CHAPTER VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK
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The newly formed state Chhattisgarh comes under sub-humid agro-climatic region. Chhattisgarh is completely dependent on monsoon with an average rainfall of 1200-1600 mm. The irrigation facilities in the state is also very meagre (about 20%) that too available as protective irrigation for rice crop only. According to its agro-climate, the state is divided into three zones i.e. Chhattisgarh plains, Bastar plateau and Northern hills. In all the three agro-climatic zones, monocropping of rice in kharif is widely practiced which covers about 80 percent of the net sown area, whereas, in rabi, only 25 percent area is under cultivation mostly with utera (relay) cropping of oilseeds and pulses. As regards to soil types, rice is mainly cultivated in matasi (Inceptisols), dorsa (Alfisols) and kanhar (Vertisols), which represents 45.5%, 10% and 25% of total net cultivated area, respectively. In the state, 10-15 percent of rice is grown in uplands having lateritic to sandy loam soil type, while 20-30 percent is cultivated in low land situation having clayey soil type.
In Chhattisgarh, the upland unbunded *bharri* (*kanhur*) occupies 10% (3.4 lakh ha) area. This situation is most favourable for cultivation of pulses in *kharif* season. Urdbean occupies an area of 1.2 lakh ha with the production of 0.39 lakh tons and productivity of 325 kg ha$^{-1}$. The wheat is also grown in 0.94 lakh ha of land with the production of 0.87 lakh tons and productivity of 975 kg ha$^{-1}$. With the availability of limited irrigation, prolonged winter season and photo-insensitive varieties wheat is widely cultivated by the farmers of the Chhattisgarh. Considering the soil and climate of Chhattisgarh, there is vast scope and greater possibilities of cultivation of urdbean-wheat cropping system in upland unbunded *Vertisols*. At present, the area and production of these crops is too less in the state. The picture can be reversed by bringing more and more area under these crops by adopting suitable cultural practices. The work on planting methods and nutrient management in *kharif* urdbean and its residual effect on succeeding wheat is very meagre in *Vertisols* of Chhattisgarh plains. It is being realized that system based research would be more advantageous for optimizing the use of different sources of plant nutrients, also due to escalation of fertilizer prices, the integrated nutrient supply approach would be more remunerative for fetching higher return with considerable fertilizer economy and better soil health.
Keeping the above facts in view, a field experiment on urdbean-wheat cropping system was conducted for two consecutive years during *kharif* seasons of 2002 and 2003 and *rabi* seasons of 2002-03 and 2003-04 at Instructional Farm, Indira Gandhi Agricultural University, Raipur (C.G.). The soil of experimental field was upland unbunded *bharri* (*Vertisols*) with neutral in reaction, low in organic carbon and available N, medium in available P and high in available K status. The climate of the region is dry moist, sub-humid with an average annual rainfall of 1326 mm. The urdbean crop received 504.4 mm and 1093.9 mm rainfall and wheat crop received 43.7 mm and 75.7 mm rainfall during first and second year, respectively.

In the present experiment, treatments related to method of planting and nutrient management were tested in *kharif* urdbean and the residual effect of *kharif* treatments and direct application of nutrients were tested in *rabi* wheat. During *kharif* seasons of 2002 and 2003, three method of planting i.e. ridge planting, paired row planting and flat planting and four nutrient management i.e. 100% rec. dose of fertilizer (RDF), 75% rec. dose of fertilizer, 50% rec. dose of fertilizer and *Rhizobium* inoculation were tested in urdbean crop. The design selected for these treatments was randomized block design (factorial) with three replications. While, during
\textit{rabi} seasons of 2002-03 and 2003-04, residual effect of \textit{kharif} treatments and direct effect of two treatment related to nutrient management i.e. 100\% rec. dose of fertilizers and 75\% rec. dose of fertilizers were tested in wheat crop. The design selected was randomized block design (factorial) with three replications. The \textit{urdbean} variety 'TAU-2' was sown on July 15, 2002 and July 9, 2003 with seed rate of 20 kg ha\(^{-1}\) and harvesting was done on September 28, 2002 and September 22, 2003. The \textit{wheat} variety 'Sujata' was sown on November 21, 2002 and November 23, 2003 with seed rate of 100 kg ha\(^{-1}\) and harvesting was done on March 18, 2003 and March 25, 2004.

In \textit{urdbean}, pre-harvest observations like plant population, plant height, number of branches plant\(^{-1}\), root length and weight, dry matter accumulation, number of flowers and pods, nodule number and weight were noted. Likewise post-harvest observations like number of pods plant\(^{-1}\), seeds pod\(^{-1}\) and seeds plant\(^{-1}\), pod weight and seed weight plant\(^{-1}\), length of pod, 100-seed weight, seed and stover yield were also recorded. Similarly, in \textit{wheat}, pre-harvest observations like plant population, plant height, number of tillers plant\(^{-1}\), dry matter accumulation, root volume and dry weight were noted. The post-harvest observations in case of \textit{wheat} included ears m\(^{-1}\) row length, length and weight of ears,
grains earhead$^{-1}$, grain weight earhead$^{-1}$, 1000-grain weight, grain yield and straw yield. Some of the computations like LAI, LAD, CGR, RGR, HI, PRI and PE were also calculated for both the crops. In chemical studies, N, P, K content and their uptake and protein content and protein yield were also estimated in plant and N, P and K availability in soil were also determined. Energy studies and economic analysis of urdbean-wheat were also worked out. The recorded data were statistically analysed and tabulated for interpretation of results.

The salient findings are presented as follows:

6.1 Studies on urdbean

➢ The maximum plant height of urdbean was recorded under ridge planting as compared to paired and flat methods of planting at all the growth stages. The tallest plants were recorded under 100% RDF treatment followed by 75% RDF at all the growth stages during both the years.

➢ The number of branches significantly increased under ridge method of planting. The maximum number of branches was recorded under treatment 100% RDF than other treatments at all the stages of crop growth. The second best treatment was 75% RDF.
The significantly higher root length was found under ridge method at 20 DAS and 40 DAS than other methods. However, it was found at par with flat method at 20 DAS and paired method at 40 DAS. The maximum root length was recorded under 100% RDF followed by 75% RDF.

The maximum root weight was found under ridge method of planting at all the stages. The significantly maximum root weight was found under 100% RDF treatment at all the stages of crop growth during both the years. However, it was mostly comparable with 75% RDF and *Rhizobium* inoculation treatments.

The highest leaf area index was found in ridge planting method at 20 DAS to at harvest. Significantly maximum LAI was recorded under 100% RDF at all the stages during both the years and on mean basis. It was followed by 75% RDF and *Rhizobium* inoculation.

Leaf area duration between 20-40 DAS and 40-60 DAS showed slightly higher value with ridge planting than other methods. The LAD between 20-40 DAS and 40-60 DAS was maximum under 100% RDF in both the years.
The maximum dry matter accumulation at 60 DAS and at harvest was found under ridge planting method. Under nutrient management treatments, the maximum dry matter accumulation was found with 100% RDF followed by 75% RDF and *Rhizobium* inoculation treatments.

The trend of crop growth rate showed that the higher value was found with ridge planting than other methods. In nutrient management, the maximum value of CGR was obtained with 100% RDF at all the growth stages.

The relative growth rate was higher with ridge planting method than others between 20-40 DAS and 60 DAS-at harvest. The maximum value of RGR was recorded with 100% RDF.

The significantly higher number of nodules was found in ridge method of planting than others. The maximum number of nodules was found under 100% RDF treatment, in all the growth stages of plant during both the years. The next best treatments were 75% RDF and *Rhizobium* inoculation.

The maximum dry weight of nodules was noted under ridge method of planting. The dry weight of nodule
under nutrient level was maximum with 100% RDF in both the years at all the growth stages. However, in most of the stages, it was at par to *Rhizobium* inoculation during both the years and in mean data also. At 20 DAS and at harvest stage during second year and in mean data and at 60 DAS during second year, treatment 75% RDF gave at par nodule dry weight.

At 45 DAS, the significantly maximum number of flowers was attained in ridge planting method during second year and in mean data. However, at 55 DAS also significantly maximum flowers was recorded with ridge planting method during first year only which was found comparable with flat method of planting. As regards to nutrient management, treatment 100% RDF had significantly maximum flowers plant$^{-1}$ as compared to rest of the treatments at all the stages of growth. However, it was statistically similar to *Rhizobium* inoculation during first year at 45 DAS and 55 DAS and in mean data at 45 DAS. The number of flowers has increased upto 45 DAS and decreased thereafter.

At 55 DAS, the ridge planting method gave significantly higher number of pods plant$^{-1}$ in first
year over other two methods. However, at par with flat planting method in second year and as per mean basis. At 45 DAS, the maximum number of pods plant\(^{-1}\) was found in 100% RDF which was at par with *Rhizobium* inoculation treatment during both the years and in mean data also. At 55 DAS, although 100% RDF was significantly superior over others and remained at par to *Rhizobium* inoculation treatment during both the years and as per mean data. Similarly, at 65 DAS, the significantly maximum number of pods plant\(^{-1}\) was observed with 100% RDF which was at par with *Rhizobium* inoculation treatment during first year.

- Significantly maximum number of pods plant\(^{-1}\) at harvest was observed under ridge planting method, however, it was at par with flat method of planting during second year of experimentation. The 100% RDF and *Rhizobium* inoculation treatment being at par gave significantly higher number of pods plant\(^{-1}\) than rest of the nutrient level in first year. However, 100% RDF proved superior over others during second year and in mean data.

- Maximum number of seeds pod\(^{-1}\) was recorded under ridge method of planting, which was at par with
paired method of planting during both the years and in mean data. A significantly maximum number of pods plant\(^{-1}\) was observed under 100% RDF, however, it was found comparable with 75% RDF and *Rhizobium* inoculation during first year and in mean data and with 75% RDF during second year.

The maximum number of seeds plant\(^{-1}\) was observed under ridge method of planting, while the lowest number was observed under flat method. Application of 100% RDF to urdbean recorded significantly higher number of seeds plant\(^{-1}\) than other treatments. The lowest number of seeds plant was observed under treatment 50% RDF.

The ridge method of planting significantly increased the length of pod than other methods of planting during both the years and in mean data. The maximum length of pod was observed under 100% RDF. However, it was at par to 75% RDF and *Rhizobium* inoculation during second year and on mean basis.

The pod weight plant\(^{-1}\) was found significantly superior under ridge planting than other methods, but at par to paired planting during first year and in
mean data and flat method during second year. Nutrient management revealed that 100% RDF produced significantly higher weight of pods plant$^{-1}$ as compared to rest of the treatments, but *Rhizobium* inoculation was comparable during first year and on mean basis.

The seed weight plant$^{-1}$ of urdbean was found significantly maximum under ridge method of planting. The maximum seed weight plant$^{-1}$ was found under 100% RDF which was significantly superior over others during both the years and in mean data.

None of the planting methods affected the 100-seed weight of urdbean significantly. As regards to nutrient management, the significantly higher 100-seed weight was obtained under 100% RDF treatment over 50% RDF, but at par to 75% RDF and *Rhizobium* inoculation treatments during both the years and in mean data.

The seed yield of urdbean remained unaffected due to the different planting methods. The 100% RDF produced significantly higher seed yield (7.95 q ha$^{-1}$ in 2002) and (8.98 q ha$^{-1}$ in 2003) than other
treatments. The stover yield of urdbean was significantly higher under ridge planting than flat method, but at par to paired method during both the years and in mean data. The maximum stover yield was obtained under 100% RDF treatment during both the years and in mean data. However, it was comparable to 75% RDF and *Rhizobium* inoculation treatments.

- Maximum HI was noted under 100% RDF which was followed by 75% RDF and *Rhizobium* inoculation. Different methods of planting could not give significant impact on HI.

- Ridge method of planting exhibited higher productivity rating index (PRI) over paired and flat methods of planting of urdbean during both the years and in mean data. The maximum PRI was obtained with 100% RDF treatment.

- Ridge planting method showed higher production efficiency than other two methods. The maximum production efficiency was found under 100% RDF.

- The N concentration in seed and stover of urdbean was non significantly influenced by different methods of planting. Application of 100% RDF accumulated
significantly higher nutrient in urdbean seed and stover than other treatments. However, it was comparable to 75% RDF for N concentration in seed during first year and on mean basis.

The nitrogen uptake in seed and stover and in their total remained unaffected by different methods of planting. The uptake of nitrogen in seed and stover and in their total was significantly the highest under 100% RDF. However, it was at par to 75% RDF in seed and in total of seed and stover during second year and to *Rhizobium* inoculation for N uptake by stover during first year.

The P concentration in seed and stover of urdbean was non significantly influenced by different methods of planting. The 100% RDF accumulated more P in urdbean seed as well as in stover than others during both the years and in mean data. However, the comparable P concentration in stover was found under 75% RDF and *Rhizobium* inoculation treatment.

P uptake under different methods of planting had no significant difference. The 100% RDF absorbed significantly more quantity of P in seed, stover and in
their total than other nutrient management treatments. However, it was at par to 75% RDF and *Rhizobium* inoculation during second year and in mean data.

▶ The potassium content in seed and stover of urdbean was non significantly influenced by different methods of planting. The 100% RDF accumulated the highest potassium in seed as well as stover. However, statistically similar K content was also noted with 75% RDF and *Rhizobium* inoculation in both the years.

▶ Planting methods of urdbean had no significant influence on potassium uptake by urdbean seed and stover. The 100% RDF had significantly higher potassium uptake than others. Treatment 75% RDF for K uptake by stover and in mean data and total of seed and stover during both the years and in their mean also gave comparable value of K uptake.

▶ The protein content in seed and stover of urdbean was not significantly influenced by different methods of planting of urdbean. The highest protein content in seed and stover was obtained with 100% RDF treatment. However, it was at par to 75% RDF and
Rhizobium inoculation treatments during both the years and in mean data.

Ridge method of planting though at par to paired planting accumulated significantly the highest protein yield in urdbean seed and stover as well as total protein yield than flat method of planting. Application of 100% RDF recorded the highest total protein yield, but remained statistically similar to 75% RDF and Rhizobium inoculation treatments.

The available N was found non significant under different methods of planting. Whereas, in case of nutrient management, significantly maximum available N was noted under 100% RDF. But in second year and in mean data, it was at par to 75% RDF and Rhizobium inoculation.

The available P was maximum after harvest under ridge planting method. The 100% RDF treatment gave higher available P in soil in comparison to other nutrient management treatments. However, it was comparable to 75% RDF and Rhizobium inoculation.

The available K in soil at harvest of urdbean under different methods of planting showed no significant variation. The maximum available K was found under
100% RDF treatment, which was at par to 75% RDF and *Rhizobium* inoculation during both the years and in mean data.

The energy output was found significantly maximum under ridge method of planting as compared to other planting methods. In case of energy use efficiency, ridge method of planting gave significantly the highest value. Similar trend was noticed for the energy output-input ratio. 100% RDF gave significantly the highest value of energy output, however, it was at par to 75% RDF during second year and in mean data. The energy use efficiency was recorded significantly the highest under *Rhizobium* inoculation.

The maximum gross and net returns were obtained under ridge method of planting followed by paired planting. The maximum benefit cost ratio was found under ridge method of planting. As regards to nutrient management, the maximum gross return was found under 100% RDF followed by *Rhizobium* inoculation during first year and 75% RDF during second year and in mean data. The highest net return was obtained under 100% RDF treatment. Similarly, the maximum benefit cost ratio was recorded under 100% RDF. The next best treatment was 75% RDF.
6.2. **Studies on wheat**

- Plant population at 15 DAS and at harvest was not affected significantly due to residual effect of *kharif* treatments and directly applied nutrients in wheat. Thus, the plant population was uniform under all treatments during both the years.

- Plant height increased progressively up to harvest of the crop under residual effect of *kharif* treatments and directly applied nutrients in wheat crop. The height increased rapidly up to 60 DAS and thereafter rate of increase declined slightly up to 90 DAS. At 60 DAS, during first year, residual effect of *kharif* treatment paired planting + 100% RDF recorded significantly the tallest plant, but at par to paired + 75% RDF and ridge + 100% RDF. At 90 DAS and harvest stage, significantly tallest plant was observed under flat + 100% RDF. However, it was comparable to ridge + 100% RDF and paired + 100% RDF. In case of directly applied nutrients, the tallest plant was noted under 100% RDF which was significantly superior over 75% RDF.

- At 30 DAS, the maximum number of tillers plant⁻¹ was produced under paired + 100% RDF, which was at par to 100% RDF or 75% RDF or *Rhizobium*
inoculation + different planting methods. At 60, 90 DAS and at harvest stage, the maximum number of tillers was obtained under flat + 100% RDF. However, it was at par to ridge + 100% or 75% RDF, paired + 100% or 75% RDF and flat + 75% RDF. In case of direct applied nutrients, 100% RDF produced maximum number of tillers plant⁻¹ of wheat.

At 60 DAS, treatment ridge + 100% RDF during first year and in mean data and treatment flat + 100% RDF during second year and in mean data also recorded the highest dry matter accumulation in wheat. At 90 DAS and harvest stage, residual of kharif treatments i.e. paired + 100% RDF in first year and in mean data and ridge + 100% RDF during second year and in mean data produced the significantly highest dry matter accumulation plant⁻¹. As regards to directly applied nutrients to wheat, significantly greater dry matter accumulation plant⁻¹ was noted under 100% RDF than 75% RDF.

Significantly more volume of roots was noted under 100% RDF treatment during both the years and on mean basis as compared to 75% RDF. Kharif treatments could not affect this parameter significantly.
Residual effect of kharif treatments and directly applied nutrient brought significant difference in dry weight of root during both the years. At late tillering stage, the maximum root dry weight was obtained under flat + 100% RDF in first year and in mean data and paired + 100% RDF in second year. At milking stage, residual effect of ridge + 100% RDF produced significantly the highest dry weight of root over others during both the years. In case of directly applied nutrient to wheat, the 100% RDF was found to be superior than 75% RDF.

Wheat crop produced more leaf area under residual effect of 100% RDF irrespective of method of sowing of urdbean. At 30 DAS, during first year and in mean data, maximum leaf area index was observed under residual of paired + 100% RDF, whereas, during second year, maximum leaf area index was observed under residual of ridge + 100% RDF. At 60 DAS, during first year, maximum leaf area index was observed under residual of flat + 100% RDF, whereas, during second year and in mean data, it was found maximum under ridge + 100% RDF. Treatments 100% RDF or 75% RDF with different methods of planting gave at par LAI during both the years and in mean
data. As regards to directly applied nutrients in wheat, use of 100% RDF gave significantly higher LAI than 75% RDF.

The residual effect of 100% RDF irrespective of methods of planting of urdbean produced more leaf area duration than others between 20-40 DAS and 40-60 DAS. In case of directly applied fertilizer to wheat, the maximum leaf area duration was recorded under application of 100% RDF.

The residual of 100% RDF applied to urdbean irrespective of methods of planting showed higher CGR values than other kharif treatments. In case of directly applied nutrients, the application of 100% RDF to wheat recorded higher values of crop growth rate at all the stages of crop growth than 75% RDF during both the years and in mean data.

The residual effect of 100% RDF along with different methods of planting gave the higher values of relative growth rate over other kharif treatments. In case of directly applied nutrients to wheat, application of 100% RDF produced more values of relative growth rate over 75% RDF.

Number of ears or effective tillers was found significantly the highest under residual effect of 100% RDF.
RDF + ridge method of planting. However, it was at par to 100% RDF, 75% RDF and Rhizobium inoculation under all methods of planting. Under directly applied nutrient, 100% RDF produced significantly the highest number of ears metre\(^{-1}\) row length.

Under residual effect of kharif treatments, the paired + 100% RDF during first year and ridge + 100% RDF during second year produced significantly maximum length of ears. In case of directly applied nutrient to wheat, 100% RDF to produced the longest ears of wheat during both the years.

The significantly heaviest ears was recorded under residual effect of flat + 100% RDP during first year and in mean data. Whereas, during second year, it was found maximum under ridge + 100% RDF. In case of directly applied nutrients to wheat, application of 100% RDF produced heavier ears of wheat.

The paired + 100% RDF and ridge + 100% RDF produced significantly higher number of grains earhead\(^{-1}\) during first year and second year, respectively. In case of directly applied nutrients,
100% RDF produced significantly higher grains earhead-1 than 75% RDF.

Paired + 100% RDF recorded the highest grain weight earhead-1, which was comparable to 100% RDF or 75% RDF with all the methods of planting during both years and in mean data. Under directly applied nutrients to wheat, treatment 100% RDF was found superior over 75% RDF and produced maximum grain weight earhead-1.

The residual effect of all methods of planting + 100% RDF ha-1 gave significantly higher and comparable 1000-grain weight than others. Under directly applied nutrients to wheat, non significant effect on 1000-grain weight was noted due to 100% RDF and 75% RDF.

The residual effect of kharif treatment flat + 100% RDF in first year and ridge + 100% RDF in second year and in mean data was found significantly the best yield producing treatment. In case of directly applied nutrients in wheat, the maximum grain yield was obtained under 100% RDF.

Under residual effect, the treatment flat + 100% RDF was found significantly the best to produce maximum straw yield during first year and in mean data.
Whereas, during second year, it was found significantly superior under ridge + 100% RDF over others, but was comparable with 100% RDF with paired or flat method. The treatment 100% RDF applied directly to wheat produced significantly higher straw yield over 75% RDF.

The harvest index was found the highest under flat + 100% RDF during first year and in mean data, which was at par with 100% and 75% RDF in all the methods of planting. Whereas, in second year, the significantly maximum harvest index was found with ridge + 100% RDF, which was at par to 100% RDF and 75% RDF under all the methods and *Rhizobium* inoculation. Under directly applied nutrients to wheat, the 100% RDF gave significantly more harvest index than 75% RDF.

N concentration in wheat grain and straw remained unaffected due to residual effect of *kharif* treatments. Under directly applied nutrients to wheat, use of 100% RDF was found significantly superior in respect of grain N content than 75% RDF during both the years and in mean data.

Significantly higher N uptake by grain was found under residual of *kharif* treatment paired + 100% RDF
in first year as compared to others, but it was at par to 100% RDF or 75% RDF with all planting methods and *Rhizobium* inoculation either with ridge or flat method. In second year, the maximum N uptake by grain was noted under ridge + 100 RDF and it was significantly superior over others, but at par with residual of 100% RDF in all the planting methods. In mean data, ridge + 100% RDF proved best than others, except ridge + 75% RDF, paired + 100% RDF or 75% RDF and flat + 100% RDF or 75% RDF which showed comparable values. In case of directly applied nutrients, application of 100% RDF increased significantly the N uptake by grain over 75% RDF during both the years and in mean data. In straw, the highest N uptake was recorded under flat + 100% RDF in first year and in mean data, which was at par with 100% RDF or 75% RDF with all the methods and *Rhizobium* + flat method. However, in second year, the highest N uptake was found in residual of paired + 100% RDF which was at par with residual of 100% RDF or 75% RDF with all the planting methods and *Rhizobium* under flat method. The N uptake by straw was significantly higher under directly applied nutrients of 100% RDF over 75% RDF. The
significantly higher total N uptake was found with residual of ridge + 100% RDF than others. However, 100% RDF or 75% RDF with all the methods of planting was found comparable. As regards to directly applied nutrients, treatment 100% RDF significantly increased the total N uptake as compared to 75% RDF.

Residual of kharif treatments did not bring significant variation in P content in grain and straw. Under directly applied nutrients to wheat, the 100% RDF registered significantly higher P content in grain as well as in straw of wheat as compared to 75% RDF.

The maximum P uptake by grain was reported under ridge + 100% RDF, which was at par to 100% RDF or 75% RDF with all the methods of planting during first year and in mean data. In second year, significantly maximum P uptake by grain was recorded under paired + 100% RDF, however, it was comparable with ridge or paired + 100% RDF. In case of directly applied nutrients to wheat, significantly maximum P uptake by grain was observed under 100% RDF as compared to 75% RDF. As regards to P uptake by straw and in total of grain and straw, the maximum P uptake was obtained under residual of flat + 100% RDF, which was at par to ridge or
paired + 100% RDF. Under directly applied nutrients, the 100% RDF gave significantly higher P uptake by straw and in total of grain and straw than 75% RDF.

Residual of *kharif* urdbean treatments did not show significant variation in K content of grain and straw. Under directly applied nutrients, application of 100% RDF during second year gave significantly higher K content in straw over 75% RDF.

Significantly the highest K uptake by grain was observed under ridge + 100% RDF during both the years and in mean data. However, it was at par with 100% RDF + paired or flat method during both the years and in mean data. Besides this, treatments ridge + 75% RDF or Rhizobium inoculation and 75% RDF + paired or flat method during first year and 75% RDF + paired or flat method in mean data were also statistically similar to best treatment. The K uptake by straw and in total of grain and straw was significantly the highest under flat + 100% RDF during first year, whereas, it was significantly the highest under ridge + 100% RDF during second year and in mean data and remained at par to 100% or 75% RDF with all methods of planting. Wheat grain and straw and their total showed significantly higher
K uptake under 100% RDF applied directly to wheat as compared to 75% RDF.

The available N, P and K in soil at harvest under directly applied nutrients to wheat showed significant variation and the application of 100% RDF had significantly higher values than 75% RDF. The residual effect of \textit{kharif} treatments was non significant.

The residual of higher fertility levels with different method of plantings gave higher values of productivity rating index (PRI). Productivity rating index was found maximum under residual of flat + 100% RDF during first year. Whereas, during second year and in mean data, the maximum PRI was noted with residual of ridge + 100% RDF. The higher PRI was noted under directly applied 100% RDF to wheat as compared to 75% RDF.

The maximum production efficiency was obtained with residual of flat + 100% RDF during first year. Whereas, during second year, the maximum production efficiency was recorded under residual of ridge + 100% RDF. In case of direct application of fertilizer to wheat, the higher production efficiency
was recorded under application of 100% RDF than 75% RDF.

The energy output was significantly the highest under residual of flat + 100% RDF during first year, however, it was comparable to 75% RDF or 100% RDF with all the methods of planting and ridge + Rhizobium inoculation. In second year, significantly maximum energy output was recorded under residual of ridge + 100% RDF, which was at par with ridge + 75% RDF and paired or flat + 100% RDF. The energy use efficiency was the highest under residual of flat + 100% RDF in first year and ridge + 100% RDF during second year and in mean data. Energy output-input ratio was found maximum in the residual of flat + 100% RDF during first year and in mean data and ridge + 100% RDF during second year. However, comparable values were also observed under 100% RDF or 75% RDF or Rhizobium inoculation with different methods of planting in second year and in mean data and under ridge + 100% RDF or Rhizobium inoculation, paired + 100% RDF or 75% RDF and flat + 75% RDF during first year. In case of directly applied nutrients, the significantly maximum energy output was recorded under 100% RDF. Whereas,
energy use efficiency and output-input ratio was recorded comparatively higher under 75% RDF than 100% RDF.

The highest gross return, net return and benefit cost ratio was obtained under residual of flat + 100% RDF during first year, whereas, during second year, the highest gross return, net return and benefit cost ratio was obtained under residual of ridge + 100% RDF. On the basis of two years average, the highest gross return (Rs 31341 ha\(^{-1}\)), net return (Rs 21446 ha\(^{-1}\)) and benefit cost ratio (1:2.16) was witnessed under residual effect of ridge + 100% RDF. The second and third best performing treatments in regards to economic parameters were flat + 100% RDF and paired + 100% RDF. As regards to directly applied nutrients, the application of 100% RDF to wheat gave higher gross and net return and benefit cost ratio during both the years and in their mean too as compared to 75% RDF.

6.3 Effect on urdbean-wheat cropping system

The highest total productivity (4183 kg ha\(^{-1}\)) has been observed under ridge method of planting + 100% RDF followed by flat + 100% RDF and paired + 100% RDF.
As regards to directly applied nutrients, the highest total productivity (4015 kg ha⁻¹) was noted under 100% RDF applied to wheat. Similarly, the two years average indicated that the net return from the system was the highest (Rs 28605 ha⁻¹) under ridge + 100% RDF followed by flat + 100% RDF and paired + 100% RDF. In case of directly applied nutrients, the net return of Rs 27407 ha⁻¹ was observed under 100% RDF applied to wheat, whereas, net return of Rs 22637 ha⁻¹ was noted under 75% RDF.

The balance sheet of available nitrogen revealed that the N status of soil decreased after two years of urdbean-wheat cropping system, the magnitude of decrease was less under higher level of fertilizer dose. In general N balance of soil showed positive values and maximum was recorded under 50% RDF treatment. Whereas, under direct application of nutrient to wheat, application of 100% RDF showed less decreasement of available N and more N balance in soil as compared to 75% RDF. The balance sheet of available phosphorus at the closing of second year revealed that the 100% RDF applied to urdbean and wheat had minimum depletion of available phosphorus from soil. But in case of P balance, the
maximum depletion of phosphorus was found under 100% RDF. In case of available potash in soil, the minimum depletion in available potash status was found under 100% RDF and maximum K balance was found under treatment of *Rhizobium* inoculation followed by 100% RDF.

CONCLUSION

The findings of urdbean-wheat cropping system under unbunded *Vertisols* of Chhattisgarh plains clearly visualized that application of 100% RDF along with either ridge or flat or paired system of planting of *kharif* urdbean followed by 100% RDF to wheat not only produced the highest total productivity of the system but also gave the highest economic returns followed by application of 75% RDF with different methods of planting in *kharif* urdbean.

These treatments showed minimum depletion of nutrients from the soil. In this way of sustainable legume-cereal crop sequence, there can be a saving of 25% RDF in *kharif* urdbean if wheat is to be followed with 100% RDF.
SUGGESTION FOR FUTURE RESEARCH WORK

Considering the findings of study, further works should be initiated to understand the nutrient availability and depletion by considering the weed flora in different soil types of Chhattisgarh. Further refinement is needed to generate more scientific information and make them farmer's friendly technology. The suggestion for further works are as follows:

- The soil analysis with amino acid analyser should be studied to further explain the behaviour of nitrogen fixed by the urdbean and their utilization by wheat crop.

- The integration of organic and inorganic fertilizer should be scheduled appropriately to maintain soil health under legume-cereal crop sequence.

- Experiments should be conducted with cereal based and legume based cropping system in unbunded Vertisols considering the various aspects of improved agro-techniques.

- Soil nutrient dynamics under legume-cereal based crop sequence should be further studied under different soil types of Chhattisgarh.