CHAPTER - I

Introduction and review of literature

Photosynthetically active green leaves play an important role on the biosphere. These leaves, known as foliage, convert the energy from sunlight into chemical energy during the process of photosynthesis. This process involves formation of simple sugars from carbon dioxide and water for which solar energy is utilized. The simple carbohydrates synthesized during the process of photosynthesis enter into different types of metabolic processes and form other complex organic molecules like carbohydrates, proteins, lipids, nucleic acid, vitamins, growth regulating substances and organic compounds.

With growth, development and differentiation of the plant, these chemical compounds get distributed into various plant parts like leaf, stem, fruit, seed, root, tubers and other tissue and organ systems. These plant products form a major source of nutrition for human as well as animals and other living organisms.

With increased civilization, human selected and domesticated several plant species for his nutrition as well as livelihood. With the initiation of agriculture he started cultivating some of them on the field and used for better quality of nutrition. The use of animals in various agricultural
processes as well as for obtaining animal products in human diet led to the domestication of animals.

The animals were domesticated by human beings for obtaining milk, meat, eggs and for employing them on farm. In order to increase the efficiency of farm animals in giving ample animal products and doing more work. It was imperative for him to take care of animal nutrition. Therefore, the farmer started cultivating crops for animal feeding. These crops are generally known as forage or fodder crops.

India, being basically an agricultural country, the peoples depends mainly on agriculture and animal husbandry. The crop-livestock integration or mixed farming is a common practice on Indian farms. On such farms, farmers rear animals to prepare land, grow plants, transfers loads and to obtain milk, meat, leather, wool, fuel and fertilizer. Cattle, sheep and goats can satisfy these needs. In order to feed the animals, it is necessary for the farmers to produce fodder by cultivating forage crops.

Proper feeding to the cattle is important, as it induce growth and maturity of the animal and promote its milk production. Adequate supply of all nutrients in proper quantity, as well as that of good quality, is essential to nourish animals. Several species have been evolved specially for the cultivation as fodder and various agronomic practices have been recommended for their cultivation in different regions. In order to get sufficient fodder from a particular species, the use of fertilizer is often made
to increase the yield of foliage. In this connection fertilizer nitrogen (N) plays an important role as it gives nutritious foliage in short time.

The systems of fodder production vary from region to region, place to place and farmer to farmer depending on availability of inputs (e.g. fertilizer, seed, irrigation etc.) and the topography. An ideal fodder system is that which gives maximum digestible nutrients per unit land area for maximum livestock production. The fodder system should also ensure the availability of soft, palatable and nutritive fodder in enough quantity throughout the year. Several fodder crops have been recommended for cultivation by ICAR (1987), Relwani (1979) and Rahudkar (1965).

A crop-livestock integration or mixed farming is a common practice on Indian farms. On such farms, where "take home" income of a farmer is generally small, the livestock husbandry provides supplementary income to the farmer, the farmer needs farm animals to prepare land, grow crops, transport loads, and to obtain meat, milk, leather, wool, fertilizer and fuel. Cattle, sheep and goats, are more efficient than other animals, can only satisfy these needs. In order to feed the animals, it is necessary for a farmer to produce fodder by cultivating forage crops. The production of forages needs high level of technology, very much similar to that in use for food grain production. It has been realized long time ago that fodder resources of India are inadequate (Relwani, 1979). Such a situation necessitates an intelligent programme of forage production. Intensive cropping and use of high yielding varieties are imperative in this contest. Apart from this, higher yields can also be obtained
with high doses of plant nutrients. It is known that green plants require at least 16 nutrient elements for various metabolic processes and growth (Vaidya and Sahasrabuddhe, 1979). These elements are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, iron, manganese, zinc, copper, molybdenum, boron and chlorides. The first three elements namely carbon, hydrogen and oxygen are supplied by water and atmospheric carbon dioxide. The remaining 13 elements are taken up by plants from the soil; out of which nitrogen (N), phosphorus (P) and potassium (K) are used in large quantities and hence known as primary elements. Majority of the soils are deficient in N, P and K; and these are made good by adding fertilizers. As their requirement is supplemented by fertilizer application these elements are sometimes referred to as fertilizer elements (Motsara and Singh, 1931). Calcium, magnesium and sulphur are known as secondary or amendment elements. The remaining 7 elements are required by plants in relatively small amounts and are called as micronutrients or trace elements.

Chemical fertilizers, used to supply N, P and K, play a crucial role in plant production. The utilization efficiency of a fertilizer element varies under different conditions. Most of the nitrogen, applied as fertilizer is lost by leaching and by conversion to gases. In case of phosphorus, only 15 - 20% of applied P is utilized by a crop leaving residual P in soil. About 60 - 70% of potassium is not used by crops in the year of application. Several factors affect fertilizer use; among these are soil, seed variety, season, time of planting,
water management, cropping sequence, fertilizer source, and time and method of fertilizer application. It thus becomes essential to take such steps which can control the management of all variables involved in the use of fertilizers. Most of our cultivated lands are rainfed, comprising of varied soils with low rain-fall of uneven distribution, varied crops under cultivation, varied skills and attitudes. They are universally deficient in N, frequently limiting in P and generally adequate in K. Under such situation, proper soil and crop husbandry, linked up with the input of chemical fertilizers, is to be practiced to push up and stabilize yields of crop plants (Venkateshwarulu, 1981).

Nitrogen is an essential constituent of amino acids, proteins, nucleic acids, chlorophyll, alkaloides and protoplasm; it makes plant dark green and succulent; it promotes vegetative growth; and it makes plant efficient in absorbing other nutrients like P, K and Ca. The organic nitrogen constitutes 1.5 - 5% of the dry weight of higher plants, and 80-90% of that is in protein. During the early stages of growth, N contributes to the development of size of photosynthetic apparatus. Production of dry matter increases due to the application of nitrogenous fertilizers, resulting in total dry matter productivity per unit time per unit area. The high dry matter yield is associated with high protein content in it, and thus high protein productivity. Extensive field trials over last 15 years in this Department have shown that large yields of dry matter and protein can be obtained from forages cultivated with liberal fertilizer use (Joshi, 1971; Deshmukh et al., 1974; Dev et al., 1974; Gore et
Apart from cultivating a single crop on farm (sole cropping) and increasing its yield by applying fertilizers, the cultivation of crops in mixture is a common practice in Indian agriculture.

Grass-legume mixture is always desirable in this regard because they produce adequate forage for animals, and as the resulting foliage is palatable, succulent and nutritive. The crop mixtures are capable of producing greater quantities of dry matter and protein throughout the growing season. Legumes usually maintain their quality, better than grasses even at maturity; and being rich in protein, enhance the forage nutritive value and also add nitrogen to the soil. The crop mixtures also improve the physical condition of the soil, check soil erosion and resist weather better than pure stands. They also help to check the spread of certain diseases and insect pests.

Intercropping (or mixed cropping) of two or more crops is an age-old practice in India, especially under rainfed conditions. Intercropping can be defined as the growing of two (or more) crops simultaneously on the same piece of land in rows with a definite geometrical pattern (De *et al*., 1978; Willey, 1979). When the crops are grown simultaneously without any row arrangement or when the crops are intermingled in each row the term "mixed cropping" is used (Andrews and Kassam, 19751, De *et al*., 1978; Rao and Willey, 1978).
Historically, intercropping is regarded as a primitive practice, but more recently it has been realized that it can give higher yields than growing sole crops. The major cause of yield advantage, and the only one for which there is much evidence to date, is the better use of growth resources. Usually the component crops differ in their use of growth resources and when they grow together they are able to "complement" each other. Obvious example here would be a tall C₄ plant growing with a short C₃ one where top of the canopy exhibit a component with high and the bottom with low light requirement. Greater nutrient uptake by an intercropping systems have been shown by several workers (Patel et al., 1968; Dalal, 1974; Natarajan and Willey, 1980). Lipman, (1913) was perhaps the first to suggest that the soluble nitrogenous compounds are utilized by adjoining porous root walls of non-legumes when they are grown in association with the legumes. It seemed well established in the 1930 that legumes could excrete nitrogen during growth and so benefit an associated non-legume (Nicol, 1935, Virtanen et al., 1937; Wilson and Burton, 1938). Observations at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India have suggested that pigeonpea may nodulate better when the roots intermingle with those of intercropped Sorghum.

Howard (1916) critically studied the Indian custom of growing grass and wheat together and indicated an advantage in doing so for an insurance against an entire failure of the harvest particularly in the years of short moisture and on soils where combined nitrogen is a limiting factor. Improved
stability of yield, therefore, is one of the major reasons why intercropping continues to be an extremely important practice in many developing areas of the world, especially those of greater risk (Aiyer, 1949; Norman, 1974; Jodha, 1979). Rao and Willey (1968) examined data from 94 experiments on Sorghum - pigeonpea intercropping experiments and found that the stability of yield is greater with intercropping than sole cropping. It was found that for a particular "disaster" level, sole pigeonpea would fail one year in five, sole Sorghum one year in eight but the intercropping only one year in thirty-six (Rao and Willey, 1980).

It has been observed that intercropping can increase the competitive ability of crops to reduce the pressure of weeds (Bentilan and Harwood, 1973). Rao and Shetty (1977) observed reduction in the weed growth to an extent of 50 - 75 % in Sorghum - pigeonpea intercropping system.

Other possible causes of yield advantages may be important in certain situations but have received little attention e.g. one crop may provide physical support for another (Aiyer, 1949), one may provide shelter for another (Rathke and Hegstrom, 1975) or a more continuous leaf cover may give better protection against erosion (Siddoway and Bennett, 1975).

In India the importance of intercropping was highlighted almost 50 years ago in a very comprehensive review by Aiyer (1949) and its current importance has been stressed by number of workers for yield advantage and monetary returns (Lingegouda et al., 1972; Prasad and Chaudhary, 1975; De et al., 1978) Gautam and Kaushik, 1980; Motha and De, 1980; Natarajan and
Willey, 1980a, 1980b; Singh and Joshi, 1980; Umrani, 1981; Singh, 1982; Zaman and Bhattacharyya, 1982). A informative report have also been very recently published (Willey, 1979) and also reviewed in the proceedings of the International Workshop on Intercropping, 10-13 January 1979, Hyderabad, India.

A yield and quality advantage has been firmly established for legume-grass mixture grown for forage (Trenbath, 1974). By growing lucerne in between the rows of Guinea-grass, more fodder, protein, fat and calcium can be obtained without increasing the area under cultivation (Patel et al., 1968). The mixed crop of berseem and sarson produced 122 and 189 per cent higher green and dry matter respectively in Hissar (Kapoor and Gill, 1975). For green fodder production round the year berseem - maize + cowpea - maize + cowpea rotation was found advantageous in Udaipur than either berseem - maize - cowpea rotation or even pure crop of lucerne (Singh and Trivedi, 1980). The possibility of gaining benefits by simply cultivating the plants together holds such attractions for agriculturists that research into the productivity of mixtures continues.

In an intercropping system crop plants enter into a complex interaction with each other, influenced by a change in the agrophytoclimatic conditions and allelopathy, resulting either in an increase or the reduction in productivity. Thus disadvantages of intercropping may take the form of yield decrease because of adverse competitive effect; although such effects are likely to be rare (Willey, 1979). Crop compatibility would dictate the success of an
intercropping system, and a careful selection of crops could reduce mutual competition to a considerable extent (De et al., 1978). Hence it is important to select the intercrops carefully on the basis of their mutual competition and the benefit of association (Singh and Joahi, 1980).

On this farm agronomic studies undertaken over last 30 years, for the measurement of green foliage, dry matter and leaf protein productivity by different species, were restricted to the sole cropping system. In the present investigation studies on the leaf protein productivity by an intercropping system with maize (Zea mays L., Ganga Safed 2), Sorghum (Sorghum bicolor (L.) Moench, (PC-6), cowpea (Vigna unguiculata (L.) Walp, Pusa Dofasli) and Dolichos (Lablab niger Medicus (Syn. Dolichos lablab L.), (Local) under various competition densities were carried out to explore the possibilities in optimizing yields.

At the Indian Agricultural Research Institute, New Delhi It was observed that cultivation of cowpea along with either wheat or Bajra Is beneficial (Balyan and Seth, 1989). Studies at Indore by Raghuwanshi et al., (1994) have shown that Sorghum based Intercropping system could share 25 % of the fertilizer requirement without affecting grain yield of Sorghum as well as the component crop of soybean. In an other study undertaken by Tiwari et al., (1994) at Tikamgarh (M.P) it was concluded that intercropping of Sorghum with Niger was beneficial In giving additional profit over sole cropping of Sorghum alone. Santalla et al., (1994) also stressed the Importance of Intercropping bush-bean with maize,
Banik and Bagchi (1994) evaluated the cultivation of legumes with rice in Bihar and concluded that cultivation of this crop with soybean and pigeonpea is more profitable. While studying Intercropping of legumes with a cotton, Tomar and Kushwaha (1991) it was observed that cultivation of black gram with cotton is beneficial. Sharma and Sukla (1994) observed that cultivation of soybean with maize as an intercrop has no adverse effect on growth of maize as was observed due to the application of fertilizer.

Cultivation of French bean In between the rows of sugarcane was found economical by Sharma et al., (1992) without any effect on the quality of sugarcane, Gill and Verma (1993) pointed out advantages of intercropping summer forages in semi arid tropics. Pal et al., (1994) recorded higher yields due to Intercropping Sorghum with pigeonpea in 2:1 proportion. Intercropping Brassica and lentils with gram was found economical by Upasani (1994). Similarly wheat + mustard intercropping were found more suitable by Dwivedi and Namdeo (1992). Decreased uptake of nutrients by wheat + mustard intercropping was, however, pointed out by Singh and Gupta (1992).

Intercropping of black gram with maize gave higher fodder yields (Gangawar and Sharma, 1990) during rainy season. At Indian Agricultural Research Institute, New Delhi, cultivation of bajra with pigeonpea in 1:1 ratio gave favourable results (Gautam, 1994). At dry farming Research Institute, Solapur, Pigeonpea + Sunflower intercropping was found suitable (Malik et al., 1993). Intercropping of pea with winter grown maize was
found to reduce the expenditure towards fertilizers as yield stability was obtained at lower levels of N, P\textsubscript{2}O\textsubscript{5} and K\textsubscript{2}O (Paralkar and Sharma, 1994). Similarly Sood and Sharma (1992) also pointed out low N requirement by \textit{Sorghum} + cowpea and \textit{Sorghum} + soybean intercropping systems.

The work on production of fodder crops and other species were initiated in this Department in 1966. The main intention was to increase the potential of plants for higher production of feed and food grade products. Under this project, agronomic investigations were initiated by the Department using facilities available in the University Botanical Garden. Dev (1972) showed that the climatic conditions at Aurangabad are suitable for cultivation of lucerne (\textit{Medicago sativa} L.), a perennial leguminous fodder crop. Dav \textit{et al.}, (1974) showed that the crop has a potential of yielding 125 t green fodder per hectare per year when harvested for 14 to 16 times. Mungikar \textit{et al.}, (1976a) showed that lucerne could yield 28.8 tons of dry matter per hectare when harvested for 16 times in 366 days. Deshmukh \textit{et al.}, (1974) cultivated various short duration crops for the measurement of their productivity and concluded that cowpea, maize and bajra could give better yield after receiving adequate fertilizer. Higher yields from cowpea were obtained due to the inoculation with rhizobia (Deshmukh and Joshi, 1973) and also due to the micro-nutrient spray on its foliage (Dev \textit{et al.}, 1975). Sowing of cowpea at a rate of 16 kg per hectare with a plant to plant distance of 37 centimetre gave good results (Deshmukh, 1983). Reddy and
Mungikar (1988) recorded increased yield from this crop with application of 20 kg of N and P$_2$O$_5$ per hecter.

Gore et al., (1974) cultivated hybrid Napier grass (Gajraj) during 1969 to 1973 and they observed that with liberal dressings of fertilizers the crop can be expected to yield 40 t of dry matter and 6000 kg crude protein from a hecter per year.

Ludlow and Wilson (1968) and Loomls et al., (1971) observed that tropical grasses were photosynthetically very efficient and they gave good response to fertilizer nitrogen (Hutton, 1970). In view of this, Mungikar et al., (1976a) studied the effect of fertilizer nitrogen (N) on the yield of seven crops and it was concluded that large yields of dry matter and protein can be obtained from non-leguminous crop by applying fertilizer nitrogen. Increased yields from maize, Sorghum and bajra due to the application of fertilizer nitrogen were also recorded during other field trials (Dakore and Shahane, 1982; Dakore and Mungikar, 1985; Dakore et al., 1985; Bhande, 1989).

Berseem was cultivated on this farm during 1971 to 1974 and it was observed that this perennial crop has a potential of yielding 704 q/ha green fodder in 190 days (Mungikar et al., 1976b).

Dakore and Mungikar (1985) studied the effect of fertilizers on maize and concluded that the crop could yield 468 q/ha green fodder, 59 q/ha dry matter, 778 kg/ha crude protein after receiving 150 kg N and 60 kg P$_2$O$_5$ per hectare. Dakore et al. (1985) recorded almost similar conclusion
with *Sorghum*. Dakore and Mungikar (1991) observed that application of fertilizer nitrogen to *Sorghum* increase nitrogen content in the foliage with subsequent increase in the yield. On an average *Sorghum* could yield 348 q/ha green fodder 66.5 q/ha dry matter and 609 kg/ha crude protein after receiving 150 kg N/ha. Studied with African tall variety of maize by Patil and Mungikar (1991) at Dhule during June to August, 1989 recorded that application of nitrogen to this crop produced succulence in plants with lush foliage. The yield of green fodder from maize during this trial reached to as high as 60 tons per hectare due to the application of 120 kg N/ha.

Patil and Mungikar (1992a) studied nutritive value of 40 grasses from west Khandesh region of Maharashtra State and recommended that some of these could be brought under cultivation for higher fodder production. Oat, a nutritious fodder from north India was cultivated at Dhule and it was observed that, though this crop responded to nitrogen fertilizer yielding 32 tons of green fodder (Patil and Mungikar, 1992b), it could not produce green fodder to the extent recorded by other workers (Gill *et al.*, 1988; Dhaliwal *et al.*, 1984; Prasad *et al.*, 1988; Vyas *et al.*, 1988). Suitability of *Sorghum controversum* for cultivation as a fodder crop was also pointed out by Patil and Mungikar (1993). Patil *et al.*, (1994) recorded data on the yields of five varieties of *Sorghum* and showed that sweet *Sorghum* is more productive yielding 88 tons of green fodder per hectare.
Till 1980 - 1981 agronomic investigation were restricted to the sole cropping system, wherein a single crop was cultivated and its agronomy studied to define cultural method for optimum yield. Kasture (1982) made attempts to undertake studies on intercropping. She cultivated crop mixtures to attain maximum productivity. Kasture and Mungikar (1981) measured the yields of dry matter and protein from *Sorghum* and cowpea grown as either sole crops or in intercropping systems with various proportions. It was observed that the cultivation of *Sorghum* with cowpea gives more dry matter and protein yields than their monocultures. Kasture and Mungikar (1984) pointed out that cultivation of *Sorghum* with cowpea or *Dolichos*, and maize with cowpea or *Dolichos* was also beneficial in giving higher dry matter and protein productivity. Intercropping of maize with cowpea in 1:1 proportion was, however, not beneficial when cultivated during the summer of 1981 and 1982 (Kasture and Mungikar, 1985). It was also pointed out that intercropping of maize with cowpea in summer had no effect on the chemical composition of the foliage. It is thus felt that the success in an intercropping system is governed by the season. Reddy and Mungikar (1985-86) observed very little response due to the fertilizer application to maize + cowpea intercropping system. The use of fertilizer in an intercropping system should therefore be made critically.

The competitive relationships between *Sorghum* - cowpea and *Sorghum* - *Dolichos* intercropping systems were studied by Kasture *et al.*, (1986). It was observed that the growth of *Sorghum* increased due to
intercropping while that of the two legumes suppressed. However, the lower yields of legumes were compensated by increased yield of *Sorghum* resulting in higher total productivity.

Dakore and Mungikar (1986) undertook studies on intercropping of lucerne and hybrid Napier grass, the two perennial fodder crops. The results indicated that the two crops can use natural resources more efficiently if they are cultivated simultaneously in association with each other, resulting in an increased biomass productivity.

In an another study maximum yield advantage (26 % for dry matter and 44 % for crude protein) was observed when maize and *Dolichos* were cultivated In 1:1 ratio during winter season of 1981 (Kasture and Mungikar, 1986). A field trial with *Sorghum* + cowpea intercropping system with two row directions, E-W and N-S, revealed no effect on the productivity of intercropping system (Kasture and Mungikar, 1987a).

Kasture *et al.*, (1987) recorded higher yield with *Sorghum* - cowpea and *Sorghum* - *Dolichos* intercropping systems than *Sorghum* sole cropping. An intercropping system with 3 rows of maize alternating with 3 rows of cowpea was found beneficial (Dakore and Mungikar, 1988). Mungikar (1988) showed that an intercropping system makes better use of light energy resulting In higher total productivity.

Apart from this, the Department has made significant contributions In the field of conservation of fodder crops. It was pointed out that the foliages of lucerne and hybrid Napier grass could be preserved in a better

Kasture (1992) showed that good quality of silage could be prepared from a mixture of Sorghum and cowpea. Mungikar (1982) has shown that silage prepared from lucerne and sugarcane tops is nutritionally better than prepared from lucerne alone. Thus, it is felt that cultivation of legume + non-legume mixture is beneficial in giving higher yields due to intercropping, and their conservation in a mixture as silage can give nutritious animal feed.

Apart from intercropping, in order to reduce the use of chemical fertilizers in agriculture amendment of the soil with manures and bio-fertilizer has been advocated. The manures include green manuring, addition of farm yard manure (FYM) and vermicompost, while the biofertilizers include the nutrients supplied to the crop plants through biological agents. Bio-fertilization include mainly the use of nitrogen fixing microbes like blue green algae (BGA), and non-symbiotic and symbiotic nitrogen (N) fixing bacteria e.g. Azotobacter and Rhizobium.
Farm Yard manure is a mixture of cattle dung and remaining unused part of straw and plant stalk fed to cattle. Daily huge quantity of organic reduce is being added in soil which must be decomposed for nutrient recycling and availability of nutrients for crop plants.

Organic manures has long history and old practice in India as per the Bombay dry Farming method 6 t/ha FYM application is recommended to dry land crops. Animal dung - major organic source, is valued at 7.2 million tones of NPK. Almost 70 % of it is mainly used as a fuel while the remaining 30 % dung is converted into Farm Yard manure (FYM).

It must be traced that the value of FYM in soil improvement is due to its content of principle nutritive elements and its ability to improve the soil health and aeration, increase the water holding capacity of the soil and stimulate the activity of microorganism that make the plant food element in the soil readily available to the crop. The supply of organic matter which is latter converted into humus is a property of farm yard manure.

Mahajan et al., (1986) undertook long term fertilizer experiment during 1972 at Coimbatore and observed that the combined application of organic fertilizers and organic manures viz., FYM improved the physical condition of the soil by increasing the hydric conductivity, porosity and aggregation and reducing the bulk density of soil. Dhillon and Dev, (1988) reported that application of FYM improve soil fertility and organic carbon status.
Bal et al., (1993) conducted an experiment during 1983 – 85 at Dapoli, and observed that incorporation of FYM @ 5 t / ha significantly increase the growth contributing character paddy viz., plant height, dry matter. Similarly Singh et al., (1997) studied comparative efficiency of FYM poultry manures and paddy straw with and without zinc on the yield of maize and soyabean in calcareous soil and reported that the dry matter was increased with the application of FYM. Tanveer et al., (1993) at Jorhat reported that application of FYM @ 12 t / ha gave a significant difference in growth characters and grain yield of paddy crop. Similarly Vasanti and Kumaraswamy (2000) reported that a green and dry fodder yield of the *Sorghum*, maize and pearl millet cereals fodder, the soil fertility status and the content and uptake of N, P and K were significantly higher due to the treatment of poultry and ship goat manure.

Vermicomposting is a high grade organic fertilizer. It is an excellent additive made up of digested and undigested compost. Vermiculture is the simplest as earthworms promote bacterial growth enhancing soil structure and fasten the decomposition of organic matter. Composting with worms is the processes of turning organic debris into worm casting. It is simplest and efficient way to recycle food scraps into a complete and balanced plant food.

Vermicompost improves soil structure, texture and aeration as well as water holding capacity. Plants grow stronger with deeper root system for better drought tolerance and disease resistance. This replaces valuable
nutrients taken out of the soil. When fruits and vegetables are harvested use of vermicompost is beneficial. Sharma et al., (1989) reported that the residual fertility of soil improves significantly due to the application with earthworms. Jambekar (1991), observed that the percentage of total nitrogen increased by 37% in the soil due to application of vermicompost over the chemical fertilizer. Similarly Dixit (1998) found that an application of vermicompost to Sorghum influenced grain yield. Rajkhowa et al., (2003) recorded that vermicompost alone or in combination with fertilizer improved the N, P and K status and organic carbon content of the soil and produced large number of nodules in Green gram.

Biofertilizer can be defined as biologically active products or bacteria, algae and fungi, single or in combination which are useful in bringing about soil nutrient enrichment. It is also a living fertilizer compost of microbial inoculants or group of microorganisms which are known as biological nitrogen fixers. They can grouped into a) free living bacteria (Azotobacter and Azospirillum), b) The blue green algae and, c) symbionts such as Rhizobium. Association between Azolla and blue green algae Anabaena is also well known. These mostly include nitrogen fixing microorganisms. Some of the biofertilizer show symbiotic relationship with legumes, Azolla, Anabaena symbiosis, free living bacteria, cyanobacteria loss association of nitrogen fixing bacteria and mycorrhiza.

Azotobacter culture has been developed especially for oil seed crop they fix atmospheric nitrogen independently near the root zone. Shroff
(1992) reported that the nitrogen fixed by these organisms varies from 0.026 to 20 kg/ha, Gulati (1978) observed an increase in the fresh and dry weight of *Sorghum* plant due to inoculation with *Azotobacter* culture. Jain *et al.*, (2003) reported that due to inoculation of *Azotobacter* resulting concentration in soil maintain the soil biological health.

*Rhizobium* biofertilizer is the best known fertilizer. *Rhizobium* fixes atmospheric nitrogen symbiotically with legumes. Legume can obtain their nitrogen from the atmosphere via the activity of N\(_2\) fixing bacteria of the genus *Rhizobium*. It is extremely important in agriculture when legumes are grown for food, fodder and it is responsible for major input for the nitrogen cycle on a global scale.

A few species of *Rhizobium* have been identified for inoculating of leguminous seed for obtaining better crop yield. Sufficient amount of phosphorous is also necessary for better nitrogen fixation. Hence, suitable amount of phosphetic fertilizer given in combination with *Rhizobium* culture appears to be more useful.

Chowdhary and Gupta (2005) reported that the dual inoculation of *Rhizobium japonicum* and *Bacillus polymxa*, phosphorus solubilizing bacteria (PSB) was found good to enhance rhizobial and PBS population in rhizosphere soil due to synergistic relationship between them. Doses of fertilizer P at the rate of 60, 80 and 100 kg/ha proved suitable for maximizing bacterial population and minimizing fungal population in rhizosphere soil at vegetative, flowering and harvest stage of crop growth.
respectively. Better nodulation of soybean was found with 80 kg P$_2$O$_5$ level with single or dual rhizobial inoculation and beyond this P level, nodulation was reduced. Grain and straw yield of soybean crop was found increased due to single inoculation of *Rhizobium* and PSB and the effect were found more pronounced when the two inoculants were used in dual combination.

In view of the above knowledge and experiences by earlier workers attempts were made during present investigation to use organic and biofertilizers alone or in combination with the chemical fertilizers. The main objective was to find out whether the use of organic / biofertilizers can reduced the use of chemical fertilizers to supply N, P and K. The another objective was to practices integrated use of fertilizers for suitable yield of crop plants without disturbing fertility of soil. Thus experiments were undertaken on integrated fertilizer management for higher productivity of green foliages from popular fodder crops of the regions.

The experimental work was undertaken on the farm located at Dr. Babasaheb Ambedkar Marathwada University Botanical garden for yield measurements and simultaneously to observe the effect of chemical fertilizers, manures and biofertilizers on growth of crop plants. The experiments were also undertaken in pots placed under glass house conditions. The chapter following this gives information about the region and crop plants under investigation along with meteorological data.

Five popular fodder crops were selected for to study the effect of chemical fertilizers; the two fodder crops, maize and *Sorghum* were
cultivated under the influence of graded levels of nitrogen, *Dolichos* and *Phaseolus* were cultivated with various levels of phosphorus; while wheat was cultivated under the influence of either N, P and / or K fertilization. Similar experiments were undertaken in the pots along with Farm Yard manure (FYM). The results obtained are presented in Chapter – III.

In order to increase soil fertility as well as productivity of crop plants modification in cropping pattern is employed to minimise the use of chemical fertilizers. This includes crop rotation, mixed cropping, intercropping etc. These cropping patterns make use of nitrogen fixing ability of the legumes, cultivated before cereals or otherwise they are grown simultaneously with them. Cultivation of a mixture of legume and cereal crops in rows with definite proportion is called intercropping. The advantages of intercropping have been mentioned earlier and in view of this, three fields and two pot experiments were undertaken on intercropping using fodder crop plants viz., maize, *Sorghum, Dolichos* and gram. The results obtained on various aspects of intercropping are presented in Chapter – IV which gives an indication of practicing intercropping for higher fodder production.

The use of organic matter as a manure is common practice in Indian agriculture. This practice not only supply nutrients to the crop plants leading to higher productivity, but also maintain soil structure and protects soil microflora. In addition, it reduces the requirement of chemical fertilizers which can deteriorate soil texture and structure. Apart from this
the use of nitrogen fixing biofertilizers in the form of *Azotobacter* and *Rhizobia* at the time of sowing is also employed to facilitate higher nitrogen fixation with increased yield. Field and pot experiments were undertaken with maize, cowpea and *Dolichos* which were treated with either varmicompost, Azo-fertilizer or Rhizo-fertilizer. The results reported during the experiments are summarized in chapter V with an emphasis on use of organic fertilizers and biofertilizers in agriculture.

Various fodder crops have been recommended for cultivation to use as fodder for cattle. These crops are normally cultivated in *kharif* and *rabi* seasons. The cultivation of these crops in summer is difficult due to the scarcity of water, which is more severe in dry land agriculture. As a result there is an acute shortage of green fodder for feeding to the animals during summer. Therefore, it is imperative to conserve the abundant foliage harvested during favourable season. In India preparation of hay from green foliage is most common practice. During present investigation foliages from fine fodder crops viz., maize, *Sorghum*, bajra, hybrid Napier and *Dolichos* were dried under different conditions. The drying rates of these crops were determined following the concept of relative water content (RWC) and the samples of hay were prepared. Chapter VI gives information of drying rates and quality of hay produced from these crops. In addition the data collected during experimentation has been supplemented with the chemical composition of fodder crops undertaken by earlier workers.
The results obtained and discussed in chapter number III to VI are summarized in chapter VII along with the conclusion. A list of references is given in the form of bibliography at the end.

It is felt that the findings reported during present research project will be useful in practicing integrated fertilizer management for higher productivity of fodder crops with limited input of chemical fertilizers. This will increase the use of manures and biofertilizers which will protect the soil health.