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EFFECTS OF *GLUCONACETOBACTER* AND *AZOTOBACTER* ON GROWTH AND YIELD OF *KHARIF* SORGHUM

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B.Sc. (Agri.)

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MASTER OF SCIENCE

IN

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(AGRONOMY)

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE, LATUR

VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH

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2015

EFFECTS OF *GLUCONACETOBACTER* AND *AZOTOBACTER* ON GROWTH AND YIELD OF *KHARIF* SORGHUM

DISSERTATION

SUBMITTED TO

VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH, PARBHANI

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

MASTER OF SCIENCE

IN

AGRICULTURE

(Agronomy)

BY

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COLLEGE OF AGRICULTURE, LATUR
VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH,
PARBHANI 431 402 (M.S.) INDIA

2015

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RESEARCH GUIDE

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I hereby declare that this dissertation or part thereof has not been previously submitted by me for a degree of any University or Institution.

Place : Latur

Date : 30/05/2015

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CERTIFICATE – I

This is to certify that the dissertation entitled **"EFFECTS OF *GLUCONACETOBACTER* AND *AZOTOBACTER* ON GROWTH AND YIELD OF *KHARIF* SORGHUM"** submitted by **Shri. MITKE MARKANDEY SHIVAJIRAO** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRONOMY** is record of original and bonafide research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.

I also certify that the dissertation or part thereof has not been previously submitted for a degree of any university. The assistance and help rendered during the course of investigation and sources of literature have been duly acknowledged.

Place : Latur
Date : 30 /05/ 2015

(Dr. V. P. Suryavanshi)
Research Guide and Chairman
of Advisory Committee

CERTIFICATE - II

This is to certify that the dissertation entitled **"EFFECTS OF *GLUCONACETOBACTER* AND *AZOTOBACTER* ON GROWTH AND YIELD OF *KHARIF* SORGHUM"** submitted by **Shri. MITKE MARKANDEY SHIVAJIRAO** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRONOMY** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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"Perfection consists not in doing extraordinary things, but in doing ordinary things extraordinarily well"

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Place: Latur

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(MITKE MARKANDEY SHIVAJIRAO)

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LIST OF ABBREVIATIONS

et al.,	-	And others
@	-	At the rate of
B:C	-	Benefit to cost ratio
cm	-	Centimetre(s)
C.D.	-	Critical difference
DAS	-	Days after sowing
°C	-	Degree Celsius
Fig.	-	Figure
FYM	-	Farmyard manure
NS	-	Non-significant
g	-	Grams(s)
ha	-	Hectare(s)
kg	-	Kilogram(s)
Lit./L	-	Litre(s)
Max.	-	Maximum
M.W.	-	Meteorological Week
m	-	Metre(s)
MOP	-	Murriate of Potash
ml	-	Millilitre(s)
Min.	-	Minimum
N	-	Nitrogen
LAI	-	Leaf area index
AGR	-	Absolute growth rate
RGR	-	Relative growth rate
viz.	-	Namely
%	-	Percent
P	-	Phosphorus
PSB	-	Phosphorus Solubilizing Bacteria
ppm	-	Parts per million
K or K_2O	-	Potassium
Q/q	-	Quintal(s)
RDN	-	Recommended dose of nitrogen
RH	-	Relative humidity
₹	-	Rupee(s)
Sr.	-	Serial
pH	-	Soil reaction
cm^2	-	Square centimetre(s)
T/t	-	tonne(s)
S.Em.	-	Standard error of mean
SSP	-	Single super phosphate
Temp.	-	Temperature
i.e.	-	That is

INTRODUCTION

Chapter-I

INTRODUCTION

In world sorghum (*Sorghum bicolor* (L.) Moench) is the fourth most important cereal following wheat, rice and maize. The word sorghum is derived from latin word 'Sargo'means 'rising above' i.e. growing taller than other crops in the field. It is probably originated in East Central Africa and it was introduced to India from East Africa in the year 1500BC. It is staple food crop of millions of the poor in semi arid tropics of Africa and Asia. It can tolerate hot and dry conditions. Because of its drought resistance, it is a very good crop for areas of scarcity rainfall. It is called the great millet because of its large size grain.

Sorghum is important feed and food in the world and used as fodder to feed millions of animals providing milk and meat for man. It is also used industrial raw material in various industries. In India flour is used after grinding the grains for preparing *'Bhakri'*. To some extent it is also eaten as parched and popped grain. Sorghum is the basic feed for humans and livestock in most regions of the world. Its fodder contains more than 50% digestible nutrients with 8% protein, 2.5% fat and 45% nitrogen free extract.

Sorghum belongs to the family gramineae. Sorghum is one of the most important cereal crops widely grown for food, feed, fodder, forage and fuel in the semi arid tropics of Asia, Africa, America and Australia. Sorghum has an immense range of genetic variability with characteristics of rich sources of resistance to diseases, insects pests and the other stresses such as high temperature and drought.Sorghum gives health benefits. Sorghum may inhibit cancer tumour growth. Sorghum may protects against diabetes and insulin resistance. It is safe for people with celiac disease. Sorghum plays important role in managing cholesterol. Sorghum may help treat human melanoma.

In India, sorghum is the third important cereal crop after wheat and rice. This crop have importance in the cropping pattern of the farmers. It is cultivated in large scale in countries like South Africa, Sudan, Egypt, North America and China. In world sorghum is grown on 40 million hectare area with production of 60.13

million tones. India has the largest share (34 percent) of the world's area under sorghum with 17 per cent of production and rank second in production after the United States. The sorghum productivity in India is less (954 kg/ha) as compared to other countries *viz.* Argentina (5090 kg/ha), China (3600 kg/ha) and Mexico (3470 kg/ha). In India; Maharashtra, Gujrat and Rajasthan are the major sorghum growing states. In India, it grown on 6.32 million hectare area with production of 6.03 million tones and productivity of 954 kg/ha (Anonymous, 2012-13).

Sorghum is main cereal crop of Maharashtra and it foremost sorghum growing states in the country with an area, production, productivity of *kharif* jowar was 6.18 lakh ha, 7.27 lakh tonnes and 2177 kg/ha, respectively. In Maharashtra it is truely the "poor man's bread". In Marathwada region, area, production, productivity of *kharif* jowar was 2.52 lakh ha, 2.77 lakh tonnes and 1099 kg/ha, respectively (Anonymous, 2013-14). Marathwada and Western Maharashtra regions of the states of Maharashtra known as the 'Sorghum Bowl of India'.

To get high yields of sorghum, the correct amount of nitrogen fertilizer should be applied. On the global scene regarding plant nutrients and their importance, N is considered the most limiting factor for plant growth after water. Grain yield of sorghum is a result of many attributing factors such as panicle length, grains per panicle and test weight, which work together to enhance yield. Almodares *et al.*, (2010) reported that application of nitrogen increased panicle length, number of grains per panicle. On the contrary, Solankey *et al.*,(1990) reported a that there was an increased test weight with nitrogen application.

The term biofertilizer or called 'microbial inoculants' can be generally defined as a preparation containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulytic microorganisms used for application of seed, soil or composting areas. In the cereal, the fertilizers requirement is more especially nitrogenous fertilizers.The inoculation of biofertilizers in sorghum crops improve the uptake of nutrient. The inoculation of biofertilizers helps in the absorption of nitrogen by roots which increase the growth and yield of crop. The inoculation of biofertilizers reduses the fertilizer requirment in sorghum crop.

Recently acetobacteraceae has been reported to include various genera, *viz. Acetobacter* , *Gluconacetobacter, Gluconobacter,* and *Acidomonas. Acetobacter diazotrophicus* has been corrected as *Gloconacetobacter diazotrophicus. Azotobacter* fixes atmospheric nitrogen asymboitically besides nitrogen fixing. It also produces antifungal metabolizes and certain vitamin and growth promoting substances which increase seed germination and plant stand.*Gluconacetobacter diazotrophicus* is a gram-negative, acid tolerant, obligate aerobe and the cells are straight rods with rounded ends (0.7-0.9 micrometer by 1-2 micrometer). The cells can be seen under microscope as single, pair or chain like structures with endospores. This bacterium grows on high sucrose concentration (10 percent sucrose) and very low pH (3.0) and has ability to fix nitrogen under microaerobic conditions. It play a crucial role, in sugarcane, but in growth promotion of other plants also. It actually fix upto 70 percent of their nitrogen requirements.

Gluconacetobacter diazotrophicus is so important that recently a complete genome sequence of the sugarcane nitrogen fixing endophytic *Gluconacetobacter diazotrophicus* has been completed. It shows multicharacteristics such as plant growth promotion, sugar metabolism pathways, secretion of organic acids, promotes an increase in the solubility of phosphate as well as zinc, synthesis of auxin and antifungal-antibacterial properties and occourance of bacteriocins.

In order to study the efficient utilization of chemical fertilizers reduce the expenditure on chemical fertilizer and use of bioinoculants for improvement in yield potential and quality of cereal crops. It is important to work on effect of different combinations of chemical fertilizers in conjugation with bioinoculants. With this background, the present investigation entitled " Effects of gluconacetobacter and azotobacter on growth and yield of *kharif* sorghum" will be carried out at Experimental Farm, College of Agriculture, Latur.

OBJECTIVES :-

1. To assess the growth and yield of *kharif* sorghum by the inoculation of carrier and liquid based *gluconacetobacter* and *azotobacter* biofertilizers

2. To calculate the economics of sorghum cultivation due to different biofertilizers

REVIEW OF LITERATURE

Chapter= II

REVIEW OF LITERATURE

Many factors are associated with crop yield in case of sorghum; biofertilizer inoculation is one of the important aspects in obtaining good yield. It has marked influence on yield of sorghum. The sorghum yield is obviously high at application of biofertilizer inoculation. So for increasing the yield of sorghum we can apply suitable fertilizer levels along with biofertilizers such as *Gluconacetobacter, azotobactor* and *azospirillum.*

The following few pages are devoted for outlining the review of published literature in respect of nitrogen levels and application of biofertilizer management in cereals and its effect on growth and yield of cereals studied by several workers are summarized in this chapter. During last some decade, researchers have undertaken studies on effect of biofertilizer inoculation on cereals. So an attempt has made to present brief review in this chapter.

2.1 Effect of biofertilizer inoculation on growth and yield of *kharif* sorghum.

Rex L. Smith *et al* (1984) conducted a field experiment at Department of Agronomy, New Mexico on responses of sorghum and *Pennisetum species* to the N2 - fixing bacterium *Azospirillum brasilense*. The yield of sorghum of the inoculated plots on a hectare basis was 5951 kg ha $^{-1}$ for an increase of 566 kg ha $^{-1}$ or 11% due to inoculation of *Azospirillum brasilense.*

Alagwadi and Gaur (1988) conducted a field experiment at Indian Agricultural Research Institute, New Delhi in sandy-loam alluvial soil to study the interaction between Azospirillum and PSB and their influence on yield, nutrient uptake and acetylene reduction activity of sorghum under greenhouse conditions. They found that there was a significant increase in the grain and dry matter yield and nutrient uptake in sorghum due to combine inoculation.

Naik *et al* (1993) conducted a field experiment at University of Agricultural Sciences, Dharwad to evaluate the effect of inoculation of *Glomus fasciculatum* in combination with different amendments and observed that combination of FYM and inoculation of *Glomus fasciculatum* showed highest percent root colonization (100%), spore count/ 50 g air dried soil (307), shoot dry biomass (18.4 g plant $^{-1}$), shoot P concentration (0.28%) and seed yield (9 g plot $^{-1}$) in DWR- 39 genotype of wheat.

Rasal and Patil (1993) conducted a field experiment at College of Agriculture, Mahatma Phule Agricultural University, Pune, Maharastra, to study the effect of organic matter with microbial inoculants on pearl millet. They reported highest grain yield (22.2 q ha $^{-1}$) and highest dry matter yield (80.0 q ha $^{-1}$) with the application of compost + cellulose decomposing culture + *Azotobacter* + phosphate solubilizing culture.

Majjigudda and Srenivasa (1996) attempted a field experiment at University of Agricultural Sciences, Dharwad on influence of VA- mycorrhizal fungi on growth and yield of wheat. They recorded the highest shoot dry weight (9.3 g plant $^{-1}$), highest shoot P concentration (0.23 %), highest shoot dry weight (9.3 g plant $^{-1}$) and highest seed yield (4.8 g plant $^{-1}$) with the inoculation of *Glomus fasciculatum.*

Pawar *et al* (1996) conducted a field experiment at College of Agriculture, Pune to study the combined effects of *Azotobacter* and *Azospirillum* with nitrogen on yield of sorghum. The application of 120 kg N ha $^{-1}$ along with dual inoculation of *Azospirillum* and *Azotobacter* resulted highest grain yield (48.45 q ha $^{-1}$) and fodder yield (127.47 q ha $^{-1}$).

Mastiholi and Itnal (1997) conducted a field experiment at Regional Reaserch Station, Bijapur, Dharwad in deep black soils on response of *rabi* sorghum to application of boifertilizers under dryland conditions. They observed that grain yield of sorghum was significantly influenced due to application of biofertilizers. The highest grain weight plant^{-1} (41.832 g), grain yield (2713 kg ha^{-1}) and number of seeds (1368 seeds ear^{-1}) were recorded with application of *Azospirillum* at 5 kg ha^{-1} + 100 percent recommended N dose.

Vivek Kumar *et al* (1999) studied the effect of phosphate solubilizing analogue resistant mutants of *Azotobacter chroococcum* on sorghum at Chaudhary Charan Singh Haryyana Agricultural University, Hisar and resulted that the strain PS 2 of *Azotobacter chroococcum* significantly enhanced highest number of plants /m row length (34.6), plant height (158.1cm), green fodder yield (21.9 t ha^{-1}) and dry fodder yield (6.9 t ha^{-1}).

Mane *et al* (2000) attempted a field experiment during *kharif* season at Marathwada Agricultural University, Parbhani Maharashtra to study the response of pearl millet to inoculation of PSB and *Azospirillum*. They examined that highest root dry weight (1.35 g $plant^{-1}$), shoot dry weight (5.80 g $plant^{-1}$) and grain yield (395 kg ha^{-1}) by dual inoculation of *Azospirillum* and PSB to pearl millet.

Swedrzynska D. (2000) carried out a field experiment on effect of inoculation with *Azospirillum brasilense* on development and yielding of winter wheat and oat under different conditions. The yield of wheat increased upto 28.7 t ha^{-1}(27%) and of oat increased upto 43.5 t ha^{-1}(6%).

Barik and Nag (2001) conducted a field experiment at Agricultural Research Farm of Palli Siksha Bhavana, Vishva-Bharati, Sriniketan, West Bengal on effect of biofertilizers with levels of nitrogen on grain yield of sorghum. They found that *Azospirillum* and *Azotobacter* increased the grain yield of sorghum by 8.73 percent and 11.91 percent respectively and the yield attributes and grain yield were increased with increasing levels of nitrogen upto 90 kg ha^{-1} where grain yield of 1514 kg ha^{-1} was achieved. The interaction effect between inoculation and N levels was found significant with respect to panicle length, grains/panicle, test weight and grain yield of sorghum.

Nayak *et al* (2001) conducted a field experiment at College of Agriculture, Indore to study the response of sorghum to *Azospirillum*. They examined highest grain yield (6027 kg ha^{-1}) and fodder yield (13961 kg ha^{-1}) was recorded under *Azospirillum* strain.

Patidar and Mali (2001) studied an experiment at Rajastan College of Agriculture, Rajastan Agriculture University, Udaipur on integrated nutrient management in sorghum and observed highest plant height (202.8 cm), grain yield (4.15 t ha^{-1}) and straw yield (9.79 t ha^{-1}) with the application on *Azospirillum*.

Deokar and Sawant (2002) conducted a field experiment at Mahatma Phule Krishi Vidyapeeth, Rahuri to study the effect of *Azotobacter* liquid bio-inoculants on grain yield, fodder yield contributing components in hybrid sorghum. They observed that the hybrid sorghum variety CSH-9 responded better for *Azotobacter* liquid bioinoculant application than Amarnath 251. The sorghum hybrid CSH-9 gave highest number of grains (2471 $earhead^{-1}$), grain weight (74.61 g $earhead^{-1}$), grain yield (48.40 g $palnt^{-1}$), dry matter yield (14.88 ton ha^{-1}), 100 grain weight (3.06 g) and harvest index (42.51 percent) with the inoculation of liquid *Azotobacter*.

Kader *et al* (2002) conducted a pot experiment at Bangladesh Agricultural University, Bangladesh to study the effect of *Azotobacter* inoculants on the yield of wheat. They examined that, the highest plant height (53.74 cm), spike length (6.31 cm), grain/ spike length (15.10), 1000 grain weight (51.72 g), grain yield (7240 mg $plant^{-1}$), straw yield (540 mg $plant^{-1}$), root weight (279 mg $plant^{-1}$) and total dry weight (1599 $mgplant^{-1}$) with the inoculation of *Azotobacter*.

Kumar and Sharma (2002) studied at Department of Agronomy, Agricultural Research Station, Durgapura, Jaipur on effect of different levels of FYM (0, 10, 20 ton ha^{-1}), nitrogen (0,40,80 and 120 kg ha^{-1}) and *Azospirillum* culture on yield and quality of fodder sorghum. They also observed that increase in green and dry fodder yield due to *Azospirillum* inoculation varied from 7.8 to 11.3 percent but its inoculation had no effect on crude protein and crude fibre.

Chandrasekar *et al* (2005) attempted a field experiment at Bharathidasan University, Tiruchirapalli, Tamil Nadu on influence of biofertilizers and nitrogen source level on the growth and yield of barnyard millet. They observed that, highest yield of *Azospirillum* with 100% urea (8525.55 kg ha^{-1}).

Banerjee *et al* (2006) presented an experiment on impact of chemical fertilizers and biofertilizers on the yield under maize- wheat cropping system. They observed that highest maize grain yield (5.13 t ha^{-1}) and wheat grain yield (6.03 t ha^{-1}) under the treatment of N120RP30PSB.

Sheoran and Rana (2006) carried out an experiment at Forage Research Section CCS Haryana Agricultural University, Hisar, Haryana to study on the relative efficiency of *Azotobacter* and nitrogen fertilizer in forage sorghum under semi arid condititions. They observed that, the green fodder and dry matter yields were increased to the tune of 7.3 and 9.3 percent due to azotobacterization over uncultured treatment and increasing level of nitrogen upto 60 kg ha^{-1} increased the forage yield of sorghum significantly..

Virendra Kumar and Ahlawat (2006) conducted a field experiment at IARI, New Delhi on effect of biofertilizer and nitrogen on wheat. They observed that *Rhizobacteria* recorded highest plant height (66.9 cm), highest leaf area index at 80 days (3.33), spike length (9.11 cm), highest spikelets/ spike (14.50), highest grain yield (4.34 t ha^{-1}) and highest straw yield (6.67 t ha^{-1}).

Gawai and Pawar (2007) conducted a field experiment at Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri in clayey soil to study the effect of Integrated Nutrient Management system in sorghum-chickpea cropping sequence and recorded that application of 75 percent RDF + FYM + Biofertilizers (*Azospirillum* and PSB) produced significantly higher grain yield (64.66 q ha^{-1}) and fodder yield (133.7 q ha^{-1}) of sorghum than those recorded in rest of treatments.

Majumdar *et al* (2007) carried out a field experiment at ICAR Research Complex for North Easern Hill Region, Umiam, Meghalaya to study the effect of nitrogen, farmyard manure and non- symbiotic nitrogen- fixing bacteria on yield of upland rice and significantly reported that, maximum grain (3.9 t ha^{-1}) and straw (5.05 t ha^{-1}) yields were recorded with 60 kg N, 5 tonnes farmyard manure and *Azotobacter* which were 7.4 and 7.9 % higher over the same dose of N, farmyard manure and *Azospirillum* application.

Patil (2007) conducted a field experiment at Chandmal Tarachand Bora College, Shirur on influence of AM fungi and *Azotobacter* on growth in *Pennisetum typhoids*. He indicated that highest grain yield (41.15 g plant $^{-1}$) and stover yield (280 g plant $^{-1}$) followed by combined treatment of *Acaulospora laevis* + *Glomus fasciculatum* + *Glomus mosseae* + *Azotobacter*.

Satyajeet *et al* (2007) conducted a field experiment at Department of Agronomy, CCS Haryana Agricultural University, Hisar to study the effect of Integrated Nutrient Management on Pearl millet. They observed that, highest grain yield (19.54 q ha^{-1}) and stover yield (53.48 q ha^{-1}) with the application of 100% RDF + Vermcompost + Azotobacter.

Singh and Dubey (2008) carried out a field experiment at Department of Agronomy, C.C.S.University, Meerut to study the effect of sources of nutrient on yield and nutritive value of fodder oat. They concluded that, addition of FYM @ 5 t ha^{-1}) along with seed inoculation with *Azotobacter* significantly enhanced the fodder yield 12.92% (1999 – 2000) and 11.38% (2000- 2001) higher yield over control.

Dadarwal *et al* (2009) conducted a field experiment at Maharana Pratap University of Agriculture and Technology, Udaipur, Rajastan on integrated nutrient management in baby corn. The result indicated that, application of 75% NPK + 2.25 tonnes vermicompost ha^{-1}) + biofertilizers (*Azotobacter* and *PSB* @ 600 g ha^{-1} each at the time of sowing) significantly improved highest plant height (239.9 cm), dry matter accumulation (80.08 g plant^{-1}), dehusked cob yield (2641 kg ha^{-1}) and green fodder yield (30.133 kg ha^{-1}).

Apporva *et al* (2010) conducted a field experiment conducted under red sandy loam soil at University of Agriculture Science, Banglore, Karnataka on STCR (Soil Test Response Approach) for optimizing Integrated Plant Nutrient supply on growth and yield of finger millet. They revealed that, the application of fertilizers and 10 t ha^{-1} FYM on STCR basis along with dual microbial inoculation (*Azotobacter* + PSB) recorded highest plant height (123 cm), number of leaves /plant 40 DAS (28.3 cm), number of

tillers/hill (4.6), number of earheads/ plant (4.6), finger length (7.3 cm), test weight of 1000 seeds (4.12 g), grain yield (3740.5 kg ha^{-1}) and straw yield (9485.9 kg ha^{-1}).

Bama and Ramkrishnan (2010) conducted a field experiment at Department of Botany, Annamalai University, Annamalainagar to find out effect of *Azospirillum* and AM fungi on growth and yield of finger millet. They concluded that, at 45 DAS, the combined inoculation of *Azospirillum* and AM reslted in highest plant biomass (8.12 g plant $^{-1}$), shoot length (52.6 cm plant $^{-1}$) and tiller production (4.8/ plant), number of finger/ plant (7.3), earhead length (8 cm plant $^{-1}$), haulms yield (6.29 t ha^{-1}) and grain yield (4.31 t ha^{-1}).

Ashok Kumar and Dhar Shiva (2010) conducted a field experiment at IARI, New Delhi to evaluate growth and yield attributes by wheat as influenced by different nutrient management practices. Highest leaf area index (4.13), dry weight (656 g/ m^2), effective tillers/ m^2 (371), grains/ ear (48.1), grain yield (5.78 t ha^{-1}) and straw yield (6.72 t ha^{-1}) were found with the application of 60 kg N/ ha (FYM) + cowpea green manuring + *Azotobacter*.

Suke *et al* (2010) conducted an experiment at College of Agriculture, Nagpur during *kharif* season on effect of nutrients and biofertilizers on morphophysiological parameters of maize. They reported that significantly highest 60 DAS plant height (50.80 cm), root length (69.16 cm), root volume (51. 16 g), dry weight of roots (21.38 g) and grain yield (46.46 plant $^{-1}$) due to inoculation of biofertilizers (Azotobacter + PSB) with the application of 90 per cent RDF.

Kumarasamy and Santhaguru (2011) conducted a field experiment at Department of Botany, Thiagarajar College (Madurai Kamaraj University), Madurai to assess the effect of *Gluconacetobacter diazotrophicus* on growth performance of sorghum. They found that, the inoculation with different isolates of *Gluconacetobacter diazotrophicus* increased dry weight (5-128 percent), total nitrogen (4-148 percent), total soluble sugars (7-46 percent) and total chlorophyll (75-419 percent) of *Sorghum bicolor*.

Naserirad Hoshang *et al* (2011) carried out an experiment at Payamnoor University, Iran on effect of integrated application of biofertilizer on grain yield, yield componants and associated traits of maize cultivars. The combination of *Azotobacter* + *Azospirillum* gave highest plant height (212 cm), number row ear (14.5), stem diameter (2.57 cm), number of grains/row (44.2), 1000 grain weight (315.4 g), grain yield (10190 kg ha^{-1}), and biological yield (21320 kg ha^{-1}).

Nath *et al* (2011) conducted an experiment on effect of integrated nutrient management under rice- wheat sequence. Application of 25% RD of inorganic NP + 100% K + biofertilizers (*Azospirillum* and *PSB*, each @ 500g for 10 kg seeds) + compost @ 2 t ha^{-1} resulted in a significant increase the grain yield (0.98 t ha^{-1}).

Chintapalli *et al* (2012) attempted an experiment at Deemed University, Agra on performance of hybrid and composite cultivars of pearl millet. For hybrid pearl millet cultivar Pusa 605, treatment of combination of *Azospirillum* + PSB +FYM showed highest plant height (151.5 cm), number of leaves/plant (45.9), internodal length (19.2 cm), tiller thickness 94.38 cm) and green fodder yield (79 t ha^{-1}). They also studies for composite pearl millet cultivar Pusa 443, treatment of combination of *Azospirillum* + PSB+FYM showed highest plant height (180.3cm), number of leaves/plant (78), internodes length (16.4 cm), tiller thickness (5.50 cm) and green fodder yield (94.5 t ha^{-1}).

Amiri Auoub and Rafiee Masoud (2013) carried out an experiment at Payamenoor University, Iran on effect of soil inoculation with *Azospirillum* and *Azotobacter* bacteria on nitrogen use efficiency and agronomic characteristics of corn. The result showed highest number of seeds per row (33.9), grains/ear (476.6), 100 grains weight (268.4 g), grain yield (11.350 t ha^{-1}) and harvest index (37.885%) with soil inoculation treatment @ 2 $kgha^{-1}$ bacteria.

Auti *et al* (2013) conducted a field experiment at Sorghum Research Station, Marathwada Agricultural University, Parbhani during *kharif* season of 2011 on Vertisol soils on influence of levels of chemical fertilizers and microbial inoculants on yield attributes of sweet sorghum. They observed significantly highest grain yield (753

kg ha^{-1}), dry matter yield (7803 kg ha^{-1}), green stalk yield (23.90 mg ha^{-1}), total fresh biomass (24.98 mg ha^{-1}) and millable cane yield (22.45 mg ha^{-1}) influenced by *Azospirillum* + *Gluconacetobacter.*

Baral Bandhu Raj *et al* (2013) conducted a field experiment to study the effect of *Azotobacter* on growth and yield of maize. The treatment of RDF (120: 60:40 kg NPK ha^{-1}) + *Azotobacter* +10 t FYM ha^{-1} resulted significantly highest plant height (210.5 cm), ear height (106.5 cm), harvested ears/ m^2 (5.41), ear length (14.1 cm), 1000 grain weight (490.8 gm), stover yield (11.92 t ha^{-1}) and grain yield (6.42 t ha^{-1}) over rest of the treatments.

Channabasava and Lakshman (2013) studied on additive effect of microbial inoculation of barnyard millet at Karnatak University, Dharwad. Under the treatment of combination of AM fungi + *Azotobacter* they recorded significantly highest shoot length (36.33 cm), root length (22.66 cm), shoot fresh weight (13.63 g), root fresh weight (1.63 g), shoot dry weight (1.76 g), root dry weight (0.61g) and grain yield (800 grains/panicle) over rest of the treatments.

Kalhapure *et al* (2013) attempted an experiment at Department of Agronomy, MPKV, Rahuri to study the effect of Integrated Nutrient Management in maize for increasing production with sustainability. They observed significantly highest plant height (172.6 cm), dry matter/plant (256.2 g), number of cobs/ plant (1.6), number of grains per cob (223.5), 100 grain weight (24.9 g), grain yield (7.4 t ha^{-1}) and stover yield (12.6 t ha^{-1}) with the application of 25% RDF + biofertilizers (*Azotobacter* + PSB) +green manuring with sunhemp + compost

Patil *et al* (2013) conducted a pot experiment on effect of co-inoculation of AM fungi and two beneficial micro-organisms on growth of finger millet. The combined application AM fungi + *Azospirillum brasilense* + Phosphate solubilising bacteria (*Bacillus polyxyma*), showed highest plant height (56.33 cm), highest dry weight of shoot (2.7 g), highest dry weight of root (1.46 g), highest % root colonization (75.2 %).

Sivakamasundari and Usharani (2013) studied at Annamalai University, Tamil Nadu on effect of endophytic *Pseudomonas fluroscence* and *Glomus fasciculatum* on the maximization of growth and yield of maize. They investigated that highest plant height (177.21 cm), number of grains cob^{-1} (480.67), number of grains (31.33), grain weight plant^{-1} (145.36 g), cob weight plant^{-1}(276.88 g) and 100 seed weight (27.62 g) under the treatment of Endophytic *Pseudomonas fluroscence* (EPFR-4) and *Glomus fasciculatum* (GF- 5) + 75% P.

Umesha *et al* (2014) conducted an experiment at UAS, GKVK, Banglore on comparative effect of organics and biofertilizers on growth and yield of maize. Results of the treatment having recommended dose of NPK + *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluroscence* + enriched compost had showed highest plant height at 30,60,90 DAS and at harvest (120 days) [31.70, 180.93, 186.07 and 188. 13 resp.] total dry matter at harvest (375.80 g) and yield parameters like weight of cob (207.63 g), highest grain yield/plant (158.93 g), grain yield ha^{-1} (54.53 g) and test weight of seeds (33.10 g).

Sharma *et al* (2015) conducted an experiment at IARI, New Delhi to evaluate the influence of varities and integrated nitrogen management on productivity in aerobic rice and observed highest grain yield (4.50 t ha^{-1}) and straw yield (8.78 t ha^{-1}) with the application of 100% N through FYM + green manure + *Azotobacter* biofertilizers.

2.2 Effect of biofertilizer inoculation on quality parameters of *kharif* sorghum.

Rex L. Smith *et al* (1984) conducted a field experiment at Department of Agronomy, New Mexico on response of *Pennisetum species* to N2- fixing bacterium *Azospirillum brasilense*. For Pearl millet, they resulted that higher dry matter (21.3%) and higher acetylene reduction activity (40 n mol) under the influence of *Azospirillum* inoculation.

Majjigudda and Srenivasa (1996) attempted a field experiment at University of Agricultural Sciences, Dharwad on influence of VA- mycorrhizal fungi on growth and yield of wheat. They recorded that highest seed protein content (10.84%) with the inoculation of *Glomus fasciculatum.*

Ganguly *et al* (1997) conducted a field experiment at Central Research Institute for Jute and Allied Fibres, Barrackpore, West Bengal on possible contribution of *Azospirillum* to the nutritional status of jute-maize system. They observed maximum crude protein (5.86 g pot^{-1}) with nitrogen level of 22.5 mg kg^{-1} and maximum total dry matter (69.5 g pot^{-1}) with nitrogen level of 7.5 mg kg^{-1} under the influence of *Azospirillum.*

Swedrzynska D (2000) attempted an experiment on effect of inoculation with *Azospirillum brasilense* on development and yielding of winter wheat and oat. He concluded that the inoculation of wheat and oat with *Azospirillum brasilense* caused a statistically significant increase of chlorophyll content in the case of oats (15%) and in wheat (15%).

Kader *et al* (2002) conducted a pot experiment at Bangladesh Agricultural University, Bangladesh to study the effect of Azotobacter inoculants on yield and N uptake by wheat. They observed with the application of 168 kg N ha^{-1} + Azotobacter + Cowdung.

Singh *et al* (2005) conducted a field experiment at Narendra Deva University of Agriculture and Technology, Faizabad, Uttar Pradesh in silt loam soil to study the effect of nitrogen and biofertilizers inoculated on production potential and protein content of forage sorghum. They found that, the sorghum seed inoculation with *azotobacter* or *azospirillum* increased forage production and crude-protein significantly over uninoculated control. They also found that, the plant height, shoot lengths, green forage and dry matter yields and crude protein significantly increased with inoculation of biofertilizers.

Adriano *et al* (2006) conducted a field experiment at Universidad Autonoma de Chiapas, Tapachula, Chiapas, Mexico in grey loam soil to study the hydrolytic enzyme activities in maize and sorghum roots inoculated with *gluconacetobacter diazotrophicus* (Pal 5, UAP 5541) and the *Arbascular mycorrhizal* fungus *Glomus intraradices* increased both the shoot and root dry weight of sorghum. They observed that co-inoculation of two biofertilizers that is *Gluconacetobacter diazotrophicus* and *Glomus mosseae* did not increase the shoot and root dry weight of sorghum.

Ramanjaneyulu *et al* (2006) conducted a field experiment at Agronomy Research Farm, IARI, New Delhi and studied the impact of biofertilizers and inorganic nitrogen and phosphorus on fodder yield and nutrient uptake in forage sorghum in sandy loam soil. They found that application of half RDF + biofertilizers not only saves half dose of N and P but also improves soil health. They also observed that application of biofertilizers enhanced sorghum dry fodder yield.

Kumarasamy and Santhaguru (2011) conducted a field experiment at Department of Botany, Thiagarajar College (Madurai Kamaraj University), Madurai to study the effect of *Gluconacetobacter diazotrophicus* on growth performance of sorghum. Sorghum plants were grown in greenhouse and the impact of inoculation with 20 isolates of *Gluconacetobacter diazotrophicus* and the reference strain. Pal5 on sorghum showed increased dry weight (5-128%), total nitrogen (4-148%), total soluble sugars (7-46%) and total chlorophyll (75-419%) of *sorghum bicolor.*

Meenakshisundaram Murugan and Santhaguru Karrupagnaniar (2011) conducted a field experiment at Department of Botany, Thiagarajar, College, Madurai, Tamilnadu and studied as association of arbuscular mycorrhizal fungi with *Gluconacetobacter diazotrophicus* and its effect on improvement of *sorghum bicolor.* They found that dual inoculation of *Gluconacetobacter diazotrophicus* and *Glomus fasciculatum* shows a significant increase in P, Soluble sugars, Photosynthetic pigments in leaves of sorghum.

Auti *et al* (2013) conducted a field experiment at Sorghum Research Station, Marathwada Agricultural University, Parbhani during *kharif* season of 2011 on Vertisol soils to study influence of levels of chemical fertilizers and microbial inoculants on yield attributes of sweet sorghum. They observed highest p^H of juice (5.06), total soluble sugar (17.15 ^{0}Brix), juice yield (5877 lit ha^{-1}), juice extraction (33.01%), reducing sugar (2.42%), non reducing sugar (14.96%) and total sugar (17.39%) under the treatment of *Azospirillum* + *Gluconacetobacter* inoculation.

MATERIAL AND METHODS

Chapter – III

MATERIAL AND METHODS

The details of the materials and methods used during the course of investigation entitled **"Effects of *Gluconacetobacter* and *Azotobacter* on growth and yield of *kharif* sorghum"** and the procedure referred for collection of data and drawing the inference are narrated in brief under suitable captions in this chapter.

3.1 General description

3.1.1 Location

The experiment was conducted during *kharif* season of the year 2014-15 at Experimental Farm, Department of Agronomy, College of Agriculture, and Latur. The topography of experimental field was uniform and leveled.

3.1.2 Soil

The soil of the experimental site was deep, black in colour with good drainage. Representative soil samples were collected. Physico-chemical properties of soil were determined by taking soil samples from 0-30 cm strata at random all over the experimental area before laying out experimental plot field. A composite soil sample was prepared and analyzed for estimation of its various physico-chemical properties. The relevant results are presented in Table 1.

The data presented in Table 1 on soil analysis showed that the soil of experimental plots was clayey in texture. The chemical composition of experimental plots indicated that the soil was low in available nitrogen (118.86 kg ha^{-1}), medium in available phosphorus (20.42 kg ha^{-1}), very high in available potassium (385.89 kg ha^{-1}) content and alkaline in reaction having pH of 8.5.

Table 1: Physico-chemical properties of composite soil

Sr. No	Particulars	Value (%)	Method used	Reference
I)	**Mechanical composition**			
a)	Fine sand (%)	23.98 %		
b)	Silt (%)	26.72 %	International pipette method	Piper, 1966
c)	Clay (%)	49.30 %		
d)	Textural class	Clayey		
II)	**Chemical composition**			
a)	Soil pH	8.5	pH meter	Jackson, 1967
b)	Electrical conductivity (dSm^{-1} at 25^0 C)	0.20	Conductivity bridge	Jackson, 1967
c)	Organic carbon ($g\ kg^{-1}$)	0.74	Walkley and Black method	Piper, 1966
d)	Available nitrogen ($kg\ ha^{-1}$)	118.86	Alkaline Permanganate	Jackson, 1967
e)	Available phosphorus ($kg\ ha^{-1}$)	20.42	Olsen method	Olsen *et al.*, 1954
f)	Available potash ($kg\ ha^{-1}$)	385.89	Flame photometer	Jackson, 1967
g)	Available zinc ($mg\ kg^{-1}$)	0.44	Atomic Absorption Spectrophotometer	Lindsay and Norvell, 1978
h)	Available iron ($mg\ kg^{-1}$)	2.87	Atomic Absorption Spectrophotometer	Lindsay and Norvell, 1978
i)	Available magnesium ($mg\ kg^{-1}$)	14.56	Atomic Absorption Spectrophotometer	Lindsay and Norvell, 1978

3.1.3 Cropping history of experimental field:

Cropping history of experimental field for previous four years is presented in Table 2. From the history of cropping pattern, it would be seen that the residual effect of the previous crop was not varied much.

Table 2: Cropping history of the experimental plot

Year	*Kharif*	*Rabi*	*Summer*
2010-11	Soybean	Gram	Fallow
2011-12	Soybean	Gram	Fallow
2012-13	Soybean	Fallow	Fallow
2013-14	Soybean	Fallow	Fallow
2014-15	Present investigation	- -	-

3.2 Climatic condition and location

Geographically, Latur is situated between 18°05' to 18°75' North latitude and between 76°25' to 77°25' East longitude. Its height from mean sea level is about 540.634 m and has sub tropical climate. The climate of Latur is characterized by a hot summer and general dryness throughout the year except during South-west monsoon. The mean annual precipitation was about 734 mm. Most of the monsoon rains (72 per cent) received from June to September.

3.2.1 Weather conditions

The meteorological data recorded at meteorological observatory, Oilseeds Research Station, Latur pertaining to the period of experimentation during 2014 are presented in Table 3 and graphically depicted in Fig. 1 (a), 1(b) and 1(c).

The total rainfall received during crop growth season was 421 mm and distributed over 29 rainy days during the course of experimentation

Table 3: Meteorological data during the course of investigation, 2014

M.W.	Date	Total rainfall (mm)	Rainy days (No.)	Temperature		Relative Humidity (%)	
				Min.	Max.	Max.	Min.
21	21 – 27 May	9.0	1	22.6	39.4	46	25
22	28 May- 3 June	3.0	0	23.8	38.4	56	36
23	4-10 June	13.8	2	23.5	36.7	71	46
24	11-17 June	9.0	1	23.6	35.7	63	45
25	18-24 June	13	3	23.7	33.6	64	50
26	25 June-1 July	00	0	24.3	35.8	59	45
27	2-8 July	70.5	2	23.8	34.8	66	54
28	9-15 July	31	1	21.1	28.8	77	77
29	16-22 July	20	2	22.2	29.7	78	68
30	23-29 July	26	3	20.9	30.3	82	64
31	30 July- 5 Aug.	7.0	1	22.2	30.9	78	57
32	6-12 Aug.	13	1	20.8	30.6	66	56
33	13-19 Aug.	24	3	21.3	29.9	72	58
34	20-26 Aug.	39.2	2	21.5	29.9	81	64
35	27Aug.-2 Sept.	108	5	20.7	26.4	88	73
36	3-9 Sept.	19	1	21.1	27.3	83	70
37	10-16 Sept.	1.5	0	22.0	28.7	69	70
38	17-23 Sept.	14	1	20.9	28.6	74	65
39	24-30 Sept.	00	0	20.3	29.1	69	71
	Total	**421**	**29**	-	-	-	-

3.3 Experimental details

3.3.1 Experimental layout

The present experiment was laid out by using Randomized block design with three replications. There were eight treatments. The details of the treatments along with symbols used are given in treatment details.

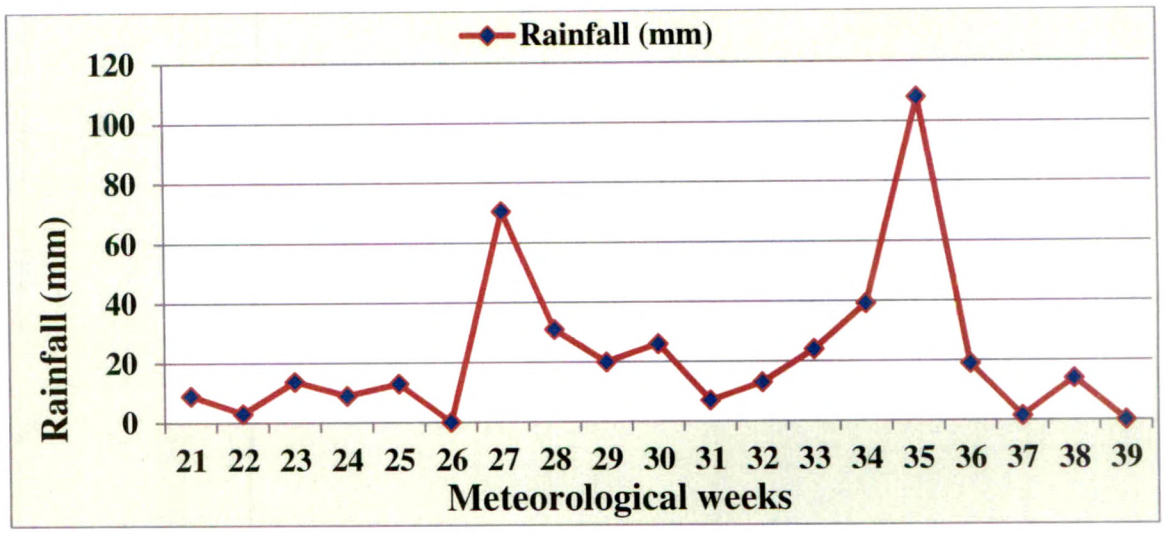


Fig. 1 (a). Rainfall (mm) during crop growth period

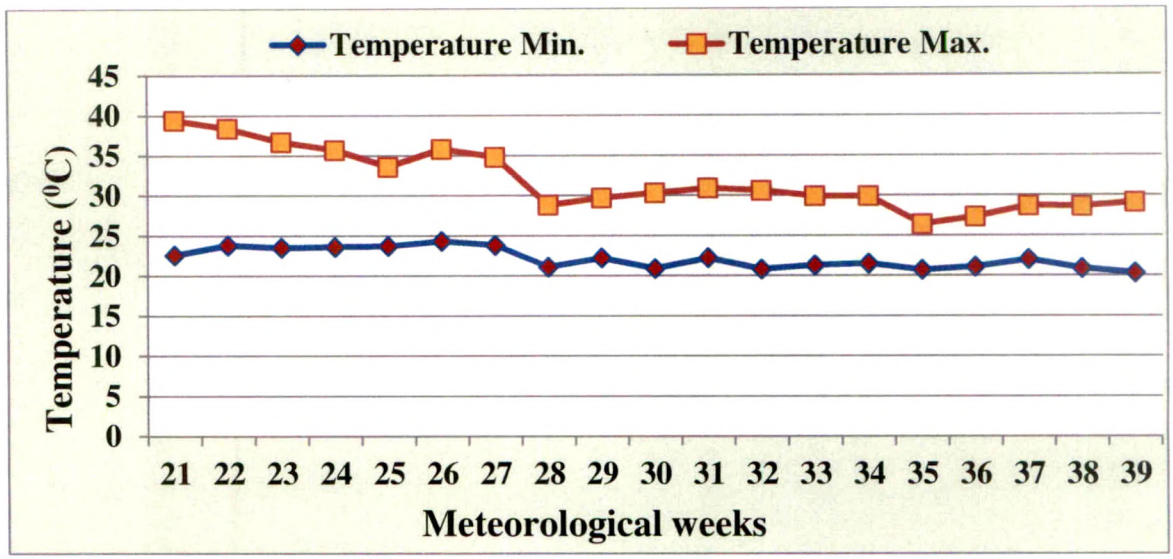


Fig.1 (b). Minimum and Maximum temperature (^{0}C) during crop growth period

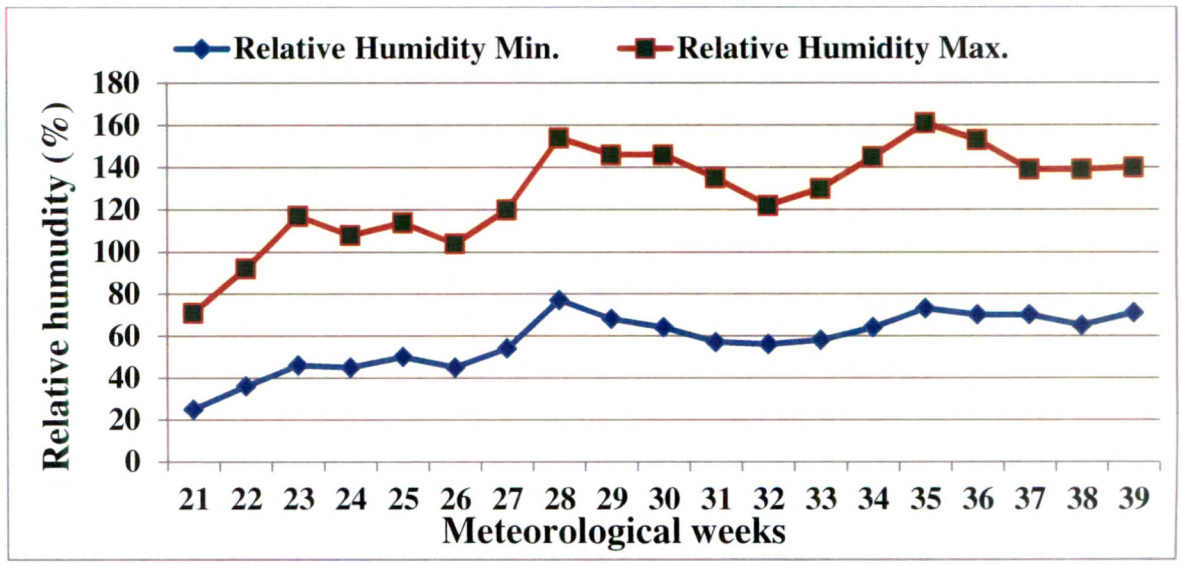


Fig.1 (c) Relative humidity (%) during crop growth period

3.3.2 TREATMENT DETAILS

T_1 - Control.

T_2 - 100% RDN.

T_3 - 100% RDN + carrier based *Gluconacetobacte.*

T_4 - 100% RDN + liquid based *Gluconacetobacter*

T_5 - 75% RDN + carrier based *Gluconacetobacter.*

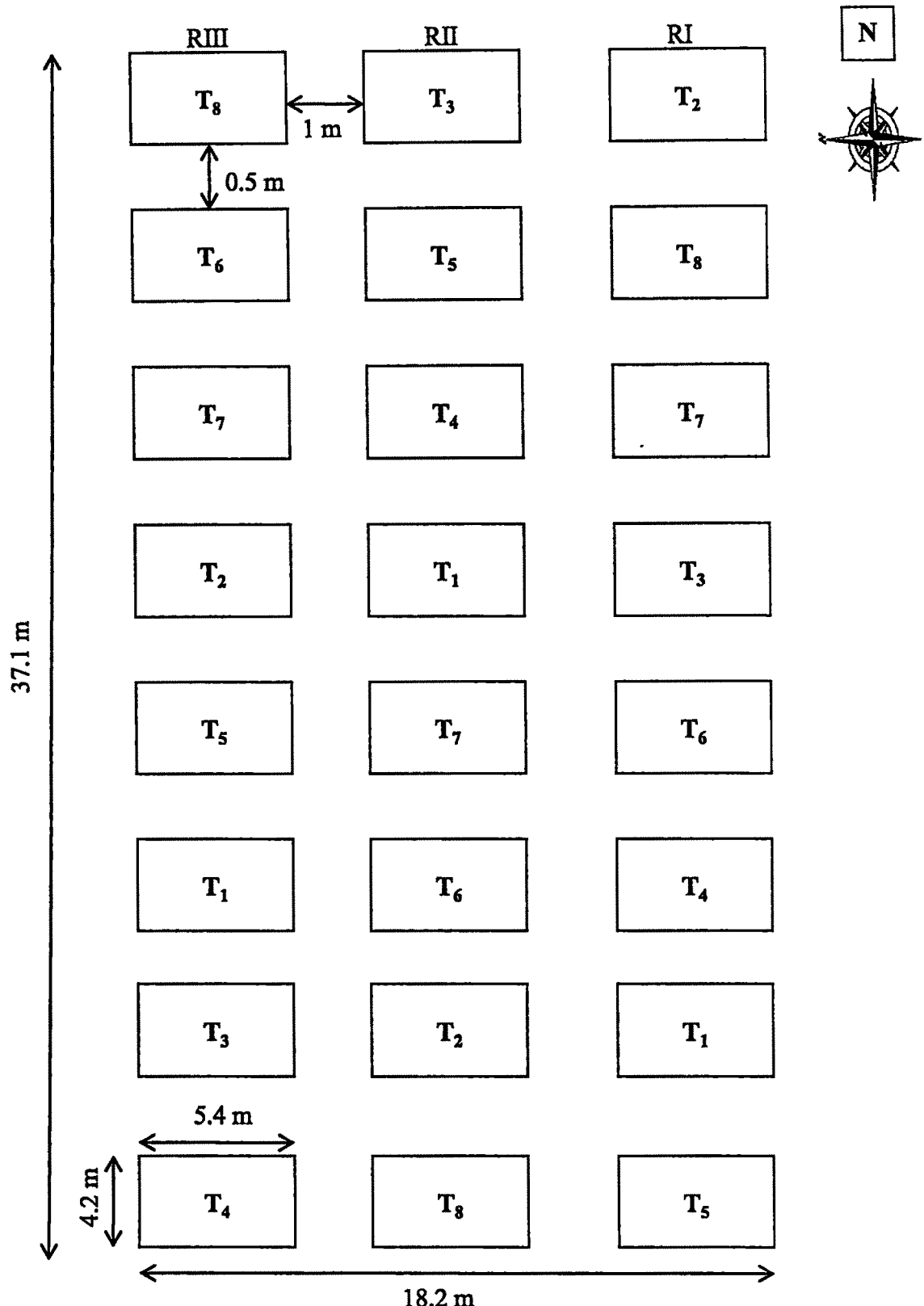
T_6 - 75% RDN + liquid based *Gluconacetobacter.*

T_7 - 75% RDN + carrier based *Azotobacter.*

T_8 - 75% RDN + liquid based *Azotobacter.*

3.3.3 OTHER DETAILS:

1)	Starting of programme	: *Kharif,* 2014-15
2)	Crop	: Sorghum
3)	Variety	: Hybrid (Proagro-8340)
4)	Design of Experiment	: Randomised block design
5)	Treatments	: 08
6)	Replication	: 03
7)	Total No. of plots	: 24
8)	Plot size	
	Gross	: 5.4 x 4.2 m
	Net	: 4.5 x 3.9 m
9)	Distance between plots	: 0.5 m
10)	Distance between replications	: 1.0 m
11)	Row to row distance	: 45 cm
12)	Plant to plant distance	: 15 cm
13)	Method of sowing	: Dibbling
14)	Seed rate	: 7.5 kg ha^{-1}
15)	RDF	: 80:40:40 NPK kg ha^{-1}
16)	Site	: College farm, Department of Agronomy, College of agriculture, Latur.



Plot size:
Gross : 5.4 x 4.2 m
Net : 4.5 x 3.9 m

Fig. 2 : Experimental Layout

3.4 Cultural Operations

The schedule of various cultural operations carried out in the experimental field is presented in Table 4.

Table 4: Schedule of cultural operations

Sr. No.	Particulars	Frequency	Date
1	Ploughing	1	25/05/2014
2	Harrowing	2	11/06/2014
			19/06/2014
3	Cleaning	1	20/06/2014
4	Soil sample taken		
	1) Initial	1	08/07/2014
5	Layout	1	06/07/2014
6	Manures application	1	09/07/2014
7	Fertilizer dose application	1	12/07/2014
8	Sowing by dibbling	1	12/07/2014
9	Thinning	1	26/07/2014
10	Hand weeding	2	31/07/2014
	Hoeing	2	15/08/2014
11	Spraying	1	
	10 % Forate @ 10 kg ha^{-1}		17/08/2014
	[Acephate + Dichlorovos]		
12	Harvesting		12/11/2014
13	Threshing		24/11/2014

3.4.1 Preparatory cultivation

The land was ploughed about 20 cm deep. It was subsequently harrowed twice with common blade harrow to achieve loose and friable seed bed. After attaining of desired tilth the field was laid out as per plan and kept ready for sowing.

3.4.2 Manure and fertilizer application

The complete dose of phosphorus (16 % P_2O_5), potash (K_2O) and half dose of urea as per treatment was drilled at the time of sowing uniformly in the plots

by using the urea (46 % N), single superphosphate (16 % P_2O_5) and muriate of potash (K_2O). The remaining half dose of urea was applied as side band placement at 30 DAS as per treatment.

3.4.3 Seeds and sowing

The pure seed of sorghum (Proagro-8340) was obtained from Department of Agronomy, College of Agriculture, Latur. The variety is recommended for the Maharashtra under rain fed conditions. Sowing was done on 12th July, 2014 by dibbling three to four seeds at each hill at a recommended spacing of 45 cm x 15 cm.

3.4.4 Biofertilizer application

The inoculation of biofertilizers i.e. carrier based and liquid based *Gluconacetobacter* and *Azotobacter* was applied as seed treatment to the sorghum crop as per treatments. Applied @ 4 ml kg^{-1} and 4 g kg^{-1}

3.4.5 Emergence count and final plant stand

Emergence count was taken 15 days after sowing and final plant stand from each net plot was recorded at the harvest.

3.4.6 Gap filling and thinning

The gap filling was done 10th days after sowing to ensure the required plant population. The thinning was done 14th days after sowing and only one healthy and vigorous seedling was kept at each hill.

3.4.7 Intercultural operations

Two hand weeding and two hoeing were given during the growth period of sorghum for control of weeds and better aeration in the soil.

3.4.8 Plant protection

For the control of shootfly and stem borer incidence on sorghum apply the 10% Forate @10 kg/ha. After 40 days of sowing, spraying of Acephate @ 15 gm

litre^{-1} + Dichlorovos @ 20 ml litre^{-1} was undertaken during the growth period of sorghum to control the aphids.

3.4.9 Harvesting

The border rows were harvested first and then harvesting of five observation plant was done and then harvesting of net plot was carried out at physiological maturity of crop with the help of manual labour by cutting plants close to the ground along with earheads by the help of sickle. The crop was harvested and plants were tied in bundles and kept for sun drying on threshing floor for few days.

3.4.10 Threshing

After sun drying of harvested five observation plants and net plot, the earhead were separated from individual plants. After separation of the earheads from plants, they were dehusked and produce of each observation plants and plot was winnowed, weighed and samples were taken for further analysis. The clean produce were dried for two days and weighed as final yield.

3.5 Biometric observations

3.5.1 Sampling technique

Five plants from each net plot of sorghum were randomly selected and labeled with wire rings and bamboo pegs for taking biometric observations at different growth stages. The biometric observations were recorded on the labeled plants at 15 days intervals. The same five plants were harvested separately for post harvest studies. The schedule of biometric observations on various parameters recorded during the present investigation is given in Table 5.

3.5.3 Final plant count

The final plant count stand was recorded by counting all the plants in net plot at the time of harvest and from this plant population per hectare was computed.

3.5.4 Plant height (cm)

The height of main shoot was measured in cm from base of the plant i.e. ground level to the legule/aurical of the fully opened top leaf. After panicle emergence, the height was measured up to the base of panicle at 30, 45, 60, 75, 90, 105 DAS and at harvest. At harvest the data was worked out and recorded.

3.5.5 Number of functional leaves

The progressive number functional leaves i.e. fully opened leaves per plant was counted from selected plants at 15 days interval from 30, 45, 60, 75, 90, 105 DAS and at harvest.

3.5.6 Leaf area per plant (cm^2)

At each observation one plant was selected randomly and the leaf area of plant was calculated by dividing the leaves in to three categories, viz., small, medium and big. The grade wise leaves were counted and their frequency was recorded. One leaflet from each category was taken and its length and breadth in cm was measured and recorded. The leaf area was calculated by using formula given by Stickler and Pauli (1951) for each grade and summation of leaf area of these grades was taken as leaf area per plant. Lengths of all the fully opened leaf lamina per plant were measured from the base to the tip of the leaf. Breadth was taken at the widest point of the leaf lamina.

The leaf area of each grade leaves was calculated by formula as given below.

The products of leaf length and breadth were multiplied by the factor 0.747 (Stickler and Pauli, 1951). The average leaf area per plant was expressed in dm per plant.

$$\text{Leaf area } (cm^2) = L \times B \times K \times N$$

Where,

A = Leaf area in dm^2 under particular group

L = Maximum length of leaf (cm)

B = Maximum breadth of leaf (cm)

K = Leaf area constant of sorghum (0.747)

N = Number of leaves

3.5.7 Stem girth

In each net plot five plants randomly selected for measurement of the stem girth of the plant at 60, 90 DAS and at harvest.

3.5.8 Number of internodes

In each net plot five plants randomly selected for counting the number of internodes per plant at 60, 90 DAS and at harvest.

3.5.9 Days to 50 percent flowering

The number of days taken for 50 percent flowering was recorded by observing plants from the net plot.

3.5.10 Dry matter accumulation

For the dry matter accumulation a representative plant was selected from each net plot randomly at every stage of sampling. The plants so selected were uprooted and its roots were removed. The aerial portion of plant was divided into various plant parts like stem, leaves and earhead according to stage of growth. These separated plant parts were collected in separate brown paper bags, properly labeled, air dried first and then dried in hot air oven at 60^0C until constant weight was obtained and then weighed. The final constant weight was recorded as the dry matter weight in grams per plant.

Table 5: Details of biometric and other observations recorded at different growth stages and their frequency

Sr. No.	Particulars	Frequeny	Days after sowing	No. of plants to be observe
	Pre Harvest Study			
1	Emergence count	1	15 DAS	All plants in net plot
2	Height of the plant (cm)	7	30, 45, 60, 75, 90, 105 and at harvest	5 plants in net plot
3	Number of functional leaves per plant	6	30, 45, 60, 75, 90 and 105	5 plants in net plot
4	Leaf area per plant (dm^2) per plant	6	30, 45, 60, 75, 90 and 105	5 plants in net plot
5	Stem girth (cm)	3	60, 90 and at harvest	5 plants in net plot
6	Number of internodes per plant	3	60, 105 and at harvest	5 plants in net plot
7	Final plant stand	1	At harvest	All plants in net plot
8	Dry matter per plant (g)	7	30, 45, 60, 75, 90, 105 and at harvest	1 plant from each net plot
9	Days to 50 % flowering	1	-----	All plants in net plot
B	**Post Harvest Study**			
1	Length of earhead (cm)	1	At harvest	5 plants in net plot
2	Breadth of earhead (cm)	1	At harvest	5 plants in net plot
3	Weight of earhead (g) per plant	1	At harvest	5 plants in net plot
4	Weight of grains (g) per plant/earhead	1	At harvest	5 plants in net plot
5	Number of grains / earhead	1	At harvest	5 plants in net plot
6	Weight of stalk (kg) per net plot	1	At harvest	All plants in net plot
7	Test weight (g)	1	At harvest	Plot - wise sample
8	Weight of earhead (kg) per net plot	1	At harvest	All plants in net plot
9	Grain yield (kg) per net plot	1	At harvest	All plants in net plot
C	**Chemical studies**			
1	Initial N,P and K status of soil	1	Before sowing	-----

3.6 Growth analysis

Data on growth characters viz., height, growth and dry matter per plant were further analyzed. This physiological determination of the plant growth affected by the treatments reflects the plants yield. Hence, these physiological constants were worked out in the present study.

3.6.1 Absolute growth rate (AGR)

The rate of increase in growth variable (W) at the time (t) is called as absolute growth rate (AGR). AGR of two growth variables *viz.,* plant height and total dry matter weight were worked out by using following formula.

For height

$$AGR = \frac{H_2 - H_1}{t_2 - t_1} \text{ cm day}^{-1}$$

1. For dry matter

$$AGR = \frac{W_2 - W_1}{t_2 - t_1} \text{ gm day}^{-1}$$

Where,

H_2 and H_1 as well as W_2 and W_1 refer to the plant height and total dry matter weight of plant at time t_2 and t_1, respectively.

3.6.2 Relative growth rate (RGR)

Blackman (1919) pointed out that increase in dry matter of plant is a process of continuous compound interest, when the increments produced in any time interval are added to the capital for the growth in subsequent period. The rate of increment is called as relative growth rate (RGR). This is calculated by formula as given below and expressed in g g^{-1} day^{-1}. This growth constant was worked out by using the formula given by Fisher (1921).

This growth constant was worked out by using the formula given by Fisher (1919).

$$AGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

Where,

Log_e – Natural Logarithms (2.3026)

W_1 and W_2 are the weight of total dry matter at time t_1 and t_2 respectively.

3.6.3 Leaf area index (LAI)

Since, the crop yield is to be assessed per unit of ground area instead of per plant, the leaf area existing on unit ground area was proposed by Watson (1952). The measure is known as leaf area index.

$$LAI = \frac{\text{Leaf area per plant } (cm^2)}{\text{Ground area per plant } (cm^2)}$$

3.7 Post harvest studies

3.7.1 Length of earhead (cm)

Length of the individual earhead from selected five plants was measured from the base of the earhead to the apex of the earhead and expressed as mean length in centimeters (cm) per plant.

3.7.2 Breadth of earhead (cm)

Breadth of the individual earhead from selected five plants was measured with the help of string at three places i.e. base, middle and top of the earhead and was taken as the breadth of the earhead and expressed as mean breadth in centimeters (cm) per plant.

3.7.3 Weight of earhead (g) per plant

Earhead from five selected plants were harvested and after drying their weight was recorded in gram and mean weight per earhead was calculated. The average was worked out and expressed as weight of earhead (g) per plant.

3.7.4 Weight of grains (g) per earhead

Five dried earhead were collected from the selected plants were threshed, winnowed and grain weight was recorded in gram and mean weight per plant was calculated. The average was worked out and expressed as weight of grains per earhead.

3.7.5 Number of grains per earhead

Five dried earhead were collected from the selected plants were threshed and winnowed properly. The total number of grains was then counted to arrive at the average grain number per earhead.

3.7.6 Test weight (g)

Sample of grains were drawn from the cleaned grain produce of each net plot, 1000 grains were counted and its weight (g) was recorded for test weight (g).

3.7.7 Weight of earhead (kg) per net plot

Earhead of harvested plants from net plot area after proper sun drying were separated from plants. The earhead weighed and expressed in weight of earhead (kg) per net plot terms of kg per hectare.

3.7.8 Grain yield

At maturity, the net plots were marked and all the plants from each net plot were harvested and kept for sun-drying for eight days, except the five sample plants which were harvested separately for individual plant yields. The earhead were cut, weighed, threshed with wooden hand thresher and grains were cleaned with hand

winnowing. The yield of the clean grains per net plot was recorded in kg and was converted to kg per hectare. The weight of five observation plants added to this.

3.7.9 Yield of bhoosa

The bhoosa yield was calculated by deduction of grains yield from the weight of earhead and then converted into kg per hectare.

3.7.10 Fodder yield

After harvest, sorghum plants were sun-dried for about 20 days and their weights were recorded treatment-wise on the spring balance and the corresponding fodder yields were calculated on hectare basis.

3.8 Biological yield

The biological yield was recorded by the following formula.

Biological yield = Grain yield + Straw yield

Where,

Straw yield = Fodder yield + Bhoosa yield

3.9 Harvest index

Ratio of grains yield to biological yield of each net plot was worked out and reported in percentage as harvest index.

$$\text{Harvest index (\%)} = \frac{\text{Total seed yield}}{\text{Total biological yield}} \times 100$$

Biological yield = Grain yield + Straw yield

Where,

Straw yield = Fodder yield + Bhoosa yield

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3.10 Chemical analysis

3.10.1 Available nitrogen

It was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.10.2 Available phosphorus

Phosphorus was extracted from the soil with 0.5M sodium bicarbonate by Olsen's method as described by Jackson (1967).

3.10.3 Available potassium

It was determined with neutral normal NH_4OA and potassium in extract was determined on Flame photometer (Piper, 1966).

3.11 Statistical analysis and interpretation of data

Data obtained on various variables were analyzed by "analysis of variance method" (Panse and Sukhatme, 1967).The total variance (S^2) and d. f. (n-1) divided into different possible sources. The variance due to replication and treatment effects were calculated and compared with error variance for finding out "F" values and ultimately for testing the significance at P = 0.05 wherever the results were found significant. Critical difference was calculated for comparison of treatment mean at 5 per cent level of significance where results are significant.

3.11.1 Simple correlation

Correlation studies were taken up between seed yield per plant in relation to various important growths and yield attributes.

3.11.2 Simple correlation studies

Simple correlation co-efficient ('r' values) were computed between weight of seed per plant (y) and the morphological characters (Xn) *viz.,*

X_1 - Height of plant (cm).

X_2 - Leaf area per plant (dm^2).

X_3 - Stem girth (cm).

General view of the experimental field

X_4 - Mean total dry matter per plant (g).

X_5 - Number of grains per earhead.

X_6 - Weight of stalk per plant (g).

X_7 - Test weight (g).

X_8 - Grain yield per plant (g).

The procedure and formula described by Snedecor and Cochran (1968) were adopted and significance was tested.

$$r = \frac{\Sigma xy}{\sqrt{(\Sigma x)(\Sigma y)}}$$

Where,

r	=	Correlation coefficient
x	=	Independent variable (attributes)
y	=	Dependent variable (yield)

3.12 Economics

3.12.1 Gross monetary returns

The gross monetary returns (`/ha) occurred due to different treatments in the present study were worked out by considering market prices of economic product, by product and crop residues during the experimental year.

3.12.2 Cost of cultivation

The cost of cultivation (`/ha) of each treatment was worked out by considering the price of inputs, charges for cultivation, labour, land and other charges.

3.12.3 Net monetary returns

The net monetary returns (`/ha) of each treatment were worked out by deducting the mean cost of cultivation (`/ha) of each treatment from the gross monetary returns (`/ha) gained from the respective treatments.

3.12.4 Benefit: cost ratio

The benefit: cost ratio of each treatment was calculated by dividing the gross monetary returns by the mean cost of cultivation.

EXPERIMENTAL FINDINGS

Chapter – IV

EXPERIMENTAL FINDINGS

The data on biometric characters, yield attributes and yield along with their statistical test and their scientific interpretations are summarized briefly in this chapter under appropriate heads.

4.1 Pre harvest studies

4.1.1 Mean emergence count and final plant stand

The data pertaining to mean emergence count and final plant stand was presented in Table. 6. The mean emergence count and final plant stand was 92.06 and 85.67 respectively.

Table 6 : Mean emergence count and final plant stand per plot (Arcsine value) of sorghum as influenced by various treatments.

Treatments	Emergence count	Final plants stand
T_1 – Control	91.59	85.14
T_2 -100% RDN	92.42	86.04
T_3 -100% RDN + carrier based *Gluconacetobacter*	92.63	86.38
T_4 -100% RDN + liquid based *Gluconacetobacter*	92.83	86.39
T_5 -75% RDN + carrier based *Gluconacetobacter*	91.04	85.28
T_6 -75% RDN + liquid based *Gluconacetobacter*	91.87	85.21
T_7 -75% RDN + carrier based *Azotobacter*	92.05	85.37
T_8 -75% RDN + liquid based *Azotobacter*	92.08	85.53
SE ±	0.49	0.50
CD at 5%	NS	NS
General Mean	**92.06**	**85.67**

Data presented in Table 6 revealed that mean emergence count and final plant stand were not influenced significantly due to different treatments which indicated that variations obtained during course of investigation were real differences due to treatments and was not influenced by population.

4.2 Growth characters

4.2.1 Plant height

Table 7: Plant height as influenced by various treatments at various stages of crop growth.

	Plant height (cm) days after sowing					
Treatments	**30**	**45**	**60**	**75**	**90**	**105**
T_1 – Control	11.28	18.93	98.02	120.68	136.64	136.64
T_2 -100% RDN	12.20	27.70	104.30	140.29	143.42	143.42
T_3 -100% RDN + carrier based *Gluconacetobacter*	12.43	27.76	105.65	141.57	143.45	143.45
T_4 -100% RDN + liquid based *Gluconacetobacter*	12.79	27.90	105.86	144.04	146.60	146.60
T_5 -75% RDN + carrier based *Gluconacetobacter*	12.00	23.45	99.47	131.55	138.98	138.98
T_6 -75% RDN + liquid based *Gluconacetobacter*	12.24	23.52	99.55	132.34	139.43	139.43
T_7 -75% RDN + carrier based *Azotobacter*	12.56	24.26	100.11	132.72	139.54	139.54
T_8 -75% RDN + liquid based *Azotobacter*	12.45	24.40	100.54	132.82	139.78	139.78
SE ±	0.36	1.02	1.58	2.00	1.69	1.69
CD at 5%	NS	3.08	4.79	6.07	5.14	5.14
General Mean	**12.20**	**24.74**	**101.69**	**134.5**	**140.98**	**140.98**

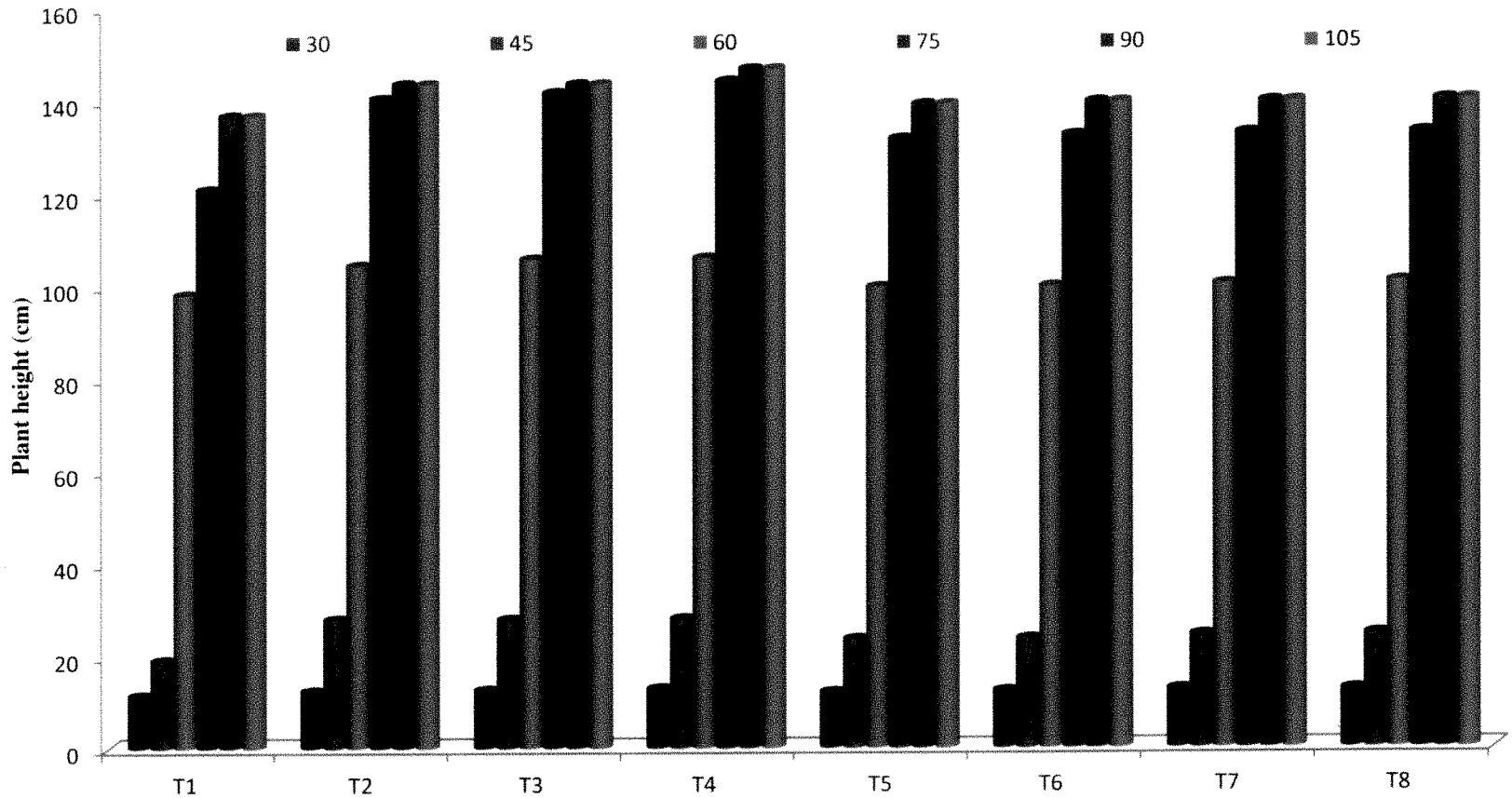

Fig. 3 : Mean plant height (cm) as influenced by various treatments at various stages of crop growth

The data on mean plant height (cm) as influenced by different treatments at various stages of the crop growth are presented in Table 7 and graphically depicted in Fig. 3.

It was observed from Table 7 that the mean plant height of sorghum was increased continuously from emergence to 90 DAS. The increase in plant height was slow up to 45 days, fast during 45 to 60 days after sowing of crop. There after increased in height but at declined rate. Maximum plant height was observed at the time of maturity.

The data on mean plant height (cm) was influenced significantly by different treatments at all stages of crop growth except at 30 days after sowing.

The data presented in Table 7 revealed that application of 100% RDN + liquid based *Gluconacetobacter* (T_4) was recorded significantly more plant height than other treatments and it was at par with 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) at all the growth stages except at 30 DAS.

4.2.2 Number of functional leaves

The data on mean number of functional leaves per plant as influenced by different treatments at various growth stages of crop growth are presented in Table 8 and depicted in Fig. 4.

Data in Table 8 showed that mean number of functional leaves per plant of sorghum were increased gradually upto 60 days after sowing and decreased thereafter due to leaf senescence.

The data on mean number of functional leaves per plant was influenced significantly due to different treatments at all stages of crop growth except at 30 days after sowing.

Application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded significantly higher number of leaves per plant over all the treatments at 45 and 90 DAS. Whereas at 60 and 75 DAS, application of 100% RDN + liquid based

Table 8 : Mean number of functional leaves plant^{-1} as influenced by various treatments at different crop growth stages

	No. of functional leaves plant^{-1} days after sowing				
Treatments	**30**	**45**	**60**	**75**	**90**
T_1 – Control	2.37	3.93	6.31	4.95	3.93
T_2 -100% RDN	3.44	5.57	9.90	6.59	5.57
T_3 -100% RDN + carrier based *Gluconacetobacter*	3.51	5.85	10.76	8.40	5.85
T_4 -100% RDN + liquid based *Gluconacetobacter*	3.64	7.04	11.82	9.13	7.46
T_5 -75% RDN + carrier based *Gluconacetobacter*	3.13	4.23	7.29	5.53	4.39
T_6 -75% RDN + liquid based *Gluconacetobacter*	3.30	4.27	7.79	5.67	4.32
T_7 -75% RDN + carrier based *Azotobacter*	3.49	4.31	8.39	5.66	4.34
T_8 -75% RDN + liquid based *Azotobacter*	3.41	4.35	8.50	5.74	4.37
SE ±	0.16	0.32	0.39	0.37	0.30
CD at 5%	NS	0.97	1.19	1.12	0.92
General Mean	**3.29**	**4.94**	**8.85**	**6.46**	**5.02**

Gluconacetobacter (T_4) recorded maximum number of functional leaves per plant which was at par with treatment, application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly superior over rest of the treatments.

4.2.3 Leaf area per plant

The data on mean leaf area per plant in (dm^2) as influenced by different treatments at various stages of crop growth are presented in Table 9 and graphically depicted in Fig. 5.

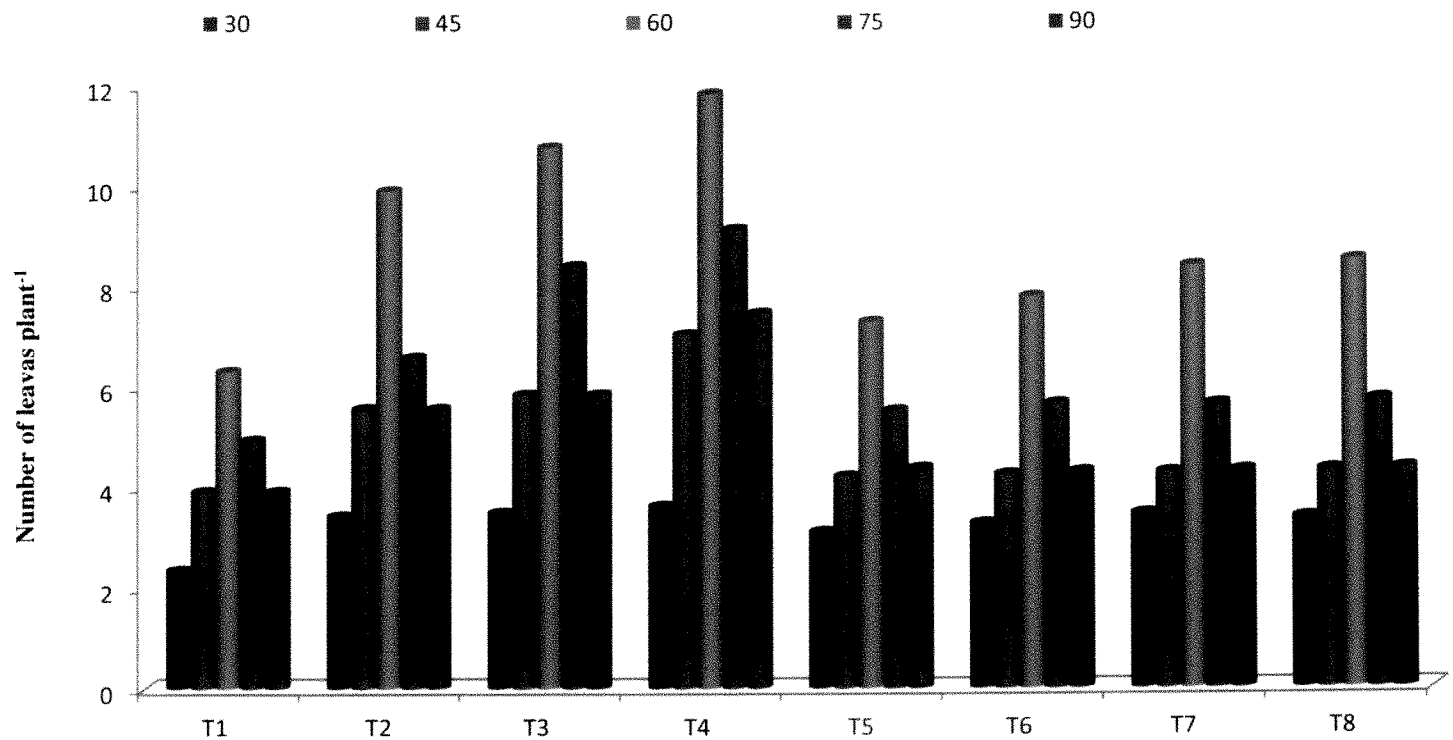

Fig. 4 : Mean number of functional leaves plant^{-1} as influenced by various treatments atdifferent crop growth stages

It is evident from Table 9 that the mean leaf area per plant (dm^2) increased rapidly from 45 to 75 days after sowing. The maximum leaf area (13.97) was recorded at 75 days after sowing. The leaf area per plant was influenced significantly due to fertilizer levels along with carrier based and liquid based biofertilizers at all growth stages of crop except at 30 days after sowing. At 45, 75 and 90 DAS application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded significantly higher leaf area per plant over all the treatments. At 60 DAS application of 100% RDN + liquid based *Gluconacetobacter* (T_4) produced higher leaf area per plant which was at par with application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly superior over rest of the treatments.

Table 9 : Leaf area plant^{-1} as influenced by various treatments at different crop growth stages

	Leaf area plant^{-1} (dm^2) days after sowing				
Treatments	**30**	**45**	**60**	**75**	**90**
T_1 – Control	3.36	4.63	6.94	10.35	4.63
T_2 -100% RDN	3.88	6.83	9.45	14.36	6.83
T_3 -100% RDN + carrier based *Gluconacetobacter*	3.84	6.90	10.57	16.80	6.90
T_4 -100% RDN + liquid based *Gluconacetobacter*	4.12	7.69	11.09	19.19	7.69
T_5 -75% RDN + carrier based *Gluconacetobacter*	3.39	6.19	7.74	12.72	6.19
T_6 -75% RDN + liquid based *Gluconacetobacter*	3.42	6.06	8.33	11.87	6.06
T_7 -75% RDN + carrier based *Azotobacter*	3.64	6.70	9.24	13.32	6.70
T_8 -75% RDN + liquid based *Azotobacter*	3.47	6.59	9.24	13.16	6.59
SE ±	0.07	0.08	0.22	0.26	0.08
CD at 5%	NS	0.23	0.68	0.80	0.23
General Mean	**3.64**	**6.45**	**9.10**	**13.97**	**6.45**

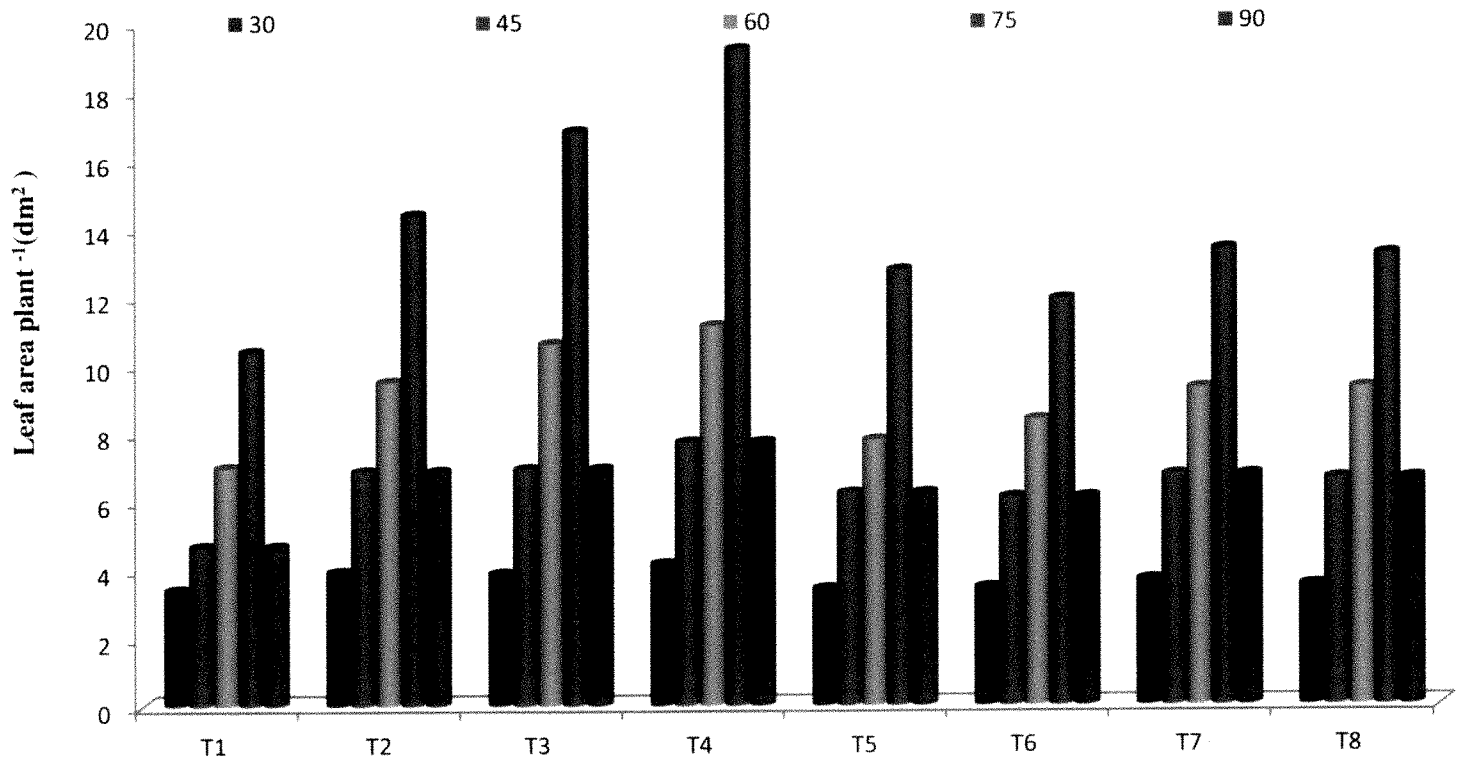

Fig. 5 : Mean leaf area plant^{-1} (dm^2)as influenced by various treatments at different crop growth stages

4.2.4 Number of internodes per plant of sorghum

Data on number of internodes per plant of sorghum at different stages of crop growth as affected by different treatments are presented in Table 10. The mean number of internodes per plant was not influenced significantly due to different treatments.

Table 10 : Number of internodes plant^{-1} as influenced by various treatments at different crop growth stages

	Number of internodes plant^{-1} days after sowing		
Treatments	**60**	**90**	**At harvest**
T_1 - Control	6.57	7.26	7.26
T_2 -100% RDN	9.28	10.40	10.40
T_3 -100% RDN + carrier based *Gluconacetobacter*	9.29	10.55	10.55
T_4 -100% RDN + liquid based *Gluconacetobacter*	9.50	11.69	11.69
T_5 -75% RDN + carrier based *Gluconacetobacter*	8.40	9.37	9.37
T_6 -75% RDN + liquid based *Gluconacetobacter*	8.41	9.18	9.18
T_7 -75% RDN + carrier based *Azotobacter*	8.78	9.76	9.76
T_8 -75% RDN + liquid based *Azotobacter*	8.75	9.82	9.82
SE ±	0.55	0.77	0.77
CD at 5%	NS	NS	NS
General Mean	**8.62**	**9.75**	**9.75**

The data pertaining to number of internodes per plant of sorghum recorded in Table 10 indicated that the mean number of internodes per plant of sorghum was increased progressively up to 90 DAS and attained the highest (11.69) number internodes per plant of sorghum with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4).

4.2.5 Stem girth of sorghum (cm)

Data on mean stem girth of sorghum at different stages of crop growth as influenced by different treatments (cm) are presented in Table 11 and graphically depicted in Fig. 6. Mean stem girth of sorghum at 60, 90 DAS and at harvest was 4.94, 6.09 and 5.31, respectively.

Mean stem girth of sorghum was influenced significantly due to different treatments at all growth stages except 60 DAS.

Table 11: Stem girth (cm) as influenced by various treatments at different crop growth stages

	Stem girth (cm) days after sowing		
Treatments	**60**	**90**	**At harvest**
T_1 – Control	4.16	5.21	4.39
T_2 -100% RDN	5.13	6.42	5.99
T_3 -100% RDN + carrier based *Gluconacetobacter*	5.14	6.53	6.02
T_4 -100% RDN + liquid based *Gluconacetobacter*	5.30	6.92	6.19
T_5 -75% RDN + carrier based *Gluconacetobacter*	4.71	5.92	4.68
T_6 -75% RDN + liquid based *Gluconacetobacter*	4.76	5.93	5.04
T_7 -75% RDN + carrier based *Azotobacter*	5.15	5.85	5.06
T_8 -75% RDN + liquid based *Azotobacter*	5.19	5.95	5.08
SE ±	0.36	0.26	0.31
CD at 5%	NS	0.79	0.94
General Mean	**4.94**	**6.09**	**5.31**

Amongst different treatments, application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded the maximum stem girth of sorghum which

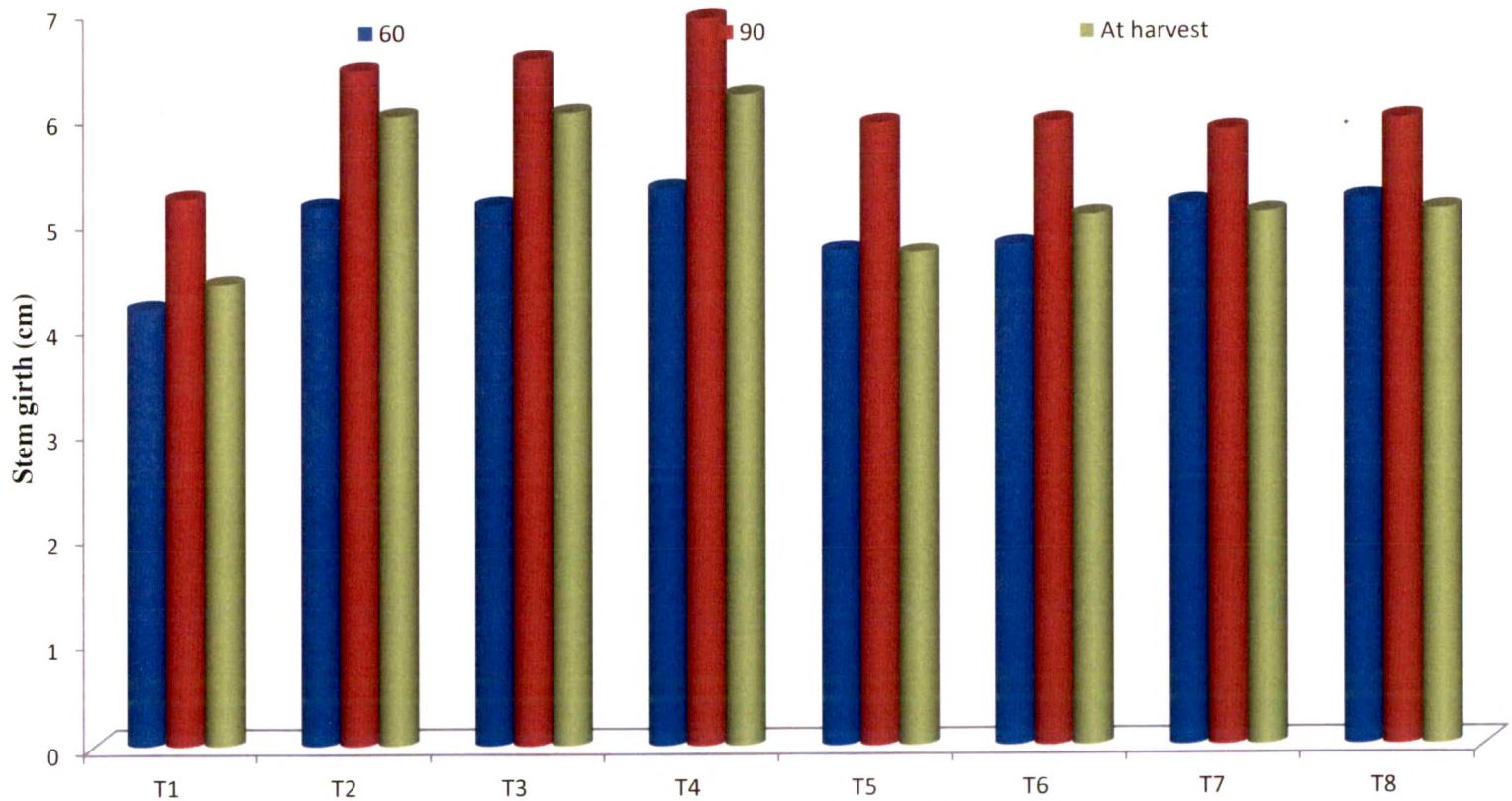

Fig. 6 : Mean of stem girth (cm) as influenced by various treatments at different crop growth stages

was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100 % RDN (T_2) and significantly superior over rest of the treatments at 90 DAS and at harvest.

4.2.6 Dry matter accumulation

The data on dry matter accumulation (g) per plant as influenced by different treatments at various stages of crop growth are presented in Table 12 and graphically depicted in Fig. 7. The perusal of data presented in Table 12 indicated that, the dry matter accumulation per plant was increased continuously up to harvest of crop. The rate of increase in dry matter accumulation was slow up to 30 days after sowing and faster between 60 to 105 days after sowing.

Table 12: Total dry matter accumulation (g) as influenced by different treatments at various stages of crop growth.

	Dry matter plant^{-1} (g) days after sowing						
Treatments	**30**	**45**	**60**	**75**	**90**	**105**	**At harvest**
T_1 - Control	1.24	2.74	7.67	31.81	58.84	79.70	82.70
T_2 -100% RDN	1.49	5.54	11.41	54.72	86.06	105.06	106.51
T_3 -100% RDN + carrier based *Gluconacetobacter*	1.51	5.73	13.83	57.28	115.07	142.97	145.97
T_4 -100% RDN + liquid based *Gluconacetobacter*	1.52	6.09	15.10	58.44	116.30	145.25	148.41
T_5 -75% RDN + carrier based *Gluconacetobacter*	1.14	4.09	8.24	39.28	68.62	91.00	93.44
T_6 -75% RDN + liquid based *Gluconacetobacter*	1.14	4.56	8.63	39.55	68.80	91.42	95.09
T_7 -75% RDN + carrier based *Azotobacter*	1.41	4.48	8.75	43.46	70.27	94.80	97.80
T_8 -75% RDN + liquid based *Azotobacter*	1.42	4.79	8.90	43.54	74.63	95.75	99.37
SE ±	0.93	0.26	0.53	1.79	3.65	6.66	6.81
CD at 5%	NS	0.79	1.60	5.43	11.06	20.21	20.64
General Mean	**1.32**	**4.75**	**10.31**	**46.01**	**82.32**	**105.32**	**108.73**

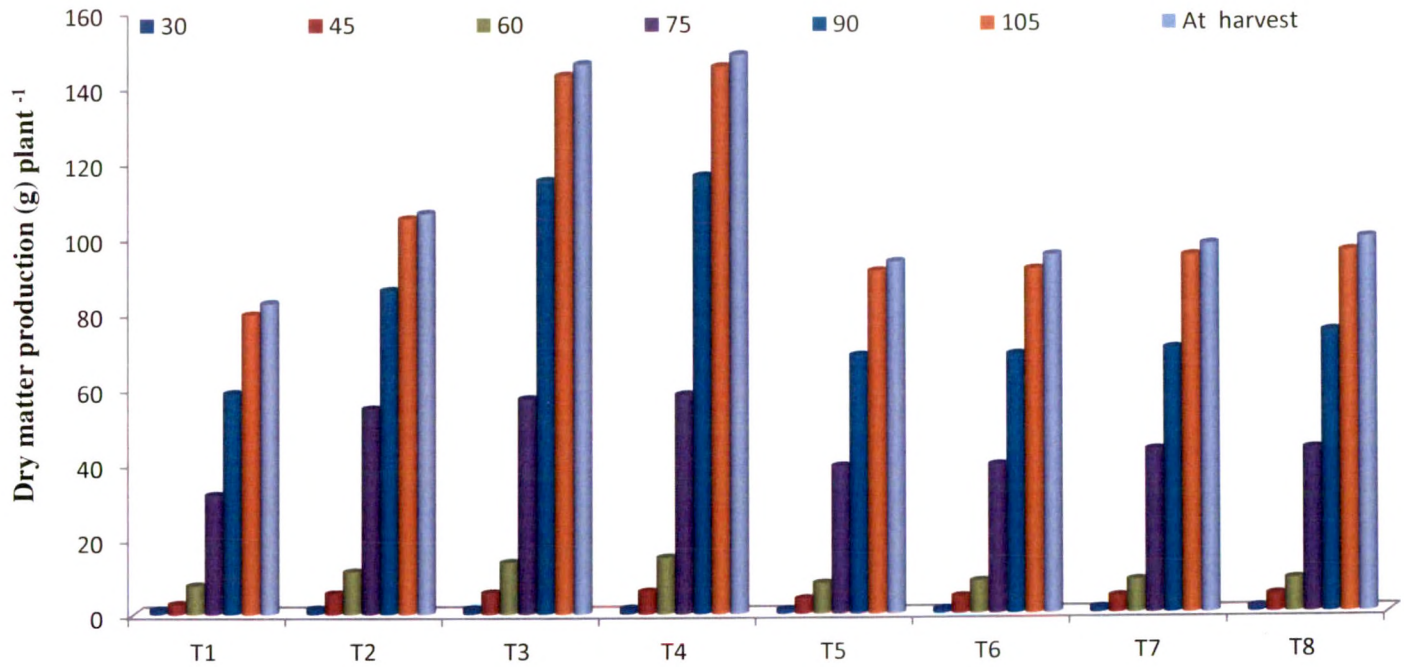

Fig. 7 : Total dry matter production (g) as influenced by different treatments at various stages of crop growth.

The data dry matter accumulation (g) per plant was influenced significantly due to fertilizer levels along with carrier based and liquid based biofertilizers at all stages of crop growth except at 30 days after sowing.

At 45 DAS, 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded significantly higher dry matter accumulation per plant over all the treatments except application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2). At 60, 75, 90, 105 DAS and at harvest 100% RDN + liquid based *Gluconacetobacter* (T_4) produced higher dry matter accumulation per plant which was at par with the application of RDN + carrier based *Gluconacetobacter* (T_3) and significantly superior over rest of the treatments.

4.2.7 Studies on 50 per cent flowering

Table 13: Mean number of days required to 50 percent flowering as influenced by treatments at different crop growth stages

Treatments	Days required for 50% flowering
T_1 - Control	57.48
T_2 -100% RDN	61.45
T_3 -100% RDN + carrier based *Gluconacetobacter*	61.86
T_4 -100% RDN + liquid based *Gluconacetobacter*	62.05
T_5 -75% RDN + carrier based *Gluconacetobacter*	58.81
T_6 -75% RDN + liquid based *Gluconacetobacter*	59.04
T_7 -75% RDN + carrier based *Azotobacter*	60.69
T_8 -75% RDN + liquid based *Azotobacter*	60.53
SE ±	2.26
CD at 5%	NS
General Mean	**60.24**

The data on mean number of days required for 50 per cent flowering of sorghum as influenced due to different treatments are presented in Table 13.

The mean number of days required for 50 per cent flowering was 60.24 days after sowing. The T_4 (100% RDN + liquid based *Gluconacetobacter*) recorded highest days for 50 per cent flowering; however, less days was required in T_1 (control) crop treatments.

The mean number of days required for 50 per cent flowering was not influenced significantly due to different treatments.

4.3 Growth analysis

4.3.1 Absolute growth rate for plant height (cm day^{-1} plant^{-1})

The mean values of absolute growth rate (AGR) of plant height (cm day^{-1} plant^{-1}) obtained at various crop growth stages are presented in Table 14. Data were not analyzed statically and the inferences are drawn on mean values.

The mean value of AGR based on plant height was 0.41, 0.84, 5.0, 2.2, 0.64 and 0.23 between 0-30, 31-45, 46-60, 61-75, 76-90 and 91-105 days respectively.

The data presented in Table 14 indicated that the AGR of plant height (cm) was very slow between 0-30, slow between 31-45, fast between 46-60 days and decreased thereafter.

The treatment T_4 (100% RDN + liquid based *Gluconacetobacter*) recorded maximum value of AGR for plant height followed by T_3 (100% RDN + liquid based *Gluconacetobacter*) and T_2 (100% RDN) treatments almost at all stages of crop growth.

4.3.2 Absolute growth rate for dry matter (g plant^{-1} day^{-1})

The mean values of absolute growth rate (AGR) of dry matter g day^{-1} obtained at various crop growth stages are presented in Table 15. Data were not analyzed statically and the inferences are drawn on mean values.

Table 14: Absolute growth rate (AGR) for plant height (cm day^{-1}plant^{-1}) as influenced by various treatments at various stages of crop growth.

	Absolute growth rate for plant height (cm day^{-1}plant^{-1}) days after sowing					
Treatments	**0-30**	**31-45**	**46-60**	**61-75**	**76-90**	**91-105**
T_1 - Control	0.38	0.51	4.6	1.5	0.22	0.13
T_2 -100% RDN	0.41	1.00	5.1	2.4	0.85	0.23
T_3 -100% RDN + carrier based *Gluconacetobacter*	0.42	1.01	5.2	2.4	0.90	0.33
T_4 -100% RDN + liquid based *Gluconacetobacter*	0.43	1.01	5.2	2.5	1.06	0.40
T_5 -75% RDN + carrier based *Gluconacetobacter*	0.40	0.77	4.9	2.1	0.43	0.16
T_6 -75% RDN + liquid based *Gluconacetobacter*	0.41	0.77	4.9	2.1	0.50	0.17
T_7 -75% RDN + carrier based *Azotobacter*	0.41	0.80	5.0	2.2	0.59	0.19
T_8 -75% RDN + liquid based *Azotobacter*	0.41	0.81	5.0	2.2	0.61	0.20
General Mean	**0.41**	**0.84**	**5.0**	**2.2**	**0.64**	**0.23**

The mean value of AGR based on dry matter was 0.05, 0.23, 0.37, 2.38, 2.42, 1.56 and 0.19 between 0-30, 31-45, 46-60, 61-75, 76-90, 91-105 and 105- at harvest respectively.

The treatment T_4 (100% RDN + liquid based *Gluconacetobacter*) recorded maximum value of AGR for dry matter followed by T_3 (100% RDN + liquid based *Gluconacetobacter*) and T_2 (100% RDN) treatments almost at all stages of crop growth.

Table 15: Absolute growth rate (AGR) for dry matter (g plant^{-1} day^{-1}) as influenced by different treatments at various stages of crop growth.

	AGR for dry matter (g plant^{-1} day^{-1}) days after sowing						
Treatments	**0-30**	**31-45**	**46-60**	**61-75**	**76-90**	**91-105**	**106-At harvest**
T_1 - Control	0.04	0.10	0.33	1.61	1.80	1.39	0.20
T_2 -100% RDN	0.05	0.27	0.39	2.89	2.09	1.27	0.06
T_3 -100% RDN + carrier based *Gluconacetobacter*	0.05	0.28	0.54	2.90	3.85	1.86	0.20
T_4 -100% RDN + liquid based *Gluconacetobacter*	0.05	0.30	0.60	2.89	3.86	1.93	0.21
T_5 -75% RDN + carrier based *Gluconacetobacter*	0.04	0.20	0.28	2.07	1.96	1.49	0.16
T_6 -75% RDN + liquid based *Gluconacetobacter*	0.04	0.23	0.27	2.06	1.95	1.51	0.24
T_7 -75% RDN + carrier based *Azotobacter*	0.05	0.20	0.28	2.31	1.79	1.64	0.20
T_8 -75% RDN + liquid based *Azotobacter*	0.05	0.22	0.27	2.31	2.07	1.41	0.24
General Mean	**0.05**	**0.23**	**0.37**	**2.38**	**2.42**	**1.56**	**0.19**

4.3.3 Relative growth rate for dry matter (g g^{-1} day^{-1})

The mean values of RGR from total dry matter accumulated per plant at various growth periods are presented in Table 16. Data were not analyzed statically and the inferences are drawn on mean values.

The mean value of RGR from total dry matter accumulated per plant was 0.010, 0.082, 0.05, 0.10, 0.038, 0.017 and 0.003 between 0-30, 31-45, 46-60, 61-75, 76-90, 91-105 and 105-at harvest respectively.

The treatment T_4 (100% RDN + liquid based *Gluconacetobacter*) and T_3 (100% RDN + carrier based *Gluconacetobacter*) recorded maximum value of RGR g g^{-1} day $^{-1}$ almost at all stages of crop growth.

Table 16: Relative growth rate (RGR) for total dry matter (g g^{-1} day^{-1}) as influenced by different treatments at various stages of crop growth.

	RGR for total dry matter (g g^{-1} day^{-1}) days after sowing						
Treatments	**0-30**	**31-45**	**46-60**	**61-75**	**76-90**	**91-105**	**106-At harvest**
T_1 – Control	0.007	0.053	0.069	0.095	0.041	0.020	0.005
T_2 -100% RDN	0.013	0.088	0.048	0.105	0.030	0.013	0.005
T_3 -100% RDN + carrier based *Gluconacetobacter*	0.014	0.089	0.059	0.095	0.047	0.014	0.003
T_4 -100% RDN + liquid based *Gluconacetobacter*	0.014	0.093	0.061	0.090	0.046	0.015	0.003
T_5 -75% RDN + carrier based *Gluconacetobacter*	0.004	0.085	0.047	0.104	0.037	0.019	0.004
T_6 -75% RDN + liquid based *Gluconacetobacter*	0.004	0.092	0.043	0.101	0.037	0.019	0.006
T_7 -75% RDN + carrier based *Azotobacter*	0.011	0.077	0.045	0.107	0.032	0.020	0.004
T_8 -75% RDN + liquid based *Azotobacter*	0.012	0.081	0.041	0.106	0.036	0.017	0.005
General Mean	**0.010**	**0.082**	**0.051**	**0.100**	**0.038**	**0.017**	**0.003**

4.3.4 Leaf area index (LAI) plant^{-1}

The data on mean values of LAI per plant at various of growth stages are presented in Table 17.

The data in Table 17 revealed that LAI increased up to 75 days then reduced onwards up to at harvest of crop.

The application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded maximum value of LAI followed by application of 100% RDN + liquid

based *Gluconacetobacter* (T_3) and 100% RDN (T_2) almost at all stages of crop growth.

Table 17: Leaf area index (LAI) plant^{-1}as influenced by various treatments at different crop growth stages

	LAI plant^{-1} days after sowing				
Treatments	**0- 30**	**31-45**	**46-60**	**61-75**	**75-90**
T_1 – Control	0.50	0.69	1.03	1.53	0.69
T_2 -100% RDN	0.57	1.01	1.40	2.13	1.01
T_3 -100% RDN + carrier based *Gluconacetobacter*	0.57	1.02	1.60	2.49	1.02
T_4 -100% RDN + liquid based *Gluconacetobacter*	0.61	1.14	1.64	2.84	1.14
T_5 -75% RDN + carrier based *Gluconacetobacter*	0.50	0.92	1.15	1.88	0.92
T_6 -75% RDN + liquid based *Gluconacetobacter*	0.51	0.90	1.23	1.76	0.90
T_7 -75% RDN + carrier based *Azotobacter*	0.54	0.99	1.37	1.97	0.99
T_8 -75% RDN + liquid based *Azotobacter*	0.51	0.98	1.37	1.95	0.98
General Mean	**0.54**	**0.96**	**1.35**	**2.07**	**0.96**

4.4 Post harvest studies

4.4.1 Yield attributes

The data regarding yield attributing characters viz., mean length, girth and weight of earhead, weight and number of grains per plant and thousand grain weights (test weight) are presented in Table 18.

4.4.1.1 Length of earhead

The mean length of earhead was influenced significantly due to different treatments. The mean length of earhead of sorghum was 21.18 cm.

Application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded higher value of length of earhead which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly superior over rest of the treatments.

4.4.1.2 Girth of earhead

The girth of earhead of sorghum was influenced significantly due to different treatments. The mean girth of earhead recorded during investigation was 6.62 cm.

The maximum girth of earhead was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) and which was at par with the application of (100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) and found significantly superior over rest of the treatments.

4.4.1.3 Weight of earhead

Weight of earhead per plant was influenced significantly due to various treatments. The mean weight of earhead recorded during investigation was 26.04 g.

The maximum weight of earhead was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly superior over rest of the treatments.

4.4.1.4 Weight of grain per plant

Weight of grain per plant was influenced significantly due to various treatments. The mean weight of grain per plant recorded during investigation was 16.24 g.

Table 18 : Yield attributing character of sorghum as influenced by various treatments

Treatments	Mean length of earhead (cm)	Mean breadth of earhead (cm)	Mean weight. of earhead (g)	Weight of grains plant^{-1} (g)	Number of grains Plant^{-1}	Test weight (g)
T_1 - Control	15.54	4.91	10.70	7.25	370	19.25
T_2 -100% RDN	21.83	6.90	28.23	18.75	865	21.52
T_3 -100% RDN + carrier based *Gluconacetobacter*	22.83	7.76	31.75	18.85	874	21.56
T_4 -100% RDN + liquid based *Gluconacetobacter*	24.47	7.85	34.35	19.78	882	21.61
T_5 -75% RDN + carrier based *Gluconacetobacter*	20.89	6.28	25.65	16.10	819	20.31
T_6 -75% RDN + liquid based *Gluconacetobacter*	21.47	6.35	25.82	16.31	831	20.41
T_7 -75% RDN + carrier based *Azotobacter*	21.65	6.44	25.86	16.44	830	20.66
T_8 -75% RDN + liquid based *Azotobacter*	21.74	6.46	25.92	16.46	834	20.62
SE ±	0.79	0.33	1.83	0.32	9.67	0.69
CD at 5%	2.40	0.99	5.56	0.98	29.32	NS
General Mean	**21.18**	**6.62**	**26.04**	**16.22**	**788**	**20.74**

The maximum weight of grain per plant was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was at par with the application of (100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly superior over rest of the treatments.

4.4.1.5 Number of grains per plant

The number of grains per plant of sorghum was influenced significantly due to different treatments. The mean number of grains per plant recorded during investigation was 788 cm.

The maximum Number of grains per plant was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) and which was at par with the application of (100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) and found significantly superior over rest of the treatments.

4.4.1.6 Test weight

The mean test weight of sorghum was 20.74 g. Test weight was not influenced significantly with different treatments of fertilizer levels and carrier and liquid based biofertilizers on *kharif* sorghum.

4.5 Yield and harvest index

The data on grain yield, straw yield, biological yield (kg ha^{-1}) harvest index are presented in Table 19 and graphically depicted in Fig.8

4.5.1 Grain yield (q ha^{-1})

The data presented in Table 19 revealed that the mean grain yield (kg ha^{-1}) was influenced significantly due to different treatments of fertilizer levels and carrier and liquid based biofertilizers. The average grain yield of *kharif* sorghum was 1915 kg ha^{-1}.

The highest grain yield was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) and which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly superior over rest of the treatments.

4.5.2 Stalk yield

The data presented in Table 19 revealed that the mean stalk yield (kg ha^{-1}) was influenced significantly due to different treatments of fertilizer levels and carrier and liquid based biofertilizers. The average stalk yield of *kharif* sorghum was 4151 kg ha^{-1}.

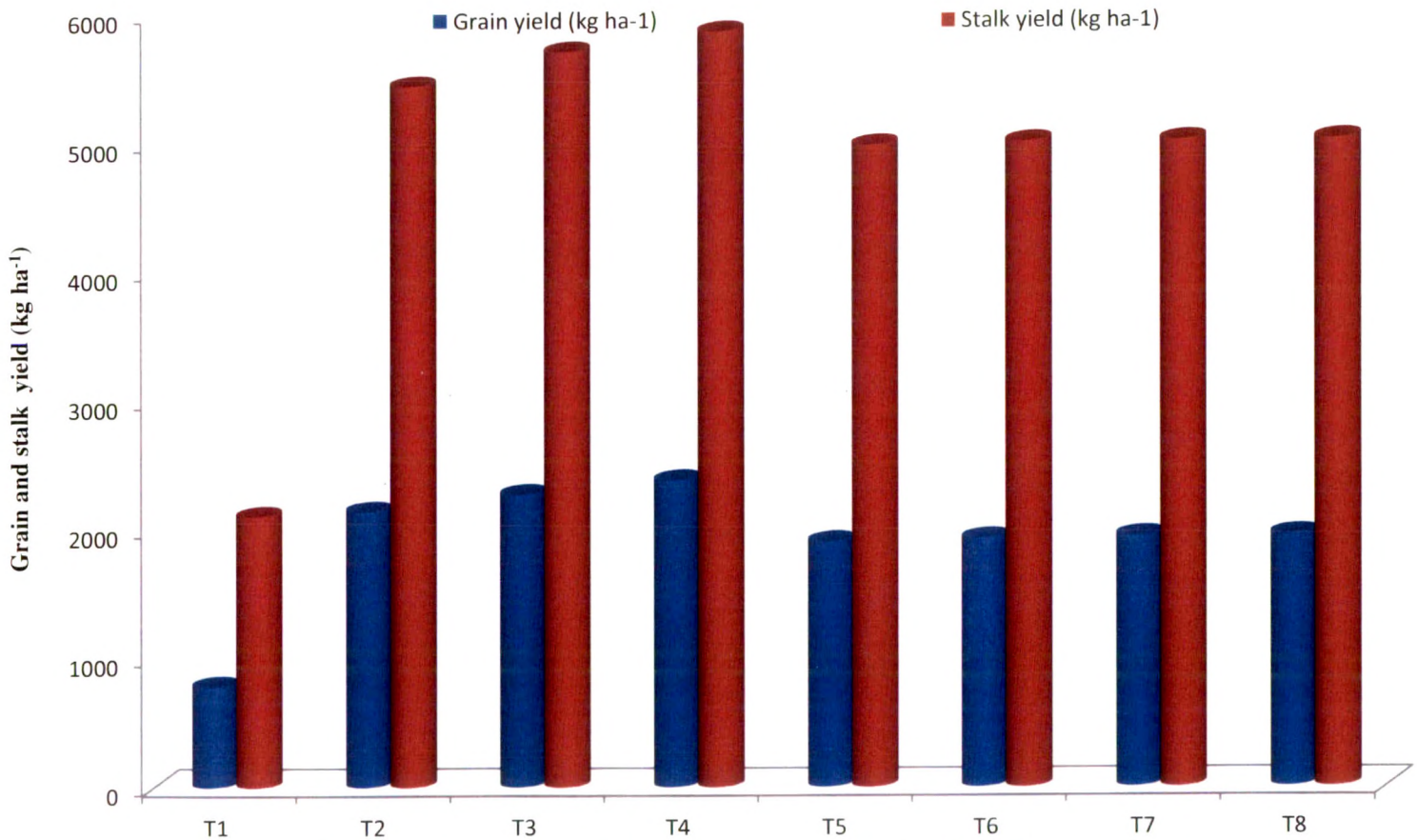

Fig. 8 : Grain and stalk yield of sorghum crop as influenced by different treatments.

Table 19: Grain yield (kg ha^{-1}), stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) as influenced by different treatments

Treatments	Grain yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1 - Control	787	2103	2890	27.24
T_2 -100% RDN	2141	4638	6779	31.59
T_3 -100% RDN + carrier based *Gluconacetobacter*	2273	4604	6877	33.05
T_4 -100% RDN + liquid based *Gluconacetobacter*	2383	4710	7093	33.60
T_5 -75% RDN + carrier based *Gluconacetobacter*	1905	4281	6186	30.80
T_6 -75% RDN + liquid based *Gluconacetobacter*	1928	4306	6234	30.93
T_7 -75% RDN + carrier based *Azotobacter*	1946	4276	6222	31.28
T_8 -75% RDN + liquid based *Azotobacter*	1956	4288	6244	31.33
SE ±	75	204	232	----
CD at 5%	227	618	702	----
General Mean	**1915**	**4151**	**6066**	**31.23**

The highest stalk yield was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was significantly superior over control and found at par with rest of the treatments.

4.5.3 Biological yield

The data presented in Table 19 revealed that the mean biological yield (kg ha^{-1}) was influenced significantly due to different treatments of fertilizer levels and carrier and liquid based biofertilizers. The average biological yield of *kharif* sorghum was 6066 kg ha^{-1}.

The highest biological yield was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) and which was at par with the application of (100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) and found significantly superior over rest of the treatments.

4.5.4 Harvest index

The data presented in Table 19 revealed that the average harvest index of *kharif* sorghum was 31.23.

The highest harvest index was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was closely followed by application of 100% RDN + carrier based *Gluconacetobacter* (T_3).

4.6 Economic studies

The cost of fertilizer and biofertilizers is an important factor which decides the magnitude of profit, hence cost of fertilizer and biofertilizers was considered in order to obtain more comprehensive picture of the benefit: cost ratio and net returns per hectare. These studies have been made by taking into consideration the cost of cultivation and gross monetary returns. The parameters considered were cost of fertilizer and biofertilizers, total cost of cultivation, gross monetary returns, net monetary returns (₹ ha^{-1}) and benefit: cost ratio (₹.₹$^{-1}$). Data are presented in Table 20 and graphically depicted in Fig. 9.

4.6.1 Gross monetary return

The data presented in Table 20 revealed that the gross monetary return was influenced significantly due to different treatments. The gross monetary return of *kharif* sorghum were ₹ 49249 ha^{-1}.

The highest gross monetary returns was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly higher over rest of the treatments.

Table 20: Economics (₹ ha^{-1}) of sorghum as influenced by different treatments

Treatments	GMR (₹ ha^{-1})	CC (₹ ha^{-1})	NMR (₹ ha^{-1})	B:C ratio
T_1 - Control	20616	18450	2166	1.12
T_2 -100% RDN	54941	22796	32145	2.41
T_3 -100% RDN + carrier based *Gluconacetobacter*	58041	22811	35230	2.54
T_4 -100% RDN + liquid based *Gluconacetobacter*	60375	22811	37564	2.65
T_5 -75% RDN + carrier based *Gluconacetobacter*	49456	22533	26923	2.19
T_6 -75% RDN + liquid based *Gluconacetobacter*	49908	22533	27375	2.21
T_7 -75% RDN + carrier based *Azotobacter*	50232	22533	27699	2.23
T_8 -75% RDN + liquid based *Azotobacter*	50424	22533	27891	2.24
SE ±	1554	---	1554	---
CD at 5%	4712	---	4712	---
General Mean	**49249**	**22125**	**27124**	**2.20**

4.6.2 Net monetary return

The data on net monetary return presented in Table 20 revealed that the mean net monetary return of *kharif* sorghum were ₹ 27124 ha^{-1}.

The highest net monetary return was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly higher over rest of the treatments.

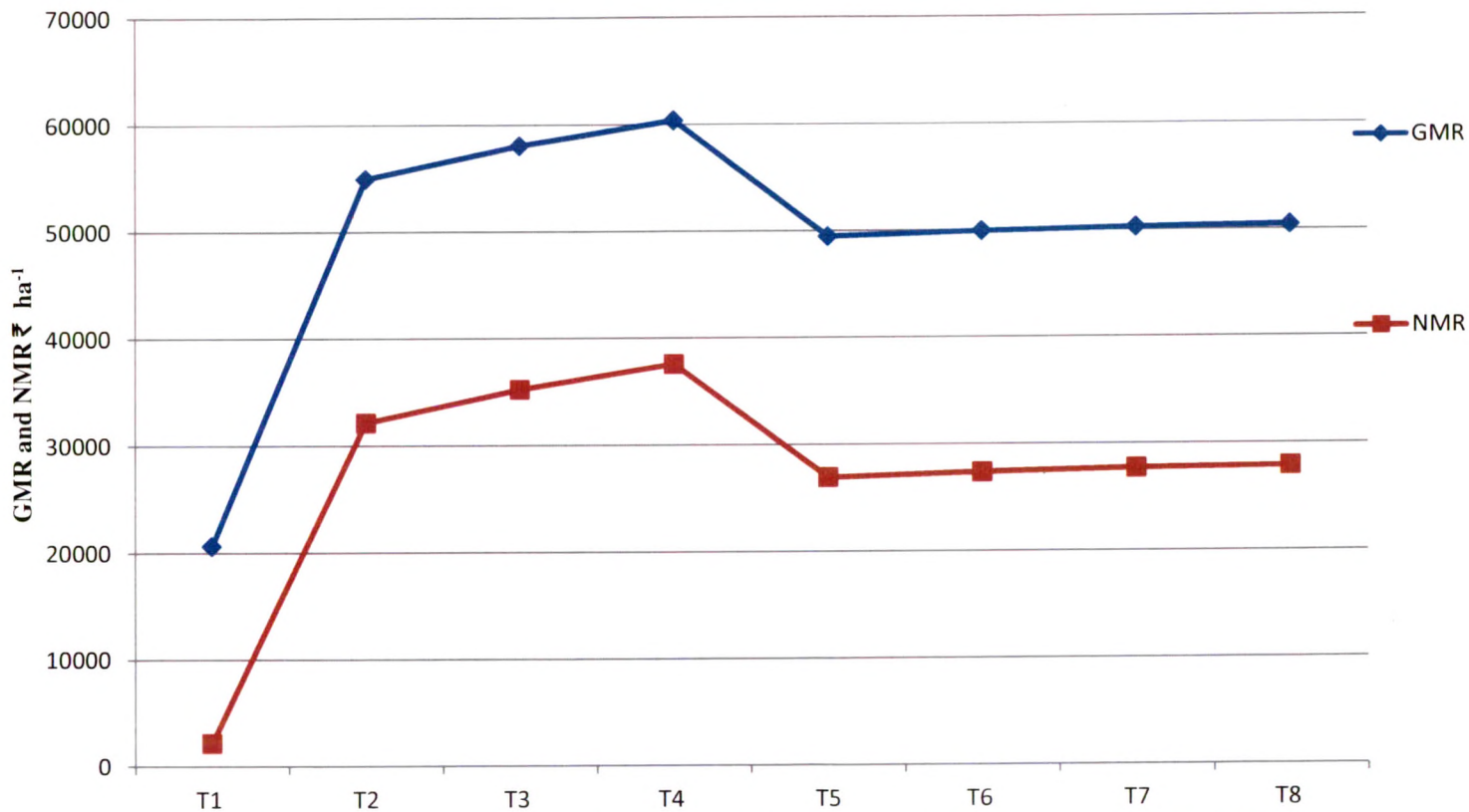

Fig. : 9 Gross monetary returns and net monetary returns of different treatments (₹ ha^{-1})

4.6.4 Benefit: cost ratio

The data on benefit: cost ratio presented in Table 20 revealed that the mean benefit: cost ratio of *kharif* sorghum was 2.20.

The highest benefit: cost ratio was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was closely followed by application of 100% RDN + carrier based *Gluconacetobacter* (T_3).

DISCUSSION

Chapter-V

DISCUSSION

The results of present investigation entitled "Effects of *gluconacetobacter* and *azotobacter* on growth and yield of *kharif* sorghum" conducted during *kharif* 2014 at college farm, Department of Agronomy, College of Agriculture, Latur are discussed in this chapter. An attempt has been made to evaluate and to offer the experimentation with experimental evidences wherever possible for noted variations in growth and development, grain and straw yield in *kharif* sorghum with a view to establish the cause and effect relationship as far as possible.

5.1 Soil

At a glance, the Table 1 of the soil properties revealed that the soil of experimental plot was low in available nitrogen (118.86 kg ha^{-1}), medium in available phosphorus (20.42 kg ha^{-1}), high in available potassium (385.89 kg ha^{-1}) and alkaline (pH 8.17) in reaction. The soil was clayey in texture with moderate moisture holding capacity which was favorable for normal growth of the crop.

5.2 Weather and climate

The weekly means of the meteorological data during the experimental period (Table 2) indicated that the total rainfall during the crop growth period was 421 mm and distributed in 29 rainy days. The average maximum and minimum temperature during experimental period was 29.12^{0}C and 21.34^{0}C, respectively. The mean relative humidity during experimental period was 77.09 percent during morning and 65.64 percent during evening.

In general climatic condition prevailed during crop growth period was favourable for proper growth and development of sorghum during *kharif* season of 2014. But even though sorghum crop was exposed to heat and water stresses caused by varying precipitation during pre-crop period as well as crop duration. The growth and yield parameters were badly affected due to uneven distribution of rain and long dry spells and insufficient rain fall. Water stress during crop growth resulted in reduced leaf area, dry matter and grain yields. The seed filling and the maturity stage

began earlier in stressed plants and the duration of the maturation period was significantly reduced by stress, leading to accelerated leaf senescence.

5.3 Emergence count and final plant stand

The plant stand was satisfactory. The mean emergence count and final plant stand (Arcsine value) was 92.06 and 85.67 per cent, respectively. The emergence and final plant stand were statistically non significant which indicated that the variations obtained in the investigation in different characters are the difference due to treatments only and not due to differential in plant population.

5.4 Growth and development

The beneficial effect of different fertilizer levels along with biofertilizers on plant height, number of functional leaves, leaf area, dry matter production, number of internodes per plant, stem girth, mean number of days required for 50 per cent flowering, AGR for height and dry matter, RGR for dry matter and leaf area index (LAI) of *kharif* sorghum were evident during active growth and maturity.

The application of 100% RDN + liquid based *Gluconacetobacter* (T_4) produced more vegetative growth in early period of crop growth. It was observed from the data that, the height was found to be increased progressively at every stage of crop growth. The increase in height was rapid during 45-60 DAS and thereafter it increased marginally up to 90 DAS. The effect of different fertilizer levels along with biofertilizers on plant height was found to be significant at all stages of crop growth except at 30 DAS. The higher plant height was observed by the application of 100% RDN + liquid based *Gluconacetobacter* followed by 100% RDN + carrier based *Gluconacetobacter* as compared to other treatments which might be because of optimum utilization of available nitrogen due to the inoculation of biofertilizer. Similar results were also obtained by Patidar and Mali (2001), Kader (2002), Apoorva *et al.* (2010) and Naserirad Hoshang *et al.*, (2011).

From the data on mean number of functional leaves and leaf area per plant it is observed that the number of functional leaves was increased upto 60 DAS and leaf area increased up to 75 days and decreased thereafter up to harvest due to senescence of leaves. Mean number of functional leaves were influenced significantly by various treatments at all stages of crop growth except at 30 DAS. The application of 100% RDN + liquid based *Gluconacetobacter* (11.28) followed by the application of 100% RDN + carrier based *Gluconacetobacter* (10.56) and 100% RDN (9.90) recorded the highest number of functional leaves at every stage of the crop growth. This might be because of optimum utilization of available nitrogen due to the inoculation of biofertilizer. Similar result was obtained by Apoorva *et al* (2010) and Chintapalli *et al* (2012).

The leaf area of sorghum (Table 10) indicated that leaf area increase up to 75 DAS and decreased thereafter upto harvest. The rate of increase was very fast during vegetative growth. It was maximum at 75 DAS in all treatments. At 45, 60, 75 and 90 DAS the highest leaf area per plant was recorded by 100% RDN + liquid based *Gluconacetobacter* (T_4) treatment followed by 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2). This might be because of optimum utilization of available nitrogen due to the inoculation of biofertilizer. Similar result was observed by Virendra Kumar and Ahlawat (2006).

The dry matter production of sorghum (Table 11) registered continuous increase up to harvest of crop. The rate of dry matter production was slow up to 30 days because of seedling stage. The rate of increase was very fast during vegetative as well as reproductive phase which indicated that the dry matter production was increased continuously in vegetative as well as in reproductive stage during crop growth.

The maximum dry matter production of sorghum was observed in 100% RDN + liquid based *Gluconacetobacter* (T_4) treatment followed by 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) which might be due to optimum utilization of moisture and available nitrogen due to the inoculation of biofertilizer. It might be due to *Gluconacetobacter* inoculation which attributed to nitrogen fixation development of better root system, production of plant growth hormones and enhancement in uptake of nutrients resulted in higher growth attributes.

Such type of results were also observed by Alagwadi and Gaur (1988), Rasal and Patil (1993), Kader (2002), Dadarwal *et al.* (2009) and Kumarasamy and Santhaguru (2011).

The data pertaining to number of internodes per plant of sorghum (Table 12) indicated that, the mean total number of internodes per plant of sorghum was not influenced significantly due to different treatments at all the growth stages of crop. Such type of improvement in number of internodes per plant was also observed by Chintapalli *et al* (2012).

Stem girth of sorghum was influenced significantly due to various treatments at all the growth stages except 60 DAS. At 90 DAS and at harvest the maximum stem girth of sorghum was also recorded by 100% RDN + liquid based *Gluconacetobacter* (T_4) treatment followed by 100% RDN + carrier based *Gluconacetobacter* (T_3) treatment and 100% RDN (T_2). Such type of observation was also observed by Naserirad Hoshang *et al* (2011).

The mean number of days required for 50 per cent flowering (Table 14) was not influenced significantly due to different treatments.

Mean value of absolute growth rate (AGR) for plant height (cm per day per plant) at various stages of crop growth is presented in Table 15 showed that, absolute growth rate increased rapidly and reaches at peak between 46-60 days (5.0 cm day^{-1} $plant^{-1}$) and then slow down till maturity. The effect of fertilizer levels along with biofertilizers on absolute growth rate (AGR) for plant height was more or less similar at all the crop growth stages.

Absolute growth rate (AGR) for dry matter accumulation presented in Table 16 showed that it was slow during early stage of crop growth, faster between 61-75 days (2.14 g day^{-1} $plant^{-1}$) and slow down thereafter till maturity. The application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded higher absolute growth rate for dry matter at all the crop growth stages. The effect of fertilizer levels along with biofertilizers on absolute growth rate (AGR) dry matter accumulation was more or less similar at all the crop growth stages.

Data on relative growth rate (g g^{-1} day^{-1}) for dry matter at various stages of crop growth presented in Table 17 showed that the relative growth rate (RGR) increased rapidly and reaches at peak between 60-75 (0.137 g g^{-1} day^{-1}) days and then slows down till maturity. The effect of fertilizer levels along with biofertilizers on absolute growth rate (RGR) for plant height and was more or less similar at all the crop growth stages. Same result was observed by Alagwadi and Gaur (1988) and Rasal and Patil (1993).

Data on leaf area index (LAI) presented in Table 18 indicated that the leaf area index (LAI) was low at initial stage of crop growth, highest at 75 days and thereafter it decreases towards maturity stage of crop growth. The application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded highest mean leaf area index (2.07) at all the crop growth stages as compared to the other treatments. Same results were also reported by Virendra Kumar and Ahlawat (2006) and Kumar and Dhar (2010).

5.5 Yield and yield attributes

The yield attributing characters of sorghum *viz.*, mean length of earhead (cm), breadth of earhead (cm), weight of earhead (g), weight of grains per plant (g), number of grains per plant and test weight (g) of were influenced significantly due to various treatments.

The application of 100% RDN + liquid based *Gluconacetobacter* (24.47) followed by the application of 100% RDN + carrier based *Gluconacetobacter* (21.83) and 100% RDN (21.83) recorded the highest mean length of earhead (cm). These are in conformity with the findings of Kader *et al.*, (2002) and Bama and Ramkrishanan (2010) and Baral Bandhuraj and Adhikari Prabhavti (2013).

The application of 100% RDN + liquid based *Gluconacetobacter* recorded the highest mean breadth of earhead (cm) which was at par with the application of application of 100% RDN + carrier based *Gluconacetobacter* and significantly superior over rest of the treatments.

Mean weight of earhead and grains per plant (Table 19) were influenced significantly and their highest value were recorded with the application of 100% RDN + liquid based *Gluconacetobacter* followed by 100% RDN + carrier based *Gluconacetobacter*. It confirms the findings Umesha *et al.*, (2014), Majjigudda and Srenivasa (1996), Barik and Nag (2001) and Deokar and Sawant (2002).

The number of grains per plant of sorghum was influenced significantly due to different treatments. Application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded significantly maximum number of grains which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) and found significantly superior over rest of the treatments. The test weight of sorghum was not influenced by different treatments. Similar results were also reported by Mastiholi and Itnal (1997), Apporva *et al.*, (2010), Kumar and Dhar (2010), Hoshang *et al.*, (2011), Channabasava and Lakshman (2013) and Kalhapure *et al.*, (2013).

The grain and biological yield of sorghum was influenced significantly due to different treatments. The higher values of grain and biological yield was observed with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) and found significantly superior over rest of the treatments. This might be due to inoculation of *Gluconacetobacter* which increased more nitrogen fixation, growth promoting substances and hormones resulted in enhanced nutrients uptake, translocation and synthesis of photosynthates assimilates which resulted increased plant growth characters and in obtaining economically profitable yields. Similar type of results were also reported by Mastiholi and Itnal (1997), Nayak *et al.*, (2001), Patidar and Mali (2001), Gawai and Pawar (2007), Singh and Dubey (2008), Naserirad Hoshang *et al.*, (2011) and Sharma *et al.*, (2015).

The highest value of harvest index was observed with the application of 100% RDN + liquid based *Gluconacetobacter* closely followed by application of 100% RDN + carrier based *Gluconacetobacter* (T_3). Similar result was also reported by Auoub and Masoud (2013).

5.6 Economics of the sorghum crop

Effect of different level of fertilizer along with inoculation of biofertilizer on gross monetary returns and net monetary returns were found significant. Application of 100% RDN + liquid based *Gluconacetobacter* (T_4) noticed higher gross monetary returns and net monetary returns which was at par with the application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and significantly superior over other treatments. The highest B: C ratio was also observed with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) followed by 100% RDN + carrier based *Gluconacetobacter* (T_3).

SUMMARY AND CONCLUSION

Chapter - VI

SUMMARY AND CONCLUSION

An agronomic investigation entitled "Effects of *gluconacetobacter* and *azotobacter* on growth and yield of *kharif* sorghum" was conducted at college farm, Department of Agronomy, College of Agriculture, Latur. The aim of present study was to assess the effect of different treatments on growth and yield of sorghum.

The soil of the experimental site was clayey in texture, alkaline in reaction, low in organic carbon and available nitrogen, medium in available phosphorus but high in available potash. It was well drained with moderate moisture retention capacity which was favourable for optimum growth. The environmental conditions were moderately congenial for normal growth and maturity of sorghum crop.

The experiment was laid out in a Randomized Block Design with 8 treatments replicated thrice. The treatments were T_1- control, T_2- 100% RDN, T_3- 100% RDN + carrier based *Gluconacetobacter.*, T_4- 100% RDN + liquid based *Gluconacetobacter*, T_5- 75% RDN + carrier based *Gluconacetobacter*, T_6-75% RDN + liquid based *Gluconacetobacter*, T_7- 75% RDN + carrier based *Azotobacter*, T_8- 75% RDN + liquid based *Azotobacter*..

The gross and net plot size of each experimental unit was 5.4 m x 4.2 m and 4.5 m x 3.9 m, respectively. Sowing was done by dibbling method on 12th July 2014 as per treatment. The recommended cultural practices and spraying of herbicides measures were undertaken. The recommended dose of fertilizer 80:40:40 NPK kg ha^{-1} was applied. The recommended dose of fertilizer (nitrogen, phosphorus and potash) was applied through Urea, S.S.P. and MOP. The crop was harvested on 12th November 2014.

The data on mean emergence count and final plant stand at harvest was uniform indicating that the differences obtained were only due to different treatments effects. Various ancillary observations on growth of crop were periodically recorded along with post harvest studies, to evaluate treatments effects.

The effects of *gluconacetobacter* and *azotobacter* treatment were noticed on important growth parameters *viz.*, plant height, number of functional leaves, and dry matter production on five sample plants selected randomly from each net plot. The leaf area and one plant samples which uprooted for dry matter studies from each gross plot.

Post harvest studies include grain, stalk yield plant^{-1}, weight of earhead and number of grains plant^{-1} were also recorded from each net plot at the time of harvest. The test weight (g), biological yield (kg ha^{-1}) and harvest index (%) were also calculated.

6.1 Effect of treatments

The effect of different treatments was noticed on important growth yield and yield attributes of sorghum.

6.1.1 Growth attributes

The plant height, number of functional, leaf area, total dry matter per plant influenced significantly due to different treatments at all growth stages of the crop except 30DAS.The above mentioned growth parameters were recorded higher values with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) during the entire crop growth period followed by application of 100% RDN + carrier based *Gluconacetobacter* (T_3).

Application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded the highest values of absolute growth rate for plant height and dry matter and relative growth rate for dry matter followed by treatment 100% RDN + carrier based *Gluconacetobacter* (T_3) almost at all growth stages of crop. The 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded the highest values of leaf area index followed by the treatment 100% RDN + carrier based *Gluconacetobacter* (T_3) and 100% RDN (T_2) at all the crop growth stages.

6.1.2 Yield and yield attributes

The effect of different treatments on yield and yield attributing characters *viz.*, grain, stalk yield plant^{-1}, test weight (1000 seeds), and harvest index

(%) was significant. Application of 100% RDN + liquid based *Gluconacetobacter* (T_4) recorded higher value of these parameters which was at par with application of 100% RDN + carrier based *Gluconacetobacter* (T_3) and found significantly superior over other treatments

6.1.4 Economics of the sorghum crop

The gross monetary returns and net monetary returns were influenced significantly due to different treatments. Application of 100% RDN + liquid based *Gluconacetobacter* treatment (T_4) recorded higher value of gross monetary returns and net monetary returns which was at par with 100% RDN + carrier based *Gluconacetobacter* (T_3) and significantly superior over rest of the treatments. The higher B: C ratio was also recorded with the application of 100% RDN + liquid based *Gluconacetobacter* treatment (T_4).

CONCLUSIONS

On the basis of field experiment conducted during *kharif* season of 2014-15 entitled "Effects of *gluconacetobacter* and *azotobacter* on growth and yield of *kharif* sorghum" it could be conducted that, application of 100% RDN + liquid based *Gluconacetobacter* (T_4) and 100% RDN + carrier based *Gluconacetobacter* (T_3) are equally effective in producing higher grain yield and profit in terms of gross monetary returns, net monetary returns and B: C ratio.

Above conclusion is based on single *kharif* season research trial and it needs further confirmation by repeating the trial for at least one more season.

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*Original not seen.

ABSTRACT

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A field experiment was conducted during *kharif* season of 2014-15 at experimentation field College of Agriculture, Latur to study the effects of carrier and liquid based *gluconacetobacter* and *azotobacter* biofertilizers on growth, yield and economics of *kharif* sorghum. The soil was clayey in texture, low in available nitrogen (118.86 kg ha^{-1}), medium in phosphorus (20.42 kg ha^{-1}), high in potassium (385.89 kg ha^{-1}) and slightly alkaline in reaction (pH 8.17). The experiment was laid out in Randomized Block Design with eight treatments viz. T_1-Control, T_2-100% RDN, T_3-100% RDN + carrier based *Gluconacetobacter*, T_4-100% RDN + liquid based *Gluconacetobacter*, T_5-75% RDN + carrier based *Gluconacetobacter*, T_6-75% RDN + liquid based *Gluconacetobacter*, T_7 -75% RDN + carrier based *Azotobacter*, T_8 -75% RDN + liquid based *Azotobacter* replicated thrice. The recommended cultivation practices were adopted. The result indicated that, the growth and yield attributing characters of sorghum viz. plant height, number of functional leaves, leaf area, dry matter accumulation per plant, length of earhead, weight of earhead and grain weight per plant were significantly higher with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) followed by application of 100% RDN + carrier based *Gluconacetobacter* (T_3). The significantly higher grain yield, gross monetary returns and net monetary returns was recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4) followed by application of 100% RDN + carrier based *Gluconacetobacter* (T_3). Highest B: C ratio was also recorded with the application of 100% RDN + liquid based *Gluconacetobacter* (T_4).

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