Introduction
I INTRODUCTION

Fast growing population in many countries is one of the reasons for enormous increasing demand for food. Farmers and researchers should be aware that cost-benefit ratio bringing new land under cultivation is smaller than that of increasing production of already cultivated land. Increase of food production in the available cultivated land is depending upon the maintenance of the soil health. Continuously growing of a same crop over years in the same cultivated area leads to ill health of the soil and cause for increase in various pest and diseases. To overcome the problem of ill health one can use alternate methods like intercropping, relay cropping, mixed cropping and so on. Many researchers have indicated that sole (say maize) crop will be problematic in the long run, further they have advocated going for intercropping which are beneficial, preferably by having legume as component crop.

RESEARCH GAP

“Days of food shortage are ahead! - Indian per capita food grain availability back to 70’s level”- Dr.Amit Bhatttacharya (Editorial coloumn report: Times of India dt. 3-4-2008) in his report said that, under Green revolution, availability of food grain during 1979 was 476.5 gm/person/day, which comes down to 444.5gm/person/day during 2005 and during 2006 it is 422.5gm/person/day. Similarly pulse availability of 60.7 gms/person/day in 1951 came down to 32.5 gm/person/day. Further he hinted ‘zero percent’ growth rate in human consumable food grain such as paddy, wheat, bajra, ragi, jowar and pulses.

Currently cereal crop Maize (*Zea mays* L.) is occupying larger area, Table 1.1 revealed the comparison of maize over other major cereals such as paddy, Jowar, Bajra, Ragi and total Pulses put together.
Table 1.1  Area (lakh ha) and Production (lakh tonnes) for Major Cereals and Pulses.

<table>
<thead>
<tr>
<th></th>
<th>CEREALS</th>
<th>All Pulses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paddy</td>
<td>Jowar</td>
</tr>
<tr>
<td>P</td>
<td>2009-10</td>
<td>14.86</td>
</tr>
<tr>
<td>%variation</td>
<td>0.1</td>
<td>-3.1</td>
</tr>
</tbody>
</table>

A: Area,  P: Production

Anon, 2011 Source: Government of Karnataka, DES publication, 2011

From the table it could be noticed that maize cultivation area has been increased to an extent of 32.5 per cent, whereas increase in production is not appreciable i.e., to the extent of 4.2 per cent. This slow increase in production is might be due to continuous growth of the same crop. Area and production was noticed to be negative in other crops except in pulses.

ABOUT THE CROPS: THEIR PROBLEMS AND ADVANTAGES

Maize is a principle rainy season crop; it is extensively grown in Karnataka. Increase in the area and production has been clearly noticed in the above table. Because of its requirement of less labour force, easy post harvest mechanism, well established marketing and prevailing rainfall distribution, this crop is very well catching up in the state. Maize requires high plant nutrients, hence growing of this crop alone over the years will barren the land and cause for decline in productivity. This decline in low productivity of only 4.2 percent as observed in table 1.1

Legumes are very much accepted as intercrops in Indian agriculture and are successful crops for soil enrichment. Nitrogen
fixation by them not only improves soil fertility but also have high nutritive value. As green manure crop, they add organic matter to the extent of 1-1.5 t/ha through their roots. Green manuring insitu of pulse crop like cowpea, green gram or black gram (urdbean) leads to an addition of organic matter to the extent of 15-20 t/ha. Growing of sole maize over years with specified plant density may be the cause for low productivity. Increase in productivity can be had with adjustment to the spacing and maintaining same plant density. The vacant interspaces can be effectively utilized by growing grain legumes which can fetch additional yield and income during initial period of establishment of the main crop. Growing grain legumes will cause for the enrichment of the soil by shedding their leaves.

**Intercropping** is the growing of two or more crops together simultaneously in the same piece of land (Fukai, 1993) and these were observed to be beneficial in terms of yield stability (Rao and Willey, 1980), increase in total yield (Li et al., 1999), pest and disease control (Sahile et al., 2008), weed management (Haymes and Lee, 1999), soil fertility (Innis, 1997; Hauggard-Nielson et al., 2006) among others. Sole cropping, that is growing a single crop in a given area often with high inputs is more pronounced, where mechanized agriculture is at its advance stage (Vanderveer, 1989; Francis, 1989). In general, there has been suggestions that intercropping benefits are usually greater when the growth duration between the component crops differs widely (suggesting temporal effects) than when the crops durations are similar (suggesting spatial effects) (Fukai and Trenbath, 1993). The crop which is of major importance are called main crop and the crops which are of relatively minor importance are called intercrops or component crops. It is generally practiced in tropics mainly as a safeguard against total crop failure.
Aggarwal et al (1992) reported that the yield advantage of any intercrop is attributed to below-and above-ground plant interactions which are likely to vary depending upon the temporal and spatial differences in resource use by component crops. Thus, a fundamental understanding of how intercrops capture and use resources would provide a scientific basis of recommending appropriate crop combinations and spatial arrangements at different locations. Willey (1979b) reported that intercrop performance can be improved with respect to temporal and spatial complementarities by improving the compatibility of genotypes used as components of the mixture. Presently, interest in intercropping is increasing and fast becoming important among the small scale farmers because of their diversified needs and low farm income from the mono-cropping system.

The challenge therefore is to identify crops capable of sustaining their potential yield when grown in specific row arrangements with other crops. Spitters (1983) reported that yield of grain per unit area is an essential measure of mixture performance which represent only a part of total plant biomass and may not fully reflect the result of competition between species in mixture. A number of indices such as land equivalent ratio, relative crowding coefficient, competitive ratio, actual yield loss, monetary advantage and intercropping advantage have been proposed to describe competition within and economic advantages of intercropping systems (Banik et al., 2000).

The idea of sustainable agriculture among others includes the adoption of agricultural practices used in low-input traditional farming such as growing arable crops in mixtures (intercrops). Intercropping of cereals with legumes has been popular in tropics (Hauggard-Nielsen et al., 2001) and rain-fed areas of the world (Banik et al., 2000) due to its various advantages (Chen et al., 2004, Agegnehu et al., 2006). Mixed
cropping or intercropping is an important practice considered as part of the subsistence farming designed to meet the increase in domestic food requirements.

There are no waste products in nature, outputs from one organism become inputs for another. One organism dies and becomes food for other organisms. Since we are modeling nature, we have to first look at some of the principles by which nature functions. By understanding these principles we can use them to reduce costs and increase profitability, while at the same time sustaining our land resource base.

Nature Cooperation is more in nature than competition. Cooperation is typified by mutually beneficial relationships that occur between species within communities.

Maturity dates are important concept in planting intercropping system. The feature of staggered maturity dates or development periods takes advantage of variations in peak resource demands for nutrients, water, and radiant energy (sunlight). Having one crop mature before its companion crop lessens the competition between the two crops. Selecting crops or varieties with different maturity dates can also assist staggered harvesting and separation of grain commodities.

**Types of intercropping practices:**

- **Mixed or multiple cropping** is the cultivation of two or more crops simultaneously on the same field without a row arrangement.

- **Relay cropping** is growing of two or more crops on the same field with the planting of the second crop after the first one has completed its development.

- **Row intercropping** is the cultivation of two or more crops simultaneously on the same field with a row arrangement.
- **Strip cropping** is the cultivation of different crops in alternate strips of uniform width and on the same field. It has two types; contour strip cropping and field strip cropping.

- **Contour strip cropping** it follows a layout of a definite rotational sequence and tillage is held closely to the exact contour of the field.

- **Field strip cropping** it has strips with uniform width that follows across the general slope of the land.

  Intercropping is beneficial, if there is no competition between the crops for nutrients and other natural resources like water, radiant energy (sunlight) etc. otherwise it is found to be disadvantageous. So the researcher should be cautious in selection of the crops in intercropping.

  Intercropping experiments consists of the treatments with sole main and intercrop, and different row ratio of main and intercrops. If experimenter tries different varieties of main and intercrops in combination, then there will be sole crop treatment for each row ratio tried with inter crop.

  Cereal-legume intercropping plays an important role in food production, especially in situations of limited water resources. Intercropping improves the utilization of available resources and cause yield advantages and increases yield stability. Yield advantages occur when intercrop components compete only partly for the same plant growth resources.

  Existing intercropping pattern, mainly with red gram or field bean are not confirming with the plant population. Green gram and black gram are short duration crops (maximum of 70-75 days) where as maize is 120-130 days crop. Initially both are sown at the same date with defined row ratio. Pulses such as green gram or black gram will come for
harvest by the time maize will come to flowering stage, till that time maize consumption for its nutrition was limited. After certain period nutrition requirement by maize will be more and waste materials of pulses remains can become manure for maize.

Analyses of intercropping data is not complete without a comparison between the performance of the intercrops to that of the component sole crop. This has been made by using various biological or economic or statistical indices such as Analysis of variance (ANOVA), Cost benefit ratio (B:C ratio ), Land equivalent ratio (LER), Area time equivalent ratio (ATER), Energy equivalent ratio, Crop performance ratio (CPR), period based crop performance ratio, Correlation analysis, Response surface methodology (RSM), Stability and Sustainability analysis etc.

Analysis of variance (ANOVA) is a methodology using which row ratio can have significantly high productivity has to be ascertained statistically.

Cost benefit ratio (B; C ratio) is an economic index using which economically feasible intercropping row ratio can be identified. In the sense that, intercrop row ratio will give better monetary return to the farmers with minimum expenditure on cost of cultivation.

Land equivalent ratio (LER) and Area time equivalent ratio (ATER) are the biological indices using which the intercropping row ratio which provides maximum productivity by utilizing the natural resources can be known.

Energy equivalent ratio, Crop performance ratio (CPR), period based crop performance ratio (CPRT), Aggressivity index, are the indices
using these, technologies will be identified based on their performance over years, which are suitable for cultivation and productivity oriented.

Correlation analysis and Response surface methodology (RSM) are the statistical tolls used to study the relation of yield and yield attributing characters and prediction of optimum productivity for a row ratio intercropping

Stability and Sustainability analysis are the statistical and biological indices using which adoptability of row ratio and a row ratio which providing sustainable productivity can be ascertained.

Since no information is available on recommendable row ratio of intercropping with proper weed control technology in the Bhadra command area of Karnataka, the study of **Statistical and Economic evaluation of intercropping of maize with urd bean- a study in Bhadra command area of Karnataka** is attempted to assess the influence of different row ratio of intercropping along with effectiveness of weed control methods on significance in yield, economically advantageous, well performing, adaptable and dominant crop of the intercropping system.

With the intention for evaluating the intercropping row ratio, present investigation has been proposed with the following objectives.

1. To study statistically and economically optimum/viable row ratio of the maize-urdbean intercropping in Bhadra command area of Karnataka

2. To study association of yield attributing parameters with the yield under different row ratios of intercropping

3. To evaluate the energy use efficiency under different row ratio
4. To evaluate sustainability of the intercropping

5. Statistical and economic evaluation of crop weed interaction

**RESEARCH HYPOTHESIS: - Probable out come from the study**

1. With adoption of parametric or non parametric tools of statistical analysis we can identify statistically significantly superior intercropping system which can provide maximum productivity.

2. Cost benefit ratio is one of the economic tool using which we can ascertain economical feasible intercropping system wherein farmers can get better monetary benefit.

3. Productivity is mainly depend on the appropriate usage of natural resources like radiant energy (solar radiation), space, available moisture, available nutrition, crop competition these are manly known by the adoption of indices such as Land equivalent ratio (LER), Area time equivalent ratio (ATER) Crop performance ratio (CPR), period based crop performance ratio (CPRT), and aggressivity etc., .

4. Yield is responsive of it’s varies associated (attributed) characters, association between the yield and yield attributing characters can be determined using correlation analysis. Yield attributing characters get effected by imposition of different row ratio, which in turn cause for change in the productivity(yield character)

5. Higher productivity (response) is also mainly due to adoption of appropriate spacing (row ratio) between the main and the component crops. Among the different row ratios, a row ratio which can cause for the optimum response has been determined with the help of functional relation between using response surface methodology.

6. An optimum intercropping row ratio provides high out put energy (in terms of yield, straw etc.,) with least usage of input energy (in terms of
man power, bullock pair, fertilizer and other inputs). This is studied by using the indices energy equivalent ratio

7. Any technology is said to be promising (stable) if it provides consistent productivity over all the periods (environments) and which provides targeted productivity. Consistent over the years and providing targeted yield can be known by usage of stability and sustainability analysis

8. Weed is one of the major problems in reduction in yield, significant weed control practice which can cause high productivity in yield has been studied using some of the above mentioned indices

ABOUT STUDY AREA – BHADRA COMMAND AREA

Plate 1.1 Areal map of BHADRA DAM
Bhadra reservoir was constructed during 1956-57 across Bhadra river near Lakkavalli, Tarikere taluk, Chikkamagaluru district of Karnataka. Bhadra Command Area Development authority has been established during 1979-80 with its head quarters at Shivamogga, in the western part of Karnataka in South India. (Bhadra Dam - Wikipedia, the free encyclopedia)

Bhadra reservoir has been constructed with a Latitude of 13° - 42’-00” N and Longitude of 75° -38’- 20” E. The reservoir is having its catchment area of 1968 sq kms with gross storage capacity of 71.535 tmc and having its irrigating area of 1,05,570 hectares. The reservoir has been constructed with multipurpose activities of providing drinking water, irrigation and power generation, but with main emphasis on irrigation.

The benefits derived from the reservoir storage are irrigation with gross irrigation potential of 162,818 hectares (402,330 acres), hydro power generation of 39.2 MW (three powerhouses, located on the right and left bank main canals), drinking water supply and industrial use. The dam commissioned in 1965 is a composite earth cum masonry structure of 59.13 metres (194.0 ft) height with length of 1,708 metres (5,604 ft) at the crest level, which submerges a land area of 11,250.88 hectares (27,801.5 acres).

The Bhadra river rises at Samse in the Western Ghats Aroli hill range of Kudremukh range, and flows east across the Deccan Plateau. It is joined by its tributaries, the Somavahini (drains from a crater and meets Bhadra River at Hebbe), Thadabehalla, and Odirayanahalla. The river flows through the city of Bhadravathi and the Bhadra Wildlife Sanctuary. The Bhadra meets the Tunga River at Koodli, a small town near Shivamogga. The combined river continues east as the
Tungabhadra, a major tributary of the Krishna, which empties into the Bay of Bengal.

The Bhadra Dam is built across the Bhadra river, 1.5 kilometres from Lakkavalli village and 50 kilometres upstream of the confluence of the Bhadra river and Tungabhadra river. Shimoga city is located 28 kilometres north of the dam. The Bhadra dam drains a catchment area of 1,968 square kilometres out of which the forest area is 717.49 hectares (1,773.0 acres), cultivable land is 3,274.65 hectares (8,091.8 acres) and fallow land is 7,258.74 hectares (17,936.7 acres). The catchment and command areas of the project lie in Chikamagalur, Shimoga and Davanagere districts. A number of industries, urban and rural settlements dependent on assured water supply lie on the banks of the river and in the project command area; Kudremukh Iron Ore Company Ltd, the Mysore Paper Mills and Vishweshvarayya Iron and Steel Industries are the major industrial activity noted in the command area of the project. Fishing activities have also increased on the bank of the Bhadra River.
The Bhadra river basin receives an average annual rainfall of 2320 mm with rainfall occurring during monsoon period (June to November). The rainfall is experienced both during the Southwest monsoon and North East monsoon; inflow contribution is 82% from SW monsoon (June to September) and 18% from North-Eastern monsoon (October to December).