SUMMARY

Mungbean [Vigna radiata (L.) Wilczek] and Urdbean [Vigna mungo (L.) Hepper] form the basic ingredients in the diet of vast majority of Indian population, as they provide a perfect mix of vegetarian protein component when supplemented with cereal since time immemorial. India is also having the distinction of being the top producer of Mungbean and Urdbean in the world.

However, pulses production as a whole has been stagnant between 11 and 14 million tonnes over the last two and a half decades. As a result, per capita pulses consumption over the years has come down from 61g/day/person in 1951 to 33g/day/person at present (Swaminathan and Kesavan 2012).

The research on Mungbean crop improvement was initiated first time in India way back in 1925 and led to major systematic cultivar development programme both in Mungbean and Urdbean. With the inception of All India Coordinated Pulse Improvement Project (1967) and deep involvement of National Agricultural Research System (NARS), these efforts not only succeeded in developing early maturating, disease and pest resistant high yielding cultivars but also making it feasible to grow them in three different seasons in India: (a) Kharif season (b) Rabi season, and (c) Summer season. The innovative Summer Mungbean Technology provided an ample opportunity to play a significant role in nutritional security and sustainability of various cropping systems, especially rice-wheat cropping system (Poehlman 1991; Ali and Kumar 2006).

In spite of the best efforts made in crop improvement of Mungbean and Urdbean (pulses in general), pulse production in India is witnessing a fatigue due to a combination of factors that include damage to ecological foundations. The Indo-Gangetic Plains of Northern India, popularly known as pulse basket of India, is showing declining trends in area, production, and yield. It is quite heavily replaced by rice-wheat and rice-based cropping systems. Pulses were pushed to marginal or sub-marginal lands and grossly neglected with respect to plant nutrient management. Crop growth, development, water use and yield require normal conditions of weather during cropping season. Even with minor deviations from the normal weather, the efficiency of externally applied inputs and food production is seriously damaged. In India, substantial work has been done in the last decade aimed at understanding...
the nature and magnitude of change in yield of different crops due to projected climate change. Mungbean and Urdbean crops are yet to be seriously considered in this regard (Mall et al., 2006; Ali and Gupta 2012).

Pusa Vikas and Pusa Vishal cultivars of Mungbean and Azad cultivar of Urdbean were selected for cultivation, monitoring of growth and reproductive performance for three successive years, under different plant nutrient treatments. Appropriate bacterial biofertilizer inoculants strains were procured from MTCC, Chandigarh. The cultures were maintained, scaled-up, tested for quality, packaged following standard procedures, and utilized in experimental plots as well as in farmers fields to assess the impact of eco-friendly integrated nutrient management of Mungbean and Urdbean. The soils were also analyzed for some selected physical, chemical and biological properties before incorporating biofertilizers. Randomized Block Design was adapted for testing the significance of integrated nutrient management practices.

The historical data of Agra for a period of about 112 years was obtained from the Indian Metrological Department, Pune. It was analyzed to observe changing trends in maximum/minimum temperatures and rainfall, especially during the respective crop duration (summer season and kharif season). An attempt was also made for estimating the probable losses in yield in Mungbean and Urdbean under the changing weather regime at Agra. The results of the above investigation are summarized as below.

A. Cropping History, Vegetative Growth and Reproductive Performance
1. Mungbean and Urdbean are grown separately as sole crops in kharif season in the fields left vacant by preceding Rabi wheat crop (Kharif Mungbean/Urdbean-Wheat rotation) in Agra, and this legume-wheat cropping system is an eco-friendly practice followed here. Mungbean is also grown in rotation during the lean months between Rabi wheat and kharif rice crop as a summer-season crop (Wheat-Summer Mungbean-Rice rotation). The primary crop is wheat or rice, although sometimes Bajra, Jowar are given priority. However, mixed cropping practice of Mungbean is not being followed at Agra.

2. *cv.* Pusa Vikas of Mungbean was selected for summer season cultivation (April-May-June) with a seed rate of 30 to 35 kg per hectare and 25 cm row spacing. While *cv.* Pusa Vishal of Mungbean and *cv.* Azad of Urdbean was selected for kharif season cultivation with a seed rate of 22 kg/ha and 25 cm row spacing in each case.
3. The population density of the Summer Mungbean crop at two regular intervals (15 DAS and 30 DAS) was monitored for three successive years. About 7% to 14% seedling mortality is recorded. The plant population density of the kharif Mungbean and Urdbean crop was also monitored at two regular intervals (15 DAS and 30 DAS) and there is significant seedling mortality 33%, 27.3%, and 25.8%, respectively in Kharif Mungbean and 15.6%, 32.9%, 11.0%, respectively in kharif Urdbean during three successive years of observation. More care during weeding operations is recommended.

4. Similarly, the other vegetative growth traits viz. Plant Height, Number of primary branches/plant, number of leaflets/plant and nodules/plant were monitored for the three years period in cv. Pusa Vikas, cv. Pusa Vishal (Mungbean) and cv. Azad (Urdbean). Plant height trait of Summer Mungbean cv. Pusa Vikas at three different periods of growth (at 15 DAS, 30 DAS, 55 DAS) indicated that the plant height suffered significantly during first two drought years 2009(10.16 cm), 2010(11.4 cm) and recovered significantly in 2011 (16.6 cm) due to return of favourable conditions.

5. Nodule number per plant is counted after 25 days of sowing. The nodulation capacity of cv. Pusa Vikas of Summer Mungbean was monitored and an average 33 nodules per plant was observed. This appears to be highly significant nodulation as the earlier reports of nodule number per plant varied from 2 to 28 at flowering and from 0 to 22 at maturity. While in kharif Mungbean and Urdbean an average of 58.1 nodules/plant and 66 nodules/plant, respectively was observed. Generally high soil temperatures (>32ºC) and soil moisture stress, pesticides residues, nematode infestation hinders effective nodulation. Prasad and Ram (1984) found that combined cultures application on seed is more effective than inoculation with single cultures and a consortium of inoculants tested in the present study supports the above conclusion.

6. The most important characters indicative of a superiority of a Mungbean and Urdbean cultivar include number of inflorescence/plant, flowers/inflorescence, total flower production per plant, floral phenology, pods/plant, pod sizes, and seeds/pod. Present study monitored the above traits of the cv. Pusa Vikas, cv. Pusa Vishal (Mungbean) and cv. Azad (Urdbean) for three successive years.

7. In Summer Mungbean the average number of inflorescence/plant (2.48), flowers/inflorescence (5.32) total flowers/plant (12.2) pods/plant (10.4) and seeds/pod (7.3) were recorded. Similarly in Kharif Mungbean the average number of inflorescence/plant (3.88), flowers/inflorescence (4.65), Pods/plant (15.16) and
seeds/pod (8.53) and in Urdbean the average number of inflorescence/plant (5.18), flowers/inflorescence (6.33) total flowers/plant (31.4) average number of pods/plant (15.16) and seeds/pod (6.08) were observed.

8. The present study included for the first time observation on the flowering phenology at individual flower level in summer Mungbean, kharif Mungbean and kharif Urdbean. The floral cycle of Summer Mungbean (cv. Pusa Vikas) was completed in 14 days. On the other hand the floral cycle of both kharif Mungbean (cv. Pusa Vishal) and kharif Urdbean (cv. Azad) was completed in 9 days each.

9. Flower drop is a major problem in Mungbean and Urdbean and became an important criteria as, ultimately the number of flowers that are retained on the plant and developed into mature pods may decide the yield pattern. In summer Mungbean, on an average 47.8 dropped flowers/m² were recorded at 49 DAS, in kharif Mungbean, on an average 35.0 dropped flowers/m² and in kharif Urdbean 35.8 dropped flowers/m² were recorded. The dropped flowers were sorted out into different floral phases in the three different cultivars.

10. Abiotic stresses especially became a major constraint therefore some efforts were undertaken to grow summer Mung as Monocrop as well as inter-cropping summer Mung with pearl-millet crop for providing suitable insulation from solar radiation and high temperatures. It is concluded from the experiments, that (1) Summer Mungbean benefitted significantly in terms of yield parameters from Bajra cover crop by overcoming constraints of abiotic stresses in the form of high solar radiation and extreme temperature events in comparison to the summer Mungbean as a Monocrop, and (2) The production of fodder Bajra is an additional bonus for the farmer, especially during the extremely fodder deficit period of the year. Kharif Mungbean crop is exempted more from abiotic stresses than summer Mungbean crop.

B. Soil and Nutrient management

1. The sandy loam soil samples from two sites each for Summer Mungbean, Kharif Mungbean and Kharif Urdbean crop fields both at pre-sowing period and also after crop harvest was analyzed. The major inferences from the above analysis showed that (a) The soils are normal without any problem of soil salinity with respect to soil pH and electrical conductivity (b) Nitrogen and Potassium fertility is generally low to medium. (c) Phosphorus level is generally found to be medium to high (occasionally even in excess amount) (d) Zinc, Copper, Iron, Sulphur, Manganese and Boron levels are generally satisfactory.
2. Survey of initial population of nematodes in selected sites of Kharif Mungbean and Urdbean brought to light the heavy infestation of local crop fields by both saprozoic (Average 4821.3 nematodes/Kg Soil) and plant parasitic nematodes (Average 4645.3 nematodes/Kg Soil). Kharif Mung was selected for conducting pot experiments with an objective to find out the impact of neem kernel and neem seed coat. In the initial phase impact of neem seed coat and neem kernel on plant parasitic nematodes in Mungbean soil was analysed in pot experiment by adopting Completely Randomised Block Design. The results were analysed with the help of analysis of variance method. It indicated that neem kernels at 0.5% dose is highly significant in controlling the soil plant nematode population when compared to neem seed coat.

3. In the present investigation, symbiotic nitrogen fixer *Rhizobium leguminosarum* (MTCC 10096), non-symbiotic nitrogen fixers *Azospirillum braselience* (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 bacterial biofertilizers were kept sealed in a duly labelled polythene packets that contained information about manufacture, expiry and instructions for use both in English and Hindi. Simultaneously, quality testing of the inoculants was also undertaken using Gibson tubes experiments and the nodulating capacity of the inoculants is established as highly satisfactory.

4. A Randomized Block Design experiment with five treatments and three replications was conducted in the experimental garden of the Institute to find out the impact of integrated nutrient management on the yield attributes of Summer Mungbean, kharif Mungbean and Urdbean. The treatments consisted of (1) Control (2) Farm Yard Manure + *Rhizobium*, (3) FYM +*Rhizobium* + PSB + *Azospirillum*, (4) FYM + Chemical Fertilizer (Urea 12.5 kg/ha and SSP 40kg/ha) and (5) FYM + Chemical Fertilizer + Biofertilizer (*Rhizobium*+PSB+*Azospirillum*).

5. The present study showed that combined application of FYM + Biofertilizer and chemical fertilizers increased the grain yield by 58.7% (2009) and 67.4% (2010) and biological yield up to 57.8% (2009) and 55.5% (2010) over control in Mungbean; and 65.8% and 34.1%, respectively in Urdbean. Similarly, impact was also observed in summer Mungbean-Bajra intercropping experiment. Integrated nutrient
management had synergistic effect in increasing grain yield instead of the application of either biofertilizer or chemical fertilizer alone.

6. In the present investigation, the three year average yield of Pusa Vikas was recorded as 858 kg/ha when the sowing of crop was done in the first fortnight of March each year. Ali and Kumar (2006) reported about 800-900 kg/ha yield in the North West Zone Plains to which Agra belongs, when the sowing is done in the second fortnight of March. A comparison of the yields of summer Mungbean of the present study over three years with that of the zonal performance indicates that the cv. Pusa Vikas is showing optimum yields, probably because of the integrated nutrient management practices observed here. The increasing temperature extremes during crop duration at Agra are not allowing it to reach maximum yields.

7. In the Kharif Mungbean the three year average yield of cv. Pusa Vishal was recorded as 1432.9 kg/ha. The average productivity of Mungbean in Uttar Pradesh was 388 kg/ha while the national average is at 351 kg/ha. However, an average yield of 470 kg/ha is recorded for Agra district which is above the Uttar Pradesh average yields (Source: Directorate of Economics and Statistics, Government of India).

8. The three year average yield of cv. Azad of Urdbean was recorded as 1487.6 kg/ha. The average productivity of Urdbean in Uttar Pradesh was 559 kg/ha while the National average is at 451 kg/ha. However, an average yield of 670 kg/ha was recorded for Agra district which is above the Uttar Pradesh average yield. (Source: Directorate of Economics and Statistics, Government of India).

The above figures clearly demonstrate that the yields obtained in the present investigation at Dayalbagh (Agra) are much above even the district average yields and almost equals to that achieved in demonstration plots of various National R&D Institutes because of efficient agronomic practices here.

C. Weather Analysis and its Probable Impact

A summary of analysis of historical weather data of Agra for a period of 112 years procured from IMD Pune is as follows:

1. Although meteorological data compiled over the past century suggested that earth is warming, there are significant differences at regional level. The present analyses of the trends in weather changes at Agra confirm that this region is most vulnerable to climate change.
1. Accelerated warming of Agra was observed over the decades with intensive warming trends noticed especially from 1991-2012.
2. Both in summer season and kharif season pronounced warming trends in mean maximum and minimum temperatures at Agra was observed.
3. In Agra, the trends of daily maximum temperatures were observed to be increasing from January and attaining a peak in the month of May.
4. The intense as well as increase in solar radiations resulted in high temperatures during the summer season (March-June). The heat wave conditions at Agra were more frequent in late April and May while very few heat waves were noticed in the month of March and early April.
5. The highest monthly mean maximum temperatures for summer season are observed as follows: March (35.5°C), April (41.5 ºC), May (44.7 ºC) and June (44.9 ºC)
6. The highest monthly mean minimum temperatures for summer season are observed as follows: March (22.5ºC), April (25.6ºC), May (30.2ºC), June (34.2ºC)
7. The rise in average minimum temperatures during the summer and kharif seasons at Agra appears to be more significant from the year 2000 to 2012, while such a trend could not be observed in the previous century historical weather data. It also indicates that hot nights have increased and cold nights have decreased in the pre-monsoon period.
8. Agra has been experiencing unpredictable monsoon rain fall pattern. Drought year is defined as the year in which rainfall is less than eighty percent. The country, as a whole, had already experienced drought conditions in the years 1951, 1966, 1979, 1983, 1992, 1997, 2003 and 2009. The western Uttar Pradesh was the worst hit in 2009 with 68% deficit in rainfall. Out of these seven years, two years 2000-01 and 2002-03 had worst drought, affecting the pulse production adversely in this region.
9. An attempt was also made for estimating the probable losses in yield in Mungbean and Urdbean under the changing weather regime at Agra. The results of the above investigation are summarized as below:
10. In summer Mungbean every 0.1°C increase in maximum and minimum temperature during cropping season may reduce the yields by 12.6 kg/ha and 25.2 kg/ha, respectively. Similarly, a 10 mm deficit in rainfall may result in decline of yields by 44.1 kg/ha.
reduction in kharif Urdbean was 65.6 kg/ha and 54.1 kg/ha, respectively and in kharif Mungbean was 94.4 kg/ha and 77.4 kg/ha, respectively. However, with a 10 mm drop in rainfall the corresponding decline in Urdbean and Mungbean yield was 9.9 kg/ha and 14.2 kg/ha, respectively.

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 indicate that the weather variables may assume a dominant role in future and threaten the sustainability of agriculture at Agra, in particular and the country, as a whole. The recent studies on climate change impact on Indian agriculture are also in agreement with the above conclusion.