 row ratio (C_3). The minimum plant population was obtained in 3:1 row ratio (C_5). This could be attributed to uniform growth of plants in sole cropping with no competition for various growth requirements such as light, water and nutrients.

5.1.2 Effect of nitrogen

5.1.2.1 Maize

From Table 3a, 3b and Table 4a, 4b it was observed that the plant height of maize differed according to different nitrogen levels. The effect of nitrogen was found to be significant only at 21 DAS during 2011 and in all the days of observation except 63 DAS during 2012 DAS where N_4 (N @ 120 kg/ha) recorded the tallest plants followed by N_3 (N @ 80 kg/ha) and the shortest in N_1 (N @ 0 kg/ha) followed by N_2 (N @ 40 kg/ha). Further, the plant height increased with every increase in nitrogen levels. The increase in plant height with N fertilizer may be due to the fact that N promotes plant growth, increases the number of internodes and length of the internodes which results in progressive increase in plant height (Gasim, 2001). Undie *et al*. (2012) found that among five N levels viz., 0, 25, 50, 75 and 100 kg/ha, significant increase in the plant height and number of leaves per plant was recorded in 100 kg N/ha as compared to plants when no nitrogen was applied which confirms the present findings.

The number of leaves per plant also showed an increasing trend with every increase in N level (Table 7a, 7b and Table 8a, 8b). At all the growth stages in both the years of experimentation, N application @120 kg/ha (N_4) recorded significantly the highest number of leaves per plant. This was followed by N @ 80 kg/ha (N_3) and N @ 40 kg/ha (N_2). The least number of leaves per plant was in N @ 0 kg/ha (N_1). Increase in the number of leaves per plant could be a result of increase in plant height (Akintoye, 1996) and increase in nitrogen application (Nadeem *et al.*, 2009; Das, 2004 and Ayub *et al.*, 2003).

Effect on plant population by different nitrogen levels did not show any marked difference during both the years and also in their pooled data (Table 11). Non significant effect of nitrogen application on plant density was also reported by Ayub *et al.* (2007) on pearl millet and Nadeem *et al.* (2009) on maize + legume mixture.

5.1.2.2 Cowpea

The different N levels resulted in increased plant height of cowpea grown as intercrop in maize during 2011 and 2012 (Table 5a, 5b and Table 6a, 6b). In both these years, tallest plants were recorded with nitrogen application at 120 kg/ha (N_4) followed by nitrogen application at 80 kg/ha (N_3), nitrogen application at 40 kg/ha (N_2) and the lowest in nitrogen application at 0 kg/ha.

The influence of nitrogen levels on the number of leaves of cowpea followed the same trend as in plant height and showed significant effect on 21, 28, 35, 42, 49, 56, 63 DAS and at harvest (Table 9a, 9b) during 2011 and on 42 and 49 DAS during 2012 (Table 10a, 10b). The present findings find similarity with that of Undie *et al.* (2012) who reported that in maize + soybean system the number of leaves in soybean significantly increased at all nitrogen rates from 0 to 100 kg/ha.

The effect of nitrogen levels on the plant population of cowpea did not reach significant level in both 2011 and 2012 and also pooled data (Table 11). However, the data from pool of two years showed N application @ 120 kg/ha (N_4) to have the maximum population (24.25 per/m^2) and the minimum (22.50 per/m^2) where there was no application of N (N_1) which might be due to the difference in N dose.

5.2 Yield and yield attributes

5.2.1 Effect of intercropping

5.2.1.1 Maize

The fresh forage yield and dry matter yield of maize in tonnes per hectare presented in Table 12a and Table 12b respectively showed significant superiority of sole treatment (C_1) in comparison to its intercropping for both the years and also their pooled analysis. This is inevitable, as pure crop of maize had more sown area under it than those in intercropping stands. Among the different row proportions, the yield in 3:1 row ratio (C_5) and 2:1 row ratio (C_4) was statistically comparable and both were significantly higher than the yield in 1:1 row ratio. This could also be attributed mainly to 75 % and 66.67 % of maize sown area in 3:1 and 2:1 ratios as compared to only 50% in 1:1 row ratio. Lower green forage yield of sorghum grown in association with legume cowpea as compared to sole crop of sorghum was also reported by Pal *et al*. (2014). However, according to Prasanthi and Venkateswaralu (2014), legume fodders intercropped within the pairs of maize performed better with lower reduction in dry matter indicating better utilization of environmental resources and the availability of ample space between paired rows. The highest total dry matter was recorded in treatments, maize pairs + cowpea.

5.2.1.2 Cowpea

From Table 13a and Table 13b it was evident that sole treatment - C_2 recorded significantly the highest fresh forage yield and dry matter yield than their intercropping with different row proportions. Among the intercropping systems, 1:1 row ratio performed better, followed by 2:1 and lastly 1:1 cropping system. Such differences might be due to the differences in plant population among treatments and also the arrangement of rows as cowpea in 3:1 row ratio would have limitation for growth resources specially sunlight as compared to 2:1 and 1:1. Fujita *et al*. (1992) in their study on the biological nitrogen fixation in mixed legume-cereal cropping systems reported that taller cereal sorghum reduced biological N-fixation and yield of associated legumes due to shading effect. The present findings find similarity with the results of Ntare *et al*. (1993) who studied the physiological determinants of cowpea seed yield as affected by phosphorus fertilizer and sowing date intercropped with millet showed that the legume was suppressed when intercropped with a C – 4 plants. Addo - Quaye *et al.* (2011) also opined that the reduction in bean yield when intercropped with maize was attributed to the inter specific competition and depressive effect of maize crop on the counter legume crop.

5.2.1.3 Total fresh forage and dry matter yield

The highest total fresh forage yield in 2011 (49.20 t/ha) was observed in C_4 row ratio followed by C_3 row ratio in 2012 (45.31 t/ha) but was found to be non-significant (Table 14a). In 2012, C_3 row ratio produced significantly highest total fresh forage yield (51.09 t/ha) closely followed by C_4 row ratio treatment (47.06 t/ha) which were statistically at par with one another. The pooled data was also found to be significantly high with C_3 row ratio which was at par with C_4 row ratio treatment. The lowest total fresh forage yield was obtained with C_5 cropping system in both the years and pooled analysis. The highest green forage yield of 12.22 t/ha and dry matter yield of 2.039 t/ ha were recorded for cowpea sown in alternate rows with forage maize (Iqbal *et al.*, 2012).

The total dry matter yield of crops was found to be significantly highest (14.94 t/ha) with C_4 row ratio as compared to other cropping systems under study in 2011, while in 2012, C_3 row ratio was observed to produce greater dry matter content (14.07 t/ha) although non-significant with other treatments (Table 14b). The pooled data resulted with significantly greater dry matter content (14.29 t/ha) with C_4 row ratio followed by C_3 treatment (3.78 t/ha). The lowest dry matter content of crops were obtained with C_1+C_2 cropping in 2011, 2012 and pooled data. According to Surve *et al*. (2012), intercropping system of maize and cowpea in 2: 1 row ratio showed higher green fodder yield than sole maize which finds credence with the present study. Works done by Mukhtar (2014) also revealed that cowpea intercropped with maize at 1:1 row arrangement recorded the highest grain yield per plant and per hectare, which was significantly different from sole crops.

5.2.2 Effect of nitrogen

5.2.2.1 Maize

Variation in the fresh forage yield (Table 12a) and dry matter yield (Table 12b) of maize was observed to be significant among the different nitrogen levels and the values between the fresh forage yield and dry matter yield corresponded with each other in both the years and also their pooled data. The maximum value was recorded in N application @ 120 kg/ha (N_4) and minimum in N application @ 0kg/ha (N_1). The present results concur with those observed by Nadeem *et al.* (2009) who reported increase in dry matter yield of maize + cowpea with increase in nitrogen levels from 0 to 150 kg N/ha. This might be the result of improvement in the vegetative characteristics (plant height, number of leaves) with increase in nitrogen fertilizer rate attributing to increased uptake of nitrogen and its associated role in chlorophyll synthesis and carbon dioxide assimilation leading to enhanced growth and consequently more fresh forage yield and dry matter yield (Safari *et al.*, 2014).

5.2.2.2 Cowpea

The positive effect of nitrogen application @ 120 kg/ha was also observed for fresh forage yield and dry matter yield in cowpea (Table 13a and Table 13b). The yield however, decreased as nitrogen levels decreased with nitrogen application @ 0 kg/ha being the lowest in both 2011, 2012 and their pooled data. This might be the result of improvement in the vegetative characteristics (plant height, number of leaves) with increase in nitrogen fertilizer attributing to increased uptake of nitrogen and its associated role in chlorophyll synthesis and carbon dioxide assimilation leading to enhanced growth and consequently more fresh forage yield and dry matter yield (Safari *et al.*, 2014).

5.2.2.3 Total fresh forage and dry matter yield

The total fresh forage yield increased with the progressive increase in nitrogen levels in both years of study (Table 14a). The greatest total fresh forage yield was recorded with N_4 treatment which was found to be significantly high in both years of study and pooled analysis. This was closely followed by N_3 treatment. The least total fresh forage yield was obtained in treatments N_1 where no nitrogen was applied in the two years of study and their pooled analysis. Adeleke and Haruna (2012) mentioned that pulses are usually intercropped with cereals which enhance land productivity over soil amelioration. Similarly, Safari *et al*. (2014) also reported that dry matter content and forage yield of corn increased with increase in the amount of N application and the highest dry matter content and forage yield was obtained in 150 and 225 kg/ha nitrogen application which was in line with the results obtained in the present investigation.

On close scrutiny of the data it was evident that the total dry matter content of intercrops increased with every increase in the nitrogen doses applied and recorded significantly highest values (16.11, 16.01 and 16.07 t/ha) with N_4 treatment in both years of study and pooled data (Table 14b). This was closely followed by N_3 treatment which was found to be statistically at par only in 2012 (14.45, 15.18 and 14.82 t/ha). The least values of total dry matter yield were recorded with N_1 treatment in both years of study and pooled data. Chaudhari *et al*. (2006) also reported that the grain and dry fodder yields of maize were significantly increased with increased levels of fertilizers owing to significant increase in leaf area, dry matter and yield attributes with higher fertilizer levels.

5.3 Quality parameters

5.3.1 Effect of intercropping

5.3.1.2 Maize

Among the cropping systems under study, intercropping treatments in different row ratios were comparatively better than its sole treatment (C_1) in all the years of observations and also their pool. C_3 treatment which had cowpea in every alternate row of maize recorded significantly the highest value and it was followed by C_4 where cowpea was sown after two rows of maize and C_5 where cowpea was sown after three rows of maize. A close observation of the data revealed that the per cent crude protein was more in treatments where the proportion of cowpea was more and decreased as the proportion decreased (Table 15a). The crude protein content of maize may have improved by intercropping with legumes due to availability of more nitrogen fixed by the legumes. It may also be attributed that a large proportion of nitrogen was available to non legumes in the mixtures when compared to pure stands.

This is supported by the findings of Amasaib *et al.* (2012) who found that the crude protein content of *Zea mays* in mixture (22.2 %) with legume was significantly higher than crude protein of *Zea mays* in pure stand (15.7 %).

An analysis of Table 16a revealed that the sole crop obtained significantly the highest crude fibre content. The reason for having higher crude fibre percentage in sole maize could be attributed to less availability of nitrogen as compared to maize sown in mixture with legumes. Crude fibre content in different row ratios were all statistically at par with each other and crude fibre decreased with decrease in the proportion of cowpea in the cropping systems. Similar observations have been made by Ibrahim *et al*. (2006) for maize – cowpea mixtures. Reza *et al*. (2012) from their study also observed the highest amount of crude fibre in pure stand of forage sorghum with 41.22 per cent and the lowest in the proportion of 25 per cent Sorghum: 75 per cent Limabean with 35.77 per cent.

From Table 17a, increase in total ash content was observed in the different intercropping systems as compared to its sole treatment only during 2012 and pool of two years data. Such increase by growing maize in mixture with legumes has been reported by Ibrahim *et al.* (2006). Further, maize in 1:1 row ratio (C_3) recorded the highest value, followed by 3:1 (C_4) and sole (C_1) row ratio which might be due to the increase in seed rate or proportion of legume in C_3 row ratio as compared to other cropping systems.

Results on *in vitro* dry matter digestibility (IVDMD) of maize did not show any significant variations due to cropping systems Table 18a. However, the positive effect of intercropping on dry matter digestibility was observed among the cropping systems. The highest IVDMD was recorded in C_3 row ratio followed by C_4 (2:1) and C_5 (3:1) treatment and the lowest in C_1 (sole). These results could be attributed to higher protein concentration for *Zea mays* when sown in mixtures with cowpea. The present findings were in line with Javanmard *et al.* (2009) who reported that intercropping of legumes with *Zea mays* significantly increased digestibility of the forages.

5.3.1.2 Cowpea

The highest per cent crude protein in cowpea cropping system was obtained from sole cowpea (C_2) compared to different row proportions in both the years and their pooled data (17.21, 18.13 and 17.68 % respectively) (Table 15b). In 2011, it was statistically at par with C_3 (16.80 %) and both treatments were markedly higher than C_4 (16.40 %) and C_5 (16.15 %). During 2012 and in pooled data the per cent crude protein content of all the cropping systems differed significantly from one another and C_5 recorded the lowest (16.98 and 16.57 % in 2012 and pooled data respectively). Muhammad *et al*. (2006) and Sebetha *et al*. (2010) reported that cowpea in sole plots had higher crude protein content than in the intercropped plots.

Data on the per cent crude fibre content of cowpea depicted in Table 16b revealed that different cropping systems showed significant differences among themselves in the per cent crude fibre content of cowpea in 2011, 2012 and pooled data. Sole cowpea - C_2 (22.79, 22.73 and 22.76 %) recorded the highest per cent crude fibre followed by C_3 (22.14, 22.09 and 22.12 %). The lowest was in C_5 treatment (20.17, 20.16 and 20.17 %).

The different row ratios significantly influenced the per cent total ash content in forage in both years of study and the pooled data (Table 17b). The maximum total ash was obtained in sole crop of cowpea (C_2) in both the years. In 2011 and 2012, the highest total ash was 9.04 per cent and 7.88 per cent respectively and 8.96 per cent in pooled data of both years which were significantly greater than all other treatments. The lowest per cent total ash of 8.18 and 7.98 were recorded in C_5 row ratio in both the years respectively and pooled data (8.08 %).

The different cropping systems did not show any significant effect on per cent IVDMD in cowpea during 2011 and 2012 (Table 18b). In general, higher IVDMD values were associated with mixtures of maize and cowpea than that of sole. Verma *et al*. (1997) and Pal *et al.* (2014) opined that the digestible dry matter yield of cowpea was recorded significantly highest under sorghum + cowpea (100%) followed by sole cowpea.

5.3.2 Effect of nitrogen

5.3.2.1 Maize

Differences in crude protein content of maize with different amount of nitrogen was observed from Table 15a. The application of 120 kg N /ha (N_4) recorded highest crude protein content than application @ 80, 40 and 0 kg N/ha. Bhillare (2007) opined that more crude protein content at higher nitrogen levels was because of more uptake of nitrogen which is a constituent of protein, amino acids and amides. Further, increase in crude protein content with increase in nitrogen levels is also associated with cell division and cell elongation.

Differing to the effect of nitrogen on crude protein, the increase in levels of nitrogen lowered the crude fibre content. Significantly higher crude fibre content was recorded in treatment where nitrogen was not applied (N_1) and the lowest was in treatment where nitrogen was applied @ 120 kg/ha (N_4) in the analysis of two years data (Table 16a). Less nitrogen supply causes carbohydrate to deposit into the cells. Higher nitrogen application accelerates the protein formation from manufactured carbohydrate and also helps in reduced rate of lignifications thereby maintaining the fodder quality. Nitrogen application increased the protein synthesis and decreased pectin, cellulose and hemicellulose contents, which are major constituents of crude fibre (Tiwana *et al.*, 2003)

The different nitrogen levels affected per cent total ash content significantly in both the years of study and in the pooled data (Table 17a). There was progressive increase in the per cent total ash content with increase in the N levels. The highest total ash content (7.65, 7.92 and 7.79 %) which was significantly highest was recorded with N_4 treatment during 2011, 2012 and pooled data of both years respectively. The lowest total ash content was recorded with control treatment in both years and pooled data (7.14, 7.16 and 7.15 % respectively)

Though the results of the effect of nitrogen levels on the IVDMD failed to differ significantly in both years of study and their pooled data, the IVDMD values were also observed to increase with increase in nitrogen rate (Table 18a). Such an increase in IVDMD values with the addition of nitrogen might be due to cumulative effect of increase in crude protein content, ash content and decrease in crude fibre.

Similar results was reported by Kalra and Sharma (2015) in maize IVDMD where the values increased with increased addition of nitrogen from 0 to 120 kg/ha.

5.3.2.2 Cowpea

In 2011, 2012 and pooled analysis, among the different nitrogen levels the maximum per cent crude protein content was obtained from N_4 treatments (16.90, 17.78 and 17.34 % respectively) and it was statistically at par with N_3 (16.81, 17.63 and 17.18 % respectively). The lowest was recorded in N_1 treatment with 16.32, 17.24 and 16.86 % in 2011, 2012 and pooled respectively (Table 15b).

For cowpea also the effect of different levels of nitrogen did not show any significance on crude fibre content during 2011 and 2012; however their pooled analysis was found to be significant Table 16b. All the treatments were found to be statistically at par with each other and N_1 recorded the highest values while N_4 recorded the lowest.

A close scrutiny of the data showed that the various nitrogen treatments significantly influenced per cent total ash content in cowpea. There was progressive increase in per cent ash content with increase in nitrogen levels where N_4 treatment recorded 8.88, 8.68 and 8.78 per cent in 2011, 2012 and pooled data respectively (Table 17b). N_4 treatment was found to be statistically at par with N_3 treatment in 2012 and pooled analysis. The lowest ash content was obtained with N_1 treatment in both years and pooled data (8.38, 8.11 and 8.20 per cent respectively).

The different nitrogen treatments showed significant variations only in 2011 and pooled data (Table 18b). N_4 treatment recorded the highest IVDMD (63.33 per cent) which was significantly highest over all the other treatments. In the second year N_4 treatment showed 61.72 per cent content of IVDMD and pooled analysis was found to contain 62.52 per cent in cowpea. The lowest per cent IVDMD was obtained from N_1 treatment which was 60.99 per cent and 60.93 per cent respectively in both the years. These findings were in line with earlier studies of Sindhu *et al*. (2006) who reported that application of nitrogen levels significantly affected the IVDMD per cent of fodder maize and the increase in IVDMD content might be due to increase in leaf: stem ratio, LAI, etc. as the leaves contained more protein and soluble carbohydrates than stem and increase in nitrogen application increased the IVDMD over control.

Azim *et al.* (1989) also reported a decline in dry matter digestibility of whole maize plant and its fractions at two vegetative stages. They further reported that maximum dry matter digestibility was found in leaves followed by whole mixed plant, middle and bottom portions of the stem.

5.3.3 Economics of cultivation

5.3.3.1 Effect of intercropping

From data in Table 19a and Table 19b, it was evident that all the intercropping systems recorded higher cost of cultivation as compared to both the sole treatments of maize and cowpea. The lowest cost of cultivation was in sole cowpea C_2 (` 24,332.09) and the highest was in $C_5$ row ratio (` 25,742.09). The data also clearly indicated differences in gross return, net return and B:C ratio among the row ratios due to inclusion of legumes in the system. Higher values of gross return, net return and B:C ratio was recorded in 1:1 and the lowest was in 3:1. Sheoran *et al*. (2010) recorded the highest B:C ratio (1.64) with intercropping of black gram with maize (50 cm) in 1:1 row. Similarly Meena *et al.* (2007) also reported significantly higher net returns in intercropping ratios 1:2 (*Cenchrus* : cowpea) followed by 1:1 intercrop. However a comparison of the cropping system showed that gross return, net return and B:C was highest in sole cowpea followed by 1:1 row in the 1st year. And in the 2nd year, maize + cowpea system in 1:1 row came up with the highest gross return, net return and B:C ratio. The higher values could be due to better yield, higher market price and lower cost incurred in their cultivation. Further it was also observed that the lowest values of gross return, net return and B:C ratio was in 3:1 row.

5.3.3.2 Effect of nitrogen

Among the different levels of nitrogen application, the highest cost of cultivation was in nitrogen application @ 120 kg/ha (N_4) and the lowest in nitrogen application @ 0 kg/ha (N_1) (Table 19a and Table 19b). The higher cost of cultivation might be due to the cost of nitrogenous fertilizer in the treatment. The effect of different levels of N application was also reflected in the gross return and net return. Highest gross and net return was recorded in nitrogen application @ 120 kg/ha and the lowest in nitrogen application @ 0 kg/ha. Parlawar *et al*. (2003) from his study on the performance of maize and sorghum to different N levels concluded that the highest gross monetary return was highest when the crop was fertilized with 120 kg N/ha. The B:C ratio was also found to be increased in all the treatments with different N application as compared to that of no nitrogen. Thought the highest B:C ratio was found to be in N_2, N_4 also recorded similar value while N_3 recorded the lowest. Studies by Bindhani *et al*. (2007) on nitrogen management in baby corn reported that, the net return and benefit cost ratio were the highest with 120 kg N/ha, which resulted in significant increase in net return and benefit cost ratio compared to that of no nitrogen.

CHAPTER-VI

SUMMARY AND CONCLUSION

The present investigation entitled, "**Fodder production potential of maize (*Zea mays* L.) + cowpea (*Vigna unguiculata* L.) intercropping under different nitrogen levels**" was conducted during *kharif* season of 2011 and 2012 in the demonstration block at Krishi Vigyan Kendra, Phek District, Porba Nagaland. The results thus obtained are summarized below:

Effect of intercropping

The plant height (cm) and number of leaves per plant in maize and cowpea were comparatively taller and more in the entire row proportions than the sole treatment. While in case of plant population per m^2, the sole treatment was higher than intercropping treatments. Differences among the intercropping treatments was not observed in plant population per m^2 for maize but in case of cowpea, significantly higher value was obtained in 1:1 ratio which was followed by 2:1 and 3:1 row ratio. Fresh forage yield and dry matter yield of both maize and cowpea showed significant superiority of sole treatment in comparison to its intercropping for both the years and also their pooled. Among the different row proportions, the fresh forage yield and dry matter yield of maize in 3:1 and 2:1 row ratio produced higher and similar yield than 1:1 ratio. While for cowpea, it was the opposite showing higher values in 1:1, followed by 2:1 and 3:1. However, the combined total fresh forage yield and total dry matter yield in tonnes per hectare registered higher yield with 1:1 and 2:1 row ratio of maize and cowpea. From combined total yield of maize and cowpea, it was apparent that total fresh and dry forage yield among the row ratio did not differ much among themselves. However the total yield was better in 1:1 and 2:1 ratio as compared to 3:1.

The effect of different cropping system on various quality parameters for both maize and cowpea were also observed to be significant. For maize, the sole treatment recorded significantly lower per cent crude protein content and higher crude fibre content than all the intercropping systems. The per cent total ash content and IVDMD also recorded comparatively lower values in sole cropping as compared to the intercropping treatments though the effect was not found to be significant for IVDMD. Among the different row proportions, one row of maize alternated with one row of cowpea showed having better quality parameters than 2:1 and 3:1 ratio. In the case of cowpea, different cropping systems produced almost similar values for all the quality parameters. However, sole crop of cowpea proved to be superior to the other cropping systems. Among the different ratios, 1:1 row ratio was significantly better for per cent crude protein and total ash content while for per cent crude fibre content 2:1 ratio was better. The IVDMD for cowpea among the different ratio did not reach any significant level.

An economic analysis of different cropping system of maize with cowpea revealed better gross return, net return and B: C ratio among the row ratios due to inclusion of legumes in the system and higher values of gross return, net return and B: C ratio was recorded in 1:1.

Effect of nitrogen

Except plant population per m^2, all the other growth and yield parameters *viz.,* plant height (cm), number of leaves per plant, fresh and dry forage yield of both maize and cowpea and also their combined total fresh and dry forage yield showed significant positive effect with every increase in N level from 0 to 120 kg/ha. In all the parameters, N application @ 120 kg/ha (N_4) recorded significantly the highest value, followed by N application @ 80 kg/ha and the lowest was recorded in no application of N (N_1).

In the present investigation conducted during 2011 and 2012 on the effect of nitrogen on per cent crude protein, crude fibre and total ash of maize and cowpea were also found to be significant however the IVDMD of both maize and cowpea was not significant. The differences among the treatments on the crude protein content due to different N levels was observed to be more in maize than in cowpea. However, in both the crops the crude protein was the lowest with N application @ 0 kg/ha and there after the crude protein content increased significantly with increase in N levels

(40, 80, 120 kg N/ha). Similar trend was observed with the total ash content of both maize and cowpea. On the contrary, the crude fibre content was statistically higher in N @ 0 kg/ha than N applied at 40, 80 and 120 kg/ha in the pool of two years for maize. Similar results were also observed with cowpea though there was not much difference among the treatment.

The response of different nitrogen levels on gross return, net return and B:C ratio was linear up to the highest level of N applied *i.e.,* 120 kg N/ha.

From the findings of the present investigation summarized above, the following conclusions may be drawn:

1. The planting geometry of 1:1 row cropping of maize and legume (cowpea) was suitable for better vegetative growth of plants, higher yield and also producing better quality forage crops having high crude protein content.
2. The highest dose of nitrogen (120 kg/ha) under the present study resulted in terms of vegetative growth, higher forage production and with better quality. There is need for more studies on the nutrient requirement for specific forage crops in order to suggest a recommendation. However, from the present investigation, 120 kg N may be applied in the intercropping system for higher yield of forage crops.
3. In the present study, the benefit-cost ratio was found highest with 1:1 row cropping system. With regards to nitrogen levels, the highest B: C ratio was obtained with N application of 40 kg/ha followed by 120 kg/ha in the present study.
4. However, the vegetative growth, yield and quality of forage crops were positively influenced by N @ 120 kg/ha treatment, therefore, it may be concluded that N @ 120 kg/ha application may be recommended for higher vegetative growth, yield and quality of forage crops.

Future thrust of work

1. To enhance quality attributes of fodder maize and cowpea with plant nutrition management.

2. Integration of organic and inorganic sources to reduce the cost of production
3. To take up research work on fodder grass under Nagaland situation.

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APPENDICES

I: Analysis of Variance of mean plant height (cm) of maize in 2011

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	1.32	0.86	0.95	0.78	0.20	0.61	1.46	2.68	6.98
Treatment	15	0.33	2.30*	1.47	2.49	2.73	1.91	2.21	1.94	3.03
Cropping system (C)	3	0.31	7.02*	1.93	0.89	1.81	2.67	4.97*	1.24	5.47
N levels (N)	3	0.84	3.30*	0.52	3.86	0.74	2.14	1.11	3.20	1.14
C×N	9	0.17	0.39	1.63	2.56	3.71	1.57	1.66	1.76	2.84
Error	30	0.44	0.40	1.03	1.83	2.49	1.72	1.10	1.95	5.35
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

II: Analysis of Variance of mean plant height (cm) of maize in 2012

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	0.08	1.61	0.07	0.04	4.03	1.88	1.18	2.21	15.00
Treatment	15	0.20*	2.56*	0.45	3.34*	7.64*	3.32*	4.42*	0.70	10.67*
Cropping system (C)	3	0.01	0.12	0.08	0.21	3.31	1.11	4.17	0.65	4.01
N levels (N)	3	0.79*	7.72*	1.94*	15.26*	27.01*	12.39*	12.43*	0.93	34.56*
C×N	9	0.08	1.66	0.07	0.41	2.62	1.04	1.83	0.64	4.92
Error	30	0.08	0.77	0.22	0.30	2.11	1.06	1.45	1.03	4.54
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

III: Analysis of Variance of mean plant height (cm) of cowpea in 2011

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	0.06	0.15	0.47	0.41	0.24	16.80	0.40	1.04	9.53
Treatment	15	0.15	1.26*	2.08*	0.72	0.99*	13.05	3.67*	1.11	12.72
Cropping system (C)	3	0.01	0.80*	0.15	0.05	0.06	14.40	0.23	0.70	3.20
N levels (N)	3	0.39*	4.50*	10.09*	3.24*	4.78*	6.62	17.18*	3.19*	33.17*
C×N	9	0.11	0.33*	0.05	0.11	0.04	14.74	0.31	0.55	9.18
Error	30	0.13	0.11	0.15	0.34	0.09	15.00	0.18	0.57	7.98
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

IV: Analysis of Variance of mean plant height (cm) of cowpea in 2012

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	0.29	0.10	0.53	1.17	0.43	0.59	0.70	0.66	0.57
Treatment	15	0.22*	1.14*	3.71*	7.62*	2.73*	2.11*	1.08*	0.53	1.59*
Cropping system (C)	3	0.26	0.81*	0.69	0.26	0.19	0.24	0.19	0.81	0.34
N levels (N)	3	0.47*	3.65*	13.73*	35.93*	13.21*	9.93*	3.37*	0.73	6.43*
C×N	9	0.12	0.41	1.23	0.64	0.08	0.12	0.61	0.37	0.39
Error	30	0.11	0.23	0.56	0.55	0.17	0.38	0.31	0.30	0.31
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

V: Analysis of Variance of mean number of leaves of maize in 2011

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	0.09	0.10	0.09	0.47	0.37	0.12	0.02	0.35	0.49
Treatment	15	0.03	0.19	0.24*	0.70*	0.49*	0.52*	0.23*	0.45*	0.47
Cropping system (C)	3	0.08	0.39*	0.22*	0.48	0.62*	0.15	0.02	0.06	0.73
N levels (N)	3	0.02	0.24	0.79*	2.44*	1.50*	2.12*	0.45*	1.79	1.03*
C×N	9	0.02	0.11	0.07	0.19	0.12	0.12	0.23*	0.13	0.19
Error	30	0.03	0.11	0.05	0.26	0.18	0.10	0.09	0.11	0.27
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

VI: Analysis of Variance of mean number of leaves of maize in 2012

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	0.06	0.09	0.06	0.37	0.32	0.04	0.02	0.01	0.46
Treatment	15	0.01	0.13	0.06	0.08	0.10	0.47*	0.34	0.66*	0.42
Cropping system (C)	3	0.001	0.10	0.11	0.07	0.02	0.12	0.27	0.05	0.06
N levels (N)	3	0.01	0.37	0.04	0.02	0.43	2.16*	0.61*	3.16*	0.17
C×N	9	0.01	0.06	0.05	0.11	0.02	0.03	0.27	0.03	0.62
Error	30	0.02	0.29	0.06	0.20	0.20	0.07	0.17	0.06	0.38
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

VII: Analysis of Variance of mean number of leaves of cowpea in 2011

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	0.15	0.68	0.65	0.33	0.47	1.11	0.80	0.38	0.25
Treatment	15	0.17	1.18*	0.70	1.44*	1.06*	5.28*	3.81*	5.55*	4.95*
Cropping system (C)	3	0.28	0.29	0.03	0.28	0.09	0.49	0.13	0.24	0.25
N levels (N)	3	0.15	5.12*	3.15*	6.24*	4.83*	25.37*	17.41*	25.02*	23.41*
C×N	9	0.14	0.17	0.11	0.23	0.13	0.18	0.51	0.82	0.36
Error	30	0.18	0.22	0.36	0.26	0.20	0.56	0.33	0.42	0.19
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

VIII: Analysis of Variance of mean number of leaves of cowpea in 2012

Sources of variation	Degrees of freedom	Mean sum of squares								
		Days after sowing								
		14	21	28	35	42	49	56	63	At harvest
Replication	2	0.03	0.01	0.06	0.34	1.18	0.54	1.14	1.54	0.70
Treatment	15	0.11	0.04	0.38	2.07	0.53	3.59	0.56	0.94	2.74
Cropping system (C)	3	0.28	0.10	0.21	3.87	0.11	0.09	0.40	0.72	7.26
N levels (N)	3	0.08	0.03	0.86	5.15	2.28*	16.78*	1.19	2.28	1.27
C×N	9	0.07	0.03	0.27	0.45	0.08	0.36	0.41	0.56	1.72
Error	30	0.10	0.08	0.30	2.01	0.57	0.68	0.76	1.26	2.74
Total	47	-	-	-	-	-	-	-	-	-

*Significant at 5 per cent level of probability

IX: Analysis of Variance of mean plant population per m^2

Sources of variation	Degrees of freedom	Maize			Cowpea		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	29.60	26.52	28.03	1.00	2.65	0.54
Treatment	15	23.53	10.71	13.02	58.17	64.20	60.19
Cropping system (C)	3	32.93	15.72	21.37	270.63*	285.85*	278.17*
N levels (N)	3	30.06	4.83	13.88	3.74	11.24	3.92
C×N	9	18.23	11.00	9.95	5.48	6.97	2.56
Error	30	27.23	8.57	9.44	1.44	3.96	1.73
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

X: Analysis of Variance of mean fresh forage yield (t/ha) and dry matter yield of maize (t/ha)

Sources of variation	Degrees of freedom	Fresh forage yield (t/ha)			Dry matter yield (t/ha)		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	4.28	38.61	8.59	1.22	4.14	0.27
Treatment	15	459.49*	372.23*	407.75*	35.83*	40.20*	36.46*
Cropping system (C)	3	1628.71*	1310.60*	1452.66*	113.97*	129.69*	120.69*
N levels (N)	3	590.76*	518.25*	552.84*	58.00*	61.51*	58.54*
C×N	9	25.99	10.77	11.09	2.39	3.26	1.02
Error	30	32.82	22.34	16.59	2.64	2.23	1.32
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

XI: Analysis of Variance of mean fresh forage yield (t/ha) and dry matter yield of cowpea (t/ha)

Sources of variation	Degrees of freedom	Fresh forage yield (t/ha)			Dry matter yield (t/ha)		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	0.41	3.52	1.19	0.08	0.20	0.12
Treatment	15	343.92*	402.41*	370.37*	23.55*	28.46*	25.84*
Cropping system (C)	3	1615.65*	1831.54*	1718.86*	108.39*	128.00*	118.05*
N levels (N)	3	100.83*	151.74*	124.84*	8.84*	11.77*	10.27*
C×N	9	1.04	9.59	2.72	0.17	0.84	0.29
Error	30	1.79	4.59	1.75	0.15	0.38	0.13
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

XII: Analysis of Variance of mean total fresh forage yield (t/ha) and total dry matter yield of cowpea (t/ha)

Sources of variation	Degrees of freedom	Total fresh forage yield (t/ha)			Total dry matter yield (t/ha)		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	4.82	40.30	16.93	0.37	3.49	0.90
Treatment	15	208.32*	222.24*	203.94*	20.53*	23.32*	20.33*
Cropping system (C)	3	68.28	150.43*	72.03*	12.45*	3.42	5.75*
N levels (N)	3	861.83*	889.17*	874.57*	80.30*	98.26*	87.92*
C×N	9	37.16	23.87	24.36	2.96	4.91	2.60
Error	30	25.63	23.47	15.03	2.09	2.23	1.18
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

XIII: Analysis of Variance of mean per cent crude protein content

Sources of variation	Degrees of freedom	Maize			Cowpea		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	4.18	3.56	0.67	0.06	0.21	0.01
Treatment	15	9.32*	12.33*	9.36*	0.67*	0.74*	0.69*
Cropping system (C)	3	9.98*	7.53*	8.60*	2.61*	2.96*	2.78*
N levels (N)	3	6.66*	18.16*	11.18*	0.51*	0.64*	0.55*
C×N	9	9.99*	11.99*	9.01*	0.08	0.04	0.04
Error	30	1.38	1.42	0.75	0.08	0.12	0.05
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

XIV: Analysis of Variance of mean per cent crude fibre content

Sources of variation	Degrees of freedom	Maize			Cowpea		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	2.27	10.15	0.77	0.18	0.00	0.05
Treatment	15	11.46*	24.40	15.34*	4.07*	3.78*	3.89*
Cropping system (C)	3	27.88*	33.37	30.32*	19.93*	18.38*	19.14*
N levels (N)	3	14.26	62.99	33.76*	0.18	0.14	0.15*
C×N	9	5.05	8.55	4.20	0.07	0.12	0.05
Error	30	5.04	22.35	5.72	0.07	0.14	0.03
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

XV: Analysis of Variance of mean per cent total ash content

Sources of variation	Degrees of freedom	Maize			Cowpea		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	0.10	0.06	0.01	0.14	0.07	0.02
Treatment	15	0.24	0.39*	0.29*	0.47*	0.51*	0.49*
Cropping system (C)	3	0.30	0.45*	0.36*	1.52*	1.71*	1.61*
N levels (N)	3	0.62*	1.33*	0.93*	0.78*	0.71*	0.74*
C×N	9	0.10	0.06	0.05	0.02	0.04	0.03
Error	30	0.11	0.07	0.05	0.04	0.03	0.02
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

Annex XVI: Analysis of Variance of mean in vitro dry matter digestibility

Sources of variation	Degrees of freedom	Maize			Cowpea		
		2011	2012	Pooled	2011	2012	Pooled
Replication	2	0.61	1.14	0.07	0.87	0.70	0.02
Treatment	15	1.91	0.56	0.86	3.44	2.73	2.17
Cropping system (C)	3	2.67	0.40	1.25	3.31	7.26	5.00
N levels (N)	3	2.14	1.19	1.11	3.72	1.27	2.89
C×N	9	1.57	0.41	0.65	1.60	1.72	0.98
Error	30	1.72	0.76	0.73	1.31	2.75	1.09
Total	47	-	-	-	-	-	-

*Significant at 5 per cent level of probability

XVII: Detailed cost of cultivation (`/ha)

Sl. no.	Item	Unit/quantity and Cost
1.	Preparatory cultivation with tractor, one ploughing and two harrowing	- ` 2,000.00
2.	FYM	5 tons @ ` 1,000.00/ ton
3.	Seed - Maize	50 kg/ha @ ` 100.00/ kg
	Cowpea	20 kg/ha @ ` 90.00/kg
4.	Fertilizers – Urea @0 kg/ha	0.00 kg/ha @ ` 0.00/kg
	@40 kg/ha	87.00 kg/ha @ ` 11.00/kg
	@80 kg/ha	174.00 kg/ha @ ` 11.00/kg
	@120 kg/ha	261 kg/ha @ ` 11.00/kg
	SSP	240.00 kg/ha @ ` 13.54/kg
	MOP	33.33 kg/ha @ ` 18.10/kg
5.	Labours	@ ` 180/manday

Treatment		No. of labours employed from land preparation till threshing and bagging	Cost @ ` 180/manday
Sole maize (C_1)	0	43	7740
	40	53	9540
	80	60	10800
	120	68	12240
Sole cowpea (C_2)	0	43	7740
	40	53	9540
	80	60	10800
	120	68	12240
1:1 (C_3)	0	45	8100
	40	55	9900
	80	62	11160
	120	70	12600
2:1 (C_4)	0	47	8460
	40	57	10260
	80	64	11520
	120	72	12960
3:1 (C_5)	0	50	9000

	40	60	10800
	80	67	12060
	120	75	13500