Chapter 5

SUMMARY

Lentil crop production under different management, soil conditions and variable weather demands a detailed understanding of crop responses.

Lentil cultivar DPL-62 was selected for experimental studies and some of the significant observations that emerged from the present investigation are summarized as follows:

A. Cropping History, Soil Analysis and Production of Biofertilizers

1. Lentil is grown separately as sole crops in Rabi season fields left vacant by preceding Kharif Rice crop in Agra (Rabi Lentil-Kharif-Rice rotation) and this legume-rice cropping system is an eco-friendly practice followed here. The primary crop is rice or wheat, although sometimes Bajra, Jowar are given priority by some farmers depending on the land holdings.

2. The sandy loam soil samples from three sites (site 1 and site 2 belong to experimental plots, while site 3 is farmer’s field) both at pre-sowing period and also after post-harvest of Lentil crop was collected and analysed for physical and chemical parameters. The major conclusions drawn from the above analysis is as follows: (a) The soils of all the three sites are normal without any problem of soil salinity with respect to soil pH and electrical conductivity. (b) Percentage of organic carbon is low in site 1 and site 3 while medium in site 2. (c) Nitrogen and Potassium fertility is generally low in all the sites. Soils are deficient in nitrogen and potassium. (d) Phosphorus level is generally found to be medium to high in the experimental plots due to the application of phosphorus solubilizing bacteria (i.e. Pnecbacillus polymyxa). However, in farmers field phosphorus is generally medium. (e) Zinc, Copper, and Manganese are medium to high, however Iron is medium in site 1 and 2 and low in site 3.

3. Among the biotic components attention was paid to plant-parasitic nematodes. In the present study, survey of initial nematode population was done in the Lentil crop fields. It indicated heavy infestation by both saprozoic and plant parasitic nematodes and the average value of different sites are as follows: saprozoic
nematode 4821.3 per kg soil, plant parasitic nematode 4645.3 per kg soil, and total nematode 9466 per kg soil.

4. Symbiotic nitrogen fixer *Rhizobium leguminosarum* (MTCC 10096), non-symbiotic nitrogen fixers *Azotobacter chroococcum* (MTCC 7724) *Azospirillum lipoferm* (MTCC 2694) and phosphate solubilizers as well as plant growth promoting *Paenibacillus polymyxa* (MTCC 122) strains were procured from Institute of Microbial type Culture Collection, Chandigarh. These strains were revived and scaled-up in the laboratory as per standard protocols and for the purpose of utilizing in the experimental plots as well as in farmers fields. Mass production of the above inoculants was done using activated charcoal as a carrier. The nodulating capacity of the above *Rhizobium* strain was also tested by bacterizing the seeds of Lentil and growing it in pots. High nodule number per plant was observed that reaffirmed the high quality of the inoculants (IS:8268-1976-1986). The above inoculants were used both in integrated nutrient management experimental plots and farmer’s field.

**B. Crop Performance and Integrated Nutrient Management**

1. Field survey was undertaken to observe seed rate, sowing time and vegetative performance of Lentil Crop for three years and data was analysed statistically. In the present study a seed rate of 35-40 kg/ha with 25 cm row spacing of Lentil cv. DPL-62 was maintained in the experimental plots. The local farmers deviated slightly from the above seed rate.

2. The sowing dates varied in different years as follows: (a) October 25, (2010); (b) November 5, (2011); (c) November 20 (2012). Sowing date is known to effect plant growth and development which in turn affect final yield.

3. The plant population density was monitored at three regular intervals (15 DAS, 45 DAS, 90 DAS) for three successive years. About 13 to 29% seedling mortality is recorded in Lentil crop and more care during weeding operations is recommended. Average population density showed a decreasing trend over different periods of growth stages. Insufficient care for crop plants during weeding operations may be responsible for the decreasing trend. It was about 90.0 plants/m² at 15 DAS 78.0 plants/m² at 45 DAS, and 47.0 plants/m² at 90 DAS, respectively.

4. Plant height trait of the cv. DPL-62 at three different growth periods was monitored for three successive years and results indicated the average plant height was in the range of 31-35 cm. Data for primary branches/plant was recorded for
three years and analysed statistically. The results showed that the primary branches/plant were in range of 7.0-9.8/ plant. Because of the importance of root traits in the capture of moisture and inorganic nutrients form soil, the observations were recorded for root length and number of primary roots/plant in the present study. The statistically analysis of data showed that there were no significant difference in root length and primary roots/plant in the three years. The root length ranges from 17-18 cm while 8.4-8.6 primary roots/plant were recorded.

5. In the present study, the number of nodules on roots of Lentil was counted at 60 DAS and 90 DAS and there was no significant difference in the number of nodules/plant. A maximum of 18 nodules/plant at 90 DAS was observed which could be due to improved plant growth (root as well as shoot) with age.

6. As the phenological studies of the flowers were neglected so far, a detailed investigation into the floral phenology of Lentil crop is attempted for the first time in the present study. Here, the changes in the floral stages of cv. DPL-62 from bud stage to pod development were noted along with the duration taken for each developmental stage. These observations were recorded from 5 plants and also 5 flowers on each plant. The different floral phases were defined as follows and duration taken for each phase were recorded separately. **A Stage:** small bud, petals not visible yet, **B Stage:** large bud, petals are visible but not expanded, **C Stage:** flower opening, **D Stage:** full blooming (anthesis), **E Stage:** flower wilting. The floral cycle of Lentil from A to E stage is completed in 6 days.

7. The pollen viability test was also undertaken and the total number of pollen grains/anther and pollen load on stigma was counted. Total fertility of the pollen was recorded on the basis of acetocarmine staining of pollen grains. Each anther on an average produced about 140 pollen grains and each stigma received about 121.2 pollen grains. The flowers are cleistogamous and almost exclusively self-pollinated.

8. The number of pods per plant, which is very important yield determinant in Lentil varies considerably depending on the genotype as well as the environment. About 52-55 pods/plant in the cv. DPL-62 were recorded in the present study. The pod length and its circumference was also measured and the average pod length was 1.84 cm and pod circumference was 1.18 cm. On an average 1.2 seeds/pod and 64.5 seeds/plant was observed in the three successive years.
9. Estimation of seed yield with respect to different sowing dates indicated that there was significant reduction in seed yield with delay in sowing after 5\textsuperscript{th} November. Lentil sown on 25\textsuperscript{th} October and 5\textsuperscript{th} November increased the seed yield up to 29 percent and 21.8 percent, respectively. The biological yield also increased up to 21 percent when sown on 25\textsuperscript{th} October and about 18 percent when sown on 5\textsuperscript{th} November. Lentil sowing after 20\textsuperscript{th} November is not recommended for Agra on the basis of the present study. The ratio of the seed yield to total above-ground dry matter (DM), the Harvest Index (HI), is determined by the DM accumulated and the amount of water available for seed development after podding. The harvest index was between 48.6-53 percent recorded.

10. As Pod drop is one of the major constraint in decreasing the seed yield of Lentil, a sample survey of pod drop in the field was also conducted in the present study. A random sampling survey indicated that there was about 84.9 dropped pods/m\textsuperscript{2} and 51.3 dropped seeds/m\textsuperscript{2} at the time of harvest. The reason for pod drop in Lentil may be due to (a) genetic (b) non-synchronous maturity, and (c) climatic factors.

11. The all the data recorded above was used for estimating the economic analysis of the Lentil Crop in the three years. The analysis of economics revealed that the Lentil sown on 25\textsuperscript{th} October gave the maximum gross return of Rs.47,985 with CBR 2.38 followed by 5\textsuperscript{th} November sown Lentil (Rs. 43,890) with CBR 2.32. The lowest gross return of Rs. 34,282.5 was obtained when sowing was done on 20\textsuperscript{th} November because late planting leads to less vegetative growth and forced maturity and consequently the grain filling is affected. Delay in planting causes reduction in yield but the magnitude of reduction is large after 20\textsuperscript{th} November.

12. The correlation coefficient was estimated between seed yield and yield attributing traits. The results of the study showed that pods/plant and 100-seed weight highly correlated with seed yield (r = 0.95, 0.96 respectively). This character could be a good index for selecting high yielding genotypes. The number of seeds/plant, is closely correlated with the number of pods per plant and is therefore, an important yield attribute. Similarly, harvest index, seed yield/plant, pods/plant also showed high degree of correlation. It seemed that harvest index, pods/plant and seed yield/plant were useful characters for breeding and improvement of Lentil.

13. The local farmers are not aware of fertilizers recommendations and they are satisfied with their present nutrient management practices, which are traditional
118

and location specific. The farmers are adjusting their nutrient management practices on the basis of their experience rather than soil-test based recommendation. In the present study the observations on the Lentil crop performance under integrated nutrient management practice were recorded.

14. The experiment was laid down in Randomized block design with five treatments and three replications, the analysis of variance (ANOVA) was done for all the treatments. The treatment consisted of (1) Control, (2) Farmyard manure + *Rhizobium*, (3) Farmyard manure + Biofertilizers (consortium of *Rhizobium*, PSB, and *Azospirillum*), (4) Farmyard manure (4tons/ha) + Chemical fertilizers (Single Super Phosphate 50 kg/ha and Urea 12.5 kg/ha) and (5) Farmyard manure + Biofertilizers (consortium of *Rhizobium*, PSB, and *Azospirillum*) + Chemical fertilizers.

15. The solution made up of 100g jaggery and 2g gum Arabic in 1 litre of water was heated for about half an hour. The solution was allowed to cool at room temperature and then one packet of culture containing the consortium of inoculants is added to it and mixed thoroughly. This mixture of culture is rubbed with the seeds to get uniform thin coating over the seeds. The bacterized seeds were then dried in the shade for an hour and sown thereafter.

16. A comparative study was undertaken to study the effects of application of: (a) FYM+ *Rhizobium* inoculants and (b) FYM + consortium of biofertilizers that included the N₂ fixer *Rhizobium, Azotobacter* and *Azospirillum* as well as the phosphorus solubilizer (*Paenibacillus*) inoculants. Differences in plant growth, seed yield and biological yield were recorded. The consortium approach proved to be highly advantageous over others. It increased the seed yield by 29.7% in the year 2010 and 30.8% in 2011, respectively. Significant increases in average pods/plant (17.2%) and 100-seed weight (2.2%) were also observed during the above period. This favourable effect of consortium treatment might be due to increased availability of nitrogen and phosphorus.

17. The impact of chemical fertilizer jointly with farm yard manure application was also studied, separately. Following this treatment the average increase in seed yield of (36.8%) and biological yield of (20.7%) was recorded. The increase in seed yield was attributed to the average increase in pods/plant (17.7%) and 100-seed weight (2.8%).
The observations on the synergistic effects of FYM, biofertilizers and basal dose of chemical fertilizer application on Lentil crop are presented below: it resulted in average increase seed yield (39%) and biological yield (27.2%). This may be due to the conservation of nitrogen by farm yard manure during the initial phase of the crop cycle. It may also reduce nitrogen loss and provides better synchronization of nitrogen availability during the latter part of annual crop cycle. Farmyard manure not only provides macro- and micro- nutrients to the crop but also improves the physical and biological properties of the soil which help in improving the grain yield. Macro-and micronutrients essential to Lentil crop growth are similar to most other legume crops. However, for maximum yield and quality most nutrients will act synergistically.

The above observations were also used for making cost benefit analysis. The details of economic analysis revealed that all the treatments gave higher gross return over control. Among all treatments, application of FYM + Biofertilizers + Chemical Fertilizer gave the maximum gross return of Rs. 56,657.2 with CBR 2.86 followed by the application of FYM + Chemical fertilizer (Rs. 54,360.6) with CBR 2.76.

Integrated nutrient management of Lentil crop should ensure that the nutrients are in available forms in adequate quantities and right proportions as per the requirement of the crop. General fertilizer recommendations are being extensively used in India and many other Asian countries for their simplicity and exclusion of cost involved in soil testing and analysis. For enhancing the input use efficiency, this kind of generalized fertilizer recommended rate approach is to be discouraged as these are based on medium soil fertility ratings at all India or regional levels. Scientific basis for balanced fertilization requires information both on soil and plant analysis. Such an information is needed for soil and crop production strategies as it helps in making suitable adjustments in fertilizer recommendations according to crop needs and responses.

A modest attempt was also made for chemical analysis of the vegetative plant body of Lentil, especially in terms of nitrogen, phosphorus, potassium, zinc, iron, magnesium and copper. Accumulation of nutrients in plant body indicates the accessibility of the conserved elements from the soil to the plant. Composition of a part or of the whole plant and also the soil test results help in the assessment of soils nutrient supply power. General sufficiency and optimum range of elements
was also taken into consideration for an understanding the required level of the above nutrients. This approach brought to light that the uptake of all the above nutrients by the Lentil crop under the abiotic regime at Agra is under sufficient category. This also ratifies the effectiveness of the integrated nutrient management results and conclusion drawn from experimental studies undertaken as above. Efficient management of plant nutrients is the key to sustained food security, particularly in Indian context. Soil testing and plant analysis information is very useful to formulate crop and site-specific plant nutrient recommendations. Recognizing the role of soil testing and plant analysis, the present investigation incorporated the results of both approaches in the Lentil crop production at Agra.

C. Integrated Weed Management

1. Lentil possesses poor competitive ability against weeds, due to the short stature and slow early season growth rates. Many cultural, physical and chemical practices have been employed and often the total elimination of weeds during the entire period of crop growth is not economical. A field survey was undertaken to observe the weed species associated with Lentil crop. Population Densities of selected weeds was monitored at different DAS by using quadrate method. Quadrates of 1 m² size was used for the study. It showed that *Chenopodium album* (14.3) was dominant weed species found in the Lentil fields followed by *Chenopodium murale* (11.2), *Fumaria officinalis* (8.6) and *Asphodelus tenuifolius* (6.5).

2. After three hand weedings, reduction in the weed population density was observed. First hand weeding was done at 45 DAS, second on 65 DAS, and the third on 100 DAS. Percentage removal was estimated for all the weeds separately. Weed removal of about 84% was observed in total weeds after three hand weeding in local farmers field.

3. To find out the impact of integrated weed management under irrigated conditions a randomized block design field experiments were conducted during Rabi season 2010-11 and 2011-12 at the experimental farms of Dayalbagh Educational Institute Agra. The treatments included: (1) control, (2) pendamethalin 0.50 kg/ha, (3) pendamethalin 0.75 kg/ha, (4) pendamethalin 1.0 kg/ha, (5) pendamethalin 1.25 kg/ha, (6) pendamethalin 1.50 kg/ha, and (7) hand weeding with three replications each.
4. *Chenopodium album*, *Asphodelus tenuifolius*, *Fumaria officinalis* were the dominant weed species observed in the control plots other species which were comparatively of less density included *Spergula arvensis*, *Amaranthus*, *Chenopodium murale* and common grass. Hand weeding provided highest weed control (84.8%). Among all the herbicidal applications, pendimethalin 1.50 kg/ha gave the maximum mortality of weeds (79.2%) followed by pendimethalin 1.25 kg/ha (75.4%). Hand weeding and herbicide treatments significantly reduced the dry weight of weeds. Among all the treatments hand weeding produced the lowest weed biomass (54.0g/m²). Application of pendimethalin as pre-emergence proved better for control of weeds and obtaining high yields. Pendimethalin herbicide can be used to control all the weeds growing before the sowing of Lentil. It provided a weed free environment for crop establishment that resulted in early crop vigour and improved competition of the crop. Pendimethalin application together with hand weeding was much more effective in reducing the dry weight of weeds.

5. The observations on the crop vegetative parameters included plant population density, plant height and primary branches/plant. Application of herbicide and hand weeding improved retention of crop population density. Application of hand weeding showed significant increase in Lentil plant population density (17.9% and 19.8%) in both the years. This increase in crop population density was due to reduction in competition between weeds and Lentil crop. However, crop population density was affected considerably as the concentration of pendimethalin increased to 1.50 kg/ha. Combined application of herbicide and hand weeding improved the plant height, and primary branches/plant.

6. Application of all the treatment influenced seed yield and biological yield significantly over control. Hand weeding treatments increase the average seed yield by 49.3 % (1540 kg/ha) and biological yield by about 30% (4150 kg/ha). This seed yield increases may be due increase in pods/plant (18.5%). Of all the herbicidal doses pendimethalin 1.25 kg/ha gave the best average yield (1360 kg/ha) followed by pendimethalin 1.0 kg/ha (1290 kg/ha). On the other hand pendimethalin 1.50 kg/ha produced lower grain yield (1060 kg/ha). It may be due to the phytotoxic effects in terms of inhibition of seed germination of Lentil crop.

7. The highest additional return of Rs. 30,850 with cost benefit ratio of 1.4.4 obtained by hand weeding. Among the herbicide pendimethalin 1.0 kg/ha gave the maximum net return of Rs. 18,329 with CBR of 1:6.0 followed by pendimethalin
1.25 kg/ha (Rs. 15488.4) with CBR of 1:6.4 and this treatment provided maximum CBR. Lowest CBR (1:2.8) was obtained by the application of pendimethalin 1.50 kg/ha due to phototoxic effect of crop by affecting germination.

8. Hand weeding and herbicide application is most effective in weed control. However, hand weeding is not an economical practice. Understanding growth and key development pattern of weeds is important for each cropping system for effective weed control. Lentil cv. “DPL-62” in the present study, not only responded well to the integrated weed management practices. It effectively controlled weeds at Agra (semi-arid region) besides increasing crop yields substantially in the marginal/sub-marginal lands. This practice can be strongly recommended as an eco-friendly measure to sustain soil health, crop production, nutritional security and livelihood opportunities.

9. Very limited range of herbicides are suitable for use in Lentil crop when compared to other pulse crops. Farmer’s are mostly selecting pendimethalin for this purpose. Hence, in the present study Allium assay technique was selected for finding out the effects of various concentrations of pendimethalin on the root initiation and growth as well as cytotoxic effects, if any, on cell division. The following conclusions were drawn from the observations on Allium assay study:

10. Root initiation was strongly inhibited when the onion bulbs were exposed to pendimethalin at the respective concentration of 0.24, 0.12, 0.09, 0.06, and 0.03 g/l. After 3 days exposure of onion bulbs to pendimethalin the bulbs were shifted in tubes containing water to observe the trends of recovery of root growth if any. Based on the above observation another set of experiment was conducted with the following lower concentration of pendimethalin at (0.05, 0.04, 0.03, 0.02 and 0.01 g/l). Recovery and elongation in root growth was observed in this second set of the experiment.

11. Cytological studies were conducted in the month of February and March (2012) to find out the mitotic index of both normal and pendimethalin exposed tissues. Maximum number of cells in division were observed during 06:00-12:00 noon and also during 21:00 to 23:00 in the night. Mitodepressive action was observed when bulbs were exposed to higher concentration of pendimethalin (0.24, 0.12, 0.09 g/l). However, lower mitotic index was observed when onion bulbs were exposed to the lower concentration of pendimethalin. It was found that pendimethalin arrests maximum cells in Anaphase followed by Prophase,
Metaphase and Telophase. Some chromosomal and nuclear aberrations were also observed. These included chromosomal clumping, bridges and fragments. Formation of micronuclei was also recorded. However, their occurrence was non-significant.

D. Weather Analysis and Systems Approach

1. Historical weather data of Agra for a period of over 112 years was collected from the Indian Metrological Department (IMD), Pune in order to understand the trends in weather changes. The data is analyzed in terms of (a) weather changes in the crop duration period, i.e., Rabi Season with respect to maximum and minimum temperatures and precipitation, (b) comparison of trends in weather changes at Agra with that of National trends as already reported in peer-reviewed publications.

2. The trend analysis of the annual maximum temperature at Agra revealed non-significant changes in the past 112 years. Similar phenomenon was also observed with regard to maximum temperature trend during rabi cropping season for nearly 70 years. However perceptible rabi season maximum temperature increases were observed since 1970 at Agra from the normal at the rate of 0.02°C/year.

3. Trend analysis was also analysed for minimum temperature at Agra for the period 1901-1970 both for annual and rabi season. Increasing minimum temperature trends were observed since 1971 onwards. The annual increase in minimum temperatures from the normal value is at the rate of 0.07°C/year while the rabi season increases are recorded at the rate of 0.08°C/year, respectively.

4. The Deviations of maximum and minimum temperature for the period 2001-12 from the last 100 years average values (i.e. 1901-2000) was also calculated. It showed a perceptible increase in minimum temperature. However such trend was not very distinct in case of maximum temperature.

5. The analysis of the annual rainfall data at Agra revealed increasing trend from 1901-1970. However, since 1971 the decreasing trend in rainfall was observed. The annual rainfall at Agra has decreased from the normal at the rate of 4.30mm/year. The rabi season rainfall at Agra during the past 112 years had not shown any perceptible trends. The deviations of rainfall at Agra for the period 2001-12 from the last 100 years (i.e. 1901-2000) was also calculated and recorded. It showed a decrease in rainfall.
6. Lentil crops yields were classified on the basis of final yield obtained at Agra district (Western Uttar Pradesh), Allahabad (Eastern Uttar Pradesh), total Uttar Pradesh, and all India Yields over the last 12 years (2001-12), as follows: (a) High Lentil Yield Season (Yield > 750 kg/ha) (b) Medium Lentil Yield Season (650-750 kg/ha) (c) Low Lentil Yield Season (<650 kg/ha).

7. It is interesting to note that Agra district maintained high yields for ten years, and Allahabad for 6 years, entire UP for 7 years and all India average yields never recorded high yields during that period. At the same period, Agra district never recorded low yields in the above period.

8. Agra district average yields are about 2.3% above the Uttar Pradesh average yield, while the yields in experimental plots under present investigation where integrated nutrient management was tried is about 25.6% above the average yield of Uttar Pradesh. The difference in yield gap in experimental plots of Agra and Agra district are due to technological component (integrated nutrient management). As the nutrient and moisture level were not limiting, any reduction in yields to medium and low yield categories in any crop season year may be attributed due to weather component. In the past 12 years, Agra district and Allahabad district fell into medium yield category twice while it was 4 times in UP and 6 times at all India level. It is concluded that any losses in Lentil yields in any cropping season year may be due to climate change in that particular year. During the year 2000 crop season, when Lentil yields at Agra fell down to medium yield category, the yields in Allahabad district, total UP and all India fell down to one step further below into low yield crop season.

9. However in the year, 2009 crop season, the Lentil yields at Agra fell down to medium yield category, in spite of the fact that yields in Allahabad district, and total UP yields raised to high Lentil yield category. Though temperature scenario was favourable during this crop year for Lentil crop development very heavy rainfall showers (62.6 mm) during month of October may have caused water logging of the root system. It may be concluded that this might be the reason of low Lentil yields in spite of the fact that temperature scenarios were quite favourable for Lentil crop.

10. It is clearly understood that yield fluctuations are always due to a complex interaction of various abiotic and biotic variables in combination. It is also a fact that from time to time, certain variables may play a dominant role. The above
studies are valid only to the extent that the weather variables may assume a dominant role in future and threaten the sustainability of agriculture in Agra, in particular and the country as a whole, in general. Ultimately, a systems approach to the entire Lentil crop production can only provide a comprehensive understanding and suggest appropriate alternate options for decision making.