MITIGATION OF GLOBAL WARMING THROUGH AGRICULTURAL MANUPULATION

P.K. GUPTA[a1], HUTESH KUMAR SHARMA[b], RAHUL KUMAR SINGH[c], RL SUWALKA[d] AND BHERU LAL KUMHAR[e]

[abcd]Department of Agriculture, School of Agriculture Sciences, DKNMU, Newai, Tonk, Rajasthan, India
[e]Jawaharlal Nehru Krishi Vishwavidyalya, Jabalpur, M.P., India

ABSTRACT

The average increase in the most important climatic parameter *i.e.* temperature of earth's near surface air and oceans is referred to as Global Warning. Human activity since the industrial revolution has increased the amount of greenhouse gases in the atmosphere, leading to increased radioactive forcing from CO_2, methane, tropospheric ozone, CFCs and nitrous oxide. The global increases in carbon dioxide concentration are primarily due to fossil fuel burning and land use changes, while those of methane and nitrous oxide are primarily due to agricultural practices. The concentrations of CO_2 and methane have increased by 36% and 148% respectively since 1750. These levels are much higher than at any time during the last 650,000 years, the period for which reliable data has been extracted from ice cores (Pearson and Palmer, 2000). Over the past 20 years fossil fuel burning has produced about three-quarters of the increase in CO_2 from human activity. Most of the rest is due to land-use changes, particularly deforestation. In India, out of total GHG emission from the anthropogenic activities, agriculture sector contributes 28%. The emissions are primarily due to methane emission from rice fields (23%), enteric fermentation in ruminant animals (59%) and nitrous oxides from application of manures and fertilizers (Das and Hati, 2013).

KEYWORDS: Climate Change**,** Global Warming**,** Green House Gases (GHGs), CO_2, Methane, Tropospheric Ozone, CFC and Nitrous Oxide

Climate change is now well recognized as the biggest challenge facing the planet. Different projections of climate change are associated with a range of limitations and uncertainties – driven mainly by the model and scenario uncertainties. It is evident from the broad range of temperature projections for India, ranging from 1°C to 8°Cover the period 1880–2099 under different scenarios and even broader range for the precipitation projections. India is one of the most vulnerable regions in the world to climate change in view of the huge population, the large number of poor facing food insecurity, inappropriate soil and management practices on marginal lands in the semi-arid regions leading to increasing rates of land degradation and the projected impacts of climate change on the agricultural, forestry and fisheries sectors. Improved understanding of the climate change impacts, vulnerability and the adaptation practices to cope with climate change is urgently needed to reduce the risk on human welfare

Climate change refers to a change in the state of the climate that can be identified (*e.g.*, by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It is a serious global environmental concern and is primarily caused by the building up of Green House Gases (GHGs) in the atmosphere. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. United Nations Framework Convention on Climate Change (UNFCC) defined Climate change as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climatic variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Climate change is poised to have a sharply differentiated effect as between agro-ecological regions, farming systems, and social classes and groups another impacts are.

1. Shift in climatic and agriculture zones
2. Impact on Agriculture soil
3. Effect on soil organic matter and soil fertility
4. Effect on biological health of soil
5. Soil erosion and sediment transport
6. Reduced soil water availability
7. Impact on soil processes

[1]**Corresponding author**

8. Salinization and alkalization
9. Pest, Diseases and Weeds
10. Impact on Plant growth
11. Impact on crop production

Advent of New Climate Smart Crop Varieties

Climate Smart Land Preparation Practice

Under conservation agriculture, farmers were introduced to laser leveller and today it is the much sought after machinery both by rainfed farmers and of command areas because of its ability to increase water use efficiency which is of paramount importance. Uniform water distribution, reduced runoff and erosion are attracting farmers. High potential of cotton mentioned previously in paddy fallows in Kasabe camp is due to laser levelling (Pyati, 2015). This also enabled large plots in case of paddy and thus eliminated mid bunds resulting in overall increased yield and saving of water compared to traditional system where due to uneven land more water was required.

Drainage, Bio drains and Conjunctive Use of Saline Water

Irrigation and drainage go hand in hand otherwise production will hamper due to water logging and salinity. Conjunctive use of poor quality water revealed that use of saline water up to 4 dS/m in direct mode had no adverse effect on cotton yield. Use of saline water (4-6 dS/m) during canal lean period and then switching over to good quality water wherever available conclusively established that early establishment (June) with available saline water (with 4 irrigations) and later switching over to canal (August) water produced highest kapas yield (22.1q/ha) compared to a crop receiving good water but sown during August (12.6 q/ha). The salt balance remained favourable and did not cause any concern.Further, evaluation of tree/grass species for the control of seepage, rising water table and soil salinity in commands (bio-drainage) revealed that *A. nilotica* was the most promising at all salinity levels ranging from < 5 to > 15 dS/m whereas *C. equisetifolia* promising initially registered high mortality and cease of growth after 6-8 years. In contrast, *H. binata* less promising initially became promising after 6-8 years. In terms of seepage control, *A. nilotica* and *C. equisetifolia* were effective in arresting emerging seepage flows from the canals. *A. nilotica* and *C. equisetifolia* intercepted seepage over 80 per cent and remained most promising over other species. The grasses in between complimented the effects. The water table receded significantly underneath the plantation while increased at the rate of 10 cm rise outside the plantation area. *A. nilotica* followed by *C. equisetifolia* also improved soil organic carbon and porosity, while bulk density decreased. Trees improved hydraulic conductivity and infiltration rate and brought about a significant change in soil stability by improving aggregates, decreased soil and water erosion.

Conservation Agriculture

CYMMIT funded experiments on farms and on farmers' fields were promising on conservation agriculture under rainfed agriculture were promising. It was found that pigeonpea could be cultivated without tillage (land ploughing,) whether bed raised or flat being immaterial provided previous crop residue is retained on the field (Anon., 2014). Because of beneficial effects of residue on physiochemical and biological properties such a practice had saving in draft/energy, reduced pest incidence apart from improved economics.

Sand Mulching

In spite of high moisture holding capacity, utilization of black soils for crop production is limited to a few crops because of poor aeration and ill drainage due to high clay content (64%). Sand mulching has been practiced by farmers in some pockets of North Karnataka on deep black soils and such a system found to help harvest two crops in northern dry zone of Karnataka namely greengram-*rabi* sorghum/safflower. This system also does not warrant yearly ploughing. Soil cracking during hot summer was either minimum or not visible. Experiments conducted at Dry farming Centre, Bijapur and Main Research Station, Dharwad, indicated distinct advantage with sand mulching (Guled, 1999 and Sudha, 1999 and Surkod, 2015). Application of gravel sand + crop residue in set furrows, however, recorded significantly lower sunflower yield (288 kg/ha) than other treatments (Yadahalli, 2008). This might be due to application of gravel sand + crop residue in set furrows to a 30 cm depth at such depth the moisture or water present was leached out into deeper layer. Therefore, the availability of moisture in the rooting zone was lower during the crop growth period. Kirkham *et al.* (1967) and Unger (1971) found that the surface sand mulch is more effective than a sub-surface layer in preventing evaporation and leaching whereas a gradual decline in the yield was observed with increase in thickness of sand mulch up to 30 cm. Similar observations were made by Sudha (1999) who revealed that 10 cm thick cover of sand gave lower groundnut pod yield compared to 5 cm sand mulch. The authors further concluded that sand application of 5 to 7.5 cm to fine textured soil is beneficial for its reclamation and for increased yield level.

CROPPING METHODS

Seed Hardening

Seed hardening involves seed soaking in chemical solution or water for a specified period (2 to 16 hrs) at room temperature followed by shade drying 24 hrs). Seed soaking in wheat (24 hr), groundnut (4 hr), green gram (4hr), Bengal gram and sorghum has been found to result in higher yields. In northern Karnataka, seed soaking with 10 % cow urine for 8 hrs has given on par yield as that of chemical seed treatment with $CaCl_2$. At Kovilpatti, water soaking for 4 hrs with Rhizobium found to increase blackgram and chickpea yields (Arunachalam, 1996). Dharmlingam and Jegathambal (1996) soaked seeds in organic substances (leaf extracts of *Prosopis* and Pungam leaf in 100 ml water for 16 hrs using 1:06 w/v, seed:solution ratio)and then coated air dried seeds with a fine leaf powder of Pungam leaf @ 300 g kg^{-1} seed using 5 % maida gruel as adhesive. Seed coating was done by mixing the seed with maida gruel (300 ml kg^{-1} seed). Organic farmers are coming out with many innovative materials and methods. Recently, IARI has come out with seed line application of hydrogel to tide over drought and has already caught the attention of farmers in Maharashtra and Karnataka.

The following seed hardening practices are suggested in UAS, Dharwad for drought proofing:

1. Soaking of sorghum in 2 % $CaCl_2$ or 0.5 % KH_2PO_4 for 10 hrs followed by drying.
2. Overnight soaking of seeds of pearlmillet and fingermillet in 1.0% $CaCl_2$ solution followed by shade drying.
3. Soaking the seeds of pearlmillet with 0.5% KH_2PO_4 or 2% $CaCl_2$ or CCC @ 5ppm solution for 10 hrs followed by air drying.
4. Soaking chickpea seeds in $CaCl_2$ (2%) solution for 1 hr, pigeonpea for 2 hrs and greengram andblackgram for 4 hrs followed by shade drying is suggested.
5. Soaking the groundnut seeds in 1 % $CaCl_2$ solution for 6 hrs and shade drying.
6. The delinted cotton seeds are to be soaked in CCC (Chloro-choline-chloride) 1000 ppm (0.1%) for 6 hrs. followed by air drying.
7. Soaking sunflower seeds in disodium hydrogen phosphate (36 mg/l) for 6 hrs followed by air drying.

Transplanting

Transplanting vegetables like chilli, tomato etc. under assured moisture or paddy under irrigation is a common practice. Transplanting of fingermillet under late sowing conditions or in case of pearlmillet to fill the gaps as a contingency measure has been suggested. Recently, in the north-eastern transitional and dry zones of Karnataka, transplanting of 25-30 days old poly bag (of 5-6" dia/height, for successful establishment the boll of earth with roots should be intact) raised pigeonpea is found to produce more yield than the conventional drilling/dibbling. Nipping of 5-6cm top at 20-25 days after transplanting may be followed in case of excessive vegetative growth which improves branching and flowering leading to higher harvest index. Particularly under drip method of irrigation, the practice found to give nearly three times higher yields (16 – 18 q ac^{-1}) over normal drill sowing (5-6 q ha^{-1}). The width of the row could be increased to 6- 8 feet under drip and the inter row space could be made use for introducing intercrop. The practice is attracting the attention of neighbouring state farmers.

Rajkumar and Gurumuthy (2008) revealed the scope of transplanting in cotton. Subsequent studies in TBP and UKP confirmed high seed cotton yield (32 %) with transplanting of cotton at 90 cm X 90 cm space over farmers' practice of dibbling due increased sympodials, bolls and seed cotton yield per plant. The cost of transplanting was covered by the increased income (39 %) realized in the technique (Honnali and Chittapur, 2013). Importantly, transplanting ensures efficient use of water and growing season and is more advantageous in UKP region, where release of water is always delayed resulting in low productivity.

Late *kharif /rabi*pigeonpea

Pigeonpea becoming bread and butter of dryland farmers and its assumed status as commercial crop forcing farmers to continue with the crop even under delayed sowing situations and some farmers are also venturing into *rabi* situation under irrigation. Some cultivators are even enquiring the possibility of summer pigeonpea. Therefore, experiments were carried out during 2010 to 2012 throughout Hyderabad –Karnataka (Anon., 2012). Late *kharif* sowings during August and September indicated superior performance of the crop during 1st and 2nd fortnights of August with improved cultivars. Interestingly, during *rabi*under protective irrigation performance of the crop was either first or next to groundnut in terms of yield and economy. When an effort was made to recommend the practice crop pathologists strongly opposed the idea for the fear of that such delayed sowing and consequent debris of live vegetation may encourage sterility mosaic virus outbreak as once experienced at Agriculture Research Station, Kalaburagi, Karnataka.

Direct Seeded Rice (DSR)

DSR though not new to farmers in many areas of Karnataka e.g. Western Ghats (Belgaum, Dharwad and Karwar districts) where farmers grow rice as DSR. During recent years due to severe water and labour shortages and high cost of production constraints; farmers in many areas of Hyderabad-Karnataka regions, are facing challenges of low productivity, profitability and even low cropping intensity. With the joint efforts of CIMMYT and University of Agricultural Sciences, Raichur, development and validation of DSR technology had shown promise for its out-scaling through innovative strategies in the areas where water supplies are limited and farmers do not get sufficient water at right time and constrained with ON-OFF canal water supply. Moreover, erratic and insufficient monsoon have further aggravated conditions leading insufficient water in barrages, delayed, erratic & untimely canal supplies leading to delayed transplanting (beyond August). Therefore a participatory intervention on DSR in the Upper Krishna Project (UKP) and TungaBhadra Project (TBP) in addressing such predicaments was initiated (GoK-CGIAR Project Progress Report (2013)-CIMMYT). Response to early dry seeding or take advantage of early rains received before canal supplies was met with imminent success with farmers. Success of Kasabe camp, Raichur today has spread over 60, 000 acres in TBP and UKP commands. In addition to increase in net income, timely sowing, reduced seed rate by half, reduced fuel consumption by 40-50 lit/ha, reduced water use by 25-35%, reduced GHGs, increased NUE are the other benefits.

Cropping System Diversification and Intensification

Paddy being a banned crop for its heavy irrigation requirement in UKP command, experiments conducted to find out suitable alternate crops revealed superiority of transplanted *Bt* cotton with maximum seed cotton equivalent yield over rice-rice, while *Bt* cotton-seame /greengram (summer), maize – chickpea and chilli + onion were at par with prevailing rice-rice system (Honnali and Chittapur, 2014). However, Protein yields were higher with maize-chickpea while carbohydrate yield was higher with rice-rice while the highest land utilization index was observed with *Bt* cotton – sesame cropping system. Thus, arable cropping is more sustainable and productive than the present system of rice-rice.

Promising Crops for Paddy Fallows

Relay cropping is such an innovative strategy to replace traditional monocrop of cotton, transplanted double cropping of rice and rice-fallow with direct seeded rice-mustard, direct seeded rice-maize, direct seeded rice-chickpea, and direct seeded rice-greengram. In addition, maize-fallow system is being intensified with maize-zero tillage chickpea. In recent years, traditional rice-rice system in South India is challenged by non-availability of water to grow 2nd rice crop. Maize has emerged as an obvious choice, as it can be grown with less than 1/3 amount of water and has potential to maintain farm profitability at paror better. However, the *spring* maize is prone to heat stress during reproductive phase, as temperature peaks during month of March/April during which availability of water is also invariably a challenge. Maize production linearly decreases with every accumulated degree day above 30°C (Lobell *et al.* 2011). However, the efforts made under Conservation agriculture and Heat resilient maize projects of CYMMIT, Mexico and UAS, Raichur attracting farmers towards maize. Half a dozen of maize hybrids are already identified for release (Kuchunur, 2015).

I*n situ* Green Manuring

Maize – safflower sequence is one of the predominant cropping sequences under rainfed conditions of northern transitional zone of Karnataka and both cops being exhaustive, organic recycling through green manuring was considered as wide spacing followed in maize provides an opportunity to introduce a green manure crop as intercrop (1 maize:2 green manure) which can be cut and spread in the inter space after 50 DAS (Nooli, et al., 2002). Though maize yields were not affected adversely the safflower greatly benefited from green manuring. Further, sunnhemp recorded significantly higher phytomass (11.38 t/ha), biomass production (2.02 t/ha) and, N accumulation (60.08 kg/ha) than *dhaincha* (37.87 kg/ha) and cowpea (37.57 kg/ha). Performance of maize intercropped with annual green manure species was near normal except in the years of stress and inadequate rainfall. The residual effect of legumes also had a considerable effect on succeeding chickpea particulaly with sunnhemp. Incorporation of sunnhemp also recorded significantly higher organic carbon content in soil after harvest of chickpea.

EFFICIENT CROPPING AND FARMING SYSTEMS

Selection of Efficient System

In addition to practical aspects of management, the major factor that will determine a farmers' choice is productivity. But, where different systems are made up of different crops, variety of options is available for comparison. For instance, yield comparisons could be made in a cereal – pulse – legume combination such as sorghum + pigeonpea, mung – sorghum, and maize – chickpea systems. This may not be meaningful in case of sorghum – safflower system involving a cereal – oilseed crop. Other possible comparisons could be nutritional output, biological efficiency (i.e. the efficiency with which systems utilize environmental resources), net total energy accumulated in the system, or economic assessment. The later approach has relevance in cash crops and in subsistence situation. Willey (1987) has given a very good account of productivity analysis of some cropping systems grown on a Vertisol at ICRISAT .

Among the sorghum + pigeonpea, mung – sorghum, maize – chickpea and sorghum – safflower, sorghum + pigeonpea has slightly lower net returns than maize – chickpea but because of lower input costs (mainly because of not to establish a second crop), it has greater rate of returns to inputs hence could be more attractive proposition. In contrast, sorghum – safflower has high costs (mainly because both crops have a high fertilizer requirement) and, therefore, a lower net return and lower rate of returns than the other two double cropping systems.

Border/Strip Planting to Evade Pests

In Indian chilli, the vast spectrum over 293 insect and mite species' debilitating the crop in the field as well as storage, enhanced pesticide usage with concomitant residue hazard often resulting in rejection of consignment. In this context, studies on barrier (different coarse grains) cropping on the performance of chilli and of leaf curl revealed that dry yield increased to the extent of 150 to 120 per cents in the leeward and windward sides of the barrier, respectively over the crop without barriers (Shivprasad et al., 2010). The leaf curl index (LCI) was lower in the chilli crop under barriers compared to no barrier (control plot) due to increased population of predators. Coccinelids and Chrysopids were more under maize barriers and spiders under sorghum barrier. Further, significantly higher dry pod yield was recorded with integrated N supp RPP (2 sprays of dimethoate @ 1.7 ml l^{-1} water + 2 sprays of dicofol @ 2.5 ml l^{-1} + carboryl @ 4 gl^{-1}) , due to reduced the leaf curl disease to the extent

Integrated Farming Systems

The integrated farming system (IFS) is 'an agriculture that is sustainable and efficiently productive and allows the welfare of man, animal and plant'. IFS is also an approach of obtaining high productivity with substantial fertilizer economy. It relies on organic recycling for maintaining soil productivity and livestock plays a key role in the system wholeness. The dairy and small ruminants (goat/sheep) are prominent. Because 85 % of Indian farmers and 98.4 % Raichur farmers practicing crop based cropping system research on IFS was initiated in Agricultural Research Station coming Falling under UAS, Raichur, in eighties and after the formation of the University the efforts were renewed both for rainfed and irrigated situations on the farms under RKVY, GoK project and under ICAR project, and on SC and ST farmers under SCP/TSP project and on 100 acres blocks under each RSK, through RKVY, IFS funding. Crossbred cows, shirohi, Jmnapari and barberi goats, Giriraj poultry, horticulture crops involving flowers, fruits, and vegetables, agricultural crops comprising commercial and food species, timber species on bunds, bio-digester, and vermicompost units formed predominant components of IFS unit.

The use of biochar as soil amendments is proposed as new approach for mitigating man induced climate change along with improving soil productivity. Although, the use of biochar in agriculture is not a newer phenomenon, in primitive time farmers were using it for enhancing the production of agricultural crops.

Charcoal is a stable solid rich in carbon content, and thus, can be used to lock carbon in the soil. Biochar is of increasing interest because of concerns about climate change caused by emissions of carbon dioxide (CO_2) and other greenhouse gases (GHG).

Adaptation and mitigation

Types of Adaptation Options in Agriculture with special reference to natural resource management

Agricultural adaptation option with special reference to natural resource management is the technological developments. The main types of adaptations are summarized in Table 1 with examples.

Table 1: Adaptations to climate change

A. Technological developments
Crop development
Develop new crop varieties, including hybrids, to increase the tolerance and suitability of plants to temperature, moisture and other relevant climatic conditions.
Weather and climate information systems
Develop early warning systems that provide daily weather predictions and seasonal forecasts.
Resource management innovations
Develop water management innovations, including irrigation, to address the risk of moisture deficiencies and increasing frequency of droughts. Develop farm-level resource management innovations to address the risk associated with changing temperature, moisture and other relevant climatic conditions.
B. Farm production practices
Farm production
Diversify crop types and varieties, including crop substitution, to address the environmental variations and economic risks associated with climate change. Diversify livestock types and varieties to address the environmental variations and economic risks associated with climate change. Change the intensification of production to address the environmental variations and economic risks associated with climate change.
Land Use
Change the location of crop and livestock production to address the environmental variations and economic risks associated with climate change. Use alternative fallow and tillage practices to address climate change-related moisture and nutrient deficiencies.
Land topography
Change land topography to address the moisture deficiencies associated with climate change and reduces the risk of farm land degradation.
Irrigation
Implement irrigation practices to address the moisture deficiencies associated with climate change and reduce the risk of income loss due to recurring drought.
Timing of operations
Change timing of farm operations to address the changing duration of growing seasons and associated changes in temperature and moisture.

C. Farm financial management
Crop insurance
Purchase crop insurance to reduce the risks of climate-related income loss.
Crop shares and futures
Invest in crop shares and futures to reduce the risks of climate-related income loss.

Mitigation Measures

There is an extensive list of technically possible options for mitigating emission in agriculture and land-use. Measures may be categorised as: reducing emissions via improved farming efficiency, including genetic improvement; displacing fossil fuel emissions via alternative energy sources; and enhancing the removal of atmospheric CO_2 via sequestration into soil and vegetation sinks. Some mitigation options, typically current best management practices, deliver improved farm profitability as well as lower emissions and thus might be adopted without government intervention beyond continued promotion/revision of benchmarking and related advisory information services.

Table 2: Mitigation measures affecting adaptation in agricultural systems

Mitigation measures	**Adaptation issues**	**Soil erosion control**	**Nutrient loss reduction**	**Soil and water conservation**	**Genetic diversity**	**Micro-climate modification**	**Land use change**
Catch crops		+	+				
Reduced tillage		+		+			
Residuemanagement		+		+			
Extensification							+
Fertilizer application			+				
Fertilizer type			+				
Rotation species		+	+		+		
Adding legumes		+	+		+		
Permanent crops		+	+		+		
Agro-forestry		+	+			+	

CONCLUSION

Our review study's findings related to thresholds in climate effects on crop yields need careful consideration by researchers and policy makers. On the policy side, it may be important to invest in new seed varieties that can better adjust to rainfall and temperature thresholds. There is also need for further research to explore the implications of adaptation responses such as adjustments in the sowing season. Such studies can be further improved by including additional factors such as the milk production, egg production, animal rearing and diversified agriculture.

REFERENCES

Aladkatti,Y. R., Response of stevia (*Stevia rebaudiana*Bertoni.)to irrigation schedule, planting geometry and nutrient levels. *Ph. D. Thesis* submitted to University of Agricultural Sciences, Dharwad, Karnataka.

Anonymous, 2012, Production potential of pigeonpea in *rabi* season under protective irrigation 2010-12. *Detailed Progressive Report of RKVY*, University of Agricultural Sciences, Raichur, Karnataka. pp 1-73.

Annonymus, 2015, Proceedings of. ZREAC and ZREFC 2014-15, University of Agricultural Sciences, Raichur, Karnataka, pp 1-223.

Anonymous, 2014, Progress report. Improving rural livelihood through innovative scaling up of science led participatory research for development, Progress report, International Maize and Wheat Improvement Centre, pp 1-38.

Arunachalam, N., 1996. Input management in dryland agriculture. In: Recent Advances in Weather Forecasting and Dryland Management(Ed. N. Balasubramaniam). Short training course, 10-23 April, 1996. Centre for advanced studies in agronomy. TNAU, Coimbatore, pp. 25-28.

Biradar, S. A., 2008, *In situ* green manuring of intercropped legumes on the performance of maize-chickpea/safflower cropping system under rainfed condition. *Ph.D Thesis*, submitted to University of Agricultural Sciences, Dharwad, pp 1-338.

Chndranath, C. T., , Investigations on nutrient management and planting geometry in companion cropping of sunflower (*Helianthus annuus*L.) and aswagandha (*Withaniasomnifera*Dunal.). *Ph. D. Thesis* submitted to University of Agricultural Sciences, Dharwad, Karnataka.

Das, D.K. and Hati, K.M. (2013) Impact of climate change and global warming on soil physical processes. In Souvenir of the 78th Annual Convention of Indian Society of Soil Science, October 23-26, 2013, Jodhpur. Pp. 37-43.

Dharmalingam, C. and Jegathambal, R., 1996. Seed hardening technology for rainfed crops.A case study with botanicals.In :*Recent Advances* in *weather Forecasting* and *Dryland*. *Management*.(Ed. N. Balasubramaniam) Short training course, 10-23 April 1996. Centre for Advanced studies in Agronomy, TNAU, Coimbatore, pp. 41-63.

Honnali, S. N. And Chittapur, B. M., 2013, Enhancing Bt Cotton (*Gossypium* spp.) productivity through transplanting in Upper Krishna Project (UKP) command area of Karnataka. Indian Journal of Agronomy, 58 (1):105-108.

IDNP, 2003, Final Report. Indo-Dutch Network Operational Research Project (IDNP) on Drainage and Water management for Salinity Control in Commands, pp 1-187.

Kirkham, D.D., Rolston. W. and Fritton, D. D., 1967, Gama radiation detection of water content in two dimensional evaporation experiments.Published by Inter. Atomic Energy Agency, Vienna, Austria, 1:3-16.

Kuchnur, P.. 2015, Performance of heat resilient CYMMIT maize hybrids in UKP and TBP commands (Personal communication).

Lobell, D.B., Bänziger, M., Magorokosho, C. and Vivek, B., 2011, Nonlinear heat effects on African maize as evidenced by historical yield trials. Nature Climate Change 1:42-45.

Mastiholi, A.B.,, Effect of spacing, time of harvest and npk levels on growth, yield and quality of medicinal coleus (*Coleus forfkohlii*briq.) under irrigated condition. *Ph. D. Thesis* submitted to University of Agricultural Sciences, Dharwad, Karnataka.

Naik, V. S., 2014, Development of cotton based integrated farming system models for irrigated ecosystem of north-east Karnataka. *Ph. D. Thesis*, submitted to University of Agricultural Sciences, Raichur, Karnataka, pp 1-213.

Nooli, S. S., Chittapur, B.M., Hiremath, S. M. And Chimmad, V.P., 2002, Effect of in situ green manuring of intercropped legumes in maize on the performance of succeeding safflower crop. J Oilseeds Res., 19(2):254.

Potdar, M. P., 2010, Spectral characterization, acreage and production estimation through remote sensing and management of pod borer (*Helicoverpaarmigera*) through polycropping in pigeonpea.*Ph.D. Thesis*, submitted to University of Agricultural Sciences, Dharwad, pp 1-273.

Prasannakumar, B. H., 2011, Agrotechniques to enhance productivity of sesame (*Sesamumindicum*L.) during *Kharif* and summer.*Ph.D. Thesis*, submitted to University of Agricultural Sciences, Dharwad, pp 1-444.

Prasannamkumar, B. H., Chittapur, B.M., Hiremath, S.M. and Malligawad, L. H., 2014, Enhancing productivity of summer sesame (*Sesamumindicum*) on paddy fallows through optimization of fertilizer, planting geometry and genotypes. Indian J. Agric. Sciences, 84 (6): 720-4.

Pyati, P., 2015, Performance of Bt cotton under nutrient omission situations in paddy lands of Kasabe camp of Raichur in TBP command (Personal communication).

Rajkumar, D. and Gurumurthy, S., 2008, Effect of plant density nutrient spray on the yield attributes and yield of direct sown and polybag seedling planted hybrid cotton. Agriculture Science Digest, 28 : 174-177.

Rathod, P. S., 2009, Performance of senna (*Cassia angustifolia*Vahl) in different cropping systems in northern dry zone of Karnataka. *Ph. D. Thesis* submitted to University of Agricultural Sciences, Dharwad, Karnataka.

Shivaprasad, M., Chittapur, B. M. And Hiremath, S. M., 2010, Effect of barrier crops on yield, incidence of leaf curl complex and population of predators in Byadagi chilli (*Capsicum annuum*L.). J. ent. Res. , 34 (4):325-332.

Shivaprasad, M., Chittapur, B. M., Mohankumar, H. D., and Patil, R.K., 2009, Effect of alternative nitrogen on the leaf curl complex and yield of chilli. J. Indian of Plant Protection, 37 (1&2):170-177.

Somanath, , Response of safedmasli (*Chlorophytumborivlianum*) to NPK and mulching in north-east transitional zone of Karnataka. *Ph. D. Thesis* submitted to University of Agricultural Sciences, Dharwad, Karnataka.

Surkod, V. S., 2015, Experience with sand mulching on crop performance and soil moisture dynamics on Verticinseptisols, Regional Research Station, Bijapur, Karnataka (Personal communication).

Sudha, K.N., 1999. Response of rainfed groundnut *(Arachishypogaea*L.) to sand mulching and organics in Verticinaceptisols.*M.Sc. (Agri.) Thesis* submitted to Univ. Agril. Sciences, Dharwad, India.

Vishwanath, 2015, AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture, Agriculrure Research Station ,Gangavati, Karnataka. Pp 1-4 (personal communication).

Unger, P.W., Stewart. B.A., Parr, J.F. and Singh, R.P., 1991. Crop residue management and tillage methods for conserving soil and water in semi-arid regions.*SoilTillage Research*, 20: 219-240.

Willey, R. W., 1987. Cropping systems for Drylands.In :*Challenges* in *Dryland Agriculture* - As *global Perspective. Proc. of* Int. conf. on dry land agric, Amarillo/Bushland. Texas. USA, August 15-19. P. 77-774.

Willey.R.W, Rao, M.R., Reddy. M.S. and Natarajan, M. 1982. Cropping systems with sorghum In: *Proceedings of Sorghum in the Eighties*. Hyderabad. India: ICRISAT. p. 477-490.

Yadahalli, G. S., 2008, Effect of physico-chemical modification of soil through set furrow amendments on crop productivity, soil fertility and water balance in Pearlmillet/sorghum based cropping systems. *Ph.D Thesis*, submitted to University of Agricultural Sciences, Dharwad, pp 1-338.