# "PERFORMANCE EVALUATION OF THE STRESS MANAGEMENT MEASURES UNDER IMPORTANT CROPPING SYSTEMS"

**DISSERTATION**

***submitted to***

*Marathwada Agricultural University*
*in partial fulfillment of the*
*requirement for the degree of*

**MASTER OF TECHNOLOGY**

**(Agril. Engineering)**



**IN**

**SOIL AND WATER CONSERVATION ENGINEERING**

**By**

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**B. Tech (Agril. Engg.)**



**UNDER THE GUIDANCE OF**

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**MAY - 2010**

# DEDICATION

DEDICATED

TO

OUR BELOVED

PARENTS,

SISTER & BROTHERS

# *CANDIDATE'S DECLARATION*

***I, Hereby Declare that the dissertation or part there of has not been submitted by me to any other University or institution for a degree or diploma.***

**Place : Parbhani**

**Date : 01/ 10 /2010**

**( MS. Garad D.E.)**

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## CERTIFICATE-I

This is to certify that the dissertation entitled **"PERFORMANCE EVALUATION OF THE STRESS MANAGEMENT MEASURES UNDER IMPORTANT CROPPING SYSTEMS"** submitted to Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the award of the degree of **Master of Technology (Agril. Engineering**) in **SOIL AND WATER CONSERVATION ENGINEERING** embodied the results of the bonafied study carried by **Ms. GARAD DIPALI EKNATH** under my guidance and supervision. I also certify that the dissertation has not previously submitted by her for the award of Degree or Diploma of any University or Institute.

**Place :** Parbhani.
**Date :** 01/ 10/2010

Bhuibhar
**Prof. B.W. Bhuibhar**
(Research Guide)

# CERTIFICATE-II

This is to certify that the dissertation entitled **"PERFORMANCE EVALUATION OF THE STRESS MANAGEMENT MEASURES UNDER IMPORTANT CROPPING SYSTEMS"** submitted by **Ms. GARAD DIPALI EKNATH** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF TECHNOLOGY (Agril. Engg.)** in the subject of **Soil & Water Conservation Engineering** has been approved by the students advisory committee after oral examination in collaboration with external examiner.

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**Place : Parbhani.** ( Garad D.E.)

**Date : 01/ 10 /2010**

# ABBREVIATIONS

| | | |
|---|---|---|
| Agril | : | Agricultural |
| C.A.E.T. | : | College of Agricultural Engineering & Technology |
| Dept. | : | Department |
| fig. | : | Figure |
| ha | : | Hectare |
| M.A.U. | : | Marathwada Agricultural University |
| cm | : | Centimeter |
| mm | : | millimeter |
| % | : | Percent |
| Sr.No. | : | Serial number |
| R.B.D. | : | Randomized block design |
| S.E. | : | Standard error |
| SCEY | : | Seed cotton equivalent yield |
| GMR | : | Gross monetary returns |
| NMR | : | Net monetary returns |
| C.V. | : | Cumulative variance |
| Viz | : | namely |
| J | : | Journal |
| et. al. | : | and others |
| E.R. | : | Effective rainfall |
| mm/ha | : | millimeter per hectare |
| Var | : | Variety |
| Max | : | Maximum |
| Min | : | Minimum |
| met | : | meteorological |
| No. | : | Number |
| Rs. | : | Rupees |
| S.L.R. | : | Stage level recorder |
| M.C. | : | Moisture content |
| e.g. | : | example |
| etc | : | extra |
| S.W.C.E. | : | Soil and Water Conservation Engineering |
| KCl | : | Potassium chloride |
| MW | : | Meteorological week |
| AICRP | : | All India Co-ordinated Research Project |
| Res. | : | Research |

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# INTRODUCTION

**CHAPTER-I**

# INTRODUCTION

India is an agricultural based country. Agriculture sector has a dominating role in Indian economy. Major source of water for agriculture in the country is the rainfall, received from Southwest monsoon during the period from June to Sept. Water is an important natural resource, essential for the life on earth surface. About 75% area of earth is covered with water. Out of total water available, 97% of water is present in ocean and seas as a saline water. Remaining 3% is freshwater. Out of total freshwater, 75% water is present as polar ice and ice glaciers and unavailable for use, 24% of the water is present in sub soil as ground water, 0.3% available in the lake and 0.03% available in rivers (Anonymous,2001). Nearly 70% of water withdrawl from rivers, lakes and underground aquifer is used for the agriculture. Day by day increasing population will put the pressure on demand of water in agriculture to meet the food requirement.

Soils are unique consequence of the life on the earth. Soil is the storehouse of mineral nutrients for most of living organisms on the land. Soils have important direct and indirect impact on agricultural productivity, water quality and global climate. Soil make it possible for the plants to grow by mediating biological, chemical and physical processes that supply the plants with nutrients, water and other elements. The soil which interacts with landscape features and plant cover is a key element in regulating and partitioning water flow through the environment.

Land and water are vital natural resources and also the basic inputs in agriculture. Bennett stated that 'Soil without water is desert and water without soil is useless'. Growing world population and increasing standard of living are placing tremendous pressure on these resources, because the land and water resources are finite. Their optimal management without adverse environmental consequences is necessary, if human survival is to be assured and development is to be sustained.

Average annual rainfall in India is 119 cm, which accounts to 400 m ha-m, out of which 70 m ha-m is evaporated and from the remaining 330 m ha-m, 115 m ha-m water goes as runoff and only 215 m ha-m water are infiltrated from that 15 m ha-m water is stored in upper substrata and only 200 m ha-m goes as ground water (Bhale,2009). Major losses are evaporation, transpiration and percolation.

The area under rainfed farming is 70 m ha. and it contributes about 45% of the country's food production. This contribution from drylands to India's total food production is by no means insignificant. More than 70% of raw materials, needed for industries, oilseeds and cotton are obtained from drylands. The problem of increasing food production is growing into stupendous challenge despite many highly developed techniques arising out of research conducted over the world, in general and India in particular. The challenge of increasing agricultural production is an external one, the required production level has to be achieved year after year. Initially at sowing moisture content is greater and periodically it goes on decreasing which referred as moisture depletion. Inadequate and ill distributed rainfall limit the crop to attain their full productivity levels (Singh,2000). Dryland agriculture is characterized by a higher frequency of erratic and uneven distribution of the rainfall in time and space. The rainfall is most uneven and varies considerably from region to region and year to year. This often causes dryspells of even 2 weeks or more resulting in the moisture stress conditions. Moisture stress is a common recurring phenomenon in rainfed agriculture. The term soil moisture stress is qualitative expression of the soil moisture below optimum level, from point of crop growth and it adversely affects crop growth. Adequate soil moisture is key to successful crop production. Water stress caused by drought, can have major impacts on the plant growth and development and will result in lower yield and possible crop failure.

Sorghum and cotton are dominant crops in Maharashtra state. In Marathwada region of the state, sorghum and cotton based cropping systems i.e. sorghum + pigeonpea, cotton + soybean, soybean + pigeonpea and green gram- rabi sorghum are adopted by small and medium farmers. During prolonged dryspells, there will be acute water stress for crop growth. Water stress may coincide with the critical growth stages of crop, resulting in potential or total crop failure. The outcome of 'Global Warming' has exaggerated the situation, leading to increase in events of drought and water scarcity. The residual soil moisture should be effectively and judiciously utilized for crop growth so that adverse effect of water stress is minimized and will not reflect in yield decrease.

The management of rain water in the rainfed areas has been crucial with particular reference to conservation of soil moisture to the maximum possible extent, through insitu rainwater and soil moisture conservation and its efficient management, which takes into account realities of relationship between land-water-plant and cultivation practices. There are plenty of techniques and measures to control the residual soil moisture loss and increase the water use efficiency. Vegetative mulching not only controls soil temperature and restricts soil evaporation but it also minimizes soil and water loss. Transpiration losses can be controlled using certain chemicals by closure of plant stomata or by reducing heat load on plants. These control measures are definitely helpful in management of water stress situation during dryspell and thus minimizing the adverse effect of water stress on crop growth, to some extent. Certain measures if found efficient and cost effective in dry spell management can be adopted to achieve sustainable production during critical crop management.

Considering the importance of water stress management in crop production, the present project was planned with the following specific objectives.

1) To study performance and feasibility of stress management measures during dryspell under important intercropping systems.
2) To study the effect of stress management measures on crop yield, soil and water loss, soil moisture use and moisture use efficiency, under important intercropping systems.

# REVIEW
# OF
# LITERATURE

**CHAPTER-II**

# REVIEW OF LITERATURE

The chapter deals with the review of literature related to the present investigation. The research conducted was reviewed and presented under the following subheads.

## 2.1 Stress management measures, runoff and soil loss

Clinton Shock and Herb Futter (1988) studied the effect of straw mulch and irrigation rate on soil loss and runoff. Soil loss at a rate of 18 ton/acre per irrigation occurred with water application rates of 4 gallons/min per furrow. At four gallons/min, 790 lbs/acre of straw mulch reduced soil loss to less than 3 tons/acre on first irrigation, but soil loss rose to 40.5 ton/acre on second irrigation. Soil loss was reduced to 2.8 tons/acre by use of 790 lbs/acre of wheat straw mulch.

Bentlur and Plaut (1989) studied the effect of cotton canopy and drying on runoff with lateral move. The percentage of surface runoff from the silt loam and vertisol under straw mulch conditions were 22% and 0% versus 53% and 39% under unmulched conditions respectively. These were mainly due to crust formation at the soil surface.

Omoro and Nair (1993) studied the effect of adding leaf mulches of cassia siamea and Gliricidia sepium on the rate of the soil and water runoff from crop field during two cropping seasons in an alfisol under semi arid conditions at machakos, Kenya.Two rates of mulch of each species (2.24 t and 4.48 t on dry basis per hectare) and no mulch control constituted 7 treatments over two seasons, the cumulative soil losses from plots mulched with cassia gliridicia and grevillea were 11%,57%,81% respectively lower than that of control plot. Similarly, water runoff losses from cassia, gliricidia and gevillea mulch plots were 28%, 48%, 58% respectively.

John and JR (1993) studied the effects of 4 rates of straw mulch on runoff, infiltration and erosion at a site in northeastern oregon. The data suggested that smaller amounts of mulch (<25%) are of little value in erosion control and that a threshold value below which surface cover is ineffective may exist. Straw mulch densities of 0, 25, 50, 75 and 100% cover were tested using rainfall applied to 3.32 $m^2$ plots located on 16% North facing slope.

Umrit and Koon (2001) worked out sustainability of sugarcane production in mauritius as indicated by soil erosion and agrochemical movement. They reported that in a silty clay loam having a 5% slope and receiving an annual rainfall exceeding 3000 mm less than 7% of annual rainfall was dissipated as surface and shallow subsurface (<90 cm) runoff with ha/yr. Due to rapid dissipation of the agrochemicals, their offsite movement was low, being less than 0.25% of the herbicides applied, 3 kg N/ha per year and 1 kg P/ha per year. This insignificant movement of soil agrochemicals was influenced more by rainfall intensity than by mulching or tillage.

Rice and Haperman (2001) studied to quantify off site movement of soil and pesticides with runoff from tomato plots containing polythene and vegetative mulch, hairy vetch. Side by side field plots were instrumented with automated flow meters and samplers to measures and collect runoff which was filtered and analysed to determine soil and pesticide loss. Seasonal losses of 2 to 4 times more water and atleast 3 times as much sediment were observed from plots with polythene mulch 55.4 to 146 $Lm^{-2}$ and 247 to 535 $gm^{-2}$ respectively. Versus plots with hairy vetch residue, 13.7 to 75.7 $Lm^{-1}$ and 32.8 to 118 $gm^{-2}$ respectively (vegetative mulch).

Milne and Eleanor (2001) studied the soil conservation in relation to maize productivity. The aim was to test hypothesis that contour cultivation and contour cultivation plus straw mulch decrease runoff and soil erosion rates on sloping land. Three treatments control, contour cultivation, contour cultivation + straw mulch with three different slope angles (I3$^0$, II10$^0$, III 27$^0$). Contour cultivation + straw mulch having 99.4% less erosion than control on $\leq$ 10 slopes, contour cultivation alone is suitable soil conservation measure. However, use of straw mulch would benefit soil moisture and nutrient status. On $\geq$ 27 slope, it is recommended that contour cultivation measure to ensure maximum soil conservation.

Rickson and Godwin (2002) studied the effect of tillage induced roughness and surface mulching on soil loss and runoff in a sandy loam soil with a simulated subsurface pan. Dried wheat straw was applied at a rate of 3 tonnes / ha in mulched treatments. In soil with a pan, increased tillage induced roughness led to a 50% reduction in soil loss compared with harrowed, bare soil. Similarly, application of surface mulch to the harrowed soil led to a 65% reduction in soil loss compared with the unmulched equivalent combining a rough surface with surface mulch led to 85% reduction in a soil loss from the soil with a pan compared with harrowed bare treatment.

Chow and Loro (2002) studied on hay mulching to reduce runoff and soil loss under intensive potato production. They reported effectiveness of applying various rates of hay mulch following potato harvest in reducing runoff and soil loss. Hay mulching at rates of 2.25, 4.50 and 9.00 t/ha conserved on average 13, 18 and 28 mm of June to September precipitation respectively. Mean annual soil losses were reduced to 14, 7, 2% of control by 2.25, 4.50, 9.00 t/ha treatments respectively on 11% slope and to 43 and 24% of control on 2.25 and 4.50 t/ha treatments respectively on 8% slope. They also reported that levels of nutrient losses from the controls were low to begin with 2.0, 0.4, 2.8, 10.9 and 1.6 kg/ha of $NO_3$-N and available P,K, Ca and irrigation respectively. Mulching at rates as low as 2.25 t/ha reduced nutrient losses of $NO_3$-N and available P,K,Ca and Mg to 26, 18, 28, 20 and 24% of control respectively on 8% slope. Hay mulching was found to be effective tool for reducing soil loss while maintaining and in some cases enhancing potato yield.

Osunbitan (2007) studied grass mulching effect on infiltration, surface runoff and soil loss. Mulching the soil surface with a layer of plant residue is an effective method of conserving water and soil because it reduces surface runoff, increase infiltration of water into soil and retard soil erosion. The results with elephant grass compared with results from experiments using rice straw. Runoff and soil loss decreased with amount of mulch used increased with slope, surface runoff infiltration soil loss had high correlations (R=0.90, 0.89, 0.86 respectively).

**2.2 Stress management measures and productivity.**

Agarwal (1977) studied the effect of N rates and antitranspirants on growth and yield barley under dryland conditions. N application upto 30 kg/ha significantly increased the grain yield. He stated that reflective antitranspirant kaoline conserved moisture in the soil by reducing transpiration loss of water by reflecting a part of solar radiation incident on leaf surface after it's application, thus making limited soil moisture available for better growth over a longer period. Kaoline gave 18.8% more grain yield than control treatment.

Rajat (1978) studied the effect of reflectant material kaoline on the yield of dryland wheat variety 'C 306'. He reported that the reduction in transpiration after coating of foliage with kaoline appears to have conserved some moisture at the non critical vegetative phase of wheat. The moisture so conserved was available at the more critical stages of flowering and grain filling. Kaoline was thus able to bring about a better distribution of the restricted soil moisture between vegetative and reproductive phases, leading to better water use efficiency.

Gidda (1981) worked out the effect of tillage practices and antitranspirant on leaf water potential, growth and yield of rainfed cotton. He stated that application of kaoline significantly increased average cotton yield by 2.37 q/ha over no kaoline spray treatment. This was due to the white colour of kaoline coated leaf, which reflected the incident light more strongly and maintained plant water balance.

Pawar (1982) studied the effects of reflectant on yield, relative turgidity of leaf and albedo of canopy of summer mung and cowpeas. He also reported that application of one spray of 10% kaoline at 35$^{th}$ day after sowing was more beneficial to mung and cowpea crop. The maximum benefit cost ratio i.e. 3.54 and 3.45 were recorded with one spray at 35$^{th}$ day to mung and cowpea respectively.

Saraf (1984) worked out response of spring/summer green gram to irrigation and antitranspirants with and without mulching. Kaoline and PMA were sprayed a month after sowing. Kaoline spray increased the number of pods/plant and grain yield significantly over no kaoline spray.

Mungse and Bhapkar (1984) studied the effects of antitranspirant and soil moisture regimes on transpiration and drymatter production of the potted sunflower. Different antitranspant sprays i.e. PMA, PMA + kaoline, kaoline, power oil and no spray water use efficiency was higher with low soil moisture regime and antitranspirants sprays.

Mandal and Ghosh (1984) studied the residual effect of organic mulches on the succeeding crops. They reported that the three treatments of mulch, husk mulch incorporated plots recorded the highest grain and straw yields. When yield was higher, grain to straw ratio was also higher. Higher grain yield was associated with significantly higher number of matured panicles/m$^2$ and higher number of filled grains/panicle. Height of plant differed significantly with different treatments.

Kaushik and Gautam (1984) studied to develop a suitable management practice to capacitate the plants to escape the adverse effects of short drought occurring during the growing period of pearlmillet. The treatments consisted of three transpiration suppressant spray T1 (borax 0.2%), T2-atrazine (100 ppm), T3-Kaoline (6%) and T4-dry surface mulch (straw mulch at 5 t/ha). Grain yield by T4 treatment higher as compared to T1,T2, T3. Grain yield obtained by T4 as 23 q/ha, moisture conservation brought about by using straw mulch.

Mandal and Ghosh (1984) studied the effect of mulches on the growth and yield of sesame. They used three mulch treatments i.e. no mulch, 7.5 t/ha of paddy husk and 7.5 t/ha of paddy straw. They reported that mulch was applied when plants attained 5 cm height, paddy straw was more efficient in reduction of soil temperature and also reduced soil water loss through evaporation which resulted in more available soil moisture which helped in improving the yield total consumptive use was lowest in straw mulching than control i.e. 247.01 mm and 303.41 mm. The increased water use efficiency with mulching was 4.42 kg/mm and decreased with control was 2.34 kg/mm.

Singh and Saraf (1984) studied to find out possibility of reducing the consumptive use of water through use of mulches grain yield observed in straw mulch, soil mulch and no mulch was 5.0 q/ha, 4.29 q/ha and 3.9 q/ha respectively. They reported that efficient soil moisture utilization and higher productivity by straw mulch observed. straw mulch increased the number of pods/plant i.e. 13.3 and no mulch no. of pods/ plant i.e. 6.3.

Girase (1985) studied the effects of defoliation, mulching and antitranspirant on yield of sugarcane. He reported that the application of kaoline 10% at an interval of 20 days upto the end of May gave additional yield of 5.5 t/ha with a very small investment on kaoline (Rs. 125/ha) an additional income of about Rs. 1325/ha could be obtained. Defoliation upto 10 months not only produced an additional yield of 6.31 t/ha but also gave an additional benefit of green fodder in the form of green leaves.

Joshi and Patel (1987) worked out the use of mulch and anti transpirant on groundnut under water stressed and non stressed conditions. They reported that mulching and use of antitranspirant considered as water saving techniques. They reported that by preventing water loss through evapotranspiration and thus, maintaining favourable water balance in the soil and plant it was possible to increase the yield of groundnut by mulch and kaoline coating to the tune of 25% over no mulch. The reduction in the weed dry matter at harvest ranged between 31 and 35% for straw mulch and straw mulch + kaoline spray. Groundnut crop grown with straw mulch or straw mulch + kaoline accounted for the saving of 10 and 8% of water when compared to 'no mulch' control.

Dhoble and Shelke (1987) studied the beneficial effects of different types of mulches in moisture conservation. They reported that artificial mulching (i.e. one weeding and two hoeing) was superior over natural mulching (i.e. only hand uprooting of weeds) by recording 15% additional monetary returns. This may be attributed to more moisture availability in the soil for the crop due to artificial mulching. Artificial mulching was proved beneficial over natural mulching by recording higher moisture use efficiency of 24.30 Rs/mm/ha which may be attributed to the advantage of intercultivation in reducing evaporation losses.

Chavan and Thorat (1987) studied the effect of different irrigation schedules and mulches on yield of sorghum. They reported that application of grass and paddy straw mulches produced more grain yield over unmulched treatment. Irrigation scheduled at 1.0 IW/CPE with paddy straw mulch recorded more grain yield (28.37 q/ha) over irrigations scheduled at 0.6 and 1.0 IW/CPE with no mulch application of mulches increased the water use efficiency and it was highest with the application of paddy straw mulch.

Lomte and Khuspe (1987) studied the effect of plant densities, levels of antitranspirant on yield of summer groundnut. The plant density of 1.77 lakh plants/ha recorded higher yield (37.08 q/ha) over other densities (2.66, 2.22, 1.48 lakh plants/ha). Kaoline spray (3%) as antitranspirant at 45 and 75 days after sowing had no influence on pod yield.

Ingawale (1988) conducted a field trial during summer, 1985 to study the effect of levels of irrigation, mulch and antitranspirants on the yield of greengram. Kaoline was sprayed at concentration of 6%. He reported that application of grass mulch + kaoline spray increased grain yield over kaoline spray alone and control. The mulch and antitranspirant, the highest net profit of Rs. 2833.82/ha was obtained farm unmulched plots (control) followed by kaoline spray, mulch and mulch + kaoline spray.

Sadasivam and Chandrababu (1990) studied the effect of potassium nutrition on growth and yield of greengram. They told that K application increased transpiration and decreased stomatal resistance and leaf water potential, vigna radiata Cv. $CO_3$ gave and 50.3, 53.8,49.7 and 61.8 g DM yield/plant and 809,833,870 and 890 kg seed/ha with no K, 25 kg $K_2O$/ha, 1% KCl spray and 1% $K_2SO_4$ spray at flowering respectively.

Kadbane (1998) worked out the effect of kaoline spray on transpiration rate, leaf temperature and RLWC (%) of mungbean. He reported that grain yield increased in all the kaoline spray treatments compared to without spray with 15 days irrigation interval. The highest increase of 53.1% was obtained with application of three kaoline sprays at 15, 30 and 45 DAS, followed by two sprays at 30 and 45 DAS (34.1%).

Venkataraman and Mohandas (2000) worked to determine the application of KCL spray 30 days after sowing improved the plant water status by reducing the leaf temperature and transpiration rate under delayed submergence. Basal application of N, superphosphate enriched FYM and potash along with seed and foliar treatment of KCL increased chlorophyll content (4.45 mg/g), net photosynthetic rate, photosynthetic efficiency of crop. It also increased yield significantly (to 5.51 t/ha) by 8.0% compared with other treatments.

Pattar and Itnal (2001) studied agronomic management of transplanted rice under late planted conditions. An experiment was conducted in Dharwad, Karnataka, India, during kharif 1996 and 1997. Eight treatments i.e. closer planting (15x10 cm), 2% urea spray, 1% diammonium phosphate (DAP) spray, 1% KCL spray, 50 PPM NAA spray, 50 PPM triacontanol spray and planting of 4-5 seedlings per hill, were compared with planting of 2-3 seedlings per hill at 20x10 cm spacing as control. The number of grains per panicle were significant higher in crops sprayed with 2% urea (82.2), followed by 1% KCL (79.4) and triacontanol spray (76.7).

Rangaraju and Kavimani (2001) studied the influence of potassium and irrigation regimes on sheath moisture, physiological parameters and cane yield. K was applied at 112 kg/ha in 3 equal splits at 30, 60 and 90 days after planting (DAP), (K1) at 56 kg/ha at 30 DAP and 56 kg/ha at 60,90 and 120 DAP ($K_2$); 56 kg/ha at 30 DAP and 84 kg/ha at 60, 90 and 120 kg/ha ($K_3$); 56 kg/ha at 30 DAP and 112 kg/ha around 60, 90 and 120 DAP ($K_4$), $K_1$+2.5% KCL spray at 45, 75 and 105 DAP ($k_5$) and control ($K_6$) $K_5$ resulted in higher dry matter production and leaf area index during early drought.

Senthivel (2001) worked out with cotton Cv. SVPR 2 during the winter season of 1993-94 in sriviliputhur, Tamil Nadu, India. The foliar treatments were control, water spray, 2% DAP spray, 1% KCL spray, 0.5% humic acid spray, 1% humic acid spray, 2% DAP + 1% KCL spray, DAP + 0.5% humic acid spray 2% DAP + 1% humic acid spray,1% KCL + 0.5% humic acid spray and topping at $15^{th}$ node. Foliar spray of humic acid either alone or in combination with 2% DAP or 1% KCL had effect on growth and yield attributes. Application of 1% KCL + 1% humic acid (1267 kg/ha) recorded significantly highest cotton yield.

Marimutha (2002) studied the water stress management for young coffee plantation. An experiment was conducted at Kodagu, Tamil Nadu, India in 1988-89 and 1989-90 to study the efficacy of irrigation interval (pot irrigation once in two, four, six weeks at 14 lit/plant) and water stress mitigation practice(control,urea and kcl spray, mulch, mulch+urea

+kcl) in reducing water stress and improving the growth of the crop. Reducing the interval of irrigation gave better plant water status and leaf water potential. Among the various stress management practices mulch alone or in combination with urea + KCL spray significantly improved plant water status and growth parameters.

Chandrasekhar (2003) worked for maximizing the yield of mung bean by foliar application of growth regulating chemicals and nutrients. The study was revealed that foliar application of growth regulating chemicals and nutrients in combination of 100 PPM salicylic acid 2% DAP, 1% KCL and 40 PPM of NAA had given higher grain yield in greengram under the irrigated conditions.

Park Mooyong and Kim Jeomkuk (2004) studied on leaf and bud responses to foliar spray of saline solution in apple, pear, peach and grape. spraying of 1%,KCL did not defoliate all fruits species tested but complete defoliation occured upon spraying 3%KCL in apple and peach trees. pear and grape showed higher defoliation rates with increasing KCL concentration. The responses of apple to Nacl spray showed similar pattern to that of KCL spray.

Anitha Aravazhi (2005) studied the effect of foliar spray of nutrients and plant growth regulators (PGRS) for yield maximization in blackgram. The treatments include foliar spray of 2% DAP, 0.2% boric acid, 0.5% FeSO4, 0.5% ZnSo4, 0.5% sodium molybdate, 2% urea, 0.1% humic acid 1% KCL, salicylic acid 100 PPM, Brassinolide 0.1 PPM and humic acid 20 kg basal application. Investigation revealed that the foliar spray of plant growth regulators and chemicals were able to influence the physiological, biochemical and yield components of the crop. Foliar spray of 2% urea was found to be most effective treatment followed by KCL 1% along with soil application of humic acid @ 20 kg/ha (926.2 kg/ha).

Dass and Paikaray (2006) worked to find out most suitable planting technique and alternate mulch materials in rainfed ginger. Among mulches paddy straw, retained higher soil moisture but yield wise gliricidia mulch with rhizome yield of 72.33 q/ha proved significantly superior to paddy straw (67.33 q/ha) and lantana (64.86 q/ha). Average net returns (Rs. 13035/ha) and B:C ratio (1.76) were also highest with Gliricidia mulch, highest rainfall water use efficiency was against observed with Gliricidia mulch (7.15 kg/ha/mm).

Sarnaik and Annu Verma (2006) conducted experiment at the farmers field on farm trial during 2001-02 in village Bhatagaon at Raipur district of Chattisgarh state locally available materials like paddy straw ($M_1$), dry grass ($M_2$), Palash leaves ($M_3$) along with plastic mulch ($M_4$) were used as mulching material in this study results indicated that treatment in which paddy straw was used as mulch gives maximum average plant height (84.40 cm) and no. of leaves (10.32) as compared to other treatments. In case of yield of turmeric also, the paddy straw mulch gave maximum yield (169.33 q/ha) followed by mulching with dry grass (131.33 q./ha).

Dutta (2006) studied the effect of planting method and mulch on summer groundnut. The results indicated that growth, yield and yield components of groundnut were increased due to polythene film (7 micron) mulching followed by rice straw mulching. Application of polythene mulch or rice straw mulch decreased depletion of soil moisture due to loss evaporation resulting in better availability of the moisture which is turn increased availability of plant nutrients in soil and their uptake by plant led to produce increased yield of the crop.

Promod and Sanjay (2006) studied the effects of irrigation regimes, mulches and antitranspirant on yield and water requirements of summer groundnut. The results indicated that total consumptive use of water was higher with WUE (4.66 kg/ha/mm) when irrigation scheduled at 75 mm CPE (736 mm) on an average ET losses reduced to extent of 25.68, 13.99 and 3.94% due to use of plastic film, sugarcane trash @ 5 t/ha and kaoline 8% spray respectively the WUE (6.95 kg/ha/mm) was maximum with use of plastic film + kaoline 8% spray and was minimum with control treatment (3.58 kg/ha/mm). Total CU of water minimum due to application of plastic film + kaoline 8%, spray this might be due to reduced ET loss from soil surface and transpiration losses from plant canopy.

Singh and Das (2007) studied the effect of water deficit and N levels on yield, N-uptake and nutrient balance in rice. The results revealed that maximum N uptake (36.99 and 42.66 kg/ha) by grain was obtained with 'So' moisture regime. Higher level of nitrogen showed maximum grain (43.43, 49.87) straw (35.18, 40.88) and total N-uptake (78.60, 90.75 kg/ha) than respective lower levels of N during 2000 and 2001 respectively. This was might be due to higher amount of biomass production with higher N levels, K balance was recorded –ve during both year this might be due to higher K removal by crop than that quantity added and might also be due to it's luxury consumption from soil reserves.

Pawar and Jadhav (2008) studied the moisture conservation techniques on growth and yield of summer groundnut, sugarcane trash mulch, wheat straw mulch, black plastic mulch, transparent plastic mulch were used. The results showed % increase soil moisture content over control was maximum in sugarcane trash mulch (13.56%) followed by black plastic mulch (12.34%), transparent plastic mulch (10.34%) maximum crop yields was observed in transparent plastic mulch (24.87 q/ha) followed by black plastic mulch 922.73 q/ha), sugarcane trash mulch (21.42 q/ha), wheat straw (21.42 q/ha) and control (10.78 q/ha).

Singh and Menhi Lal (2008) studied the effect of planting method and drought management technique on growth, yield and quality of spring planted sugarcane with limited irrigations on clay loam soil at Lucknow. The drought management treatment involving lime soaking of setts + farm yard manure (FYM) in furrow + trash mulch at 60 days after planting (DAP) + Kcl and Urea spray significantly improved the cane productivity its quality. The treatment consisting of ring pit planting method with sett soaked in saturated lime water + FYM + trash mulching + Kcl and urea spray fetched the highest net profit (Rs. 62791/ha).

Pandey and Vishal nath (2008) studied to assess the effect of different types of organic mulches on growth, yield and soil moisture in turmeric grown as inter crop in mango orchard. Five treatments i.e. paddy straw mulch (1 kg/m$^2$), paddy straw mulch (0.5 kg/m$^2$), local grass mulch (1 kg/m$^2$), local grass mulch (0.5 kg/m$^2$) and control the result indicated that the soil moisture content was higher during rhizome formation, development and maturation stage in plots where paddy straw applied @ 1 kg/m$^2$ (1 t/ha). An average maximum fruit yield of mango (5.5 t/ha) was recorded in control plots which was as per with other treatments.

### 2.3 Stress management measures and moisture use

Singh (1984) worked out water consumption and economics of wheat production influenced by transpiration suppressants under drylands. He reported that wheat with application of kaoline and CCC consumed water economically and saved about 36.0 and 15.0 mm water against 218 mm used by untreated control. Kaoline was observed to be more effective in reducing rate of moisture use net returns were high from these treatments, kaoline increased net profit by 30% and CCC by 50% over control.

Khade and Patil (1989) worked out the effects of irrigation schedules and antitranspirant on yield of sunflower. Kaoline (6%) spray was applied as antitranspirant 20, 40 and 60 days after sowing, grain yield without kaoline was 1.15, 1.03, 0.90, 0.73 t/ha when cumulative pan evaporation was 40, 60, 80 or 100 mm respectively, corresponding yields with kaoline were 1.32, 1.12, 0.94 and 0.83. Water use efficiency without kaoline was 1.92, 2.46, 2.51 and 2.44 for 40, 60, 80, 100 mm respectively. Corresponding values with kaoline were 2.20, 2.66, 2.60 and 2.78.

Zaffaroni and Schneiter (1989) studied water use efficiency and light interception of semidwarf and standard height sunflower hybrids grown under various row spacing. Soil water depletion was greater under solid sowing. Total water use and WUE were not statistically different between, hybrids or among row arrangements in combined analysis. WUE was higher for SD hybrid (4.69 kg/ha per mm) as a result of decreased yield in 50 hybrid. Energy use efficiency significantly increased from 0.93 to 1.33% as plant population increased.

Kalane and Sagare (1990) studied moisture use pattern and yield of hybrid sorghum under different moisture conservation practices in vertic ustochrepts. They used a) vertical mulch (trenches 30 cm wide and 30 cm deep filled with Jowar (sorghum) stubbles, b) sowing across the slope and c) sowing along slope (control). Treatments a), b) c) gave grain yields of 2.53, 1.84 and 1.55 t/ha and showed water use efficiency of 6.55, 6.69 and 5.21 kg grains/ mm per ha, respectively.

Kaushik and Gautam (1991) worked out the effects of sowing on a flat seed bed, in ridges and furrows or in bunded seedbed, 3 moisture conservation practices (untreated, rice straw mulch or kaoline spray) and plant densities of 100000, 150000 or 200000 plants/ha on yield and water use efficiency of pearlmillet. Straw mulch and kaoline spray increased grain yield by 0.42 and 0.22 t/ha and water use efficiency by 2.46 and 1.28 kg grain/ha per mm, respectively compared with untreated controls yield and water use efficiency increased with increase in plant density.

Singh and Kaul (1993) studied the water relations and moisture use efficiency of summer greengram as influenced by irrigation and cycocel application four irrigations produced 1.09 t seed/ha water use efficiency was lowest with 9 irrigation and highest with 1 or 4 irrigation mean yield was 0.82 t/ha without cycocel and 0.85-0.87 t with foliar sprays of 100 or 200 ppm cycocel at flower initiation cycocel slightly increased water use efficiency.

Yadav and Suraj (1994) worked out yield and moisture use efficiency of mustard in relation to sowing date, variety and spacing. In

1987-89 at Kanpur, UP, brassica juncea Cv. Vardan, Rohini, Varuna and Vaibhav were sown on 5,15 or 25 Oct at 45 x 10 or 20 cm spacings. Seed yield, water use and water use efficiency decreased with delay in sowing date and with increase in plant spacing and were highest in Cv. Vaibhav.

Joseph and Varma (1994) studied on increasing moisture use efficiency using 'Jalshakti' in chickpea under rainfed conditions. Mean seed yield was also increased by soil incorporation or seed coating with jalshakti water use efficiency and seed yield increased with increasing P rate (15-45 kg $P_2O_5$/ha) but were little affected by 5 rate (20 or 40 kg/ha).

Saxena and Singh (1995) studied the effect of irrigation, mulch and nitrogen on yield and composition of Japanese mint oil. They conducted trial on silty clay loam. Soil, plants received 50 mm of irrigation at different frequencies were mulched with sugarcane trash at 0 or 5 t/ha and received N at 0, 50, 100 or 150 kg/ha. Soil moisture extraction was highest between soil depths of 15 and 30 cm consumptive use, water use efficiency and moisture use rate were higher under mulch application, reflecting higher availability of moisture in the soil profile under this condition.

Gupta and Tyagi (1995) worked out the uses of antitranspirants in dryland farming. Water relations in plants are discussed in relation to water use efficiency, moisture conservation and importance of ionic balance in water uptake and loss. The use of antitranspirants in increasing the survival of transplants and cut flowers along with use in controlling disease.

Ghodpage and Kalane (1998) studied the effect of mulching on moisture use and yield of safflower on swell-shink soil. Bhima was mulched with glyricidia leaves, wheat straw or dry grass or plots were hoed 3 times. Grain and straw yields and water use efficiency were higher with mulching or hoeing than in controls. Wheat straw gave highest yield, with lowest water use and highest water use efficiency.

Singh and Dwivedi (2002) studied the effect of Nal mulch and lindane insecticide on soil moisture use, growth and yield of wheat. Results revealed that application of nal mulch + lindane increased the soil moisture, water use efficiency and grain and straw yield of wheat. This treatment resulted in highest crop yield (34.11 q/ha) and increased grain yield by about 13.32 q/ha per year over control.

**2.4 Stress management measures and uptake of nutrients.**

Dhillon and Sidhu (1989) studied the release of potassium from some benchmark soils of India. Solutions of $BaCl_2$, $CaCl_2$, $NH_4Cl$ and Nacl was studied in soils either untreated or pretreated with 5 x $10^{-3}$ m kcl. Cumulative K-release was greatest from black soils followed by red and alluvial soils from soils pretreated with Kcl, more K was released than retained and more native K was released than from untreated soils.

Senthivel and Palaniappan (1989) studied the effect of topdressing potash on rice nutrient uptake and yield. Application of Kcl or NK granules increased N and K uptake and grain yield to 100-118 kg/ha, 169-186 kg/ha and 5.0-5.9 t/ha respectively compared with 91 kg, 147 kg, 4.2 t respectively without applied K. K uptake was highest (115 and 204 kg/ha respectively) with basal application of Kcl and highest yields were 5.0 t with basal application of Kcl or NK granules.

Subramanian (1994) studied the influence of soil and foliar application of potassium on growth, nutrient utilization, yield and quality of sugarcane. The studies conducted at Bhavanisagar, Tamilnadu, Sugarcane Cv. CO-6304 was given 0,125 or 187.5 kg $K_2O$ as soil application or 1% Kcl spray at 30, 60 and 90 days after planting with or without soil application of 125 kg $K_2O$/ha. Cane and sugar yields and N, P and K uptake were highest with combination of soil + foliar applications of K.

Rana (2007) conducted a field experiment on moisture conservation and nutrient management practices in pigeonpea +

greengram intercropping systems under rainfed conditions. He reported that application of soil mulch + FYM 5 t/ha + kaoline 6% spray was found the best moisture conservation practice be recording maximum values of pigeonpea equivalent yield, nutrient uptake and water use efficiency. The maximum uptake of P and S was recorded under soil mulch + FYM 5 t/ha + kaoline 6%. The increased uptake of P and S under these treatments attributed to the higher grain and stalk yields, apparently because of increased availability of water to the plants. The combined effect of these components in more effectively reducing the evapotranspiration losses and increasing the water holding capacity of the soil.

## 2.5 Cropping systems and soil and water loss, productivity and moisture use efficiency.

Singh *et al.* (1979) studied the effect of row cropping of maize and soybean on erosion losses. They reported that the reduction in soil loss (35, 46 and 61%) and runoff loss (45, 68 and 71%) in pure soybean, maize + soybean (4:6 rows) and maize + soybean (2:8 rows) respectively as compared to pure maize.

Mann *et al.* (1981) conducted a series of experiment to evolve efficient dryland technology for stable and higher crop yields at central Arid Zone Research Station, Jodhpur, (Rajasthan). They observed higher moisture use efficiency in intercropping of one row of pearlmillet in 2 rows of mungbean or guar or mothbean as compared to sole crop.

Umarani *et al.* (1984) studied suitability of pulses as an intercrops in sorghum at Rahuri (M.S.) on medium black soils in kharif season and observed that inter cropping of sorghum + cowpea and sorghum + achor produced higher grain yield as compared to sole sorghum. The average monetary returns of intercropping of mug. Cowpea and achor as an intercrop with sorghum recorded higher monetary returns (Rs. 5126, 5156 and 7253 respectively), over sole sorghum (Rs. 4215).

Pathak *et al.* (1985) worked out improved rainfed farming for semi arid tropics.They found minimum runoff of 91 mm when sorghum Intercropped with pigeonpea in kharif season (ICRISAT, Hyderabad) as compared to 220 mm from sole crop of sorghum grown traditionally.

Dhoble (1987) studied on sorghum +pigeonpea intercropping as affected by planting patterns.He conducted an experiment on sorghum + pigeonpea intercropping in kharif season on vertisol at Parbhani and concluded that intercropping of sorghum + pigeonpea recorded more or less equal grain and fodder yields of sorghum (35.86 and 73.06 q /ha) as compared to sole sorghum (36.33 and 72.06 q /ha) respectively with an additional bonus yield of pigeon pea (4.25 q /ha). Similarly higher gross and net monetary returns Rs. 8626 + 5231 /ha as compared to sole crop of sorghum (Rs. 6090 and 3364 / ha respectively).

Bhagwandin and Bhatia (1989) studied the effect of seedbed configuration and mulches on grain yield of rainfed maize. They observed maximum water use efficiency in maize + urd intercropping system (8.45 kg/ha/mm) than sole maize (6.40 kg/ha/mm) on sandy loam soils at Kanpur (U.P.).

Lomte and Dabhade (1990) conducted an experiment on vertisols at Parbhani to study yield recovery of intercrops viz. pigeon pea, greengram and sunflower with sorghum. The intercropping systems of sorghum + pigeon pea (3: 3 rows) and sorghum + greengram (4: 2 rows) recorded higher net returns i.e. Rs. 8366 of Rs. 59.89/ha. respectively over sole sorghum (5606 /ha). Similarly higher LER was also recorded by intercropping system than sole sorghum. Similar results were also reported by Rao and Rana (1980).

Verma *et al.* (1990) studied runoff and soil loss under sorghum at 1% landslope in kola clay soil. They found that the highest runoff (37%) and soil loss (3.46 t/ha) was from cultivated fallow and lowest runoff and soil loss (7% and. 0.21 t/ha respectively) from Dichanthium annulatum grass plot at

Kota (Rajasthan). Contour cultivation of sorghum and sorghum + pigeonpea recorded lower runoff and soil loss as compared to up and down cultivation. Cropping management factor 'C' of USLE remained 0.50 and 0.60 for sorghum and sorghum + pigeonpea (1:1 row), respectively.

Kale *et al.* (1992) studied the effect of conservation measures and cropping systems in different microwatersheds.They observed minimum runoff (118.75 mm) and soil loss (2.47 t/ha) with the intercropping system of pearl millet + redgram (2:1 rows) at 1 per cent slope as compared to sole crop of pearrl millet (133 mm runoff and 3.03 t/ha soil loss). Intercropping at 1 per cent soil slope reduced the nutrient losses of N, P and K to the extent of 48.9, 45.0 and 92.3 per cent, respectively over sole cropping of pearl millet.

Subuddi and Senapati (1995) studied the effect of cropping systems on runoff, soil loss and productivity. They revealed that efficient cropping system reduces soil erosion due to adequate vegetative cover, rainfall reduce soil erosion due to-interception and obstruction against flow. The maximum runoff (25.6%) and soil loss (9.38 t/ha) under cultivated fallow.

Khistaria *et al.* (1996) studied on intercropping of important pulses and oil seeds in sorghum under rainfed conditions.They concluded that sorghum + pigeon intercropping (1 : 1 row) produced higher sorghum equivalent yield (38.87 q /ha) and gross monetary returns of Rs. 13538 /ha. Intercropping also recorded higher LER 1.145 than sole sorghum combined effect of land configuration and cropping systems on soil and work conservation in yield and monetary returns.

Parlawar and Kamble (1998) studied the effect of intercropping of legumes in cotton,pigeonpea and sorghum.The experiment was carried out with intercropping of cotton + soybean,sorghum + pigeonpea and soybean + pigeonpea under rainfed condition. The results revealed that the highest monetary returns of 12722 Rs/ha were recorded from soybean + pigeonpea (1:2) intercropping system,which was 25.17% and 29.42% more than other intercropping i.e. cotton + soybean(1:1) ratio with monetary returns of 10163 Rs/ha and sorghum + pigeonpea (3:3) ratio with monetary returns of 9830 Rs/ha.

Munish kumar and Warsi (1998) studied role of soil and water conservation measures on crop yield and ground water recharge.They reported that the wheat + mustard gave highest net return (Rs. 13023/ha) followed by Bengal gram + mustard (Rs.17817/ha) and bengalgram + Linjeed (Rs. 10107/ha).

# MATERIAL AND METHODS

CHAPTER-III

# MATERIAL & METHODS

This chapter presents the pertinent aspects on soil, climate, methodology and techniques used in conducting the project.

## 3.1 Experimental details

### 3.1.1 Location

A field experiment was conducted during kharif season – 2009 on research farm of All India Co-ordinated Research Project for Dryland Agriculture, Marathwada Agricultural University, Parbhani.

### 3.1.2 Climate and weather conditions

Geographically, Parbhani is situated at $19^0 16'$ North latitude and $76^0 47'$ East longitude with an elevation of 409 m above mean sea level. Parbhani has subtropical climate with an average annual rainfall of 863.0 mm. About 90% of the rainfall is being received during the month of June to September and 10% during the rest of the period of the year.

The average maximum temperature in kharif (June to September) $30.45^0C$, $30.06^0C$ in Rabi (October to January) and $36.25^0C$ in summer (February to May). May is generally the hottest month with maximum temperature reaching above $45^0C$ for a short period of 5-8 days whereas minimum temperature varies between 6.4 to $23.4^0C$ while humidity varies from 37.2 to 74.7 per cent.

### 3.1.3. Soil and it's Characteristics

Soils at experimental location were vertisol, mostly deep black soil depth ranging more than 90 cm. Soil consists montmorillonite clay mineral dominantly, due to which it possessed swelling – shrinkage characteristics. Considering the textural composition, soils were clay type, comprising 54.40% clay particles,21.44% silt particles and 16.88% sand particles. Among chemical characteristics, the pH, EC and $CaCo_3$ constituents of soil were, 8.02, 0.16 $dSm^{-1}$and 5.7 percent respectively. The total available nitrogen, phosphorus and potassium in the soil at preseason period were,135.6,4 and 829.4 Kg/ha respectively (Table 3.1).

**Table 3.1 : Physico-chemical properties of experimental soil.**

| Sr.No. | Soil characteristics | Unit | Value |
|---|---|---|---|
| **A** | **Mechanical composition *** | | |
| 1 | Coarse sand | Percent | 6.58 |
| 2 | Fine sand | Percent | 10.30 |
| 3 | Clay | Percent | 54.40 |
| 4 | Silt | Percent | 21.44 |
| **B** | **Chemical composition** | | |
| 1 | pH | -- | 8.02 |
| 2 | EC | $dSm^{-1}$ | 0.16 |
| 3 | Organic carbon | Percent | 0.62 |
| 4 | $CaCo_3$ | Percent | 5.7 |
| 5 | Available N | Kg/ha | 135.6 |
| 6 | Available P | Kg/ha | 4 |
| 7 | Available K | Kg/ha | 829.4 |

**( * Anonymous ,1980)**

## 3.2 Treatment details

The study was conducted during Kharif-2009 season, on research farm, AICRP for Dryland Agriculture, MAU, Parbhani with following intercropping systems.

### 3.2.1 Treatments

**a) Cropping systems (C)**

$C_1$ - Sorghum + pigeonpea (4:2)

$C_2$ - Soybean + pigeonpea (4:2)

$C_3$ - Cotton + Soybean (1:1)

**b) Stress management measures (T)**

$T_1$ - Kaoline spray @ 6%

$T_2$ - Kcl spray @ 2%

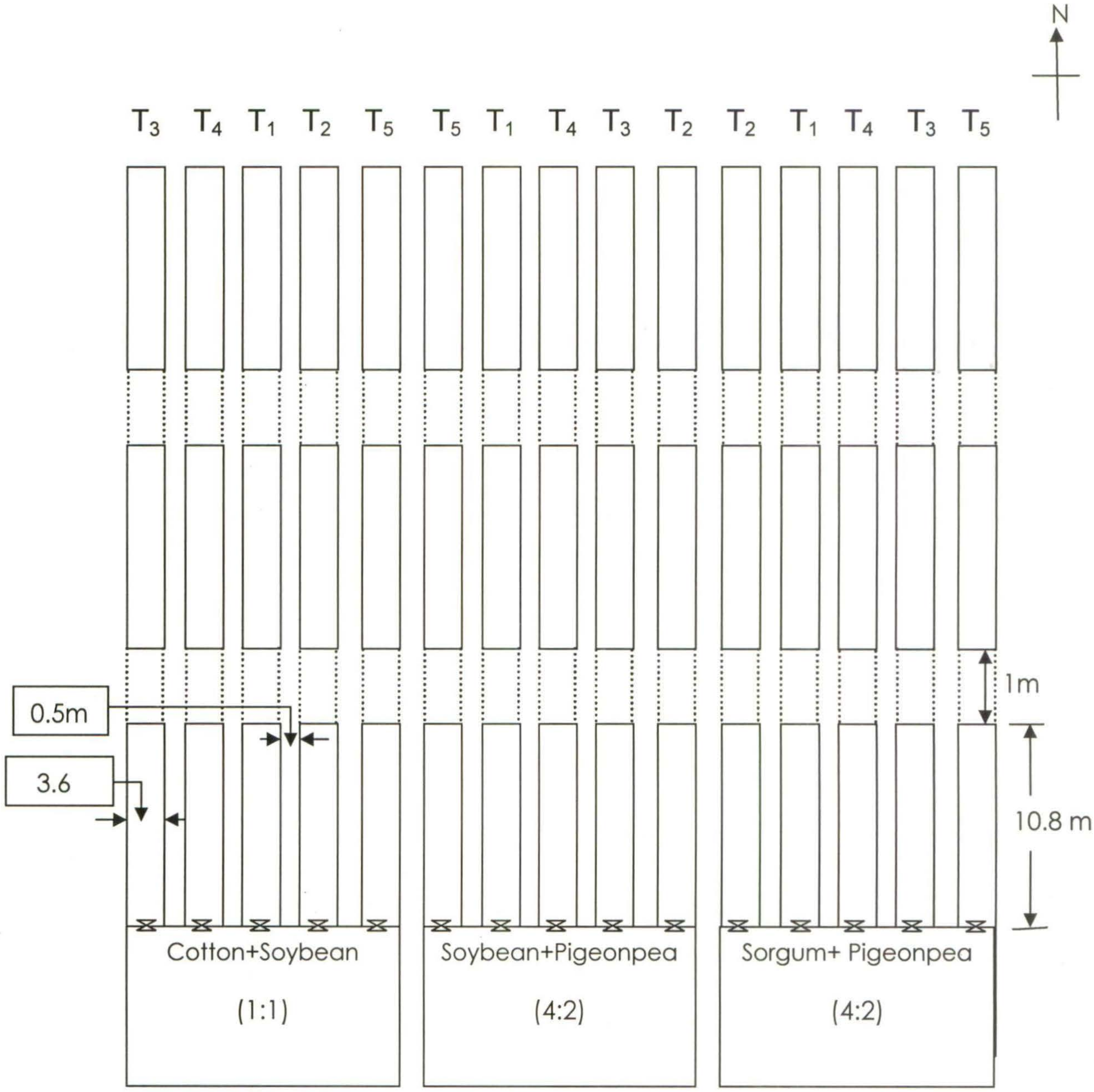
$T_3$ - Vegetative mulching @ 2.0 t/ha

$T_4$ - Combination (Treatment with Kaoline, Kcl spray and vegetative mulching).

$T_5$ - Control (without any stress management measures)

### 3.2.2 Other details

| | | |
|---|---|---|
| Design | - | R.B.D.(F) |
| Replications | - | Three |
| Plot size | - | 3.6 m x 10.8 m |
| Crop | - | Cotton, Sorghum, Soybean and Pigeonpea |
| Variety | - | Cotton - Bunny Bt.<br>Sorghum - PVK-801<br>Soybean - MAUS-71<br>Pigeonpea - BSMR-853 |
| Spacing | - | Cotton - 90 cm x 60 cm,<br>Sorghum - 45 cm x 15cm,<br>Soybean – 45 cm x 5 cm and<br>Pigeonpea - 45 cm x 20 cm. |




- Gauging for runoff measurement

**Treatment details**

T1 - Kaoline spray
T2 - KCl Spray
T3 - Vegetative mulching
T4 - Combination (T1 to T3)
T5 - Control

**Fig 3.1 : Experimental layout**

Sowing methods- Bullock drawn seed drill, except for cotton, where dibbling was done.

### 3.2.3 Administration of treatments

The treatments of the study were administered during dryspell, exceeding 21 days occurred during the crop growing season - 2009.

#### a) Kaoline spray

Measured quantity of kaoline powder was thoroughly ground and soaked in the water for 2 to 3 hours,quantitatively distributed while making spray suspension and sprayed @ 6% with knapsack sprayer to cover the complete canopy of the crops.

#### b) KCl spray

To apply KCl spray, measured quantity of murate of potash (MOP) @ 2% was soaked in water for 1 hr and then sprayed on crops with the help of knapsack sprayer.

#### c) Vegetative mulch

The mixture of vegetative mulch, comprising straw of soybean, sorghum and pigeonpea were spread in layers to cover completely the open soil between crops. The mulch was applied @ 2 t/ha during dryspell and once in the growing season.

## 3.3 Details of cultural operations

The schedule of cultural operations followed during the course of investigation is given in table 3.2.

### 3.3.1 Preparatory cultivation

The land was ploughed 30 cm deep with tractor drawn mouldboard plough. It was subsequently harrowed twice with a blade harrow to achieve loose and friable seedbed. Stubbles of previous crops and weeds were collected and removed from the field.

### 3.3.2 Fertilizer and nutrient requirement

Recommended dose of nutrients were applied through inorganic fertilizers such as 20:20:0, urea and murate of potash. The recommended dose of fertilizers for the cropping systems considered are,

| | | |
|---|---|---|
| Sorghum + pigeonpea | - | 80:40:40 NPK kg/ha |
| Soybean + pigeonpea | - | 30:60:30 NPK kg/ha |
| Cotton + soybean | - | 100:50:50 NPK kg/ha |

### 3.3.3 Seeds and sowing

Sowing was done with the help of bullock drawn seed drill except that of cotton. Dibbling of cotton as per recommended spacing was done simultaneously with sowing between the rows of soybean drilled.

### 3.3.4 Post sowing operation

As part of intercultural operations,one hoeing and one hand weeding were done as per schedule to control weeds.

### 3.3.5 Plant protection

One spray of monocrotophos, 36% WSC,@ 20 ml per 15 litre was applied on cotton to control sucking pest attack.

### 3.3.6 Harvesting and threshing

The crops were manually harvested at the proper maturity time of respective crops, dried in sunshine and threshed with electric powered multicrop thresher. While threshing, grains and straw were collected separately, weighted and replicationwise weights were recorded.

**Table 3.2 : Schedule of cultural operations carried out in experimental plot during 2009.**

| Sr. No. | Particular | Frequency | Dates |
|---|---|---|---|
| **A) Presowing operations** | | | |
| 1. | Ploughing | 1 | 25.4.2009 |
| 2. | Harrowing with blade harrow | 2 | 17.5.2009/ 2.7.2009 |
| 3. | Cleaning the field | 1 | 4.7.2009 |
| 4. | Layout of experiment | 1 | 13.7.2009 |
| 5. | Fertilizer application | 1 | 16.7.2009 |
| **B) Sowing** | | | |
| 1. | Sowing | 1 | 16.7.2009 |
| **C) Post sowing operation** | | | |
| 1. | Weeding | 1 | 14.8.2009 |
| 2. | Spraying ( monocrotophos) | 1 | 13.9.2009 |
| 3. | Hoeing | 1 | 8.8.2009 |
| **D)** | **Administration of treatments** | | |
| 1. | Kaoline spray | 1 | 17.8.2009 |
| 2. | KCl spray | 1 | 17.8.2009 |
| 3. | Vegetative mulching | 1 | 17.8.2009 |
| **E) Harvesting and threshing** | | | |
| 1. | Harvesting ( soybean) | 1 | 3.11.2009 |
| 2. | Harvesting ( sorghum) | 1 | 18.11.2009 |
| 3. | Harvesting ( pigeonpea) | 1 | 20.1.2010 |
| 4. | Threshing, winnowing and cleaning | 1 | 20.2.2010 |
| 5. | Cotton picking dates | | |
| | $1^{st}$ | 1 | 16.11.2009 |
| | $2^{nd}$ | 1 | 2.12.2009 |
| | $3^{rd}$ | 1 | 27.1.2010 |
| | $4^{th}$ | 1 | 10.2.2010 |
| | $5^{th}$ | 1 | 17.2.2010 |
| **F) Soil moisture content** | | | |
| | $1^{st}$ sampling | 1 | 23.7.2009 |
| | $2^{nd}$ sampling | 1 | 8.8.2009 |
| | $3^{rd}$ sampling | 1 | 26.9.2009 |
| | $4^{th}$ sampling | 1 | 16.12.2009 |
| | $5^{th}$ sampling | 1 | 16.1.2010 |
| **G)** | **Soil sample for chemical analysis** | | |
| | Pre season | 1 | 23.7.2009 |
| | Post season | 1 | 23.1.2010 |

## 3.4 Soil – water loss and soil moisture monitoring

### 3.4.1 Runoff and soil loss

Each treatment plot was considered as unit for measurement of runoff and soil loss. For measurement of runoff, combination of stage level recorder (daily type) and 6 inch 'H' flume were installed in the center of downstream boundary bund of the treatment plot. Stormwise runoff was recorded for each treatment. The stage level recorder graph was analysed to determine stormwise runoff. Runoff for the season was obtained by adding stormwise runoff over period. Stormwise runoff and total runoff for season was recorded and analysed. Stormwise soil loss from each treatment, corresponding to runoff for that treatment was determined. Finally, treatmentwise total soil loss in tonnes/ha during the season was calculated and analysed.

### 3.4.2 Crop yield

Harvesting and threshing of each crop in the cropping systems were performed separately, to maintain replicationwise yield data. Replicationwise yield of main and intercrop were recorded to determine yield parameters viz. productivity, seed cotton equivalent yield, gross monetary returns, net monetary returns and B.C. ratio and then subjected to statistical analysis.

### 3.4.3 Soil moisture

Soil moisture content was determined using gravimetric method. Soil samples were collected from treatment plots of stress management measures,with the help of screw auger, from the soil depth of 15, 30 and 60 cm. The soil samples were collected in moisture boxes i.e.airtight Aluminium boxes. The soil samples were weighted and dried in an oven at $105^0$C for about 24 hrs. After drying, soil samples were weighted and analysed to determine water content on dry basis.

The following formula was used to calculate the soil moisture content on dry basis.

$$\text{Soil moisture content, (\%)} = \frac{W_1 - W_2}{W_2} \times 100$$

Where,

$W_1$ = Weight of the moist sample, gm

$W_2$ = Weight of oven dried sample, gm

### 3.4.4 Soil moisture use

The field consumptive use of soil moisture was determined and computed by the formula,

$$Cu = \sum_{i=1}^{N} \frac{(M_1i - M_2i)}{100} \times Asi \times Di \times ER$$

Where,

| | | |
|---|---|---|
| Cu | = | Consumptive use,cm |
| $M_1i$ | = | Moisture content (d.b.) at first sampling in $i^{th}$ layer, (%) |
| $M_2i$ | = | Moisture content (d.b.) at second sampling in $i^{th}$ layer, (%) |
| Asi | = | Apparent specific gravity of soil in the $i^{th}$ layer, gm/cc |
| Di | = | Depth of soil in cm of $i^{th}$ layer. |
| ER | = | Effective rainfall, cm |
| N | = | Number of soil layers sampled in root zone at depth D. |

### Effective rainfall

Treatmentwise effective rainfall was computed for crop growing season during 2009. For determination of effective rainfall, the following criteria suggested by Kaore and Bathkal,(1982) was adopted.

| Month | criteria |
|---|---|
| June | a) Less than 10 mm per day is disregarded. |
| | b) Greater than 100 mm per day is disregarded. |
| | c) Rainfall on consecutive days excess of ($ET_o$ + 100 mm) is disregarded. |
| July | a) Less than 5 mm per day is disregarded. |
| | b) Greater than 75 mm per day is disregarded. |
| | c) Rainfall on consecutive days excess of ($ET_o$ + 75 mm) is disregarded. |
| August | a) Less than 2.5 mm per day is disregarded. |
| | b) Greater than 75 mm per day is disregarded. |
| | c) Rainfall on consecutive days excess of ($ET_o$ + 75 mm) is disregarded. |
| September | a) Less than 2.5 mm per day is disregarded. |
| | b) Greater than 50 mm per day is disregarded. |
| | c) Rainfall on consecutive days excess of ($ET_o$ + 50 mm) is disregarded. |

### 3.4.5 Moisture use efficiency

Moisture use efficiency with respect to cropping systems and stress management measures, was computed on the basis of seed cotton equivalent yield and gross monetary returns using following formula.

$$\text{Moisture use efficiency, kg/mm/ha} = \frac{\text{Seed cotton equivalent yield (kg/ha)}}{\text{Moisture use (mm)}}$$

$$\text{Moisture use efficiency, Rs/mm/ha} = \frac{\text{Gross monetary returns (Rs/ha)}}{\text{Moisture use (mm)}}$$

### 3.4.6 Soil chemical analysis

Treatmentwise composite soil samples were collected at pre and post harvest period of the study. The soil samples were analysed in

Soil science and Agril. Chem. Laboratory, MAU, Parbhani, to determine nutrient status and organic carbon.

### 3.4.6.1 Soil characteristics

The results of the soil analysis at pre and post harvest period were studied to determine the effect of stress management techniques with respect to nutrient status and uptake of major nutrients during the crop growing season. The available organic carbon of soil samples at pre and post harvest period were also analysed to determine change in organic carbon.

### 3.4.6.2 Status and uptake of major nutrients viz. Nitrogen, Phosphorus and Potassium.

The analysis of the soil samples at pre and post harvest period, was used to determine available (present) status and uptake of N,P,K nutrients with respect to stress management measures and cropping systems.

The uptake of N,P,K was calculated by using formula,

$$\text{Uptake of N or P or K} = \left( \text{Initial available N or P or K} + \text{Additional dose of N or P or K} \right) - \left( \text{Availability of N or P or K at harvest} \right)$$

Plate 1 : Cotton + soybean with Kaoline spray treatment during 2009.

Plate 2 : Cotton + soybean with KCl spray treatment during 2009.

**Plate 3 :** **Sorghum + pigeonpea with vegetative mulching treatment during 2009.**

**Plate 4 :** **Cotton + soybean with combination treatment during 2009.**

Plate 5 : Stage level recorder with 'H' flume installed for runoff and soil loss measurement.

Plate 6 : Soil sampling for moisture content observation during 2009.

# RESULTS AND DISCUSSION

CHAPTER-IV

# RESULTS AND DISCUSSION

The present investigation entitled "Performance evaluation of the stress management measures under important cropping systems" was undertaken to study the response of different stress management measures for dryspell management under dominant intercropping systems of Marathwada region, with respect to soil and water loss, moisture use, crop yield, nutrients availability and their uptake.

A field experiment was conducted during kharif-2009 at Research Farm, All India Co-ordinated Research Project for Dryland Agriculture, Marathwada Agricultural University, Parbhani on vertisol with 1% land slope. The characteristics of soil such as pH, electrical conductivity, $CaCo_3$ were 8.02, 0.1 dSm-1 and 5.7% respectively.

The treatments of stress management were kaoline spray @ 6%, Kcl spray @ 2%, vegetative mulching @ 2.0 t/ha, combination of above and control with three intercropping systems viz. sorghum + pigeonpea (4:2), soybean + pigeonpea (4:2) and cotton + soybean (1:1).

The results obtained were statistically analysed, interpreted and presented accordingly.

## 4.1 Rainfall season 2009

During 2009, onset of effective monsoon was on 5th July 2009, with receipt of 50.6 mm rainfall, just sufficient to meet the evapotranspiration requirement and satisfying useful water holding capacity upto 15 cm soil depth. Total seasonal (June-Sept) rainfall received during 2009 was 492.9 mm as against 750 mm average seasonal rainfall, whereas the annual rainfall received during 2009 was 672.9 mm, which accounts about 70% of average annual rainfall 863 mm. The total rainfall received during crop growing season (July-Dec) was 528.7 mm (Appendix-A) .

During 2009, the rainfall of 672.9 mm received in 40 rainy days as against normal of 863 mm over 48 days. The seasonwise distribution indicated that 22.4 mm (3.33%) rainfall received as pre-monsoon, 492.9 mm (73.25%) rainfall during monsoon and 157.6mm (23.42%) rainfall in post monsoon period. During this year, onset of effective monsoon was delayed i.e. in 28$^{th}$ MW, because of which kharif sowing was delayed. There was first dry spell from 23$^{rd}$ July to 10$^{th}$ August (19 days) and its adverse effect was reflected on seedling stage. Second dry spell occurred from 7$^{th}$ Sept to 28$^{th}$ Sept (22 days), which affected grand growth stage of the crops. Third dry spell was observed from 5$^{th}$ Oct to 8$^{th}$ Nov, coinciding with the pod filling and maturity stage in soybean.

### 4.1.1 Runoff and soil loss

Rainfall events occurred during 2009 were not of sufficient magnitude, intensity and duration to cause substantial runoff from any of the experimental plot, during the crop season. However, on 25$^{th}$ August 2009, 103.5 mm rainfall was received during 12 hrs 45 minute duration in two major storms, corresponding runoff observed in all treatments was in trace and could not be recorded with 'H' flume. Similarly, on 4th October, 2009, 82.2 mm rainfall was received during 7 hr duration with low intensity in the form of interrupted storms and was not sufficient to generate runoff. Therefore, the total runoff occurred during season-2009 was observed as 0 mm and the corresponding soil loss as affected by different treatments was also observed as 0 t/ha (Appendix-C).

## 4.2 Crop yield and yield parameters

Data on yield parameters viz. crop yield, productivity, seed cotton equivalent yield, gross monetary returns, net monetary returns and B.C. ratio as affected by stress management measures and cropping systems during 2009-10 have been presented in table 4.1.

### 4.2.1 Productivity

Data presented in table 4.1 and depicted in fig 4.1 & 4.2 with respect to productivity indicated that among cropping systems, sorghum + pigeonpea recorded significantly highest productivity (1861 kg/ha), whereas cotton + soybean recorded significantly lowest productivity (1403 kg/ha).

Among stress management measures, combination treatment recorded significantly highest productivity (1992 kg/ha), than rest of stress management measures except treatment of vegetative mulching (1745 kg/ha). Productivity under kaoline spray and KCl spray was found significantly higher than control treatment.

Interaction between cropping systems and stress management measures was found non significant.

### 4.2.2 Seed cotton equivalent yield

Data presented in table 4.1 and depicted in fig. 4.3 & 4.4 with respect to seed cotton equivalent yield indicated that among cropping systems, soybean + pigeonpea recorded significantly highest seed cotton equivalent yield (1788 kg/ha), whereas cotton + soybean recorded significantly lowest seed cotton equivalent yield (1295 kg/ha).

Among stress management measures, combination treatment recorded significantly highest seed cotton equivalent yield (1796 kg/ha) than rest of stress management measures except treatment of vegetative mulching. Vegetative mulching recorded on par seed cotton equivalent yield (1596 kg/ha) with kaoline spray and KCl spray and significantly higher than control treatment. The percentage seed cotton equivalent yield increase over control was highest in combination treatment (43.79%), followed by vegetative mulching and KCl spray treatment (27.78% and 20.81% respectively), whereas percentage seed cotton equivalent yield increase over control was lowest in kaoline spray treatment (16.73%).

Interaction between cropping systems and stress management measures was found non significant.

**Table 4.1 : Crop yield, productivity, seed cotton equivalent yield, gross monetary returns, net monetary returns and B.C. ratio as affected by cropping systems & stress management measures during 2009-10.**

| Treatment | Yield, Kg/ha | | Productivity, kg/ha | SCEY, kg/ha | GMR, Rs/ha | NMR, Rs/ha | B.C. ratio |
|---|---|---|---|---|---|---|---|
| | Main crop | Inter crop | | | | | |
| **Cropping systems (C)** | | | | | | | |
| $C_1$-Sorghum + Pigoenpea (4:2) | 695 (1321)* | 1166 | 1861 | 1514 | 45399 | 32878 | 2.62 |
| $C_2$-Soybean + Pigoenpea (4:2) | 465 | 1321 | 1786 | 1788 | 52726 | 39864 | 3.09 |
| $C_3$-Cotton +Soybean (1:1) | 913 | 490 | 1403 | 1295 | 38791 | 22183 | 1.32 |
| S.E.$\pm$ | -- | -- | 75 | 71 | 2136 | 2125 | 0.16 |
| C.D. (P=0.05) | -- | -- | 218 | 206 | 6177 | 6146 | 0.45 |
| **Stress management measures** | | | | | | | |
| $T_1$-Kaoline spray @ 6% | 705 | 945 | 1650 | 1458 (16.73%)$^+$ | 43745 | 30157 | 2.31 |
| $T_2$-KCl spray @ 2% | 654 | 1025 | 1680 | 1509 (20.81%)$^+$ | 45247 | 31718 | 2.44 |
| $T_3$-Vegetative mulching @ 2.0 t/ha | 708 | 1037 | 1745 | 1596 (27.78%)$^+$ | 47858 | 33305 | 2.38 |
| $T_4$-Combination T1 to T3 | 894 | 1098 | 1992 | 1796 (43.79%)$^+$ | 53879 | 38351 | 2.56 |
| $T_5$-Control | 493 | 857 | 1350 | 1249 | 37461 | 24676 | 2.02 |
| S.E.$\pm$ | -- | -- | 97 | 92 | 2758 | 2744 | 0.20 |
| C.D. (P=0.05) | -- | -- | 281 | 266 | 7974 | 7935 | NS |
| **Interaction** | | | | | | | |
| S.E.$\pm$ | 85 | 143 | 168 | 159 | 4776 | 4753 | 0.35 |
| C.D. (P=0.05) | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| Mean | 691 | 992 | 1683 | 1522 | 45638 | 31641 | 2.34 |
| CV% | 21 | 25 | 17 | 18 | 18 | 26 | 26 |

* Fodder yield

\+ % increase over control

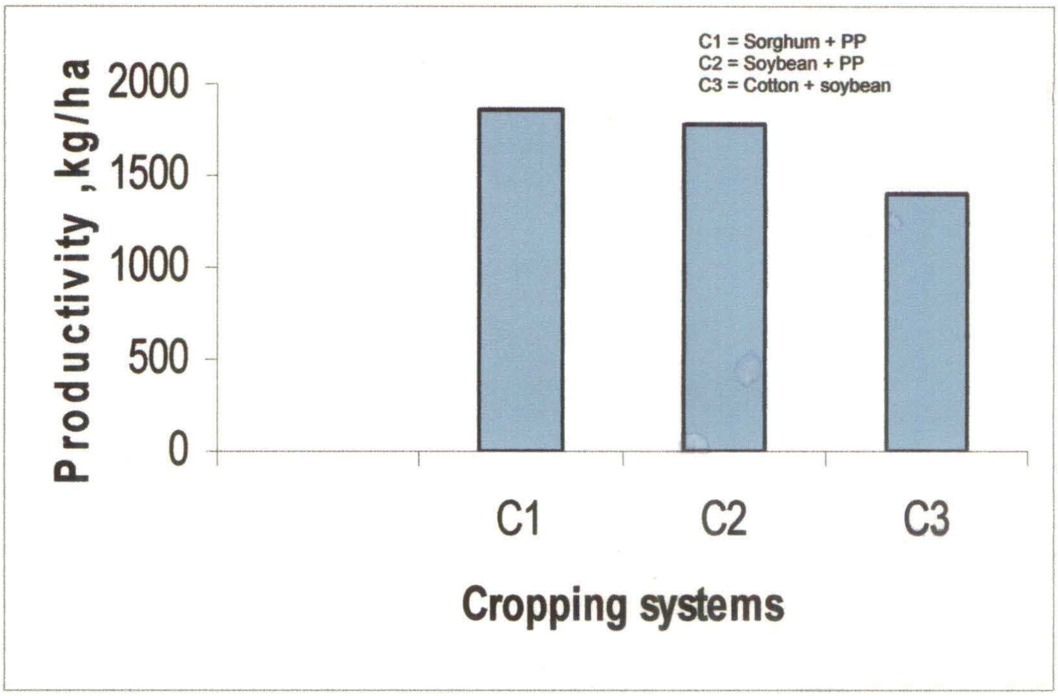



**Fig 4.1 : Productivity under different cropping systems during 2009-10.**

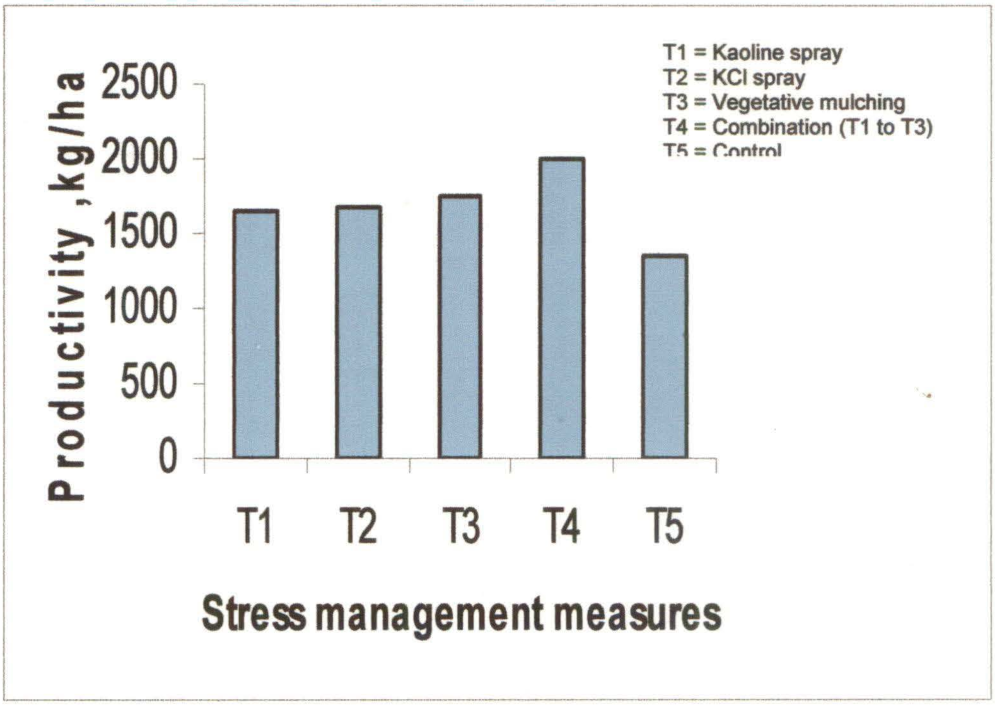



**Fig 4.2 : Productivity under different stress management measures during 2009-10**

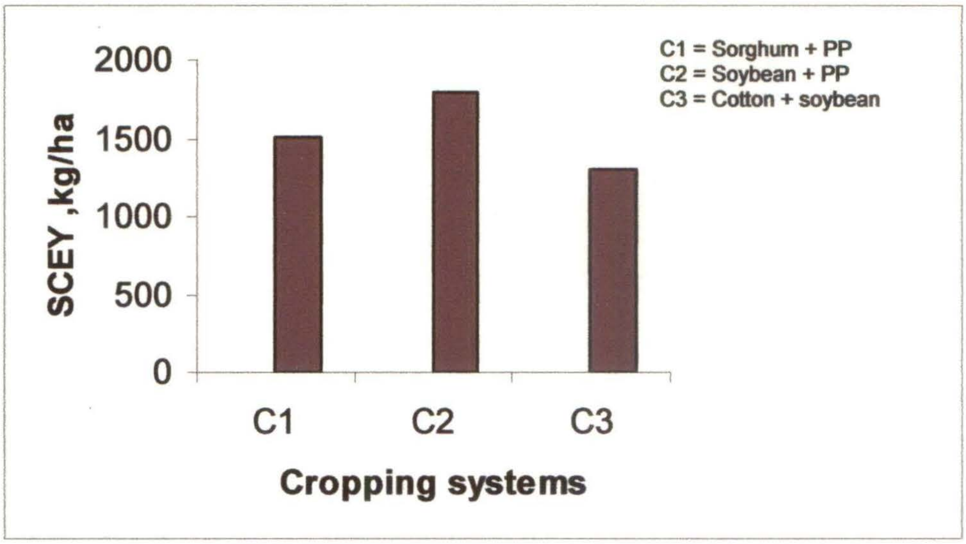



**Fig 4.3 : Seed cotton equivalent yield under different cropping systems during 2009-10**

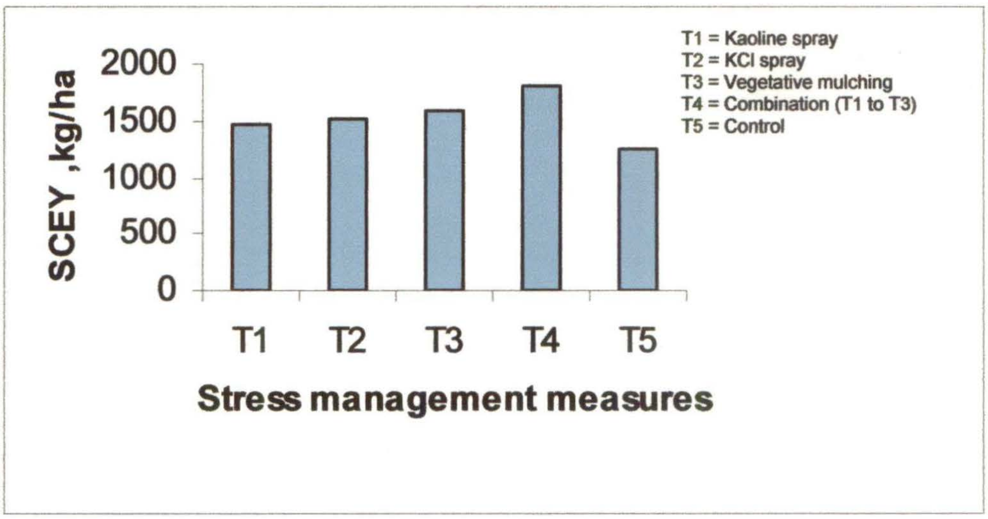



**Fig 4.4 : Seed cotton equivalent yield under different stress management measures during 2009-10**

### 4.2.3 Gross monetary returns

Data presented in table 4.1 and depicted in fig. 4.5 & 4.6 with respect to gross monetary returns indicated that among cropping systems, soybean + pigeonpea recorded significantly highest gross monetary returns (52726 Rs/ha), whereas cotton + soybean recorded significantly lowest gross monetary returns (38791 Rs/ha).

Among stress management measures, combination treatment recorded significantly higher gross monetary returns (53879 Rs/ha) than rest of stress management measures except treatment of vegetative mulching (47858 Rs/ha). Gross monetary returns with kaoline spray and KCl spray were significantly higher than that of control treatment.

Interaction between cropping systems and stress management measures was found non significant.

### 4.2.4 Net monetary returns

Data presented in table 4.1 and depicted in fig.4.7 & 4.8 with respect to net monetary returns indicated that among cropping systems, soybean + pigeonpea recorded significantly highest net monetary returns (39864 Rs/ha), whereas cotton + soybean recorded significantly lowest net monetary returns (22183 Rs/ha).

Among stress management measures, combination treatment recorded significantly highest net monetary returns (38351 Rs/ha) than rest of stress management measures except treatment of vegetative mulching (33305 Rs/ha). Net monetary returns with kaoline spray and KCl spray were significantly higher than in control treatment.

Interaction between cropping systems and stress management measures was found non significant.

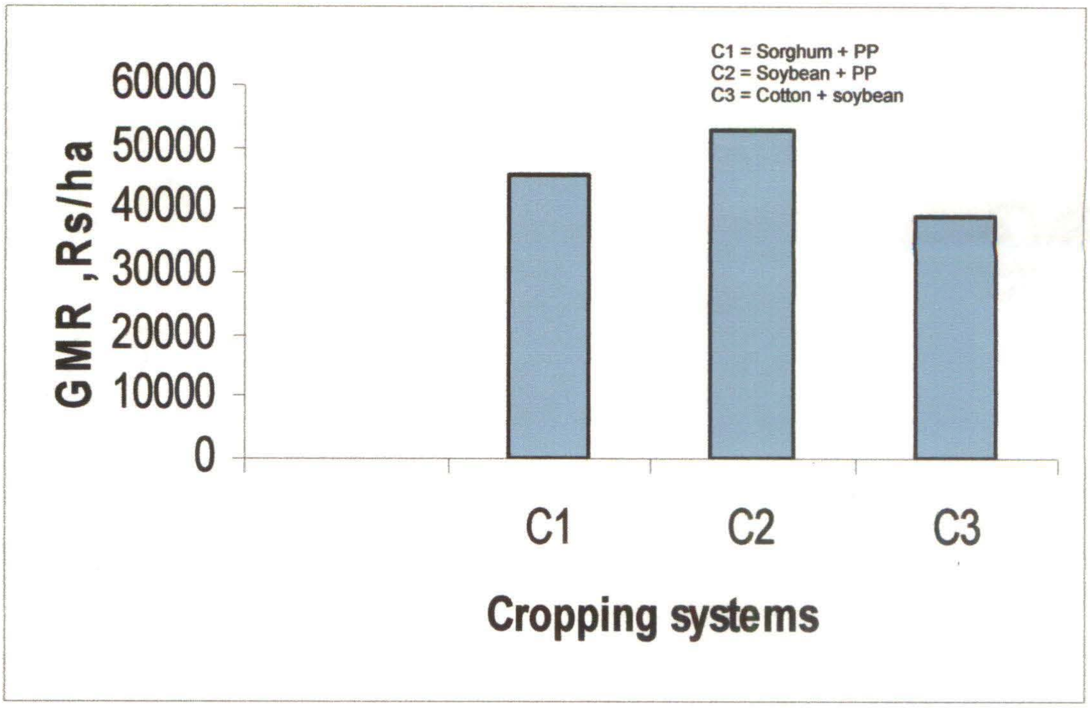



**Fig 4.5 : Gross monetary returns under different cropping systems during 2009-10**

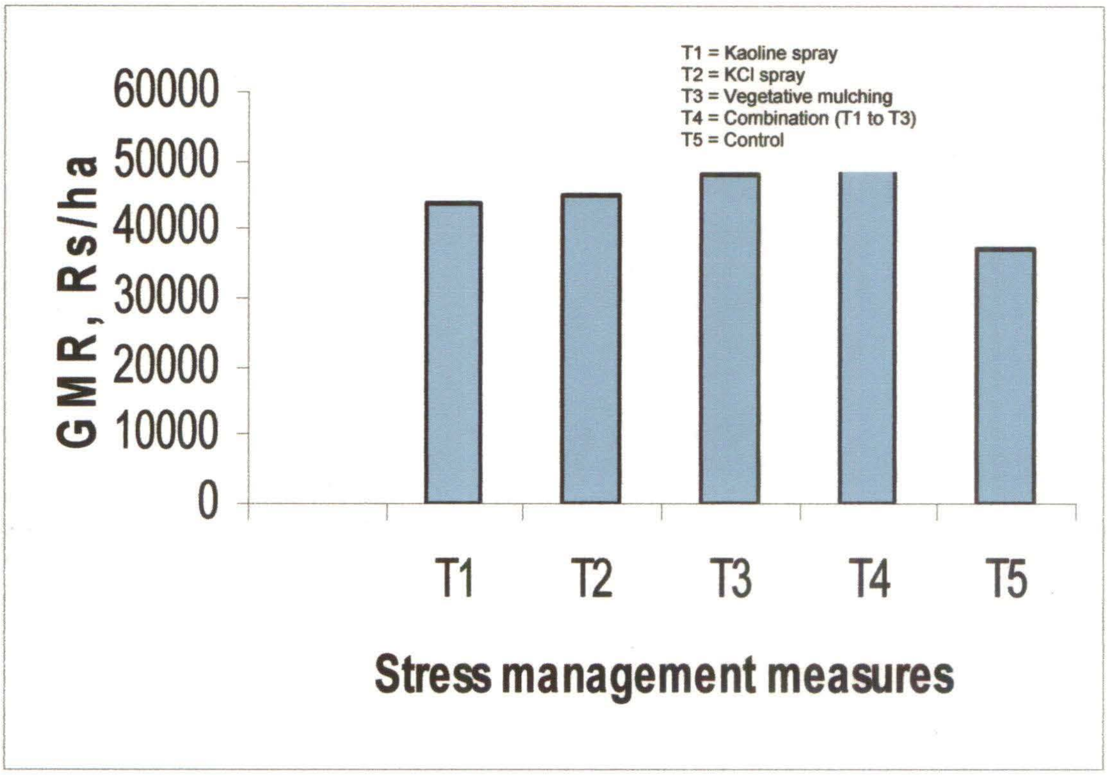



**Fig 4.6 : Gross monetary returns under different stress management measures during 2009-10**

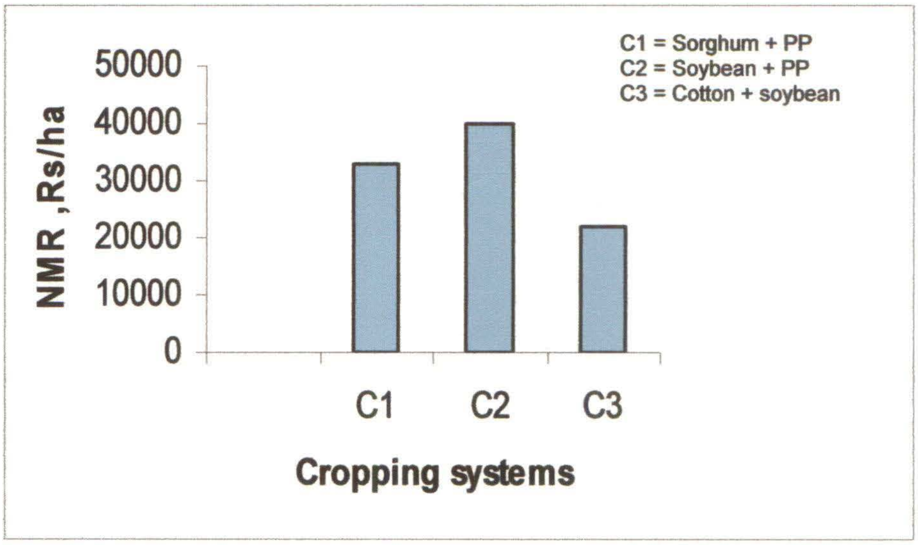



**Fig 4.7 : Net monetary returns under different cropping systems during 2009-10**

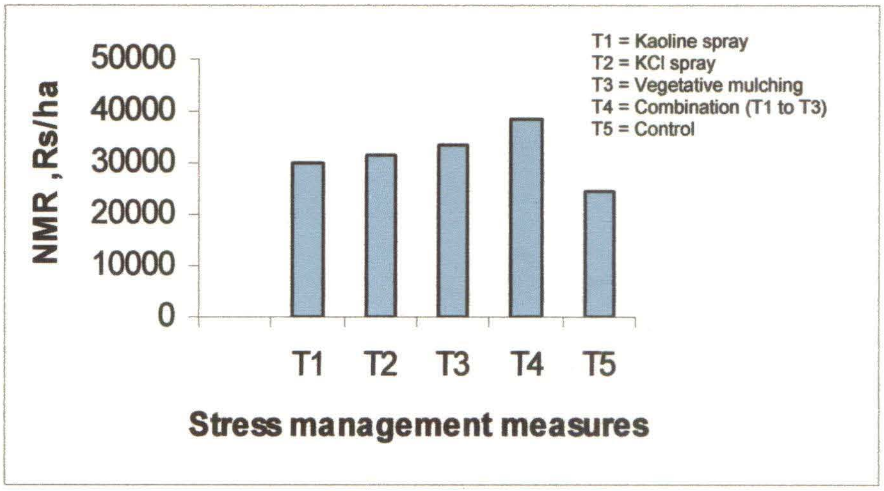



**Fig 4.8 : Net monetary returns under different stress management measures during 2009-10**

### 4.2.5 B.C. ratio

Data presented in table 4.1 and depicted in fig.4.9 & 4.10 with respect to B.C. ratio indicated that among cropping systems, soybean + pigeonpea recorded significantly highest B.C. ratio (3.09), whereas cotton + soybean recorded significantly lowest B.C. ratio (1.32).

Among stress management measures, combination treatment recorded significantly highest B.C. ratio (2.56) than rest of stress management measures except treatment of KCl spray (2.44). B.C. ratio with kaoline spray and vegetative mulching significantly higher than control treatment.

Interaction between cropping systems and stress management measures was found non significant.

## 4.3 Soil moisture study

Soil moisture use (mm) and moisture use efficiency (Kg/mm/ha and Rs/mm/ha) were determined using soil moisture observations recorded during crop growing season and water balance equation method (Kaore and Bathkal,1982). The data on moisture use and moisture use efficiency as affected by cropping systems and stress management measures have been presented in table 4.2.

### 4.3.1 Soil moisture use (mm)

Soil moisture use with respect to cropping systems and stress management measures indicated that highest soil moisture use was recorded in soybean + pigeonpea with kaoline spray (403.2 mm), whereas lowest soil moisture use of (377.10 mm) was observed in cotton + soybean with vegetative mulching .

On an average, among cropping systems, higher soil moisture use (403.62 mm) was recorded in sorghum + pigeonpea, whereas minimum soil moisture use (394.96 mm) was recorded in cotton + soybean. Among stress management measures, kaoline spray treatment recorded higher soil moisture use (406.93 mm) followed by combination

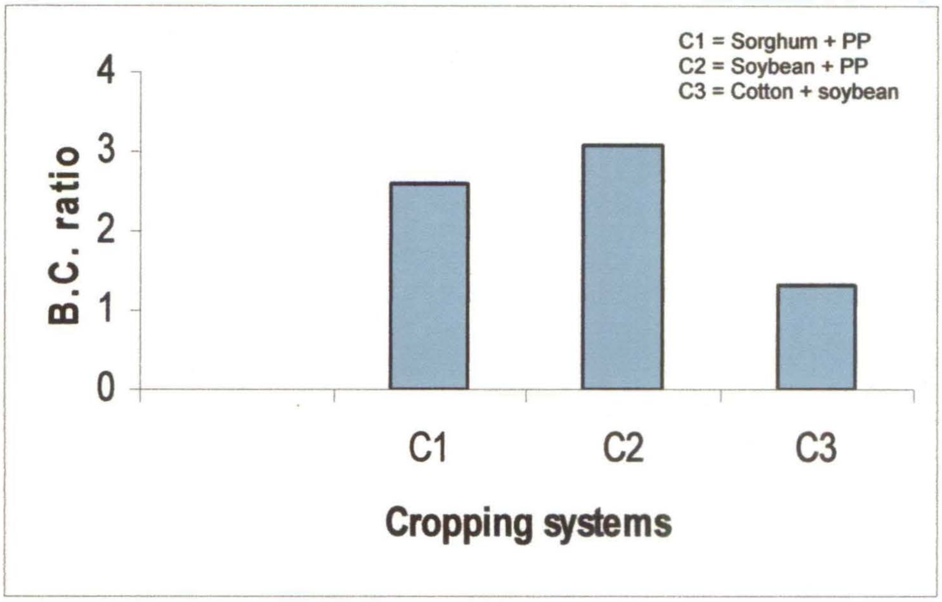



**Fig 4.9 : B.C. ratio under different cropping systems during 2009-10**

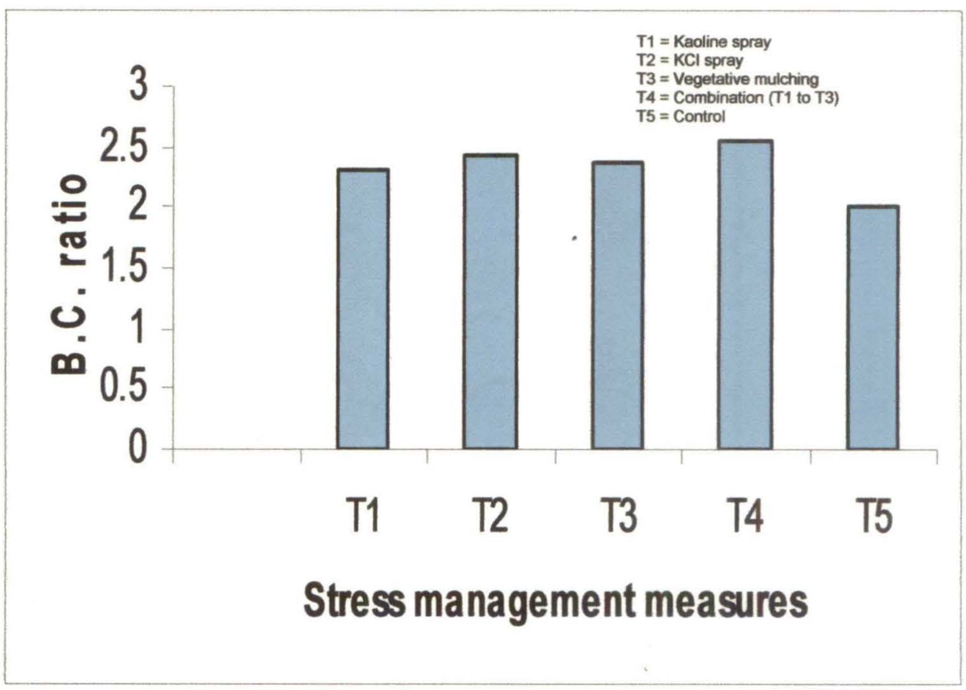



**Fig 4.10 : B.C. ratio under different stress management measures during 2009-10**

treatment whereas, minimum soil moisture use was recorded in control treatment (397.56 mm).

**Table 4.2 : Soil moisture use (mm) and moisture use efficiency (Kg/mm/ha & Rs/mm/ha) as influenced by cropping systems and stress management measures during 2009.**

| Cropping systems | Rainfall (mm) | Stress management measures | | | | | |
|---|---|---|---|---|---|---|---|
| | | Kaoline spray | KCl spray | Vege -tative mulching | Combi- nation | Control | Mean |
| **Moisture use (mm)** | | | | | | | |
| $C_1$-Sorghum+ Pigeonpea | 528.70 | 412.3 | 412.6 | 388.9 | 405.3 | 399.0 | 403.62 |
| $C_2$-Soybean+ Pigeonpea | | 413.3 | 394.3 | 400.7 | 408.6 | 390.5 | 401.48 |
| $C_3$- Cotton + Soybean | | 395.2 | 397.7 | 377.1 | 401.1 | 403.2 | 394.96 |
| Mean | | 406.93 | 401.53 | 388.90 | 405.0 | 397.56 | -- |
| **Moisture use efficiency (kg/mm/ha)** | | | | | | | |
| $C_1$-Sorghum+ Pigeonpea | 528.70 | 3.56 | 3.69 | 3.86 | 4.28 | 3.35 | 3.75 |
| $C_2$-Soybean+ Pigeonpea | | 4.20 | 4.67 | 4.67 | 4.78 | 3.62 | 4.37 |
| $C_3$- Cotton + Soybean | | 2.96 | 2.99 | 3.73 | 4.24 | 2.48 | 3.28 |
| Mean | | 3.57 | 3.76 | 4.09 | 4.43 | 3.15 | |
| **Moisture use efficiency (Rs/mm/ha)** | | | | | | | |
| $C_1$-Sorghum+ Pigeonpea | 528.70 | 106.79 | 110.69 | 116.19 | 128.33 | 100.49 | 112.49 |
| $C_2$-Soybean+ Pigeonpea | | 126.01 | 137.84 | 140.15 | 143.55 | 108.54 | 131.22 |
| $C_3$- Cotton + Soybean | | 88.89 | 89.82 | 111.97 | 127.07 | 74.17 | 98.38 |
| Mean | | 107.23 | 112.78 | 122.77 | 132.98 | 94.40 | -- |

### 4.3.2 Moisture use efficiency (Kg/mm/ha and Rs/mm/ha)

Moisture use efficiency with respect to cropping systems and stress management measures during 2009-10 (table 4.2) indicated that Soybean + pigeonpea recorded highest moisture use efficiency of 4.78 Kg/mm/ha & Rs.143.55/ mm/ha with combination treatment, whereas cotton + soybean recorded lowest moisture use efficiency of 2.48 Kg/mm/ha & Rs.74.17 /mm/ha with control treatment.

On an average among cropping systems, higher moisture use efficiency of 4.37 Kg/mm/ha and Rs.131.22/mm/ha was recorded in soybean + pigeonpea, whereas cotton + soybean recorded minimum moisture use efficiency of 3.28 kg/mm/ha & Rs.98.38 /mm/ha. Among stress management measures, combination treatment recorded higher moisture use efficiency of 4.43 kg / mm/ha & Rs.132.98 /mm/ha whereas, as usual control recorded minimum moisture use efficiency of 3.15 kg /mm/ha & Rs. 94.40 /mm/ha.

## 4.4 Soil characteristics

Soil samples collected at pre and post season period were analysed to determine the status of major nutrients viz. Nitrogen, phosphorus and potassium after crop growing season and uptake of these nutrients for crop production. Status of organic carbon at pre and post crop season period was also analysed, to evaluate the effect of cropping systems and stress management measures on organic carbon balance of the soil. The change in organic carbon was also determined. The data on nutrients status, uptake of nutrients, available organic carbon and change in organic carbon have been presented in table 4.3 to table 4.10.

### 4.4.1 Nutrients status and uptake of nutrients

The analysis of the soil samples collected at pre and post harvest period, was used to determine available (present) status and uptake of N,P,K nutrients with respect to stress management measures and cropping systems.

#### 4.4.1.1 Available nitrogen (N) (kg/ha)

Data on available nitrogen after harvest of crops (table 4.3) indicated that higher available nitrogen (143.29 kg/ha) was observed in sorghum + pigeonpea, whereas minimum available nitrogen (126.39 kg/ha) was observed in cotton + soybean.

Among stress management measures, higher available nitrogen (153.09 kg/ha) was observed in KCl spray followed by kaoline spray and then control treatment, whereas minimum available nitrogen (118.54 kg/ha) was observed in combination treatment.

In sorghum + pigeonpea higher available nitrogen (168.50 kg/ha) was observed with KCl spray treatment, whereas minimum (120.25 kg/ha) with combination treatment. In soybean + pigeonpea higher available nitrogen (152.30 kg/ha) with KCl spray treatment, whereas minimum (125.26 kg/ha) with combination treatment. In cotton + soybean higher available nitrogen (138.48 kg/ha) with KCl spray treatment and minimum (109.95 kg/ha) with vegetative mulching treatment (Table 4.3).

**Table 4.3 : Available nitrogen (N) (kg/ha) as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | 131.20 | 168.50 | 140.25 | 120.25 | 156.25 | 143.29 |
| Soybean + Pigeonpea | 150.53 | 152.30 | 144.25 | 125.26 | 126.25 | 139.71 |
| Cotton + Soybean | 138.18 | 138.48 | 109.95 | 110.13 | 135.22 | 126.39 |
| Mean | 139.97 | 153.09 | 131.48 | 118.54 | 139.24 | -- |

#### 4.4.1.2 Available phosphorus (P) (kg/ha)

Data on available phosphorus after harvest of crops (table 4.4) indicated that higher available phosphorus (5.98 kg/ha) was observed in cotton +soybean, whereas minimum available phosphorus (5.62 kg/ha) was observed in sorghum +pigeonpea.

Among stress management measures, higher available phosphorus (6.5 kg/ha) was observed in Kaoline spray treatment followed by combination treatment and then control treatment, whereas minimum available phosphorus (5.3 kg/ha) was observed in KCl spray treatment.

In sorghum + pigeonpea higher available phosphorus (6.3 kg/ha) was observed with KCl spray treatment, whereas minimum (5.0 kg/ha) with vegetative mulching treatment. In soybean + pigeonpea higher available phosphorus (7.3 kg/ha) with control treatment, whereas minimum (4.5 kg/ha) with KCl spray treatment. In cotton + soybean higher available phosphorus (7.9 kg/ha) with Kaoline spray treatment,whereas minimum (4.4 kg/ha) with control treatment (Table 4.4).

**Table 4.4 : Available phosphorus (P) (kg/ha) as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | 5.2 | 6.3 | 5.0 | 5.7 | 5.9 | 5.62 |
| Soybean + Pigeonpea | 6.5 | 4.5 | 5.3 | 6.2 | 7.3 | 5.96 |
| Cotton + Soybean | 7.9 | 5.2 | 6.4 | 6.0 | 4.4 | 5.98 |
| Mean | 6.5 | 5.3 | 5.6 | 5.96 | 5.86 | -- |

#### 4.4.1.3 Available potassium (K) (kg/ha)

Data on available potassium after harvest of crops (table 4.5) indicated that higher available potassium (814.06 kg/ha) was observed in cotton + soybean, whereas minimum available potassium (736.04 kg/ha) was observed in sorghum + pigeonpea.

Among stress management measures, higher available potassium (871.7 kg/ha) was observed in KCl spray followed by kaoline spray and control treatment, whereas minimum available potassium (705.4 kg/ha) was observed in combination treatment.

In sorghum + pigeonpea higher available potassium (809.0 kg/ha) was observed with KCl spray treatment, whereas minimum (627.20 kg/ha) with combination treatment. In soybean + pigeonpea higher available potassium (848.60 kg/ha) with KCl spray treatment, whereas minimum (802.60 kg/ha) with Kaoline spray treatment. In cotton + soybean higher available potassium (957.50 kg/ha) with KCl spray treatment, whereas minimum (682.90 kg/ha) with combination treatment (Table 4.5).

**Table 4.5 : Available potassium (K) (kg/ha) as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | 786.10 | 809.0 | 743.0 | 627.20 | 714.90 | 736.04 |
| Soybean + Pigeonpea | 802.60 | 848.60 | 777.80 | 806.10 | 812.50 | 809.52 |
| Cotton + Soybean | 854.20 | 957.50 | 763.50 | 682.90 | 812.20 | 814.06 |
| Mean | 814.3 | 871.7 | 761.43 | 705.4 | 779.8 | -- |

### 4.4.1.4 Uptake of nitrogen (N) (Kg/ha)

Data on uptake of Nitrogen (Table 4.6) indicated that higher nitrogen uptake (109.2 kg/ha) was observed in cotton + soybean, whereas minimum nitrogen uptake (25.90 kg/ha) was observed in soybean + pigeonpea.

Among stress management measures, higher nitrogen uptake (87.05 kg/ha) was observed in combination treatment, followed by vegetative mulching and the control treatment, whereas minimum nitrogen uptake (52.50 kg/ha) was observed in KCl spray treatment.

In sorghum + pigeonpea higher nitrogen uptake (95.35 kg/ha) was observed with combination treatment whereas, minimum was observed with KCl spray treatment (47.1 kg/ha). In soybean + pigeonpea, higher nitrogen uptake (40.34 kg/ha) was observed with combination treatment, whereas minimum was observed with KCl spray treatment (13.3 kg/ha). In cotton + soybean higher nitrogen uptake (125.65 kg/ha) was observed with vegetative mulching and minimum was observed with KCl spray treatment (97.12 kg/ha) (Table 4.6).

**Table 4.6 : Uptake of nitrogen (N) (kg/ha) as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | 84.4 | 47.1 | 75.35 | 95.35 | 59.35 | 72.31 |
| Soybean + Pigeonpea | 15.07 | 13.3 | 21.35 | 40.34 | 39.35 | 25.90 |
| Cotton + Soybean | 97.42 | 97.12 | 125.65 | 125.47 | 100.38 | 109.2 |
| Mean | 65.53 | 52.50 | 74.12 | 87.05 | 66.36 | -- |

### 4.4.1.5 Uptake of Phosphorus (P) (Kg/ha)

Data on uptake of Phosphorus (Table 4.7) indicated that higher Phosphorus uptake (58.04kg/ha) was observed in soybean + pigeonpea, whereas minimum Phosphorus uptake (38.38kg/ha) was observed in sorghum + pigeonpea.

Among stress management measures, higher Phosphorus uptake (48.66 kg/ha) was observed in KCl spray treatment, followed by vegetative mulching and combination treatment, whereas minimum Phosphorus uptake (47.46 kg/ha) was observed in Kaoline spray treatment.

In sorghum + pigeonpea, higher Phosphorus uptake (39.0 kg/ha) was observed with vegetative mulching treatment, whereas minimum was observed with KI spray treatment (37.7 kg/ha). In soybean + pigeonpea higher Phosphorus uptake (59.5 kg/ha) was observed with KCl spray treatment, whereas minimum was observed in control treatment (56.7 kg/ha). In cotton + soybean, higher Phosphorus uptake (49.6 kg/ha) was observed with control treatment, whereas minimum was observed with Kaoline spray treatment (46.1 kg/ha) (Table 4.7).

**Table 4.7 : Uptake of Phosphorus (P) (kg/ha) as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | 38.8 | 37.7 | 39.0 | 38.3 | 38.1 | 38.38 |
| Soybean + Pigeonpea | 57.5 | 59.5 | 58.7 | 57.8 | 56.7 | 58.04 |
| Cotton + Soybean | 46.1 | 48.8 | 47.6 | 48.0 | 49.6 | 48.02 |
| Mean | 47.46 | 48.66 | 48.43 | 48.03 | 48.13 | -- |

### 4.4.1.6 Uptake of Potassium (K) (Kg/ha)

Data on uptake of Potassium (Table 4.8) indicated that higher Potassium uptake (133.36 kg/ha) was observed in sorghum + pigeonpea, whereas minimum Potassium uptake (49.88 kg/ha) was observed in soybean + pigeonpea.

Among stress management measures, higher potassium uptake (144.0 kg/ha) was observed in combination treatment, followed by vegetative mulching and control treatment, whereas minimum potassium uptake (49.76 kg/ha) was observed in KCl spray treatment.

In sorghum + pigeonpea, higher potassium uptake (242.2 kg/ha) was observed with combination treatment, whereas minimum was observed with KCl spray treatment (60.4 kg/ha). In soybean + pigeonpea, higher potassium uptake (81.6 kg/ha) was observed with vegetative mulching treatment, whereas minimum was observed with KCl spray treatment (10.8 kg/ha). In cotton + soybean, higher potassium uptake (136.5 kg/ha) was observed with combination treatment, whereas minimum was observed with Kaoline spray treatment (25.2 kg/ha) (Table 4.8).

**Table 4.8 : Uptake of Potassium (K) (kg/ha) as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | 83.3 | 60.4 | 126.4 | 242.2 | 154.5 | 133.36 |
| Soybean + Pigeonpea | 56.8 | 10.8 | 81.6 | 53.3 | 46.9 | 49.88 |
| Cotton + Soybean | 25.2 | 78.1 | 115.3 | 136.5 | 67.2 | 84.46 |
| Mean | 55.1 | 49.76 | 107.76 | 144.0 | 89.53 | -- |

### 4.4.2 Organic carbon (%)

Data on available organic carbon (%) after harvest of crops (Table 4.9) indicated that among cropping systems, available organic carbon was observed higher in cotton + soybean (0.60 %) whereas, minimum of 0.53% organic carbon was observed in sorghum + pigeonpea. Among stress management measures, the higher available organic carbon was observed in control (0.60%), whereas the minimum of 0.26% was observed in Kaoline spray treatment.

**Table 4.9 : Organic carbon (%) as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | 0.53 | 0.53 | 0.42 | 0.50 | 0.68 | 0.53 |
| Soybean + Pigeonpea | 0.62 | 0.47 | 0.49 | 0.55 | 0.60 | 0.55 |
| Cotton + Soybean | 0.65 | 0.71 | 0.62 | 0.50 | 0.52 | 0.60 |
| Mean | 0.26 | 0.57 | 0.51 | 0.51 | 0.60 | -- |

### 4.4.3 Change in organic carbon (%)

Data on change in organic carbon over pre season organic carbon status (table 4.10) indicated that among cropping systems, the higher increase in organic carbon was observed in sorghum + pigeonpea (0.088%) followed by in soybean + pigeonpea (0.074%). The lowest increase in organic carbon was observed in cotton + soybean (0.020%).

Among stress management measures, the highest change in organic carbon was observed in vegetative mulching (0.11%) followed by that in combination treatment (0.103%). The minimum increase in organic carbon was observed in Kaoline spray (0.02%).

**Table 4.10 : Change in organic carbon (%)as affected by cropping systems and stress management measures during 2009.**

| Treatment | Kaoline spray | KCl spray | Vegetative mulching | Combination | Control | Mean |
|---|---|---|---|---|---|---|
| Sorghum +Pigeonpea | +0.09 | +0.09 | +0.20 | +0.12 | -0.06 | +0.088 |
| Soybean + Pigeonpea | 0 | +0.15 | +0.13 | +0.07 | +0.02 | +0.074 |
| Cotton + Soybean | -0.03 | -0.09 | 0 | +0.12 | +0.10 | +0.020 |
| Mean | +0.02 | +0.05 | +0.11 | +0.103 | +0.02 | - |

# SUMMARY AND CONCLUSIONS

CHAPTER-V

# SUMMARY AND CONCLUSIONS

The study entitled "Performance evaluation of the stress management measures under important cropping systems" was conducted during Kharif-2009 on Research Farm of All India Co-ordinated Research Project for Dryland Agriculture, Marathwada Agricultural University, Parbhani. The study was conducted on vertisol, with 1 per cent land slope in randomized block design (factorial), with three replications. Three important intercropping systems of Marathwada region viz. sorghum + pigeonpea (4:2), soybean + pigeonpea (4:2) and cotton + soybean (1:1) and the stress management measures viz. kaoline spray @ 6%, KCl spray @ 2%, vegetative mulching @ 2 t/ha, combination of above three and control i.e. without any stress management measures, were considered for the study. There were 15 treatment combinations with plot size of 3.6 m x 10.8 m. The treatments of stress management measures were administered during dryspell exceeding 21 days in the crop growing season. The standard package of practices with respect to seed bed preparation, sowing, intercultural operations, plant protection, harvesting and threshing were followed throughout crop growing season. To evaluate the treatment effect, data pertaining to crop yield, runoff, soil loss, soil moisture, pre and post season soil analysis were recorded at appropriate time during crop growing season. Soil moisture monitoring was done during crop growing season by collecting treatment wise soil samples from soil depth of 15, 30 and 60 cm with screw type auger and using gravimetric method for soil moisture determination. Data on soil moisture content and effective rainfall were used to workout soil moisture use and moisture use efficiency. Crops were harvested manually and data on yield of main and by product were maintained replication wise and used to workout yield parameters and cost economics of the treatments.

The results of the soil analysis at pre and post season period, were used to evaluate the treatments with respect to nutrient status, nutrient uptake and organic carbon balance.

The salient results of the study and conclusions are summarized below.

i) During season - 2009, there were three probable rain storms on $25^{th}$ August, $2^{nd}$ September and $4^{th}$ October amounting rainfall of 103.5, 49.1 and 82.2 mm respectively. But the rainfall pattern was such that none of the rain storms could cause runoff event, under any of the treatment combination. Therefore, the total runoff during the season was considered as 0 mm and the corresponding soil loss 0 t/ha.

ii) Among stress management measures, treatment of combination of kaoline spray, KCl spray and vegetative mulching ($T_1$ to $T_3$) was found significantly superior over rest of stress management measures except vegetative mulching ($T_3$). Combination treatment ($T_4$) recorded significantly higher productivity (1992 kg/ha), seed cotton equivalent yield (1796 kg/ha), gross monetary returns (Rs.53879/ha) and net monetary returns (Rs.38351/ha). The significant difference among stress management measures was not observed with respect to B.C. ratio. However, combination treatment recorded higher B.C. ratio of 2.56.

iii) Among cropping systems, soybean + pigeonpea (4:2) was found significantly superior over sorghum + pigeonpea (4:2) and cotton + soybean (1:1). Soybean + pigeonpea recorded significantly higher productivity (1786 kg/ha), seed cotton equivalent yield (1788 kg/ha), net monetary returns (Rs.39864/ha),gross monetary returns (Rs.52726/ha) and B.C. ratio (3.09) over rest of cropping systems.

iv) Among stress management measures, kaoline spray treatment recorded higher soil moisture use of 406.93 mm whereas, control treatment recorded minimum soil moisture use (397.56 mm).

v) Among cropping systems, higher soil moisture use of 403.62mm was recorded in sorghum + pigeonpa, whereas minimum soil moisture use of 394.96 mm was recorded in cotton + soybean.

vi) Combination treatment recorded higher moisture use efficiency of 4.43 kg/mm/ha and Rs.132.98/mm/ha whereas, as usual, control treatment recorded minimum moisture use efficiency of 3.15 kg/mm/ha and Rs.94.40/ mm/ha.

vii) Higher moisture use efficiency of 4.37 kg/mm/ha and Rs.131.22 /mm/ha was recorded in soybean + pigeonpea whereas, cotton + soybean recorded minimum moisture use efficiency of 3.28 kg/mm/ha and Rs.98.38/mm/ha.

viii) Higher available nitrogen and potassium nutrients were observed in KCl spray treatment whereas, minimum available of these nutrients were observed in combination treatment. With respect to available phosphorus, the higher nutrient availability was observed in kaoline spray treatment whereas, minimum in KCl spray treatment.

ix) Combination treatment of stress management recorded higher uptake of nitrogen and potassium nutrients and it utilized N and K nutrients higher respectively by 34.55 and 94.24 kg/ha over KCl spray treatment. With respect to phosphorus uptake, KCl spray treatment recorded higher uptake by 1.20 kg/ha of P nutrient over kaoline spray treatment.

x) The higher addition of organic carbon was observed in vegetative mulching closely followed by combination treatment and the change in organic carbon status by these treatments compared to preseason status was to the tune of 0.11%. The minimum increase in organic carbon was observed in kaoline spray treatment.

On the basis of results of the study, it is concluded that combined application of alternative stress management measures is definitely helpful in management of water stress situation during dryspell, to minimize its adverse effect on crop growth to some extent and to achieve sustainable production during deficit rainfall year. In the present study, combination treatment is found effective in stabilizing the crop yield during critical rainfall year and on an average under three cropping systems, it increased the seed cotton equivalent yield to the tune of 43.79% over the treatment without any stress management measures. The B.C. ratio of combination treatment is worked out as 2.56, compared to 2.02 in control treatment. Combination treatment of stress management is also found effective with respect of nutrient uptake and addition of organic carbon to the soil.

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# APPENDIX

# APPENDIX-A

## Meteorological data during experimental period (2009).

| WK | Period | Rainfall (mm) | R.D. | Temperature °C | | Humidity (%) | | EVP | BSS (Hrs.) | W. V. (Kmph) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Max. | Min. | AM | PM | | | |
| 1 | 01-07 Jan. | 0.0 | 0.0 | 30.4 | 10.7 | 76 | 31 | 4.0 | 9.6 | 2.2 |
| 2 | 08-14 Jan. | 0.0 | 0.0 | 30.7 | 13.3 | 76 | 37 | 4.5 | 9.2 | 3.6 |
| 3 | 15-21 Jan. | 0.0 | 0.0 | 30.6 | 10.3 | 78 | 29 | 5.3 | 10.1 | 3.5 |
| 4 | 22-28 Jan. | 0.0 | 0.0 | 33.8 | 10.4 | 76 | 21 | 5.4 | 10.7 | 2.5 |
| 5 | 29-04 Feb. | 0.0 | 0.0 | 34.9 | 12.9 | 66 | 19 | 5.6 | 10.2 | 2.7 |
| 6 | 5-11 Feb. | 0.0 | 0.0 | 34.5 | 13.2 | 63 | 21 | 5.8 | 10.3 | 2.7 |
| 7 | 12-8 Feb. | 0.0 | 0.0 | 33.4 | 13.3 | 58 | 25 | 5.9 | 9.7 | 2.3 |
| 8 | 19-25 Feb. | 0.0 | 0.0 | 35.7 | 15.4 | 53 | 22 | 6.3 | 9.8 | 3.2 |
| 9 | 26-4 Mar. | 0.0 | 0.0 | 38.0 | 14.1 | 53 | 15 | 8.3 | 10.7 | 3.0 |
| 10 | 5-11 Mar. | 0.0 | 0.0 | 38.5 | 15.6 | 49 | 21 | 8.9 | 10.5 | 3.2 |
| 11 | 12-18 Mar. | 0.0 | 0.0 | 35.7 | 16.1 | 55 | 25 | 7.9 | 8.6 | 4.0 |
| 12 | 19-25 Mar. | 3.4 | 1.0 | 37.7 | 17.0 | 54 | 22 | 8.6 | 10.3 | 4.0 |
| 13 | 16-1 Apr. | 0.0 | 0.0 | 38.8 | 17.1 | 50 | 15 | 9.3 | 10.8 | 3.3 |
| 14 | 2-8 Apr. | 0.8 | 0.0 | 40.8 | 19.3 | 46 | 12 | 11.4 | 9.9 | 4.7 |
| 15 | 9-15 Apr. | 1.6 | 0.0 | 39.9 | 18.4 | 38 | 12 | 10.2 | 11.6 | 3.8 |
| 16 | 16-22 Apr. | 0.0 | 0.0 | 42.4 | 21.3 | 33 | 11 | 13.7 | 10.0 | 6.0 |
| 17 | 23-29 Apr. | 0.0 | 0.0 | 42.6 | 19.3 | 37 | 11 | 13.6 | 10.7 | 4.7 |
| 18 | 30-6 May | 0.0 | 0.0 | 44.0 | 21.1 | 35 | 12 | 14.0 | 10.5 | 6.1 |
| 19 | 7-13 May | 0.0 | 0.0 | 43.0 | 21.9 | 37 | 11 | 15.3 | 10.8 | 7.7 |
| 20 | 14-20 May | 14.5 | 2.0 | 41.9 | 22.7 | 62 | 27 | 11.4 | 7.7 | 7.4 |
| 21 | 21-27 May | 2.1 | 0.0 | 40.3 | 24.0 | 66 | 25 | 11.9 | 9.3 | 8.5 |
| 22 | 28-3 June | 7.4 | 1.0 | 41.3 | 24.6 | 68 | 23 | 12.4 | 10.5 | 8.9 |
| 23 | 4-10 June | 4.0 | 1.0 | 39.1 | 24.8 | 64 | 28 | 11.1 | 10.1 | 10.4 |
| 24 | 11-17 June | 0.0 | 0.0 | 41.0 | 25.6 | 60 | 26 | 12.1 | 11.1 | 9.2 |
| 25 | 18-24 June | 28.3 | 1.0 | 38.8 | 22.4 | 73 | 38 | 8.8 | 8.8 | 7.3 |
| 26 | 25-1 July | 12.5 | 1.0 | 35.6 | 23.1 | 76 | 51 | 7.2 | 5.7 | 6.6 |
| 27 | 2-8 July | 24.0 | 1.0 | 34.6 | 23.2 | 74 | 51 | 6.4 | 4.8 | 7.0 |
| 28 | 09-15 July | 34.8 | 4.0 | 32.2 | 22.8 | 88 | 60 | 4.0 | 2.4 | 6.5 |
| 29 | 16-22 July | 18.2 | 2.0 | 31.7 | 22.6 | 85 | 60 | 4.9 | 3.7 | 8.2 |
| 30 | 23-29 July | 0.0 | 0.0 | 32.6 | 22.5 | 77 | 48 | 5.6 | 6.1 | 8.7 |
| 31 | 30-05 Aug | 0.0 | 0.0 | 34.0 | 20.7 | 73 | 43 | 5.8 | 5.6 | 6.6 |
| 32 | 06-12 Aug | 20.4 | 1.0 | 33.3 | 22.0 | 77 | 48 | 5.8 | 4.9 | 6.5 |
| 33 | 13-19 Aug | 10.6 | 3.0 | 32.3 | 21.4 | 85 | 52 | 3.5 | 3.3 | 6.0 |
| 34 | 20-26 Aug | 207.7 | 6.0 | 29.0 | 20.7 | 95 | 88 | 2.9 | 2.4 | 4.4 |

| WK | Period | Rainfall (mm) | R.D. | Temperature °C | | Humidity (%) | | EVP | BSS (Hrs.) | W. V. (Kmph) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Max. | Min. | AM | PM | | | |
| 35 | 27-2 Sept | 64.6 | 2.0 | 30.7 | 21.1 | 89 | 75 | 3.3 | 4.1 | 5.6 |
| 36 | 03-09 Sept | 21.8 | 3.0 | 29.8 | 21.3 | 89 | 69 | 3.1 | 3.2 | 6.6 |
| 37 | 10-16 Sept | 0.0 | 0.0 | 33.5 | 21.9 | 79 | 52 | 5.6 | 7.2 | 3.7 |
| 38 | 17-23 Sept | 0.0 | 0.0 | 34.4 | 21.0 | 73 | 41 | 6.5 | 8.7 | 3.5 |
| 39 | 24-30 Sept | 38.6 | 2.0 | 35.3 | 22.0 | 80 | 52 | 6.3 | 8.3 | 5.4 |
| 40 | 01-07 Oct. | 100.1 | 3.0 | 30.8 | 21.5 | 92 | 73 | 3.7 | 4.6 | 4.9 |
| 41 | 08-14 Oct. | 0.0 | 0.0 | 32.8 | 19.0 | 77 | 47 | 5.1 | 10.2 | 3.0 |
| 42 | 15-21 Oct. | 0.0 | 0.0 | 34.1 | 16.2 | 69 | 31 | 4.8 | 9.8 | 2.6 |
| 43 | 22-28 Oct. | 0.0 | 0.0 | 33.2 | 12.0 | 75 | 23 | 4.5 | 10.2 | 3.0 |
| 44 | 29-04 Nov. | 0.0 | 0.0 | 33.1 | 10.5 | 70 | 25 | 6.0 | 10.6 | 4.9 |
| 45 | 05-11 Nov. | 17.5 | 2.0 | 31.3 | 16.6 | 78 | 54 | 4.2 | 7.0 | 6.0 |
| 46 | 12-18 Nov. | 30.2 | 3.0 | 30.8 | 19.5 | 88 | 63 | 3.0 | 4.5 | 4.2 |
| 47 | 19-25 Nov. | 0.0 | 0.0 | 28.9 | 10.9 | 76 | 41 | 3.4 | 9.3 | 2.9 |
| 48 | 26-02 Dec. | 0.0 | 0.0 | 29.5 | 9.0 | 78 | 39 | 3.6 | 10.5 | 2.8 |
| 49 | 03-09 Dec. | 0.0 | 0.0 | 30.8 | 11.0 | 81 | 34 | 3.7 | 9.2 | 2.4 |
| 50 | 10-16 Dec. | 0.0 | 0.0 | 30.5 | 11.5 | 77 | 36 | 3.8 | 9.5 | 2.9 |
| 51 | 17-23 Dec. | 1.3 | 0.0 | 29.6 | 12.5 | 78 | 43 | 4.0 | 8.6 | 4.4 |
| 52 | 24-31 Dec. | 8.5 | 1.0 | 28.1 | 8.5 | 77 | 41 | 3.7 | 8.0 | 4.0 |

## APPENDIX-B

### Daily rainfall (mm) at Parbhani during 2009

| Date | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Jan (2010) | Feb (2010) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 49.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.4 | 0.0 | 0.0 | 14.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 82.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 24.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 3.4 | 0.0 | 0.0 | 0.0 | 10.6 | 0.0 | 0.0 | 0.0 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.2 | 2.0 | 0.0 | 0.0 | 4.7 | 0.0 | 0.0 | 0.0 |
| 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 18 | 18.4 | 0.0 | 0.0 | 2.2 | 0.0 | 0.0 | 0.0 |
| 12 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 | 0.0 | 1.5 | 0.0 |
| 13 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.6 | 0.0 |
| 14 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 0.0 | 0.0 | 0.0 | 0.0 | 5.2 | 0.0 | 7.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| 16 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.6 | 0.0 | 0.0 | 7.2 | 0.0 | 0.0 | 1.5 |
| 18 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 19.2 | 1.3 | 0.0 | 0.0 |
| 19 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | 0.0 | 0.0 | 0.0 | 0.0 | 7.3 | 2.0 | 0.0 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 21 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 25.6 | 13.0 | 31.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.2 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 23 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | 0.0 | 0.0 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 23.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 103.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 26 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | 0.0 | 0.0 | 22.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 27 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 29 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 10.8 | 0.0 | 0.0 | 4.4 | 0.0 | 0.0 | 8.0 | 0.0 | -- |
| 30 | 0.0 | -- | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.2 | 0.0 | 0.0 | 0.5 | 0.0 | -- |
| 31 | 0.0 | -- | 0.0 | -- | 0.0 | -- | 0.0 | 0.0 | -- | 0.0 | -- | 0.0 | 0.0 | -- |
| Total R.D. | 0 | 0 | 1 | 0 | 2 | 4 | 7 | 11 | 6 | 3 | 5 | 1 | | |

# APPENDIX-C

**Analysis of potential rainstorms during 2009 at Parbhani**

| Date | Period, hr-min | | Depth, mm | Duration, hr | Rainfall intensity, cm/hr |
|---|---|---|---|---|---|
| | From | To | | | |
| 25.8.09 | 12-15 | 13-20 | 54.0 | 1.08 | 5.0 |
| | 13-20 | 15-00 | 16.00 | 1.67 | 0.96 |
| | 15-00 | 18-45 | 4.5 | 5.75 | 0.12 |
| | 18-45 | 21-00 | 10.0 | 2.25 | 0.44 |
| | 21-00 | 1-00 | 10.0 | 4.0 | 0.25 |
| 2.9.09 | 9-30 | 12-30 | 1.0 | 3.0 | 0.03 |
| | 12-30 | 13-00 | 20.0 | 0.5 | 4.0 |
| | 13-00 | 14-30 | 2.0 | 0.5 | 0.4 |
| | 14-30 | 20-30 | 22.0 | 6.0 | 0.37 |
| 4.10.09 | 12-15 | 12-30 | 5.0 | 0.25 | 2.0 |
| | 12-30 | 14-30 | 31.5 | 2.0 | 1.58 |
| | 14-30 | 16-30 | 42.0 | 2.0 | 2.1 |
| | 16-30 | 19-15 | 2.0 | 2.75 | 0.07 |

# APPENDIX-D

**Moisture content (%) observed during study period (2009).**

**1. Date : 23.7.09**

| Treatments | 0-15 (cm) | 15-30 (cm) | 30-60 (cm) |
|---|---|---|---|
| $C_1T_5$ | 33.72 | 24.43 | 6.97 |
| $C_2T_5$ | 36.01 | 25.36 | 5.69 |
| $C_3T_5$ | 33.74 | 21.34 | 7.82 |

**2. Date : 8.8.09**

| Depth (cm) / Treatments | 0-15 | 15-30 | 30-60 |
|---|---|---|---|
| **Sorghum + pieonpea (C1)** | | | |
| $T_1$ | 18.20 | 15.74 | 17.64 |
| $T_2$ | 16.27 | 17.09 | 20.19 |
| $T_3$ | 19.61 | 22.25 | 22.54 |
| $T_4$ | 21.35 | 22.25 | 23.76 |
| $T_5$ | 18.20 | 21.35 | 21.95 |
| **Soybean + pieonpea (C2)** | | | |
| $T_1$ | 18.76 | 19.05 | 18.20 |
| $T_2$ | 15.74 | 16.55 | 19.61 |
| $T_3$ | 19.90 | 22.54 | 22.54 |
| $T_4$ | 21.95 | 22.55 | 23.15 |
| $T_5$ | 18.76 | 20.48 | 21.06 |
| **Cotton + Soybean (C3)** | | | |
| $T_1$ | 19.33 | 14.03 | 17.64 |
| $T_2$ | 17.28 | 13.88 | 21.82 |
| $T_3$ | 20.19 | 22.14 | 22.38 |
| $T_4$ | 22.54 | 23.45 | 24.68 |
| $T_5$ | 18.48 | 21.06 | 21.35 |

(Cont..)

3. **Date : 26.9.09**

| Depth (cm) / Treatments | 0-15 | 15-30 | 30-60 |
|---|---|---|---|
| **Sorghum + pieonpea (C1)** | | | |
| $T_1$ | 16.82 | 18.76 | 18.20 |
| $T_2$ | 18.20 | 17.64 | 20.48 |
| $T_3$ | 17.09 | 19.90 | 23.15 |
| $T_4$ | 22.25 | 22.55 | 23.45 |
| $T_5$ | 18.76 | 17.64 | 19.33 |
| **Soybean + pieonpea (C2)** | | | |
| $T_1$ | 16.82 | 17.92 | 17.09 |
| $T_2$ | 17.92 | 16.82 | 19.33 |
| $T_3$ | 17.37 | 20.48 | 22.54 |
| $T_4$ | 16.55 | 19.61 | 22.25 |
| $T_5$ | 14.94 | 17.64 | 20.48 |
| **Cotton + Soybean (C3)** | | | |
| $T_1$ | 17.64 | 18.48 | 17.92 |
| $T_2$ | 18.48 | 15.20 | 19.90 |
| $T_3$ | 17.64 | 20.19 | 22.55 |
| $T_4$ | 22.55 | 23.15 | 23.22 |
| $T_5$ | 16.82 | 19.33 | 20.48 |

**(Cont..)**

4. **Date : 16.12.09**

| Depth (cm) / Treatments | 0-15 | 15-30 | 30-60 |
| --- | --- | --- | --- |
| **Sorghum + pieonpea (C1)** | | | |
| $T_1$ | 15.47 | 17.92 | 15.74 |
| $T_2$ | 15.74 | 16.82 | 18.76 |
| $T_3$ | 19.04 | 19.61 | 20.48 |
| $T_4$ | 21.65 | 21.95 | 25.62 |
| $T_5$ | 17.09 | 16.00 | 18.48 |
| **Soybean + pieonpea (C2)** | | | |
| $T_1$ | 16.00 | 18.48 | 16.00 |
| $T_2$ | 16.27 | 18.20 | 18.76 |
| $T_3$ | 19.33 | 19.90 | 19.61 |
| $T_4$ | 21.35 | 21.65 | 19.04 |
| $T_5$ | 16.82 | 15.74 | 18.76 |
| **Cotton + Soybean (C3)** | | | |
| $T_1$ | 16.27 | 19.04 | 16.27 |
| $T_2$ | 18.42 | 16.27 | 13.63 |
| $T_3$ | 19.04 | 19.04 | 21.95 |
| $T_4$ | 21.95 | 21.95 | 19.04 |
| $T_5$ | 14.28 | 16.27 | 19.04 |

**(Cont..)**

5. **Date : 16.1.2010**

| Depth (cm) / Treatments | 0-15 | 15-30 | 30-60 |
|---|---|---|---|
| **Sorghum + pieonpea (C1)** | | | |
| $T_1$ | 19.63 | 18.62 | 16.82 |
| $T_2$ | 15.10 | 19.05 | 19.85 |
| $T_3$ | 21.35 | 21.65 | 22.77 |
| $T_4$ | 20.19 | 20.19 | 19.85 |
| $T_5$ | 17.64 | 19.33 | 19.33 |
| **Soybean + pieonpea (C2)** | | | |
| $T_1$ | 20.00 | 14.15 | 17.92 |
| $T_2$ | 19.74 | 19.61 | 21.22 |
| $T_3$ | 19.04 | 19.61 | 21.95 |
| $T_4$ | 15.18 | 20.77 | 19.90 |
| $T_5$ | 17.92 | 19.05 | 20.71 |
| **Cotton + Soybean (C3)** | | | |
| $T_1$ | 21.95 | 21.65 | 19.54 |
| $T_2$ | 21.95 | 21.35 | 20.21 |
| $T_3$ | 23.43 | 24.68 | 24.37 |
| $T_4$ | 21.06 | 21.65 | 14.18 |
| $T_5$ | 21.65 | 21.65 | 14.18 |

(Cont..)

## APPENDIX-E

**Sample calculation for soil moisture use (mm) and moisture use efficiency (kg/mm/ha & Rs/mm/ha)**

i) Field consumptive use by cotton + soybean (1:1) under control treatment was calculated using formula.

$$Cu = \sum_{i=1}^{N} \frac{(M_1i - M_2i)}{100} \times Asi \times Di \times ER$$

Where,

| | | |
|---|---|---|
| Cu | = | Consumptive use in cm. |
| $M_1i$ | = | Moisture content (d.b.) at first sampling in $i^{th}$ layer, (%) |
| $M_2i$ | = | Moisture content (d.b.) at second sampling in $i^{th}$ layer, (%) |
| Asi | = | Apparent specific gravity of soil in the $i^{th}$ layer (gm/cc) |
| Di | = | Depth of $i^{th}$ layer soil (cm) |
| ER | = | Effective rainfall, (cm) |
| N | = | Number of soil layers sampled in root zone at depth D |

ii) Apparent specific gravity dry density for vertisol was considered as 1.3 gm/cc.

iii) The effective rainfall during crop growing season (2009) was calculated using criteria suggested by Kaore and Bathkal (1982).

iv) The product of Asi x Di x M using moisture content at the time of sowing was calculated as,

$$\frac{(33.74 \times 15 + 21.34 \times 15 + 7.82 \times 30)}{100} \times 1.3 = 13.79 \text{ cm}$$

| Date | Rainfall | Effective rainfall |
|---|---|---|
| 27.7.2009 | 13 | 8.0 |
| 11.8.2009 | 18.4 | 15.9 |
| 20.8.2009 | 15.0 | 13.5 |
| 21.8.2009 | 31.4 | 29.9 |
| 22.8.2009 | 12.0 | 9.8 |
| 24.8.2009 | 23.0 | 20.5 |
| 25.8.2009 | 103.5 | 73.5 |
| 26.8.2009 | 22.8 | 20.3 |
| 27.8.2009 | 14.0 | 11.5 |
| 2.9.2009 | 49.1 | 46.8 |
| 3.9.2009 | 14.0 | 11.5 |
| 30.9.2009 | 34.2 | 28.9 |
| 1.10.2009 | 14.2 | 10.7 |
| 4.10.2009 | 82.2 | 75.4 |
| 9.11.2009 | 10.6 | 7.4 |
| 17.11.2009 | 7.2 | 4.2 |
| 18.11.2009 | 19.2 | 17.2 |
| Total effective rainfall | | 405 mm |

v) In similar manner, moisture content in percentage was converted into depth of moisture available in the soil and added for each time interval of moisture observation during crop growing season. The values for cotton + soybean cropping system under control treatment, thus obtained were,

| Date | Soil moisture depth (cm) |
|---|---|
| 8.8.2009 | 16.26 |
| 26.9.2009 | 15.04 |
| 16.12.09 | 13.38 |
| 16.1.2010 | 13.97 |

vi) Soil moisture use (cm) thus worked out as

(13.79-16.26) + (16.26-15.04) +(15.04-13.38) + (13.38-13.97) + 40.5

= 40.32 cm

vii) Moisture use efficiency under cotton + soybean with control treatment corresponding to seed cotton equivalent yield of 997.94 kg/ha and gross monetary returns of Rs. 29905 mm/ha were,

i) Moisture use efficiency = SCEY (kg/ha) / MU (mm)

= 997.94/403.2

= 2.48 kg/mm/ha

ii) Moisture use efficiency = $\dfrac{\text{GMR (Rs/ha)}}{\text{MU (mm)}}$

= 29905/403.2

= Rs 74.17/mm/ha

## APPENDIX-F

## Cost of cultivation

| Field operations | Sorghum + pigeonpea | Soybean + pigeonpea | Cotton+ soybean |
|---|---|---|---|
| **Preparatory tillage** | | | |
| Ploughing (summer) | 2000 | 2000 | 2000 |
| Harrowing (Two) | 2000 | 2000 | 2000 |
| Stubble collection and cleaning | 500 | 500 | 500 |
| **Sowing** | | | |
| Seed | 450 | 1625 | 2000 |
| Fertilizers/manures | 2000 | 1765 | 2200 |
| Operation cost (sowing and fertilizer application) | 750 | 750 | 1000 |
| **Cultural operations** | | | |
| Thinning/gap filling | -- | -- | -- |
| Weeding / weedicide application | 1000 | 1000 | 1000 |
| Hoeing | 700 | 700 | 700 |
| Plant protection | -- | -- | 500 |
| Irrigation (protective) | -- | -- | -- |
| Other operation top dressing | 100 | -- | 200 |
| **Harvesting, threshing, cleaning, transportation and bagging** | 2000 | 1500 | 750+P.C.* |
| Miscellaneous | -- | -- | -- |
| Total Rs/ha (control) | 11500/- | 11840 | 12850+P.C. * |
| Rs/plot (control) | 44.71 | 46.10 | 49.36 +P.C. |
| **Treatments cost** | Rs/ha / Rs/plot | Rs/ha / Rs/plot | Rs/ha / Rs/plot |
| Kaoline spray (@ Rs700/ha) | 12200/47.45 | 12540/48.75 | 13550+P.C./ 52.68+P.C. |
| Vegetative mulching (@ Rs 1500/ha) | 13000/50.55 | 13340/51.85 | 14350+P.C./ 55.80 +P.C. |
| Combination (@ Rs 2200/ha) | 13700/53.25 | 14040/54.60 | 15050+P.C./ 58.51 +P.C. |
| KCl spray(@ Rs 700/ha) | 12000/47.45 | 12540/48.75 | 13550+P.C./52.68 +P.C. |

* Picking charges @ Rs. 3 per kg of seed cotton

## APPENDIX-G

## Soil analysis report

| Treatment | pH | Ec ($dSm^{-1}$) | OC (%) | $CaCo_3$ (%) | Available nutrients (kg/ha) | | |
|---|---|---|---|---|---|---|---|
| | | | | | N | P | K |
| $C_1T_1$ | 7.52 | 0.12 | 0.53 | 3.1 | 131.20 | 5.2 | 786.10 |
| $C_1T_2$ | 8.03 | 0.19 | 0.53 | 4.9 | 168.50 | 6.3 | 809.00 |
| $C_1T_3$ | 7.88 | 0.13 | 0.42 | 5.0 | 140.25 | 5.0 | 743.00 |
| $C_1T_4$ | 8.10 | 0.12 | 0.50 | 5.1 | 120.25 | 5.7 | 627.20 |
| $C_1T_5$ | 8.24 | 0.10 | 0.68 | 5.7 | 156.25 | 5.9 | 714.90 |
| $C_2T_1$ | 8.22 | 0.10 | 0.62 | 3.3 | 150.33 | 6.5 | 802.60 |
| $C_2T_2$ | 8.10 | 0.12 | 0.47 | 3.7 | 152.30 | 4.5 | 848.60 |
| $C_2T_3$ | 8.03 | 0.12 | 0.49 | 3.7 | 144.25 | 5.3 | 777.80 |
| $C_2T_4$ | 7.88 | 0.12 | 0.55 | 5.1 | 125.26 | 6.2 | 806.10 |
| $C_2T_5$ | 7.73 | 0.15 | 0.60 | 5.4 | 126.25 | 7.3 | 812.50 |
| $C_3T_1$ | 8.18 | 0.11 | 0.65 | 5.5 | 138.18 | 7.9 | 854.20 |
| $C_3T_2$ | 8.17 | 0.14 | 0.71 | 3.5 | 138.48 | 5.2 | 957.50 |
| $C_3T_3$ | 7.97 | 0.11 | 0.62 | 4.1 | 109.95 | 6.4 | 763.50 |
| $C_3T_4$ | 8.13 | 0.11 | 0.50 | 3.1 | 110.13 | 6.0 | 682.90 |
| $C_3T_5$ | 8.16 | 0.12 | 0.52 | 4.3 | 135.22 | 4.4 | 812.20 |
| General | 8.02 | 0.16 | 0.62 | 5.7 | 135.60 | 4.0 | 829.40 |

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## APPENDIX-H

**Average seed cotton equivalent yield (kg/ha) and gross monetary returns (Rs/ha) during 2009.**

| Treatments | Gross monetary returns | | Seed cotton equivalent yield | |
|---|---|---|---|---|
| | Rs/plot | Rs/ha | Kg/plot | Kg/ha |
| C1-Sorghum + pigeonpea | | | | |
| $T_1$ | 171.19 | 44030.34 | 5.71 | 1468.62 |
| $T_2$ | 177.56 | 45668.72 | 5.92 | 1522.63 |
| $T_3$ | 175.69 | 45187.75 | 5.86 | 1507.20 |
| $T_4$ | 202.23 | 52013.89 | 6.74 | 1733.53 |
| $T_5$ | 155.89 | 40095.16 | 5.20 | 1337.45 |
| C2-Soybean + pigeonpea | | | | |
| $T_1$ | 202.48 | 52078.19 | 6.75 | 1736.11 |
| $T_2$ | 211.31 | 54349.28 | 7.05 | 1813.27 |
| $T_3$ | 218.35 | 56159.98 | 7.28 | 1872.42 |
| $T_4$ | 228.05 | 58654.83 | 7.60 | 1954.73 |
| $T_5$ | 164.79 | 42384.26 | 5.50 | 1414.60 |
| C3-Cotton+soybean | | | | |
| $T_1$ | 136.58 | 35128.60 | 4.55 | 1170.27 |
| $T_2$ | 138.89 | 35722.74 | 4.63 | 1190.84 |
| $T_3$ | 164.17 | 42224.79 | 5.47 | 1406.89 |
| $T_4$ | 198.17 | 50969.65 | 6.61 | 1700.10 |
| $T_5$ | 116.27 | 29904.80 | 3.88 | 997.94 |

## APPENDIX-I

**Weighted average prices of Agril. Commodities for the year 2009-10 considered for calculation of monetary returns**

| Sr.No | Crop | Grain (Rs/Qt.) | Fodder/straw (Rs/Qt.) |
|---|---|---|---|
| 1 | Cotton (Bunny Bt.) | 3000 | -- |
| 2 | Soybean | 2327 | -- |
| 3 | Pigeonpea | 3167 | 60 |
| 4 | Hybrid/HYW Sorghum | 840 | 150 |