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Forage production in Panicum grass-legumes intercropping by combining geometrical configuration, inoculation and fertilizer under rainfed conditions

Muhammad Arshad Ullah

Fachgebiet Landschaftsökologie und Naturschutz

Herausgeber: Universität Kassel
Fachbereich Ökologische Agrarwissenschaften
Fachgebiet Landschaftsökologie und Naturschutz
Nordbahnhofstr. 1a
D-37213 Witzenhausen

Schriftleitung: Prof. Dr. H. Schmeisky

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Supervisor:	Prof. Dr. Helge Schmeisky, Dept. of Landscape Ecology and Nature Conservation University of Kassel
Co-Supervisor:	Dr. Nazir Hussain Katar

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(MUHAMMAD ARSHAD ULLAH)

LIST OF ABBREVIATIONS

Abbreviation	Meaning	Abbreviation	Meaning
%	Percent	GOP	Government of Pakistan
C	Carbon	CP	Crude Protien
Ca^{2+}	Calcium	CF	Crude Fiber
Cm	Centimeters	TDN	Total Digestible Nutrients
$dS\ m^{-1}$	Desi Siemens per meter	NFE	Nitrogen Free Extract
EC	Electrical conductivity	EE	Ether Extract
G	Grams	P	Phosphorus
$mg\ Kg^{-1}$	Miligram per Kilogram	DM	Dry Matter
Ha	Hectare	$q\ ha^{-1}$	Quantal per hectare
K	Potassium	N	Nitrogen
Kg	Kilogram	SNB	Symbiotic Nitrogen Fixing Bacteria
M	Meter	m^2	Meter square
ha^{-1}	Per hectare	Kg^{-1}	Per kilogram
$t.ha^{-1}$	Ton per hectare	C^o	Centigrade
USDA	United State Department of Agriculture	Pr	Protien
Wt.	Weight	L	Litre
Yr.	Year	Mm	Milimeter
pH	Negative logarithm of hydrogen ion activity	Ml	Milliliter
Ppm	Parts per million	OM	Organic matter
RCBD	Randomized complete block design	Km	Kilometer
SO_4^{2-}	Sulphates	FAO	Food and Agricultural Organization
GDP	Gross Domestic Product	AOAC	Association of Official Analytical Chemists.
<	Less than	>	Greater than
TB	Tepary Bean	:	Ratio
PBV	Protien Balance Values	NDF	Neutral Detergent Fibre
DAE	Days after Emergence	NP	Nodule Primordian
LUE	Land Use Efficiency	NUE	Nitrogen Use Efficiency
J	Joles	LM	Live Mulching
CPC	Crude protein concentration	IM	Induced Mulching
GCA	General Combining Ability	NO_3-N	Nitrate Nitrogen
Mg	Miligram	Lbs	Pounds
IVDMD	In vitro Dry Matter Digestibility	$Acre^{-1}\ yr^{-1}$	Per acre per year
LER	Land Equivalent Ratio	$Plant^{-1}$	Per plant

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Abstract

Livestock has become very important component of agriculture sector in the world due to a variety of food products and high income. Livestock accounts for 52.2 percent of agricultural value added products in Pakistan, contributes 11 percent to GDP and affects the lives of 30 – 35 million people in rural areas with a wealth of 150.5 million heads. But this vast resource of the country faces many crucial challenges like; deficient and high priced feed and fodder, low in quality and limited chances of increasing area under fodder due to competition for food crops. Thus, intercropping of legumes within grasses and non-leguminous crops with a theme to produce more from the same area, inoculation of legume seeds and fertilizer application are the only ways to increase quantity of forages and improving their quality. The present study was conducted to investigate effects of intercropping *Panicum maximum* grass and legumes (*Vicia sativa* and cowpeas) alone or coupled with inoculation or fertilizer. The study comprised of two field experiments conducted under rain fed conditions for two years (June, 2005 to September, 2007) at National Agriculture Research Center (NARC) Islamabad, Pakistan. In one experiment intercropping (33, 50 and 67%) of grass and legumes alone as well as coupled with seed inoculation were studied while same set of treatments was combined with fertilizer application at the rates of 25, 75 and 50 kg ha^{-1} (N, P_2O_5 and K_2O) in the second experiment. All the three factors of this study not only increased fodder biomass production but also improved its quality significantly along with enhancement of soil N and organic matter during two years. The grass and legumes biomasses without any treatment were recorded as 7.09 and 8.17 t ha^{-1} respectively during two years. Mixed fodder production increased to 11.62, 13.6 and 14.13 t ha^{-1} with 33, 50 and 67% intercropping respectively. Respective values of biomass were 13.18, 13.70 and 17.87 t ha^{-1} when combined with inoculation whereas the quanta were 12.71, 14.79 and 17.72 t ha^{-1} due to fertilizer supplementation. Thus, combination of intercropping by 67% either with inoculation or fertilizer proved as the best treatment in both experiments. The 6-7 % higher crude protein (CP) of mixed fodder was recorded from intercropping in comparison to grass alone while inoculation or fertilizer increased it by further 1-2 %. Crude fiber (CF) and ash contents decreased 2-5% due to these treatments. Total digestible nutrients (TDN) increased by 2-4%. Total soil N increased by 0.008% due to symbiotic fixation in addition to plant uptake under best treatment when compared with grass alone while soil organic matter increased by 0.19%.

CHAPTER 1

INTRODUCTION

Livestock is considered very important component of agriculture sector in the world because it earns high income for the farming communities, especially those who are landless but are an integral part of rural populations in developing countries. This is sometimes a part of their livelihood earning or they may totally depend upon it as source of income and employment. The animal production brings milk, milk products, meat, wool, hides, bones and many associated products like manures etc for the benefits of man kind. Livestock accounts for 52.2 percent of agricultural value added products in Pakistan, contributes 11 percent to GDP and affects the lives of 30 – 35 million people in rural areas. It is highl labour intensive and if proper attention is given to this sector, it will not only absorb more rural workforce but also help to alleviate rural poverty in the country. In order to achieve higher sustained growth in agriculture, it is absolutely necessary for the government to give more attention to livestock and dairy sector (ANONYMOUS, 2008). It is, therefore, not surprising that food production in this country has been listed among the nation's top research and development priorities. Pakistan has a wealth of 150.5 million heads with contribution of 11% towards GDP (ANONYMOUS, 2008) that was 135 million heads in 2005 which was accounting 10.8% to GDP (ANONYMOUS, 2005). Thus, there has been only increase of 0.2 % share in GDP in last three years that indicted very poor condition of this basic sector and urged that the vast resource of the country is not being managed on scientific basis. Thus, only 10-50% of their actual potential is being realized (ALI *et al.*, 2001).

Production of livestock in Pakistan faces the most crucial challenges; prices of food from animal origin are very high that are increasing everyday and making the reach of poor communities impossible. Feed and fodder are not only deficient but also very high priced as well as low in required ingredients and the inevitable results are less number of animals compared with accelerating population. These phenomena are closely connected with energy crises, poor health of people and inflation. Social and environmental problems of food producing systems have, thus, multiplied. One of the major problems hindering expansion of ruminant production in the country is the un-availability of good quality fodder in sufficient quantity (SARWAR *et al.,* 2002). Production of good quality fodder is of great importance for economical animal production. Both quality and quantity of fodder are influenced due to plant species (KAISER and PILTZ, 2002), stage of growth (KIM et al; 2001) and agronomic practices (REHMAN and KHAN, 2003).

The nutritive value of forage or feed is a measure of proximate composition, digestibility and nature of digested products and there by its ability to maintain or promote growth, milk production, pregnancy or other physiological functions in the animal body. Assessment of herbage quality is an integrated evaluation of nutritive value and factors of consumption by the animal. Animal is the best judge for forage quality assessment, which can be determined through palatability, growth rate and milk production. Protein is the most demanded feed ingredient of ruminant ration, required substantially for milk or meat production as well as for reproduction. If the crude protein is below 6-7% in the ration, the microbial activity in the rumen is depressed due to lack of N. The forage digestibility is related to changes in chemical composition, particularly of fiber, lignin and silica contents and to some extent crude protein (BOSE and BALAKARISHNAN, 2001). Livestock in the country is deficient in crude protein and total digestible nutrients by 38.1 and 24.0 % respectively. Livestock was receiving 51, 38, 3, 6 and 2 % of nutrients from green fodder, crop residues, grazing (bare lands and post harvest), cereal-by products and oil cakes meals respectively (SARWAR *et al.,* 2002).

Grasses are an important component of Graminae family. Apart from cereals, many grass species provide forage for livestock, protect the soil from erosion, improve soil structure and hence water retention (AHMAD *et al*, 2001). The carrying capacity of the highly depleted rangelands of Pakistan could be increased by growing grass species (SULTANA *et al*, 2000 and PARMAR *et al*, 2000). The grass species *Panicum maximum* var. Tanzani is a tall growing (2-3 m), vigorous, coarse, tufted perennial and shows considerable variation in growth habit. It is a native grass of tropical and sub-tropical Africa but has been introduced in more humid tropics and sub-tropics throughout the world. It is drought resistant but does not stand long periods of complete desiccation. It grows well on a wide variety of well drained soils but not on black cracking clays (Vertisol) i.e. heavy clay soils or in areas liable to prolonged water logging or flooding. It is shade tolerant and grows well under trees, valuable grass for grazing, green soiling hay and silage making. Its nutritive value is quite high when leafy and young (10 % crude protein) but it falls rapidly with increasing maturity (BOSE and BALAKARISHNON, 2001).

Forage legumes have immense value in animal nutrition because of their higher protein content, vitamins and specific minerals such as P and Ca etc. Even through their yields are less compared to fodder, cereals or grasses but legumes are superior in terms of fodder quality and hence referred as 'Masalas' in local language meaning triggers. Leguminous plants supply the major portion of protein consumed by man either directly or indirectly through animals (BOSE and BALAKARISHNAN, 2001). Forage legumes are usually lower in fiber and higher in crude protein than forage grasses at advance maturity stages. Good quality grass forage is relatively low in fiber and in lignin which at suitable grazing heights may average about 22 and 4 percent by dry weight composition respectively. Such herbage is palatable and offers a favorable ratio of digestible energy bulk to indigestible bulk or waste fiber.

The efficacy of feed utilization is an arithmetic value obtained by dividing the weight of body gain by the weight of feed consumed for that gain. The productive value of a feed is dependent not only upon its context of available nutrients but also upon the quality of feed consumed per day. In general, poor consumption means that the forage is poor. Highly digestible forage is a satisfactory feed only if consumed in adequate amounts to achieve satisfactory production. Ordinarily, consumption of high digestibility forages is greater than that of low digestibility. Approximately 85 to 90 percent of cellular nitrogen of forage plants is crude portion, synthesized from amino acids. The nitrogen of forage protein is derived from soil nitrogen and from symbiotic nitrogen fixed in legume nodules. Grass protein is not considered inferior to legume protein. The amino acid balance in forage protein is quite satisfactory; wide quality differences between forage spices are not usually found. When chemically analyzed, forages may contain from 3 to 25 percent crude protein. Although forage crops harvested at earlier stages of development normally have lower yields, yet they generally contain higher levels of crude protein, minerals and carbohydrates and are thus more digestible than material harvested closer to maturity (BOSE and BALAKARISHNAN, 2001)..

Vetches (Vicia species) are legumes which are well adapted to winter growth in Mediterranean environments throughout the world on a variety of soil types and are used in West Asia and Australia for various purposes as green forage, hay, seed crop or green manure. Although vetches dry matter is generally lower than that of cereals, yet these usually have substantially of growing in farming system of the rain fed parts of the Punjab and North Western Frontier

Province in Pakistan, which have a Mediterranean environment in the winter season. Vetches have the potential to increase animal feed supply substantially and thus can considerably improve animal productivity. Forage yield is affected by the stage at which the crops are harvested.

Cowpeas (the legume species *Vigna unguiculata*) native to South and Southern Asia are known for their diverse distribution and range of adoption from the humid sub-tropical to warmed cool temperate climate. It is highly palatable, nutritious and rich in protein, calcium and phosphorus than many other summer legumes. The crop is adapted to high temperature, humidity as well as heavy soil. It has high yield potential and under sound management practices, can produce 3 t ha^{-1} (30 q ha^{-1}) seeds and 32-82 q. ha^{-1} dry herbage to meet scarcity of green forage. It is a dual purpose crop. It contains higher protein contents, amino acids and vitamins (BOSE and BALAKARISHNAN, 2001). Legume forages are rich in proteins, minerals and vitamin. Forage legumes increase soil fertility and control soil erosion. These are also used with diets that are largely consisting of grasses and their protein content often falls below minimum critical level. Therefore, increasing leguminous portion in animal diet not only increase protein content but also enhance voluntary intake and digestibility of entire diet (PARVEEN *et al.*, 2001).

Most of the legumes are grown in rain-fed areas of marginal lands where indigenous rhizobial population is low in these soils. The result is low yield of legumes as compared with other countries. Low rhizobial population is the main cause of low legume yield in these areas. The use of inoculation is very low; just below 1-3 percent of the total area under legumes which is negligible (ASLAM *et. al*., 2000). When a legume is introduced in a new locality, it is necessary to inoculate seed with proper rhizobium culture otherwise crop may not thrive and produce nodules. These bacteria although present in most of the soil, vary in number, effectiveness in nodulation and N-fixation. It has been argued that usually native soil rhizobial populations are inadequate and ineffective in biological nitrogen fixation. To ensure optimum rhizobial population in the rhizosphere, seed inoculation of legumes with an efficient rhizobial strain is necessary. This helps to improve nodulation, N fixation, crop growth and yield of leguminous corps (ZAMAURD *et al.,* 2006).

Symbiotic nitrogen fixing bacteria (SNB) are root nodule bacteria and fix nitrogen in association with leguminous plants. The rhizobium bacteria living in the soil enter the root hairs of the leguminous plants, develop into colonies and form small nodules on the roots. They take their food (carbohydrate) from the leguminous plants and absorb nitrogen from the atmosphere. The legume roots excrete available nitrogenous compound to the soil and enrich it. Rhizobium species invade the root hair of legumes and result in the formation of nodules where free nitrogen is fixed. The amount of nitrogen added to the soil by rhizobium bacteria varies from 50-150 kg ha^{-1}. Biofertilizers (inoculation material) are apparently environmental friendly, low cost, non bulky agricultural inputs which could play a significant role in plant nutrition as a supplementary and complementary factor to mineral nutrition (SAHAI, 2004). Rhizobium strains enhance nodulation and the host plant component. It is an attempt to increase nitrogen fixation and the yield at all the sites of harsh climate. Therefore, it is possible to increase nodulation causing improvement in yield from marginal lands by inoculation with rhizobium. (ASLAM *et al.,* 1999). The combination of P and inoculation has maximum positive effect on P-uptake and P concentration in plant. (KHAN *et al.,* 2002).

Thus, keeping in view the limitations and constraints faced by the farmers busy in livestock production, a comprehensive study was conducted with the following objectives:

i) To evaluate the yield performance of grass – legume mixtures under different growing seasons.

ii) To assess the impact of inoculation of legumes and appropriate use of fertilizer for maximum fodder production.

iii) To determine forage quality through grass – legumes intercropping, inoculation and fertilizer use.

iv) To monitor effect of grass- legumes on soil fertility status.

CHAPTER 2

REVIEW OF LITERATURE

The related research work conducted in various parts of the world was reviewed. Salient researches relevant to this study are being presented under different sub-titles.

2.1 Development of fodder production

The development of fodder production systems is the dire need in developing countries so that deficiencies in quantity and quality of fodder can be removed. The systems developed and the systematic research conducted in developed countries can serve as examples. Warm-season grasses and legumes have the potential to provide forage throughout the Mediterranean summer when there are high temperatures and low rainfall and where cool-season grasses become less productive. Twenty nine non-native warm-season pasture species (twenty-three grasses and six legumes) were assessed by GHERBIN *et al*. (2007) for their adaptability to the coastal plain in terms of their productivity and nutritional quality. The investigated species were compared with two reference species widely used in a Mediterranean environment: a grass (*Festuca arundinacea*) and a legume (*Medicago sativa*). The species differed from each other and from the control species in their phenological and biological characteristics i.e. start of vegetative resumption, first flowering and cold resistance. From the second year after establishment, warm-season perennial grasses had high dry-matter (DM) yields and, in many cases, a more than adequate nutritional quality. The *Medicago sativa* gave the best results in all the investigated characters among the investigated legumes. Among the grasses, seven species (*Chloris gayana, Eragrostis curvula, Panicum coloratum, Paspalum dilatatum, Pennisetum clandestinum, Sorghum almum and Sorghum hybrid species*) had DM yields greater than the control species and had their maximum growth during the hottest period of the year, when *Festuca arundinacea*, the control grass species, was dormant. *Eragrostis curvula* had the highest annual DM yield (21.1 t ha^{-1}) and *P. clandestinum* provided the best combination of agronomic and yield characteristics which were similar to those of *M. sativa*. The seven above-mentioned species have the potential to supply hay or grazing and contribute to broadening and stabilizing the forage production calendar in Mediterranean-type environments.

Forage legumes are playing an expanded and invaluable role in the nitrogen economy, in animal productivity and in sustainability of temperate grasslands, and advances in their technology are foreseen. The large pool of genetic variability among the genera and their species is being exploited further by the development of cultivars adapted to different edaphic, climatic and biotic conditions, though not forgetting the value of already adapted landraces. Some lesser species have shown promise as pioneer swards for difficult soils, degraded land and extreme climates, though sufficiency of certified seed supplies can be a problem. The N2-fixing capacity of forage legumes is expressed in terms of rhizobial efficiency, N transference to associated companion grasses, provision of on-farm protein, and N supply to subsequent arable crops. Individual animal performance is enhanced by high intake and nutritive value characteristics of legume-rich diets (FRAME *et al*; 2005).

LAURIAULT *et al.* (2005) studied persistence and yield of Altai wildrye, *Leymus angustus* (Trin.) Pilg; beardless wildrye, *triticoides* (Buckley) Pilg; creeping foxtail, *Alopecurus arundinaceus* Poir; grazing bromegrass, *Bromus stamineus;* intermediate-pubescent wheatgrass. *Elytrigia intermedia* Nevski; meadow bromegrass, *B. riparius* (Rehmann); meadow fescue, *Festuca pratensis*; orchardgrass, *Dactylis glomerata;* prairie bromegrass, *B. willdenowii*, syn. *catharticus* Vahi var. *catharticus;* reed canarygrass, *Phalaris arundinacea* Rs; wheatgrass, *E. repens* var. repens. Desv. Ex B.D. Jackson x pseudoroegneria spicata (Pursh), A. Love; russian wildrye *Psathrostachys juncea* (Fisch.), Nevski; smooth bromegrass, *B. inermis* Leyss; tall fescue *F. arundinacea* Schreb.; tall wheatgrass, *E. elongate* (Host) Nevski; and western wheatgrass, *Pascopyrum smithii* (Rybd.). Soil moisture treatments were: (i) Furrow irrigation once before each harvest, which was typical management; (ii) Typical irrigation plus irrigated monthly during winter; and (iii) Poorly drained, saline/sodic soil, irrigated less than once per cutting. Russian wildrye, RS wheatgrass, tall fescue, tall wheatgrass, and western wheatgrass maintained ground cover across soil moisture treatments, Stand development by Altai wildrye and Smooth bromegrass was inconsistent across soil moisture treatments, but eventfully complete. Beardless wildrye established only in poorly drained soil, while in that soil no other species established or maintained satisfactory stands after 3 years in any soil moisture treatment. Winter irrigation increased early-season yield of intermediate-pubescent wheatgrass, but decreased late-season yields of several species. Distribution of all wheatgrass and Altia wildrye yield appear complementary, and binary mixture might provide uniform season-long yields, in this region.

IMTIAZ and ARSHAD (2002) studied exotic forage germplasm comprising seven forage grasses viz *Panicum maximum* var. Gaton, *Panicum maximum*, var. Tanzania, *Brachiaria humidicla, B. brizantha, B. decumbens*, *Eragrotis curvula*, and *Panicum antidotale* and five forage legumes viz. *Arachis grabata* (perennial peanut) *Glycine wightii*, *Lablab purpureum* (lablabbean) *Peuraria lobata* (kudzu) and *Caganus cajan* variety Archar. These species were evaluated for fresh and dry matter yield at National Agricultural Research Centre, Islamabad under the sub-tropical and sub-humid conditions of Pothwar Plateau of Pakistan during 1999 and 2000. The grass *Brachiaria hunidicola* and legume *Arachis grabata* could not germinate and did not grow in new climate. Among grasses; *Panicum maximum* var Gaton and *B. decumbens* were significantly high yielding with 31.58 and 31.14 t ha^{-1} fresh matter and 10 and 11.98 t.ha^{-1} dry matter respectively while among legumes; *Lablab purpureum* remained the most successful producing 42.59 t.ha^{-1} fresh matter and 5.00 t ha^{-1} dry matter. It was emphasized that legumes and forage grasses must be planted on a large scale when returning arable land to pasture and forest in western China. Inoculating the legumes with rhizobia can avoid N deficiency in artificial [sown] forest and pasture. When legumes in sterile soil were inoculated with rhizobia, growth increment and annual hay yield could be increased by 15-50% and 750-1200 kg ha^{-1}, respectively. Inoculating legumes with rhizobium is important in returning arable land to pasture and forest, and could not be substituted by other techniques (NING *et al.,* 2001). The rotation of legumes with cereals improved the grain and N yield of the succeeding cereal compared with a cereal following a cereal crop (AHMAD *et al*., 2001).

BELESKY *et al.* (2001) reported that small-scale farms in the Appalachian Region were a mosaic of traditional pasture and wooded sites. Topography along with temperature and moisture extremes influences the quality and seasonal distribution of herbage in pasture. Tree canopies modify the microclimate and could buffer periods of weather extremes and influence the distribution and nutritive value forage grown as an under story crop. A grass-legume mixture was grown in light gradient created by a 35 year old, mixed-species conifer stand. Herbage production, seasonal distribution and botanical composition of the sward were quantified as a function of light intensity. The site was limed and treated with phosphorus fertilizer. Mature weather sheep were used to control existing under story vegetation and to tread in surface broadcast seed. Accumulated herbage was grazed at three-week intervals. Herbage yield was greatest at 80 % of full light at 2 tons/ acre, while cumulative yields at 50 and 20 % light reached 1.5 tons/ acre. The presence of white clover and perennial ryegrass was greatest at 80 % full light and increased over the growing season. While the proportion of bare ground orchard grass and other grasses declined. Intensive cultivation and higher crop yields were likely to affect the soil nutrients status. Legumes help in maintaining soil fertility that contains nitrogen-fixing bacteria (JILANIA *et al*., 2001). Decrease in organic fertilizer use in 1996-2000 in Russia lead to negative nitrogen balance, where its output with crops is only compensated by 1.6 %. This does not allow production of sufficient protein content in meadow fodder. Cultivation of leguminous crops and mixed legumes-grasses became particularly important under those conditions. A forecast system for nitrogen balance and protein production in meadow as well as fodder cultivation areas indicated a need to increase 6-7 million ha as legume-grass mixture area in order to meet increasing crude protein demand. (KUTUZOVA *et al*., 2001). Changes in fodder production in Russia brought about by economic reforms of the 1990s were analyzed. The authors stated that average input of inorganic and organic fertilizers in fodder crop production in 1999 was 11.5 kg and 0.6 t ha^{-1} has compared to 84 kg and 3.2 t per ha in 1985. All Russian Research Institute of Feeds were introduced to develop fodder production. Among directions for future development were wider use of sown meadows and legumes. Outcomes of the studies conducted in 1996-2000 included development of principles of fodder crops positioning in crop rotation system, fodder production systems for animal husbandry, mixed grass/ legumes providing green fodder during 100-105 days of the season, and green manure systems (SHPAKOV, *et al*., 2001). Based on trials in 1996-2000 in Kaluga provinces, Russia, a scheme of line type system was introduced for the continuous production of high protein fodder from the end of May to the end of August by perennial and annual fodder legumes, with or without grasses, as well in fodder cereals. The use of fodder legumes in the system allowed grass land productivity to be increased and mineral N fertilizer application on energy costs to be reduced (BOGOMOLOV *et al.*, 2001).

2.2 Mixed growing of fodder/field crops, grasses and legumes

Intercropping, which grows at least two crop species on the same pieces of land at the same time, can increase grain yields greatly as well as improve fodder quality if a legume is added because of legume nitrogen fixation. However, many agricultural soils are deficient in phosphorus. Hence, a new mechanism of over yielding, in which phosphorus can be mobilized by introduction of appropriate crop species was investigated. There was an increase in the growth of a second crop species grown in alternate rows that led to large yield increments on phosphorus-deficient soils. In 4 years of field experiments, maize (Z*ea mays*) over yielded by 43 % and faba bean (*Vicia faba*) over yielded by 26 % when intercropped on a low-phosphorus but high-nitrogen soil. It was found that over yielding of maize was attributable to below-ground interactions between faba bean and maize in another field experiment. Intercropping with faba bean improved maize grain yield and above-ground biomass significantly compared with maize grown with wheat, at lower rates of P fertilizer application (<75 kg of P_2O_5 per hectare), and non-significantly at high rate of P application (>112.5 kg of P_2O_5 per hectare). By using permeable and impermeable root barriers maize over yielding resulted from its uptake of phosphorus mobilized by the acidification of the rhizosphere via faba bean root release of organic acids and protons. Faba bean over yielded because its growth season and rooting depth differed from maize. The large increase in yields from intercropping on low-phosphorus soils was especially important on heavily weathered soils. (LI-LONG et. al., 2007)

In a study conducted during 1998-2001 in Himachal Pradesh, India, perennial grasses (*Setaria anceps* [*S. sphacelata var. sericea*]; hybrid napier [*Pennisetum purpureum*]; Guinea grass (*Panicum maximum*) and green panic grass (*Panicum maximum var. trichoglume*) were cropped with soybeans in the Kharif (summer) season, and oats, peas and mustard [*Brassica campestris var. sarson*] in the Rabi (winter) season for enhanced forage production as well as duration of forage availability. Hybrid Napier alone and its mixture with soybeans produced significantly higher green (62.99 and 68.18 t/ha) and dry (8.38 and 9.21 t/ha) biomass. *S. anceps* and hybrid Napier produced higher biomass during their second cuts, while, Guinea and green panic grasses produced higher biomass in the first cut. Crude protein content under different cuts ranged from 5.26 to 8.99 % in *S. anceps*, 7.02 to11.03 % in hybrid Napier, 6.94 to 8.13 % in Guinea grass and 6.32 to 9.18 % in green panic grass. Crude protein content was higher in perennial grasses when cut along with intercropped legumes. Hybrid Napier and its mixture with soybean had higher crude protein content and lower amounts of lignin and silica. During the Rabi season, there was no significant difference in biomass production among treatments. The average crude protein contents under different cuts in oats, peas and mustard were 11.07, 19.32 and 11.64 %

respectively. The herbage mixtures of both seasons had adequate amounts of macro and trace minerals to meet the minimum requirements of animals. Hybrid Napier intercropped with legume and non-legume fodders during the Kharif and Rabi seasons produced the highest green biomass and net profit (87.64 t/ ha and Rs. 18861 ha^{-1} respectively). Hybrid napier and its intercropping was better than the other combinations and can be cultivated in grasslands and waste lands under rain fed conditions in the humid sub-tropics of Himachal Pradesh (SUDESH *et. al*., 2006).

Tepary bean (TB), a drought tolerant bean variety has become popular among poor small-scale farmers in semi-arid Kenya, where it is predominantly intercropped with maize. The nitrogen fixation and yield of intercropping tepary bean-maize in comparison to sole crops as affected by nitrogen fertilizer application and inoculation were investigated during two successive growing seasons. Experimental design was randomized complete block with eight treatments: TB sole crop not inoculated with Rhizobium (R3254) and without N fertilizer (N), TB sole crop not inoculated with R 3254 with or without N, TB sole crop inoculated with R3254 without N, TB with maize intercrop not inoculated with R3254 with or without N and maize sole crop with or without N. Each treatment was replicated four times. Significant differences (P#0.05) were observed in total plant dry mass between inoculated and un-inoculated treatments on 21 and 42 days after emergence (DAE). TB yields were significantly reduced in un-inoculated intercrop. Inoculated TB treatments had significantly higher seed dry weights and yields ha-1 compared to un-inoculated. Intercropping TB and maize suppressed the yield of the former under semi-arid conditions. Inoculating TB with Rhizobium strain R3254 was effective and significantly improved TB yields in sole and intercrop. Soil analysis after the two cropping seasons indicated enhancement of soil N in sole TB plots above pre-planting leaves. Maize plots exhibited a decline in soil N. Total N concentration in plant tissues was significantly enhanced in treatment R3254. There was a marked increase in soil P in all treatment plots following amendment. (SHISANYA, 2005).

The experiment of KARADAG (2004) aimed at determining the optimal proportion of timothy in an alfalfa mixture, and at investigating respective changes in nutritive value and protein quality of forage. Two hybrid alfalfa (*Medicago varia* Mart.) and two high-quality alfalfa (*Medicago sativa* L.) varieties were cultivated in unmixed and mixed sowings with timothy. The yields were measured and herbages' chemical compositions were determined for each cut of monocultures and mixtures from 2000-2003. The dry matter yields of bi-crops were higher than those of monocultures. The increase of timothy's sowing norm was accompanied by plausible decrease of crude protein content in the first cut harvests. The variations in the timothy's sowing norm had no impact on the contents of metabolical energy in the dry matter. The harvests of the alfalfa-timothy mixtures had positive protein balance values (PBV) in the rumen. These values decreased with the increase of timothy's sowing norm. In the harvest of the third cut, the PBV was 2-3 times higher than in the previous cuts and the effect of timothy's sowing norm was reduced. (TAMM and TAMM, 2005). The forage and seed yields of common vetch (*Vicia sativa*), Hungarian vetch (*Vicia pannonica*), hairy vetch (*Vicia villosa*), grass pea (*Lathyrus sativus*) and barley (*Hordeum vulgare*) grown as mixture were investigated in field experiments, designed in a factorial randomized complete block with three replications, were conducted at the Faculty of Agriculture, Gaziosmanpasa University, Turkey, in 2001-02 and 2002-03. The highest dry matter (14 435.8 kg ha^{-1}) and total seed yields (3274.3 kg ha^{-1}) were obtained from the mixture including 34 % barley and 66 % grass pea line 455, while the highest green forage yield (423.401.5 kg ha^{-1}) was obtained from the mixture including 34 % barley and 66 % peas. In addition, the highest barley ratio in dry mater (95.67 %) was achieved with the 34 % barley and 66 % Urem-79 mixture. The mixture of 34 % barley and 66 % Menemen-79 produced the highest legume ratio in dry matter (7.86 %). The mixtures out yielded the pure barley sowing with respect to green forage, dry matter and total seed yields.

LAURIAULT and KIRKSEY (2004) reported that with the decrease in water supplies, alfalfa (*Medicago sativa*) and corn (*Zea mays*) producers in the Southern High Plains (USA) seek alternative forages for the dairy industry. At New Mexico State University's Agricultural Science Center at Tucumeari, cereal forage monocultures and intercrops with legumes were subjected to two irrigation treatments during two growing seasons in a Canez fine sandy loam (Fine-loamy, mixed, thermic Ustollic Haplargid). Dry matter (DM) yield of monocultures averaged 3.76, 3.90, 5.55, 5.59 and 3.17 Mg ha^{-1} for rye (*Secale cereale*) barley (*Hordeum vulgare*), wheat (*Triticum aestivum*) triticale (x *Tritcasecale rimpaui*), and oats (*Avena sativa*) respectively. Cereal forages irrigated once in a growing season yielded equally to those watered twice with average precipitation (2000-2001, 408 mm) but not in a dry growing season (2001-2002, 245 mm) (6.15,5.41,1.90, and 3.21 Mg ha^{-1} for cereal forages irrigated once or twice in

200-2001 or 2001-2002,, respectively). Also, levels of forage nutritive components were greatest when irrigated once in 2001-2002. Intercropping with winter pea (*Pisum sativum* subspecies. *arvense*) Oir or hairy vetch (*Vicia villosa*) reduced yield of wheat and triticale compared with monocultures, but these yields were still greater than those of the other cereal forages and winter pea improved quality indicators when intercropped with wheat or triticale. Water can be conserved in the Southern High Plains by irrigating cereals only as needed for germination or promote fall growth. A study was conducted to determine the persistence of forage legume, grass species and cultivar mixtures suitable for growing at grazing systems. The botanical composition of swards, dry matter (DM) yield by cycles, grass (with mineral and organic fertilizers; unfertilized), intake by cows during grazing, were investigated. The white clover and lucerne were more sensitive to weather conditions. The highest annual DM yields were obtained in sward grass sown with mineral fertilizers and with red clover grass mixture. The white clover has the best tolerance for grazing and was highly consumed by cows. The highest intake was observed in swards of red clover and white clover with PK fertilizers and non-fertilized area. Results indicated the importance of growing legumes and the use of fertilizers. It was concluded that fertilizer application was one of the main factors affecting the yield of sown pastures (GEHERMAN and PAROL, 2004).

A new opportunity to use mixtures of green fodder crops for ruminant nutrition was investigated in Hungary. Upon joining EU, there was a subsidy for cattle breeders who preferred the extensive way of breeding. The objective was to determine which plant species and varieties could be used in the green fodder feeding system. The small plant trials with rye (*Secale cereale*), winter barley (*Hordeum vulgare*), triticale, hairy vetch (*Vicia villosa*) and common vetch (*Vicia pannonica*) were performed in four repetitions. The mixtures of temporary certified seeds: Triticale and vetch, rye and vetch, and winter barley and vetch were sown. Immediately after harvesting, yields of fodder from plots were weighed and the samples were analyzed for dry matter, crude protein and crude fiber. The yields of green fodder, dry matter and crude protein were determined. In the production year 2002-2003, there was a significant difference between the two mixtures of rye and hairy vetch (R and HV) but none of them differed from the triticale and panon vetch (T and PV) mixture. In the crude protein yield, there was significant difference between the T and PV and R and HV. In the production year 2003-04, T and PV gave the highest grain yield (45.10) and crude protein yield but were not-significantly different from B and PV.

Significant differences among the same varieties were found. The variety had a huge effect on yield results. Based on the two years of study, the most productive mixtures was the Triticale mixed with vetch varieties Filius and Beta. If the weather was humid like in 2004, then winter barley mixed with vetch varieties Viktor and Beta was more favorable than the rye mixed with vetch. A continuous research on green fodder was needed to determine the nutritive value of the mixtures for ruminant feed (HOFFMANN *et al*., 2004).

The objective of the experiment of KWIATKOWSKI (2004) was to analyze the effect of several intercrop plant species on the yield of spring barley in many-years monoculture. The field experiment was conducted in 2001-03 in Czesawice (Lublin Agricultural University), Poland. The experiment was localized on loess soil classified as the second evaluation class. The soil was characterized by high acid reaction and a very high content of available forms of phosphorus, potassium and magnesium. Two forms of barley; naked and husked, were tested. The other factors were treatments with intercrops for ploughing: A. without intercrop (control treatment) B. white mustard (*Sinapis alba*) C. spring vetch (*Vicia* sp.) and field pea (*Pisum sativum*) D. rye grass (*Lolium* sp.). Protection of the canopy consisted of seed dressing and mechanical removal. In the protection herbicides, fungicides, insecticides and growth regulators were applied. The sowing rate for both forms of barley was identical and equaled 300 grains m^{-2}. It was found that the highest crop of intercrop dry weight was obtained through the sowing of spring vetch on field pea.

Information was presented on the scale of fodder crop production in the Republic of Tatarstan, Russia. Production of leguminous-Poaceae mixture for grain, hay and green fodder, use of rotations, haymaking and use of pastures were considered. Investigations were conducted to study to use of 9 grain crops and fodder rotations with 33.3 % Lucerne, 33.3 % annual grasses, and 33.4 % industrial grain and grain-fodder crops. The total share of perennial and annual legumes, and leguminous-Poaceae mixtures was 72.2 %. Crop rotations allowed complete replacement of nitrogen fertilizer use through nitrogen fixation by legumes. Productivity of rotation protein content, dry matter content, exchange energy and nutritive value in fodder were considered (MALIKOV, 2004). During the period 1994-1997 a field trial was carried out in the north central region of Bulgaria. The objective of the study was to establish the forage productivity of some Bulgarian Lucerne (*Medicago sativa*) cultivars in pure stand and in double component mixtures with the grasses, cocksfoot and tall fescue, each in proportion 1:1. The

Lucerne cultivars Obnova 10, Pleven 1 and Victoria wee used. It was found that Victoria was the most productive in all tested stands. The average annual dry matter (DM) yield in the pure stand was 15 673 kg ha^{-1} and in the mixture with cocksfoot 16809 kg ha^{-1}. There were no-significant differences between the yields of the cultivars in the mixtures with tall fescue. The DM yield was higher in the mixed stands by 8.8 % (VASILEV; 2004).

The productivity of the existing dominant perennial forages such as Rhodes grass (*Chloris gayana*; cultivars Katambora, Callide and Top Cut), Lucerne cv. Batinah and their mixtures (1:1, 1:2 and 2:1) were investigated from January 1998 to August 1999 in an experiment conducted in Oman. Rhodes grass cultivars produced significantly ($P<0.01$) higher green (230.50-306.10 t/ha) and dry matter yields (52.39-67.48 t ha^{-1}) during the experimental period, followed by the mixture treatments (green matter; 223.51-241.76 t ha^{-1} and dry matter: 49.02-53.11 t ha^{-1}) and Lucerne cultivars (green matter: 182.05-184.04 t $ha^{-1}$and dry matter: 40.83-44.67 t ha^{-1}). Among the Rhodes grass cultivars, Callide had a very high significant yield potential ($P<0.05$) in terms of both green and dry matter yields followed by Katambora and Topcut, a newly introduced cultivar. In Lucerne, both green and dry matter yields of 1:2 mixture of Lucerne and Rhodes grass were significantly higher than the other 2 mixture proportions i.e. 1:1 and 2:1 ($P<0.05$). (NADAF *et al.,* 2004). The compatibility of two tropical grasses (*Brachiaria humidicola* (Bh) and *Panicum mixium* (Pm) and three legumes (*Arachis pintoi* (Ap), *Stylosanthes capitata* (Sc) and *Stylosanthes guianensis* (Sg) were examined at two fertilizer application levels in a tropical South America savanna region. Pairs consisting of one grass and one legume were planted on reclaimed Colombian lowland. Changes in biomass over time, growth patterns, and the relative palatability of these species indicated by grazing preference were measured. Among the two grass species, Bh showed strong growth, even under the low fertility condition, while Pm required the high fertilizer application level for establishment and growth. Among the legumes, Sg grew vigorously, even at the low fertility level, and could compete with Bh in biomass production. The Sc was less vigorous than Sg but was preferred by cattle. The growth habit of Ap was stoloniferous, it required a long time period to make a dense sward, because its spreading rate was low due to the bigger seed size. Among the three legume species, Ap was most preferred by cattle, and Sg was the least, but was nevertheless eaten by cattle if no other legumes were present. Considering the compatibility of these grasses and legumes, the mixture of Sg and legume (Pm) produced a higher level of herbage biomass than the other grass-legume mixtures examined in this study. The Ap and Pm mixture also had good compatibility, and its palatability to cows was higher than the other mixtures. (SAITO, 2004).

Legume-grass mixed crops provide the cheapest feedstuffs, demand the least energy consumption for cultivation and can be grown without the use of nitrogen fertilizers. Mixed cultivation of *Trifolium pratense* with barley improved in soil fertility due to cultivation of legumes in rotation systems and the efficiency of fertilizer use was also increased (SEREGIN et al; 2003). Field experiments were conducted over 2 seasons in Kenya to determine the effect intercropping maize and Tepary Bean (*P. acutifolius* var. *acutifolius*) on N fixation and yield under semi-arid conditions. The treatments comprised Tepary Bean (TB) as sole crop with N fertilizer and no inoculation; TB as sole crop with no N fertilizer and no inoculation (control); TB as sole crop and inoculated with Rhizobium strain 3254 and no N fertilizer; TB + maize (M) intercrop with N fertilizer and no inoculation; TB + M with no N fertilizer and no inoculation; TB + M inoculated with *Rhizobium* strain 3254 and no N fertilizer M as sole crop with N fertilizer; and M as sole crop with no N fertilizer. TB was sampled at 21, 42 and 70 days after emergence (DAE). Data were recorded for number of nodules, nodule dry weight, and total plant dry weight, number of pods and pod dry weight plant^{-1}. Total seed dry weight, total plant dry weight, 100 seed dry weight per plot, TB and maize yield, and total TB N content. At 21 DAE, the effect of inoculation TB with R 3254 had positive significant effects. The infectivity and effectively of Rhizobium strain R3254 on TB was more pronounced at 42 and 70 DAE. During all plant sampling stages, N treated plots had significantly lower dry weight of the parameters studied than the inoculated treatments. N fertilizer application had no significant effects on dry matter production or grain yield. There were significant differences at harvest between sole cropped-and intercropped-inoculated TB. However, the yield parameters were higher in the second than first season. The analysis of various plant tissues in different treatments showed that inoculated TB plants had high N content during the vegetative cycle. Soil analysis of N showed that the inoculated treatment plots under sole and intercropping systems enhanced soil N by 15-70 % and soil P by 10-66 %. (SHISANYA, 2003).

BERGKVIST (2003a) studied in two field experiments conducted in Southern Sweden the potential to use differences in traits of white clover (*Trifolium repens.*) to improve mature yield of winter wheat or winter oilseed rape (*Brassica napus.*) sown in white clover living mulch The clover varieties Sonja, S-184 and Aber Crest, differing in leaf size and winter hardiness, were under sown in spring barley. Three consecutive crops of winter wheat or one crop of winter rape sown at two densities followed the barley. In the first year, the mature yields of wheat and high density rape equaled yields without white clover when Aber Crest was used. While Sonja reduced the wheat yield by one third and the rape yield to nothing. S-184 was intermediate. White clover increased yields by 14-19 % in the second wheat crop but had no effect in the weed infested third wheat crop. The average amount of white clover at flowering of wheat was always largest with Sonja which increased its biomass earlier in spring than Aber Crest. It was concluded that white clover traits are important when developing the intercropping system for large mature yields, especially when herbicides are avoided.

Experiments were conducted on sandy clay soil to determine suitable species and varieties of cereal crops for growing in mixture with common vetch [*Vicia sativa.*]. In 1997 common vetch was mixed with three different wheat varieties (Heta, Satu and Manu) and oats cv. Jaak and Miku. As the preceding crop had been barley, where wheat was grown alone the yield was low, averaging only 1982 kg ha^{-1} over the three varieties. The yield of the mixture of common vetch and wheat was up to 3248 kg ha^{-1}, with the highest yield when vetch was sown at 66 germinating seeds m^{-2} in mixture with wheat. The preceding cereal crop was more suitable for oats and therefore, the pure oats gave a yield of 2953 kg ha^{-1} while the mixture of common vetch and oats yielded up to 4621 kg ha^{-1} at a vetch content of 71 germinating seeds. Differences in the yields between different varieties were insignificant. Vetch seed yields were higher when grown in mixture with oats. In 1998, the cereals were grown after clover as the preceding crop. Thanks to clover, pure wheat and oats gave higher yields than the mixtures of common vetch and cereals. From the mixtures sown in 1998, the highest yields were given by common vetch + wheat, while common vetch + oats gave a low yield (LAUK and LAUK, 2003).

GIACOMINI *et al*. (2003) studied an increase in the use of winter mixed cover crops in Southern Brazil. A field experiment was carried out from 1998 to 2000, in UFSM (RS), on a typic Paludalf soil. Black oat (*Avena strigosa* Sehieb) + common vetch (*Vicia sativa* L.) and black oat + oilseed radish (*Raphanus sativus* L.var. *oleiferus* Metzg.) were cultivated in different proportions of seed mixing. There were nine treatments: (1) 100% black oat (AP), (2) 100% common vetch (FC), (3) 100% oilseed radish (NF), (4) 15% AP + 85% EC, (5) 30 % AP + 70 % EC, (6) 45 % AP + 55% EC, (7) 15 % AP + 85% NF, (8) 30% AP + 70% NF, and (9) fallow (spontaneous vegetation). Dry matter (DM) and the concentrations of nitrogen, phosphorus, potassium and carbon in cover crop biomass were determined. The crop mixture DM yield was similar to that of single oat and single oilseed radish and greater than single vetch. Nitrogen in the biomass of oat + vetch mixtures did not differ from that of single vetch in the three years. The C/N ratio of oat + common vetch was 67 % higher compared to the single vetch crop. The cover crops provided greater DM and were more efficient in N, P and K accumulation than the winter fallow spontaneous vegetation. Results of this study indicated that the cultivation of a mixture of oat + common vetch and oat + oilseed radish was more efficient than single crops since it combined the high biomass production capacity of black oat and oilseed radish with the ability of common vetch to fix atmospheric N_2.

KUCHINDA *et al*., (2003) conducted two on-farm trails in 1999 and 2000 to evaluate the use of tolerant maize varieties intercropped with some legumes in the management of the parasitic weed. Striga incidence and mazie reaction score were significantly (P=0.05) reduced by the variety Acr.97 TZL comp 1 intercropped with soybean (var. SAMSOY II) and groundnut (Var.RMP-91) in both years and by Oba Super I intercropped with the two legumes in 2000. Oba Super 1 +RMP-91 increased cob numbers and weight and grain yield over the local cultivar in the two years. Acr.97 TZL comp. 1 + RMP-91 increased cob number and weight in both the years and grain yield in 1999, grain yield and cob weight had significant (P 0.05) negative correlations with Striga incidence and crop reaction score. Intercropping the two improved varieties with either soybean or groundnut was more profitable than the local cultivar grown alone.

KURDALI *et al.* (2003) conducted two field experiments on *Sesbania aculeata* (Dhaincha) and sorghum (*Sorghum bicolor* L.) grown in mono-cropping and intercropping systems under non-saline and saline conditions to evaluate dry matter production, total nitrogen (N) yield, land equivalent ratio (LER), soil N uptake and N2 fixation using N-15 isotope dilution method. The first experiment was conducted under non-saline conditions. Three different combinations of sesbania (ses) and sorghum (sor) were investigated in the intercropping system whereas in the second experiment only one combination was tested under saline conditions. Results of the first experiment showed that dry matter yield of sole sorghum was higher than that of sole sesbania and was similar to the intercropping treatments. However, its total N uptake was the lowest, with non- significant differences between sole sesbania and intercropping treatments. A greater advantage of intercropping system in terms of land use efficiency was recorded. In the second experiment dry matter yield of a sole crop of sesbania was significantly higher than that of a sole sorghum or a mixed treatment. Total N uptake in sesbania grown alone was four times higher than that of sole sorghum: whereas, the mixed cropping was 260 % greater that of the sole sorghum.

POLTHANEE and TRELO-GES (2003) conducted a field experiment to investigate growth, yield and yield components of corn, peanut, soybean and mung bean under intercropping and single cropping as well as to assess the land use efficiency. Yield and yield components of corn was unaffected by intercropping system. In legume crops, peanut, soybean and mung bean, intercropping systems reduced the leaf area and top dry weight per plant as compared with single cropping. Grain yield of peanut, soybean and mung bean was reduced by 28, 39 and 51 % respectively, as compared with single cropping. The pod number per plant was the most affected by intercropping among the yield components. However, corn-legume intercropping increased land use efficiency by 48 to 66 % depending on legume species. Corn-peanut intercropping gave the highest land use efficiency.

ZHANG and LI (2003) conducted research on the processes involved in the yield advantage in wheat (*Triticum aestivum*)/maize (*Zea mays*) wheat/ soybean (*Glycine max*), faba been (*Vicia faba*)/ maize, peanut (*Arachis hypogaea*)/ maize and water convolvulus (*Ipomoea aquatica*)/ maize intercropping. In wheat/maize and wheat/soybean intercropping systems, a significant yield increase of intercropped wheat over sole wheat was observed, which resulted from positive effects of the border row and inner rows of intercropped wheat. The border row effect was due to inter-specific competition for nutrients as wheat had a higher competitive ability than either maize or soybean. There was also compensatory growth, or a recovery process, of subordinate species such as maize and soybean, offsetting the impairment of early growth of the subordinate species. Finally, both dominant and subordinate species in intercropping obtained higher yields than that in corresponding sole wheat, maize or soybean. These processes were summarized as the competition-recovery production principle. The inter-specific facilitation was observed where maize improved iron nutrition in intercropped peanut. Faba bean enhanced nitrogen and phosphorus uptake by intercropped maize, and chickpea facilitated P uptake by associated wheat from phytate-P. Furthermore, intercropping reduced the nitrate content in the soil profile as intercropping used soil nutrients more efficiently than sole cropping.

Green fodder crops in pure stand and in mixture have great potential and will have a great role in the nutrition of ruminants. Therefore an experiment was carried out to study green fodder crop production in the present situation of cattle husbandry. The type of the soil was brown forest soil with clay illuvitation. Small plot trials were carried out in four repetitions using conventional random adjustment. After harvesting, the yield of the plots was determined and the dry matter content, crude protein yield and crude fiber content were determined. The species used in the small plot trial were: spring barley, peas and vetch. The highest green and dry matter yield were measured in barley grown in pure stands. Between the barley varieties, Annabell gave the highest green DM and crude protein yield. Spring Barley cv. Annabell and pea cv. Rubin in mixture livestock gave the highest yield of crude protein (TROTS and YAKOVLEV, 2003).

A field experiment was conducted in Sicily (hilly central area), in which binary mixtures of barley and *Medicago polymorpha*, *Medicago scutellata*, *Trifolium alexandrinum, T. incarnatum, T. resupinatum*, *T. squarrosum,* and *Vicia sativa* (sowing ratio 100:0, 75: 25, 50, 50, or 0:100) were harvested by moving at heading or via simulated pasture. In the mixtures, the effects of legume species on total yield and N-Uptake of barley were studied. For the sum of the two pasture cuttings, mowing at heading and their average, the yield of the pure barley stand was the highest (9.753, 11.895, and 10.824 kg ha^{-1} respectively). N-uptake by the barley component, averaged over all the mixtures, was significantly higher in the sum of pasture cuttings than in mowing at heading (100.8 and 76.3 kg ha^{-1} respectively). Barley in pure stand had the highest N content, relative to the other mixtures, when averaged over harvest managements. The relative yield index of N-uptake of barley in mixture was highest than that of the pure stand only for mixtures with *M .polymorpha* and *V .sativa.* Therefore, the influence of legumes on the N-uptake of barley differed in relation to legume crop adopted (KIRILOV *et al.,* 2003).

The efficiency of grain forage production in legume companion crops was investigated in the Non-Chernozem Zone of Russia. The crops were spring wheat cv. Lada, barley cv. Elf and oats cv. Kozyr. These were sown in mixtures with narrow-leaf blue lupin cv. Kristall, yellow lupin cv. Branzkii 17, garden pea cv. Nord, filed pea cv. Malinovka and spring vetch cv. Lyudmilla. The yield of grain mixtures with blue lupin was higher by 2.5-5.6 centers ha^{-1} compared to pure crops, 6.4 and 7.9 center $ha^{-1}$for oats, and barley and wheat, respectively. Legume-grass mixtures with yellow lupin also showed higher yield than pure crops, except for pure oat. The highest crude protein content was observed in yellow lupin seeds (41.9 %), followed by blue lupin (35 %), spring vetch (31.2 %), field pea (24.2 %) and garden pea (22 %). The energy efficiency coefficient in mixtures with blue lupin was the same as the pure-sown counterpart, but other legume-grass mixtures showed higher values compared to pure crops (LIKHACHEV *et al*., 2003).

Mixed cultivation of fodder beans [*Phaseolus* sp.] with peas, vetch [*Vicia*] and oats was studied in 1997-1999 in Russia. Plots were set up on leached heavy loam chernozem. The cultivars grown were: drug (oats), Chisminskii 242 (peas), Yantarnye (fodder beans) and L'govskaya and Orlovskaya (vetch). Data on fresh weight yield, crude protein, silage characteristics, and energy efficiency of cultivation were recorded. The highest yield of fresh weight was obtained using a mixed crop of 75 % fodder beans + 25 % vetch (30.4 t ha^{-1}). However gross and net energy were the highest for 50 % fodder beans + 50 % peas mixed crop i.e.117.6 and 61.5 GJ ha^{-1}, respectively (KUZEEV., 2002). ZIMKOVA *et al*. (2002) evaluated grass (*Lolium perenne, Festuca pratensis, Dactylis glomerata and Phleum pratense*)/legume (*Trifolium repens* and *Medicago sativa*) mixtures in Central Slovakia (site: Flos, near Banska Bystrica: altitude of 460 m) during 1998-2000. The botanical and chemical composition of the grass/legume mixtures was assessed and the relationships with soil chemical composition were determined. Grass/legume mixtures were managed without mineral fertilizer application or *Rhizobium* inoculation. The botanical composition in the grass/*T. repens* and grass/*M. sativa* mixtures varied during the years. While in the grass/*T. repens* mixture grass occurrence increased (30-58 %), *M. sativa* became dominant in the grass/*M. sativa* mixture (70-93 %) in 1998-2000. The chemical composition of both grass/ *T. repens* and grass/ *M. sativa* mixtures showed a sufficient concentration of crude protein, P and Ca. The chemical composition of the soil confirmed a positive impact of the grass/legume mixtures on soil.

SPRINGER *et al.* (2001) estimated combining ability for native, warm season grasses and legumes grown in binary mixture in the field using a combining ability analysis of variance. Six monocultures and 15 binary mixtures of species: big bluestem, *Andropogon gerardii* Vit., Illinois; bundle flower, *Desmanthus ukkuibesus* (Michx) MacM; roundhead lespedeza, *Lespedza capitata* Michx; slender lespedeza, *L. virginica* Britt; switch grass, *Panicum virgatum* L. and Indian grass, *Sorghastum nutans* were studied. General combining ability (GCA) effects were found for forage dry matter yields (P less than or equal to 0.05) of Illinois bundle flower (1240 kg ha^{-1}) *Slender lespedeza* (3300 kg ha^{-1}) and switch grass (8370 kg^{-1}). General combining ability and SCA effects were found for crude protein concentration (CPC) of all species and mixtures (P less than or equal 0.01) respectively. On the basis of total forage protein (DMY times CPC), the only compatible grass legume mixture was Indian grass – Illinois bundle flower (SCA effect = 100 kg ha^{-1}, P less than or equal to 0.05).

GIL and FICK (2001) investigated soil N availability in monoculture and binary mixtures of alfalfa (*Medicago sativa*) or red clover (*Trifolium pratense* L.) with eastern gamma grass (*Tripsacum dactyloides*) on sandy and clay loam soils near Manhattan, KS. Soil inorganic N and *in situ* net N mineralization were monitored monthly during the growing seasons of 1996 and 1997. Soil organic N was three fold higher with alfalfa red clover and gamma grass alfalfa mixture than with gamma grass in monoculture at the end of 1996. At the mid season of 1997, soil inorganic N was three to nine fold higher at the clay loam site, but at the sandy site, only alfalfa monoculture was three to five times higher than the other treatments in both years. Soils under alfalfa at both sites in 1997 had the highest cumulative net N mineralized (35-100 kg N ha^{-1} yr^{-1}) followed by the gamma grass legume mixture (15-62 kg N ha^{-1} yr^{-1}) and than the gamma grass monoculture treatment (2-15 kg ha^{-1} yr^{-1}). A high correlation ($r(2)>0.9, P<0.05$) was found between C/ N ratio of the above ground biomass and the total net N mineralized in the 2nd year for both sites, suggesting that litter quality is an important driving variable on N mineralization.

ODHIAMBO and BOMKE (2001) concluded a 2nd year study to determine the effect of grass and legume cover crops on spring DM production and N accumulation. Each year cover crops were planted in late August and late September on a loamy, mixed, mesic Humaquept in the Fraser River Delta. Wheat (*Triticum aestivum* L.) rye (*Secale cereale*) and rye grass (*Lolium multiflorum*) were planted in monoculture and in mixture with crimson clover (*Trifolium incarnatum*) and wheat – hairy vetch (*Vicia villosa* Roth) mixture. Cover crop biomass was sampled three times in 1995 and four times in 1996 during the spring growth period. Dry matter accumulation of early planted cover crops increased by 26 to 29% during the spring growth period, ranging between 0.6 mg ha^{-1} for clover and 10 mg ha^{-1} for wheat, wheat-clover and wheat-vetch treatments. Late-planted cover crops produced between 15 and 75% lower DM yield compared with early planted cover crops. Nitrogen accumulation increased by 3 to 74 kg ha^{-1} for early planted crops and by 3 to 47 kg ha^{-1} for late planted crops.

MOHAPATRA *et al*. (2001) conducted an experiment during 1996-1998 to evaluate the production potential and economic returns of Sabai grass [*Eulaliopsis binata* (Retz.] based intercropping systems on rain fed upland of Similipal foothills of Orissa, India. Intercropping of forage legumes like Moth bean (*Vigna aconitifolius*), Marce*, Stylosanthes hamatai*, cowpeas (*Vigna unguiculata*), butterfly-pea (*Clitoria ternatea*), cluster bean (*Cyamopsis tetragonoloba* and rice-bean (*Vigna umbellata*) was investigated. Rice bean was better than sole Sabai grass both in terms of total production and net return. Sabai grass and styles recorded highest yield, returns (Sabai grass yield =5.98 $t.ha^{-1}$ and net return Rs. 7626 ha^{-1}) and benefit cost ratio (2.78) followed by cowpeas (5.39 $t.ha^{-1}$, Rs. 6689 ha^{-1}, 2.67).

Cultivation of 16 mixed spring fodder crops was studied in Russia in 1999-2000 (GUBKINA, 2001). The crops studied were barley cv. Nosovskii, oats cv. Skakun, peas cv. Talovets 60, vetch cv. Lugovskaya and lupin cv. Ladnyi, Kristall and Bryanskii, plots were set up on grey forest medium loam soil. Data on productivity, digestible protein, energy, fodder unit yields, coefficient of energy efficiency and profit were tabulated. The best results were achieved using barley + vetch mix (3.02 t.ha-1), barley + oats + pea (3.02 t ha^{-1}) and barley + oats + lupin + pea (2.99 t ha^{-1}). The field experiment research, conducted in the experimental fields of the Institute of Field Crop Husbandry of the Estonian Agricultural University in Erika Tartu, Estonia, on pseudo podzolic soils, showed that cereal-legume mixes produced relatively abundant and high-quality crops. Mixed crops might replace cereal on 1-2 fields of a crop rotation. Cereal-legume mixes did not need application of N fertilizer. In a potato-cereal rotation, a legume-wheat mix was recommended instead of the cereal. The seed mix should contain 300 germinating wheat seeds and 40 germinating vetch seeds per one square meter. In a cereal-cereal rotation, a cereal (wheat or barley) or a winter cereal might the followed by a legume-oat mixture. A vetch-oat mix might even follow a pea-wheat mix. The seed mix should contain 250 germinating oat seeds and 60 germinating pulses seed per one square meter. The results showed that mixed crops are able to compete with weeds in the agricultural community. Mixed crops reduced the number of weeds against the backdrop of no crops (LAUK *et al*., 2001). Field trails carried out in 1996-98 in the southern forest steppe zone of the Bashkir Republic, Russia on a moderately deep clay loam leached Chernozem are reported. Experimental plots were sown with combinations of 1 or more of barley, oats, peas or vetch. Percentages of individual crop types in mixed intercropping were also varied. It was concluded that feeds obtained using mixed intercropping were cheaper and had a higher feed value than those obtained using sole cropping (KUZEEV and GAFOROW., 2000).

A local six-row barley cultivar (ACSAD 176) and common vetch (*Vicia sativa*) cv. Beekia were grown as monocultures or in mixed cropping or intercropping systems, with seed ratios of 1:1, 1:2, 1:3, 2:1 or 3:1 in field trials under semi-arid conditions at Ramtha, Jordan. Mixed cropping generally gave higher dry matter and grain/seed yields than intercropping, and both these cropping systems gave higher dry matter and grain/seed yields than monocultures. Dry matter and grain/ seed yields increased as the barley proportion increased. Monoculture of barley gave the highest number of tillers per barley plant, while monoculture of vetch gave the highest number of branches per vetch plant. Using a 1:3 barley/ vetch seed ratio under either mixed cropping or intercropping gave the highest crude protein content (TURK, 2000). SLEUGH *et al*, (2000) evaluated the effects of alfalfa, bird's foot trefoil (*Lotus corniculatus*) and Kura clover grown in binary mixtures with orchard grass (*Dactylis glomerata*), smooth brome grass and intermediate wheat grass on seasonal distribution of forage yield and quality. Plots of each species in monoculture and binary grass legumes mixtures were established in a randomized complete block design. Yield was measured monthly during. *Invitro* dry matter, digestibility (IVDMD, neutral – detergent fiber (NFD), and crude protein (CP) concentrations were determined. Dry matter for monoculture alfalfa, alfalfa – intermediate wheat grass, and alfalfa smooth brome grass were recorded as 13400, 12700 and 12600 kg ha $^{-1}$ respectively in 1995 and 7500, 6800 and 6700 kg ha^{-1}1996. Kura clover had the highest IVDMD (740 g kg^{-1}) concentrations compared with other forages. Yield, CP and INDMD concentrations of monoculture grasses were lower than those of legume-grass mixtures or of the monoculture legumes. Legumes improved the seasonal distribution of yield and forage quality by being more productive at later harvests. Yield of alfalfa intermediate wheat grass was equal to or better than other alfalfa grass mixtures and could make a valuable legume-grass alternative.

2.3 Inoculation of legumes and N-fixation

Usually, introduction of legumes in a fodder cropping system after inoculation of the former prove highly useful in qualitative terms as well as improvement of fodder quality. In a pot experiment, the pots were separated into two equal parts with nylon meshes or plastic sheet (with no barrier as the control) before seeds of faba been (*Vicia faba*) and wheat (*Triticum aestivum*) were sown in them and supplied with nitrogen (N) at 0 or 100 mg/kg and inoculated with Rhizobium strain NM353 at 0 or 10 ml/pot (XIAO- YAN *et al.,* 2006). Rhizobium inoculation promoted the growth of the faba bean plants that in turn benefited the intercropped wheat. With

N application, the biomass of faba bean plants increased by 15,16 and 5 % in the inoculated treatments as compared with the non-inoculated control in plastic sheet barrier, nylon mesh barrier and no barrier treatments, respectively, and their N uptake increased by 17, 9 and 12 %. In the no barrier treatment, Rhizobium inoculation improved the growth of wheat, enhancing its biomass and N uptake by 13 and 22 %, respectively, as compared with the non-inoculcated treatment. It was, therefore, concluded that inoculation of appropriate strain of Rhizobium could improve nitrogen fixation of legume crop and benefit the cereal crop in a faba bean/ wheat intercropping system.

The effects of bio-fertilizer seed inoculation and N top design on the performance of winter pea (*cv.* Maksimirki ozimi) + wheat (cv. Sana) Italic Intercropping system were studied during 1999-2001. Before sowing, pea seeds were inoculated with *Rhizobium leguminosarum* cv. *Viciae* (UHER *et al., 2006*). The highest number of nodules (24.5 per plant) and nodule dry weight (0.145 g per plant) in pea were obtained with seed inoculation + N top dressing. The average yield of winter pea ranged from 1930 (control) to 2822 kg/ha (inoculation). The average yield of winter wheat varied from 2250 (control) to 3300 kg ha^{-1} (N top dressing). The average yield of winter pea + wheat was lowest in the control (4180 kg ha^{-1}) and highest in N-treated plants (5708 kg ha^{-1}). Seed inoculation + N top dressing also gave the highest number of pods (12.5) and seeds (52.0) per plant, 1000-seed weight (117.5 g) and weight of seeds per plant (6.07 g). Forage legumes are playing an expanded and invaluable role in the nitrogen economy, in animal productivity and in sustainability to temperate grass lands, and advances in their technology foreseen. The large pool of genetic variability among the genera and their species is being exploited further by the development of cultivars adapted to different edaphic, climatic and biotic conditions, though not forgetting the value of already adapted landraces. Some lesser species have shown promise as pioneer swards for difficult soils, degraded land and extreme climes, though sufficiency of certified seed supplies can be a problem. The N_2-fixing capacity of forage legumes is discussed in terms of rhizobial efficiency, N transference to associated companion grasses, provision of on-farm protein, and N supply to subsequent arable crops. Individual animal performance is enhanced by high intake and nutritive value characteristics of legume-rich diets. Condensed tannins, present in certain legumes, e.g. birds foot (*Lotus corniculatus*), have benefited ruminant animal nutrition through protein protection and bloat prevention and reduction of internal parasites (REYNOLDS, 2005).

In many legumes, including *Lotus japonicus* and *Medicago truncatula*, susceptible root hairs are the primary sites for the initial signal perception and physical contact between the host plant and the compatible nitrogen-fixing bacteria that leads to the initiation of root invasion and nodule organogenesis. However, diverse mechanisms of nodulation have been described in a variety of legume species that do not rely on root hairs. To clarify the significance of root hairs during the *L. japonicus-Mesorhizobium loti* symbiosis, four independent *lotus japonicus* root hair developmental mutants were. Although important for the efficient colonization of roots, the presence of wild-type root hairs is not required for the initiation of nodule primordian (NP) organogenesis and the colonization of the nodule structures. In the genetic background of the *L. japonicus* root hairless 1 mutant, the nodulation factor dependent formation of NP provides the structural basis for alternative modes NP-associated cortical root hairs, which, in turn, support bacterial invasion (KARAS *et a*l., 2005).

A study was conducted in Turkey to investigate the effects of inoculation and N fertilizer on the yield and components of soybean *Glycine max*. Six soybean cultivars belonging to maturity groups II (Corsoy 79 and Dwight), III (Williams 79 and Maverick) and IV (CF-492 and pyramide) were grown following wheat in an intercropping system in a clay soil without *Bradyrhizobium japonicum* in 2002. A split plot design with inoculation or no inoculation as main plot treatments and cultivars as subplot treatments were used with 3 replications. Inoculation was more effective in enhancing seed yield in late-maturing cultivars, such as CF 492 and Williams 79 (SOGUT, 2005). The symbiotic compatibility of *Sinorhizobium meliloti* [*Ensifer meliloti*, *Rhizobium lelguminosarum*] by trifolii and *R. leguminosarum* by viciae strains with various Lucerne, clover (*Trifolium pratense*), pea and vetch (*Vicia sativa*) cultivars has been investigated. It was established that the genomes of the majority of legume cultivars and Rhizobium strains were compatible for effective symbiosis. However, the clover cultivar Kamaniai and the pea cultivar Zalsviai did not make effective symbiosis. The effective combinations of Rhizobium strain and legume cultivars increased the dry matter yield from 0.39 to 1.23 t. ha^{-1} and of clover by 0.31-0.57 t. ha^{-1}. Nodule formation on pea roots was controlled by the strain genotype by 21 % and by the cultivar genotype by 31 %. On the other hand, nodule formation in vetch was controlled by the strain genotype by 32 % and by the cultivar genotype by only 3 % (LAPINSKAS, 2005).

A broad range of genotypes of *Medicago sativa*, and annual medics including *M. polymorpha,* *M. tornata* and *M. littoralis* were inoculated with strains of *Sinorhizobium meliloti* or *S. mediace* of differing effectiveness for symbiotic N2 fixation sown at 4 field locations. Dry matter production over 2 seasons was strongly related to plant density, which in turn was related to symbiotic effectiveness. Eighteen months after sowing Esperance, Western Australia, Lucerne inoculated with strain WSM922 showed 79 % higher plant density and 43 % more production than control strain CC169. Non- significant differences existed in dry matter production between Lucerne cultivars inoculated with strains WSM922, WSM826 and U45. Across all Lucerne genotypes, inoculation with WSM922 out yielded those inoculated with CC169 by 99 %. The difference in yield between these 2 inoculant strains was 44 %. Results were consistent with those previously obtained under controlled conditions and emphasized the necessity to remain aware of the symbiotic requirements of newly produced cultivars. An analysis of nodule occupancy using PCR-RAPds revealed the dominance of a particular rhizobia strain (WSM922) in un-inoculated plots which had become colonized over 3 seasons. The necessity for separate inoculant species of *Sinorhizobium* in Australia to satisfy the symbiotic requirements of the acid and alkaline groups of medics was reaffirmed (EVAN *et al*., 2005).

A study was conducted for three years in two localities: Cacak (Mojsinje) and Kraljevo (Adrani), in Yugoslavia to evaluate the effects pre-sowing seed inoculation on the yield and quality of lucerne and red clover (*Trifolium pratense*) swards on a acidic soil. Lucerne seeds (cv. Medijana and Slavija) were inoculated with two pH resistant Rhizobium meliloti strains, and red clover (cv. Kolubara), with *R. leguminosarum* (cv. trifoii). The inoculated lucerne and red clover seeds sown on acid soils recorded a significant increase in dry matter yield. The strains used for inoculation proved to be persistent resulting in a significant increase in dry matter yield. The strains used for inoculation proved to be persistent resulting in a significant yield increase in the third year of utilization even in locations with low soil pH value. In general, the symbiotic performances of the chosen Rhizobium strains have justified the selection of strains tolerant of stressful factors, particularly to acidity, and therefore the fuse of such strains in growing perennial legume crops on acid soils. (STEVOVIC *et al*., 2005).

The effect of inoculating nodulating bacteria on nodules formation and biomass yields of different Lucerne (*Medicago sativa*) cultivars was investigated. The results indicated that nodule numbers and percentages were significantly improved by inoculating matched rhizobial strain. Inoculation significantly increased biomass yields and crude protein of Lucerne. The nitrogen contents in the plant roots were not correlated with inoculation. The effects of increasing nodule percentage and biomass yields of inoculating rhizobial on seeds were greater than that of inoculating rhizobial on soil. (HAUNG *et al*., 2005). Increase in importance and successful production of perennial leguminous grasses has been reported from the Tula region, Russia. Use of meadow clover as a fore crop increased quality and yield of winter wheat by 40, and 80-92 % compared with fallow, oats and barley used as fore crops. Decrease in application of organic fertilizers on fallow lands related to high costs and implications of soil fertility. The role of perennial leguminous grasses used in crop rotations to increase soil fertility and crop yield was emphasized (NIKITIN, *et al*., 2003).

Rhizobia induce the formation on specific legumes of new organs, the root nodules, as a result of an elaborated developmental program involving the two partners. In order to contribute to a more global view of the genetics underlying this plant-microbe symbiosis, a genome sequence for genes potentially relevant to symbiosis was determined. It was expressed that 200 of these genes in a variety of environmental conditions were pertinent to symbiosis. Five new genes induced by luteolin have been identified as well as nine new genes induced in mature nitrogen-fixing bacteroids. A bacterial and a plant symbiotic mutant effective in nodule development have been found that is of particular interest (AMPE *et al*., 2003).

The effects of mixed granular rhizobial strains and application of modest amount of nitrogen fertilizer (starter nitrogen fertilizer) on yield and nodulation of five common bean (*Phaseolus vulgaris*) cultivars under bean-sorghum intercropped conditions was investigated for two crop season (1992 and 1993) in Ethiopia. The soil upon which the study was conducted has been noted for its low organic matter content and low nitrogen status. Results showed that inoculation with mixed granular rhizobial inoculant and use of starter nitrogen fertilizer significantly improved both yield and nodulation of common bean cultivars in most of the cases. Some cultivars were noted to be non-responsive to inoculation with mixed granular rhizobia and application of nitrogen fertilizer. Yield and nodulation were found to have significant positive correlation for both crop seasons. For the bean-sorghum intercropped conditions, the use of mixed granular rhizobial inoculant and starter nitrogen fertilizer was found to be indispensable to realize the benefits of biological nitrogen fixation on highly degraded Regosols of the Hararghe Highlands (DABA and HAILE, 2002).

Nodule formulation in the seed inoculation treatments was restricted to the crown region of the root system, whereas soil inoculation enhanced nodulation on the lateral roots. The enhanced lateral root nodulation from placement of the granular inoculant in the seed furrow, compared with the seed applied inoculants, further indicated the poor mobility of rhizobia in the soil when placed on the seed. These lateral formed nodules may be important in supplying fixed N_2 to the plant at a period when the N requirement is at its maximum (STEPHAN *et al*., 2002). Symbiotic N2 fixation in legumes is regulated at all stages of nodule development of the N2 fixation activity till the onset of nodule senescence. Symbiotic N2 fixation starts after nodule formation, generally reaches a peak at early pod filling and declines during the late reproductive phase (GAR *et al*., 2002). ABBAS *et al*. (2001) evaluated intercropping of *Leucaena* and *Sesbania* with some annual grasses (barley, pearl millet, and Rhodes rye and Sudan grasses) under semi-arid desert conditions in a series of field trials. Inoculation of specific rhizobia for legumes and a composite of associative diazotrophs for non legumes were applied in the presence or absence of N fertilizers. Rhizobium inoculation was indispensable, and supported better growth legumes, which extended to the neighboring non-legumes. Associative diazotrophs improved biomass and N yields of non-legumes, particularly in the presence of moderate N fertilization for winter barley and rye grass and of higher doses of 300 kg N ha^{-1} for summer pearl millet and Sudan grass. Intercropping improved productivity of non-legumes, in particular barley mixed with *Sesbania* while the calculated N-transfer from legumes to non-legumes ranged from 20 to 70 kg N ha^{-1}.

BENITEZ *et al*. (2001) conducted an experiment on a glay plastic brown soil to assess the effect of the inclusion of *Neonotonia wightii* cv. Glycine and *Maeroptilium atropurpureum* cv Siratro on yield and quality of *Chloris gayana* cv Callide. The growth dynamics, dry matter yield, crude protein and organic matter digestibility of the pure or associated species were measured. Results showed a higher grass quality with inclusion of legume as well as an increase in the dry matter, crude protein and yield of the association compared to the pure grass. It was concluded that inclusion of these legumes improved the quality and yield of grassland. Nitrogen fertilization of legumes is usually associated with a reduction in nodulation and N_2 fixation but there is variation in this response, depending on the host–*Rhizobium* species association. Legumes with slow nodulation development and or legumes and/or low N_2 fixation levels may benefit from moderate N fertilization (PHILIPEE *et al*., 2001). Rhizobial inoculation of legume seed was well studied and exploitation of this beneficial N_2–fixing root-nodule symbiosis represented a hallmark of successfully applied agricultural microbiology (JATISH *et al.*, 2000).

2.4 Effect of legumes on soil productivity

Soils are generally deficient in nutrients, a situation that has negative implications on crop and livestock intensification and hence on food security. The exclusive use of inorganic fertilizers to bring about increased crop production sometimes has negative impact on the soil. On the other hand, the adoption of fallow systems to rejuvenate the soils is becoming even impossible as a result of high population pressures, urbanization and industrialization. Alternative strategies for improving on and sustaining food production are therefore required. Organic manure availability is low since livestock population is low, and intensification without appropriate interventions could even worsen existing soil problems. The adoption of alley cropping is limited by the fact that its practice is restricted to the wetter regions. Modified forms of green manure, which involve the use of food/cash crops that farmers will accept and protect, if needed, are therefore suggested. Pigeon pea (*Cajanus cajan*) is persistent and, if intercropped with other crops, serves as a cover crop that will protect the soil against adverse weather conditions during the dry season (ODION *et al*., 2007). This legume crop can take up nutrients from the depth of the soil profile and also serve as green manure at the beginning of the next growing season. Clipping of dual-purpose cowpea at 7-8 weeks after planting (WAP) gives over one ton of fodder, that is available for green manuring. Over-seeded legumes can also be thinned down and the fodder so derived incorporated into the soil. Incorporated cowpea (*Vigna unguiculata*) fodder can improve soil fertility, and thus reduce the need for chemical fertilizer; while also controlling obnoxious weeds. Cowpea fodder can be fed to livestock, to produce rich organic manure for use by the farmer. Also, clipped lablab (*Lablab purpureus*), which has been observed to have good nutritive value as animal feed, could be used. In addition, other legumes such as soybean (*Glycine max*), which have been found to produce up to 20-89 kg N ha^{-1} in 42-63 days, can be grown as companion crops with cereals and can later be incorporated to supply N, among other nutrients. The farmer thus becomes a producer of his own N, instead of entirely relying on imported inorganic fertilizers.

The most widespread and consistent effect of legumes is to improve the N economy of soil through N2 fixation. The N-balance of legume-cereal sequence in most cases is more positive than that of a cereal-cereal sequence in the same soil. Nitrogen fertility inevitably accompanies intensive agriculture and, at least, reduces the requirements of inputs of fertilizer N (MUHAMMAD *et al*., 2003). BERGKVIST (2003b) compared the response of grain yield to fertilizer N in a winter wheat-white clover intercropping system with the response in wheat alone. Clover was under sown in spring barley and remained established in two consecutive crops of wheat in two filed experiments. Clover reduced grain yield in the first crop of wheat and increased it in the second. There was more inorganic N in the soil and a higher concentration of N in the grains in the intercropping system. The grain and N yield response to fertilizer N was equal or less with intercropped than with wheat alone. The reduction of clover biomass with herbicide increased grain yields of the first crop of wheat without reducing the clover biomass or the positive residual effect in the second wheat crop. It was concluded that in order to produce large grain yields competition from clover needed to be kept small when wheat was at the tillering stage.

Forage legumes are important sources of protein and do not require nitrogen fertilization for higher yields. These plants have a symbiosis (partnership) with specific bacteria called rhizobia. The specific rhizobia species are often not present in soil in sufficient numbers to be effective in nodulating the roots of a specific forage legume. Inoculating the legume seed with proper rhizobia at planting introduces the necessary number of bacteria into the soil. As the seedling develops, the bacteria and the root cells multiply until, eventually a nodule (gall-like structure) forms on the root. The nodule is the actual site of nitrogen fixation. Vetch crop fixed 80 to 140 pounds nitrogen per acre per year while cowpeas fixed 44 to 132 pounds nitrogen per acre per year. A sufficient number of effective rhizobia for a given legume may not exist in the soil unless the specific legume has been grown in the previous two and three years and it nodulated well. Well nodulated legumes contain large amounts of protein, calcium, magnesium and other essential elements. Because of this improved nutrition, seedling legumes have improved winter hardiness and better yield the next year. Specific Rhizobium species for cowpeas and vetch is *Leguminosarum* (JOHN, 2002).

Increasing use of herbaceous legumes such as Mucuna (*Mucuna pruriens* var. *utilis*) and lablab (*Lablab purpureus*) in the derived savannas of West Africa can be attributed to their potential to fix atmospheric nitrogen (N2). The effects of management practices on N2 fixation in Mucuna and lablab were examined using 15N isotope dilution technique. Dry matter yield of both legumes at 12 weeks was two to five times more *in situ* mulch (IM) than live mulch (LM) systems. Land Equivalent Ratios, however, showed 8 to 30 % more efficient utilization of resources required for biomass production under LM than IM systems. Live mulching reduced nodule numbers in the legumes by one third compared to values in the IM systems. Similarly, nodule mass was reduced by 34 to 58 % under LM compared to the IM systems. The proportion of fixed N2 in the legumes was 18 % higher in LM than IM systems. Except for inoculated Mucuna, the amounts of N fixed by both legumes were greater in IM than LM systems. Rhizobia inoculation of the legumes did not significantly increase N2 fixation compared to un-inoculated plots. Application of N fertilizer reduced N2 fixed in the legumes by 36 to 51 % compared to inoculated or un-inoculated systems. The implications of cover cropping, N fertilizer application, and rhizobia inoculation on N contributions of legumes into tropical low-input systems in Nigeria were considered very important (IBEWIRO *et al*., 2002).

Nitrogen fertilization of legumes is usually associated with a reduction in nodulation and N_2 fixation but there is variation in this response depending on he host – *Rhizobium* species association. Legumes with slow nodulation development and or legumes and/or low N_2 fixation levels may benefits from moderate N fertilization (PHILIPPE *et al*., 2001).

Competitiveness of *Brachiaria decumbens* cv. Basilisk and *Stylosanthes guianensis cv. Minerao* was investigated in a pot experiment either without root restriction or by separating their root systems with a fine mesh or a solid barrier in the presence or absence of mycorrhiza (*Glomus clarum*). Nitrogen transfer between the legume and the grass was assessed with the 15N isotope dilution technique using a relatively stable 15N-enriched soil derived from a long-term labeling experiment. During establishment, legume development was severely restricted by competition from the grass in pots without a root barrier. However, as the system became N limited, the legume became dominant due to its access to atmospheric N_2 which contributed over 80 % of the legume N requirements. *Stylosanthes guianensis* was highly mycotrophic and inoculation with mycorrhiza favored rapid establishment even in the treatments with no root barrier. Only in the presence of root barriers, either a mesh or a complete compartment separation was the proportion of N derived from N_2 fixation positively affected by the presence of the fungus. No significant direct below-ground N transfer from legume to grass was observed during the lifetime of the legume suggesting that the legume maintains a highly efficient recycling under N-limited conditions. However, after cutting the shoot at ground level, the grass assimilated significant amounts of N derived from decaying legume roots. The main pathway of below-ground N transfer from *S. guianensis* to associated *B. decumbens* occurred via decomposing roots rather than via root exudates or direct mycorrhizal hyphae transfer (TRANNIN *et al.,* 2000).

2.5 Use of fertilizer for fodder and legumes

Appropriate use of fertilizer is the most essential during fodder production when these are grown alone or in combination with legumes so that their quantity and quality meets the established standards. Inter-seeding of non-traditional cool-season legumes into Bermuda grass (Cynodon dactylon) was evaluated as an approach to increase the quality and duration of forage production and replacing a portion of the required N fertilizer. The effects of inter-seeding either grass pea (*Lathyrus sativa* 'AC-Greenfix') or lentil (*Lens culinaris* Med. 'Indianhead') with N fertilizer rates of 0, 45, or 90 kg ha^{-1} N were assessed. All plots received 60 kg P_20_5 ha^{-1} in early March. The legume and fertilizer treatments were imposed in mid-March during 2001, 2002, and 2003. Forage samples were clipped from 0.25 m^{-2} quadrants on five sampling dates between 1 May and 15 July each year. Yield, N concentration, species composition, and in vitro digestible dry matter (IVDDM) were determined. Year, sampling date, and treatment showed significant ($P<0.05$) effects, as did the two-way interactions between all three factors. Total end-of-season standing dry matter of Bermuda grass and grass pea was 5550+or-423 (SEM) kg ha^{-1}, which was similar to biomass production with 45 kg ha^{-1} N (5305+or-570 kg ha^{-1}) and less than that produced with 90 kg ha^{-1} N (7785+or-725 kg ha^{-1}). Forage N and IVDDM concentrations for the grass pea treatment were 34 and 6 % higher than for Bermuda grass, but N and IVDDM concentrations of the forage mixture were intermediate between the higher N rates. Although additional studies were needed to optimize management for inter-seeded legumes but it was concluded that this practice could improve the quality and duration of Bermuda grass forage production (RAO *et al*., 2007).

Nitrogen fixation is relatively low in response to high inorganic N supply that was estimated less than 20 % of the harvested N in alfalfa. Where forage yield was high and inorganic N supply was low, N_2 fixation by alfalfa appeared to be greater than 400 kg N ha^{-1}. Therefore, the use of Barsin – wide means of N_2 fixation is not appropriate for analysis of N sources and cycling within sub watersheds (RUSELLI *et al.,* 2004). Biological nitrogen fixation occurs mainly through symbiotic association of legumes and some woody species with certain N2-fixing microorganisms that convert elemental nitrogen into ammonia (SHIFERAW *et al*., 2004).

The optimum management intensity of grassland swards is mainly judged by dry matter (DM) and protein-yields. The efficiency of the applied nitrogen and of technical equipment has to be considered for the sustainable use of grassland system. In an experiment in Aulendorf, South Germany, 9 alternative grassland swards (late and early varieties of *Lolium perenne, Trifolium repens and Medicago sativa*) with different cutting frequencies (4 to 6 per year) and different date of first harvest of primary growth were compared. These swards were compared and judged on the basis of yields of dry matter, crude protein and net energy. Moreover, N-use efficiency and economic parameters like machinery costs and fertilization were also determined. After 2 experimental years, the results of the on-going experiment showed that legume-based grassland swards have higher N efficiency than grass-based swards. On average 50 kg DM kg^{-1} N for grass-based swards compared with 130 for white clover and more than 200 kg DM kg^{-1} N for Lucerne was recorded. Dry matter yields were the highest in Lucerne variants with 4 cuts. Net-energy consumption was the highest in grass-based swards with a high cutting frequency of 6 cuts. The results suggested that the optimum intensity of grassland use in South-Germany depended on the reference factors. Highest quality in grassland growth may be obtained with high cutting frequency and highest N-efficiency will be achieved by 4 cuts. Sustainable farming systems should be based on legumes (ELESSESSER, 2004).

Acid soils, with an expressed calcium deficiency, account for 60 % of arable soils in the Republic of Serbia that is a regular cause of low crop yields. Two cultivars of Lucerne 9NS-Medijana ZMS V, NS-Slavija) and one of red clover (Kolubara) were studied, using soil liming and pre-sowing seed inoculation. Liming resulted in significantly higher yields of Lucerne in the sowing year and pre-sowing seed inoculation also resulted in significantly higher yields, particularly in the variants with liming. No significant differences in the yield of red clover were observed when comparing liming and inoculation and inoculation itself. These treatments were found significant to increase the yields of plants on less suitable acid soils (STEVOVIC *et al*., 2004).

The effectiveness of fertilizers in increasing forage dry matter yield (DMY) and economic return is dependent upon the levels of nutrients in soil, climatic conditions, source, rate and method of fertilizer application, soil type and forage species. Grass forages respond very well to nitrogen (N) fertilizer on most soils in western Canada and DMY increases from N application are much greater in moist areas than in dry areas. Average increase in DMY was 0.50, 0.96, 1.33 and 2.25

tones ha-1 (50 kg N ha^{-1}) in brown, dark brown, gray luvisolic and black soil zones, respectively; and it was 1.60, 1.46 and 1.05 tones ha^{-1} (84 kg N ha^{-1}) for the intermediate wheatgrass, smooth brome grass, created wheatgrass and Russian wildrye grass, respectively. Protein content in grass forage can be improved with N application, but the risks of residual N accumulation and downward movement of nitrate-N (NO_3-N) in soil, and high NO3-N levels in the forage increases when N is applied in excess of crop requirements. A large initial one-time application of N produces less sustained production of forage than the equivalent amount of N applied annually in split doses. Splitting annual application into two or three parts may not necessarily increase DMY, but it tends to redistribute forage production in a longer portion of the growing season. Where early spine establishment is practiced, rates of these fertilizers should be increased to compensate for lower efficiency (MALHI et al., 2004).

BURLE *et al*. (2003) conducted a grazing trial to quantify N cycling in degraded *Leucaena leucocephala* (*Leucaena*)-*Brachiaria decumbens* (signal grass) pastures grown on an acid, infertile, podzolic soil in South-east Queensland. Nitrogen accumulation and cycling in *Leucaena* signal grass pastures were evaluated for 9 weeks until all of the *Leucaena* on offer (mean 600 kg edible dry matter (EDM)/ha, 28 % of total pasture EDM) was consumed. Nitrogen pools in the grass, *Leucaena*, soil, cattle live weight, feces and urine were estimated. Grazing was found to cycle 65 % of N on offer in pasture herbage. However, due to the effect of the plant nutrient imbalances described above, biological N fixation by *Leucaena* contributed only 15 kg/ha N to the pasture system over the 9-month re-growth period of which 13 kg ha^{-1} N was cycled. Cattle retained 1.8 kg/ha N (8 % of total N consumed) in body tissue and the remainder was excreted in dung and urine in approximately equal proportions. Mineral soil N concentrations did not change significantly (3.5 kg ha^{-1} N) over the trail period.

LI *et al*. (2003) studied a root barrier in which belowground partitions were used to determine the contribution of inter-specific root interactions to crop nutrient uptake. Nitrogen uptake by intercropped faba bean was higher than (no P fertilizer) or similar to (33 kg P ha^{-1} of P fertilizer) that by sole faba bean during the early growth stages (first to third sampling) of faba bean and was similar to (no P fertilizer) or higher than (33 kg P ha^{-1} of P fertilizer) that of sole faba bean at maturity. Nitrogen uptake by intercropped maize did not differ from sole maize maturity except when P fertilizer was applied. Intermingling of maize and faba bean roots increased N uptake of both crop species by about 20 % compared with complete or partial separation of the root systems. Intercropping also led to some improvement in P nutrition of both crop species. Maize shoot P concentrations were similar to those of sole maize during early growth stages and became progressively higher until they were significantly higher than sole maize at maturity. Intercropping increased shoot P concentration in faba bean at the flowering stage and in maize at maturity, and increased P uptake by both plant species at maturity. Phosphorus uptake by faba bean with root intermingling (no root partition) was 28 and 11 % higher than with complete (plastic sheet) and partial (400 mesh nylon net) root barriers, respectively. Maize showed similar trends, with corresponding P uptake values of 29 and 17 %. The P and K nutrition was not affected by the presence of rot barriers unlike N.

The overall input of nitrogen into global agriculture for food and feed production is estimated to be approximately 120 million tones/ year. Biological nitrogen fixation (BNF) accounts for 40 while 80 million tones/ year is accounted for by N-fertilizer production from ammonia. In cereal production, fertilizer use dominates. If cereals were able to "fix" their own nitrogen the situation could be very different. However, this is unlikely to be realized in the near future unless the technological complexities of inducing BNF in non-legume crops can be overcome. Traditionally, work in this area has tended to focus on the transfer of legume-like BNF characteristics to non-legumes and so far commercially, this strategy has not been successful. More promising may work that has purported to show that some species of endophytic bacteria living within non-legumes (e.g. grasses) can supply nitrogen to their host plants. Many of the current environmental concerns about the use of mineral fertilizers can also be applied to the use of N-inoculants. It was concluded that if N-inoculants for non-legume crops are developed then these will have to be at least as convenient, safe, reliable and effective in growing crops for increasing global population as N-fertilizers are today (GODDARD *et al*., 2003)

2.6 Quality and digestibility of fodders

Quality of fodders is as important as their quantitative production because the importance lies not only in the animal health but also human diet and safety who will ultimately be utilizing livestock products. BERDAHL *et al.* (2004) conducted a study to compare nutritive quality of four cool-season grass monocultures and their respective binary grass-alfalfa (*Medicago sativa*) mixtures receiving annual applications of 0 and 50 kg N ha^{-1} and cut in mid-June when alfalfa was at early-bloom or in mid-July at late-bloom to early-pod stage of plant development. Reliant and Manska intermediate wheatgrass (*Thinopyrum intermedium*) Lincoln, smooth bromeyrass (*Bromus inermis*) and Nordan crested wheatgrass *Agropyron desertorum*) were seeded in monoculture and in binary mixtures with Rangelander alfalfa (*M.sativa* subsp.*varia* (Martyn Areang)} on a parshall fine sandy loam (coarse-loamy, mixed superactive, frigid, pachic Haplustolls). Nitrogen fertility level did not affect IVDMD, which was adequate for grass monocultures and grass-alfalfa mixtures at both the mid-June and mid July cutting dates. Feasibility of deferring hay harvest of grass-legume mixtures until mid-July in the Northern Great Plains is dependent on maintaining the legume component in the mixture, which increased CP from 71 g kg^{-1} for grass monocultures to 109 g kg^{-1} for grass-alfalfa mixtures when no supplemental nitrogen fertilizer was used.

The forage yield and quality of common vetch (*Vicia sativa*), grass pea (*Lathyrus sativus*) and barley grown alone and as mixtures were investigated in field experiments conducted at the Faculty of Agriculture, Gaziosmanpasa University in Tokat, Turkey, in 2001 and 2002. The highest green forage (39.65 t ha^{-1}) and dry matter yields (10.71 t ha^{-1}) were obtained from the mixture including 25 % common vetch and 75 % barley, while the highest total seed yield (2.95 t ha^{-1}) was obtained from the mixture including 25 % grass pea and 75 % barley. In addition, the highest crude protein yield (1.53 t ha^{-1}) was achieved with the 50 % grass pea and 50 % barley mixture. The mean relative yield total values of dry matter and total seed yields were 1.78 and 1.79, respectively. In conclusion, the mixture comprising 25 % common vetch or grass pea and 75 % barley was recommended for green forage, dry matter and seed yield. The 50 % grass pea and 50 % barley mixture produced the highest crude protein yield and therefore, was recommended for this region (KARADAG and BUYUKBURC, 2003).

INAM-UL-HAQ and JAKHRO (2001) reported that symbiotic fixation increases the protein contents of the plant. Symbiotic bacteria used energy gained by (20 kg CH_2O) for fixing one kg nitrogen. Nitrogen fertilizers increased the growth of legume crops but considerably reduce the amount of nitrogen fixed. Forage legumes fix more nitrogen than grain legumes and they add more nitrogen to the soil if they are grazed rather than harvesting. Cowpeas and vetch fixed 90 and 80 lbs $acre^{-1}$ yr^{-1} respectively. The Rhizobium inoculation for cow peas and vetch is *Rhizobium leguminosarum*. Generally, extent of digestion of legume NDF was lower than that of grass because of lower cell content and higher lignifications of the farmer (KAISER and COMBS, 1989).

2.7 Silage production

SENGUL (2003) conducted an experiment in order to investigate hay yield and nitrogen harvest through tall wheat grass (*Agropyron eleongatum*), creasted wheat grass (*Agropyron cristatum*), and smooth brome grass (*Bromus inermis*) mixtures with sainfoin (*Onobrychis sativa*) and alfa-alfa (*Medicago sativa*) for three years under dry land conditions in Erzurum, Turkey. The hay yield, nitrogen harvest, protein concentration, and land equivalent ratio (LER) in the mixtures were investigated under fertilized and unfertilized conditions. The mixtures were sown with legumes in crossing lines. Seeding rates were 8.0 g m^{-2} in Sainfoin, 4.0 g m^{-2} in alfalfa and 3.0 g m^{-2} in grasses, 2.2 g m^{-2} in autumn and 5.0 g $m.^{-2}$ Nitrogen was applied in spring to each sub plot. The contribution of the mixtures of alfalfa and sainfoin with grasses to the hay yield differed between years. Legume mixtures with one or two grass species gave higher dry matter yield than the single crop. Use of fertilizers increased the hay yield, which was statistically significant ($P<0.01$) in all combinations. Under fertilized and unfertilized conditions, the crop yield was higher in the presence of one or two grass species than mixture of grasses with alfalfa. The superiority of the mixtures was also reflected in their large N harvests compared to pure stands of sainfoin or alfalfa and pure grasses. Further more, the protein concentration of the hay from the mixtures was higher than that of *B.inermis*, *A. elongatum* or *Agropyron cristatum* but lower than *M. sativa*.

AZIM *et al*. (2000) prepared four different types of silages from: (I) maize alone (ii) maize + cowpea (85:15) (iii) maize + cowpea (70:30) (IV) maize supplemented with 2.5 % urea. After 60 days of ensiling *in situ,* DMD was maximum (61.8 %) for maize + cowpea (70:30) silage followed by 59.3 % for maize + cowpea (85:15) silage, 57.5 % for maize silage supplemented with 2.5 % urea and 55.7 % for maize silage alone. The digestibility of NDF and hemicellulose declined non-linearly with increasing maturing stage. *In situ* DMD of corn silage was lower than silage of corn and cowpeas. The reason of higher DM digestibility of corn + cowpeas silage was that legumes have higher digestibility than grasses.

CHAPTER 3

MATERIAL AND METHODS

The study comprised of two field experiments conducted under rain fed conditions for two years (2005-2006 to 2006-2007) in the experimental area of Rangeland Research Program, National Agriculture Research Center (NARC) Islamabad, Pakistan (Altitude=518 m longitude= 73° 08'E & latitude= 33° 42'N). The experimental site is situated in sub-humid, sub-tropical region. There were two separate experiments of the study.

3.1 Experiment No. 1: Assessment of inoculation effect on grass-legumes intercropping

3.1.1 Treatments

T1= 100 % grass
T2= 100 % seasonal legumes
T3= Grass + 33 % legumes
T4= Grass + 50 % legumes
T5= Grass + 67 % legumes
T6= T2 + inoculation
T7= T3+ inoculation
T8= T4+ inoculation
T9= T5+ inoculation

3.1.2 Methodology

An appropriate site was selected, leveled and soil samples were obtained from 0-15 cm soil depth. The sample was prepared and analyzed for soil pH, ECe, texture and fertility parameters (Table 3.1). *Panicum maximum* grass was planted in 2005 as perennial fodder. After its establishment, winter legume (*Vicia sativa* commonly known as vetch) and summer legume (*Vigna unguiculata* commonly known as cow peas) were sown as inter crop in the established grass but after it's harvesting. Summer legume followed winter legume in the next year. Two lines of legumes with four lines of grass were grown to establish T3 (33 % legumes) while there were three lines of each in case of T4 (50 % legumes). In case of T5, four lines of legumes were grown with two lines of grass to obtain the share of 67 % of the former. Seed of legumes was inoculated (see a separate section) before sowing to obtain T6 to T9. The experiment was conducted under rain fed conditions and no irrigations were applied. There was also no fertilizer application either to grass or legumes. Grass was harvested at panicle stage whereas legumes were harvested at 100 % flowering. Fresh and dry matter yield, plant height and tillers were recorded. However, plant samples (grass as well as legumes) were obtained to assess the fodder quality when there was 50 % flowering of legumes. Soil samples were obtained from each treatment separately after harvesting of fodder crops and analyzed for different parameters.

3.2 Experiment No. 2: Evaluation of fertilizer effect on biomass production of grass-legumes intercropping

3.2.1 Treatments

T1= Grass 100 %
T2= Seasonal legume 100 %
T3= Grass + 33 % legumes
T4= Grass + 50 % legumes
T5= Grass + 67 % legumes
T6= T1+ NPK fertilizer
T7= T2+ NPK fertilizer
T8= T3 +NPK fertilizer
T9= T4 +NPK fertilizer
T10= T5 +NPK fertilizer

3.2.2 Methodology

Methodology for this experiment was almost the same as described under experiment 1. However, fertilizer as a basal dose was applied to the treatments T6 to T10 at the rates of 25, 75 and 50 kg ha^{-1} (N, P_2O_5 and K_2O) as urea, single superposphate and sulphate of potash respectively.

3.3 Experimental Design

Both the experiments were laid out using randomized complete block designs (RCBD) with 4 replications. Main plot and sub-plot sizes were 910 recorded and 15 m^2 respectively with 1m path between each sub-plot.

3.4 Preparation of inoculant and inoculation of legume seeds

Two 250 flasks containing 100 ml of YM broth with were inoculated with *Rhizobium leguminosarum* at $26^{o}C$ – $28^{o}C$ and was shaken well with the laboratory shaker. Broth culture sample was taken after 7 days and tested for purity by Grain Stain. The pH of a broth culture was found as alkaline that was verified by adding one drop of bramthymol solution (0.07 to 1 ml of broth culture). The broth culture was turned blue and introduced into the peat under strict aseptic conditions. A small area close to the corner of the inoculant bag was sterilized with a cotton swab wet with 70 % alcohol. A 50 ml sterile syringe fitted with an 18 G needle was used to withdraw 40 ml broth culture from its flask. The bag was punctured in the sterilized area and the needle was horizontally inserted to avoid piercing the opposite wall of the bag aiming it towards the center of the bag and then inoculum was injected. The punctured was sealed with plastic tape for labeling the treatment numbers and date of preparations. The bag was massaged until all the inoculum was uniformly absorbed by peat for one minute then it was incubated at $26^{o}C$ – $28^{o}C$ for two weeks to mature the peat inoculant. Two 250 ml batches of YM broth were inoculated with *Rhizobium leguminosarum* after one week initiation of the peat culture and then incubated at $26^{o}C$ – $28^{o}C$ on the shaker for 7 days. The broth culture was kept in the refrigerator until maximum turbidity had reached and was be used as inoculum in this study. Peat inoculant was mixed with 5 percent methyl cellulose (Celeofas A) as an adhesive to form slurry that was coated on the seeds of legume crops during inoculation.

3.5 Cultural practices

3.5.1 Cultural practices for grass

The land was well prepared by plowing and planking after leveling. The grass *Panicum maximum* var. Tanzania tufts were planted during the first week of July at the onset of monsoon season as perennial grass. Plant to plant and row to row distance was kept as 50 cm. A basal dose of fertilizer (25 kg N ha^{-1} 75 kg P_2O_5 and 50 kg K_2O ha^{-1}) was applied at the time of sowing in the second experiment, while no fertilizer was used in the first experiment. Hoeing was done twice after the sowing of legumes as inter-crop. The grass was harvested at the panicle stage. No irrigation was provided and fodder production totally depended on rains (Table 3.3)

3.5.2 Cultural practices for legumes

Line sowing was done with the help of manual drill for *Vigna unguiculata* var. P-518 as summer legume and *Vicia sativa* as winter legume. The seeds of *Vigna unguiculata* and *Vicia sativa* were drilled with a seed rate of 90 and 75 kg ha^{-1} respectively having row to row distance 50cm. The legumes were harvested at 100% flowering.

3.6 Data collection

Data were collected for the following parameters.

3.6.1 Growth and yield parameters

3.6.1.1 Number of tillers per plant

Number of tillers of grass was taken at the panicle stage in different treatments. Number of tillers of randomly selected 5 plants from each treatment was recorded and mean was calculated.

3.6.1.2 Plant height

The height (cm) of 5 plants was recorded at random from the ground to the apex of the plants in each plot and then average was computed. This procedure was adopted for both grass and legumes.

3.6.1.3 Fresh biomass

Fresh biomass (t ha^{-1}) was collected in each plot of grass and legumes. The grass was harvested at panicle stage while legumes were harvested at 100 % flowering. All the plants in one square meter were clipped close to ground level. Three quadrates were harvested randomly for fresh biomass. The data were calculated on t.ha^{-1} basis.

3.6.1.4 Dry matter yield

The fresh samples were oven dried to a constant temperature at 70^{o}C for 72 hours. The dry samples were weighed and dry matter yield (t ha^{-1}) was recorded.

3.6.1.5 Number of nodules per plant

The nodules of 5 plants of legume crops form each plot was counted by uprooting the plants. Effective number of root nodules was counted by matching the color (pink) of the nodules. The effective number of nodules was calculated on the average basis.

3.7 Plant analysis and fodder quality

3.7.1 Moisture and dry matter contents

The moisture contents of plant samples were determined by drying the sample in an oven at 105C to a constant mass. The loss of weight after drying was regarded as the moisture that was converted to percentage. Practically, 4.0 to 5.0 g of grinded sample was weighed accurately in to a clean weighed aluminum basin with lid partially covered and placed in the oven the temperature of which was set at 105^{o} C. The loss of weight was determined after attaining a constant weight. Samples were stored in the desiccator for desiccation and cooling down before weighing (AOAC, 1994). Moisture percentage and dry matter content were computed using the following formulae.

$$\text{Moisture (\%)} = \frac{W2 - W3}{\text{Sample fresh weight (W2-W1)}} \times 100$$

Dry matter (%) = 100- moisture percentage

Where

W1 = weight of basin

W2 = weight of basin + sample weight (before drying)

W3 = weight of basin + sample weight (after drying)

3.7.2 Crude protein (CP)

Nitrogen concentration of grass and legume plants was determined by grinding the plant material, its digestion and distillation by micro-Kjeldhal method (AOAC, 1994). Ten (10) grams of soil was added in 30 ml of concentrated H_2SO_4 and 10 grams of digestion mixture (K_2 SO_4: Fe SO_4: Cu SO_4 = 10: 1: 0.5) and then digesting the material using Kjeldahl's digestion tubes, cooled and volume was made to 250 ml. An aliquot of 10 ml was taken from it for distillation of ammonia, into a receiver containing 4 % boric acid solution and mixed indicator (bromocresol green and methyl red). Sodium hydroxide was added to the distillation flask to make the contents alkaline. After distillation, the material in the receiver was titrated against standard N/10 H_2SO_4 by Gunning and Hibbard's method of H_2SO_4 digestion and distillation with micro Kjeldahl's apparatus. Crude proteins were calculated by using the following formula.

$$\text{Crude protein (as fed)} = \frac{(V1-V2)}{1000\ W} \quad N \times 14 \times 6.25 \times 100$$

Where

V1 = Volume of H_2SO_4 used in titration for the test sample (in ml)

V2 = Volume of H_2SO_4 used in titration for the blank (in ml)

N = Normality of standardized H_2SO_4

W = Sample weight

The above calculation was adjusted to dry matter (DM) basis by the following computation

$$\text{Per cent crude protein (DM)} = \frac{\text{\% crude protein as fed}}{\text{\% dry matter of sample}} \times 100$$

3.7.3 Ethere extract

Two to four g of moisture free sample was weighed in to a clear previously dried extraction thimble that was plugged with absorbent cotton wool. The thimble was placed in an extractor and fixed under the condenser of the extraction apparatus. Water and heater were turned on for 10 hours at a rate of condensation at 3-4 drops/sec. The thimble was removed from the extractor and continued the process to recover the solvent for future use. The extract was transferred in to a tarred evaporating basin with ether washings. The contents were evaporated to the dryness on water bath and the basin was placed in oven at 105°C for 2 hours, then cooled in desicator for 30 minutes and weighed (Harris *et al.,* 1972). Calculations were made according to the formulas under.

$$\text{\% Ether extract (DM)} = \frac{\text{weight of ether extract}}{\text{Sample weight}} \times 100$$

3.7.4 Crude fiber (CF)

Crude fiber is defined as the organic residue that remains after burning (taken to be as digested) first with a dilute acid solution and then a dilute alkali solution. A sample (1.5 to 2.0 g) of a moisture free grinded and ether extract fodder material was put in tall farm beaker, 200 ml boiling dilute H_2SO_4 was added, digested for 30 minutes on crude fiber extraction apparatus and filtered through sintered glass Buckner funnel with the aid of suction air pump. The material was transferred in to tall farm beaker again, 200 ml boiling dilute NaOH was added, digested for 30 minutes, filtered through sintered glass Buckner funnel with the aid of suction air pump and ignited in muffle furnace at 600^{o}C for 30 minutes. Content were cooled in desiccator for 1 hour and weighed (Harris *et al.,* 1972). The CF was calculated with the following formulae.

$$\% \text{ crude fiber (as fed)} = \frac{\text{loss in weight ignition}}{\text{Sample weight}} \times 100 - \% \text{ moisture} - \% \text{ ether extract}$$

$$\% \text{ crude fiber (DM)} = \frac{\% \text{ crude fiber (as fed)}}{\% \text{ dry matter of sample}} \times 100$$

3.7.5 Ashes

The organic carbon-free substance which remains at all temperature is called ash. Empty clean crucible was weighed, 2-4 g of sample was added into the crucibles, weighed again and by difference weight of samples were calculated. The crucibles (with samples) were placed in the muffle furnace; the samples were ignited at 600^{o}C for 4 hours. Muffle furnace was switched off, cooled down to 200-300^{o}C, crucibles were transferred to the descicator for one hour to cool down at room temperature. Crucibles were weighed. The ash samples were kept for mineral determination. Ash percentage was calculated by using the following formulae (AOAC, 1994)

$$\% \text{ Ash (as fed)} = \frac{\text{Weight of ash}}{\text{Weight of samples}} \times 100$$

$$\% \text{ Ash (DM)} = \frac{\% \text{ Ash (as fed basis)}}{\% \text{ dry matter of sample}} \times 100$$

3.7.6 Nitrogen-free extract (NFE)

Nitrogen-free extract was determined by difference after the analysis of all the other items in proximate analysis on dry matter percent basis by following equation (Harris *et al.,* 1972).

. % NFE = 100 – (% crude protein + % crude fiber + % ether extract + % Ash)

3.7.7 Total digestible nutrients (TDN)

Total digestible nutrients were calculated by the equation of Wardeh (1981).

% TDN= -26.685 + 1.334(CF) + 6.598 (EE) + 1.423 (NFE) + 0.967 (Pr) – 0.002 $(CF)^2$ – 0.670 $(EE)^2$ – 0.024 (CF) (NFE) – 0.055 (EE) (NFE) – 0.146 (EE) (Pr) + 0.039 $(EE)^2$ (Pr)

3.8 Agro-meteorological data

Meteorological data on rainfall, humidity, pan evaporation, wind speed, sunshine hours and temperature during the study period were obtained from Water Resources Research Institute, NARC to elaborate and understand the experimental results under the light of climatic changes.

3.9 Soil analysis

Soil samples were collected from 0-15 cm before starting the experiment and after harvesting grass and legumes from all the treatment plots.. These samples were air dried ground and passed through 2 mm sieve. Analysis work was carried out in the laboratories of Land Resources Research Program, National Agricultural Research Center Islamabad, Pakistan. Analytical methods of U.S. Salinity Laboratory Staff (1954) were followed or otherwise mentioned. All the calculations were made on oven dried soil weight basis.

3.9.1 Preparation of saturated soil paste and extract

Saturated soil paste was prepared according to Method 2. Saturated soil extract was obtained by vacuum pump (Method 3a).

3.9.2 Particle size analysis

Soil textural analysis was done by Bouyoucos hydrometer technique (MOODIE *et al*., 1959). Dispersion was made with 1 % sodium hexameta phosphate solution and soil texture was determined by using International Textural Triangle.

3.9.3 The pH of saturated soil paste

Soil pH of the saturated paste was determined by pH meter having combination electrode after calibrating with buffer solutions of pH 7.0 and 9.0 (Method 21a).

3.9.4 Electrical conductivity of saturation extract

After calibrating the instrument with 0.01 N KCl, the EC_e was measured with (LF-191 Conduktometer) conductivity meter (Method 4b).

3.9.5 Organic matter

Organic carbon was determined by titrating the sample containing soil, potassium dichromate and sulphuric acid using ferroin indicator (Method 24). Organic matter was determined by applying following formula:

Organic matter in percent = Organic carbon in percent X 1.72

3.9.6 Total nitrogen (%)

Nitrogen was estimated through sulphuric acid digestion. Distillation was made with micro-Kjeldhal method (AOAC, 1994).

3.9.7 Available phosphorus

Oleson's method was followed to determine the available phosphorus contents in the soil using $NaHCO_3$ solution as extracting agent. Standard stock P solution was prepared by dissolving exactly 0.439 g potassium dihydrogen orthophosphate (KH_2PO_4) analytical grade in half liter distilled water. Then 25 ml 7 N H_2SO_4 were added and volume was made one liter to get 100 ppm P standard stock solution. Soil sample of 2.5 g was weighed and 50 ml Oleson's reagent (0.5 M $NaHCO_3$, pH = 8.5) was added and this suspension was shaken for 30 minutes and filtered. Five ml of the filtrate was used to develop color and then reading was noted using Spectrophotometer (TANDON, 2001).

3.9.8 Extractable potash

Soil was saturated with normal NH_4 OAC (pH 7.0). Extraction was made with same solution and extractable (Available) K was determined by Jenway Flame photometer (Method 18)

3.10 Statistical analysis

Data were analyzed using one-way analysis of variance with the help of software package of MSTAT-C Microcomputer program, Version 1.3. A least significant difference (LSD) was applied for multiple comparisons. (BICKER,1991).

Table 3.1: Original soil analysis experimental site

Sr. No	Determinations	Unit	Values
1	pH_s	-	8.4
2	EC_e	dS m^{-1}	0.53
3	Sand	%	61
4	Silt	%	12
5	Clay	%	27
6	Textural class	-	Sandy clay
7	O.M	%	0.53
8	Total N	%	0.037
9	Available P	mg kg^{-1}	4.70
10	Extractable K	mg kg^{-1}	79.6

Table 3.2: Crops, varieties and fertilizers used for different experiments

Date of Harvesting	Crop	Variety	Date of Plantation / sowing
April 25, 2006 September 15, 2006	*Panicum maximum*	Tanzania	July 5, 2005
April 26, 2006	*Vicia sativa* (winter legume)	Common vetch	October 27, 2006
September 15, 2006	*Vigna unguiculata* (summer legume)	Cowpeas P-518	June 25, 2006
April 29, 2007 September 13, 2007	*Panicum maximum*	Tanzania	-
April 28, 2007	*Vicia sativa* (winter legume)	Common vetch	October 22, 2007
September 14, 2007	*Vigna unguiculata* (summer legume)	Cowpeas P-518	June 26, 2007

Table 3.3: Metrological data for the experimental duration

Rainfall (mm)				Wind Speed km day^{-1}			Pan Evaporation mm day^{-1}			Sunshine Hours		
Year	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Month												
January	59	54	0	40	23	27	1.1	1.1	1.6	5.2	5.4	7.5
February	184	23	94	60	29	37	1.5	1.9	1.6	4.7	5.6	5.8
March	75	52	179	35	35	52	2.4	3.3	3.2	7.2	7.0	8.3
April	14	21	3	64	48	51	4.2	3.4	5.2	8	8.2	9.0
May	20	41	58	98	44	80	7.2	4.2	7.1	10.1	9.99	10.1
June	73	62	141	108	61	84	9	5.1	8	9.8	8.7	9.3
July	183	493	335	75	95	57	4.6	8.1	5.3	7.1	10.6	8.4
August	270	312	456	61	87	47	5.2	8	4.1	8.6	8.8	8.1
September	73	13	133.13	52	69	42.81	4.3	6.1	3.61	8	7.3	9.4
October	68	35	0	45	49	33.97	3.4	2.9	3.50	9	8.5	8.8
November	4	15	13.35	46	36	17.31	2.4	2.4	1.78	6.7	8.3	7.1
December	9	124	0	36	36	21.01	1.6	1.4	1.34	7.6	5.4	7.8

Source: Agricultural Meteorological field station at Water Resources Research Institute,NARC, Islamabad

Table 3.4: Temperature and relative humidity data for the experimental period

Temperature °C							Relative Humidity %					
Year	**2005**		**2006**		**2007**		**2005**		**2006**		**2007**	
Month	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**
January	15	3	17	3	19	2	96	64	96	63	92	46
February	16	5	24	8	19	7	95	67	94	51	95	67
March	22	10	24	9	23	9	95	64	87	45	92	58
April	30	12	32	13	33	15	73	38	84	51	71	37
May	33	17	38	21	34	19	54	32	90	74	58	33
June	39	20	37	22	38	23	62	28	90	69	65	43
July	33	23	33	24	34	23	86	70	57	33	88	65
August	33	22	32	23	33	23	89	68	51	28	91	70
September	33	21	33	20	32	20	87	57	58	26	90	62
October	30	14	30	16	31	11	83	39	90	52	81	29
November	24	7	24	9	25	7	84	33	89	55	89	43
December	21	1	18	5	19	3	88	33	92	63	90	49

Source: Agricultural Meteorological field station at Water Resources Research Institute, NARC, Islamabad

CHAPTER 4

RESULTS AND DISCUSSION

Livestock sector is developing in Pakistan and its growth rate is the highest among different components of agriculture. However, scarcity of fodder and the low quality are the major constraints that retard expansion of this profitable and supporting source of income of poor and small farmers as well as landless people in the rural population. The scope of increasing area under fodder crops is not possible because production of cereals and cash crops severely compete with it. The only solution under present situation is to produce more fodder from the presently occupied area. Therefore, increase in biomass of fodder per unit area and intercropping of fodder crops are the only alternatives. Present studies were conducted to accomplish investigations on this very important aspect. Two field experiments with separate objectives and various treatments were conducted.

Experiment No. 1: Assessment of inoculation effect on grass-legumes intercropping

Experiment No. 2: Evaluation of fertilizer effect on biomass production of grass-legumes Intercropping.

The salient results of these experiments are presented and discussed under various sub-titles as under.

4.1 Assessment of inoculation effect on grass-legumes intercropping (Experiment No. 1)

Inoculation is a useful technique to increase population of rhizobia in a soil and resultant nitrogen fixation by legumes. The experiment was conducted to investigate the effect of inoculating *Vicia sativa* and *Vigna unguiculata* (cowpeas) legumes, when these were intercropped with Panicum maximum grass up to the extent of 33, 50 and 67%.

4.1.1 Growth and yield parameters

The plant height, number of tillers, number of nodules, fresh and dry biomass was recorded.

4.1.1.1 Plant height

The growth of grass (*Panicum maximum*) as well as legumes was positively affected when *Vicia sativa* and *Vigna unguiculata* (cowpeas) forage legumes were inoculated (Table 4.1). A significant increase was recorded in plant height of *Vicia sativa* in all the three planting geometries (33, 50, and 67% intercropping). Similar trend was also observed in case of cowpeas. The intercropping of grass and legumes improved the plant height of grass as well as *Vicia sativa* forage legume, whereas the height of cowpeas was suppressed in intercropping treatment but positive effect on grass growth was still persistent. Most of these results were also verified in the second year (2007) of the study.

The better growth of grass when intercropped with legumes could be attributed to the nitrogen fixation by the legumes that became available to the grass as well. The increased nitrogen content of the soil (Table 4.15) as observed after harvesting of crops also supports this logic. The inoculation of legume seeds helped in increasing the bacterial population of the soil which proved helpful in more nitrogen fixation from the air that was translated into better growth of all the plants. The intercropping treatment results revealed a positive behavior and no negative competition existed for water, nutrients and light up to the extent of 67% intercropping. Hence this planting geometry did not alter the situation significantly, rather proved beneficial. TRANNIN *et al*. (2000) reported assimilation of significant amount of nitrogen derived from legume roots after harvesting of the crops. They claimed that nitrogen transfer was via decomposing organic matter of legume rather than roots exudates or direct mycorhizal hyphae. Positive results of inoculation of legume seeds were also supported by JATISH *et al*. (2000), STEPHAN *et al*. (2002), AMPE *et al*. (2003) and KARAS et al. (2005). ABBAS *et al*. (2001) reported better growth of barley, pearl millet as well as Rhodes, rye and Sudan grasses when these were intercropped with legumes. ZHANG and LI (2003) also recorded the positive effect on growth when wheat/maize was intercropped with soybean. They reported a compensatory growth of non-legume species as well when intercropped with soybean. They attributed this effect as the competition - recovery production principle. The improved nutrition of non-legumes especially nitrogen and phosphorus were also found by them when faba bean legume was intercropped.

4.1.1.2 Number of tillers (plant^{-1})

Tillering, if it is possessed as a peculiar plant character, is favored by presence of ample quantity of water, balanced nutrition, aeration, proper reception of light and so many other environmental factors. In the present investigation all other factors were uniformed except space due to intercropping and transfer of fixed N by legumes.

Tillering of grass (*Panicum maximum*) as well as forage legumes *Vicia sativa* and *Vigna unguiculata* (cowpeas) had favorable effect when legumes were sown after seed inoculation (Table 4.2). A significant increase was noted in tillering of *Vicia sativa* in all three planting patterns (33, 50 and 67%). In case of cowpeas, tillering responded a normal behavior. The tillering of grass was increased after every harvest due to its perennial nature. The tillering behavior of cowpeas was suppressed due to intercropping as well as inoculating treatment because of creeping behavior. Most of the results of grass and *Vicia sativa* were also confirmed in second year of the study. Non-significant result was indicated in tillering behavior of cowpeas during second year as well. However, a small increase was observed in intercropped treatments. Similar impact was in case of cowpeas inoculation.

The influence of inoculation on tillering of grass and legumes was very clear indicating that well establishment of rhizobial population not only favored the legumes but also the companion grass. The decomposition of residual organic matter (leaf litter and decay of legume roots after harvest) improved the overall plant nutrition and positively affected the tillering of crops. The legume *Vicia sativa* has an erect growing behavior therefore, did not negatively affect the tillering of grass even when intercropped up to 67%. However, cowpea has a little erect growing behavior and subsequent creeping of the crops decreased its tillers due to space competition. TURK (2000) also recorded less tillering of monoculture barley as well as vetch as compared with intercropping. However, the intercropping ratio in his study was 1:3 due to which there was more plant competition for space and light, whereas in the present study such situation was not created keeping in view the addition of appropriate plant population of legumes in the growing grass that is why the negative effect of intercropping was not observed in case of vetch.

4.1.1.3 Biomass production

The growth of plants can be measured through characters like plant height, tillering, branching and bearing of new leaves etc. These characters are ultimately translated into biomass produced in a field. The fresh biomass (Table 4.3) includes moisture contents while the dry biomass is without water contents (Table 4.4.). Unless water treatments or salinity/sodicity are the investigating factors, there is a little difference in variation pattern between these two parameters. This fact was also found in the present study because wide variations were not found when fresh and dry biomasses were compared. The common finding observed was the increase in weight of fodder biomass of the grass as well as legumes when the later were inoculated (Fig. 1). Positive effect of inoculation was consistent in all the four crops of the study spread over two years. However, biomass increase was more in the later three crops as compared to the first crop that might be due to more rhizobial population established due to inoculation with passage of time. The effect of intercropping of legumes up to the level of 67% was not found negatively affecting the biomass production, although plant population increased. Rather a significant increase in biomass production was recorded than grass alone when legumes were intercropped by 67% (Fig. 2). Intercropping geometry of 50% was also found to be statistically significant in all the four crops except 3rd crop while intercropping of 33% remained significant over monoculture grass during the first year. However, inoculation of legumes and intercropping geometry when coupled together proved more beneficial and caused significant increase in biomass over monocultures of grass or legumes (Fig. 3). The combination of 67% intercropping with inoculation proved the most successful and produced the maximum biomass that was significantly higher than all the other treatments of the experiment. The increases in biomass production due to this treatment was computed as 304, 230, 132, and 60% over grass alone in the first, second, third and fourth crops respectively indicating a decrease of increase quantum with time due to establishment and tillering of grass. The increases were calculated as 101, 151, 165 and 74% over monoculture legumes in case of first, second, 3rd and 4th crops respectively.

Plant growth is positively affected when all the soil, water and environmental factors are favorable and there is no stress like salinity, sodicity, water logging, extreme temperatures and rainfall. No such stresses were given under the planned treatments of the experiment. There was only one possibility that was competition for space, light, water and nutrients due to increased plant population in the shape of intercropping (33, 50 and 67%). Increased population up to 67% as grass- legume intercropping did not prove harmful due to which increased biomass was recorded. This also illustrated that competition of plants did not interrupt growth of each other. Hence, conditions of plant growth remained favorable and resulted in more biomass production. Inoculation of both the legumes *Vicia sativa* and *Vigna unguiculata* proved also useful and its coupling with intercropping further enhanced the total fodder yield of four crops in two years (Fig 1). This may be due to symbiotic nitrogen fixation by establishment of rhizobial population, more elemental nitrogen fixation that was also transmitted to the subsequent grass harvest.

TRANNIN *et al.* (2000) reported significant assimilation of nitrogen by companion crop that was derived from legume roots and decomposition of roots after harvest. It has already been observed (sections 4.1.1.1. and 4.1.1.2) that plant height and tillering increased due to different treatments of this study. An increase in nitrogen content of the soil were also recorded (Table 4.15). So the increase in biomass production was logically expected. The results met this hypothesis. TURK (2000), SLEUGH *et al.* (2000), ODHIAMBO and BOMKAKE (2001), MOHAPATRA *et al*. (2001), ABBAS *et al.* (2001), GUBKINA (2001), KUZEEV (2002), ZIMKOVA *et al.* (2002), DABA and HAILE (2002), SHISANYA (2003), BERGKVIST (2003 a & b), LAUK and LAUK (2003), GIACOMINI *et al.* (2003), KUCHNIDA *et al*. (2003), KURDALI *et al.* (2003), ZHANG and LI (2003), KIRILOV *et al*. (2003), KARADAG (2004), GEHERMAN and PAROL (2004), HOFFMANN *et al*. (2004) MALIKOV (2004), TAMM and TAMM (2005), SUDESH *et al.* (2006) and LI-LONG *et al.* (2007) also recorded higher dry matter yield when different leguminous crops were intercropped with non leguminous crops or grasses. LI-LONG *et al*. (2007) found an increased growth of a second crop species grown in alternate rows that led to large yield increments on phosphorus-deficient soils. In 4 years of field experiments, maize (Z*ea mays*) over yielded by 43 % and faba bean (*Vicia faba*) over yielded by 26 % when intercropped on a low-phosphorus but high-nitrogen soil. More yield of maize was attributable to below-ground interactions between faba bean and maize in another field experiment. Intercropping with faba bean improved maize grain yield and above-ground biomass significantly compared with maize grown with wheat, at lower rates of P fertilizer application.

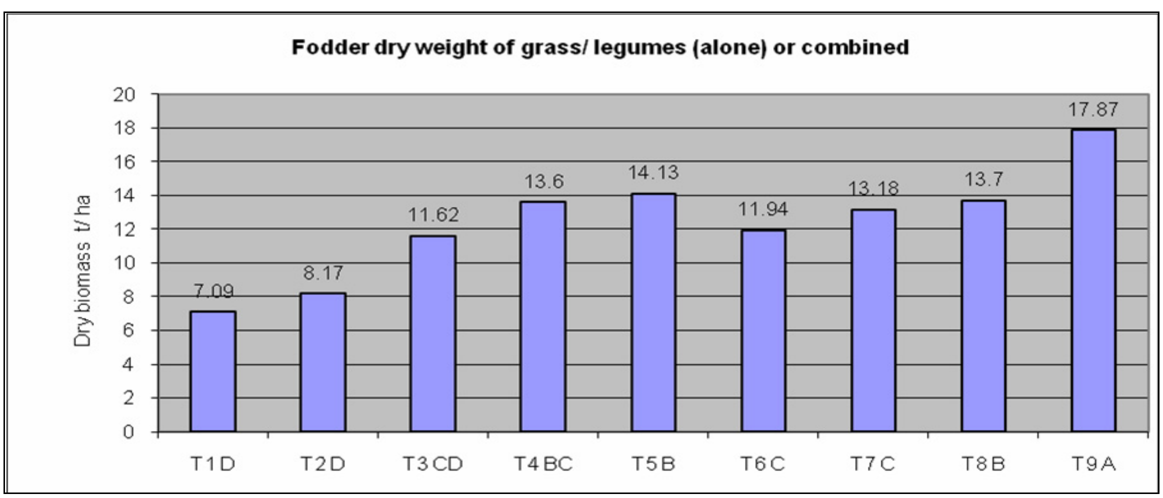


Fig 1: Effect of grass-legumes intercropping and inoculation on dry fodder weight (n= 4 SD= 0.395)

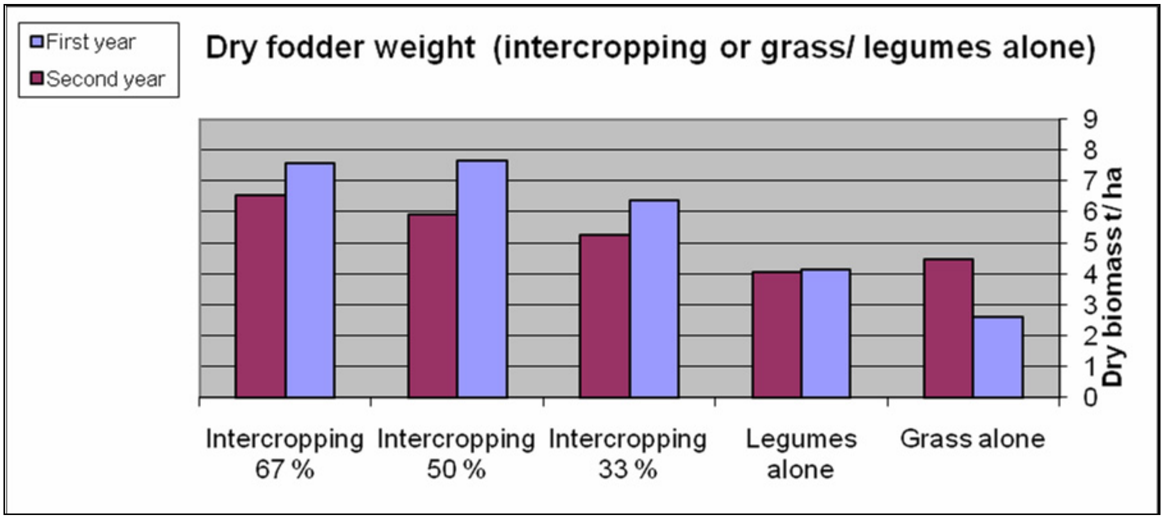


Fig 2: Year wise comparison of different intercropping intensities (grass+ legumes) for fodder production (n=4 SD First year= 0.568 SD Second year= 0.222)

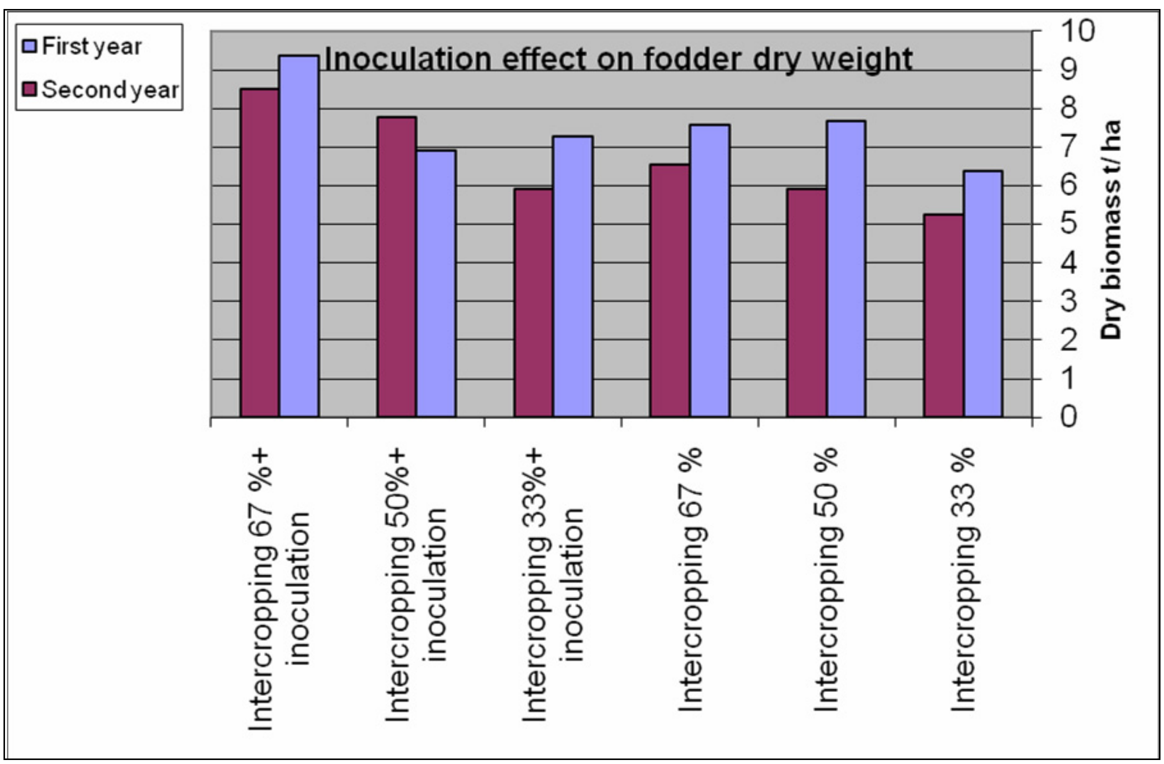


Fig 3: Year wise comparison of different intercropping intensities (grass+ legumes) and inoculation of legumes for fodder production (n=4 SD First year= 0.578 SD Second year= 0.243)

4.1.1.4 Nodulation

Symbiotic rhizobial bacteria form colonies on the root of specific legumes to form root nodules which fixes atmospheric nitrogen. Rhizobia live in the soil independently, when they come in contact with the roots of leguminous plants, they infect the root hairs and penetrate through the roots hairs into tissues. The number of infected root hairs increases until the nodule is formed.

At the harvest of 1st crop roots showed no nodulation (Table 4.5). This might be due to absence of natural inoculi in the experimental site. The second crop showed a significant trend, 67% intercropping performed better than others but combination of intercropping and inoculation showed the increasing trend in nodule number. Similar results were also recorded in 3rd and 4th crops as well. However, nodulation increased after every harvest. ASLAM *et al*. (2000) described 100 percent increase in nodulation by applying inoculant in chickpea, whereas increase in yield ranged from 20-33 percent. The nitrogen fixation was also significantly increased due to increasing trend in nodulation. KARAS et al (2005) reported that nodule formation factor was dependent of nodule primordial (NP) which in turn, supports the bacterial invasion in case of luceren varieties. LAPINSKAS (2005), NIKITIN et al (2003), AMPE *et al*. (2003), DABA and HAILE (2002) also recorded higher nodulation when leguminous crops where inoculated with specific rhizobium strains. The effect of inoculating nodulating bacteria on nodules formation and biomass yields of different Lucerne (*Medicago sativa*) cultivars was investigated by HAUNG *et al*. (2005). The results indicated that nodule numbers and percentages were significantly improved by inoculating matched rhizobial strain. Inoculation significantly increased biomass yields and crude protein of Lucerne. The nitrogen contents in the plant roots were not correlated with inoculation. The effects of increasing nodule percentage and biomass yields of inoculating rhizobial on seeds were greater than that of inoculating rhizobial on soil. XIAO- YAN *et al.* (2006) reported that rhizobium inoculation promoted the growth of the faba bean plants that in turn benefited the intercropped wheat. With N application, the biomass of faba bean plants increased by 15, 16 and 5 % in the inoculated treatments as compared with the non-inoculated control in plastic sheet barrier, nylon mesh barrier and no barrier treatments, respectively, and their N uptake increased by 17, 9 and 12 %. In the no barrier treatment, rhizobium inoculation improved the growth of wheat, enhancing its biomass and N uptake by 13 and 22 %, respectively, as compared with the non-inoculcated treatment. It was, therefore, concluded that inoculation of appropriate strain of rhizobium could improve nitrogen fixation of legume crop and benefit the cereal crop in a faba bean/ wheat intercropping system.

4.1.2 Forage quality parameters

Production of increased biomass of fodder is important in the developing countries in order to meet the requirements of enhancing number of livestock that is in turn necessarily desired for meeting the demands of ever increasing population. However, the quality of produced fodder is also of equal importance because balanced nutrition and protein and mineral requirements of people fed on animal products eating quality fodders meeting international standards is also of utmost importance. Therefore, higher production of fodder will only be appreciable if its quality simultaneously is acceptable as well because production of milk, meat and associated products of livestock depends upon hereditary factors by approximately 25 % while 75% is dependent on the feed quality and quantity. The nutritive value of a forage feed is a measure of proximate composition, digestibility and nature of digested products and thereby its ability to maintain or promote growth, milk production, pregnancy or other physiological function in the animal body. The assessment of herbage quality involves an integrated evaluation of nutritive value and factors of consumption by the animal. The chemical analysis of any feed stuff is important due to having quantitative information regarding nutrients. Thus forage quality evaluation holds the key to economic livestock production. Therefore, moisture contents, crude protein, crude fibre, ash ether extract, nitrogen free extract, and total digestible nutrient parameters were determined in the present study.

4.1.2.1 Moisture contents

In addition to higher yield, digestibility is one of the major qualities of forage. Apart from other factors, it also depends upon the succulence of the forage. Moisture contents in plant tissues increase their succulence. The old leaves of plant tissues generally contain water from 75 to 85 percent of the fresh weight. A significant effect on moisture contents were observed during quality assessment of the fodder of first and second crops while recorded differences of this parameter were found to be non-significant in 3^{rd} and 4^{th} crops (Table 4.6). Intercropping of 33 and 50% has no effect on the moisture contents but 67% decreased moisture of first crop fodder significantly. Inoculation showed an increasing trend that became significant at 67% intercropping and thus decrease of moisture without inoculation in this treatment was overcome, as regards first crop. Cowpeas legume (second crop) had more moisture than *Vicia sativa* that was significantly higher than grass. Mixed fodder from intercropping had significantly more moisture as compared with sole grass and inoculation increased it further except 67 % where it remained the same after second crop harvest. Non-significant trend was indicated in 3rd and 4th crops but a slightly increasing behavior was showed by the inoculation treatments. The forage legumes increased the succulence due to having more moisture content than grass. The moisture contents were more in forage legume in cowpeas than *Vicia sativa.* This showed that cowpeas had more succulence property than *Vicia sativa*. Thus, quality of mixed fodder improved due to higher succulence. KUZEEV and GAFOROW (2000) also reported that intercropped forage had a higher feed value than sole cropping.

4.1.2.2 Crude protein (CP)

Protein is very important and the most demanded feed ingredient of ruminant rations. It is required substantially for milk or meat production as well as for reproduction. The ration deficient in crude protein depressed the microbial activity in the rumen due to lack of N. Thus, many health problems may emerge due to deficiency of CP. Large and highly significant differences were noted in between grass and both the legumes (*Vicia sativa* and cowpeas) during the study period (Fig. 4). For example CP in grass was 5.77% while both the legumes were having about 20% (Table 4.7). Intercropping improved CP content of grass as well but decreased slightly of legumes that could not become significant. Intercropping of grass and legumes by 67% proved better and significant in case of cowpeas in both the years Fig. 5). Coupling of intercropping and inoculation increased crude protein of grass a little bit further due to more presence of nitrogen in soil and plants but differences, when compared without inoculation could not be evaluated as significant (Fig. 6). The grass alone showed decreasing trend due to more maturation (woodiness in stem behavior). Second year investigation were found to be in agreement with first year. However, the crude protein of forage legumes increased after every harvest indicating a gradual effect of growing legumes and increasing effectiveness of inoculation. The effect of both the legumes was comparable, as far as CP was concerned because the residual effect of accumulating N in soil through symbiotic fixation might be there.

Increasing CP in fodders through growing of leguminous crops with grasses and non-legume fodders has always been an interesting topic of research in the world. KUTUZOVA *et al*. (2001)

described the crude protein demand in meadow fodder. They urged to increase 6-7 million ha as legume – grass mixture area in order to meet increasing crude protein demand. SUDESH et al (2006) noted that mixture of grass and legume produced more crude protein than grass and cereal mixture. Thy also reported that this increase in crude protein was due to more nitrogen assimilation by legume nodulation formations. TAMM and TAMM (2005); HOFFMANN et al. (2004); MALIKOV (2004); TROTS and YAKOVLEV (2003); LIKHACHEV *et al*. (2003); ZIMKOVA *et al*. (2002) and REYNOLDS (2005) also observed the increasing trend of crude protein when different leguminous crops were intercropped with non leguminous crops or grasses. They also noted that crude protein percentage was increased more by inoculation of legume seeds that was due to fixation of atmospheric nitrogen. BERDAHL *et al.* (2004) conducted a study to compare nutritive quality of four cool-season grass monocultures and their respective binary grass-alfalfa (*Medicago sativ*a) mixtures. Great Plains was dependent on maintaining the legume component in the mixture, which increased CP from 71 g kg^{-1} for grass monocultures to 109 g kg^{-1} for grass-alfalfa mixtures when no supplemental nitrogen fertilizer was used. The forage yield and quality of common vetch (*Vicia sativa*), grass pea (*Lathyrus sativus*) and barley grown alone and as mixtures were investigated in field experiments by KARADAG and BUYUKBURC (2003).

The highest crude protein yield (1.53 t ha^{-1}) was achieved with the 50 % grass pea and 50 % barley mixture. The mean relative yield total values of dry matter and total seed yields were 1.78 and 1.79, respectively. In conclusion, the mixture comprising 25 % common vetch or grass pea and 75 % barley was recommended for green forage, dry matter and seed yield. The 50 % grass pea and 50 % barley mixture produced the highest crude protein yield and therefore, were recommended to be grown for improving quality of fodder in respect of crude protein. INAM-UL-HAQ and JAKHRO (2001) reported that symbiotic fixation increases the protein contents of the plant. Symbiotic bacteria used energy gained by (20 kg CH_2O) for fixing one kg nitrogen. Nitrogen fertilizers increased the growth of legume crops but considerably reduce the amount of nitrogen fixed. Forage legumes fix more nitrogen than grain legumes and they add more nitrogen to the soil if they are grazed rather than harvesting. Cowpeas and vetch fixed 90 and 80 lbs $acre^{-1}$ yr^{-1} respectively. Generally, extent of digestion of legume NDF was lower than that of grass because of lower cell content and higher lignifications of the farmer (KAISER and COMBS, 1989).

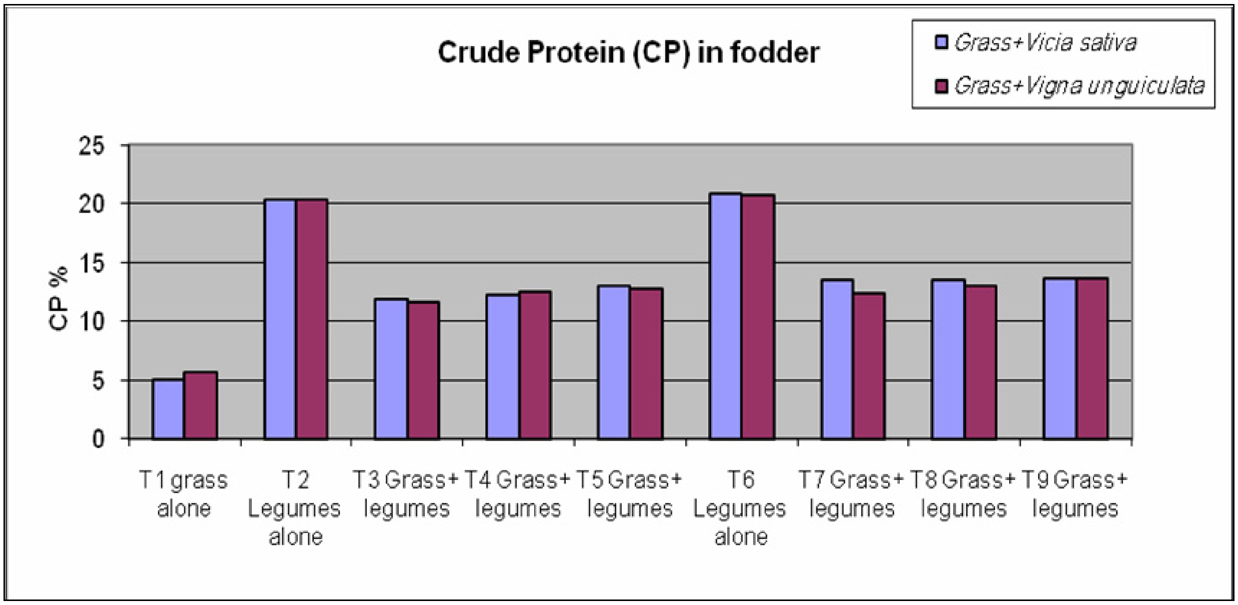


Fig. 4: Effect of grass legumes intercropping and inoculation on crude protein of fodder after two years (n= 4 SD *Vicia sativa* = 0.702 SD *Vigna unguiculata*= 0.663)

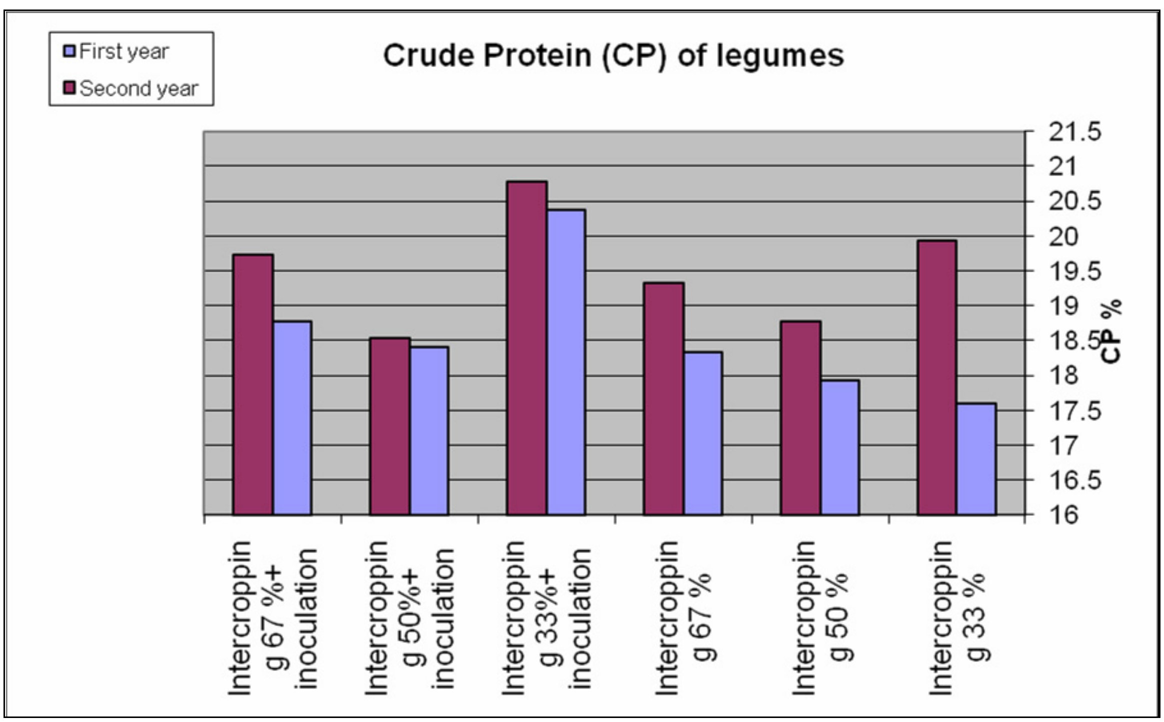


Fig. 5: Year wise effect of intercropping and inoculation on crude protein of legumes (n= 4 SD First year= 0.932 SD Second year= 0.628)

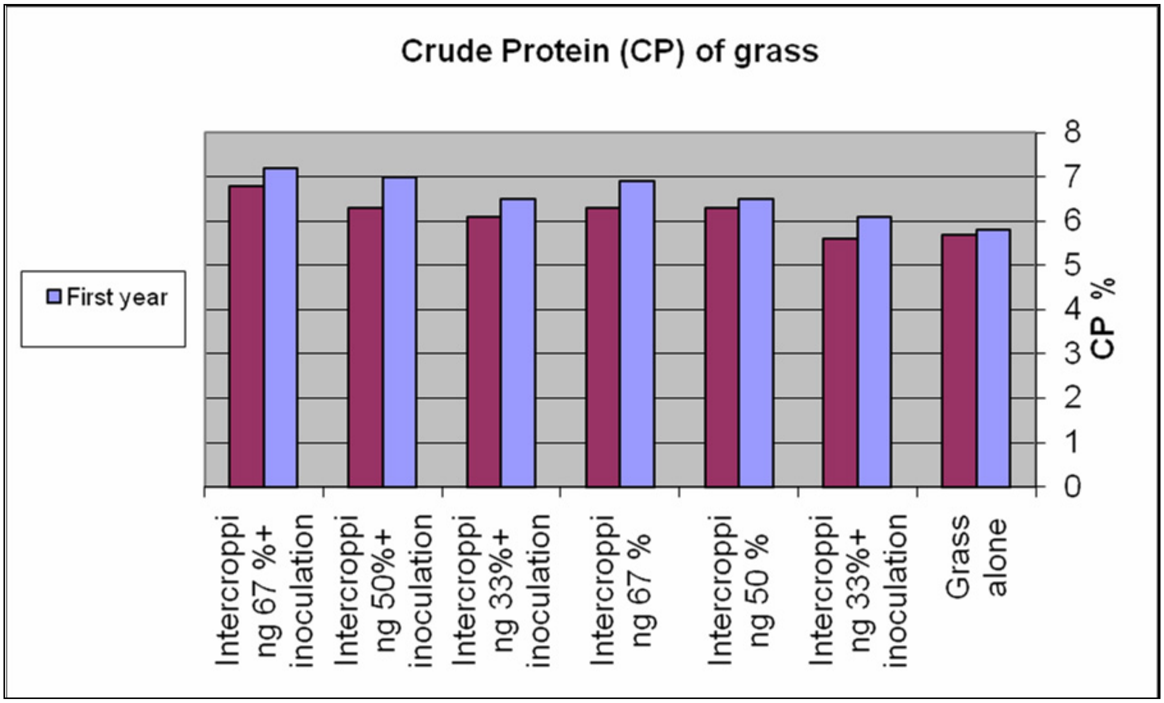


Fig. 6: Year wise effect of intercropping and inoculation on crude protein of grasses (n= 4 SD First year= 0.952 SD Second year= 0.648)

4.1.2.3 Crude fiber (CF)

The forage digestibility is related to chemical composition, particularly of fiber, lignin and silica contents and to some extent of more crude protein. Crude fibre mainly consists of cellulose, hemicellulose and lignin. The lignin content generally reduces the digestibility of forage. Significant differences were depicted in crude fibre due grass and legumes intercropping and inoculation (Table 4.8). Crude fiber of grass (when grown alone or in combination with legumes) was more than legumes or mixed fodder that increased after every harvest due to more maturity and establishment of stem thickness (Fig. 7). Intercropping practice deceased analyzed values of this parameter in all the four crops. Leguminous crops (*Vicia sativa* and *Vigna unguiculata)* had significantly lesser crude fiber than grass that was further reduced because of intercropping as well as inoculation but latter was more effective than the former (Fig. 8 & 9). The best treatment (T9) found on basis of data in this regard was combination of intercropping by 67% and 35.03% that were decreased to 32.70% due to intercropping by 67% and 31.73% with inoculation (Fig. 7). For example CF contents of legume *Vicia sativa* in the first year were inoculation. This showed that symbiotic nitrogen fixation not only increased crude protein but also decreased crude fibre. In other words reduction of crude fibre increased the digestibility of the fodder. SUDESH *et al*. (2006) studied the hybrid Napier intercropped with soybean. They reported that hybrid Napier grass and soybean mixture increased the protein contents and decreased the amounts of lignin and silica. They also mentioned that leguminous crops had low lignin contents than grasses or non-leguminous crops. Thus, crude fiber was more in grasses or non-leguminous crops than leguminous forages. KAISER and COMBS (1989) indicated generally that extent of digestion of legumes NDF was lower than that of grass because of lower cell contents and higher lignification of the former. Well nodulated legumes contain large amounts of protein, calcium, magnesium and other essential elements. Because of this improved nutrition, seedling legumes have improved winter hardiness and better yield the next year. Specific Rhizobium species for cowpeas and vetch is *Leguminosarum* (JOHN 2002).

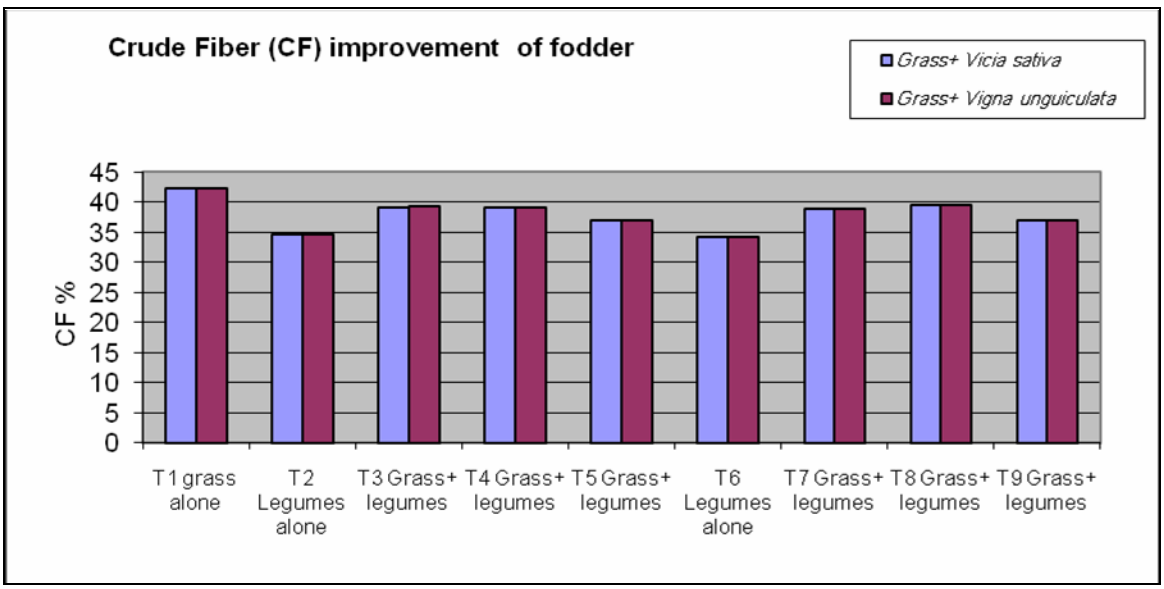


Fig. 7: Effect of intercropping and inoculation treatments on crude fiber (CF) of fodder (n= 4 SD *Vicia sativa* = 1.406 SD *Vigna unguiculata* = 2.885)

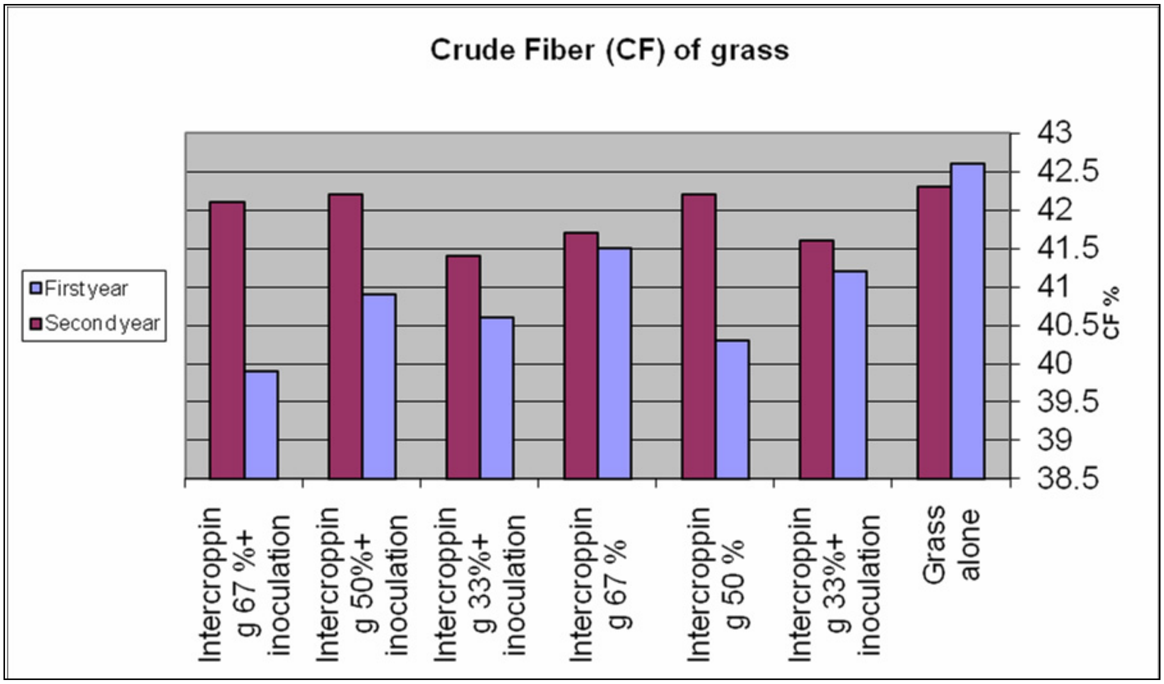


Fig. 8: Year wise effect of intercropping and inoculation on crude fiber of legumes (n= 4 SD First year= 2.158 SD Second year= 2.145)

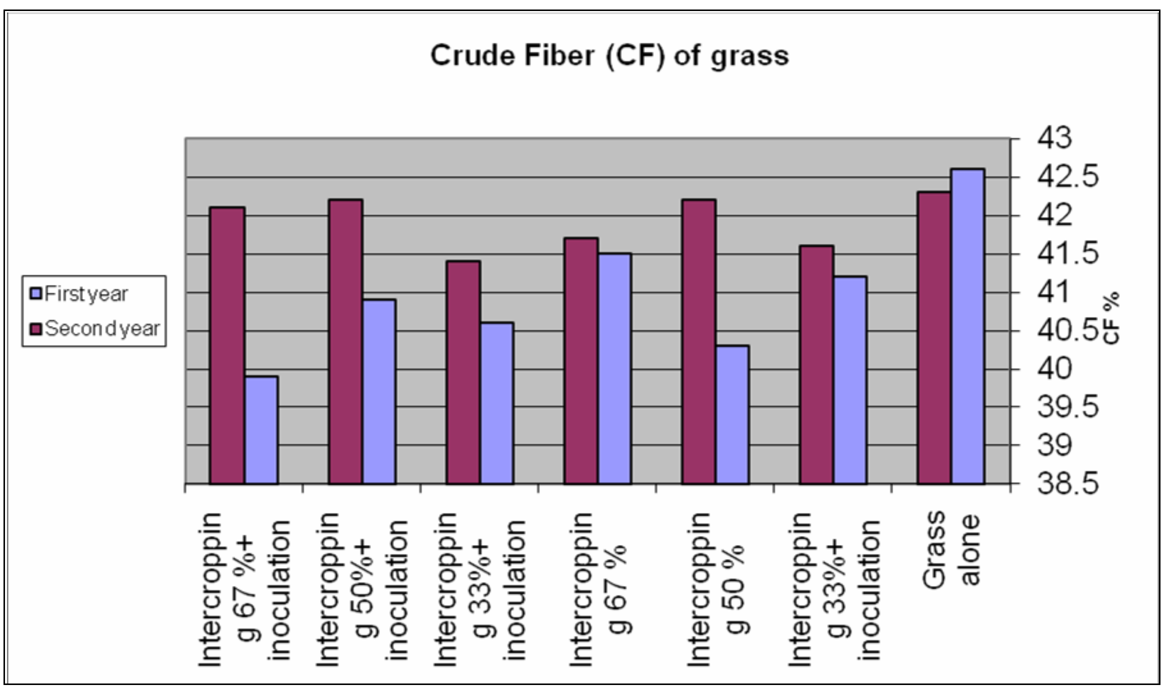


Fig. 9: Year wise effect of intercropping and inoculation on crude fiber of grass (n= 4 SD First year= 2.248 SD Second year=2.235)

4.1.2.4 Ash content

The organic carbon free substance which remains at 600 ^{o}C is called ashes. It is the combination of essential and non-essential minerals along with plant silica. Acid soluble material is called minerals while acid insoluble is plant silica. Leguminous crops have less ash content than grass species. The ash contents of different fodders of this experiment revealed significant differences (Table 4.9). The grass (grown alone) showed gradually decreasing ash content after every harvest but the difference was very small. Similar trend was also recoded in case of both forage legumes during the study period. However, large differences were recorded in between grass and legumes at all the equivalent treatments (Fig. 11 & 12). Intercropping of grass and legumes decreased ash content significantly except by 33% that may be due to the presence of more plant silica. The combination of intercropping and inoculation performed still better and ash content were further decreased. The intercropping of 67% coupled with inoculation remained as the best treatment (T9) that caused reduction of ash content to the maximum in case of both legumes in two years study (Fig 10). The decreasing of ash contents proves beneficial for feeding livestock due to reduction of plant silica that disturbs the digestibility of feed. SUDESH *et al.* (2006) conducted a study including four grasses that were intercropped with soybean in summer season and oats, peas and mustard in the winter season for enhanced forage production. They reported that ash contents i.e. plant silica was lower in forage legumes but more in grasses or non-leguminous crops. The grasses had more lignifications than legumes. So the combination of legumes with grass lowered the ash contents. Forages are more digestible when harvested at early stage than at maturity or nearer to it due to more crude proteins, minerals and carbohydrates in composition (BOSE and BALAKARISHAN, 2001).

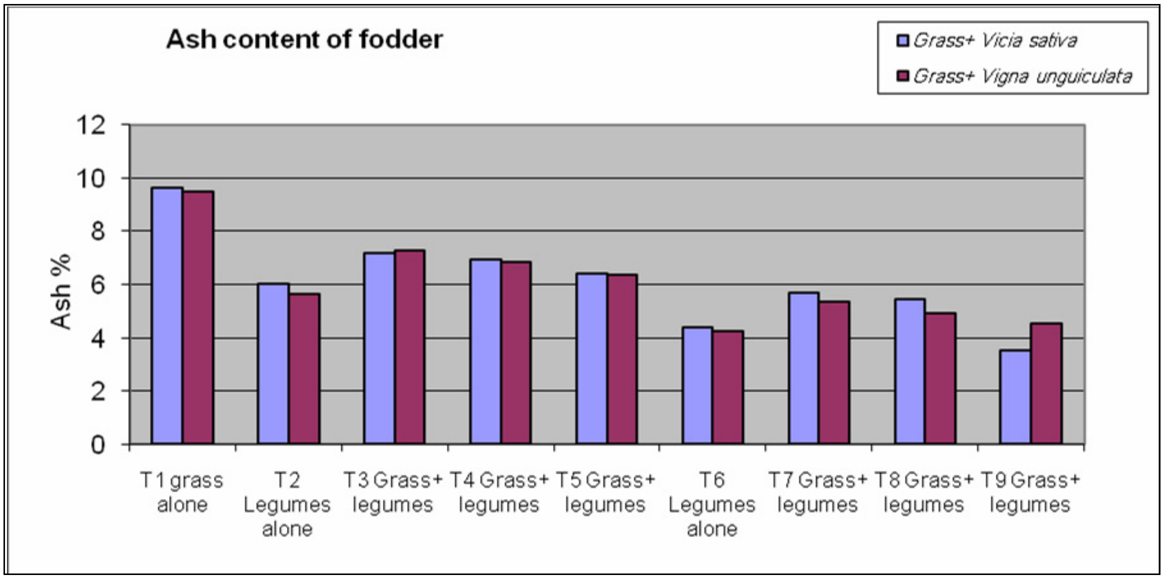


Fig.10: Changes in ash content fodder because of grass-legumes intercropping and inoculation (n= 4 SD *Vicia sativa* =0.542 SD *Vigna unguiculata* =0.643)

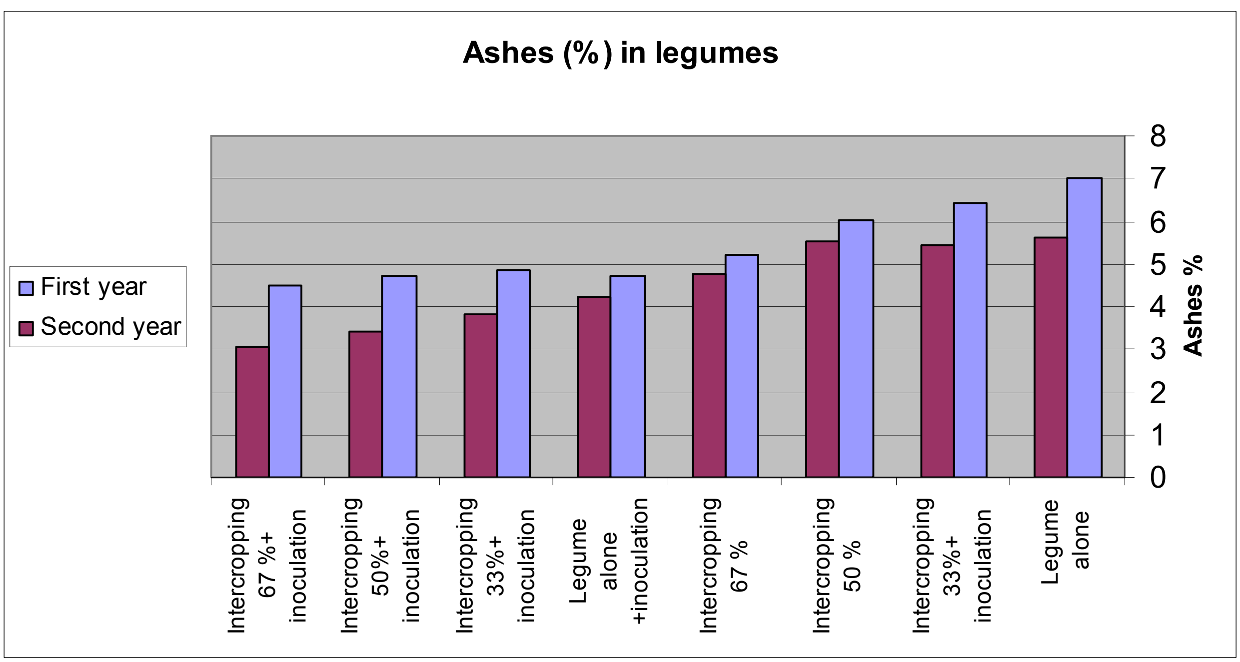


Fig. 11: Year wise effect of intercropping and inoculation on ash content of legumes (n= 4 SD First year=0.404 SD Second year=0.592)

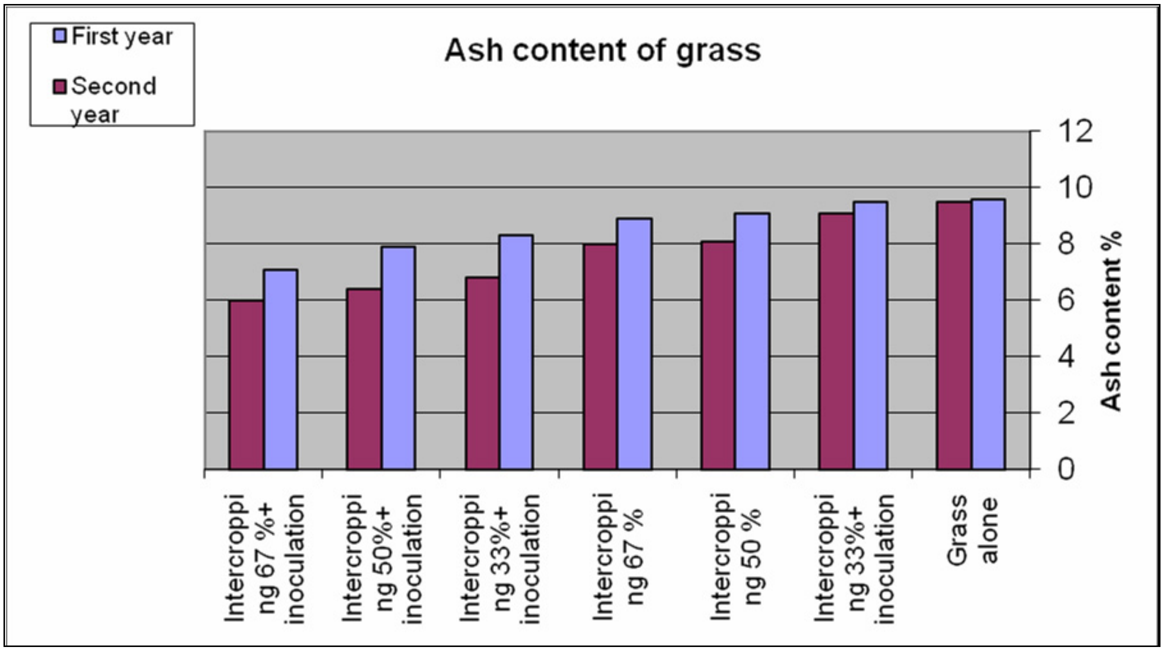


Fig. 12: Year wise effect of intercropping and inoculation on ash content of grass (n= 4 SD First year= 0.413 SD Second year= 0.482)

4.1.2.5 Ether extract

The ether extract is composed of fats, oils, waxes, organic acids, pigments, sterols and vitamins A, D, E and K. Among these, vitamins are of chief concern in animal feeding. These compounds are the components of enzymatic systems that catalyze metabolic reactions. Vitamin D is found in sun dried herbage, although this source is not always dependable. The ether extract was significantly decreased when *Vicia sativa* forage legume was inoculated (Table 4.10). Similar general trend was also observed in case of *Vigna unguiculata* (cowpeas) with exceptions at intercropping by 67% whereas significant decrease was recorded in ether extract of *Vicia sativa* in all three planting patterns (33, 50 and 67%). The intercropping of grass and legume improved the forage quality by decreasing the ether extract in case of both legumes and all the crops. The ether extract percentage was more in grass alone than legume alone. Sleugh *et al*. (2000) also reported that legumes improved forage quality and dry matter digestibility (DMD). The CP and DMD were lower in monoculture grasses and higher in legume-grass mixtures.

4.1.2.6 Nitrogen Free Extracts (NFE)

The chemical analysis for nitrogen free extract (NFE) indicates nitrogen free compounds like sugar, fructosans, starch, pectin, organic acids, resins, tannins, pigments and water-soluble vitamins. In the chemical analysis, the carbohydrates are divided into two main classes, crude fibre and nitrogen free extract. The nitrogen free extract includes the soluble proteins of the carbohydrates that increase the digestibility. The NFE of grass and legumes increased in the second year of the study. This parameter of grass significantly increased when intercropping was introduced. However, this trend remained non-significant in the second year in case of *Vicia sativa* but in the first year for cowpeas. In contrast, the NFE of legumes increased but insignificantly because of intercropping (Table 4.11). Inoculation also increased NFE of legumes as well grass. The increasing trend may be due to symbiotic nitrogen fixation from air and soil. MALIKOV (2004) conducted a study to use 9 grain crops and fodder rotation with 33% Lucerne, 33.3% annual grasses and 33.4 % industrial grain and grain fodder crops. He reported that Lucerne being the leguminous crop increased the nutritive value of fodder crops. The leguminous crops having more nitrogen increased the digestibility of forages/herbages. SAITO (2004) reported (after conducting study of 3 forage legumes with two grasses) that mixture of legumes with grasses has good capatibility and palatability to cows than two grasses alone.

4.1.2.7 Total Digestible Nutrients (TDN)

Voluntary intake of fodder is the primary factor for higher productivity. The higher dry matter intake is related to better voluntary intake and thereby for higher nutrient intake. The intake is higher for legumes than for non-legumes and for immature than for mature forages. The TDN is the physiological equivalent of digestible energy and also is a feed – feces difference. It is the only feeding standard that does not openly indicate the basis of energy as underlying the appraisal. A clear and significant difference was observed in between grass and legumes for TDN content indicating that latter have more potential for supplying digestible nutrients to animals (Fig 13). There was a marked difference of TDN of both legumes within two study years, showing a decrease of almost 5% (Table 4.12). Three planting geometries (33, 50 and 67%) did not affect significantly TDN composition of either grass or legumes. As far as inoculation was concerned, it increased TDN of grass that was assessed significant statistically only with intercropping of 67% with inoculated legumes (Fig. 14 & 15). TDN decrease in legumes in the second year may be due to more maturation as was also argued by IKHACHEV et al. (2003) who investigated the efficiency of grain forage production in legume companion crop. The legume (Lupin) and wheat and oats mixture attained higher forage nutritive value in this study. Nutritive value is main factor of digestibility. XIAO–YAN *et al*. (2006) reported that inoculation of appropriate strain of Rhizobium improved nitrogen fixation of legume crops that ultimately increased the digestibility of livestock feed. AZIM *et al*. (2000) observed that digestibility of NDF and hemicellulose declined non-linearly with increasing maturing stage. They also reported that legumes had higher digestibility than grasses, therefore corn + cowpeas silage DM increased TDN.

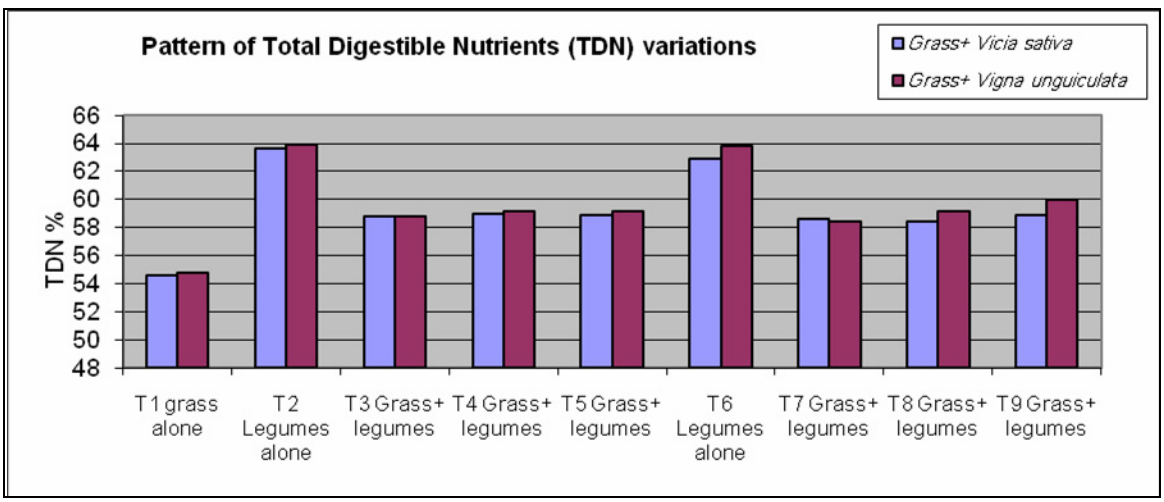


Fig. 13: Improvement of total digestible nutrients of fodder due to intercropping and Inoculation (n=4 SD *Vicia sativa*=0.709 SD *Vigna unguiculata*= 0.961)

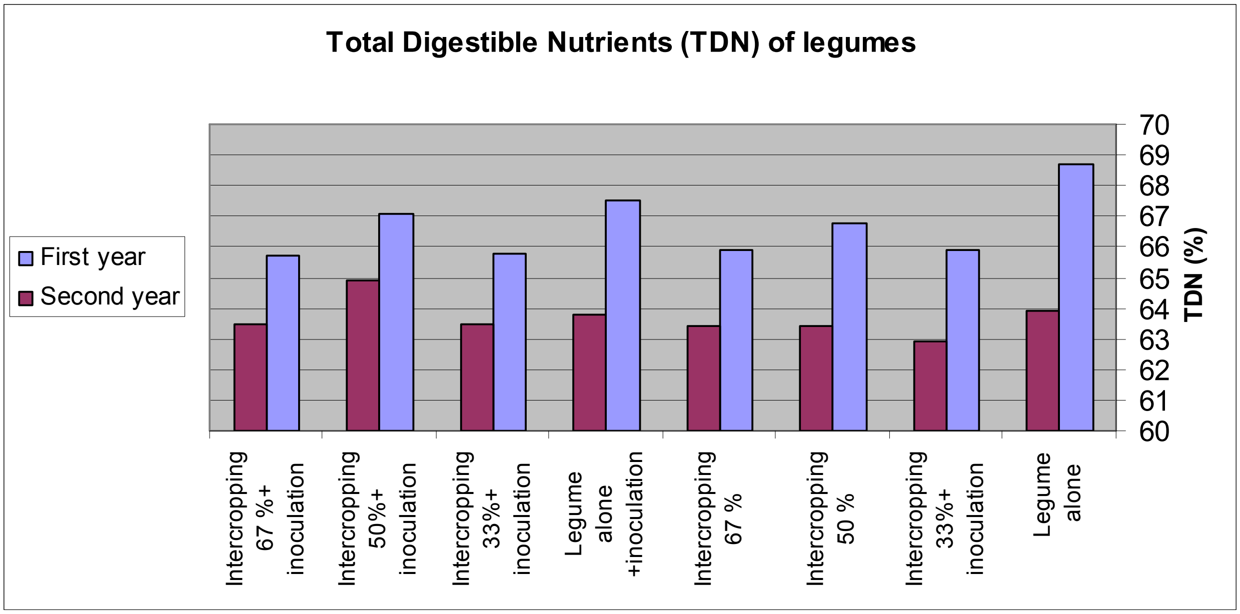


Fig.14: Yearwise effect of intercropping (grass+ legumes) and intercropping on TDN of legumes (n= 4 SD First year= 1.467 SD Second year= 0.835)

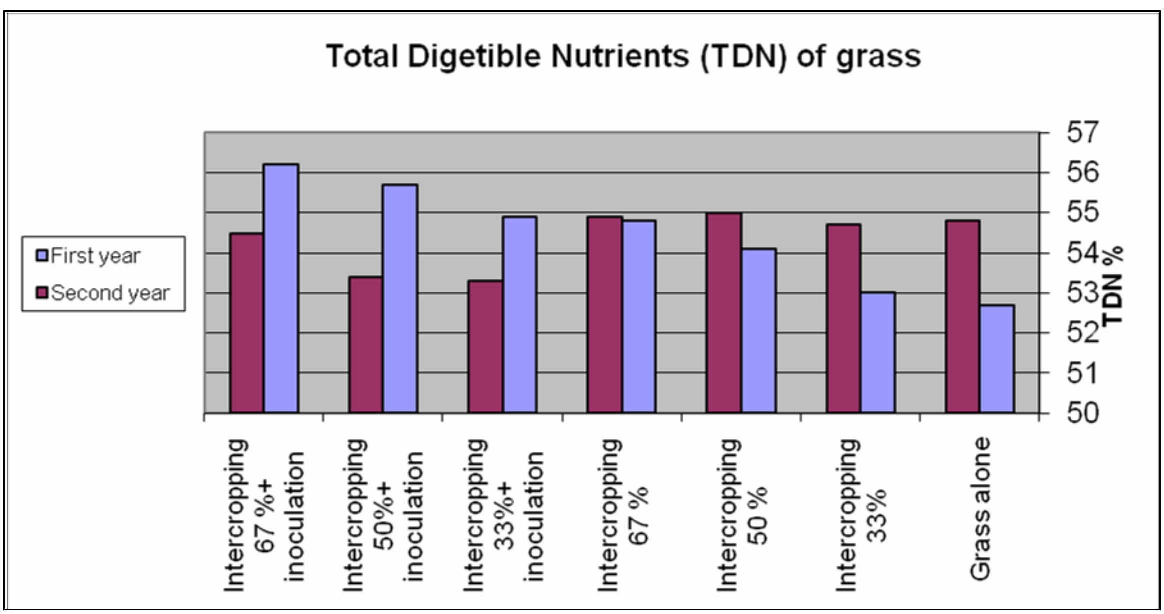


Fig. 15: Year wise effect of intercropping (grass+ legumes) and intercropping on TDN of grass (n= 4 SD First year= 1.352 SD Second year=0.945)

4.1.3 Soil parameters

Soil is a living body because soil consists of micro fauna and flora such as bacteria, actinomycetes, fungi and nematodes. Soil not only supports plants but also supplies these with water and required nutrients. A fraction of nutrients may be in inorganic form unless added as fertilizers; the major source is raw organic matter in the soil that is not directly available to the plants. Raw organic matter is broken down by microorganisms into simpler products before it can be utilized. The life in the soil is responsible for making numerous transformations which change plant nutrients to more readily available forms. Soil analysis indicates the potential of supplying capacity of nutrients and necessarily required for any scientific study so that results coming out of the treatments can be well understood and explained on the basis of processes undergoing in the soil. For this purpose soil, ECe, pH, total N, extractable K, available Phosphorus and organic matter were analyzed.

4.1.3.1 Electrical conductivity (ECe)

It is a parameter that indicates conductance of electric current and indirectly denotes the total concentration of soluble salts in a soil. The ECe of a soil increase as the soluble salts concentration increases. Electrical conductivity of the experimental soil was 0.53 dS m^{-1} that was within normal limits (> 4 dSm^{-1}, Table 3.1), therefore did not affect significantly the plant responses. The post harvest values of ECe also did not vary significantly during the study period (Table 4.13). Intercropping and inoculation of legumes had no measurable effect at least on soil ECe. Hence recorded differences on plant height, tillering, biomass production and nodulation of grass/ legume and grass legume mixtures and forage quality may be claimed as treatment differences.

4.1.3.2 Soil pH_s

Soil pH is the single characteristic which elucidates an overall picture of the medium for plant growth including nutrient supply trend, fate of added nutrients, salinity/ sodicity status, soil aeration, soil mineralogy and ultimate weather condition of the region. The pH is alkaline in many areas of Pakistan that are mainly arid and semi-arid. The numerical values for the soils of this country are mostly more than 8.0 even in normal soil. The determined value of the experimental soil was 8.4 and it was also within normal limits (> 8.5 to be declared as a sodic soil) and caused neither any detrimental effect on plant performance nor disturbed effects of experimental treatments. Post harvest values of this parameter were also noticed as normal and the minor observed differences were not found significant statistically (Table 4.14). Inoculation along with intercropping of legume + grass had negligible effect on soil pH.

4.1.3.3 Total nitrogen

Nitrogen is essential for plant growth as it is a constituent of all proteins and nuclei acids and hence of all types of protoplasm. The effect of nitrogen in increasing biomass is not only due to its direct effect on the plant growth as structural constituents but also because of rapidly synthesis of carbohydrates that are converted to proteins and ultimately to protoplasm when N supply is in ample quantities. Only smaller proportion remains available for cell wall material which is mainly free carbohydrates in the form of more complex compounds such as calcium pectate, cellulosans, cellulose and low nitrogen lignins.

The original status of total N was very low because soil analysis indicated its numerical value just as 0.037% (Table 3.1) and responses of symbiotic N fixation by rhizobia on legumes was expected because their activity becomes rapid when soil has clear deficit of N. Non-significant performance was observed after the harvest of first crop (Table 4.15). However, legume alone had slightly more nitrogen than grass alone due to symbiotic nitrogen fixation effect. A very small N percentage was also increased by intercropping of grass and legumes but combination of intercropping and inoculation increased this amount comparatively more (Fig. 16). Nevertheless, significant pattern of variation was observed after 2nd, 3rd and 4th crop harvest by all three planting geometries (33, 50 and 67%). The intercropping of 67% increased total N as the highest. Combinations of intercropping and inoculation had more effect on soil nitrogen but it was not found significant. This may be due to consumption of fixed N by the grass under nitrogen deficit conditions. There was a significant difference in between legumes and grass alone and inoculation further departed this variation. This revealed clear effect of legumes that were successful to increase soil N as well along with meeting their own requirements. The root nodulation and fixation of atmospheric nitrogen by rhizobia was its only cause. FRAME *et al*. (2005) also certified N_2 fixation of forage legumes in terms of rhizobial efficiency, N transference to associated companion grasses. The most widespread and consistent effect of legumes is to improve the N economy of soil through N2 fixation. The N-balance of legume-cereal sequence in most cases is more positive than that of a cereal-cereal sequence in the same soil. Nitrogen fertility inevitably accompanies intensive agriculture and, at least, reduces the requirements of inputs of fertilizer N (MUHAMMAD et al., 2003). Biological nitrogen fixation occurs mainly through symbiotic association of legumes and some woody species with certain N2-fixing microorganisms that convert elemental nitrogen into ammonia (SHIFERAW *et al*., 2004).

The increasing efficiency of N increased the biomass production of forage legume mixtures (Tables 4.3 and 4.4). SHISANYA (2005) investigated the effect of inoculation on Tepary bean – maize mixture in comparison to soil crop. He reported that inoculating Tepary bean (TB) with Rhizobium strain was effective that significantly improved bean and mixed intercropped forage due to more accumulation of nitrogen. VASILEV (2004), SHISANY (2003). ZHANG and LI (2003), ODHIAMBO and BOMKE (2001), XIA-YAN et al. (2006), REYNOLDS (2005) and ABBAS *et al*. (2001) also reported the increase in N_2 by intercropping along with inoculation of legume seeds. The overall input of nitrogen into global agriculture for food and feed production is estimated to be approximately 120 million tones/ year. Biological nitrogen fixation (BNF) accounts for 40 while 80 million tones/ year is accounted for by N-fertilizer production from ammonia. In cereal production, fertilizer use dominates because if cereals were able to "fix" their own nitrogen the situation could be very different.

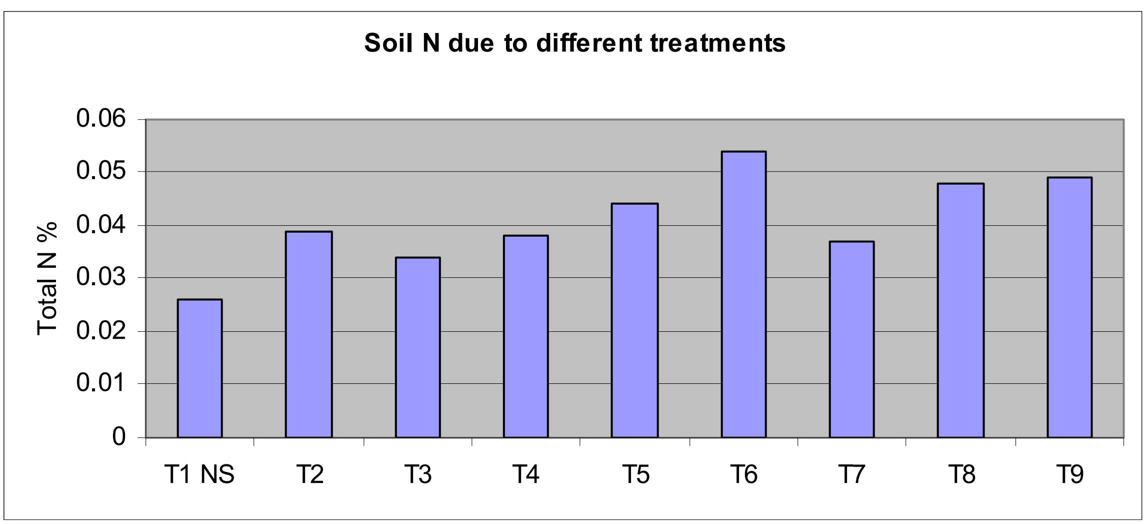


Fig. 16: Changes in soil N due to grass-legumes intercropping and inoculation (n= 4 SD = 0.01)

4.1.3.4 Phosphorus

Phosphorus plays a fundamental role in the very large number of enzymatic reactions that depend on phosphorylation. Possibly for this reason it is a constituent of the cell nucleus and is essential for cell division and for the development of meristematic tissue. Phosphate deficiency can be difficult to diagnose, a crops can be suffering from serve starvation without any obvious signs. This phenomenon is called hidden hunger. The pre-sowing phosphorus status of original soil (4.70 ppm) was very low that decreased to 3.99 ppm due to utilization of phosphorus by plants (Table 4.16). The crops were sown without fertilizer except legume seeds inoculation, so available phosphorus was utilized by plants that decrease soil available phosphorus status. The post harvest P values in different treatments after all the four crops did not apart significantly. LI-LONG *et al*. (2007) conducted 4 years field experiment and reported that maize over yielded by 43% and Faba bean (*Vicia faba*) over yielded by 26% when intercropped on low phosphorus but high nitrogen soil. They also reported large increase in yields from intercropping on low phosphorus heavily weathered soils. ZHANG and LI (2003) conducted research on the processes involved in the maize intercropping with Faba bean. They noted that intercropping used soil nutrients more efficiently than sole cropping. Hence, in the present experiment intercropping reduced the available phosphorus by its efficient utilization.

4.1.3.5 Potassium

Potassium is one of the essential elements in the nutrition of the plant and one of the major three nutrients that are commonly in short supply in most of the soils to limit crop yield. It is important in the synthesis of amino acids and proteins from ammonium ions. An adequate supply of potassium in the leaf is probably essential for the photosynthetic process to go efficiently.

The available K status of original soil was deficient. The post-harvest P values in all the treatments (Intercropping and inoculation) departed non-significantly. There was no change of behavior after harvesting of any of the four crops (Table 4.17). An important observation was that grass and legumes utilized original soil P and post-harvest values became even lower than the original magnitudes. Potassium deficient soils produced better biomass of forages (Tables 4.3, 4.4 and 4.15) using ample supplies of nitrogen fixed during symbiotic N fixation and more efficient utilization of soil potassium but reduced the amount of potassium in the soil.

ZIMKOVA *et al*. (2002) reported that grass legume intercropping had positive effect on soil nutrients.

4.1.3.6 Organic Matter (OM)

Organic matter in the soil comes from the remains of plants and animals. New organic matter is formed in the soil from new additions when a part of the old is mineralized. The original source of soil organic matter is plant tissue. Under natural conditions, the tops and root of trees, grasses and other plants annually supply large quantities of organic residues. Thus, higher plant tissue is the primary source of organic matter. Animals are usually considered secondary source of organic matter. The original status of OM was very poor (0.53%). Non-significant differences were noticed within all the treatments after the harvest of first crop (Table 4.1.8). However, growing of legume or its intercropping with grass in subsequent three crops increased soil OM that was significant with 67% intercropping or legume alone. Whereas inoculation further increased efficiency of intercropping of 33 and 50% in statistical terms, although even OM values were also higher in treatments of legumes alone and 67% intercropping as well. A constant increase in OM content of soil with gradual growing of legumes or intercropping was recorded while the values remained almost the same in case of grass only. The end values were higher in intercropping treatments alone or when these were combined with inoculation (Fig. 17). The cause of these differences depended upon differences in biomass produced in different treatments (Table 4.3 and 4.4) that resulted burying in of different quantities of crop residues. SEREGIN *et al.* (2003) discussed that mixed cultivation of *T. pratense* and barley improved soil fertility due to cultivation of legumes in rotation system.

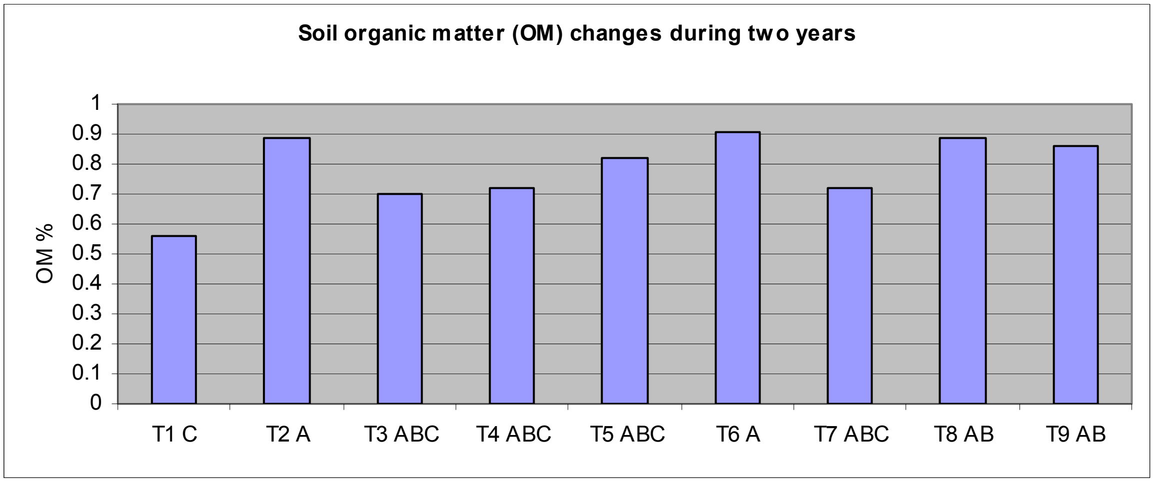


Fig. 17: Variations in soil organic matter due to grass-legumes intercropping and inoculation (n= 4 SD = 0.185)

4.2 Experiment No. 2: Evaluation of fertilizer effect on biomass production of grass-legumes intercropping

The fertilizer effect on grass/legumes when these were intercropped with *Panicum maximum* grass to the extent of 33, 50 and 67% was investigated in this experiment. The main objective of this experiment was to assess the potential of improvement through fertilizer application when compared with farmers' fodder production technology generally without fertilizer application.

4.2.1 Growth and yield parameters

The plant height, number of tillers, fresh and dry biomass and number of nodules were evaluated and results are presented subsequently.

4.2.1.1 Plant height

A significant increasing trend was showed in plant height of *Vicia sativa* in all three planting geometries (33, 50 and 67% intercropping) when compared with grass or legume alone (Table 4.19).. Similar trend was also noted in case of cowpeas (*Vigna unguiculata*). Thus, intercropping of grass and both legumes showed better performance but the height of cowpeas was more than the *Vicia sativa* that may be due to genetic character of the former. However, positive effect of legumes on grass growth was still constant. The growth of grass (*Panicum maximum*) as well as legumes was positively affected when fertilizers were supplemented to these crops along with intercropping. The difference of 33% intercropping coupled with fertilizer application compared with respective alone height values of either grass or legumes was found to be non significant while other two levels of intercropping (50 and 67%) remained significant. Most of these results were also similar with the results of second year of the study. The better growth of grass when intercropped with forage legumes could be attributed to the nitrogen fixation by legumes and fertilizer application that made essential nutrients available under original deficit conditions of soil (Table 3.1) to the grass as well as well as legumes. The increased nitrogen content of the soil (4.33) as observed after harvesting of crops also supports this view. The intercropping treatment results depicted a positive trend and no negative competition existed for light, nutrients and water to the extent of 67% intercropping. Therefore, this planting geometry did not alter the situation significantly and proved positively successful. TRANNIN *et al*. (2000) noted that significant amount of nitrogen was assimilated by the legume roots after the harvest of the crop that further explained the transference of N by decomposing organic matter rather than root exudates or direct mycorrhizal hyphae. Positive results of fertilization to these crops were also reported by RAO *et al*. (2007), SHIFERAW *et al*. (2004), STEVOIC *et al*. (2004).and MALHI *et al.* (2004). BURLE *et al*. (2003) reported better growth of *Brachiaria decumbens* when it was intercropped with legume crop *Leucaena leucocephala*. LI *et al.* (2003) recorded the positive trend on growth when maize was intercropped with legume crop Faba bean. The improved nutrition of maize crop especially nitrogen was also found by them when Faba bean (legume) was intercropped.

4.2.1.2 Number of tillers (plant^{-1})

. Intercropping of both legumes increased tillering of grass appreciably. Tillers of *Vicia sativa* were more statistically due to intercropping of 67% whereas tillering of cowpeas remained unaffected in the first crop. However, this became alike *Vicia sativa* during second crop. Tillering capacity of grass was increased after every harvest due to its perennial nature. Most of the results of grass and forage legumes were also similar in second year study.

The influence of fertilizer on tillering of legumes was very clear indicting that it did not only favor the legumes but also the companion grass Legume *Vicia sativa* having an erect growth pattern therefore, its tillering was not negatively affected even when intercropped upto 67%.

However, cowpeas has creeping growth pattern, therefore subsequent creeping of both crops (grass and cow peas) suppressed tillering of cow peas due to space competition but it was affected negatively and significantly. TURK (2000) observed less tillering trend in barley/vetch alone as comparing with intercropping. The intercropping pattern in that study was having more plant population and more competition of space, nutrition and light, whereas in the present protocol such condition was not created keeping in view the addition of suitable plant population in the growing grass. Therefore, negative results were not obtained.

4.2.1.3 Biomass production

The parameters like: plant height, branching/tillering and new leaves are the main source of biomass production in a field. The fresh biomass (Table 4.21) includes water contents while the dry biomass is without moisture (Table 4.22). Unless a water treatment or salinity/sodicity is the investigating factors, there is a minute difference in patterns of variations between fresh and dry biomass.. Therefore, a lot of difference was not found while comparing fresh and dry biomass. Biomass of legumes was recorded higher than grass while intercropping increased the fodder production of grass as well in the absence of any fertilizer production. A significant increase in forage production of grass as well as legumes was recorded when these were fertilized with NPK as starter dose. Such effect was observed not only in case of grass and legumes alone but also all the intercropping levels (33, 50 and 67 %). Positive effect of fertilizer was persistent in all the four crops of the two years study. However, increase in biomass production was more in the later three crops as compared to the first crop that might be due to more production of legumes. The effect of intercropping of legumes to extent of 67% was not found detrimental in biomass yield. A significant increase was observed over grass alone when legumes were intercropped by 33, 50 and 67%. Intercropping was statistically significant in all the crops. However, fertilization and intercropping combinations proved more economical and caused significant increase in biomass over monoculture of grass or legumes. The combination of 67% intercropping and fertilization proved the most beneficial and produced maximum biomass that was significantly higher than all the other treatments of the experiment (Fig. 18). The overall production of biomass of fodder from four crops during two years was 13.35 and 17.72 t ha^{-1} due to intercropping of grass-legumes by 67% alone and coupled with inoculation as against 7.9 t ha^{-1} of grass alone. The increases in biomass production due to this treatment was calculated as 122, 195, 141 ad 61%

over grass alone in the first, second, third and forth crops respectively indicating more effectiveness of legumes in earlier stage because an increasing quantum of grass alone was recorded as well with time due to establishment of grass being of perennial habit. The increases were computed as 82, 206, 199 and 53% over monoculture legumes in case of first, second, 3rd and 4th crops respectively.

Growth of plants is mainly affected by the soil, water and environmental factors. When these are favorable and no stress like waterlogging, extreme rainfall, temperatures, and salinity/sodicity are present, the plant growth remains normal.. No stresses were provided under this experiment and there was only factor of intercropping that might create space problem and light competition due to more plant population. Intercropping 67% did not show negative trend due to which increased biomass was recorded. This was further resulted that competition of crops did not disturb plant growth of each other. Therefore, conditions of plant growth remained favorable and produced maximum biomass. Fertilization of crops remained also beneficial and its combination with intercropping further increased forage yield Fig. 19 & 20). This may be due to more establishments of forage grass and legumes by root nodulation. ELESSESSER (2004) also noted significant increase in dry matter yield in Lucerne varieties with 4 cuts due to more assimilation of nitrogen in legume root's nodules. An increase in nitrogen content of the present experimental soil was also recorded (Table 4.33). It has also been discussed (section 4.2.1.1 and 4.2.1.2.) that plant height and tillering increased due to different treatments of this second experiment. Hence, as a result the biomass increased that could logically be argued. These results were in conformity with other investigations as wellbecause GHERBIN *et al.* (2007) SHISANYA (2005), HOFFMANN *et al.* (2004) KWIATKOWSKI (2004), VASILEV (2004), SAITO (2004), GIACOMINI *et al.* (2003) KUZEEV (2002), ODHIAMBO and BOMKE (2001), MOHAPTRA *et al.* (2001) TURK (2000), SOGOT (2005), IBEWIRO *et al.* (2002) ELESSESSER (2004) and MALHI *et al* (2004) also recorded higher fresh/dry biomass when different leguminous crops were intercropped with non-leguminous crops or grasses. Nitrogen fixation is relatively low in response to high inorganic N supply that was estimated less than 20 % of the harvested N in alfalfa. Where forage yield was high and inorganic N supply was low, N_2 fixation by alfalfa appeared to be greater than 400 kg N ha^{-1}. Therefore, the use of Barsin – wide means of N_2 fixation is not appropriate for analysis of N sources and cycling within sub watersheds (RUSELLI *et al.,* 2004). Biological nitrogen fixation occurs mainly through symbiotic association of legumes and some woody species with certain N2-fixing microorganisms that convert elemental nitrogen into ammonia (SHIFERAW *et al*., 2004).

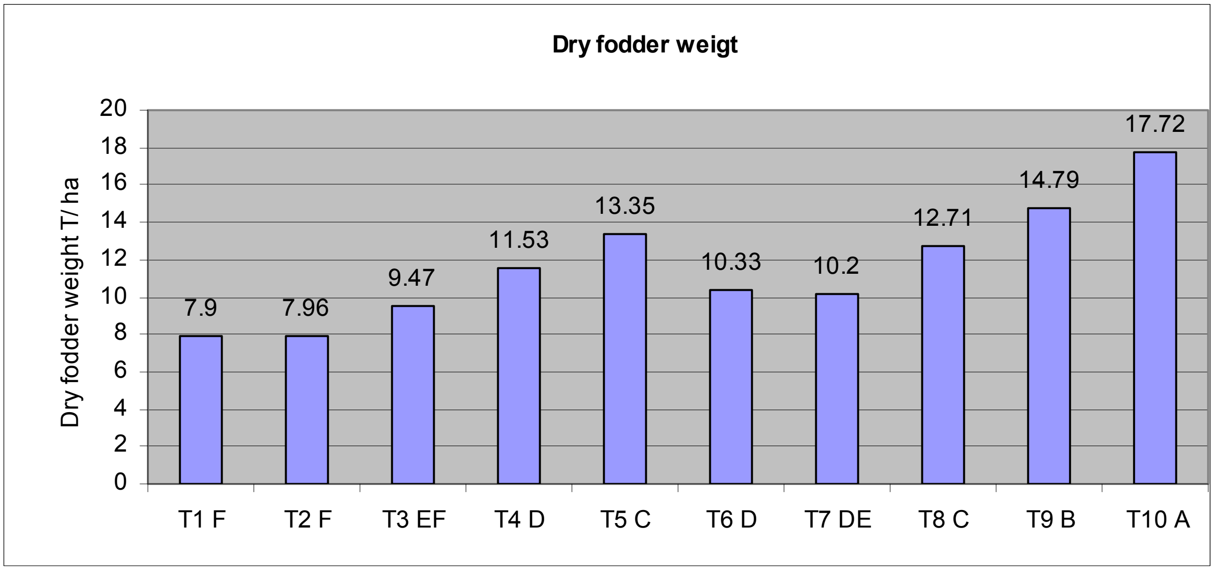
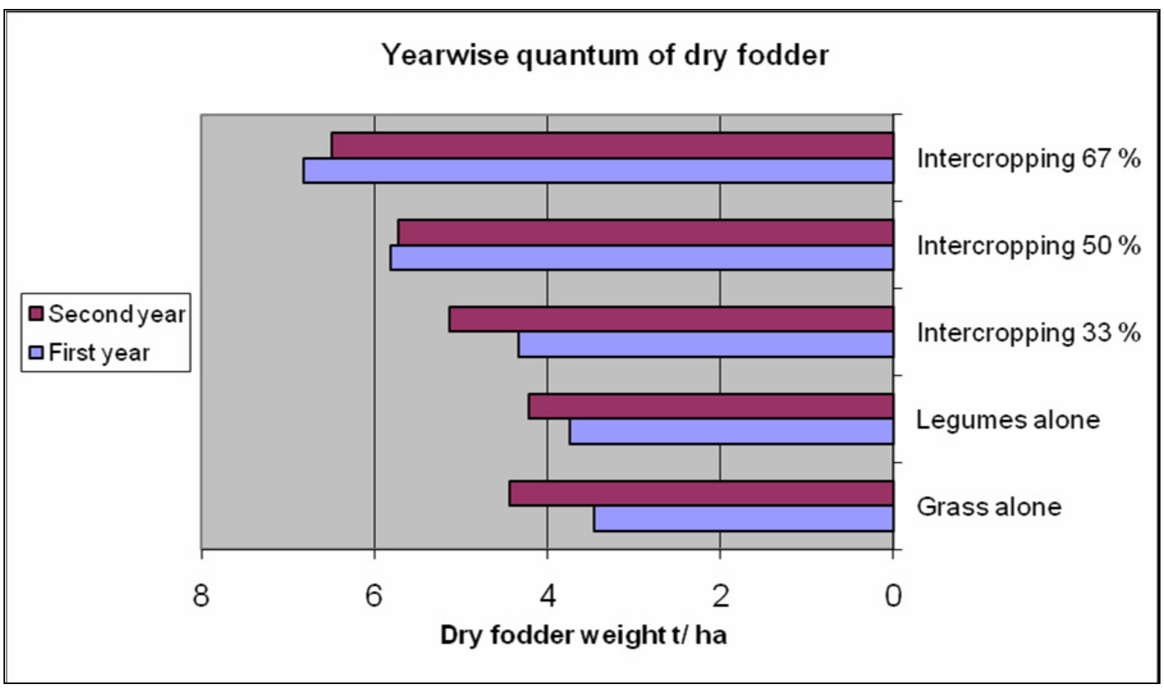


Fig.18: Effect of grass-legumes intercropping and fertilizer application on dry weight of fodder (n= 4 SD =0.469)



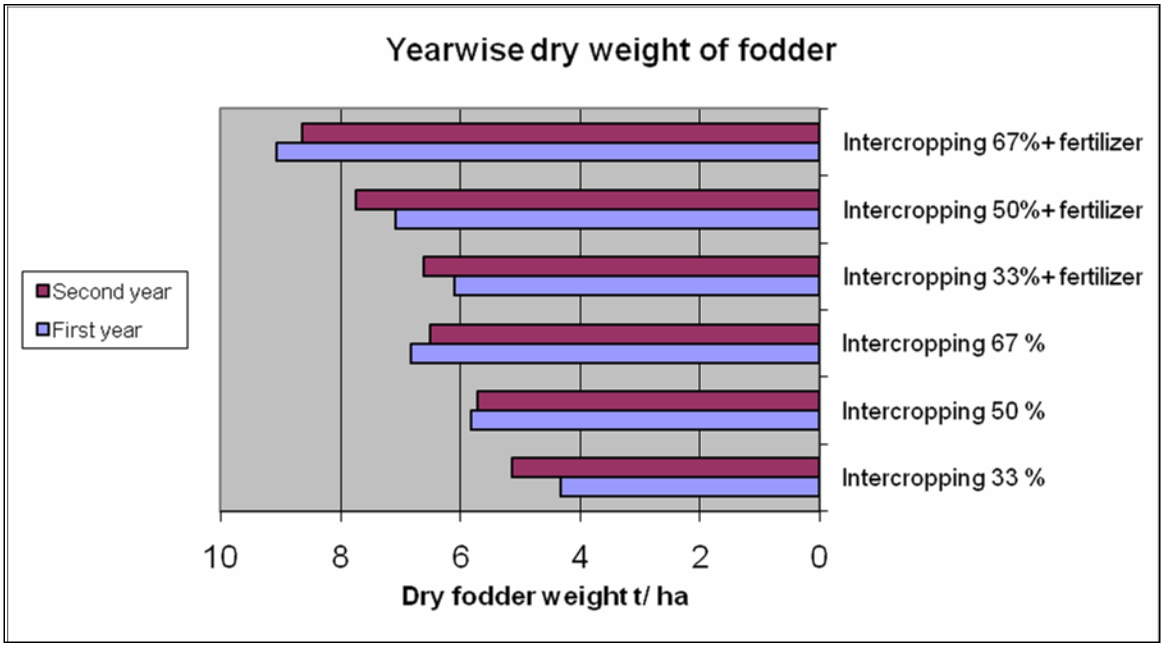


Fig. 19: Year wise effect of intercropping on dry fodder weight of fodder (n= 4 SD First year= 0.675 SD Second year= 0.263)

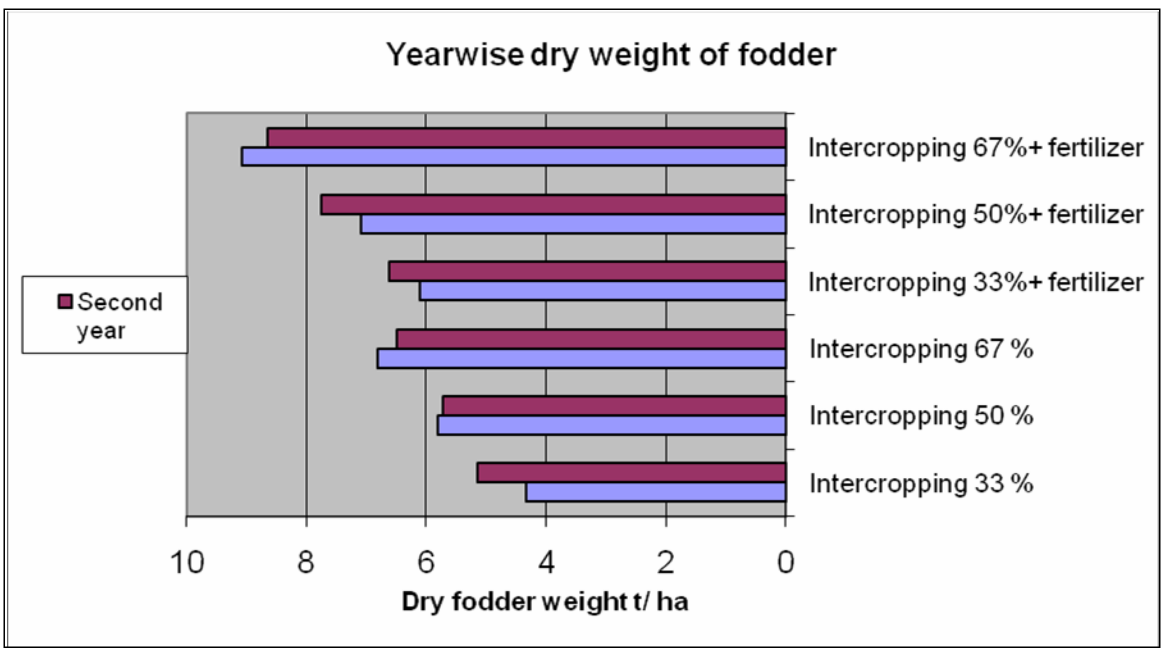


Fig. 20: Year wise comparison of fodder production due to fertilizer application (n= 4 SD First year= 0.589 SD Second year= 0.342)

4.2.1.4 Nodulation

Symbiotic nitrogen fixation bacteria (SNB) fix nitrogen in association with leguminous plants. The Rhizobium bacteria living in the soil enter the root hairs of leguminous plant, develop into colonies and form small nodules on the roots. They take their food (carbohydrates) from the leguminous plants and absorb nitrogen from the atmosphere. Rhizobium species invade the root hairs and result in the formation of nodules where free nitrogen is fixed.

No nodulation was found in the first leguminous forage *Vicia sativa* (Table 4.23) due to absence of proper rhizobium strain in the experimental site. Nodule count of second legume (*Vigna unguiculata*) remained non-significant while application of fertilizer decreased nodulation. However, nodulation of 3rd crop (*Vicia sativa*) revealed a positive trend that remained significant due to intercropping treatments of 50 and 67%. Although 33% intercropping also increased nodulation but it was not assessable as significant. Coupling of intercropping and fertilizer showed no response that might be because of reduction of microbial activity in the soil. The similar trend of nodulation was also found in 4th crop as in the second leguminous crop and observed variations were not measurably statistically. BENITZ *et al*. (2001) recorded the growth dynamics, dry matter yield and organic matter digestibility of pure or associated species. They reported that inclusion of legumes improved the quality and yield of grassland but nitrogenous fertilization of legumes reduced the nodulation and nitrogen fixation. The results of present experiment were similar with the findings of PHILIPPE *et al.* (2001) who reported that nitrogen fertilizer of legumes reduced nodulation.

4.2.2 Forage quality parameters

The productive value of any feed depends on the quantity eaten and the extent to which the consumed feed supplies the animal with the required energy, protein, minerals and vitamins. The application of nitrogen fertilizer to forage usually increases the level of crude protein, but has no effect on dry matter digestibility. The proportion of legumes and grass has a marked effect on forage quality. Nutritious forage contains a maximum proportion of leaf tissue to culm.

4.2.2.1 Moisture contents

Succulence is an important property of forage quality. More moisture contents in a fodder produce high quality of succulence that helps in the forage digestibility. Increasing of moisture was recorded due to fertilizer application combined with intercropping during first and 2nd crops

(Table 4.24). Fertilizer and intercropping 67% showed maximum moisture contents in the first crop but in the second crop the highest moisture contents were attained by fertilization of legumes. Sole intercropping did not reveal statistical difference. Variations in moisture contents remained non-significant in 3rd crop. Significant results were depicted at the harvest of 4th crop and fertilizer with 50% intercropping caused highest moistures in plant tissues. AZAM *et al*. (2000) argued the reason of higher DM digestibility of corn and cowpeas silage because of more moisture content.

4.2.2.2. Crude protein (CP)

Highly positive trend was observed by intercropping of legumes in grass during first year (Table 4.25). However, fertilizer and intercropping combinations proved highly positive that caused a significant increase of CP in grass. The CP of legumes was too high than grass but fertilizer application did not yielded materially as far this parameter was concerned. Intercropping treatments (33, 50 and 67%) slightly increased CP percentages but these remained non significant. *Vicia sativa* legume had a little bit more crude protein than cowpeas but pattern of variation was almost similar with the exception that CP in case of 67% intercropping in the first year (Fig. 22 & 23). General improvement in crude protein of grass was also recorded in different treatments of the experiment also in the second year of the study (Fig. 21). KARADAG and BUYUKBURC (2003) reported that 50% grass pea and 50% barley mixture produced highest crude protein yield and therefore, was recommended for Turkey. SENGOL (2003) reported that legume mixtures with one or two grass species gave higher crude protein of the hay from the mixture than grasses alone that was due to the large N harvests compared to pure stands of grasses. KUTUZOVA *et al*. (2001), SUDESH *et al*. (2006), HOFFMANN *et al*. (2004), MALIKOV (2004), LIKHACHEV et al. (2003), ZIMKOVA et al (2002), SPRINGER et al. (2001), REYNOLDS (2005), RAO *et al*. (2007), ELESSESSER (2004) and BERDAHL *et al*. (2004) also reported the improvement of crude protein by intercropping of legumes and fertilization that might be the accumulation of nitrogen by fixation of atmospheric nitrogen as well as the application of nitrogen fertilizer.

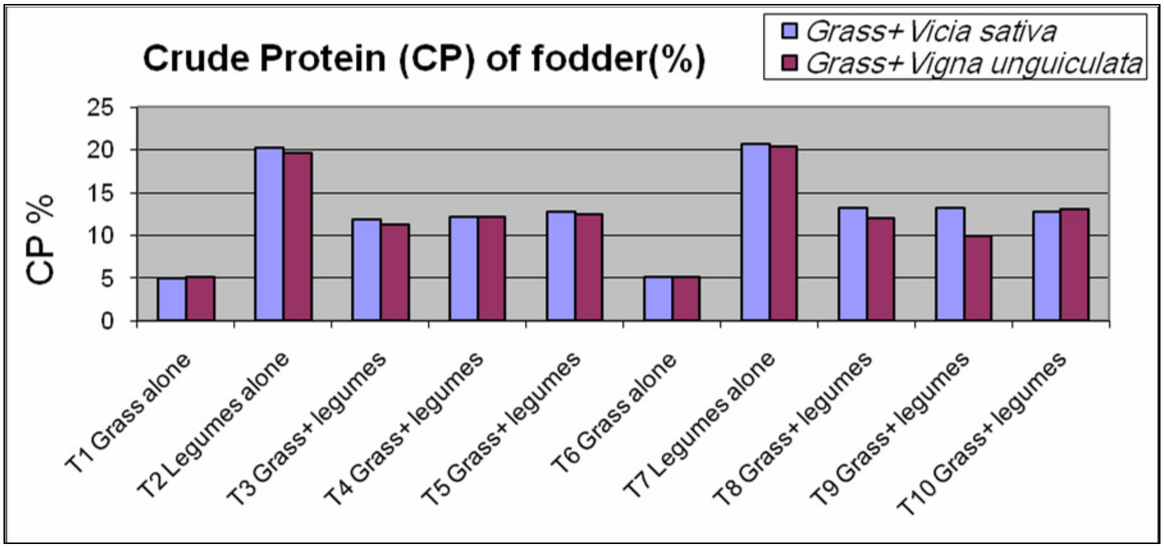


Fig. 21: Effect of intercropping (grass-legumes) and fertilizer application on crude protein (CP) of fodder (n= 4 SD *Vicia sativa* = 0.677 SD *Vigna unguiculata* = 0.748)

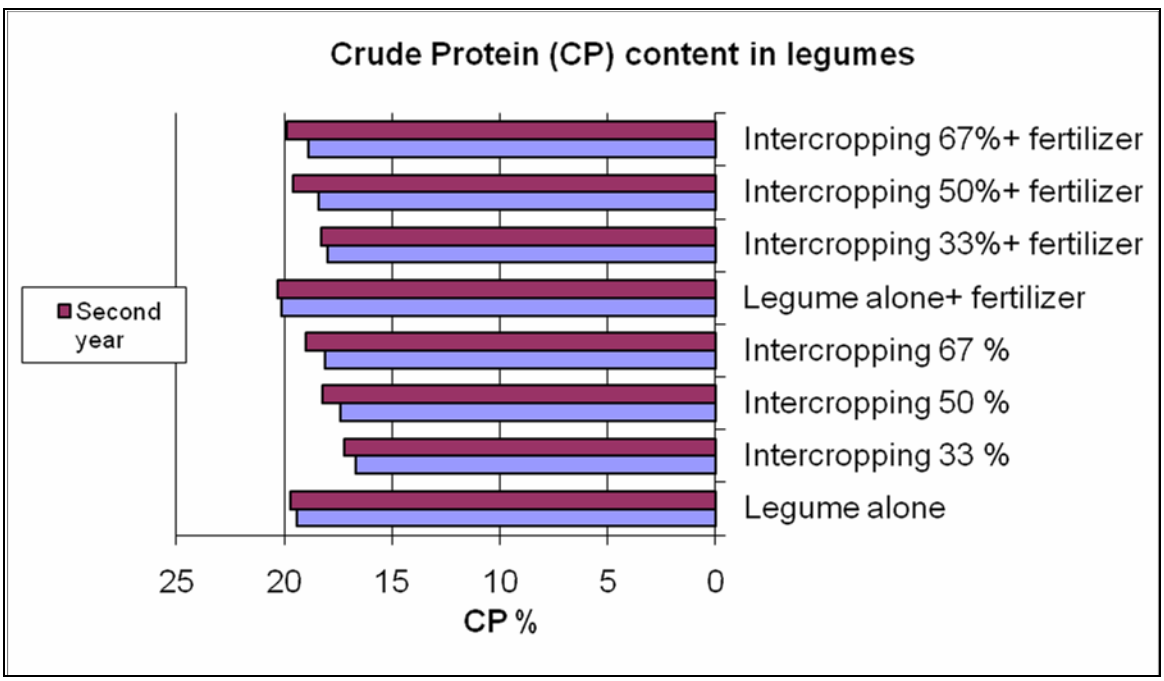


Fig. 22: Year wise effect of intercropping and fertilizer on crude protein (CP) of legumes (n= 4 SD First year= 1.017 SD Second year= 0.711)

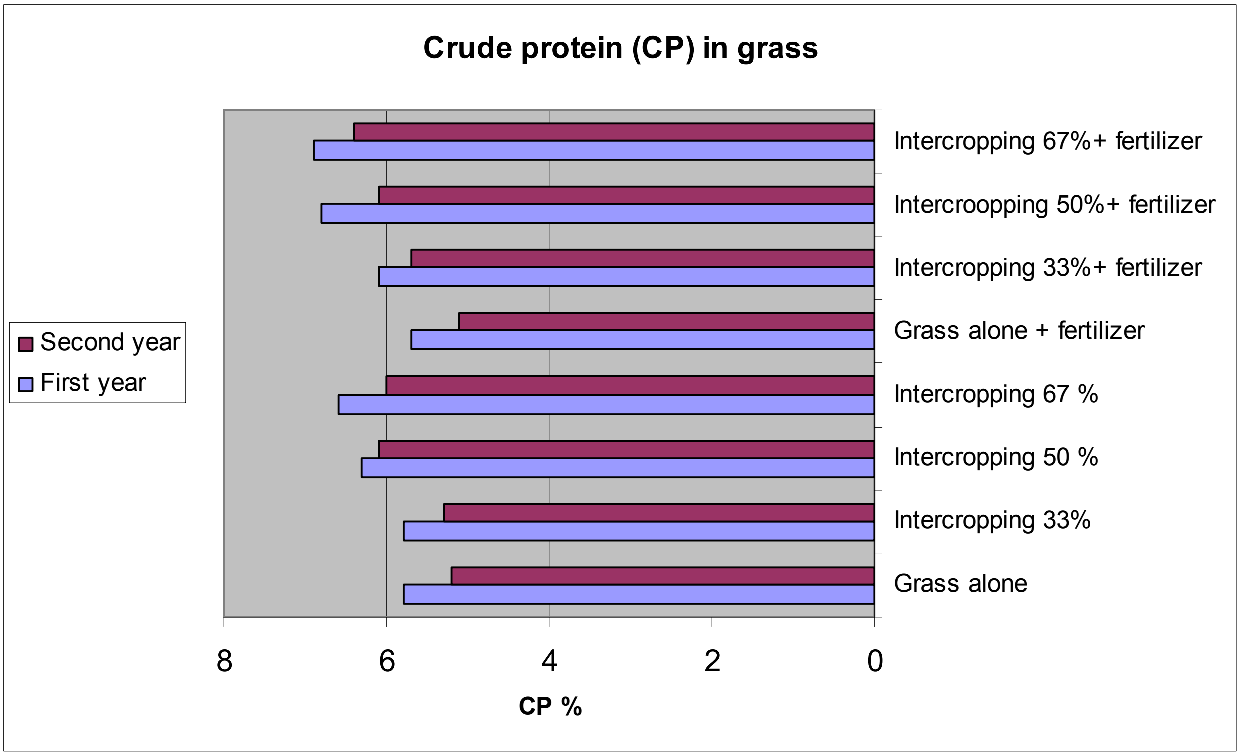


Fig. 23: Year wise effect of intercropping and fertilizer on crude protein (CP) of grass (n= 4 SD First year= 0.987 SD Second year= 0.723)

4.2.2.3 Crude fiber (CF)

Forage legumes usually are lower in fiber and higher in crude protein than forage grasses. Good quality forage is relatively lower in fiber and lignin. Palatable herbage offers a favorable ratio of digestible energy bulk to indigestible bulk or waste fiber. Significant results were attained in *Vicia sativa* as well as cowpeas along with grass by intercropping and intercropping + fertilizers (Table 4.26). The CF of grass was decreased while that of legumes increased due to intercropping. Crude Fiber of grass alone was more than legumes because grass may be having more cellulose and lignin. Intercropping and combination of intercropping and fertilizer improved forage quality by decreasing crude fiber of grass as a whole (Fig. 25 & 26) and that of forge legumes by some treatments like intercropping of 67% alone or with fertilizer (Fig. 24). Reduction in fiber and lignin improved the digestibility of forage. Similar trend was also recorded during the 2^{nd} year of the study. SUDESH *et al*. (2006) also noted that Hybrid Napier and its mixture with soybean had higher crude protein and lower amounts of lignin and silica. They also recorded that intercropping of legumes was better than other non-leguminous combinations. Low content of crude fiber increased the digestibility of forages, ultimately improved the nutritive value that increased the meat, and milk production.

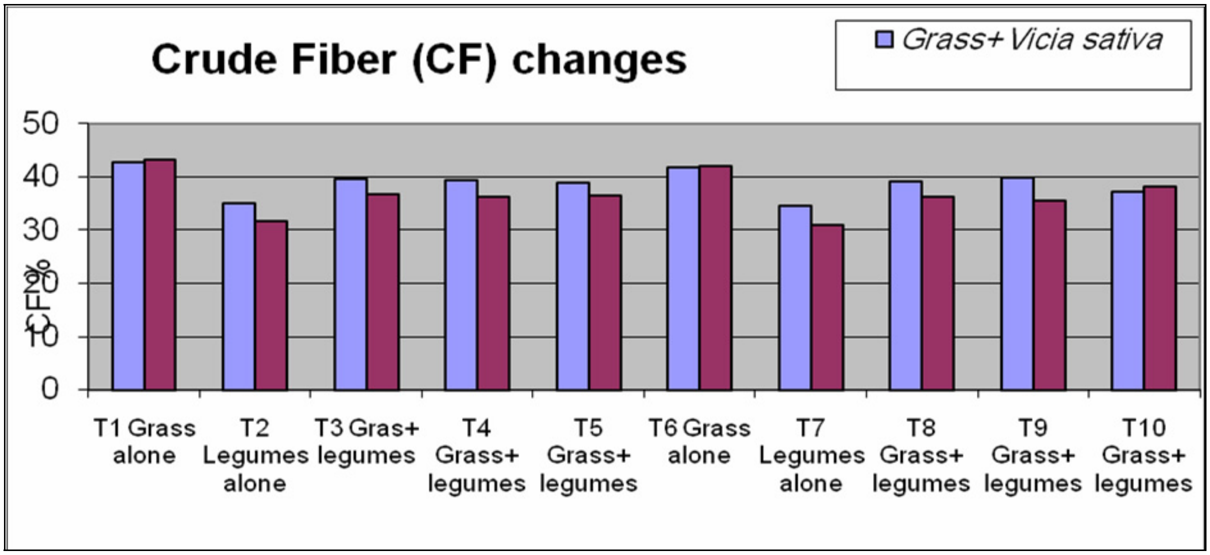


Fig. 24: Effect of intercropping (grass-legumes) and fertilizer on crude fiber (CF) of fodder (n= 4 SD *Vicia sativa* = 2.898 SD *Vigna unguiculata* = 1.844)

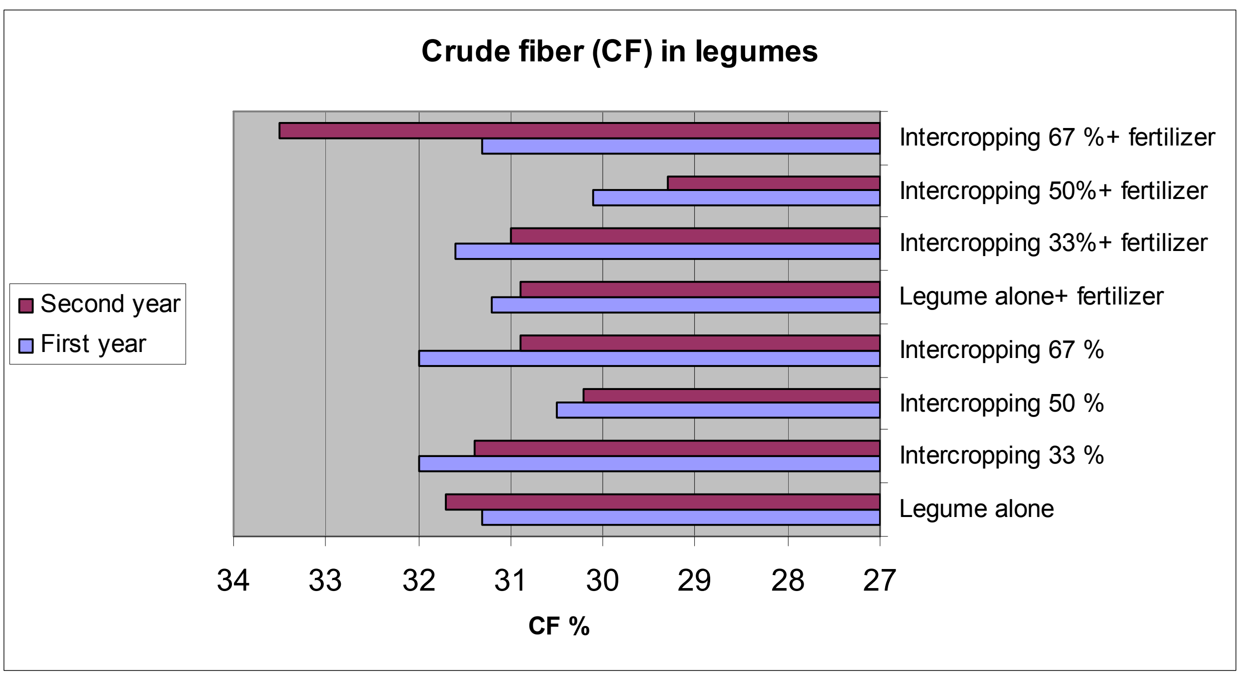


Fig. 25: Year wise effect of fertilizer during intercropping (grass-legumes) on crude fiber of legumes (n= 4 SD First year= 2.706 SD Second year= 2.371)

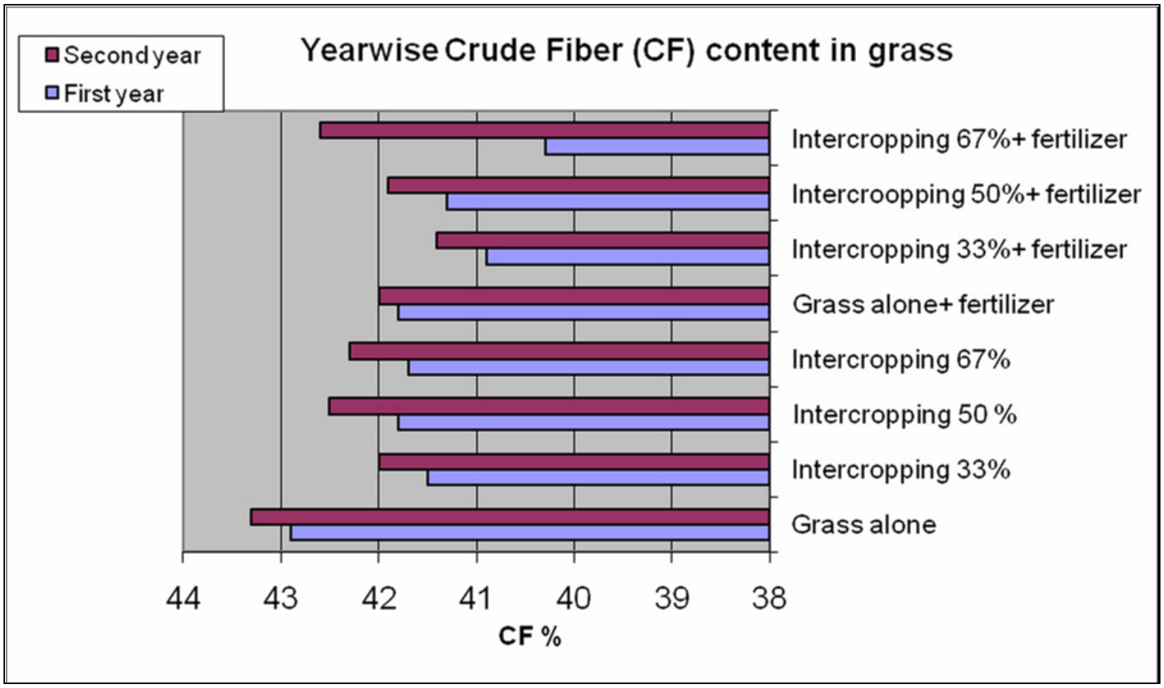


Fig. 26: Year wise effect of fertilizer during intercropping (grass-legumes) on crude fiber of grass (n= 4 SD First year= 2.524 SD Second year= 2.234)

4.2.2.4 Ash

Grass contained significantly higher ash content compared with legumes of the study. Intercropping of grass and legumes decreased ash content in both that generally became significant at 67% level (Table 4.27). Hence, reduction in ash contents could improve the forage quality and increase voluntary intake that is the major factor for determining the digestibility of fodders or forages. Similar positive trend was also found during the second year of study. However this decrease was more in legumes. The effect of fertilizer was more decreasing and clear on monoculture as well as intercropping (Fig. 27, 28 & 29). KAISER and COMBS (1989) noted that legumes forage had lower cell wall contents i.e. NDF (Neutral Detergent Fiber) than that of grass. They also reported more lignifications in grasses than legumes. The present study results were also in agreement of their findings.

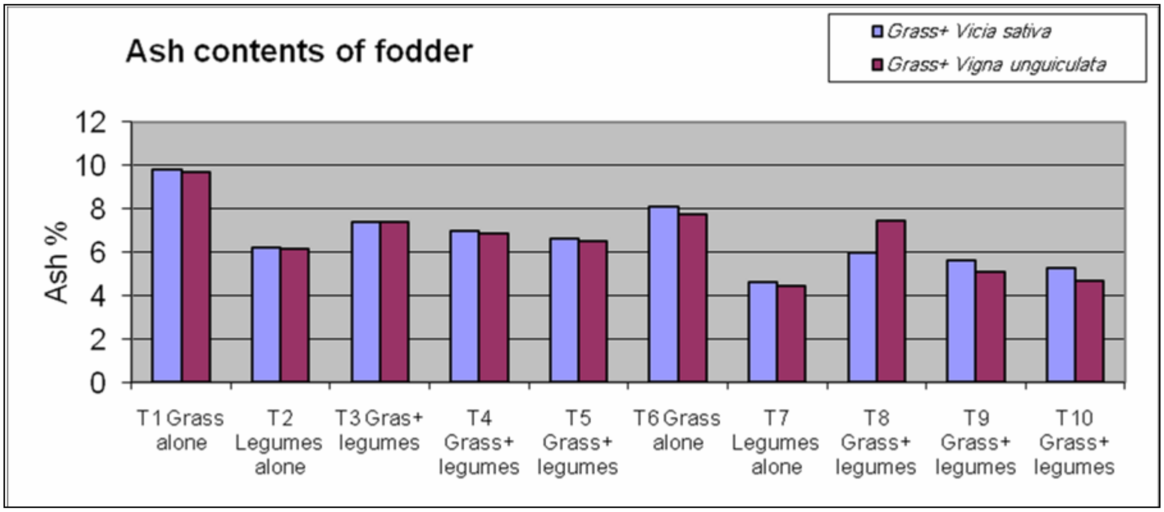


Fig. 27: Effect of intercropping (grass-legumes) and fertilizer on ash content of fodder (n= 4 SD *Vicia sativa* = 0.683 SD *Vigna unguiculata* = 0.563)

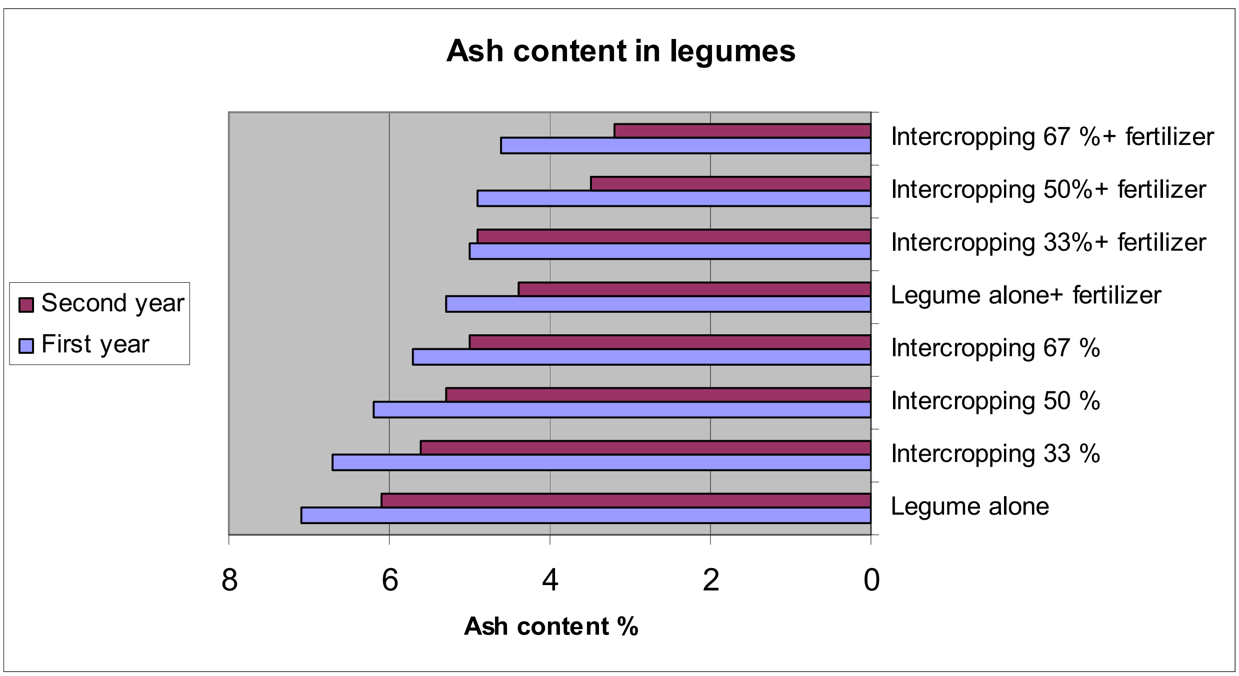


Fig. 28: Year wise comparison of fertilizer effect during intercropping (grass-legumes) on ash content of legumes (n= 4 SD First year= 0.428 SD Second year= 0.623)

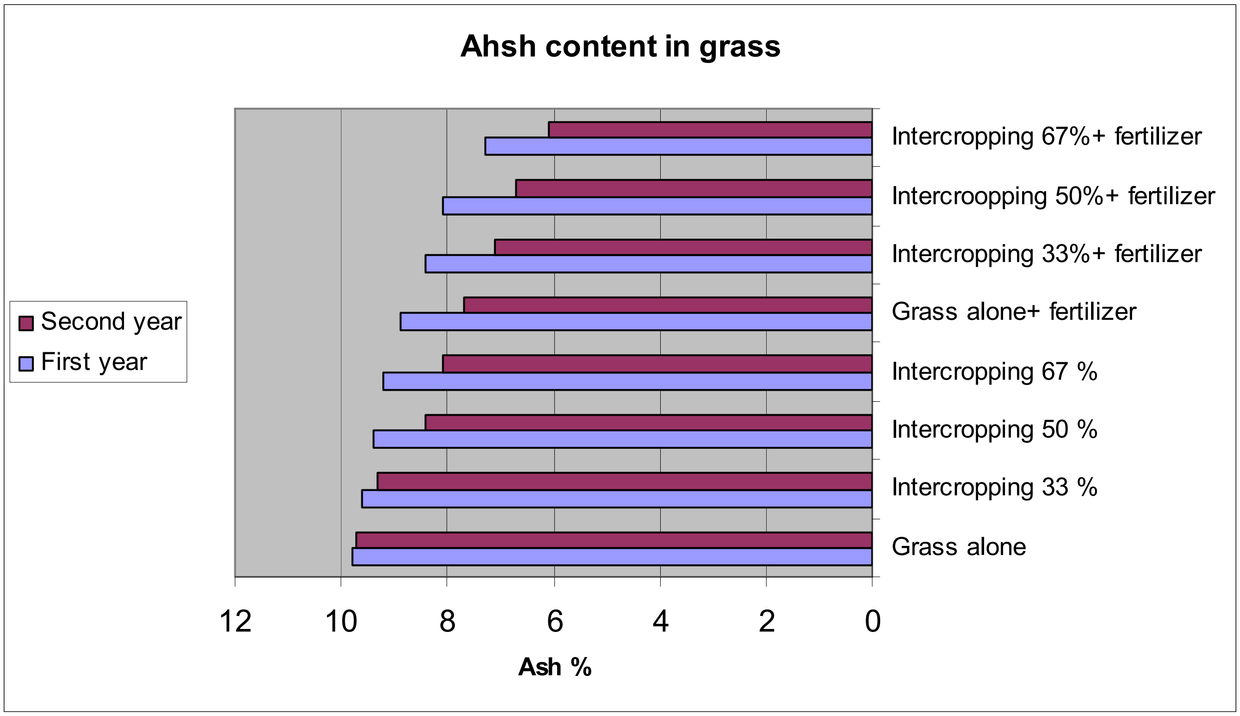


Fig. 29: Year wise comparison of fertilizer effect during intercropping (grass-legumes) on ash content of grass (n= 4 SD First year= 0.621 SD Second year= 0.453)

4.2.2.5 Ether extract

Significant results were recorded in reduction of ether extract by intercropping as well as combination of intercropping and fertilization (Table 4.28). Cowpeas had less ether extract than *Vicia sativa* in the first year while it was opposite in the second year. Data showed decreasing trend in case of grass and legumes but reduction of ether extract was higher in legumes than grasses, especially by the combination of intercropping and fertilization. Similar results were also noted during the second year of the study. Differences of fertilizer combination with intercropping compared with sole intercropping or single treatments were very high and significant.

4.2.2.6 Nitrogen free extracts (NFE)

The main portion of NFE is soluble protein of carbohydrates. Solubility of proteaneous carbohydrates is the important character of forage quality. Nitrogen free compounds increase the digestibility of forage grass as well as forage legumes. Increasing effects were observed in case of grass as well as forage legumes (Table 4.29). Grass had more nitrogen free extract that was improved by the intercropping as well as combination of intercropping and fertilization. Increasing trend was also noted up to the 4^{th} crop. The nitrogen free extract increase was more in legumes than grass due to intercropping fertilizer. The 67% intercropping alone and its combination with fertilizer showed maximum nitrogen free extract in grass as well as forage legumes that might have increased the forage digestibility due to having soluble protein of the carbohydrates. Carbohydrates are the main source of balanced diet of livestock but their digestibility is low due to non solubility of proteins but nitrogen free extract included soluble protein of carbohydrates. AZIM *et al.* (2000) reported that digestibility decreased by the presence of NDF and increasing the maturing stage. So NFE improved the quality of forage by increasing the voluntary intake due to the presence of soluble protein component of carbohydrates.

4.2.2.7 Total digestible nutrients (TDN)

Many different terms are used to designate nutritive value of fodders. These include TDN (Total Digestible Nutrients), digestible energy, digestible proteins, metabolized energy, net energy and efficiency of feed utilization. The feeding value of the forages may be divided into different aspects. A high percentage of protein is required in the diet of ruminants because production of milk and meat as well as reproduction mainly depends on the protein ingredient of the animal diet. Another important factor of feeding value is the digestibility by which animal converts forage to human foods. Digestibility is mainly depends upon the availability of the total digestible nutrients (TDN).

The values of this important parameter were found significantly higher in legumes compared with grass in the study due to presence of more crude protein in legumes as already discussed in section (4.2.2.2). The TDN for livestock in grass were increased when forage legumes were intercropped with grass or further supplemented with fertilizers (Table 4.30). However, increasing effect was found significant only when fertilizer and intercropping were combined together whereas these two factors individually failed to contribute significantly. Such differences were recorded in both the years. But individual impact was exceptionally found significant only in first year cowpeas crop. Maximum TDN values were recorded in case of both the legumes when grown alone (Fig. 30, 31 & 32) but quantum of this parameter decreased non-significantly when intercropping of these legumes was introduced within the grass. FRAME *et al.* (2005) concluded that animal performance enhanced by high intake and nutritive value characteristics of legume – rich diets. LIKHACHEV *et al*. (2003) recorded higher digestibility in legume-grass mixturescompared to pure crops. KAISER and COMBS (1989) and AZIM *et al.* (2000) were also of the view that digestibility of legume and non leguminous mixture was higher than non-leguminous crop that may be due to inclusion of high crude protein legumes.

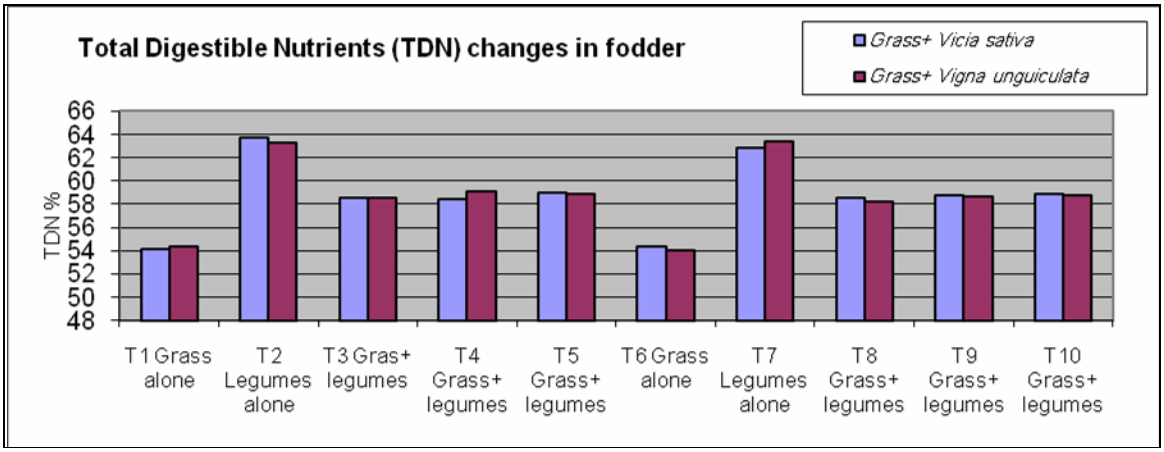


Fig. 30: Effect of intercropping (grass-legumes) and fertilizer on total digestible nutrients (TDN) of fodder (n= 4 SD *Vicia sativa* = 0.862 SD *Vigna unguiculata* = 0.881)

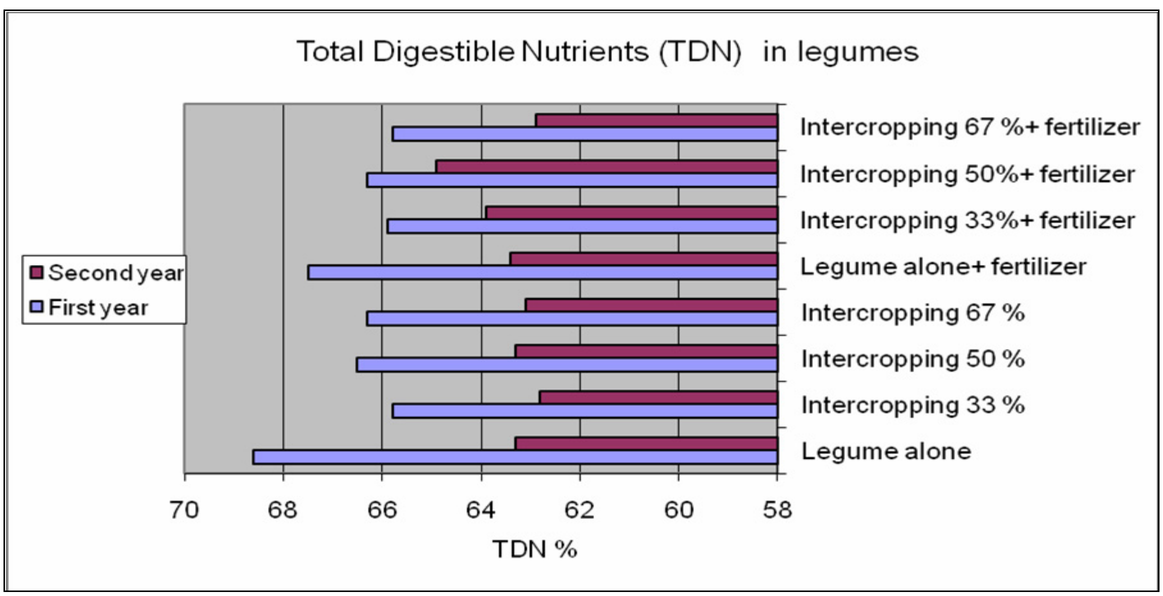


Fig. 31: Year wise comparison intercropping (grass-legumes) alone and coupled with fertilizer on total digestible nutrient (TDN) in legumes (n= 4 SD First year= 1.561 SD Second year= 0.871)

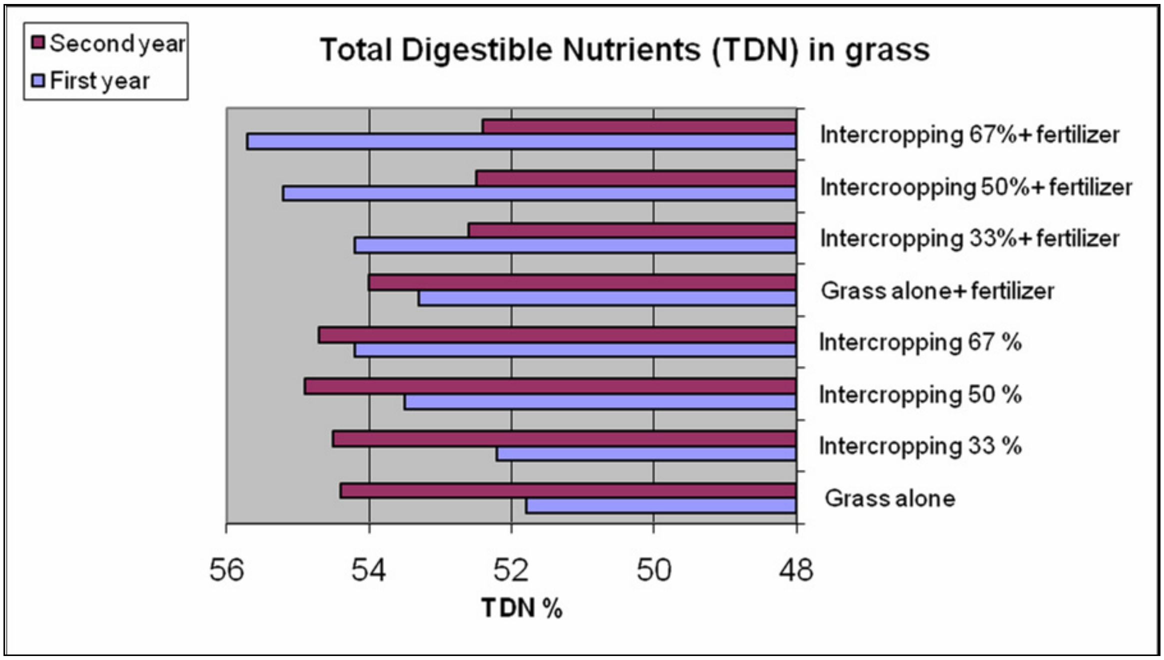


Fig. 32: Year wise effect of intercropping and fertilizer on total digestible nutrients (TDN) content of grass (n= 4 SD First year= 1.231 SD Second year= 0.786)

4.2.3 Soil parameters

When some treatments are employed in any experiment the soil itself is expected to be affected first and then the plants growing on it. The important dynamic characters are either related to salinity/ sodicity/ pH or to availability of nutrients. Therefore ECe, pH, Total N, extractable K, available phosphorus and organic matter were determined in order to understand major soil changes, if any.

4.2.3.1 Soil electrical conductivity (ECe)

The increased soluble salts create salinity/ sodicity problem for the plants growing in that soil conditions.. This study showed non-significant changes in soil ECe when grass/legumes alone or grass-legume mixture were grown and fertilized during the experimental period (Table 4.31). A normal electrical conductivity was recorded under all the treatments that did not disturb the soil quality or crops behavior. Similar results were obtained during both the years of the study. Therefore, intercropping of legumes and fertilization maintained the soil nutrition and increased the biomass production as mentioned in earlier section (4.2.1.3).

4.2.3.2 Soil pH_s

Soil reaction is the most important single chemical characteristics influencing many physical and chemical properties of soil. Plant growth and microorganisms activity largely depends upon soil reaction (pH) and the factors associated with it. Three conditions possible in the soil are: acidity, neutrality and alkalinity. The main effect of soil pH is on the availability of plant nutrients. However, the plants have preference for a specific range of soil pH. It increases or decreases the availability of nutrient elements. Intercropping and combination of intercropping and fertilizers showed normal values of soil pH (Table 4.32). All the soil pH in different treatments remained statistically the same and none of the treatments disturbed it largely.

4.2.3.3. Total nitrogen

Nitrogen makes plant dark green and increases vegetative growth. It increases the protein because nitrogen is the main component of protein and also encourages the good quality of forage. It also improves the cation exchange capacity (CEC) of plant roots that increase the absorbing capacity of other nutrients like phosphorus, potassium and calcium. Nitrogen is the most important part of chlorophyll that increases the photosynthesis process in plant or indirectly produces food in the presence of sunlight for human and livestock sector. Total soil nitrogen recorded in grass grown plots increased when legumes were grown alone or intercropped (Table 4.33). This increase was due to symbiotic N fixation by legumes. Intercropping decreased soil N when it was compared with legumes alone but still it remained higher than grass alone. Both types of result were found to be non-significant in respective comparisons with single grass or legume crops during first crop of *Vicia sativa* but significant in other crops. Addition of fertilizer to grass added nothing in soil N during first two crops but significant increase was recorded during last two crops. Maximum values were observed when intercropping was introduced up to the extent of 67% and fertilizer was supplemented (Fig 33). However, these values of soil N were still found similar with legumes alone. The biomass production was also maximum in this treatment (Section 4.2.1.3) due to which maximum crop residues were also returned into the soil that on decomposition increased soil N in addition to Rhizobial fixation and fertilizer contribution. GIACOMINI et al. (2003) concluded that cultivation of oat, common vetch and oil seed radish was more efficient than single crops since it combined the high biomass production capacity of black oat and oil seed radish with the ability of common vetch to fix atmospheric N_2.

GEHERMAN and PAROL (2004) reported that fertilizer application was one of the main factors affecting the yield of sown pastures by the maximum utilization of readily available nutrients to the crops. BOGOMOLV et al. (2001) recorded that the use of fodder legumes in the grass helped the reduction of mineral N fertilizer application on energy.

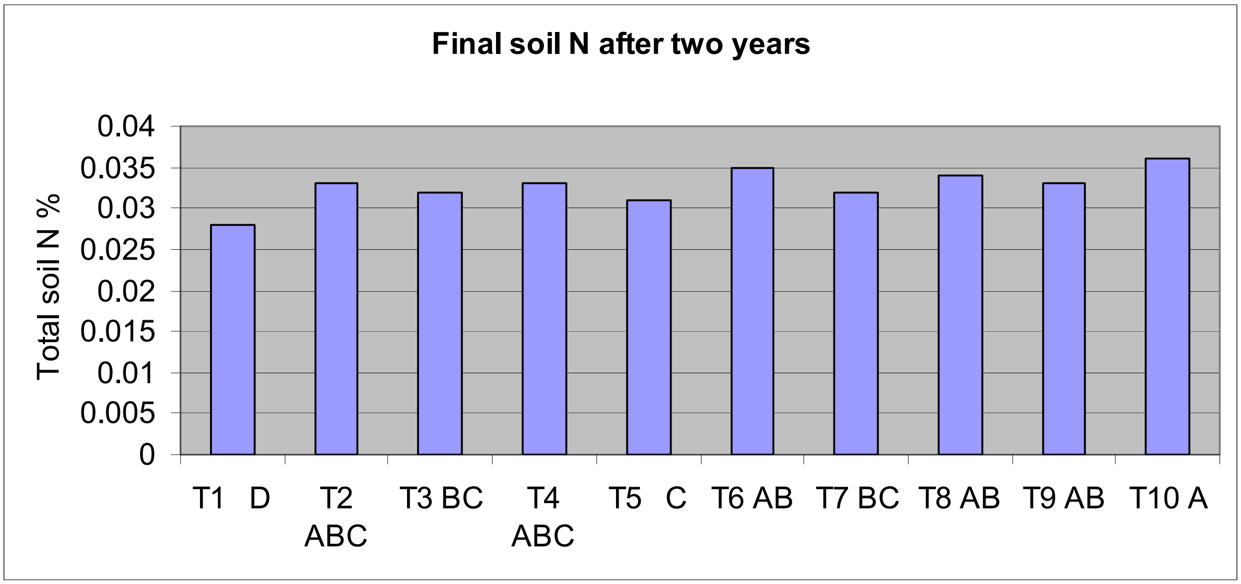


Fig. 33: Effect of intercropping (grass-legumes) and fertilizer after two years on soil nitrogen (n= 4 SD= 0.003)

4.2.3.4 Phosphorus

Phosphorus is the major nutrient of plant that stimulates root formations and growth, helps in cell division, hastens maturity, makes plant more drought resistant and winter hardy and strengthens stem of plants. It also helps in nodule formation of legumes which fix nitrogen. It is very useful for increasing number of tillers in plants.

Non-significant variation of treatments was obtained during soil analysis of different experimental plots in available phosphorus level (Table 4.34). However, maximum values of P were recorded when intercropping of 67% was combined with fertilizer followed by fertilizer alone, the differences remained non-significant. Just a slight increase was recorded due to intercropping. ZHANG and LI (2003) also concluded that Faba bean (leguminous crop) enhanced nitrogen and Phosphorus uptake when intercropped with maize. Chick pea facilitated P uptake by associated wheat. They also reported that intercropping used the soil nutrients more efficiently than sole cropping.

4.2.3.5 Potassium

Potassium is the macronutrient of plants that helps in translocation of food, imparts; vigour, drought resistance and winter hardiness in plants, favors the growth of forage legumes, reduces lodging by producing stiff stalks/stems, increases the availability of other nutrients and size of roots that is helpful for nodulation especially in legume crops.

Fertilizer application, intercropping of legumes with grass and combining of intercropping and fertilization showed non-significant performance in all the treatments (Table 4.35). As the K status of original soil was very low (Table 3.1), hence added P as fertilizer or crop residues was used by the crops of the rotation and could not increase overall P level of the soil. ZIMKOVA *et al* (2002) reported as well that grass-legume intercropping showed positive trend on the availability of soil nutrients.

4.2.3.6 Organic matter

Soil organic matter is a transitory soil constituent and renewed constantly by the addition of plant residues and decomposed subsequently to supply plant nutrients mainly nitrogen, phosphorus, potash and sulphur. It greatly controls soil properties and consequently plant growth. It functions as granulator of mineral particles. It is responsible for the loose, easily managed condition of productive soils. It improves physical condition of soil and increases water holding capacity. Finally, it is the main source of energy for soil microorganisms. Effect of organic matter was noted to be increasing one due to growing of legumes, intercropping of legumes with grass and application of fertilizer but became significant only with combination of intercropping by 67% and fertilizer application when compared with growing of grass alone during first two crops (Table 4.36). However, during the later two crops legumes alone, intercropping and fertilization became significant except intercropping of 33%. Maximum values were recorded when intercropping of 67% was coupled with fertilizer application (Fig 34). The burying in of more crop residues due to increased biomass production in different treatments could only be the reason for enhancement of organic matter status. GODDARD *et al.* (2003) concluded that forage legumes played an important role in the production of organic matter in legume alone as well as legume-grass mixed sown pastures but increase in biomass production.

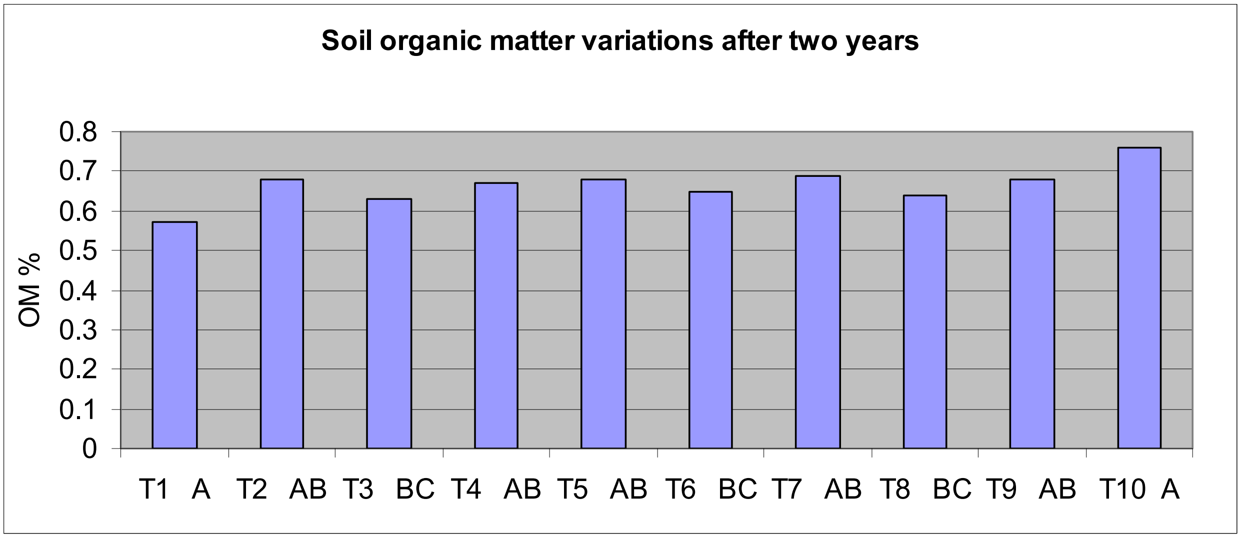


Fig. 34: Effect of intercropping (grass-legumes) and fertilizer after two years on soil organic matter (n= 4 SD= 0.01)

Data Tables

Experiment 1: Growth and yield parameters

Table 4.1: Assessment of inoculation effect on plant height (cm) in grass-legumes intercropping (Experiment 1)

Treatments	**First year (2005-06)**				**Second year (2006-07)**			
	Grass	*Vicia sativa*	Grass	Cowpeas	Grass	*Vicia sativa*	Grass	Cowpeas
T1 Grass alone	114 b	-	166 b	-	103.0 d	-	176.8 c	-
T2 Legume alone	-	44 c	-	184 ab	-	55.00 c	-	115.7 c
T3 Intercropping 33%	117 b	44 c	163 b	182 b	131.0 c	60.33 b	188.0 b	109.0 d
T4 Intercropping 50%	120 b	46 b	184 a	163 c	143.7 b	56.00 c	199.0 ab	130.0 c
T5 Intercropping 67%	118 b	48 b	189 a	158 c	146.0 b	61.33 b	208.0 a	139.3 b
T6 Legume inoculated	-	53 a	-	193 a	-	56.67 c	-	132.0 c
T7 Intercropping 33% + inoculated	120 b	48 b	182 a	180 ab	163.7 a	63.00 a	208.3 a	107.0 d
T8 Intercropping 50% + inoculated	129 a	54 a	191 a	187 a	146.3 b	60.33 b	202.7 a	149.3 b
T9 Intercropping 67% + inoculated	134 a	55 a	196 a	197 a	151.0 b	65.33 a	214.0 a	174.3 a
LSD	9.593	2.969	17.78	12.64	11.45	3.052	16.41	15.12

Table 4.2: Assessment of inoculation effect on number of tillers (per plant) in grass-legumes intercropping (Experiment 1)

Treatments	First year (2005-06)				Second year (2006-07)			
	Grass	*Vicia sativa*	Grass	Cowpeas	Grass	*Vicia sativa*	Grass	Cowpeas
T1 Grass alone	7 d	-	25 d	-	25.33 c	-	24.33 a	-
T2 Legume alone	-	7 d	-	3.00 a	-	10.00 e	-	6.33 NS
T3 Intercropping 33%	7 d	8 c	30 c	2.67 b	30.13 bc	11.00 de	30.33 cd	7.33
T4 Intercropping 50%	8 c	9 b	32 b	2.67 b	38.33 a	12.00 d	35.00 bc	7.00
T5 Intercropping 67%	8 c	10 ab	34 ab	3.00 a	43.33 a	13.67 c	36.67 b	7.00
T6 Legume inoculated	-	10 ab	-	2.00 c	-	12.67 c	-	6.67
T7 Intercropping 33% + inoculated	9 b	10 ab	28 c	2.00 c	37.67 b	13.33 c	28.33 de	7.00
T8 Intercropping 50% + inoculated	10 ab	11 a	37 a	2.00 c	39.33 a	15.00 b	42.33 a	7.67
T9 Intercropping 67% + inoculated	11 a	11 a	38 a	2.67 b	42.00 a	18.00 a	44.67 a	7.33
LSD	0.1616	0.1424	2.044	0.1106	6.902	0.4365	4.963	-

Table 4.3: Assessment of inoculation effect on fresh weight (t ha^{-1}) in grass- legumes intercropping (Experiment 1)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	3.07 e	3.78 e	5.21 f	7.35 e
T2 Legume alone	5.91 d	6.77 d	4.26 g	7.02 e
T3 Intercropping 33%	6.15 d	6.78 d	6.32 e	8.03 d
T4 Intercropping 50%	6.57 d	12.23 bc	7.19 d	9.17 c
T5 Intercropping 67%	7.67 c	12.80 ab	8.58 c	9.37 c
T6 Legume inoculated	8.75 b	11.98 c	5.11 f	8.64 d
T7 Intercropping 33% + inoculated	9.30 b	12.20 bc	8.28 c	9.04 c
T8 Intercropping 50% + inoculated	10.72 a	12.33 abc	10.81 b	11.31 b
T9 Intercropping 67% + inoculated	10.90 a	13.11 a	12.07 a	12.33 a
LSD	0.6681	0.6402	0.5002	0.2750

(Fresh weight included grass and respective legume together)

Table 4.4: Assessment of inoculation effect on dry weight (t ha^{-1}) in grass - legumes intercropping (Experiment 1)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	1.01 e	1.60 e	1.85 c	2.63 d
T2 Legume alone	2.03 d	2.10 d	1.62 d	2.42 d
T3 Intercropping 33%	2.35 cd	4.03 c	2.53 bc	2.71 cd
T4 Intercropping 50%	2.75 bc	4.92 ab	2.62 bc	3.31 bc
T5 Intercropping 67%	2.42 cd	5.17 a	2.99 abc	3.55 b
T6 Legume inoculated	3.03 b	3.92 c	1.87 c	3.12 c
T7 Intercropping 33% + inoculated	3.02 b	4.25 bc	2.82 bc	3.09 c
T8 Intercropping 50% + inoculated	2.59 bc	4.33 bc	3.92 ab	3.86 b
T9 Intercropping 67% + inoculated	4.08 a	5.28 a	4.30 a	4.21 a
LSD	0.4957	0.6405	0.1399	0.3045

(Dry weight included grass and respective legume together)

Table 4.5: Assessment of inoculation effect on number of nodules (one plant roots) in grass- legumes intercropping (Experiment 1)

Treatments	1st Crop (*Vicia sativa*)	2nd Crop (*Vigna unguiculata*)	3rd Crop (*Vicia sativa*)	4th Crop (*Vigna unguiculata*)
T1 Grass alone	-	-	-	-
T2 Legume alone	-	5 c	5.67 f	9.00 e
T3 Intercropping 33%	-	5 c	6.67 e	7.00 f
T4 Intercropping 50%	-	4 d	7.67 d	9.00 e
T5 Intercropping 67%	-	8 b	8.33 d	10.00 d
T6 Legume inoculated	-	6 bc	8.33 d	11.00 c
T7 Intercropping 33% + inoculated	-	8 b	10.33 c	10.33 d
T8 Intercropping 50% + inoculated	-	10 a	11.667b	11.67 b
T9 Intercropping 67% + inoculated	-	11 a	13.00 a	13.33 a
LSD	-	0.1535	0.6460	0.3523

Experiment 1: Forage quality parameters

Table 4.6: Assessment of inoculation effect on moisture content (%) in grass legumes- intercropping (Experiment 1)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	60 ab	58 B	64.33	64.33
T2 Legume alone	63 ab	69 A	61.00	65.33
T3 Intercropping 33%	63 ab	59 B	59.33	66.33
T4 Intercropping 50%	65 ab	66 A	63.67	63.67
T5 Intercropping 67%	59 b	60 B	65.00	64.00
T6 Legume inoculated	67 a	67 A	63.33	65.33
T7 Intercropping 33% + inoculated	64 ab	65 A	65.33	65.33
T8 Intercropping 50% + inoculated	64 ab	65 A	63.67	66.00
T9 Intercropping 67% + inoculated	63 ab	60 B	64.33	66.00
LSD	7.290	6.473	NS	NS

Table 4.7: Assessment of inoculation on proximate composition of crude protein (%) at 50 % flowering (on dry matter basis)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Crude protein Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Crude protein Grass/ Cow peas	Dry Matter Grass/ *Vicia*	Crude protein Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Crude protein Grass/ Cow Peas
T_1	Grass	33.31	5.77 e	34.35	5.77 h	33.43	5.10 g	34.12	5.67 hi
T_2	Legume	36.19	20.03 ab	32.8	19.93 ab	36.02	20.40 bc	32.85	20.37 ab
T_3	Grass	39.69	5.70 e	32.13	6.10 gh	40.13	5.30 fg	32.03	5.63 i
	Legume	37.96	17.70 d	32.63	19.93 e	38.56	18.87 d	32.78	17.60 f
T_4	Grass	32.9	6.10 e	44.36	6.53 fgh	33.04	5.73 efg	43.87	6.33 gh
	Legume	33.64	18.30 cd	33.96	17.93 d	32.97	18.93 d	33.88	18.77 de
T_5	Grass	33.72	6.37 e	33.9	6.90 fg	33.87	5.67 efg	33.95	6.27 ghi
	Legume	32.34	19.03 bc	34.46	18.33 cd	32.43	20.27 c	34.47	19.33 cd
T_6 Inoculation	Legume	34.44	20.60 a	31.94	20.37 a	34.45	20.90 abc	31.89	20.70 a
T_7 Inoculation	Grass	33.59	6.13 e	32.76	6.47 fgh	33.67	5.53 efg	32.03	6.13 hi
	Legume	32.38	19.90 ab	33.91	18.40 cd	32.39	21.47 a	33.14	18.53 e
T_8 Inoculatio n	Grass	34.69	6.27 e	32.61	7.00 fg	34.8	6.03 e	32.65	6.33 gh
	Legume	33.06	20.07 ab	32.04	18.77 cd	33.61	21.03 ab	32.23	19.73 bc
T_9 Inoculation	Grass	33.41	6.73 e	32.47	7.20 f	34.02	6.00 ef	39.97	6.80 g
	Legume	33.61	20.10 ab	32.19	19.17 bc	33.48	20.43 bc	36.78	20.43 a
-	LSD	-	1.138	-	0.7252	-	0.7017	-	0.6627

Table 4.8: Assessment of inoculation on proximate composition of crude fiber (%) at 50 % flowering (on dry matter basis)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Crude Fiber Grass/ *Vicia*	Dry Matter Grass / Cow peas	Crude Fiber Grass/ Cow peas	Dry Matter Grass / *Vicia*	Crude Fiber Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Crude Fiber Grass/ Cow peas
T_1	Grass	33.31	41.87 a	34.35	42.60 a	33.43	42.33 a	34.12	42.33 a
T_2	Legume	36.19	35.03 d	32.8	31.07 c	36.02	34.67 c	32.85	34.67 c
T_3	Grass	39.69	40.90 ab	32.13	41.17 ab	40.13	41.63 a	32.03	41.63 a
	Legume	37.96	37.00 c	32.63	31.63 c	38.56	37.03 b	32.78	37.03 b
T_4	Grass	32.9	41.67 a	44.36	38.27 b	33.04	42.07 a	43.87	42.07 a
	Legume	33.64	36.47 cd	33.96	30.27 c	32.97	36.33 b	33.88	36.33 b
T_5	Grass	33.72	41.03 ab	33.9	41.53 ab	33.87	41.67 a	33.95	41.67 a
	Legume	32.34	32.70 e	34.46	31.67 c	32.43	32.40 d	34.47	32.40 d
T_6	Legume	34.44	33.30 e	31.94	31.00 c	34.45	34.23 c	31.89	34.23 c
T_7	Grass	33.59	40.30 ab	32.76	40.63 ab	33.67	41.37 a	32.03	41.37 a
	Legume	32.38	36.23 cd	33.91	31.33 c	32.39	36.50 b	33.14	36.50 b
T_8	Grass	34.69	40.37 ab	32.61	40.87 ab	34.8	42.23 a	32.65	42.23 a
	Legume	33.06	36.23 cd	32.04	29.90 c	33.61	37.00 b	32.23	37.00 b
T_9	Grass	33.41	39.60 b	32.47	39.90 ab	34.02	42.07 a	39.97	42.07 a
	Legume	33.61	31.73 e	32.19	31.07 c	33.48	32.03 d	36.78	32.03 d
-	LSD	-	1.698	-	2.618	-	1.406	-	2.885

Table 4.9: Assessment of inoculation on proximate composition of ash (%) at 50 % flowering (on dry matter basis)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Ash Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Ash Grass/ Cow peas	Dry Matter Grass/ *Vicia*	Ash Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Ash Grass/ Cow peas
T_1	Grass	33.31	9.83 a	34.35	9.63 a	33.43	9.63 a	34.12	9.50 a
T_2	Legume	36.19	6.63 f	32.8	7.00 ef	36.02	6.00 f	32.85	5.63 e
T_3	Grass	39.69	9.57 a	32.13	9.47 ab	40.13	9.17 ab	32.03	9.07 a
	Legume	37.96	6.33 f	32.63	6.43 fg	38.56	5.20 g	32.78	5.43 e
T_4	Grass	32.9	9.20 b	44.36	9.13 ab	33.04	8.67 bc	43.87	8.13 b
	Legume	33.64	5.90 g	33.96	6.03 g	32.97	5.27 g	33.88	5.53 e
T_5	Grass	33.72	8.80 c	33.9	8.90 bc	33.87	8.17 c	33.95	8.00 b
	Legume	32.34	5.43 h	34.46	5.23 h	32.43	4.73 gh	34.47	4.77 f
T_6	Legume	34.44	5.13 hi	31.94	4.70 hi	34.45	4.40 hi	31.89	4.23 fg
T_7	Grass	33.59	7.80 d	32.76	8.27 cd	33.67	7.33 d	32.03	6.83 c
	Legume	32.38	4.83 i	33.91	4.87 hi	32.39	4.03 ij	33.14	3.83 gh
T_8	Grass	34.69	7.70 d	32.61	7.93 d	34.8	7.17 d	32.65	6.43 cd
	Legume	33.06	4.27 j	32.04	4.73 hi	33.61	3.73 jk	32.23	3.40 hi
T_9	Grass	33.41	6.97 e	32.47	7.13 e	34.02	6.60 e	39.97	6.03 be
	Legume	33.61	4.00 j	32.19	4.50 i	33.48	3.43 k	36.78	3.07 i
-	LSD	-	0.338	-	0.470	-	0.542	-	0.643

Table 4.10: Assessment of inoculation on proximate composition of ether extract (%) at 50 % flowering (on dry matter basis)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Ether extract Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Ether extract Grass/ Cow peas	Dry Matter Grass/ *Vicia*	Ether extract Grass/ *Vicia*	Dry Matter Grass/ Cow peas	Ether extract Grass/ Cow peas
T_1	Grass	33.31	5.73 a	34.35	6.27 a	33.43	3.57 a	34.12	3.53 a
T_2	Legume	36.19	4.67 ef	32.8	5.27 bc	36.02	2.63 bcd	32.85	2.50 b
T_3	Grass	39.69	5.53 ab	32.13	6.20 a	40.13	3.27 a	32.03	3.17 a
	Legume	37.96	4.20 g	32.63	5.03 cd	38.56	2.70 bcd	32.78	2.07 c
T_4	Grass	32.9	5.33 abc	44.36	6.00 a	33.04	2.87 b	43.87	2.67 b
	Legume	33.64	4.27 fg	33.96	4.87 cd	32.97	2.77 bc	33.88	1.83 cd
T_5	Grass	33.72	5.17 bcd	33.9	5.80 ab	33.87	2.47 cd	33.95	2.63 d
	Legume	32.34	4.30fg	34.46	4.10 ef	32.43	1.83 ef	34.47	1.57 de
T_6	Legume	34.44	3.73 hi	31.94	4.10 ef	34.45	1.60 fgh	31.89	1.27 ef
T_7	Grass	33.59	4.7.3 def	32.76	5.27 bc	33.67	2.40 d	32.03	1.10 f
	Legume	32.38	4.17 gh	33.91	3.83 ef	32.39	1.50 fgh	33.14	1.20 ef
T_8	Grass	34.69	5.00 cde	32.61	5.13 bc	34.8	2.00 e	32.65	1.10 f
	Legume	33.06	3.50 ij	32.04	4.33 de	33.61	1.43 gh	32.23	1.33 ef
T_9	Grass	33.41	4.33 fg	32.47	4.83 cd	34.02	1.70 efg	39.97	1.00 f
	Legume	33.61	3.13 j	32.19	3.43 f	33.48	1.27 h	36.78	1.27 ef
-	LSD	-	0.4671	-	0.5289	-	0.3587	-	0.4297

Table 4.11: Assessment of inoculation on proximate composition of nitrogen free extract (%) at 50 % flowering (on dry matter basis)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	N free extract Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	N free extract Grass/ Cow peas	Dry Matter Grass/ *Vicia*	N free extract Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	N free extract Grass/ Cow peas
T_1	Grass	33.31	36.80 defg	34.35	35.73 f	33.43	39.37 ab	34.12	38.17 g
T_2	Legume	36.19	33.63 h	32.8	36.73 ef	36.02	36.30 b	32.85	39.70 fg
T_3	Grass	39.69	38.30 cde	32.13	37.07 def	40.13	40.63 ab	32.03	40.30 ef
	Legume	37.96	34.77 gh	32.63	39.97 abc	38.56	36.20 b	32.78	43.70 cd
T_4	Grass	32.9	37.70 de	44.36	36.73 ef	33.04	40.67 ab	43.87	40.60 ef
	Legume	33.64	35.07 fgh	33.96	40.90 abc	32.97	36.70 b	33.88	43.87 cd
T_5	Grass	33.72	38.63 bcd	33.9	36.87 def	33.87	42.03 ab	33.95	41.03 ef
	Legume	32.34	38.53 cd	34.46	40.67 abc	32.43	40.77 ab	34.47	43.67 cd
T_6	Legume	34.44	37.23 def	31.94	39.83 abc	34.45	38.87 ab	31.89	43.20 cd
T_7	Grass	33.59	41.03abc	32.76	39.37 bcd	33.67	43.37 ab	32.03	44.70 abc
	Legume	32.38	34.53 gh	33.91	41.57 abc	32.39	36.50 b	33.14	45.97 ab
T_8	Grass	34.69	40.67 abc	32.61	39.07 cde	34.8	421.57 ab	32.65	44.43 bc
	Legume	33.06	35.93 efgh	32.04	42.27 a	33.61	46.80 a	32.23	46.53 ab
T_9	Grass	33.41	42.37 a	32.47	40.93 abc	34.02	43.63 ab	39.97	44.17 bc
	Legume	33.61	41.03 ab	32.19	41.83 ab	33.48	42.83 ab	36.78	42.20 de
-	LSD	-	2.412	-	1.875	-	8.072	-	1.935

Table 4.12: Assessment of inoculation on proximate composition of total digestible nutrients (TDN %) at 50 % flowering (on dry matter basis)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	TDN Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	TDN Grass/ Cow peas	Dry Matter Grass/ *Vicia*	TDN Grass/ *Vicia*	Dry Matter Grass / Cowpeas	TDN Grass/ Cowpeas
T_1	Grass	33.31	53.43 e	34.35	52.70 h	33.43	54.57 e	34.12	54.77 d
T_2	Legume	36.19	67.50 ab	32.8	68.73 a	36.02	63.63 a	32.85	63.90 b
T_3	Grass	39.69	53.53 e	32.13	53.00 h	40.13	54.47 e	32.03	54.67 d
	Legume	37.96	64.87 c	32.63	65.90 cd	38.56	63.07 abc	32.78	62.90 c
T_4	Grass	32.9	54.33 be	44.36	54.07 g	33.04	54.70 e	43.87	55.03 d
	Legume	33.64	65.50 c	33.96	66.77 bc	32.97	63.27 abc	33.88	63.37 bc
T_5	Grass	33.72	54.83 de	33.9	54.83 fg	33.87	54.47 e	33.95	54.93 d
	Legume	32.34	66.47 abc	34.46	65.90 cd	32.43	63.30 abc	34.47	63.40 bc
T_6	Legume	34.44	66.33 abc	31.94	67.47 b	34.45	62.90 bcd	31.89	63.80 bc
T_7	Grass	33.59	55.13 de	32.76	54.87 fg	33.67	54.63 e	32.03	53.30 e
	Legume	32.38	68.03 a	33.91	65.83 cd	32.39	62.63 cd	33.14	63.53 bc
T_8	Grass	34.69	55.07 de	32.61	55.67 ef	34.8	54.40 e	32.65	53.37 e
	Legume	33.06	65.70 bc	32.04	67.13 b	33.61	62.43 d	32.23	64.93 a
T_9	Grass	33.41	56.10 d	32.47	56.20 e	34.02	54.13 e	39.97	54.50 e
	Legume	33.61	65.77 bc	32.19	65.73 d	33.48	63.60 ab	36.78	63.47 bc
-	LSD	-	1.898	-	1.036	-	0.7096	-	0.9608

Experiment 1: Soil parameters

Table 4.13: Assessment of inoculation effect on soil EC_e (dsm^{-1}) in grass-legumes intercropping (Experiment 1)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	0.46 NS	0.47 NS	0.49 NS	0.47 NS
T2 Legume alone	0.49	0.49	0.47	0.48
T3 Intercropping 33%	0.48	0.50	0.51	0.50
T4 Intercropping 50%	0.49	0.51	0.52	0.53
T5 Intercropping 67%	0.50	0.48	0.50	0.51
T6 Legume inoculated	0.48	0.50	0.52	0.54
T7 Intercropping 33% + inoculated	0.46	0.48	0.48	0.49
T8 Intercropping 50% + inoculated	0.50	0.46	0.49	0.48
T9 Intercropping 67% + inoculated	0.50	0.49	0.50	0.51

Original Soil ECe = 0.53 dSm^{-1}

Table 4.14: Assessment of inoculation effect on soil pH in grass- legumes intercropping (Experiment 1)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	8.3 NS	8.2 NS	8.0 NS	8.4 NS
T2 Legume alone	8.2	8.3	8.2	8.3
T3 Intercropping 33%	8.4	8.4	8.4	8.2
T4 Intercropping 50%	8.4	8.2	8.4	8.3
T5 Intercropping 67%	8.4	8.3	8.3	8.4
T6 Legume inoculated	8.4	8.3	8.3	8.3
T7 Intercropping 33% + inoculated	8.2	8.4	8.4	8.4
T8 Intercropping 50% + inoculated	8.3	8.3	8.4	8.4
T9 Intercropping 67% + inoculated	8.4	8.4	8.4	8.4

Original Soil pH = 8.4

Table 4.15: Assessment of inoculation effect on total N (%) in grass- legumes intercropping (Experiment 1)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	0.028 NS	0.027e	0.025e	0.026d
T2 Legume alone	0.033	0.039abc	0.034de	0.039bc
T3 Intercropping 33%	0.029	0.031cd	0.033bc	0.034d
T4 Intercropping 50%	0.030	0.033cde	0.037abc	0.038bcd
T5 Intercropping 67%	0.031	0.034bcd	0.038bcd	0.044abc
T6 Legume inoculated	0.034	0.043a	0.046a	0.054a
T7 Intercropping 33% + inoculated	0.032	0.037bcd	0.042abcd	0.037bcd
T8 Intercropping 50% + inoculated	0.033	0.040ab	0.045ab	0.048ab
T9 Intercropping 67% + inoculated	0.034	0.039abc	0.044abcd	0.049ab
LSD	-	0.007	0.008	0.013

Original total N = 0.037%

Table 4.16: Assessment of inoculation effect on soil available P (ppm) in grass- legumes intercropping (Experiment 1)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	3.93NS	3.99NS	3.96NS	3.96NS
T2 Legume alone	3.53	3.85	3.81	3.73
T3 Intercropping 33%	4.13	4.23	4.23	4.20
T4 Intercropping 50%	4.60	4.73	4.56	4.63
T5 Intercropping 67%	3.83	4.03	3.93	3.93
T6 Legume inoculated	3.87	4.07	3.97	3.97
T7 Intercropping 33% + inoculated	3.80	4.00	3.88	3.89
T8 Intercropping 50% + inoculated	3.87	4.10	3.97	3.98
T9 Intercropping 67% + inoculated	3.93	4.30	4.03	3.99

Available P (ppm) = 4.70ppm

Table 4.17: Assessment of inoculation effect on extractable K (ppm) in grass- legumes intercropping (Experiment 1)

Treatments	**1st Crop**	**2nd Crop**	**3rd Crop**	**4th Crop**
T1 Grass alone	68.7 NS	68.9 NS	70.1 NS	69.2 NS
T2 Legume alone	67.8	67.9	68.2	68.0
T3 Intercropping 33%	68.3	68.6	68.8	68.6
T4 Intercropping 50%	69.3	69.5	69.4	69.4
T5 Intercropping 67%	68.1	68.2	68.8	68.4
T6 Legume inoculated	69.0	69.3	69.5	69.3
T7 Intercropping 33% + inoculated	68.3	68.8	68.6	68.6
T8 Intercropping 50% + inoculated	65.1	66.2	66.8	66.0
T9 Intercropping 67% + inoculated	68.8	69.2	69.3	69.1

Extractable K (ppm) = 79.6 ppm

Table 4.18: Assessment of inoculation effect on organic matter (%) in grass- legumes intercropping (Experiment 1)

Treatments	**1st Crop**	**2nd Crop**	**3rd Crop**	**4th Crop**
T1 Grass alone	0.55NS	0.54d	0.55c	0.56c
T2 Legume alone	0.66	0.69abc	0.81ab	0.89a
T3 Intercropping 33%	0.58	0.62cd	0.65bc	0.70bc
T4 Intercropping 50%	0.60	0.65bcd	0.71abc	0.72abc
T5 Intercropping 67%	0.63	0.68abc	0.78ab	0.82abc
T6 Legume inoculated	0.67	0.77ab	0.76abc	0.91a
T7 Intercropping 33% + inoculated	0.61	0.78ab	0.81ab	0.72abc
T8 Intercropping 50% + inoculated	0.65	0.79a	0.88a	0.89a
T9 Intercropping 67% + inoculated	0.68	0.76ab	0.85ab	0.86ab
LSD	-	0.1340	0.2250	0.1450

Organic Matter = 0.53 %

Experiment 2: Growth and yield parameters

Table 4.19: Evaluation of fertilizer effect on plant height (cm) in grass-legumes intercropping (Experiment 2)

	First year (2005-06)				Second year (2006-07)			
	Grass	*Vicia sativa*	Grass	Cowpeas	Grass	*Vicia sativa*	Grass	Cowpeas
T1 Grass alone	100 d	-	167 b	-	103.7e	-	175.0d	-
T2 Legume alone	-	39 c	-	125 b	-	56.00	-	128.0b
T3 Intercropping 33%	120 b	44 b	180 a	101 c	131.3c	64.00	187.7c	107.7c
T4 Intercropping 50%	123 b	43 b	186 a	115 b	142.7b	57.00	200.0c	131.7b
T5 Intercropping 67%	131 a	44 b	191 a	120 b	147.0a	51.00	217.3b	140.7b
T6 Grass + Fertilizer	115 c	-	168 b	-	119.7d	-	178.0d	-
T7 Legume + Fertilizer	-	44 b	-	141 a	-	62.33	-	165.7a
T8 Intercropping 33%+ Fertilizer	127 ab	45 b	185 a	122 b	142.0b	64.33	199.3c	134.3b
T9 Intercropping 50% + Fertilizer	136 a	48 a	189 a	138 a	148.3a	64.67	222.7b	156.3a
T10 Intercropping 67% + Fertilizer	136 a	51 a	195 a	151 a	151.0a	68.33	237.7a	170.7a
LSD	6.996	3.489	22.21	18.31	3.894	-	14.34	14.66

Table 4.20: Evaluation of fertilizer effect on number of tillers (plant^{-1}) in grass-legumes intercropping (Experiment 2)

	First year (2005-06)				Second year (2006-07)			
	Grass	*Vicia sativa*	Grass	Cowpeas	Grass	*Vicia sativa*	Grass	Cowpeas
T1 Grass alone	11 c	-	23 c	-	25.00d	-	25.00e	-
T2 Legume alone	-	9 b	-	3 b	-	10.00c	-	6.33c
T3 Intercropping 33%	11 c	9 b	27 b	3 b	31.67c	11.00c	31.00c	7.67b
T4 Intercropping 50%	12 b	9 b	28 b	2.67 b	38.00b	12.00bc	34.00b	6.00b
T5 Intercropping 67%	13 b	10 a	30 a	2.67 b	40.67ab	14.67ab	36.67b	6.33b
T6 Grass + Fertilizer	13 b	-	26 b	-	30.00c	-	28.00d	-
T7 Legume + Fertilizer	-	10 a	-	4 ab	-	13.33bc	-	8.00b
T8 Intercropping 33%+ Fertilizer	13 b	10 a	30 a	4 ab	38.67ab	12.33bc	36.67b	8.67a
T9 Intercropping 50% + Fertilizer	15 a	11 a	32 a	5 a	41.33ab	13.33bc	39.00a	10.33a
T10 Intercropping 67% + Fertilizer	16 a	11 a	34 a	4.67 a	43.33a	17.00a	40.67a	11.33a
LSD	1.96	1.77	5.49	1.44	4.7	3.50	3.42	2.89

Table 4.21: Evaluation of fertilizer effect on fresh weight (t ha^{-1}) in grass-legumes intercropping (Experiment 2)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	5.13 i	4.40 g	5.36f	7.67g
T2 Legume alone	5.62 h	4.75 fg	4.28g	7.53h
T3 Intercropping 33%	5.93 g	5.42 e	6.34e	8.25f
T4 Intercropping 50%	7.00 f	8.58 d	7.22d	9.34d
T5 Intercropping 67%	7.37 e	10.03 b	8.58c	10.08c
T6 Grass + Fertilizer	7.77 d	5.93 e	6.37e	9.20d
T7 Legume + Fertilizer	7.84 cd	8.82 cd	5.25f	8.79e
T8 Intercropping 33%+ Fertilizer	7.98 c	8.97 bcd	8.24c	10.42c
T9 Intercropping 50% + Fertilizer	9.47 b	9.63 bc	10.94b	11.61b
T10 Intercropping 67% + Fertilizer	9.70 a	12.38 a	12.30a	12.57a
LSD	0.1394	0.7980	0.5895	0.3970

(Fresh weight included grass and respective legume together)

Table 4.22: Evaluation of fertilizer effect on dry weight (t ha^{-1}) in grass-legumes intercropping (Experiment 2)

Treatments	1st Crop	2nd Crop	3rd Crop	4th Crop
T1 Grass alone	1.56 e	1.90 g	1.87g	2.57f
T2 Legume alone	1.91 d	1.83 g	1.51g	2.71f
T3 Intercropping 33%	1.95 d	2.38 i	2.19f	2.95ef
T4 Intercropping 50%	2.16 d	3.65 d	2.50b	3.22d
T5 Intercropping 67%	2.29 d	4.53 d	2.93c	3.60c
T6 Grass + Fertilizer	2.41 c	2.50 i	2.20e	3.22d
T7 Legume + Fertilizer	2.71 b	2.63 i	1.80g	3.07de
T8 Intercropping 33%+ Fertilizer	3.00 a	3.10 d	2.94c	3.67bc
T9 Intercropping 50% + Fertilizer	3.03 a	4.02 d	3.91b	3.84b
T10 Intercropping 67% + Fertilizer	3.47 a	5.60 a	4.51a	4.14a
LSD	0.5715	0.7780	0.2878	0.2385

(Dry weight included grass and respective legume together)

Table 4.23: Evaluation of fertilizer effect on number of nodules (one plant roots) in grass-legumes intercropping (Experiment 2)

Treatments	1st Crop (*Vicia sativa*)	2nd Crop (*Vigna unguiculata*)	3rd Crop (*Vicia sativa*)	4th Crop (*Vigna unguiculata*)
T1 Grass alone	-	-	-	-
T2 Legume alone	-	4 NS	5.33b	7.33
T3 Intercropping 33%	-	3	6.67b	6.00
T4 Intercropping 50%	-	4	7.67a	5.00
T5 Intercropping 67%	-	4	7.66a	5.67
T6 Grass + Fertilizer	-	-	5.00c	-
T7 Legume + Fertilizer	-	3	6.00b	5.33
T8 Intercropping 33%+ Fertilizer	-	3	6.67b	5.00
T9 Intercropping 50% + Fertilizer	-	3	7.00b	4.67
T10 Intercropping 67% + Fertilizer	-	4	8.79a	4.33
LSD	-	-	0.1693	-

Experiment 2: Forage quality parameters

Table 4.24: Evaluation of fertilizer effect on moisture contents (%) in grass-legumes intercropping (Experiment 2)

Treatments	**1st Crop**	**2nd Crop**	**3rd Crop**	**4th Crop**
T1 Grass alone	64 bc	57 b	65 NS	64bc
T2 Legume alone	65 c	61 ab	65	62c
T3 Intercropping 33%	68 abc	56 b	65	64bc
T4 Intercropping 50%	66 bc	57 b	65	65ab
T5 Intercropping 67%	63 bc	55 b	66	64bc
T6 Grass + Fertilizer	67 bc	58 ab	65	65ab
T7 Legume + Fertilizer	61 c	70 a	66	65ab
T8 Intercropping 33%+ Fertilizer	61 c	65 a	65	65ab
T9 Intercropping 50% + Fertilizer	71 a	58 ab	64	67a
T10 Intercropping 67% + Fertilizer	75 a	55 b	63	66ab
LSD	8.771	7.837	-	2.363

Table 4.25: Evaluation of fertilizer on proximate composition of crude protein (%) at 50 % flowering (on dry matter basis, Experiment 2)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Crude protein Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Crude protein Grass/ Cow peas	Dry Matter Grass/ *Vicia*	Crude protein Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Crude protein Grass/ Cow peas
T1	Grass	33.15	5.00 f	34.4	5.57 i	33.75	4.91 d	33.61	5.17 fg
T2	Legume	32.35	19.83 ab	36.5	19.37 ab	36.34	20.23 b	32.73	19.70 ab
T3	Grass	34.31	5.50 ef	33.73	5.80 hi	34.01	5.10 d	32.37	5.33 fg
	Legume	32.26	17.43 d	34.36	16.70 f	35.33	18.67 c	34.33	17.23 d
T4	Grass	34.17	5.87 ef	34.49	6.30 ghi	34.53	5.53 d	32.16	6.07 efg
	Legume	32.22	18.03 cd	33.4	17.40 ef	33.87	18.73 c	34.72	18.20 cd
T5	Grass	33.17	6.10 ef	33.89	6.60 gh	33.08	5.47 d	33.81	6.00 efg
	Legume	33.3	18.80 bc	33.25	18.13 cde	32.87	20.07 b	33.25	19.03 bc
T6	Grass	34.04	5.30 ef	33.03	5.67 i	32.99	5.10 d	34.12	5.10 g
T7	Legume	30.9	20.30 a	32.29	20.07 a	33.8	20.63 ab	30.97	20.33 a
T8	Grass	32.48	5.87 ef	32.47	6.13 ghi	32.01	5.23 d	32.03	5.73 efg
	Legume	31.88	19.40 ab	33.75	18.03 de	33.87	21.20 a	32.11	18.27 c
T9	Grass	34.58	6.10 ef	31.76	6.67 g	31.33	5.70 d	34.87	6.13 ef
	Legume	33.4	19.77 ab	31.39	18.43 cd	31.45	20.73 ab	33.44	19.63 ab
T 10	Grass	35.08	6.37 e	33.23	6.90 g	33.72	5.67 d	35.01	6.40 e
	Legume	34.07	19.77 ab	31.37	18.87 bc	31.88	20.07 b	34.71	19.87 ab
-	**LSD**	-	1.20	-	0.834	-	0.677	-	0.747

Table 4.26: Evaluation of fertilizer on proximate composition of crude fiber (%) at 50 % flowering (on dry matter basis, Experiment 2)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Crude Fiber Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Crude Fiber Grass/ Cow peas	Dry Matter Grass/ *Vicia*	Crude Fiber Grass/ *Vicia*	Dry Matter Grass/ Cow peas	Crude Fiber Grass/ Cow peas
T1	Grass	33.15	42.13 a	34.4	42.90 a	33.75	42.63 a	33.61	43.27 a
T2	Legume	32.35	35.27 de	36.5	31.27 bef	36.34	34.93 bc	32.73	31.70 bc
T3	Grass	34.31	41.13 abc	33.73	41.47 bc	34.01	41.83 a	32.37	42.03 a
	Legume	32.26	37.20 abcde	34.36	31.97 d	35.33	37.33 b	34.33	31.43 bc
T4	Grass	34.17	41.83 ab	34.49	41.83 ab	34.53	42.27 a	32.16	42.50 a
	Legume	32.22	36.83 abcde	33.4	30.53 ef	33.87	36.60 bc	34.72	30.20 c
T5	Grass	33.17	41.27 abc	33.89	41.70 ab	33.08	42.03 a	33.81	42.30 a
	Legume	33.3	32.90 e	33.25	31.97 d	32.87	35.87 bc	33.25	30.90 c
T6	Grass	34.04	40.77 abce	33.03	41.77 ab	32.99	41.90 ab	34.12	42.00 a
T7	Legume	30.9	33.53 e	32.29	31.23 def	33.8	34.57 bc	30.97	30.87 c
T8	Grass	32.48	40.43 abcd	32.47	40.93 bc	32.01	41.67 a	32.03	41.40 a
	Legume	31.88	36.40 bcde	33.75	31.57 de	33.87	36.40 bc	32.11	31.03 c
T9	Grass	34.58	40.53 abcd	31.76	41.30 bc	31.33	42.53 a	34.87	41.87 a
	Legume	33.4	35.83 cde	31.39	30.10 f	31.45	37.30 b	33.44	29.30 c
T 10	Grass	35.08	40.03 abcd	33.23	40.30 c	33.72	42.30 a	35.01	42.63 a
	Legume	34.07	31.93 e	31.37	31.33 def	31.88	32.30 c	34.71	33.53 b
-	LSD	-	4.162	-	1.251	-	2.898	-	1.844

Table 4.27: Evaluation of fertilizer on proximate composition of ash (%) at 50 % flowering (on dry matter basis, Experiment 2)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Ash content Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Ash content Grass/ Cow peas	Dry Matter Grass/ *Vicia*	Ash content Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Ash content Grass/ Cow peas
T1	Grass	33.15	9.80 a	34.4	9.80 a	33.75	9.83 a	33.61	9.70 a
T2	Legume	32.35	6.83 e	36.5	7.10 fg	36.34	6.20 g	32.73	6.13 ef
T3	Grass	34.31	9.73 a	33.73	9.57 ab	34.01	9.40 ab	32.37	9.27 a
	Legume	32.26	6.57 e	34.36	6.70 gh	35.33	5.40 h	34.33	5.57 fg
T4	Grass	34.17	9.40 ab	34.49	9.40 abc	34.53	8.67 bc	32.16	8.37 b
	Legume	32.22	6.13 f	33.4	6.23 h	33.87	5.30 h	34.72	5.33 g
T5	Grass	33.17	9.00 b	33.89	9.20 bc	33.08	8.37 cd	33.81	8.13 b
	Legume	33.3	5.70 g	33.25	5.67 i	32.87	4.93 hi	33.25	4.97 gh
T6 Fertilizers	Grass	34.04	8.50 c	33.03	8.90 cd	32.99	8.10 d	34.12	7.73 bc
T7 Fertilizers	Legume	30.9	5.10 h	32.29	5.30 ij	33.8	4.60 ij	30.97	4.43 hi
T8 Fertilizers	Grass	32.48	7.83 d	32.47	8.43 de	32.01	7.77 de	32.03	7.07 cd
	Legume	31.88	4.80 h	33.75	5.03 jk	33.87	4.20 jk	32.11	4.87 i
T9 Fertilizers	Grass	34.58	7.60 d	31.76	8.07 e	31.33	7.20 ef	34.87	6.67 de
	Legume	33.4	4.33 i	31.39	4.87 jk	31.45	4.07 jk	33.44	3.50 j
T10 Fertilizers	Grass	35.08	7.57 b	33.23	7.30 f	33.72	6.80 fg	35.01	6.17 ef
	Legume	34.07	4.20 i	31.37	4.57 k	31.88	3.80 k	34.71	3.20 j
-	**LSD**	-	0.3164	-	0.5403	-	0.6833	-	0.5630

Table 4.28: Fertilizer effect on proximate composition of ether extract (%) at 50% flowering (on dry matter basis, Experiment 2)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	Ether extract Grass/ *Vicia*	Dry Matter Grass/ Cow Peas	Ether extract Grass/ Cow peas	Dry Matter Grass/ *Vicia*	Ether extract Grass/ *Vicia*	Dry Matter Grass/ Cow peas	Ether extract Grass/ Cow peas
T1	Grass	33.15	5.93 a	34.4	6.57 a	33.75	3.77 a	33.61	3.47 a
T2	Legume	32.35	4.73 cdefg	36.5	5.43 de	36.34	2.80 cde	32.73	2.37 de
T3	Grass	34.31	5.73 ab	33.73	6.40 ab	34.01	3.50 ab	32.37	3.20 ab
	Legume	32.26	4.53 defg	34.36	5.23 e	35.33	2.63 cde	34.33	2.10 de
T4	Grass	34.17	5.53 abc	34.49	6.20 abc	34.53	3.13 bc	32.16	2.87 bc
	Legume	32.22	4.33 efgh	33.4	5.03 e	33.87	2.33 ef	34.72	1.90 ef
T5	Grass	33.17	5.33 abcd	33.89	6.00 bc	33.08	2.90 cd	33.81	2.57 cd
	Legume	33.3	4.13 fghi	33.25	4.53 f	32.87	2.03 fgh	33.25	1.73 fg
T6	Grass	34.04	5.13 abcde	33.03	5.80 cd	32.99	2.73 cde	34.12	2.20 de
T7	Legume	30.9	3.93 ghi	32.29	4.33 fd	33.8	1.73 ghi	30.97	1.20 gh
T8	Grass	32.48	4.93 bcdef	32.47	5.47 be	32.01	2.50 def	32.03	0.90 hi
	Legume	31.88	4.40 defgh	33.75	4.13 fg	33.87	1.57 hi	32.11	1.90 ef
T9	Grass	34.58	5.07 abcdef	31.76	5.27 e	31.33	2.10 fg	34.87	0.80 hi
	Legume	33.4	3.53 hi	31.39	3.93 gh	31.45	1.50 i	33.44	1.60 fg
T 10	Grass	35.08	4.53 defg	33.23	5.07 e	33.72	1.73 ghi	35.01	0.67 i
	Legume	34.07	3.27 i	31.37	3.60 h	31.88	1.37 i	34.71	1.13 ghi
-	**LSD**	-	0.7153	-	0.4505	-	0.3729	-	0.3576

Table 4.29: Fertilizer effects on proximate composition of nitrogen free extract (NFE %) at 50 % flowering (on dry matter basis, Experiment 2)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass / *Vicia*	NFE Grass/ *Vicia*	Dry Matter Grass / Cow peas	NFE Grass/ Cow peas	Dry Matter Grass/ *Vicia*	NFE Grass/ *Vicia*	Dry Matter Grass / Cow peas	NFE Grass/ Cow peas
T1	Grass	33.15	36.90 ef	34.4	35.17 i	33.75	38.87 bcdef	33.61	38.40 f
T2	Legume	32.35	33.33 h	36.5	36.83 h	36.34	35.83 f	32.73	40.10ef
T3	Grass	34.31	37.87 be	33.73	36.77 hi	34.01	40.17 abcde	32.37	40.17ef
	Legume	32.26	34.30 gh	34.36	39.40 defg	35.33	35.97 f	34.33	43.67bc
T4	Grass	34.17	37.37 e	34.49	36.27 hi	34.53	40.20 abcde	32.16	40.20ef
	Legume	32.22	34.67 fgh	33.4	40.80 bcd	33.87	37.03 def	34.72	44.37abc
T5	Grass	33.17	38.30 cde	33.89	36.50 hi	33.08	41.23 abc	33.81	41.00 be
	Legume	33.3	38.47 bcde	33.25	39.70 cdef	32.87	400.43 abcd	33.25	43.57 bc
T6	Grass	34.04	40.20 abcd	33.03	37.87 gh	32.99	42.17 abc	34.12	42.97 bcd
T7	Legume	30.9	36.93 ef	32.29	39.07 efg	33.8	38.47 cdef	30.97	43.17 bcd
T8	Grass	32.48	40.63 abc	32.47	39.03 efg	32.01	42.83 ab	32.03	44.90 ab
	Legume	31.88	34.80 fgh	33.75	41.23 abc	33.87	36.63 def	32.11	44.93 ab
T9	Grass	34.58	40.43 abc	31.76	38.70 fg	31.33	35.80 f	34.87	44.53 abc
	Legume	33.4	36.20 efg	31.39	42.67 a	31.45	36.40 ef	33.44	46.30 a
T 10	Grass	35.08	41.83 a	33.23	40.43 bcde	33.72	43.50 a	35.01	44.13 abc
	Legume	34.07	40.70 ab	31.37	41.63 ab	31.88	42.47 abc	34.71	42.27 cde
-	**LSD**	-	1.752	-	1.612	-	2.976	-	1.765

Table 4.30: Evaluation of fertilizer on proximate composition of total digestible nutrients (TDN %) at 50 % flowering (on dry matter basis, Experiment 2)

Treatments		First year (2005-06)				Second year (2006-07)			
		Dry Matter Grass/ *Vicia*	TDN Grass/ *Vicia*	Dry Matter Grass / Cow Peas	TDN Grass/ Cow peas	Dry Matter Grass / *Vicia*	TDN Grass/ *Vicia*	Dry Matter Grass/ Cow peas	TDN Grass/ Cow peas
T1	Grass	33.15	52.03 d	34.4	51.83 h	33.75	54.17 c	33.61	54.37 d
T2	Legume	32.35	67.47 a	36.5	68.60 a	36.34	63.67 a	32.73	63.33 bc
T3	Grass	34.31	52.93 cd	33.73	52.20 gh	34.01	54.33 c	32.37	54.50 d
	Legume	32.26	65.27 a	34.36	65.83 c	35.33	62.73 ab	34.33	62.67 c
T4	Grass	34.17	53.83 bcd	34.49	53.47 f	34.53	54.63 c	32.16	54.93 d
	Legume	32.22	65.40 a	33.4	66.53 bc	33.87	62.30 b	34.72	63.33 bc
T5	Grass	33.17	54.33 bcd	33.89	54.17 ef	33.08	54.63 c	33.81	54.70 b
	Legume	33.3	65.87 a	33.25	66.27 bc	32.87	63.37 ab	33.25	63.10 bc
T6	Grass	34.04	53.73 bcd	33.03	53.27 fg	32.99	54.37 c	34.12	53.97 d
T7	Legume	30.9	66.47 a	32.29	67.50 ab	33.8	62.80 ab	30.97	63.40 bc
T8	Grass	32.48	54.57 bc	32.47	54.23 ef	32.01	54.40 c	32.03	52.57 e
	Legume	31.88	67.10 a	33.75	65.87 c	33.87	62.60 ab	32.11	63.87 ab
T9	Grass	34.58	54.70 bc	31.76	55.17 de	31.33	54.27 c	34.87	52.53 e
	Legume	33.4	65.43 a	31.39	66.30 bc	31.45	63.27 ab	33.44	64.87 a
T 10	Grass	35.08	55.57 b	33.23	55.70 d	33.72	53.87 c	35.01	52.37 e
	Legume	34.07	65.60 a	31.37	65.77 c	31.88	63.27 ab	34.71	62.93 bc
-	**LSD**	-	1.873	-	1.249	-	0.8616	-	0.8808

Experiment 2: Soil parameters

Table 4.31: Evaluation of fertilizer effect on soil ECe (dsm^{-1}) in grass-legumes intercropping (Experiment 2)

Treatments	After 1st Crop	After 2nd Crop	After 3rd Crop	After 4th Crop
T1 Grass alone	0.53NS	0.47NS	0.50NS	0.50NS
T2 Legume alone	0.53	0.45	0.49	0.49
T3 Intercropping 33%	0.43	0.47	0.45	0.45
T4 Intercropping 50%	0.47	0.51	0.47	0.49
T5 Intercropping 67%	0.45	0.45	0.46	0.46
T6 Grass + Fertilizer	0.43	0.48	0.51	0.46
T7 Legume + Fertilizer	0.50	0.52	0.54	0.51
T8 Intercropping 33%+ Fertilizer	0.50	0.57	0.56	0.54
T9 Intercropping 50% + Fertilizer	0.50	0.61	0.49	0.56
T10 Intercropping 67% + Fertilizer	0.43	0.55	0.55	0.49

Original Soil ECe = 0.53 dSm^{-1}

Table 4.32: Evaluation of fertilizer effect on soil pH in grass-legumes intercropping (Experiment 2)

Treatments	After 1st Crop	After 2nd Crop	After 3rd Crop	After 4th Crop
T1 Grass alone	8.2NS	8.1NS	8.0NS	7.4NS
T2 Legume alone	8.3	8.0	8.3	8.4
T3 Intercropping 33%	8.2	8.3	8.0	8.4
T4 Intercropping 50%	8.3	8.4	8.3	8.4
T5 Intercropping 67%	8.1	8.0	8.2	8.4
T6 Grass + Fertilizer	8.2	8.3	8.3	8.4
T7 Legume + Fertilizer	8.2	8.2	8.4	8.4
T8 Intercropping 33%+ Fertilizer	8.2	8.4	8.3	8.3
T9 Intercropping 50% + Fertilizer	8.2	8.4	8.1	8.4
T10 Intercropping 67% + Fertilizer	8.3	8.4	8.4	8.4

Original Soil pH = 8.4

Table 4.33: Evaluation of fertilizer effect on soil total N (%) in grass-legumes Intercropping (Experiment 2)

Treatments	After 1st Crop	After 2nd Crop	After 3rd Crop	After 4th Crop
T1 Grass alone	0.027d	0.028d	0.029d	0.028d
T2 Legume alone	0.037ab	0.036ab	0.035ab	0.033abc
T3 Intercropping 33%	0.030bcd	0.034abc	0.032abc	0.032bc
T4 Intercropping 50%	0.031bcd	0.030cd	0.034ab	0.033abc
T5 Intercropping 67%	0.032abcd	0.033abc	0.033ab	0.031c
T6 Grass + Fertilizer	0.028d	0.029cd	0.036a	0.035ab
T7 Legume + Fertilizer	0.035ab	0.033abc	0.031bcd	0.032bc
T8 Intercropping 33%+ Fertilizer	0.029cd	0.031bcd	0.032abc	0.034ab
T9 Intercropping 50% + Fertilizer	0.030bcd	0.031bcd	0.033ab	0.033abc
T10 Intercropping 67% + Fertilizer	0.038a	0.037a	0.036a	0.036a
LSD	0.006	0.005	0.004	0.003

Original Total N = 0.037%

Table 4.34: Evaluation of fertilizer effect on soil available P (ppm) in grass-legumes intercropping (Experiment 2)

Treatments	After 1st Crop	After 2nd Crop	After 3rd Crop	After 4th Crop
T1 Grass alone	5.67NS	5.72NS	5.46NS	5.62NS
T2 Legume alone	5.73	5.83	5.41	5.73
T3 Intercropping 33%	5.77	5.79	5.64	5.74
T4 Intercropping 50%	5.73	5.83	5.27	5.61
T5 Intercropping 67%	6.07	6.17	5.48	5.91
T6 Grass + Fertilizer	5.30	5.80	5.32	5.47
T7 Legume + Fertilizer	6.10	6.12	5.73	5.98
T8 Intercropping 33%+ Fertilizer	5.80	5.92	5.68	5.81
T9 Intercropping 50% + Fertilizer	6.00	6.05	5.68	5.91
T10 Intercropping 67% + Fertilizer	6.67	6.65	5.88	6.29

Available P (ppm) = 4.70ppm

Table 4.35: Evaluation of fertilizer effect on extractable K (ppm) in grass-legumes intercropping (Experiment 2)

Treatments	After 1st Crop	After 2nd Crop	After 3rd Crop	After 4th Crop
T1 Grass alone	75.4NS	75.4NS	76.2NS	75.7NS
T2 Legume alone	76.7	75.7	77.1	76.5
T3 Intercropping 33%	76.1	76.2	76.6	76.3
T4 Intercropping 50%	75.4	75.8	76.0	75.7
T5 Intercropping 67%	75.9	76.1	76.3	76.1
T6 Grass + Fertilizer	76.3	76.4	76.7	76.5
T7 Legume + Fertilizer	75.4	75.9	76.4	75.9
T8 Intercropping 33%+ Fertilizer	75.7	76.0	75.9	75.9
T9 Intercropping 50% + Fertilizer	74.9	75.2	75.7	75.3
T10 Intercropping 67% + Fertilizer	75.5	75.5	76.5	76.8

Extractible K (ppm) = 79.6 ppm

Table 4.36: Evaluation of fertilizer effect on soil organic matter (%) in grass-legumes intercropping (Experiment 2)

Treatments	After 1st Crop	After 2nd Crop	After 3rd Crop	After 4th Crop
T1 Grass alone	0.60bc	0.57c	0.57c	0.57c
T2 Legume alone	0.65abc	0.63bc	0.69ab	0.68ab
T3 Intercropping 33%	0.57c	0.67ab	0.61bc	0.63bc
T4 Intercropping 50%	0.59bc	0.59bc	0.65abc	0.67ab
T5 Intercropping 67%	0.63abc	0.64bc	0.66abc	0.68ab
T6 Grass + Fertilizer	0.56c	0.59bc	0.67abc	0.65bc
T7 Legume + Fertilizer	0.67ab	0.67ab	0.70ab	0.69ab
T8 Intercropping 33%+ Fertilizer	0.59bc	0.62bc	0.63abc	0.64bc
T9 Intercropping 50% + Fertilizer	0.62abc	0.65bc	0.68ab	0.68ab
T10 Intercropping 67% + Fertilizer	0.76a	0.75a	0.73a	0.76a
LSD	0.0950	0.0910	0.1020	0.0980

Organic Matter % = 0.53

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 Summary

Livestock has become very important component of agriculture sector in the world due to high income, a part of livelihood earning and employment of poor rural communities, especially landless people and the associated support to crop production through manures etc. The animal production brings milk, milk products, meat, wool, hides and bones for the benefits of man kind. Food production in Pakistan has always been listed among the nation's top research and development priorities because of ever increasing population. Livestock has been regarded an important sector that accounts for 52.2 percent of agricultural value added products in Pakistan, contributes 11 percent to GDP and affects the lives of 30 – 35 million people in rural areas. It is highly labor intensive and if proper attention is given to this sector, it will not only absorb more rural workforce but also help to alleviate rural poverty in the country. In order to achieve higher sustained growth in agriculture, it is absolutely necessary for the government to give more attention to livestock and dairy sector. Pakistan has a wealth of 150.5 million heads but this vast resource of the country is not being managed on scientific basis.

Production of livestock in Pakistan faces the most crucial challenges; prices of food from animal origin are very high, feed and fodder are not only deficient but also very high priced as well as low in required ingredients. Inevitable results are less number of animals compared with accelerating population. These phenomena are closely connected with energy crises, poor health of people and inflation. Social and environmental problems of food producing systems have, thus, multiplied. One of the major problems hindering expansion of ruminant production in the country is the un-availability of good quality fodder in sufficient quantity. Production of good quality fodder is of great importance for economical animal production. Both quality and quantity of fodder are influenced due to plant species, stage of growth and agronomic practices. Present conditions demand that not only more biomass of forages should be produced from the same area due to occupation of major agricultural area by cereal crops for feeding the large population but also its quality be improved to solve health and mal-nutrition problem. Thus, intercropping of legumes within grasses and non-leguminous crops, inoculation of legume seeds and fertilizer application are the only ways to increase quantity of forages and improving their quality. The present study was conducted to investigate effects of these factors on quality and quantity of selected grass and legumes.

The study comprised of two field experiments conducted under rain fed conditions for two years (June, 2005 to September, 2007) in the experimental area of Rangeland Research Program, National Agriculture Research Center (NARC) Islamabad, Pakistan (Altitude=518 m longitude= 73° 08'E & latitude= 33° 42'N). The experimental site is situated in sub-humid, sub-tropical region. There were two separate experiments of the study.

Experiment No. 1: Assessment of inoculation effect on grass-legumes intercropping

Treatments

T1= 100 % grass
T2= 100 % seasonal legume
T3= Grass + 33 % legume
T4= Grass + 50 % legume
T5= Grass + 67 % legume
T6= T2 + inoculation
T7= T3+ inoculation
T8= T4+ inoculation
T9= T5+ inoculation

Experiment No. 2: Evaluation of fertilizer effect on biomass production of grass-legumes intercropping

Treatments

T1= Grass 100 %
T2= Seasonal legume 100 %
T3= Grass + 33 % legume
T4= Grass + 50 % legume
T5= Grass + 67 % legume
T6= T1+ NPK fertilizers
T7= T2+ NPK fertilizers
T8= T3 +NPK fertilizers
T9= T4 +NPK fertilizers
T10= T5 +NPK fertilizers

Methodology

An appropriate site was selected, leveled and soil samples were obtained from (0-15 cm), prepared and analyzed for soil pH, ECe, texture and fertility parameters. The grass *Panicum maximum* var. Tanzania tufts were planted during the first week of July at the onset of monsoon season as perennial grass. Plant to plant and row to row distance was kept as 50 cm. Grass was planted in 2005 as perennial fodder. After its establishment, winter legume (*Vicia sativa* commonly known as vetch) and summer legume (*Vigna unguiculata* commonly known as cow peas, variety P-518) were sown as inter crop in the established grass but after its harvesting. Summer legume followed winter legume in the next year. Line sowing of legumes was done with the help of manual drill with a seed rate of 90 and 75 kg ha^{-1} respectively having row to row distance 50cm. Two lines of legumes with four lines of grass were grown to establish T3 (33 % legumes) while there were three lines of each in case of T4 (50 % legumes). In case of T5, four lines of legumes were grown with two lines of grass to obtain the share of 67 % of the former. Seed of legumes was inoculated before sowing to obtain T6 to T9 in experiment 1.

The experiments were conducted under rain fed conditions and no irrigations were applied. No fertilizer was applied either to grass or legumes in experiment 1. However, fertilizer as a basal dose was applied to the treatments T6 to T10 at the rates of 25, 75 and 50 kg ha^{-1} (N, P_2O_5 and K_2O) as urea, single superphosphate and sulphate of potash respectively in case of experiment 2. Both the experiments were laid out using randomized complete block designs (RCBD) with 4 replications. Main plot and sub-plot sizes were 910 m^2 and 15 m^2 respectively with 1m path between each sub-plot. Grass was harvested at panicle stage whereas legumes were harvested at 100 % flowering. Fresh and dry matter yield was recoded along with plant height and tillers. Plant samples (grass as well as legumes) were obtained to assess the fodder quality (Moisture and dry matter contents, crude protein, ether extract, crude fiber, ash and nitrogen-free extract) when there was 50 % flowering of legumes. Soil samples were obtained from each treatment separately after harvesting of fodder crops and analyzed for ECe, pH, total N, available P, extractable K and organic matter. Agro-meteorological data were also recorded.

Data were analyzed using one-way analysis of variance with the help of software package of MSTAT-C Microcomputer program, Version 1.3. A least significant difference (LSD) was applied for multiple comparisons.

5.2 Salient Results

Following salient results were obtained based upon data of different plant, forage quality and soil parameters.

1. **1.** Plant height of *Panicum maximum* grass was significantly increased due to intercropping (33, 50 and 67%) of *Vicia sativa* as well as cowpeas during two years study except the first leguminous crop (*Vicia sativa*). Seed inoculation of legumes also increased this parameter during first two crops. Application of fertilizer (N, P_2O_5 and K_2O = 25, 75 and 50 kg ha^{-1} respectively) alone remained effective in case of legumes but non-significant for grass. Intercropping of grass and legumes by 67% coupled with either inoculation or fertilizer was assessed as the best treatments.
2. **2.** Intercropping was found significantly positive for tillering of grass that was further enhanced by seed inoculation of legumes or application of fertilizer. Maximum tillers were recoded when intercropping of 67% was either combined with seed inoculation or application of fertilizer.
3. **3.** Similar trend of variations was observed when fresh and dry biomasses of fodders were compared because plant moisture contents were insignificant in most of the treatments. Intercropping of grass and legumes, seed inoculation, fertilizer application and different combinations proved useful and increased forage production. The best treatment was the combination of 67% intercropping and inoculation that produced the maximum biomass. The increases were computed as 304, 230, 132, and 60% over grass alone in the first, second, third and fourth crops while respective increases were 101, 151, 165 and 74% over monoculture legumes. Same treatment remained the highest when intercropping and fertilizer were coupled together
4. **4.** Nodulation of first *Vicia sativa* was found to be non-significant being the initial crop. Inoculation of legume seeds proved significantly useful in establishing nodules on roots while there was no materialistic contribution by fertilizer towards this parameter.
5. **5.** Crude Protein (CP) of grass were largely lesser than legumes that were slightly increased due to intercropping of legumes in the established grass. However, effect of legume inoculation or fertilizer application combined with intercropping proved more effective in this regard. Fertilizer did not contributed much towards CP improvement of legumes.

6. The values of Crude Fiber (CF) were clearly higher in grass compared with legumes but decreased with intercropping, inoculation of legumes, supplementation of fertilizer or any of the combination. Significant reductions were recorded in CF constituents of legumes due to intercropping.

7. Ash percentage of *Vicia sativa* was about 3% lesser than *Panicum maximum* grass while first and second crops of cowpeas had 2 and 4% less than the grass respectively. Intercropping caused reduction of this quality characteristic in case of grass as well as legumes. Inoculation and fertilizer application reduced it further but maximum reduction was recorded when 67% intercropping was combined with inoculation or fertilizer.

8. Ether extract is also very important forage quality character that was significantly affected due to treatment of the experiments. The pattern of changes was found to be just like Ash Percentage. A decrease in quantum of this parameter was observed in grass and both the legumes during all the four crops of this study. The most effective treatments were intercropping (especially 67%) of grass and legumes +inoculation/ fertilizer application.

9. Nitrogen Free Extract (NFE) of legumes was found to be lower than grass except second crop of cow peas. However, differences were found to be non-significant with the exception of first crop of *Vicia sativa* whereas differences of grass were evaluated as significant. Intercropping, especially 67%, inoculation, fertilizer application or combining these factors increased NFE. Most of the treatments under combination of intercropping either with inoculation or fertilizer application indicted maximum increase in NFE.

10. Total Digestible Nutrients (TDN) was very high in legumes than grass and remained significantly different under various treatments when grass and legumes were compared. The treatments of the experiment increased significantly TDN of grass but the content of this parameter generally decreased in case of legumes. These differences were appreciable in case of cowpeas but similar statistically even with combination of treatments like intercropping and inoculation/ fertilizer.

11. The experimental soil was free from salinity/ sodicity and its ECe and pH values were lesser than 4.0 dS m^{-1} and 8.5 respectively. The effect of all the treatments did not affect both these parameters significantly.

12. After crop harvest soil N content were determined to be higher in all the treatments of the experiment compared with growing grass alone. Legumes caused rhizobial N fixation that caused an increase in soil N. Similarly, intercropping and inoculation increased this soil characteristic that was found to be non-significant in the first crop but later on became significant, especially when intercropping of grass with legumes after seed inoculation was investigated or fertilizer was supplemented to the crops. Thus, not only grass used the symbiotically fixed N by companion legumes but also enhanced the soil N content.

13. The original soil was highly deficient in available P and K. All the treatments did not affect these two soil characteristics significantly but values were just slightly higher where fertilizer was applied in comparison to no fertilizer.

14. The effect of fertilizer was not measurable statistically in case of soil organic matter. This parameter, in general, was not affected significantly when assessed after first crop harvest. Nevertheless, legumes alone or intercropped within grass increased this important soil constituent. Inoculation proved further beneficial in this regard but combination of intercropping (especially 67%) either with seed inoculation or application of fertilizer was found as the best technique for increasing soil organic matter.

5.3 Conclusions

1) Biomass production of grass (*Panicum maximum*) can be increased significantly by intercropping of legumes (*Vicia sativa* or cow peas) with levels of 33, 50 or 67%, the last one proved the most effective. This technique also improved quality of forages through a positive effect on quality parameters (Crude protein, crude fiber, ash and total digestible nutrients).
2) Inoculation of legume seeds and fertilizer application (N, P_2O_5 and K_2O at the rates of 25, 75 and 50 kg ha^{-1} respectively) not only increased biomass production but also improved some of the quality parameters of grass resulting in reduction of crude fiber and increase in crude protein as well as total digestible nutrients..
3) Intercropping of grass and legumes, inoculation, fertilizer application and different combinations did not affect post harvest soil ECe, pH, available P and K significantly but organic matter content were significantly increased in two years.

Total soil N was also enhanced, especially where legumes were grown alone or intercropped because of symbiotic atmospheric nitrogen fixation. These techniques were successful to meet nutritional requirements of plants because a good biomass production was obtained even from highly deficient soil.

5.4 Recommendations

Farmers can not only remove deficiency of fodders requirements for their animals but can also have good quality forages through intercropping of legumes upto the extent of 67% in established grass fields without increasing the area under fodder crops. Inoculation of legume seeds can be further helpful in this regard. However, present practice of applying no fertilizer to fodders by the farmers in Pakistan has to be changed and recommended doses of fertilizer have to be included in agronomic practices even for fodder crops.

5.5 Future research required

The present studies have opened new corners of research in Pakistan and needed to be continued in future as well. The major deficient fields are as under.

1) Different combinations of leguminous and conventional non-leguminous crops like: sorghum, pearl millet, Napier hybrid, barley and oats etc have to be investigated and level of intercropping has to be standardized.
2) With the increase in plant population, requirements for nutrients will definitely increase. Therefore, fertilizer recommendations for individual crops will no more remain workable and have to be standardized for new situations.
3) Separate investigations have to be conducted under various agro-ecological zones and in variable soils.
4) Research on quality of fodders and forages have now to be strengthened because animal and human health problems, especially malnutrition can only be controlled by feeding good quality fodder to the animals.

Kapitel 5

Zusammenfassung und Schlussfolgerung

5.1 Zusammenfassung

Die Viehhaltung hat sich zu einem sehr wichtigen Bestandteil der Landwirtschaft entwickelt. Sie verschafft ein hohes Einkommen, bietet eine Existenzbasis und Arbeitsplätze für die arme, ländliche Bevölkerung, besonders für die ohne Grundbesitz; und trägt zu besseren Erträgen in der Landwirtschaft mit der Beisteuerung von Mist als Düngemittel bei. Viehhaltung steuert viele Produkte zum Wohl der Menschheit bei: Milch, Milchprodukte, Fleisch, Wolle, Felle und Knochen. Die Lebensmittelproduktion hat in Pakistan schon immer einen hohen Rang in der Forschung und Entwicklung eingenommen. Grund hierfür ist die stetig wachsende Bevölkerung. Die Viehwirtschaft wird als ein wichtiger Bereich angesehen, der 52,5 Prozent der landwirtschaftlichen Produkte in Pakistan ausmacht und außerdem elf Prozent des Bruttoinlandsprodukts. Zudem beeinflusst sie das Leben von 30-35 Millionen Menschen in ländlichen Gebieten. Dieser Sektor benötigt viele Arbeitskräfte und wenn ihm die angemessene Aufmerksamkeit zukommt, wird er nicht nur einen Großteil der ländlichen Arbeiterschaft aufnehmen können, sondern zudem dazu beitragen die Armut in ländlichen Gebieten des Landes zu verringern. Um ein fortbestehendes Wachstum in der Landwirtschaft zu erreichen ist es notwendig, dass die Regierung den Sektoren Viehhaltung und Milchwirtschaft mehr Aufmerksamkeit zuwendet. Obwohl Pakistan eine 150,5 Millionen Köpfe starke Bevölkerung vorweisen kann, wird trotz dieser enormen Ressource des Landes, nicht ausreichend auf wissenschaftlicher Basis in diesem Bereich gearbeitet.

Viehhalter in Pakistan werden mit großen Herausforderungen konfrontiert. Preise für Lebensmittel, die vom Tier stammen sind sehr hoch, Viehfutter ist nicht nur mangelhaft, sondern auch überteuert und zudem enthält es nur ein Minimum der vorgeschriebenen Inhaltsstoffe. Das unumgängliche Ergebnis dessen ist eine immer weiter schrumpfende Anzahl von Zuchttieren im Vergleich zu der stetig wachsenden Bevölkerung. Dieses Phänomen steht im engen Zusammenhang mit Energiekrisen, dem schlechtem Gesundheitszustand vieler Menschen und der Inflation. Infolgedessen haben sich die gesellschaftlichen und umweltbedingten Probleme der Lebensmittelproduktion vermehrt. Eines der Hauptprobleme, das die Expansion der Viehwirtschaft behindert ist das Nicht-Vorhandensein von Viehfutter in guter Qualität und in ausreichender Menge. Die Produktion von qualitativ hochwertigem Viehfutter ist für die wirtschaftliche Viehhaltung von großer Bedeutung. Qualität und Quantität des Viehfutters werden beeinflusst durch die Art der verwerteten Pflanzen, ihrer Wachstumsphasen und der jeweiligen Methode des Ackerbaus. Die derzeitigen Bedingungen erfordern, dass mehr Biomasse für Futter auf der gleichen Fläche produziert wird, denn die größten Agrarflächen sind mit dem Anbau von Getreide zur Ernährung der großen Population besetzt. Zudem soll die Qualität des Futters verbessert werden, um Gesundheitsproblemen und Fehlernährung entgegenzuwirken. Folglich sind das Anlegen einer Mischkultur zwischen Hülsenfrüchten, Gräsern und anderen Kulturen, sowie die Inokulation der Hülsenfruchtsamen und der Gebrauch von Düngemitteln die einzige Möglichkeit die Quantität des Futters zu steigern und die Qualität zu verbessern. Ziel der derzeitigen Studie war es zu untersuchen, welche der genannten Faktoren zu einer Steigerung der Qualität und Quantität ausgewählter Gräser und Hülsenfrüchte führen können.

Die Studie bestand aus zwei Feldexperimenten, die unter regengespeisten Bedingungen für zwei Jahre (Juni 2005 bis September 2007) im experimentellen Bereich des Rangeland Research Program, National Agriculture Research Center (NARC) in Islamabad, Pakistan durchgeführt wurde. (Höhe über NN: 518 m, Längengrad= 73° 08’E , Breitengrad33° 42’N). Das experimentelle Gelände liegt in einer subhumiden, sub-tropischen Region. Es gab zwei separate Experimente zur Studie.

Experiment Nr. 1: Bewertung des Inokulationseffekts bei einer Mischkultur aus Gräsern und Hülsenfrüchten

Verfahren

T1= 100 % Gras
T2= 100 % Saisonale Hülsenfrüchte
T3= Gras + 33 % Hülsenfrüchte
T4= Gras + 50 % Hülsenfrüchte
T5= Gras + 67 % Hülsenfrüchte
T6= T2 + Inokulation
T7= T3+ Inokulation
T8= T4+ Inokulation
T9= T5+ Inokulation

Experiment Nr. 2: Auswertung des Düngemitteleffekts bei der Produktion von Biomasse bei einer Gras-Hülsenfrucht Mischkultur

Verfahren

T1= Gras 100 %
T2= Saisonale Hülsenfrüchte 100 %
T3= Gras + 33 % Hülsenfrüchte
T4= Gras + 50 % Hülsenfrüchte
T5= Gras + 67 % Hülsenfrüchte
T6= T1+ NPK Düngemittel
T7= T2+ NPK Düngemittel
T8= T3 +NPK Düngemittel
T9= T4 +NPK Düngemittel
T10= T5 +NPK Düngemittel

Methodik

Ein geeignetes Gebiet wurde ausgesucht und eingeebnet. Von dort wurden Erdproben eingeholt (0-15cm), und auf die Parameter pH-Wert,Leitfähigkeit (ECe), Beschaffenheit und Fruchtbarkeit untersucht. Büschel von *Panicum maximum* var. Tanzania, ein mehrjähriges Gras, wurden während der ersten Juliwoche zu Beginn der Monsunsaison gepflanzt. Der Abstand von Pflanze zu Pflanze, sowie der Reihenabstand betrugen 50 cm. Dieses Gras wurde im Jahr 2005 als mehrjähriges Viehfutter gepflanzt. Im Anschluss an seine Etablierung wurde eine Winterhülsenfrucht (*Vicia sativa,* allgemein bekannt als Futterwicke) und eine Sommerhülsenfrucht (*Vigna unguiculata,* allgemein bekannt als Augenbohne, Sorte P-518) hinzu gesät, sodass eine Mischkultur entstand. All dies geschah jedoch erst nach der Ernte des Grases *Panicum maximum.* Die Sommerhülsenfrucht wurde erst im folgenden Jahr hinzugesät. Das reihenweise Aussäen wurde mithilfe eines manuell betriebenen Bohrers ausgeführt, bei einer Samenrate von 90 und 75 kg ha^{-1} und einem Reihenabstand von jeweils 50 cm. Es wurden zwei Reihen Hülsenfrüchte mit vier Reihen Gras gepflanzt, um T3 (33% Hülsenfrüchte) zu etablieren, während es bei T4 (50% Hülsenfrüchte) drei Reihen von beidem gab. Im Fall von T5 wurden vier Reihen Hülsenfrüchte mit zwei Reihen Gras angebaut, um einen 67%-igen Anteil des vorigen zu bekommen. Die Samen der Hülsenfrüchte wurden vor der Saat inokuliert, um T6 bis T9 im Experiment 1 zu erhalten.

Die Experimente wurden unter regengespeisten Bedingungen durchgeführt und es gab keine künstliche Bewässerung. Beim ersten Experiment wurde weder beim Gras, noch bei den Hülsenfrüchten Düngemittel angewendet. Beim zweiten Experiment wurde Düngemittel jedoch flächendeckend bei T6 bis T10 angewendet, in Form von Carbamid, einfachem Superphosphat und Sulfat aus Kalisalz in einer Menge von 25, 75 und 50 kg ha^{-1} . (N, P_2O_5 und K_2O) Beide Experimente waren auf Basis eines zufällig angeordneten, geschlossenen Blockaufbaus (RCBD) mit vier Replikationen angelegt. Die Größe der Hauptfläche betrug 910 m^2, die der untergeordneten Flächen jeweils 15 $m^{2,}$ wobei der Abstand zwischen den untergeordneten Flächen jeweils 1 m betrug. Das Gras wurde in der Rispenphase geerntet, während die Hülsenfrüchte erst beim 100%-igen Blühen geerntet wurden. Der Ertrag an Frischmasse und Trockenmasse wurden neben Pflanzenhöhe und der Bildung von Ausläufern notiert. Pflanzenproben wurden bei 50%-igem Blühen der Hülsenfrüchte beschafft, um die Qualität des Viehfutters abschätzen zu können. Die Pflanzenproben wurden getestet auf: Feuchtigkeits- und Trockenanteile, rohes Protein, Ether-extrakt, rohe Ballaststoffe, Asche und Stickstoff-freien Extrakt. Von jeder Versuchsfläche wurden zudem Bodenproben entnommen, nachdem die Viehfutter-Kulturen abgeerntet wurden. Die jeweiligen Bodenproben wurden auf ECe, ihren pH-Wert, den Gesamtanteil an Stickstoff, den verfügbaren Anteil von Phosphor, den extrahierbaren Anteil von Kalium, sowie organische Substanzen untersucht. Agrar-meteorologische Daten fanden ebenfalls Berücksichtigung. Das Datenmaterial wurde durch eine einfache Streuanalyse, mithilfe der Software MSTAT-C Microcomputerprogramm, Version 1.3 analysiert. Die geringstmögliche Abweichung (least significant difference - LSD) wurde zwecks mehrfacher Vergleiche zugrunde gelegt.

Die folgenden hervorstehenden Ergebnisse wurden errechnet auf Basis verschiedener Messwerte von verschiedenen Faktoren (Pflanze, Futterqualität, Boden)

1. Die Höhe der Pflanzen des *Panicum maximum* Grases wurden durch Anlegen einer Mischkultur (33, 50 und 67%) mit *Vicia sativa,* sowie Augenbohnen, während der zwei Jahre sichtlich gesteigert. Ausgenommen ist die erste fruchtbringende Ernte der *Vicia sativa.* Inokulation der Samen führte außerdem zu einem Anstieg dieses Wertes während der ersten beiden Ernten. Die Anwendung von Düngemittel allein (25, 75 und 50 kg ha^{-1} (N, P_2O_5 and K_2O at 25, 75 und 50 kg ha^{-1} jeweils) bewies sich als effektiv für die Hülsenfrüchte, war jedoch unbedeutend für das Gras. Eine Mischkultur von 67% zwischen Gras und Hülsenfrüchten in Kombination mit entweder Inokulation oder Düngemittel erwies sich als das beste Verfahren.

2. Das Anlegen einer Mischkultur hat sich als besonders positiv für die Ausläuferbildung des Grases erwiesen, die zudem noch angereichert wurde durch die Inokulation der Samen der Hülsenfrüchte oder dem Gebrauch von Düngemittel. Maximale Ausläuferbildung wurde verzeichnet, als die Mischkultur von 67% entweder mit Sameninokulation oder Anwendung von Düngemittel kombiniert wurde.
3. Ähnliche Tendenzen wurden beobachtet als frische und trockene Biomasse von Viehfutter verglichen wurden, da der Feuchtigkeitsgehalt der Pflanze bei den meisten Verfahren unwichtig war. Mischkulturen aus Gras und Hülsenfrüchten, Sameninokulation, Gebrauch von Düngemittel und verschiedene Kombinationen der Verfahren erwiesen sich als hilfreich bei der Produktion von Viehfutter. Das Beste, welches die maximale Biomasse produzierte, war eine 67%-ige Mischkultur kombiniert mit Inokulation. Der Anstieg wurde festgehalten als 304, 230, 132, und 60% gegenüber Gras allein während der ersten, zweiten, dritten, und vierten Ernte. Gegenüber der Monokultur einer Hülsenfrucht konnte ein Anstieg von 101, 151, 165 und 74% verzeichnet werden. Dasselbe Verfahren erwies sich als das Beste, als man eine Mischkultur mit Düngemittel koppelte.
4. Nodulation bei der ersten *Vicia sativa* erwies sich als unbedeutend, da dies die anfängliche Ernte war. Inokulation der Hülsenfruchtsamen stellte sich als besonders hilfreich heraus, wenn es darum ging Knollen an den Wurzeln zu bilden, während es keineAuswirkungen durch Düngemittel bei diesem Wert gibt.
5. Grobproteinanteile im Gras waren weitgehend geringer als die der Hülsenfrüchte, die leicht erhöht waren aufgrund der Mischkultur der Hülsenfrüchte im bereits vorhandenen Gras. Eine Mischkultur in Kombination mit Inokulation der Hülsenfrüchte oder Gebrauch von Düngemitteln erwies sich in dieser Hinsicht als die beste Methode. Düngemittel allein steuerte nicht viel zur Verbesserung der Grobproteinanteile der Hülsenfrüchte bei.
6. Die Grobfaserwerte (CF=crude fiber)bei Gras waren im Vergleich zu Hülsenfrüchten höher nahmen jedoch durch Mischkulturen, Inokulation der Hülsenfrüchte, Ergänzung von Düngemitteln oder eine Kombination dieser ab. Aufgrund dieser Verfahren wurde eine sichtliche Abnahme des CF Werts bei Hülsenfrüchten verzeichnet.
7. Der Anteil von Asche war bei *Vicia sativa* etwa 3% geringer, als beim *Panicum maximum* Gras. Die erste und zweite Ernte der Augenbohnen hatte jedoch 2 und 4%

weniger Ascheanteil als das Gras. Mischkulturen bewirkten die Abnahme dieser qualitativen Besonderheit sowohl bei Gras als auch bei Hülsenfrüchten. Inokulation führte zu einer weiteren Abnahme, auch der Gebrauch von Düngemitteln hatte den gleichen Effekt. Die höchste Abnahme wurde jedoch verzeichnet, als eine 67%-ige Mischkultur mit Inokulation oder Düngemittel kombiniert wurde.

8. Etherextrakt ist eine weitere positive Besonderheit des Viehfutters, dass durch die Experimente mit den Verfahren bedeutsam beeinflusst wurde. Das Muster der Veränderung lässt sich mit dem des Ascheanteils vergleichen. Eine Abnahme dieses Wertes wurde bei Gras und Hülsenfrüchten bei allen vier Ernten dieser Studie beobachtet. Das effektivste Verfahren war eine Mischkultur (besonders 67%) zwischen Gras und Hülsenfrüchten in Kombination mit Inokulation oder Gebrauch von Düngemitteln.
9. Stickstofffreier Extrakt (NFE) von Hülsenfrüchten erwies sich als niedriger, als der des Grases, ausgenommen die zweite Ernte der Augenbohnen. Unterschiede, die bei den Hülsenfrüchten auftraten wurden als unbedeutend erklärt (mit Ausnahme der ersten Ernte von *Vicia sativa*), während Unterschiede beim Gras als wichtig gewertet wurden. Mischkulturen, besonders 67%, Inokulation, Gebrauch von Düngemitteln oder eine Kombination dieser Methoden zeigte eine maximale Steigerung des stickstofffreien Extrakts.
10. Die Gesamtsumme der verdaulichen Nährstoffe (Total Digestible Nutrients (TDN) war bei Hülsenfrüchten weitaus höher als bei Gras und blieb bedeutend unterschiedlich bei verschiedenen Verfahren, wenn Gras und Hülsenfrüchte verglichen wurden. Die Verfahren des Experiments erhöhten die TDN von Gras in bedeutender Weise aber der Inhalt dieses Wertes nahm bei Hülsenfrüchten generell ab. Diese Unterschiede waren beträchtlich im Fall der Augenbohnen, jedoch von der Statistik ähnlich, sogar wenn die Verfahren mit Mischkulturen, Inokulation oder Gebrauch von Düngemitteln kombiniert wurden.
11. Der Versuchsboden hatte keinen Salzgehalt und war frei von Natriumsättigung. Die ECe und pH-Werte waren jeweils geringer als 4.0 dSm^{-1} und 8.5. Die hervorgerufenen Effekte der verschiedenen Verfahren haben diese beiden Werte nur in unbedeutender Weise verändert.

12. Der Stickstoffgehalt des Bodens nach der Ernte war bei allen Verfahren des Experiments höher als bei einer reinen Graskultur. Hülsenfrüchte bewirkten eine rhizobiale Stickstofffixierung, die zu einem Anstieg des Stickstoffgehalts des Bodens führte. Mischkulturen und Inokulation bewirkten einen ähnlichen Anstieg des Stickstoffgehalts, was bei der ersten Ernte als unbedeutend galt, später aber an Bedeutung gewann. Besonders, als die Mischkulturen untersucht wurden, deren Hülsenfruchtsamen inokuliert oder gedüngt worden waren. Hieraus folgt, dass nicht nur das Gras den symbiotisch fixierten Stickstoff der Hülsenfrüchte genutzt hat, sondern auch den Stickstoffgehalt im Boden angereichert wurde. Der ursprüngliche Boden hatte hohe Defizite, was Phosphor und Kalium betrifft. Keines der Verfahren beeinflusste diese Bodeneigenschaften in bedeutender Weise. Die Werte waren nur beim Gebrauch von Düngemittel ein wenig höher.
13. Die Wirkung von Düngemitteln auf die organischen Anteile im Boden konnte nicht statistisch nachgewiesen werden. Dieser Parameter wurde allgemein nicht signifikant beeinflusst nach der Ernte. Dennoch steigerte der Anbau von Hülsenfrüchten allein oder in einer Mischkultur den Anteil dieses wichtigen Bodenbestandteils. Inokulation trug positiv dazu bei, aber eine Kombination von Mischkulturen (besonders bei 67%) mit Sameninokulation oder Düngemitteln erweis sich als am effektivsten für die Steigerung der organischen Anteile im Boden.

5.2 Conclusions

1) Die Produktion der Biomasse von Gras (*Panicum maximum*) kann in bedeutender Weise erhöht werden durch eine Mischkultur mit Hülsenfrüchten (*Vicia sativa* oder *Vigna unguiculata*) mit einem Gehalt von 33, 50 oder 67%, wobei sich letzteres als am Effektivsten erwies. Dieses Verfahren verbesserte außerdem die Qualität des Viehfutters, was durch den positiven Effekt auf die Qualitätswerte (Rohprotein, Rohballaststoffe, Asche und Gesamtsumme der verdaulichen Nährstoffe) gezeigt wird.

2) Inokulation der Hülsenfruchtsamen und Gebrauch von Dünger (N, P_2O_5 und K_2O bei einer Rate von jeweils 25, 75 and 50 kg ha^{-1}) erhöhte nicht nur die Produktion der Biomasse, aber auch einige Qualitätswerte des Grases waren betroffen.

Rohballaststoffe nahmen ab, während Rohproteine und die Gesamtsumme der verdaulichen Nährstoffe zunahmen

3) Mischkulturen aus Gras und Hülsenfrüchten, Inokulation, Gebrauch von Düngemitteln und Kombinationen derer hatten nach der Ernte keine Auswirkung auf die ECe und pH-Werte des Bodens, oder auf die vorhandenen Phosphor- und Kaliumvorkommen, aber der Anteil an organischen Stoffen stieg signifikant an nach der zweiten Ernte. Der Stickstoffgehalt des Bodens wurde außerdem angereichert, besonders dann, wenn Hülsenfrüchte allein angebaut wurden oder in eine Mischkultur gerieten, aufgrund der symbiotischen atmosphärischen Stickstofffixierung. Diese Methoden waren sehr erfolgreich in Bezug auf die Ernährungsbedingungen, weil eine gute Produktion der Biomasse geschaffen wurde, obwohl der Boden nährstoffarm ist.

5.3 Empfehlungen

Landwirte können nicht nur die Defizite des Futters für ihre Tiere beheben, sondern sogar qualitativ hochwertiges Viehfutter produzieren, indem sie Mischkulturen anbauen und Hülsenfrüchte mit Gras bis zum Anteil von 67% mischen, ohne einen größere Anbaufläche zu benutzen. Die Inokulation von Hülsenfruchtsamen kann in dieser Hinsicht zusätzlich von Hilfe sein. Der derzeitige Zustand in Pakistan, dass dem Futter keine Düngemittel zugefügt wird, muss geändert werden und empfohlene Dosierungen von Düngemittel für das Getreide müssen in den landwirtschaftlichen Gebrauch aufgenommen werden.

5.4 Notwendige zukünftige Forschungen

Die bisherigen Studien haben neue Türen für die Forschung in Pakistan eröffnet und müssen in der Zukunft weiterhin betrieben werden. Die hauptsächlichen Defizite sind die im Weiteren genannten.

1) Verschiedene Kombinationen aus Hülsenfrüchten und konventionellen Gräsern, wie zum Beispiel Hirse, Perlhirse, Napier hybrid, Gerste und Hafer müssen untersucht werden und die Art der Mischkultur muss standardisiert werden.
2) Durch das Wachstum der Pflanzenpopulation werden die Anforderungen für Nährstoffe

ansteigen. Deshalb muss es Düngemittelempfehlungen für unterschiedliche Getreide gebenund die neuen Situationen, in standardisierter Weise, angepasst werden

3) Separate Untersuchungen müssen in verschiedenen agrar-ökologischen Zonen durchgeführt werden, sowie mit verschiedenen Bodenbeschaffenheiten.

4) Forschung, die sich mit der Qualität des Viehfutters auseinandersetzt muss gestärkt werden, weil Gesundheitsprobleme von Mensch und Tier, besonders Fehlernährung nur durch das Füttern von qualitativ hochwertigem Viehfutter kontrolliert werden kann.

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