Chapter V

SUMMARY AND CONCLUSIONS

The present investigation entitled “Studies on the Effect of Integrated Nutrient Management on Soil Properties, Yield and Quality of Mustard and its Residual effect on Summer Moong” was carried out during Rabi season of 2009-10 and 2011-12 with a view to study the effect of various combinations of inorganics and organics and its residual effect on preceding crop under field conditions. The investigation was aimed to test the various combinations of inorganics, organics and biologicals in order to obtain higher & sustainable crop productivity, oil yield and better quality of grains with respect to protein content vis-a-vis preserving soil health for future generations to come. The experiments were laid out in Randomised Block Design (RBD) and replicated thrice growing Mustard as a test crop succeeded by Moong on residual fertility. The treatments comprised of 0, 75%, 100% and 150% RFD of NPK integrated with FYM, Azotobacter and sulphur. The effects of INM practices were studied on yield and yield attributing characters of mustard, harvest index, N, P, K & S content and their uptake in mustard. The protein content, oil content and oil yield were also computed. The residual effects were also studied on moong including yield, N, P, K & S content & their uptake and protein content as well. Post harvest soil studies were also conducted to investigate the influence of treatments on soil quality and nutrient balance.

The chief findings of the investigation are summarized as under.
A. Mustard

1. Yield attributes

(i) A significant increase in number of effective branches was observed against the treatments comprising of NPK clubbed with FYM, Azotobacter and sulphur. A maximum of 17 branches were recorded with the treatment $T_{15}$ comprised of 100% NPK + FYM + Azotobacter + S as compared to 8.5 with control. This treatment was also found superior to 150% NPK alone in this regard.

(ii) An individual application of NPK brought about a significant increase in number of siliquae per plant and integration of NPK with FYM + Azotobacter + S produced furthermore of siliquae per plant registering a maximum of 285 siliquae by the treatment containing all three inputs integrated with 100% NPK.

(iii) Number of seed per siliquae was also affected significantly by the treatment involving INM. The number of seed per siliquae increased from 10.0 with control (no fertilizer) to 14.0 with 100% NPK + FYM + Azotobacter + S ($T_{15}$) which out-classed even higher level of NPK (150%) which recorded only 13.0 seeds per siliquae.

(iv) Length of siliquae was another yield attribute which was affected significantly by increasing levels of NPK alone as well as while clubbed with FYM + Azotobacter + S. A maximum value of siliquae length (4.01 cm) was noted with $T_{15}$ treatment as compared to a lowest level of 3.25 cm with the control (no fertilizer), other treatments registered a moderate siliquae length.

(v) The 1000 grain weight of mustard increased significantly with each successive increment in NPK levels. The test weight increased further
when NPK was integrated with FYM, Azotobacter and S as such recording a highest test weight 4.67 gm with treatment $T_{15}$ as compared 3.61 gm with the control (no fertilizer).

An improvement in yield attributes by treatments involving INM is an indication of higher crop productivity being resulted by enhanced photosynthetic activities due to adequate and balanced nutrition.

2. Grain yield, Stover yield and Harvest Index (HI)

(i) Grain yield of mustard increased consistently with each successive additions of increasing levels of NPK either alone or in integration with FYM, Azotobacter and sulphur. A two fold increase in grain yield was noted with integrated use of inputs as compared to control, the grain yield being 18.95 q ha$^{-1}$ with treatments consisting of 100% NPK +FYM + Azotobacter + S and 18.48 q ha$^{-1}$ with treatment containing 75% NPK + FYM + Azotobacter + S as compared to control (8.01 q ha$^{-1}$). Both the treatments were found superior to even 150% NPK neat where the corresponding yield was 16.17 q ha$^{-1}$. The integration of organics at 100% NPK was found to be most effective as compared 75% NPK as well as 150% NPK as regards their effects on yield attributes & finally grain yield.

(ii) A higher stover yield (43.70 q ha$^{-1}$) was recorded against the treatment comprising of 100% NPK + S as against 24.09 q ha$^{-1}$ with the control. The stover yield recorded with other treatments were found in between these values.

(iii) HI (%) values were found to have increased significantly by the integrated use of inorganics and organics. A higher 31.66% value of HI was computed with the treatment containing 100% NPK +FYM + Azotobacter + S as compared to a lowest of 25.02% with control (no
fertilizer), other treatments registered a moderate HI (%). An application of 150% NPK alone could make up to only 28.87% HI which was lower then many treatments involving INM.

3. Protein content, Oil content and Oil yield

(i) Protein content of the grain increased with increasing levels of NPK from 0, 75%, 100% to 150% NPK. However, integration of FYM, Azotobacter or/ and S both levels of NPK (75% & 100%) made a pronounced increase in grain protein which outclassed even 150% NPK neat (21.53%). A higher protein content of 21.63% was registered with 100% NPK + FYM + Azotobacter + S followed by 21.50% with 75% NPK + FYM + Azotobacter + S as compared to control (17.19%)

(ii) The oil content (%) in mustard grain increase significantly by integration of 100% NPK with S (37.66%) as well as integration with FYM + Azotobacter + S (38.96%). The integration of organics was more effective at 100% NPK than their counterparts containing 75% NPK. Among the inputs, S additions made a higher oil content as compared to FYM or Azotobacter.

(iii) Oil yield ( q ha\(^{-1}\)) rose from a low of 2.46 q ha\(^{-1}\) with control to a high of 7.38 q ha\(^{-1}\) with the treatment (T\(_{15}\)) consisting of 100% NPK + FYM + Azotobacter + S. Among the integrating inputs, sulphur was found to be more effective in this regard.

4. Nitrogen, Phosphorus, Potassium and Sulphur content in grain and stover

(i) Nitrogen content increased significantly from 2.75% (control) to 3.46% with treatment T\(_{15}\), the treatments T\(_{16}\) (3.45%) and T\(_{13}\) (3.44%)
were found at par in this regard. A little variation were noted in nitrogen content in the stover as affected by the treatments.

(ii) Phosphorus content (%) in the grain increased from a low of 0.286 with control to a high of 0.449% with 150% NPK. The integration of organics with either 75% NPK or 100% NPK did not result a hike in P content comparable to the treatment T16 (150% NPK). The effects of the treatments were found to be non significant on P content of the stover.

(iii) Potassium content of the grain and stover increased significantly with increasing levels of NPK up to its 150% level. A minimum of 0.38% K was recorded in control whereas a maximum of 0.814% K with treatment having 150% NPK neat. Integration of NPK resulted a higher content yet below the level obtained with 150% NPK. The trends were similar in the stover resulting an increase from 0.64% with control 1.45% with 150% NPK and 1.43% with treatment T15 comprising of 100%NPK + FYM + Azotobacter + S.

(iv) An increase in S content was noted against treatments involving S. The treatment T14 and T15 registered a highest S content in grain, the values were being 1.21% and 1.23% respectively. The effects were not found, however, significant as regards the effect of the treatment on S content in the stover.

5. Uptake of Nitrogen, Phosphorus, Potassium and Sulphur by Mustard

(i) The total nitrogen uptakes increased from a low of 34.16 kg ha\(^{-1}\) with control to a high of 113.42 kg ha\(^{-1}\) with treatment T15 containing 100% NPK + FYm + Azotobacter + S as compared to 105 kg ha\(^{-1}\) with 150% NPK thus signifying the role of integration.
(ii) A significant increase in P total uptake by crop was noted being 6.06 kg ha\(^{-1}\), a minimum with control whereas a maximum was computed with treatment T\(_{13}\) (15.04 kg ha\(^{-1}\)) where sulphur integration boosted its uptake. This treatment out-classed all the treatments including T\(_{15}\) and T\(_{16}\) treatments.

(iii) Total K uptake by mustard varied from a minimum of 18.47 kg ha\(^{-1}\) with control to a maximum of 72.98 kg ha\(^{-1}\) with treatment T\(_{15}\) which was comparable to treatments T\(_{9}\) (72.32 kg ha\(^{-1}\)) and T\(_{16}\) (72.33 kg ha\(^{-1}\)).

(v) Sulphur uptake in mustard grain & stover was found to be exceptionally higher by integration of NPK with S alone or in combination with FYM and azotobacter, thus registering total uptake of S to a maximum of 37.75 kg ha\(^{-1}\) with treatment T\(_{15}\) followed by T\(_{14}\) treatment (35.68 kg ha\(^{-1}\)). The uptake values were correspondingly higher when inorganics were integrated with S as compared to FYM or Azotobacter.

B. Moong (Residual Effect)

1. Grain yield, Stover yield & Harvest Index (HI)

Grain yield, Stover yield and Harvest Index (H.I.%), increased significantly by applying INM practices coupled with enhanced fertility levels from 75% to 100%. Highest grain yield (5.83 Q ha\(^{-1}\)), stover yield (3.63 Q ha\(^{-1}\)) and Harvest Index (61.64%) were noticed with the treatment T\(_{15}\) comprising of 100 % NPK + FYM + Azotobacter + Sulphur, which was significant over control and its counterparts of neat NPK. The lowest grain yield (2.60 Q ha\(^{-1}\)), stover yield (2.21 Q ha\(^{-1}\)) and Harvest Index (54.13%) were recorded with the control.
2. Protein content

Protein content in moong (succeeding crop) was recorded significantly higher (25.97%) with treatment T\textsubscript{15} comprising of 100% NPK + FYM + Azotobacter + sulphur, followed by T\textsubscript{16} (25.72%) comprising 150% NPK and T\textsubscript{14} (25.69%) comprising of 75% NPK + FYM + Azotobacter + sulphur, whereas lowest (19.03%) was noted with control followed by treatment T\textsubscript{2} (23.31%).

3. Nitrogen, Phosphorus, Potassium and Sulphur content in grain and stover

Nitrogen, Phosphorus, Potassium content were found significantly higher with treatment T\textsubscript{16} comprising 150% RFD of NPK, while sulphur content was significantly higher in the treatment T\textsubscript{15} comprising of 100% NPK + FYM + Azotobacter + sulphur. A highest N content in moong grain record with 150% NPK (0.79%) followed by treatment T\textsubscript{15} (0.73%) and T\textsubscript{14} (0.72%) as compared to control. P content were found to at par with treatments T\textsubscript{12} (0.20%), T\textsubscript{14} (0.20%), T\textsubscript{15} (0.20%) and T\textsubscript{16} (0.21%). K content in grain also vary from 0.22% with control to 0.45% with T\textsubscript{5}, T\textsubscript{11} & T\textsubscript{13} as compared to T\textsubscript{15} (0.41%) and 0.42% with T\textsubscript{16}. Sulphur content also increased from 0.119% with control to 0.239% with T\textsubscript{15} treatment comprised of 100% NPK + FYM + Azotobacter + sulphur.

4. Uptake of Nitrogen, Phosphorus, Potassium and Sulphur by Moong

Uptake of Nitrogen, Phosphorus, Potassium and sulphur uptake in grain and stover of moong (succeeding crop) were found significantly higher under treatment T\textsubscript{15} consisting of 100% NPK + FYM + Azotobacter + sulphur as compared to control and its counterparts of 75% NPK and
100% NPK whether applied in combination with FYM, Azotobacter and sulphur or even 150% NPK alone. The N, P, K and S total uptake increased from a low of 8.79, 1.48, 3.31 kg ha\(^{-1}\) and 0.77 ppm respectively with control to a high of 26.85, 3.97, 9.98 kg ha\(^{-1}\) and 3.23 ppm with \(T_{15}\) treatment which consist of 100% NPK + FYM + Azotobacter + S.

C. Post harvest soil characteristics

1. Water holding capacity (WHC%), Bulk Density (B.D.), pH and ECe
   (i) A significant variations were noted in Water holding capacity (WHC%) as influenced by INM. An integration of NPK with FYM caused a marked increase in WHC, however, a maximum value of WHC were noted against treatment \(T_{15}\) (45.25%) followed by \(T_{14}\) (45.16%) as compared to control (42.45%).
   (ii) The effect of INM on B.D., pH and ECe in post harvest soils were found non significant. The trends were almost indicated in both years of investigation.

2. Organic carbon content (O.C.)
   Organic carbon (O.C.) content were found to have increased due to the treatments. It rises from 2.2g kg\(^{-1}\)soil with control to 3.7g kg\(^{-1}\)soil with treatment \(T_{11}\) followed by \(T_{5}\) (3.6g kg\(^{-1}\)soil) and \(T_{15}\) (3.5g kg\(^{-1}\)soil). The effects were more pronounced with treatment containing 100% NPK with FYM + Azotobacter.

3. Available Nirogen, Phosphorus, Potassium and Sulphur
   Available N, P, K and S increased with increasing levels of NPK coupled with integration with FYM + Azotobacter + S. Availability of N increased from 147.6 kg ha\(^{-1}\) with control to 231.0 kg ha\(^{-1}\) with 150%
NPK followed by treatment \( T_{15} \) (225.5 kg ha\(^{-1}\)) and \( T_3 \) (224.9 kg ha\(^{-1}\)). As regards P availability, it rises from 8.6 kg ha\(^{-1}\) with control to 20.2 kg ha\(^{-1}\) with 150\% NPK followed by \( T_{15} \) (18.6 kg ha\(^{-1}\)) & \( T_{14} \) (16.7 kg ha\(^{-1}\)).

Post harvest availability of K varied from 81.0 kg ha\(^{-1}\) with control to 135.0 kg ha\(^{-1}\) with 150\%NPK and 130.7 kg ha\(^{-1}\) with treatment \( T_{15} \) comprised of 100\% NPK + FYM + Azotobacter + S.

An integration of sulphur with NPK resulted in a maximum residual S availability than other counterparts. As such a highest available S was recorded with treatments \( T_{15} \) (11.3ppm), \( T_{13} \) (10.9ppm), \( T_{12} \) (10.7ppm), \( T_9 \) (10.6ppm) and \( T_8 \) (10.3ppm) where S was incorporated with NPK, FYM & Azotobacter.

**D. Nutrient balance in soil**

(i) **Balance of available Nitrogen**

There was a positive balance of available nitrogen in the soil after the harvest of mustard & moong, the highest build up being with 150\% NPK \( T_{16} \) treatment (+35.0 kg ha\(^{-1}\)) and 28.5 kg ha\(^{-1}\) balance of N with treatment \( T_{15} \) consisting of 100\% NPK + FYM + Azotobacter + S.

(ii) **Balance of available Phosphorus**

A highest available P balance was recorded with treatment \( T_{16} \) 150\% NPK(+11.1 kg ha\(^{-1}\)) followed by treatment \( T_{15} \) (+9.9 kg ha\(^{-1}\)) as against -0.5 with the control.

(iii) **Balance of available Potassium**

A positive balance of available K also seen in the soil except control. A highest net gain of +24.0 kg ha\(^{-1}\) was recorded from 150\% NPK followed by +19.7 kg ha\(^{-1}\) noted with treatment \( T_{15} \).
(iv) Balance of available Sulphur

Available sulphur balance was recorded with the treatments where sulphur was integrated. A highest positive balance of available S (+3.2ppm) was noted with treatment $T_{15}$ followed by treatments $T_{14}$ (+2.9) and $T_{15}$ (2.8). A negative S balance was noted with treatments where S uptakes were higher.

E. Conclusions

An imbalanced and inadequate use of chemical fertilizers has resulted in the decline of soil health and its productivity. The intensive agriculture, while increasing the food production, has also caused second generation, problems of acute nutrient imbalances and emerging deficiencies of secondary and micronutrients and deterioration in soil health and a substantial decline in organic carbon contents. In view of the above, integrated nutrient management (INM), which encompasses all the sources of nutrients i.e. chemical fertilizers, organic manures and biofertilizers, offers a viable option for sustainable crop production. The present investigation was also planned to shape the ideal nutritional model for mustard-moong crop sequence.

On the basis of the present investigation it may be concluded that substituting inorganic fertilizers by integrating with FYM, Azotobacter and sulphur improved yield attributes, grain yield and harvest index of the test crops. This was also observed that clubbing FYM, Azotobacter and S with 100% NPK gave more grain yield & higher HI than 150% NPK alone.

The integration of NPK with FYM, Azotobacter and sulphur with its 100% RFD proved superior as regards its effect on grain quality in
terms of protein content, oil content and oil yield. A higher N, P, K and S content and their uptake in both the crops was found to be higher using nutrient combinations involving INM. However, a highest N, P & K content and their uptake was recorded with 150% RFD of NPK neat.

An improvement in post harvest soil characteristics viz. Water holding capacity and organic carbon content as well enhanced availability of N, P, K and S coupled with net positive nutrient balance are the landmark observations recorded in mustard-moong crop sequence involving use of FYM, Azotobacter & sulphur with graded dose of NPK. Overall the treatment comprised of 100% NPK + FYM + Azotobacter + Sulphur proved most effective and promising for sustained crop productivity & better soil health.

The soils were being rapidly exhausted and now showing a signs of fatigue, especially in the highly productive Indo-Gangatic plains during Post Green Revolution era, a partial substitution of chemical fertilizers (NPK) by organic sources and biofertilizers as well as inclusion of sulphur in the crop sequence involving mustard and moong, is the best approach to cope up with the situation, ensuring food security especially with respect to availability of pulses and also saving soil & environment for future generations to come.

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