Chapter 2

REVIEW OF LITERATURE

Pulses are the second important group of crops after cereals. Pulses have contributed significantly in providing nutritionally balanced food for predominantly vegetarian population in India. This shortfall in pulses is mainly due to near stagnation in production at 13-15 million tonnes on account of poor spread of improved varieties and technologies, abrupt climate changes, complex weed-pest-disease syndrome and declining factor productivity. The country resorts to import of pulses to the tune of 3-4 million tonnes every year to narrow down the demand-supply gap. In order to ensure self-sufficiency, a critical review of Lentil crop production system is required (Handbook of Agriculture, 2009; Ali and Gupta, 2012).

Cropping History

Monocropping in Lentil is a common practice in India in the heavy textured soil where rainfall does not support a good kharif (monsoon) crop. Hence, fields are left fallow during kharif season and Lentil is sown on the conserved moisture. It is also practiced in heavy rainfall areas (>1000 mm) of Bihar, West Bengal, Orissa and eastern Uttar Pradesh in the areas of Diara lands and Tal lands. In these areas, frequent floods and poor drainage do not allow raising a kharif crop. Thus Lentil is sown as monocrop after the flood water recedes. Diara lands are highly fertile due to deposition of silt during flood and hence a bumper crop of Lentil is harvested (Erskine et al., 2009).

The inclusion of Lentil in various cropping systems benefits the companion crop or succeeding crop by improving the physical and chemical properties of soil (Ali 1994, Shah et al., 2003; Wisal 2003). Experiments conducted in the temperate ecosystem of Kashmir, India showed that nutrient status and the balance of nutrients were significantly influenced by the cropping system. The rice-Lentil system increased the nutrient status of soil (Singh and Sofi, 2007).

“Lentil had adapted to three major climatic regions of the world. (a) In sub-tropical regions. (b) In West Asia, North Africa and Australia Lentil is sown in winter in areas that receive annual rainfall of 300-450 mm. In these regions, low temperature and radiation
restrict vegetative growth during winter, but growth is rapid in spring when temperatures are rising. Ripening occurs prior to, or early in summer when temperature and evaporation are high and rainfall low. (c) In high altitude and/or latitude areas such as central Turkey, USA, Europe and Canada where the winters are too cold for Lentils to grow reliably, sowing is delayed until spring. Lentils are grown in stored moisture and/or snow melt supplemented by rainfall during spring and summer when temperatures are warm and day lengths long. Presently, India accounts for 76% of production and 80% of area of the total South Asian region, followed by Nepal, Bangladesh and Pakistan” (Erskine et al., 2009).

The Indo-Gangetic Plains (IGP) of northern India, is showing declining trends in area which is quite heavily displaced by rice, wheat and maize due to better irrigation facilities. It is serious concern for sustainability of agro-ecosystem of northern India. In north India, rice-wheat crop rotation is predominant, and there is little scope for replacing wheat with rabi pulse crops; while in south India, there are vast patches of rice fallows, which can be utilized for sowing rabi pulse crops, as there is no strong competitive crop in the rabi season. Agricultural development pathways followed in different states of the IGP varied in intensity and extensity of the agricultural growth (Singh et al., 2010).

**Soil and Nutrient Management**

Lentil is grown on a wide range of soils ranging from light loamy sand to heavy clay soils in northern parts, and in moderately deep, light black soils in Madhya Pradesh and Maharashtra. Its range of cultivation extends to an altitude of 3,500 m in north-west hills. The optimum temperature for its growth and development ranges from 15-25ºC. It is generally grown as a rain-fed crop during rabi after rice, maize and pearl millet. The magnitude of nutrient removal from the soil by a Lentil crop is dependent on nutrient availability, crop growth and development, and ultimately yield (Handbook of Agriculture, 2009).

Lentil performance is severely hampered in soil with acidic (< 5.0) and high (>9.0) pH. Soil pH influences nutrient availability, making some nutrients deficient while others highly available to the point of becoming toxic for growing plants (Erskine, 2009).

Soil acidity leads to deficiency of P, K, Ca, Mo and B; it can also lead to toxicity of Al, Fe and Mn. Molybdenum deficiency leads to hampered nodulation and symbiotic N₂ fixation of legumes. Owing to the above effects, Lentil productivity was reduced by 71% in acidic soils as compared to normal soil. To alleviate the adverse effects of acidity, liming of
soil is advocated to bring the soil pH around 6.0. Application of 6t lime/ha resulted in increased Lentil seed yield from 325 to 1125 kg/ha due to decrease in exchangeable Al, Fe and Mn (as a result of their precipitation as carbonates, oxides and hydroxides respectively) coupled with an increase in pH, exchangeable Ca and Mg (Diwedi, 1996).

Lentil is one of the most salinity sensitive crop when it is grown on residual moisture in the post-rainy season (after rice or fallowing in the rainy season in South Asia) it is prone to salinity stress and salts accumulate in the soil solution and are then precipitated towards the soil surface as the soil dries out. Lentil yield and its biological N contribution get reduced by 9-100% (Hoorn et al., 2001; Katerji et al., 2003) at an electrical conductivity (EC) of 3.1. At over 0.8 ECe in saline soils, deficiency of K and Ca (Finck, 1977) coupled with toxicity of Na sulphates and chlorides results in reduced nodulation of legumes (Bhardwaj, 1975). This results in poor yield performance. Salinity-induced nodulation inhibition in Lentil was ascribed to inhibition of root hair expansion leading to root curling (Sprent and Zahran, 1988).

An increase in NaCl concentration in the soil resulted in increase uptake of Na and Cl, and reduced dry weight, K concentration and K:Na ratio of Lentil. The high Chloride (Cl-) content of saline soils competitively inhibits phosphate uptake of plants (Zhukovskaya, 1973). Application of Ca was found to reduce the Na:Ca ratio and the deleterious effects of NaCl salinity on germination and seedling growth of Lentil were reduced to a 14:1 ratio (Astaraei and Forouzan, 2000). Inoculation of Lentil seeds with *Rhizobium* in saline soils with an EC of 6ds/m increase dry matter production by 22.9% (Ahmad, *et al*., 1986). Inoculation also increased the N and P contents of plants. Seed pelleting of *Rhizobium*-inoculated seeds with CaSO$_4$ enhanced Lentil performance in a saline soil (Poi, 2005).

Soil alkalinity leads to deficiency of Na, Zn, Mn and Fe. Excess of Na that adversely effects the physical properties of soil under water-logging and nutrient availability to plants. In sodic soil (pH>8.5), N availability (owing to high volatization losses) as well as Fe is reduced. The reduced Fe availability due to high CaCO$_3$ and production of bicarbonate with decomposing organic matter that increases the available phosphate which reduces Fe availability to plant (Singh *et al*., 1985).

The recommended dose of fertilizers is 20 kg N, 40 kg P$_2$O$_5$ and 20 kg K$_2$O and 20 kg S/ha. In soils, low in zinc (Zn), 20 kg ZnSO$_4$ is recommended under rain-fed and late sown conditions; foliar spray of 2% urea improved yield. Light irrigation 40-45 days after sowing
and at pod formation is beneficial. The average yield is 0.8 to 1.0 tonnes/ha under rain-fed and 1.2-1.5 tones/ha under irrigated conditions. Under good management, it may yield up to 2.0 tonnes/ha. However, in several countries, in particular Canada and USA, over the past 25 years, Lentil production has increased greatly in high fertility soils with adequate soil moisture. Under these conditions, yields of 3 t/ha was achieved (Andrews et al., 2001; FAOSTAT, 2006).

Inoculation of Lentils and added P has been shown to increase root biomass, number of nodules, plant growth and nutrients (Shah et al., 2002; Balyan and Singh, 2005).

Low P can also reduce nodulation and N$_2$ fixation processes. Gupta and Sharma (1989) reported increases in seed protein with addition of P fertilizer and reduction of nodulation and N$_2$ fixation process whenever the phosphorus level was low. Similar to N and P, positive grain yield and biomass response to K, S, Mg and Ca have been observed (Singh and Chauhan, 2005). Increased K and Mg have also been shown to have benefits for N2 fixation (Srinivasarao et al., 2003; Kiss et al., 2004).

Chanway et al., (1989) examined the effect of plant-growth-promoting Rhizobacteria on grain legumes and found that Lentil inoculated with bacteria had greater emergence, growth, nodulation and root weight. Zarei et al., (2006) conducted a green house study to evaluate the effect of arbuscular mycorhizas (AM) and indigenous Rhizobacteria strains on Lentil in calcareous soil with high pH and low amounts of available P and N. They found that mycorhizas, Rhizobial strain and addition of P had significant effects on nitrogen fixation in Lentil, and Rhizobia and AM was synergistic. Lentils inoculated with phosphate-solubilizing bacteria can increase above-and below-ground biomass, nodulation and P-use efficiency (Singh et al., 2005).

The concentration of nitrogen effects nodulation and nitrogen fixation of all legumes. High levels of soil N reduce nodulation and fixation, thus minimizing the benefit of the symbiotic relationship. Considerable research has been conducted to select genotypes and strains of Rhizobia that maximize nitrogen fixation in N-rich soils (Giller and Cadisch, 1995; Wani et al., 1995; Herridege and Rose, 2000).

The application of 18 kg N+46 kg P$_2$O$_5$+20 kg K$_2$O+20kgZnSO$_4$/ha provided the highest nodulation (Jain et al., 1995) and grain yield of Lentil. Sharma et al., (1993) reported higher grain yield and N uptake by Lentil with the combined inoculation of Rhizobium and
Azospirillum brasilense. The combination of phosphobacterial inoculation and 35 kg P<sub>2</sub>O<sub>5</sub>/ha provided higher water use efficiency, total P uptake and net returns compared with no P application or 35 kg P<sub>2</sub>O<sub>5</sub>/ha alone (Venkateshwarlu and Ahlawat, 1993). In the absence of Rhizobium inoculation, application of 12.5 kgN+40 kg P<sub>2</sub>O<sub>5</sub> is recommended. However, when seed is inoculated with Rhizobium, then 12.5 kg N+20 kg P<sub>2</sub>O<sub>5</sub>/ha is sufficient, thus offering an opportunity to save 20 kg P<sub>2</sub>O<sub>5</sub>/ha (Zarei et al., 2006).

Estimates of the percentage of plant N derived from fixation in Lentils ranged from 28 to 87% with an average of 63%. Walley et al., (2007) summarized results from 38 field experiments with Lentils conducted in Canada and reported a range of 9-88% N derived from fixation, with a median value of 60%.

Published estimates of the total amount of N fixed by Lentil range from 0 to 192 kg/ha with an average value of about 80 kg N/ha in shoots and roots. This estimate is similar to quantities fixed by chickpea and dry bean. The Lentil root system takes about 20-25% of fixed N in the plant, or about 22 kg N/ha in the roots and nodules (Ukovich and Pate, 2000).

Ghosh et al., (2007) concluded that the carryover of N from grain legumes for succeeding crops (e.g. sorghum, pearl millet, maize, castor) in dry-lands and marginal and sub-marginal lands ranged from 30-120 kg N/ha. The carryover for Lentils is probably at a lower end of the range, estimated as 45 kg N/ha by McNeil and Materne (2007) and 23 kg N/ha by Van kessel and Hartley (2000). In comparison to other grain legumes (i.e. common pea, chickpea), Lentils are likely to have positive N balances (Walley et al., 2007).

Slattery et al., (2004) conducted a survey of the effectiveness of Rhizobia communities at 50 sites in Southern Australia and found that nitrogen-fixing effectiveness was related to pH and location. Only 54% of the sites had sufficient resident populations of R. leguminosarum biovar viciae for effective nodulations of Lentils. Low populations (<10 Rhizobia/g soil) of R. leguminosarum biovar viciae in acidic soils. Evans (2005) also found that strains of R. leguminosarum vary considerably in their ability to nodulate Lentil, fix N and contribute to plant growth in acidic soils. High alkalinity also reduces nodulation, nodule biomass and legheamoglobin content of Lentil nodules (Misra et al., 2002).

Soil micronutrient affect the nodulation, nitrogen fixation and soil health (Wani et al., 1995). Prasad et al., (2004) found that Rhizobia strain and Sulphur affected grain yield of Lentil, nodules per plant, S content in nodules, total N uptake, and nitrogenase activity.
Additions of micronutrient (Mo, Co, B) was shown to increase Lentil nodule biomass, plant biomass, N content, seed yield and seed size and N and P content for Lentil, chickpea and lupin (Yanni, 1992).

The contribution of the *Rhizobia*-Lentil symbiosis to soil health is affected by intrinsic biotic factors, such as plant genotype, strain of *R. leguminosarum* biovar viciae, and interactions between the two. Studies have shown significant variation among Lentil genotype among nodule number, nodule biomass and nitrogen fixation (Bhattacharya and Sengupta, 1984; Hafeez *et al*., 2000) root-hair density and micronutrient uptake (Gahoonia, *et al*., 2006), and root growth and weight (Sarkar *et al*., 2005). Small seeded genotypes of Lentils have greater nodule biomass than those of large seeded, and vary in total fixed nitrogen and sol N uptake (Kurdali *et al*., 1997).

Several studies have shown considerable variation between strains of *R. leguminosarum* biovar *viciae* in nodule number and biomass, nitrogen fixation, proportion of N derived from fixation, total plant N content, grain yields and root growth (Bremer *et al*., 1992; Hafeez *et al*., 2000; Martenz Romero, 2003).

Because nodulation, nitrogen fixation and photosynthesis are linked, factors. Insects, plant pathogens and weeds can adversely affect symbiosis and fixation in Lentil. For example, Weigand *et al*., (1992) conducted a 3-year study on the effects of nodule-feeding insect (Sitona crinitus), planting date, and fertilizer and insecticide application on plant damage and yield of Lentil in different locations in north Syria. They found that insect caused significant nodule damage (up to 75%) and yield reductions. The overall effect of the insect was related to precipitation and planting date (Yadav *et al*., 2007).

Researchers have examined and linked a variety of factors responsible for broad range of estimates, including lack of effective strains of *Rhizobia*, Lentil genotype, use of inoculants, soil type, existing soil N levels, crop phenology and type of cropping system.

**Crop Performance**

“World Lentil production has increased four times from 1 million tonnes in 1971 to 4.5 million tonnes in 2012, and this has been accompanied by increased yields from 611 to 1070 kg/ha, respectively (FAOSTAT, 2013). Three top ranking countries, namely India, Canada and Turkey have increased their productivity and production. Lentil area has increased greatly in India, Canada, Australia and Ethiopia. However, area expansion and
productivity has increased in the developed world most particularly in Canada and the USA, compared to the traditional Lentil-growing countries. Systematic research for its improvement is being carried out at some national institutions and at ICARDA, Syria during the last three decades. Bulk pedigree method is generally used to construct new genotypes to different national programmes” (Handbook of Agriculture, 2009; Erskine et al., 2009).

In Mediterranean region of west Asia and North Africa Lentil plants make fast vegetative and reproductive growth and reach maturity in 75-100 days after sowing. However, in most Lentil producing countries, plant growth of winter-sown crop is rather slow in the early vegetative phase because of the sub-optimum ambient temperatures and it gains momentum only in spring when temperatures rise. As a result, the winter-sown crop takes 120-160 days to reach maturity. Moisture supply during the reproductive phase of the crop growth much affects the complete realization of the growth and yield potential of Lentil genotypes (Saxena and Hawtin, 1981).

Response of Lentil to plant densities had been variable, depending upon genotype, planting time and sowing conditions. In Alberta, Canada 107 seeds/m² (Muehlbauer et al., 1998) and in North Dakota, 172-220 seeds/m² was optimum (Eriksmoen et al., 2008). In Lentil, the seed rate varied according to seed size. The small-seeded cultivar L9-6 produced a higher yield with a seeding rate of 30 kg/ha while a large seeded cultivar AARIL 355 gave more yield with a 40 kg/ha seed rate. In Bangladesh seed rate of 30-35 kg/ha with a plant density of 250 plants/m² has been found optimum (Rahman and Miah, 1989).

It appears that with domestication there was not only the development of pod dehiscence but also a gradual increase in seed size. However, these two groups (macrosperma and microsperma) are freely intercressable and a complete range of seed sizes, is present in cultivated species. During the last decades, through broadening of the genetic base, these two groups of Lentils have become indistinguishable, and the grouping is no longer much used by Lentil workers (Zohary and Hopf, 2000; Mulbauher et al., 1985).

The flowering response of Lentil is a key to understand its adaptation. Roberts et al., (1988) found no evidence for a specific low-temperature response in Lentil, while Tyagi and Sharma (1989) reported a small response. Like most annual winter crops, the timing of phenological events in Lentil is modulated primarily by the responsiveness to photoperiod and temperature (Summerfield et al., 1996).
In Lentil, 231 accessions were characterized for their flowering response to photoperiod and temperature in glasshouse experiments which were confirmed in field experiments in Syria and Pakistan. In both studies, a large proportion of the variation among accessions for time to first flower and response to temperature and photoperiod was related to origin. In particular, sensitivity to photoperiod was dependent on the latitude of origin. Accessions from lower latitude countries such as, India, Ethiopia and Egypt had a longer non-responsive phase, less sensitive to photoperiod and more sensitive to temperature. (Erskine et al., 1994).

Kant and Sharma (1975) observed that all microsperma lines in a germplasm collection were early flowering (flowering in 60-80 days) and remaining macropserma genotypes originating from the western hemisphere were always late, producing flowers after 80 days. Some of these macropserma genotypes did not produce flowers under the short-day conditions of Indian winter.

Presently, the understanding of the genetic control of flowering is limited. However, the available results show that early flowering is largely determined by a single recessive gene \( sn \) in addition to some polygenes. Transgressive segregation in the progeny of crosses between early and late flowering parents was also studied. Pod dehiscence is a trait of great economic value as it sometimes causes significant losses before or during harvest. Pod dehiscence is a survival trait in wild species such as \( Lens orientalis \). Among the cultivated Lentil also, the oriental microsperma Lentils have a higher degree of dehiscence than their occidental macrosperma counterparts (Tyagi and Sharma, 1989; Sarkar et al., 1999).

Mauhlbaeur et al., (1985) concluded that branching pattern and number of fruits to reach maturity are the most important characters that contribute positively to yield. Therefore, early maturing plants having early growth vigour and greater number of pods should be selected for short season environments, as they will be able to escape terminal stresses. In South Asia, small-seeded and semi-spreading cultivars are mostly grown under normal and late sown situations, and yields are stable because the plants are able to fill the available space by initiating lateral branches and compensating for poor emergence. Early flowering combined with early growth vigour, larger seeds and cold tolerance are some of the desirable attributes of new plant types. For late sown conditions, semi-spreading growth, early maturity and large seeds are important traits (Singh, 1997).
The scope of selection for desirable genotypes depends on the extent of exploitation of genetic variability. Some of the promising traits in the indigenous gene pool of South Asia are early maturity and more pods per plant and per cluster (Bhag Singh and Rana, 1993). Extreme specificity of adaptation limits the scope of direct introduction of exotic germplasm in this region. Sharma et al. (1993) reported that most of the Indian Lentils (microsperma type) are early maturing and the Mediterranean macrosperma Lentils are late maturing. Podding potential was higher in small-seeded genotypes than large-seeded ones and small-seeded types have better stability.

The mechanism identified as important in drought escape is the ability of a plant to complete its life cycle before the commencement of severe water deficits. This improves rapid phenological development such as rapid germination and seedling establishment, early flowering, early podding, early maturity, and phenological plasticity to take advantage of longer and cooler seasons (Turner et al., 2001).

**Weed Management**

Directorate of Weed Science Research, Jabalpur, MP (DWSR), number of Crop Research Institutes of ICAR, and state Agricultural Universities (SAAU’s) are actively involved in Weed control research.

Singh et al. (1996) indicated that yield losses were not greater than 10% when the weeds could be allowed to grow in Lentil from 34 or 41 days after emergence of crop. Mohamed et al., (1997) observed that the critical weed-free period between 2 and 4 weeks after seedling in Sudan under irrigation.

In some areas of the Indian subcontinent, Lentil may be grown in rotation with millet, sorghum, maize, cotton, guar, sesame or rice. The farmers’s generally neglect weed control measures in Lentil crop. Moreover, Lentil could become a liability with regards to weed control because of the increased weed-seed production due to poor competition (Ali et al., 1993; Yenish, 2007).

*Orobanche* spp is most severe in Lentil in Europe and Asia. The 30% of the cropped area in Egypt is infested with *Orobanche* of which 50% is considered very serious. *O. ramosa* is a serious weed of beans and peas in Egypt, of chickpea and Lentil in the near and middle east and of several legumes in Czechoslovakia, Italy, Egypt, Australia and Hungary. The planting of beans and peas has been abandoned in some areas of Malta, Morocco and Sicily.
due to severe infestation of crops with O. ramosa. The growth of parasitic plant biomass below ground is so vigorous at times that it may weigh several times more than crop to which it in attached. Delayed sowing of Lentil and chickpea is also reported to reduce the infestation of Orobanche—a root parasite (Linke and Saxena, 1989).

Mixing two or more of weed management principles is the basis for integrated weed management. Each of the five principal techniques is of equal value in managing weeds in Lentil with the exception of biological control. Few biological methods of weed control have proven effective in annual cropping systems and individual weed species which are problematic in legumes are largely a function of cropping systems or rotation rather than the individual crop of Lentil (Anderson, 2004).

**Climate Change Impacts and Systems Approach**

According to Swaminathan, (2010) the losses of agricultural income can be minimised if we undertake studies about the resilience of crops to climate change. Mark New *et al.*, (2012) investigated the climate of the Indo-Gangetic Plain and the implication of climate change on agriculture was assessed in terms of: (a) the recent trends and projected future changes in climate, specifically focused on the IGP, (b) the potential changes in crop suitability of key crops grown in IGP, and also summarized the key advances that can be expected in climate model information over the next few years.

Nadarajan *et al.*, (2010) estimated the impact of drought on pulses to loss of area to the tune of almost 2-3 million ha and drop in productivity by 50-70 kg/ha. There is an urgent need to increase the resilience of the production systems and improve drought management strategies via technical, institutional and policy options. A powerful example of drought impact on pulses production can be seen from the zigzag trend in pulses production in country since 1997.

Optimum temperature for Lentil growth and development ranges from 15 to 25°C. Crop duration is extended by cool weather (Summerfield, 1981). The Lentil season in South Asia coincides with a sharp rise in temperature (>30°C) by end of February in central India, West Bengal, Bangladesh and early April in northern India, Nepal and Pakistan. The rising temperatures coupled with receding soil moisture push the plants into forced maturity. Thus the crop duration in this region varies from 100-140 days depending on the location. Therefore, cultivars with high yield potential should have a crop duration of around 100 days
in central India, 110 days in Bangladesh and 140 days in the cooler areas of the region (Clarke et al., 2005).

In India, Lentil crop mainly encounters terminal drought in central parts resulting in heavy loss of yield. Therefore, it is suggested to develop early flowering variety for avoiding the terminal drought. However, such varieties of Lentil may encounter cold or low temperature in India with the changing environmental conditions happening due to global warming as noticed in recent past years. In the year 2011, minimum air temperature during the first fortnight of January varied from 3.55 to 12.59°C (average minimum temperature 6.10°C) when flowering and development of pods were initiated in some genotypes. In the coming years, the minimum temperature may dip further beyond 6°C. Prolonged low temperature causes slower growth and injuries to flowers, leading to degeneration and dropping of flowers. In India low temperature during flowering and pod-filling stage can reduce the yield potential in early to lowering genotypes as observed in other highland areas of the world. Therefore, it is more desirable to breed genotype having ability to withstand prolonged low temperature mainly during flowering and pod-filling stages (Muehlbauer et al., 2006).

“Climate change, declining yield potential and environmental degradation, are more complex in nature. The search for their solution has necessitated more focused yet interdisciplinary efforts. Organized thinking about future farming requires forecasting of the implications of alternate ways to develop agriculture. Systems thinking and systems simulation are indispensable tools for such integration and extrapolation, of issues related to: (a) Crop production under genotypic constraints, (b) Crop production under weather-related constraints, (c) Crop production with soil constraints, (d) Crop production with biological constraints, or (e) Education, training and technology transfer” (Teng, P.S., 1992).

Sarveswara Rao et al., (2009) presented an overview of the state of development and application of these models as well as the Indian experience. They emphasized the need for integration and quantification of knowledge about crop-soil-weather and management interactions at Eco-village level before we take advantage from the agricultural systems models in the Indian context.