PERFORMANCE OF CHILLI (*Capsicum annuum* L.) AS INFLUENCED BY NK RATIO, BIOFERTILIZER AND SHADE

SREEJA. M.

2003

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695522

PERFORMANCE OF CHILLI (*Capsicum annuum* L.)
AS INFLUENCED BY NK RATIO, BIOFERTILIZER AND SHADE

SREEJA. M.

**Thesis submitted in partial fulfilment of the requirement
for the degree of**

Master of Science in Agriculture

**Faculty of Agriculture
Kerala Agricultural University, Thrissur**

2003

**Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695522**

DECLARATION

I hereby declare that this thesis entitled "**Performance of chilli (*Capsicum annuum* L.) as influenced by NK ratio, biofertilizer and shade**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
25-10-2003.

SREEJA. M.
(2001-11-35)

CERTIFICATE

Certified that this thesis entitled "**Performance of chilli (*Capsicum annuum* L.) as influenced by NK ratio, biofertilizer and shade**" is a record of research work done independently by Ms. SREEJA. M. (2001-11-35) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
25-10-2003.

Shri. S.M. SHAHUL HAMEED
(Chairman, Advisory Committee)
Associate Professor,
Department of Agronomy,
College of Agriculture, Vellayani
Thiruvananthapuram.

Approved by

Chairman :

Shri. S.M. SHAHUL HAMEED
Associate Professor,
Department of Agronomy,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

Members:

Dr. S. JANARDHANAN PILLAI
Associate Professor and Head,
Department of Agronomy,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

Dr. L. RAJAMONY
Associate Professor and Head,
Department of Olericulture,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

Dr. K. HARIKRISHNAN NAIR
Professor and Head,
Instructional Farm,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

External Examiner :

Dedicated to My

Beloved Parents and Brother

ACKNOWLEDGEMENT

My sincere gratitude and obligations to my Chairman Shri. S.M. Shahul Hameed, Associate Professor, Department of Agronomy, for his valuable guidance, constant and inspiring encouragement, constructive criticism and valuable suggestions throughout the course of this investigation and in the preparation of thesis.

Grateful and sincere thanks are due to Dr. V. Muraleedharan Nair, Former Professor and Head, Department of Agronomy, for his timely suggestions and kind help.

I wish to express my profound thanks and gratitude to Dr. S. Janardhanan Pillai, Professor and Head, Department of Agronomy for his constant wholehearted help and valuable suggestions for the constructive perusal of the manuscript.

My heartfelt thanks to Dr. L. Rajamony, Associate Professor and Head, Department of Olericulture, for his critical comments and constructive suggestions throughout the study.

I extremely thankful to Dr. K. Harikrishnan Nair, Professor and Head, Instructional Farm, College of Agriculture, Vellayani and member of my advisory committee for his valuable suggestions and guidance rendered to me in formulating this thesis.

My sincere thanks to Dr. P. Sivaprasad and Dr. Roy Stephen for their wholehearted technical support during the course of study.

I wish to place on record my thanks to each and every teaching, non-teaching staff and students of Agronomy Department and Instructional Farm for their sincere and wholehearted co-operation throughout the research work.

No word can truly represent deep sense of gratitude to Dr. Vijayaraghavakumar, Associate Professor, Department of Agricultural Statistics, for his timely help and suggestions rendered during the analysis of data.

I gratefully acknowledge Sri. C.E. Ajithkumar, Programmer, Department of Agricultural Statistics for his co-operation during the statistical analysis of the data.

I am deeply obliged to my friends Pamila, Bijily, Anu, Robi, Ninitha, Simi and all my junior friends for their voluntary and selfless help, which I cannot express in words.

My hearty thanks to Sindhu M.S., Geetha chechi, Vandana chechi and Usha chechi for their everwilling help and good company at times when I needed it most. I remember with much gratitude the wholehearted help rendered by Anitha chechi, Liza and Saritha in the analysis of samples.

I am thankful to Kerala Agricultural University for providing the Kerala Agricultural University Junior Fellowship.

Grateful acknowledgement to Biju. P. of ARDRA for prompt and timely help rendered in typing the thesis.

At this moment I recall with love and gratitude, the constant encouragement and inspiration given to me by my family members. I am deeply obliged to them in making this endeavour a success.

Above all, I bow my head before God Almighty for the blessings showered upon me through out which made this venture a success.

SREEJA. M.

CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF APPENDIX

LIST OF ABBREVIATIONS

%	-	Per cent
@	-	At the rate of
BCR	-	Benefit Cost Ratio
BNF	-	Biological Nitrogen Fixation
cfu	-	Colony forming units
cv.	-	Cultivar
cm	-	Centimetre
cm^2	-	Square centimetre
CGR	-	Crop Growth Rate
DAT	-	Days after Transplanting
DMP	-	Dry Matter Production
et al.	-	And others
Fig.	-	Figure
FYM	-	Farm Yard Manure
FIB	-	Farm Information Bureau
g	-	Gram
GA	-	Gibberlic acid
ha	-	Hectare
IAA	-	Indole Acetic Acid
K	-	Potassium
K_2O	-	Potash
kg ha^{-1}	-	Kilogram per hectare
kg	-	Kilogram
LAI	-	Leaf Area Index
m	-	Metre
mg	-	Milligram
ml	-	Millilitre
mm	-	Millimetre
MOP	-	Muriate of Potash
N	-	Nitrogen
nm	-	Nanometre
^0C	-	Degree celsius
^0E	-	Degree East
^0N	-	Degree North
P	-	Phosphorous
P_2O_5	-	Phosphate
RH	-	Relative humidity
Rs	-	Rupees
t ha^{-1}	-	Tonnes per hectare
t	-	Tonnes
μg	-	Microgram
WUE	-	Water use efficiency

Introduction

1. INTRODUCTION

Vegetables are major source of bioactive compounds whose health protecting properties are universally accepted. India is the second largest producer of vegetables after China (Chadha, 1999). According to the recent reports, vegetable cultivation has touched about 87.5 million ha (Saigal, 2001). The per capita availability of vegetables in India is only about 135 g day^{-1}, which is far below the minimum dietary requirement of 285 g vegetables per day. To get about 285 g vegetable per capita per day, there is a need to achieve the target of about 100 million tonnes per annuum (Attavar, 2000). A planned development in the vegetable production will not only improve the nutritional requirement of the masses, but can also meet the challenge of adequate food supply to the growing population in our country.

Chilli or red pepper is an important vegetable-cum-spice crop grown throughout India, for domestic as well as export markets. It is an indispensable adjunct to the diet of people. Chilli imparts pungency for culinary purpose. The pungency is due to the active principle, capsaicin. The fruit is a rich source of vitamin C. Chilli belongs to family Solanaceae and comes under the genus *Capsicum. C. annuum* is the most widely cultivated species.

India is the largest producer, consumer and exporter of chillies in the world, with an annual production of 8.21 lakh tonnes from an area of 9.57 lakh hectares. It is grown throughout India and Andhra Pradesh leads both in area and production. In Kerala, cultivation of chilli is limited to an area of 312 ha with an annual production of 310 tonnes (FIB, 2002).

As far as Kerala is concerned, the extend of cultivated land is limited and most of the vegetable crops are raised in summer. High temperature during summer is one of the constraints which adversely affects the water use efficiency and nutrient use efficiency. This not only reduces the production potential but also incurs high expenditure. Hence, we should exploit the potential of vegetable production fully through proper agronomic practices like optimum dose of nutrients, provision of shade etc.

Homestead farming is an unique system of agriculture traditionally followed in Kerala. As the availability of open land is meagre in the state, farmers utilize the interspaces of perennial crops for growing vegetables. Estimates made at Central Plantation Crops Research Institute, Kasargode, have shown that light infiltration in coconut gardens ranged from 10 to 70 per cent depending on the age of palms. Shade tolerant varieties of chilli can be economically cultivated in the interspaces of coconut where temperature and light intensity are lower than in open. Thus, homesteads can be effectively utilized for the production of good quality chilli. Moreover, there are reports of equal yield both in open and under partial shade in the crop (Sreelathakumary, 2000).

Chilli being a fertilizer responsive crop requires a good amount of nutrient supply. High rate of fertilizer is required for promoting vigorous growth and quality especially for improved varieties (John, 1989). Limited effort has been made to study the management aspect of chilli under shaded situation. The present study will reveal the influence of nutrients (N, K) and its ratio on growth, uptake pattern, yield and quality of chilli under shaded and open condition.

Biofertilizers are environment friendly and play a pivotal role in integrated nutrient supply to the vegetable crops in contrast to the use of chemical fertilizers. Nutrient requirement of vegetables in general is high due to show duration crop, which cannot be supplied by biofertilizers alone. Thus, the current trend is to explore the possibility of supplementing chemical fertilizers with biofertilizer for sustainable vegetable production. Under optimum weather conditions like low temperature, biological nitrogen fixation is found to increase. This study will reveal the interaction effect of shade and biofertilizer. High susceptibility of chilli to leaf curl limits its cultivation in the state. Shaded situation reduces the vector transmitting this virus disease during summer. This would be of great help to vegetable growers raising the crop during summer, in reducing the cost of plant protection and improving the quality of chilli.

With this background the present study was undertaken with the following objectives.

1. To find out the effect of NK ratio on the growth, yield and quality of vegetable chilli variety Jwalasakhi under shaded condition
2. To study the nutrient biofertilizer interaction for yield maximization of chilli under different shade levels
3. To evaluate the economic feasibility of different treatments.

Review of Literature

2. REVIEW OF LITERATURE

Chilli, important and remunerative solanaceous vegetable crop is found to have tolerance to partial shaded condition. One of the major constraints in increasing its level of production in Kerala is limited land area and shade tolerant variety has got much promise in the homesteads of Kerala. Microbial inoculants form an integral part in integrated nutrient management for higher yield with better quality. A perusal of literature pertaining to the investigation revealed that there is dearth of specific information on influence of crop management practices of chilli under shaded condition. Hence, the relevant literature on the influence of shade, N and K levels and bioinoculants on chilli and other crops are reviewed in this chapter.

2.1 EFFECT OF NITROGEN

Nitrogen plays a key role for proper growth and development of all cultivated crops. Nitrogen stimulated root and shoot growth of capsicum (Leskovar *et al*., 1989). As nitrogen levels increased, proportionate increase was also observed in growth and yield.

2.1.1 Effect on Growth Characters

2.1.1.1 Height of Plant

Increase in level of nitrogen in chilli resulted in a sequential increase in plant height as noticed by Srinivas (1983). Sundstrom *et al*. (1984) observed that, plant height of tabasco pepper increased with increase in nitrogen rate from 0 to 112 kg ha^{-1}. According to Prabhakar *et al*. (1987) nitrogen application at the rate of 90 kg ha^{-1} recorded the maximum plant height in chilli. Similar effects of nitrogen in chilli was also observed by Shukla *et al*. (1987), Singh and Srivastava (1988), John (1989), Natarajan

(1990), Ahmed and Tanki (1991) and Pandey *et al*. (1992). Sherly (1996) noticed that plant height was maximum at higher level of nutrients (100 : 40 : 33.3 NPK kg ha^{-1}) in chilli. Similar result was reported by Anitha (1997).

2.1.1.2 Number of Branches Plant^{-1}

Joseph (1982) noticed that branching in chilli was significantly increased by nitrogen application. Srinivas (1983) observed significant increase in number of branches per chilli plant with increase in nitrogen. Increase in number of branches with increased nitrogen application in chilli was also recorded by Singh and Srivastava (1988), John (1989), Natarajan (1990) and Pandey *et al*. (1992). Sherly (1996) noticed that number of branches produced per plant was maximum at higher level of nutrients. Anitha (1997) observed that nitrogen application in chilli @ 12.8 g N $plant^{-1}$ recorded the maximum number of branches.

2.1.1.3 Dry Matter Production

A positive correlation between nitrogen application and total dry matter production in chilli was observed by Dod *et al*. (1983). Singh *et al*. (1986) showed that higher doses of nitrogen significantly increased the total weight of dry matter produced per plant of chilli. Hegde (1987) observed that, increase in nitrogen application increased the dry matter production in chilli through higher LAI and CGR. Increased dry matter production with increase in nitrogen application in chilli was also noted by Manchanda and Singh (1987), Hegde (1988), John (1989) and Prabhakar and Naik (1993). Sherly (1996) observed maximum DMP in chilli at higher level of nutrients. Anitha (1997) noted that nitrogen application in chilli @ 12.8 g N $plant^{-1}$ recorded maximum DMP.

2.1.2 Effect on Yield and Yield Attributes

2.1.2.1 Days for 50 per cent Flowering

Rao and Gulshanlal (1986) noted a significant increase in the number of days to 50 per cent flowering with the increased levels of nitrogen upto 150 kg ha^{-1}. John (1989) observed that, time taken for 50 per cent flowering significantly delayed with graded levels of nitrogen. Plants with 125 kg ha^{-1} nitrogen took about 36 days while that with 75 kg ha^{-1} took only 32 days for 50 per cent flowering. Subhani *et al*. (1990) reported that 120 kg ha^{-1} nitrogen, recorded minimum time for 50 per cent flowering. Sherly (1996) observed that with increase in level of nutrient time taken for 50 per cent flowering was increased in chilli. Similar result was obtained by Anitha (1997).

2.1.2.2 Number of Flowers per Plant

Splittstoesser and Gerber (1986) found that number of flowers $plant^{-1}$ increased with increased dose of nitrogen. Singh and Srivastava (1988) reported that, number of flowers per plant increased with increase in nitrogen application upto 120 kg ha^{-1}. According to John (1989), maximum flower production in chilli was obtained with 100 kg nitrogen ha^{-1}. Sajitharani (1993) observed that maximum flower production of 39.69 $plant^{-1}$ was obtained with higher levels of nutrients (330 : 110 : 220 kg NPK ha^{-1}) in bhindi. Sherly (1996) noted that number of flowers $plant^{-1}$ was highest in chilli plants at higher level of nutrients. Number of flowers $plant^{-1}$ was highest with 12.8 g N $plant^{-1}$ in chilli (Anitha, 1997).

2.1.2.3 Number of Fruits per Plant

Number of fruits $plant^{-1}$ was highest with 120 kg nitrogen $hectare^{-1}$ (Joseph, 1982). Shukla *et al*. (1987) reported that number of fruits $plant^{-1}$ was significantly influenced by varying levels of nitrogen. Similar results were noted by Ahmed and Tanki (1991), Kumar and Thakral (1993), Lata and Singh (1993) in chilli. Sajitharani (1993) showed that maximum number of fruits per bhindi plant (20.93) was recorded at the highest dose of nutrient (330 : 110 : 220 kg NPK ha^{-1}). Sherly (1996) showed that higher level of nutrients recorded maximum fruits in chilli. Number of fruits plant^{-1} was highest with 12.8 g N plant^{-1} in chilli (Anitha, 1997).

2.1.2.4 Total Yield of Chillies

Srinivas and Prabhakar (1982) reported that mean fruit yield was 11.3 q ha^{-1} by the application of 150 kg nitrogen hectare^{-1} while in control it was only 25.71 q ha^{-1}. According to Srinivas (1983), increase in nitrogen application increases the yield of chilli. Ahmed (1984) reported that, highest yield was obtained by the application of 80 kg nitrogen hectare^{-1}. Narasappa *et al*. (1985) observed that, application of 150 kg ha^{-1} nitrogen recorded fertilizer five times from anthesis to harvest increased yield by 167 to 232 per cent over those of control plants (Song, 1987). Nitrogen fertilizers upto 120 kg ha^{-1} increased the yield by 119 per cent over control (Hegde, 1988). Mary and Balakrishnan (1990) reported that increase in nitrogen application increases the yield of chilli. Similar results were reported by Jayaraman and Balasubramanian (1991), Subbiah (1993), Gulati *et al*. (1995) and Sherly (1996). Plants treated with 12.8 g N plant^{-1} recorded maximum yield (Anitha, 1997).

2.1.3 Effect on Quality Characters

2.1.3.1 Ascorbic Acid Content of Fruits

Dod *et al*. (1983) reported profound effect of nitrogen fertilization on the ascorbic acid content of fruits. Ascorbic acid content was increased by nitrogen application (Thomas and Leong, 1984). Singh *et al*. (1986) showed that vitamin C content was increased with enhanced levels of nitrogen and the response was linear upto 90 kg ha^{-1}. Manchanda and Singh (1987) noted that vitamin C content in bell pepper increased significantly with incremental rates of nitrogen and ranged from 55.42 mg per 100 g of fruit at 0 kg nitrogen to 97.12 mg per 100 g of fruit at 160 kg ha^{-1}. Application of 87.5 kg nitrogen hectare^{-1} recorded maximum ascorbic acid content (Amritalingam, 1988). Mary and Balakrishnan (1990) stated that, increase in nitrogen application increased the ascorbic acid due to enhancement of enzymatic activities for amino acid synthesis. Similar results were reported by Lata and Singh (1993). Sherly (1996) observed that plants at higher level of nutrients recorded maximum ascorbic acid content in chilli. Plants treated with 12.8 g N plant^{-1} recorded maximum ascorbic acid content (Anitha, 1997).

2.1.4 Effect on Nutrient Uptake

Asif and Greig (1972) found that in bhindi application of nitrogen increased nitrogen content but decreased phosphorus content. Joseph (1982) observed that in chilli total uptake of nitrogen was increased significantly by increased levels of nitrogen. The beneficial effect of higher levels of nutrients in increasing the uptake of nitrogen has been reported by Dolkova *et al*. (1984), Hegde (1988), John (1989) and Sajitharani (1993). Anitha (1997) reported that application of higher levels of nitrogen in chilli increased the nitrogen and potassium uptake by plants.

2.2 EFFECT OF POTASSIUM

Plant requirements for available potassium are quite high. It plays an important role in enzyme activation, water relations, energy relation, translocation of assimilates, nitrogen uptake and protein synthesis (Tisdale *et al*., 1995).

2.2.1 Effect on Growth Characters

2.2.1.1 Height of Plant

Joseph (1982) found that potassium exerted appreciable influence on plant height at the time of final harvest. Significant increase in plant height due to application of potassium was reported by Lakatos (1982).

According to Dolkova *et al*. (1984) increased potassium application increased the height of plant. Similar results were reported by Zayed *et al*. (1985), Shukla *et al*. (1987) and Damke *et al*. (1988).

However, John (1989) noted that increased dose of potassium did not significantly influence the height of plant.

2.2.1.2 Number of Branches Plant^{-1}

Branching of chilli was significantly increased by increased doses of potassium (Lakatos, 1982). Dolkova *et al*. (1984) reported an increase in number of branches in chilli with increasing potassium. According to Zayed *et al*. (1985) number of branches plant^{-1} in chilli increased upto 160 kg potassium application.

Contrary to above findings, Joseph (1982) observed no significant difference in number of branches due to graded levels of potassium. Similar results was reported by John (1989).

2.2.1.3 Dry Matter Production

Pandev *et al*. (1980) reported that, low potassium application decreased the dry matter production of plant. Increase in potassium application increased the dry matter production (Lakatos, 1982). Joseph (1982) found that higher doses of potassium in chilli significantly increased the total dry matter yield plant^{-1}. Similar results were reported by Zayed *et al*. (1985) and John (1989). Kanaujia *et al.* (1997) found that dry matter was significantly influenced by potassium level upto 60 kg k_2O ha^{-1} in pea.

2.2.2 Effect on Yield Attributes and Yield

2.2.2.1 Days for 50 per cent Flowering

Joseph (1982) observed that effect of potassium on earliness of flowering in chilli was not significant in the first season, but in the second season, the effect was significant. John (1989) stated the effect of potassium in reducing the mean number of days required for 50 per cent flowering. Potassium at 65 kg ha^{-1} induced earliness in flowering significantly.

2.2.2.2 Number of Flowers Plant^{-1}

John (1989) found that potassium application in chilli has not resulted in any significant influence in increasing the number of flowers $plant^{-1}$.

Contrary to this, Jayaraman and Balasubramanian (1991) reported that potassium application in chilli increased the number of flowers $plant^{-1}$.

2.2.2.3 Number of Fruits Plant^{-1}

Zayed *et al*. (1985) found that number of fruits $plant^{-1}$ was highest with 160 kg ha^{-1} of K_2O. Increasing potassium levels increases the number of fruits $plant^{-1}$ (Belickhi, 1988). Similar result was reported by Jayaraman and Balasubramanian (1991). Yahiya *et al.* (1996) noted that application of 50 kg K_2O ha^{-1} significant increased pods per plant in pea.

However, Joseph (1982) showed that, higher doses of potassium had not influenced the number of fruits $plant^{-1}$. John (1989) noted that there was no significant increase in the number of fruits $plant^{-1}$ with increased doses of potassium.

2.2.2.4 Total Yield of Chillies

Application of 200 kg ha^{-1} potassium increased yield by 106 per cent over control (Lakatos, 1982). Joseph and Pillai (1985) reported that the yield of chilli was maximum at 30 kg ha^{-1} of potassium. Maximum yield of chilli was reported by the application of 75 kg ha^{-1} of potassium (Narasimhan and Alagianagalingam, 1986). Increase in potassium application increased the yield of chilli (Wankhade and Morey, 1986). Similar results in chilli were reported by Damke *et al*. (1988), Mary and

Balakrishnan (1990), Jayaraman and Balasubramanian (1991) and Kaminwar and Rajagopal (1993). Patra *et al*. (1996) observed that application of potassium @ 50 kg ha^{-1} increased pod yield in ground nut.

2.2.3 Effect on Quality Characters

2.2.3.1 Ascorbic Acid Content

According to Mary and Balakrishnan (1990) application of 52.5 kg potassium $hectare^{-1}$ recorded maximum ascorbic acid content due to increase in protein synthesis which is important in improving the quality.

However Joseph (1982) observed that potassium had no significant effect on fruit ascorbic acid content. John (1989) noted that the effect due to increased levels of potassium on ascorbic acid content of fresh fruits was not significant.

2.3 EFFECT OF NUTRIENT INTERACTION ON GROWTH, YIELD, YIELD ATTRIBUTES AND QUALITY

2.3.1 Effect on Growth Characters

Pandev *et al.* (1980) reported that deficiency of NPK in the medium adversely affect the dry matter production in chilli. Increasing NPK levels increased both shoot growth and dry matter production in chilli (Lakatos, 1982). Dolkova *et al*. (1984) observed that vegetative growth in chilli increased with NPK application. Everett and Subramanya (1984) reported that plant height in chilli increased by the application of 205 kg N along with 415 kg K_2O. Application of NPK at the rate of 240 kg $feddan^{-1}$ each recorded maximum plant height and number of branches (Zayed *et al*. 1985). Prabhakar *et al*. (1987) noted that plant height increased significantly with N fertilization upto 60 kg ha^{-1} but plant height and number of branches was not affected by P fertilization. According to Belichki (1988) plant height and dry matter production increased with graded doses of NPK upto 320 kg each. Damke *et al*. (1988) found that plant height was highest when P_2O_5 and K_2O were applied at the rate of 50 kg each. John (1989) reported that all the growth characters were increased with increased doses of N and P. K had no significant influence on these characters.

2.3.2 Effect of Yield and Yield Attributes

Subbiah *et al*. (1982) showed that N in combination with K tended to produce more yield in chillies. Dolkova *et al.* (1984) observed that increased NPK application increased fruit production in chilli. Highest yield was reported by the application of 360 kg each. Highest dry fruit yield in chilli under rainfed condition was obtained by application of 112.5: 60: 30 kg NPK hectare^{-1} (Joseph and Pillai, 1985). Green chilli yield increased with level of N upto 90 kg and P upto 30 kg (Prabhakar *et al*. 1987). Rao *et al.* (1988) reported that highest economic yield of dry chilli pods was obtained with 120 kg N in combination with 50 kg K_2O. According to Shin *et al*. (1988) optimum NPK rate for maximum yield was 23 : 20.2 : 18 kg NPK ha^{-1}. John (1989) noted that higher doses of N and P significantly increased number of flowers plant^{-1}, number of pods plant^{-1} and per cent fruit set while K had no significant influence on this. Highest fruit yield of 2.6 t ha^{-1} was obtained by the application of 120 : 90 : 90 kg NPK ha^{-1} (Nasreen and Islam, 1989). Increase in NPK rates increased the yield in chilli (Surlekov and Rankov, 1989). Similar results in chilli was reported by Subhani *et al*. (1990), Jayaraman and Balasubramanian (1991), Kaminwar and Rajagopal (1993) and Subbiah (1994).

2.3.3 Effect on Ascorbic Acid Content of Fruits

Ascorbic acid content of chilli fruit decreased as the application of NPK increased (Belichki, 1988). Mary and Balakrishnan (1990) reported that ascorbic acid content of green and red ripe chillies increased significantly with nitrogen upto 87.5 kg and potassium 52.5 kg ha^{-1}.

Uddin and Begum (1990) found that nitrogen alone or in combination had negative effect on ascorbic acid content in chilli while phosphorus had positive effect. According to Kaminwar and Rajagopal (1993) application of NPK at the rate of 100: 75: 100 kg ha^{-1} recorded the highest ascorbic acid content in chilli.

2.3.4 Effect on the Uptake of Nitrogen, Phosphorus and Potassium

Joseph (1982) observed that total uptake of nitrogen by chilli was significantly increased by increased levels of N, P and K. Similar trends were also noted in the uptake of P and K. To produce an average chilli yield of 3.8 t ha^{-1}, total uptake of NPK by plant was 205, 58 and 445 kg ha^{-1} respectively (Roman, 1982). For producing 1000 kg fruits, control chilli plants and plants receiving highest NPK removed from soil 6.91 and 6.37 kg ha^{-1} N, 1.89 and 1.63 kg ha^{-1} P_2O_5 and 7.3 and 6.13 kg ha^{-1} K_2O respectively (Dolkova *et al.*, 1984). Greatest amount of nutrient uptake occurred during the last third of the growing season and was in the order K>N>P (Santiago and Goyal, 1985). Chilli removed 47-67 per cent of 47-67 per cent of fertilizer N applied (Jinadas *et al.*, 1987). According to Hegde (1988) in chilli, N fertilization upto 120 kg ha^{-1} significantly increased the nutrient uptake by 128, 64 and 76 per cent NPK respectively. John (1989) reported that, uptake of N and K by chilli was significantly increased by higher doses of NPK. Russo (1991) observed that the levels of nutrients in leaves and fruits of bell pepper did not respond to fertilizer application. To produce 1q of dry chilli pods, the nutrient requirement was found to be 1.94, 0.25 and 1.6 kg NPK respectively (Kaminwar and Rajagopal, 1993). Subbiah (1994) noted that at 100 per cent of the recommended dose of N and P, chilli crop had recorded the highest N, P and K uptake. Uptake of nitrogen and potassium increased with increasing levels of nutrient in chilli reported by Sherly (1996).

2.4 EFFECT OF NK RATIO

Thomas (2000) obtained remarkable increase in growth and yield attributing characters upon addition of 60 : 45 kg ha^{-1} of NK compared to lower levels in upland rice, while Anu (2001) reported that the fertilizer level of 80 : 45 kg ha^{-1} NK improved the growth and yield characters in rice.

2.5 EFFECT OF INOCULATION OF *AZOSPIRILLUM*

Azospirillum is an associative nitrogen fixing bacterium which grows in association with various graminae and other host plants. They occur freely in rhizosphere also, but fix nitrogen only under microaerophilic condition (Lakshmikumari *et al*., 1976).

2.5.1 Effect on Growth Characters

One of the striking responses of crop plants upon inoculation with *Azospirillum* is the increased root and shoot growth and biomass accumulation (Smith *et al*., 1978). *Azospirillum* has the ability for better root induction in inoculated plants mainly due to the production of plant growth hormones like IAA and GA. As a result of this, such plants are capable of absorbing more and more available nutrients from the soil, which in turn results in better establishment of plant seedling and subsequent growth (Tien *et al*., 1979). Kapulnic *et al.* (1981) studied the effect of *Azospirillum* inoculation on wheat, sorghum and Panicum and observed that inoculation with *Azospirillum brasilense* resulted in significant increase in plant height in all three crops. Karthikeyan (1981) found that inoculation of *Azospirillum* increased the plant height and dry matter accumulation in rice. Prasad and Singh (1984) found that the use of *Azospirillum* alone produced better growth response equivalent to that of 30 kg N ha^{-1} in rice.

Wam and Konde (1986) reported that performance of *Azospirillum* was better at lower dose of nitrogen. Hadas and Okon (1987) reported that there was significant increase in root length (35 per cent), root dry weight (50 per cent) and total leaf area of 18 day old tomato seedling due to *Azospirillum* inoculation. Purushothaman (1988) reported that root surface area of rice plants inoculated with *Azospirillum* was significantly greater than in uninoculated plants. They also concluded that this increase in root surface area was more pronounced along with the application of 50 and 75 kg N ha^{-1} than at 100 kg N ha^{-1}.

Bashan *et al*. (1989) observed that in *Azospirillum* treated brinjal seedlings, the plant height significantly increased from 11.2 to 15.3 mm as compared to uninoculated treatment. There was also significant increase in dry weight of foliage and number of leaves per plant due to *Azospirillum* inoculation. Parvatham *et al*. (1989) observed that seed, soil and foliage application of *Azospirillum brasiliense* not only increased the root biomass but also shoot biomass and plant height in bhindi. Dhanlakshmi and Pappiah (1995) reported that application of 75 per cent fertilizer nitrogen (112.5 kg N) increased plant height and number of secondary branches formed in tomato. Seed inoculation of *Azospirillum brasiliense* in wheat plants increased the leaf area, chlorophyll concentration and total biomass production (Panwar and Singh, 2000). Significant increase in height, root length, dry weight of shoot and root were obtained with *Azospirillum* (Kavitha, 2001).

2.5.2 Effect on Yield Attributes and Yield

Significant increase in yield was recorded in rice, cabbage and brinjal and evidence of a positive increase in yield obtained in wheat, onion and tomato on Azospirillum inoculation of seed or seedling (Rao et al., 1963; Lehri and Mehrotra, 1972 and Shinde et al., 1977). Cohen et al. (1980) obtained increased yield for a wide range of tropical and temperate crops by Azospirillum inoculation. Plant responses to inoculation with Azotobacter and Azospirillum in cereals and non cereals are often reported in terms of increased grain yield, plant biomass yield, nutrient uptake, grain and tissue N content, nitrogenase activity, early flowering, tiller numbers, greater plant height, leaf size, enzyme levels in plant parts, number of spikes and grains per spikes, thousand grain weight, root length and volume, reduced insect and disease infection (Okon, 1985; Wani, 1990). Shukla and Kundu (1986) obtained increased yields in plants by bacterial inoculation. *Azospirillum* inoculation was known to increase the yield of crop by 5 to 20 per cent with savings of 40 per cent recommended dose of nitrogen (Dart, 1986).

The mechanism by which the plants inoculated with *Azospirillum* and *Azotobacter* derive positive benefits in terms of increased grain yield, plant biomass and N uptake are attributed to small increase in N input from BNF, development and branching of roots, production of plant growth hormones, enhancement on uptake of NO_3, NH_4, H_2PO_4, K^+, Pb^+ and Fe^{2+}, improved water status of plants, increased nitrate reductase activity in plants, production of antibacterial and antifungal compound (Okon, 1985; Pandey and Kumar, 1989; Wani, 1990).

(FAI, 1994) reported that field trials conducted to study the influence of *Azotobacter* and *Azospirillum* inoculation on several non leguminous crops experienced 5-15 per cent increase in yield and a nitrogen contribution of about 25 kg ha^{-1}. Balasubramani and Pappiah (1995) found that seed and soil treatment of bhindi with *Azospirillum* along with 30 kg N ha^{-1} (75 per cent of recommended dose) recorded highest yield of 17.5 t as compared to only 9.6 t for control treatment. Dhanlakshmi and Pappiah (1995) reported that application of 75 per cent fertilizer N (112.5 kg N) resulted in highest number of flowers, fruit set and maximum yield. Rajasekhar *et al.* (1995) also got better yield in bhindi from plants treated with *Azospirillum* + FYM + inorganic fertilizers. Jha and Mishra (1999) could obtain higher tuber yield of sweet potato when 40 kg N ha^{-1} was supplemented with 10 kg *Azospirillum* ha^{-1}

as soil application. Seed inoculation of *A. brasilense* in wheat plants increased the grain yield (Panwar and Singh, 2000).

2.5.3 Effect on Quality Parameters

Inoculation with *Azospirillum* increased capsaicin and ascorbic acid contents in chilli (Balakrishnan, 1988). Subbiah (1990) observed that *Azospirillum* inoculation recorded the highest ascorbic acid content in tomato. Subbiah (1991) reported that in bhindi, *Azospirillum* inoculation saved upto 50 per cent of fertilizer N, besides increasing yield and quality. Anitha (1997) observed that *Azospirillum* inoculation recorded maximum ascorbic acid content.

2.6 RESPONSE OF CROP TO VARYING SHADE INTENSITIES

Solar radiation is considered as an essential component in biosphere activity via the photosynthetic performance of plants. Productivity of a plant depends on its capacity to efficiently harvest solar energy for the metabolic production and also the partitioning efficiency of same for higher productivity. This character of a plant is controlled by the genetic make up of it to a certain extent. However, the environmental conditions under which it grows also control the above to a great extent. The influence of shade on growth, yield and quality has been studied in many crops of commercial importance.

2.6.1 Growth Character

The experiment conducted by Deli and Tiessen (1969) to study the effect of light on young chilli plants maintained under low light intensity resulted an increased growth and yield. Under high solar radiation, at an early stage of plant development, shading increased cell division and whole plant dry matter in pepper (Schoch, 1972). High temperature caused higher rates of transpiration which limited the growth of stem, roots and fruits in tomato (Stevens and Ruchid, 1978).

Heat stress induced all stages of crop growth, reduced the plant height significantly in all tomato cultivars compared to non stressed plants (Arora and Pandita, 1982). Kamaruddin (1988) reported that tomato plants shaded with muslin were taller than unshaded plants mainly due to longer internodes. Shaded plants of tomato grew taller with more leaves in a given time with slightly greater internodal length (Smith *et al*., 1984 and Thangam, 1998). The effect of different levels of shading (0, 12, 26 and 47 per cent) on pepper grown under high solar radiation was investigated by Rylski (1986) during summer and winter. In both the seasons, when solar radiation was decreased, the plant height, no of nodes and leaf size increased.

Kadam *et al*. (1991) stated that poor vegetative growth of tomato plants in summer might be due to high temperature which led to high transpiration and respiration. Cockshull *et al*. (1992) reported the tomato plants under heavy shade were not significantly taller than those under unshaded condition.

A field trial was conducted by El-Gizawy *et al*. (1993a) in tomato to study their performance under shading (0, 35, 51 or 63 per cent) provided by nets. They found that shading increased plant height and leaf area but reduced leaf no and dry weight.

Jung *et al*. (1994) reported that main stem and branch length of pepper increased significantly under shaded condition. Increase in plant height was reported in tomato due to increase in period of shading (Nasiruddin *et al*., 1995). Yinghua and Jianzen (1998) reported increased plant height due to shade in capsicum. Increase in plant height, internodal length and leaf size was reported in different chilli species under shade Sreelathakumary (2000).

Smitha (2002) stated that height and internodal length of plants increased with increase in shade levels.

2.6.2 Physiological Attributes

2.6.2.1 Leaf Area Index (LAI)

Positive influences of shade on various growth attributes had been reported by many workers. Rice crop shaded during the vegetative phase were smaller with a lower LAI and hence had better light penetration than the control during the reproductive phase (Yoshida and Parao, 1976) Thangaraj and Sivasubramanian (1990) reported that irrespective of varieties, low light intensity significantly increased the LAI in rice.

In ginger, turmeric and coleus, Bai (1981) did not find any influence of shade on their leaf area indices. However a high LAI was reported by Ravisankar and Muthuswamy (1988) when ginger was grown as an intercrop in six year old arecanut plantations. Ancy (1992) observed that the LAI in ginger was significantly lower under open condition compared to other shade levels in all growth stages. The highest LAI was recorded at 25 per cent shade.

Smith *et al*. (1984) observed that shaded plants of tomato produced a greater leaf area with more dry matter in leaves and stem. Heuvelink and Marcelis (1996) reported that area of individual leaves of tomato increased with increasing light intensity. Similar trends were reported by Yinghua and Jianzhen (1998) and Sreelathakumary (2000) in capsicum.

2.6.2.2 Dry Matter Production

Monteith (1969) reported that the maximum amount of DMP by a crop was strongly correlated with the amount of light intercepted by its foliage. Ravisankar and Muthuswamy (1988) reported an increase in level of DMP with decreased light intensity in ginger. This was further confirmed by Varughese (1989) and Babu (1993).

Ancy (1992) observed significant variations among shade levels with respect to DMP. Shade levels, 25 and 50 per cent were found to be on par with each other but significantly superior to zero. Pushpakumari and Sasidhar (1996) reported in greater yam, lesser yam, tannia and elephant foot yam that the total dry matter production at 25 per cent shade was superior to all other treatments throughout the growth stages except in harvest stage, where in the open treatment (0 per cent shade) recorded maximum dry weight which was on par with 25 per cent shade. In sweet potato, deep shade (>55 per cent) reduces total DMP due to suppression of both initiation and growth of storage roots (Ravi and Indira, 1999).

2.6.3 Flowering Characters

Wallace and Enriquiz (1980) reported that when the temperature increase, there was decrease in days to 1st flower opening in beans. Number of days from sowing to flowering and per cent of flower drop increase in pepper as shade increased (Jeon and Chung, 1982). Papadopoulos and Tissen (1983) reported that flowering in tomato cv. Ohio MR-13 was delayed significantly at 24^0C/ 8^0C (day and night) temperature, while marketable yield was not affected under greenhouse condition.

Shading was investigated as a factor to delay fruit development of sweet pepper by Rylski and Spigelman (1986 a). They observed delay in fruit picking by about 1 month when plants were grown throughout the winter in screen houses and by eleven days, when they were covered only at a later stage of their development. In all experiment, fruit ripening and shrinking was slowed down due to shading leading to a larger yield of top quality fruits.

Baki (1991) observed that in tomato high temperature induced flower abscission which reduced fruit set and yield.

El-Gizawy *et al*. (1993 a) observed delay on flowering in tomato as the shade level increased. Whereas the number of flowers per plant decreased under all shading levels (35, 51 or 63 per cent shade) compared with full sunlight. In pepper, early screening resulted in taller plants, delayed harvest and prolonged harvesting period compared with later screening. Harvest was delayed under screens giving high per cent of shade (Zuieli *et al.*, 1993). Fruit set, days to harvest, no and weight of fruits per plant. Weight and diameter of fruits of tomato was significantly influenced by shading (Sharma and Tiwari, 1993). Rylski and Aloni (1994) reported that in the very early stage, flower development was highly sensitive to temperature in tomato. Romano and Leonardi (1994) observed that in tomato, days to flowering from transplanting was delayed by about four days by lower temperature.

Peit *et al*. (1996) reported that tomato fruit set and fruit weight per plant decreased as mean daily temperature increased from 25 to 29^{0}C. Sreelathakumary (2000) observed that number of days for flower initiation in chilli increased with increase in shade level. Shading delayed flowering in tomato (Smitha, 2002).

2.6.4 Fruit and Yield Character

Calvert and Slack (1980) reported increased fruit yield when night temperature was lowered in tomato.

Achhireddy *et al*. (1982) studied the effect of light on the growth rate of fruit wall plus placenta and seeds in chilli. They found that after 65 days of development, fruit held in the dark weighed 15 per cent less than those receiving light whereas the seed weight remained unaltered.

Smith et al. (1984) found that tomato yields were best under 15 per cent shade than 40 per cent shade and open. Rylski and Spigelman (1986 b) investigated the effect of different levels of shading (0, 12, 26 and 47 per cent) on yield of capsicum under higher solar radiation during summer and winter. Shading inhibited the development of lateral shoots on the main stem of plant below the first flower. The changes in plant development due to shading affected fruit set, number of fruits per plant, fruit location on the plant, fruit development and yield. The lateral shoots, which developed under high light intensity, provided 25 per cent of total yield. Lowest number of fruits per plant was obtained under 47 per cent shade. Under shading individual fruits were larger and had a thicker pericarp. The highest yield of high quality fruits was obtained with 12 and 26 per cent shade.

El-Aidy (1986) found higher yield in tomato plants grown under shade than those in open field, but this trend could be reduced by increased shade with 40 per cent shade being the best.

The micro-climatic and eco-physico effect of shading and pinching on capsicum were reported by Hou *et al*. (1987). Fruit yield was highest when the plants were pinched and shaded with plastic film.

In tomato and sweet pepper grown in a greenhouse with natural sunlight, 35 and 55 per cent shading, the light intensity decreased dry weight and fruit yield with greatest effect on tomatoes and least effect on sweet pepper (Zhong and Kato, 1988).

Shade studies on tropical crops *viz*., colocasia, coleus, cowpea, brinjal, amaranthus, cluster bean, bhindi and sweet potato were conducted in KAU under 0, 25, 50 and 75 per cent shade levels (Nair, 1991). In all these crops, the yield was highest in open and declined with increased shade levels.

El-Gizawy *et al*. (1993 b) found increased number of fruits per plant and total yield in tomato. Highest yield were obtained under 35 per cent shading. Shading significantly improved physical characteristics of fruits. Weight, length, diameter and volume of fruits were higher from plants grown under 35 per cent shading.

Shukla *et al*. (1997) reported the effect of subabul canopy on yield of vegetable like chilli, brinjal, cauliflower and okra. Yield of all vegetables were significantly lower when grown under shade than in open. Yinghua and Jianzhen (1998) reported highest yield in pepper under 20 per cent shade. No significant reduction in yield was noticed in different chilli species under mild shade of 25 per cent while dense shade of 50 and 75 per cent reduced yield considerably (Sreelathakumary, 2000).

Smitha (2002) found that mild shade of 25 per cent did not affect per cent fruit set in tomato whereas it reduced under 50 per cent shade.

2.6.5 Effect on Quality Characters

2.6.5.1 Ascorbic Acid Content

El-Gizawy (1993 b) reported that in tomato with increased shading, vitamin C content decreased. Sharma and Tiwari (1993) observed that tomato fruits harvested from shaded plants accumulated significantly higher vitamin C as compared to non-shaded plants. Extended shading period decreased the vitamin C content of fruits considerably (Nasiruddin *et al.*, 1995). Yanagi *et al.* (1995) reported that in both summer and autumn crops of tomato vitamin C and reducing sugar content of fruits significantly decreased with increased shading.

Yinghua and Jianzhen (1998) found that vitamin C content of pepper fruits decreased with increase in shade. Soohyun *et al.* (1998) analysed the chemical constituents of fruits of red pepper (*C. annuum*) and reported that the total amount of vitamin C in fruits was 121 mg per 100 g of fresh weight.

The fruit of most *Capsicum* species contain high amounts of vitamin C upto 340 mg per 100 g when in fresh state (Anu and Peter, 2000). Sreelathakumary (2000) observed no significant difference for ascorbic acid content between open and 50 per cent shade.

Smitha (2002) reported that mild shade of 25 per cent increased vitamin C content of tomato fruits compared to open. But under 50 per cent shade, vitamin C content reduced significantly.

2.6.5.2 Proline

Proline is a heat shock protein. Accumulation of proline under water stress has been reported in crops *viz*., coffee (Vasudeva *et al*., 1981), cocoa (Balasimha, 1982), tea (Rajasekhar *et al*., 1988) and coconut (Voleti *et al*., 1990).

Yao *et al*. (1998) in an experiment with three pepper (*C. frutescens*) varieties differing in heat tolerance found that when subjected to temperature of 35 to 40 °C for two to eight days, there was free proline accumulation in the leaves. Highest proline content was recorded from chilli plants grown in open condition (Sreelathakumary, 2000). Smitha (2002) reported significant variation in proline content between shade levels. Maximum accumulation of proline was recorded in open.

2.6.5.3 Capsaicin

Reduction of solar radiation by 50 per cent had no effect on the capsaicin content of fruits of pepper (Bigotti, 1974). Jeon and Chung (1982) also reported that capsaicin content of pepper was not affected by different shade intensities. Minami *et al*. (1998) reported that capsaicinoid concentration was highest between 20 and 40 days after flowering in *Capsicum annuum*. A longer photoperiod compensated for a low photosynthetic photon flux.

Soohyun *et al*. (1998) analysed the chemical constituents of fruits of red pepper, *C. annuum*. They found that concentration of total capsaicinoid in fruit was 5.4 mg per 100 g of fresh weight.

Sreelathakumary (2000) observed no significant difference in capsaicin content of chilli between open and 50 per cent shade.

2.6.6 Pest and Disease Incidence

Shade increased yield due to reduction of disease incidence. It is suggested that the temperature around the crop may have been reduced by shading and this could ultimately suppress the growth of fungus.

The leaf spot incidence in ginger was comparatively low under shade (Premanathan, 1981).

Francescangeli *et al.* (1994) observed reduced incidence of blossom end rot under shade in tomato. Incidence of spotted wilt disease in tomato was also reduced due to shade (Smitha, 2002). Sreelathakumary (2000) reported reduced incidence of mite in chilli under 50 per cent shade.

2.6.7 Content and Uptake of NPK

According to Maliphant (1959), in cocoa, shading increased N content of leaf but P content was decreased. Prameela (1990) recorded highest N, P and K contents under 25 per cent shade in colocasia.

Bai (1981) observed an increase in the contents of N, P and K in coleus, colocasia, sweet potato, turmeric and ginger with increase in shade. In ginger, George (1992) observed significant difference with respect to NPK content in haulm.

Magalthaes and Wilcox (1983) reported that heavy shading (50-67 per cent) of tomato plants grown with nitrate nitrogen only decreased the uptake of N, P, K, Ca and Mg while plants grown with ammoniacal nitrogen only tended to accumulate more N, P and K as shading increased. The uptake of N, P and K in ginger increased from 0 to 50 per cent shade and then showed a decrease at 75 per cent (Ancy, 1992).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was undertaken to study the response of vegetable chilli cv. Jwala Sakhi to different NK ratios and biofertilizer under different shade intensities. The experiment was laid out at the Instructional Farm, College of Agriculture, Vellayani during January–May 2003. The materials used and methods adopted in the experiment are detailed below.

3.1 MATERIALS

3.1.1 Experimental Site

The experiments were conducted in the garden land at the Instructional Farm, College of Agriculture, Vellayani. The farm is situated at 8° 30' N latitude and 76° 54' E longitude at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experiment area was red sandy loam belonging to taxonomical order oxisol, acidic in reaction. The physico-chemical properties of the experimental site are presented in Table 3.1.

Table 3.1 Physico-chemical properties of soil

A. Physical composition

Sl. No.	Parameter	Content (%)	Methods used
1	Coarse sand	36.35	
2	Fine sand	15.00	Bouyoucos Hydrometer method
3	Silt	17.50	Bouyoucos, 1962
4	Clay	30.50	

B. Chemical composition

Sl. No.	Parameter	Content	Rating	Methods used
1	PH	4.8	Acidic	pH meter with glass electrode (Jackson, 1973)
2	Available N (kg ha^{-1})	222.65	Medium	Alkaline potassium permanganate method (Subhiah and Asija, 1956)
3	Available P_2O_5 (kg ha^{-1})	32.80	Medium	Bray colorimetric method (Jackson, 1973)
4	Available K_2O (kg ha^{-1})	61.28	Low	Neutral normal ammonium acetate method (Jackson, 1973)

3.1.3 Cropping History of the Field

The experimental area was under bulk crop of red banana before the experiment.

3.1.4 Climate and Season

The experimental area enjoys a humid tropical climate. The field experiment was conducted during the period from 19-02-2003 to 29-05-2003.

3.1.5 Meteorological Parameters

The data on meteorological parameters *viz*., rainfall, minimum and maximum temperature, relative humidity and evaporation during the cropping period are furnished in Appendix I and presented graphically in Fig. 1.

3.1.6 Variety

The variety used was Jwala Sakhi, a high yielding variety of vegetable chilli evolved by Kerala Agricultural University by crossing

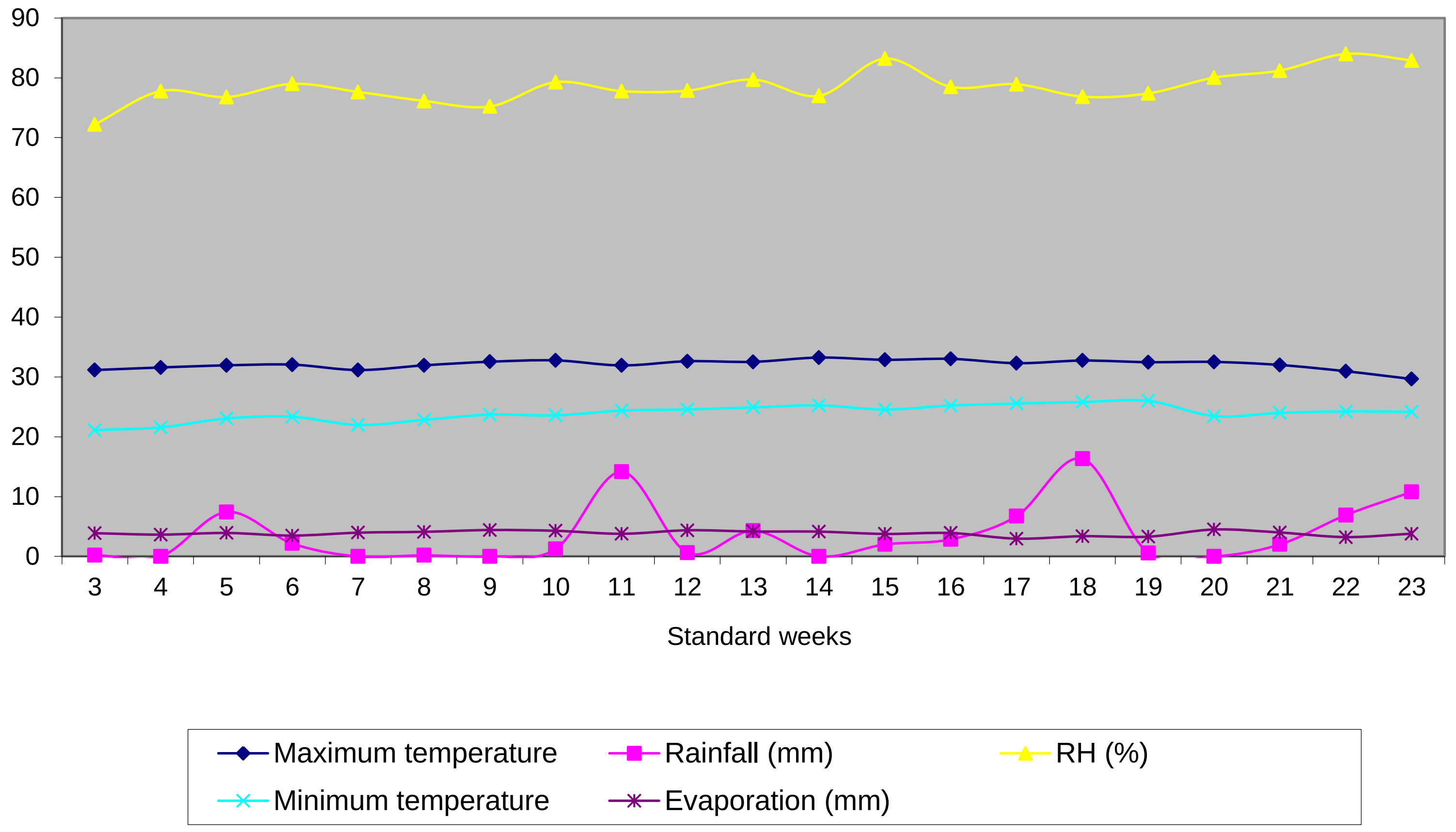

Fig.1. Weather parameters during the cropping period

Vellanotchi, a popular local cultivar of South Kerala with Pusa Jwala. It has got high yield potential, ideal for culinary purpose and suited for high density planting.

3.1.7 Seed

The seed material was obtained from Instructional Farm, College of Agriculture, Vellayani.

3.1.8 Manures and Fertilizers

FYM (0.4 per cent N; 0.2 per cent P, 0.3 per cent K) was used as organic manure. Urea (46 per cent N), mussoriephos (20 per cent P_2O_5) and murate of potash (60 per cent K_2O) were the fertilizers used for the experiment. The biofertilizer used was *Azospirillum*.

3.2 METHODS

Three separate experiments were carried out under 25 and 50 per cent shade along with open condition.

3.2.1 Design and Layout

The experiments were laid out as a factorial experiment in Randomised Block Design. The layout of the experiments are given in Fig. 2.

Details of Layout are given below:

Number of treatment combinations	:	6
Number of replications	:	3
Total number of plots	:	54
Gross plot size	:	3.6 x 3.6 m
Net plot size	:	2.7 x 2.7 m
Spacing	:	45 x 45 cm
Number of plants in net plot	:	36

N ←

Experiment I

Open		
F_3B_2	F_2B_1	F_1B_2
F_1B_1	F_1B_2	F_3B_2
F_1B_2	F_1B_1	F_2B_2
F_2B_2	F_2B_2	F_3B_1
F_2B_1	F_3B_1	F_1B_1
F_3B_1	F_3B_2	F_2B_1
R_1	R_2	R_3

Experiment II

25 % shade		
F_3B_2	F_2B_1	F_1B_2
F_1B_1	F_1B_2	F_3B_2
F_1B_2	F_1B_1	F_2B_2
F_2B_2	F_2B_2	F_3B_1
F_2B_1	F_3B_1	F_1B_1
F_3B_1	F_3B_2	F_2B_1
R_1	R_2	R_3

Experiment III

50 % shade		
F_3B_2	F_2B_1	F_1B_2
F_1B_1	F_1B_2	F_3B_2
F_1B_2	F_1B_1	F_2B_2
F_2B_2	F_2B_2	F_3B_1
F_2B_1	F_3B_1	F_1B_1
F_3B_1	F_3B_2	F_2B_1
R_1	R_2	R_3

Fig. 2. Layout plan of the experiments

3.2.2 Treatments

The treatments consisted of three levels of NK ratio and two levels of biofertilizer.

(i) Factor 1

NK ratio

F_1 – 1 : 1 (50 : 50 NK kg ha^{-1})

F_2 – 2 : 1 (100 : 50 NK kg ha^{-1})

F_3 – 3 : 1 (150 : 50 NK kg ha^{-1})

(ii) Factor 2

Biofertilizer

B_1 – with *Azospirillum*

B_2 – without *Azospirillum*

The different treatment combinations were as follows :

T_1 – F_1B_1	T_4 – F_2B_2
T_2 – F_1B_2	T_5 – F_3B_1
T_3 – F_2B_1	T_6 – F_3B_2

3.2.3 Cultural Operation

3.2.3.1 Nursery

Eighty gram seeds were sown in well prepared nursery beds of 1.2 m width and 15 cm height with channels around them to facilitate the drainage. The seeds were sown on 17-1-2003. The seedlings were irrigated every day. Hand weeding and plant protection measures were undertaken periodically as per the package of practices recommendation (KAU, 2002). The seedlings were ready for transplanting in 34^{th} day.

3.2.3.2 Field Culture

The main field was ploughed, clods broken, cleared off stubbles and plots were laid out with bunds of 30 cm width all round. Individual plots were again dug and perfectly levelled. Ridges and furrows were formed 45 cm apart. Well decomposed FYM was applied at the time of land preparation and mixed well with the soil.

Shade net installation: Green shade net fabricated for 25 and 50 per cent light intensity was used. The nets were spread at a height of 2.50 m from ground levels and supported on bamboo poles of 6.50 cm diameter. Care was taken to avoid natural shade in the experimental area.

3.2.3.3 Application of Manures and Fertilizers

A uniform dose of 25 t cattle manure ha^{-1} was applied in the experimental area at the time of preparatory cultivation. N, P_2O_5 and K_2O were applied in the form of urea, mussoriephos and MOP. Uniform dose of phosphorus (40 kg ha^{-1}) was given as basal. Nitrogen and potassium fertilizers were applied as per the treatment schedule. Half of nitrogen and half potash were given as basal. One fourth nitrogen and half potash were applied to the soil at 25 days after transplanting. The remaining quantity of nitrogen was applied one month after the first top dressing.

Application of biofertilizer

Azospirillum @ 1 kg ha^{-1} was used. Half the dose was prepared in the form of slurry. In *Azospirillum* inoculated treatments, the seedlings were dipped in the slurry for 10 minutes and transplanted. After 30 days, remaining dose was sprayed.

3.2.3.4 Transplanting

The seedlings were ready for transplanting on 34th day. They were pulled out and kept in trays. Planting was done at a spacing of 45 x 45 cm. Plants were given uniform irrigation. Necessary shade was also provided for first four days after planting using banana leaves.

3.2.3.5 After Cultivation

Gap filling was done with healthy seedlings on the seventh day after transplanting. Regular irrigation and weeding were carried out.

3.2.3.6 Plant Protection

As a prophylatic measure against pest attack, Rogor was sprayed repeatedly at 14 days interval for getting satisfactory fruit yield. Fytolan drenching was also done to prevent wilt.

3.2.3.7 Harvest

The crop was ready for first harvest 55 days after transplanting and subsequent harvest were made at an interval of 7-10 days.

3.3 OBSERVATIONS

The observation was taken from five plants at random in each plot after eliminating border rows. Parameters considered and methods followed are briefly stated below:

3.3.1 Growth Characters

3.3.1.1 Height of Plant

The height of plants were measured from the base to the growing tip of the plants at three stages *viz.*, 30, 60 and 90 days after transplanting. The mean plant height was worked out and expressed in cm.

3.3.1.2 Number of Branches Plant^{-1}

The total number of branches per plant at three growth stages *viz*., 30, 60 and 90 DAT were recorded from five observational plants and mean values recorded.

3.3.1.3 Girth of Stem

The girth of main stem at 15 cm above soil surface was taken at three growth stages and mean values recorded.

3.3.1.4 Dry Matter Production (DMP)

The entire dry weights of shoots and fruits of four observational plants were recorded. The samples were dried to constant weight in a hot air oven at a temperature of 80 ± 5° C the mean dry weights were recorded and expressed in g plant^{-1}.

3.3.1.5 Leaf Area Index (LAI)

Leaf area index was worked out at three stages *i.e.*, 30, 60 and 90 days after transplanting and expressed in square centimeter. LAI was worked out using the equation suggested by Watson (1958).

$$\text{Leaf area index} = \frac{\text{Total leaf area}}{\text{Land area}}$$

3.3.2 Yield and Yield Attributes

3.3.2.1 Days for Flower Initiation

Number of days from sowing to first flowering of plants was computed.

3.3.2.2 Days for 50 per cent Flowering

Total number of days taken for 50 per cent of the plant population to flower in each treatment was recorded.

3.3.2.3 Number of Flowers per Plant

Flower production in the observational plants was recorded from the first flower opening till the flower production was ceased.

3.3.2.4 Number of Fruits per Plant

The total number of fruits on the five observational plants was recorded and the average worked out.

3.3.2.5 Total Yield of Chillies per Plot

From each plot, fresh weight of fruits were recorded and expressed in t ha^{-1}.

3.3.2.6 Number of Harvest

Number of economic harvests possible for each treatment was recorded.

3.3.3 Quality Characters

3.3.3.1 Shelf Life

The fruits collected from different treatments were kept under ambient conditions and the days upto which quality was maintained without deterioration *i.e.,* change in colour, shrinkage, rotting etc. were recorded.

3.3.3.2 Ascorbic Acid

Ascorbic acid content of the fruits at red ripe stage was estimated by 2, 6-dichlorophenol indophenol dye method (Sadasivan and Manickam, 1992). Ascorbic acid content of the sample was calculated using the formula.

$$\text{Ascorbic acid content In mg/100 g fresh fruit} = \frac{\text{Titre x dye factor x volume made upto x 100}}{\text{Aliquot of extract taken x weight of sample taken}}$$

3.3.3.3 Proline

Plants grown in open, 25 per cent and 50 per cent shade were analysed for the proline content during fruiting stage.

Proline present in the leaves was extracted using sulphosalicylic acid. The extracted proline was made to react with ninhydrin in acidic condition to form a red colour and intensity was read at 520 nm (Sadasivam and Manickam, 1992). Amount of proline in the sample was calculated from a standard curve of pure proline and was expressed as micromoles per gram tissue.

$$\text{Proline content } (\mu\text{moles per g tissue}) = \frac{\mu\text{g proline / ml x ml toluene x 5}}{\text{115.5 g of sample}}$$

3.3.3.4 Capsaicin

Capsaicin content was determined by Folin-Dennis method. The pungent principle reacts with Folin-Dennis reagent to give a bluish complex which was estimated colorimetrically (Mathew *et al*., 1971).

3.3.4 Pest and Disease Scoring

3.3.4.1 Incidence of Bacterial Wilt

Incidence of bacterial wilt was reckoned by visual observation. Scoring was done by computing the per cent of infection.

$$\text{Per cent of infection} = \frac{\text{Number of plants infected per plot}}{\text{Total number of plants per plot}}$$

3.3.4.2 Incidence of Leaf Curl

A scoring procedure with a 0 – 5 scale was adopted based on the extent of damage caused by chilli mite *Polyphagotarsonemus latus* to the plants.

0 – No incidence

1 – Mild (25 per cent)

3 – Medium (50 per cent)

5 – Severe (75 per cent)

3.3.5 *Azospirillum* Population Count

Pooled soil samples collected from each treatment were enumerated by soil dilution and plate technique using nitrogen free semi-solid malate agar medium (Baldani and Doberiner, 1980).

3.3.6 Chemical Analysis

3.3.6.1 Soil Analysis

Before the commencement of the trial, composite soil sample from the experimental site was taken and subjected to analysis for chemical properties and fertility status in terms of available N, P and K.

After the experiment, the effect of individual treatment on the residual soil fertility was determined. Soil from each experimental plot was analysed for available N, P and K. The methods followed for the assay of various soil parameters are given in Table 3.2.

3.3.6.2 Plant Analysis

The plant samples collected from the observational plants on each plot at the time of final harvest were separated into stem and root, fruits and leaves. They were chopped and dried in a hot air oven at 80 ± 5°C separately till constant weights were obtained. Samples were then ground to pass through 0.5 mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in a physical balance and analysed. N, P and K were determined by methods given in Table 3.2.

3.3.6.2.1 Uptake of Nitrogen, Phosphorus and Potassium

The total uptake of nitrogen, phosphorus and potassium by the stem and root, leaves and fruits were calculated as the product of the per cent content of these nutrients in the plant samples and the respective dry weights and expressed in kg ha^{-1}.

Table 3.2 Analytical methods for plant and soil parameters

Sl. No.	Parameter	Method	Reference
1	Soil analysis		
i	Available N	Alkaline potassium permanganate method	Subbiah and Asija, 1956
ii	Available P_2O_5	Bray No. 1 extract	Bray and Kurtz, 1945
iii	Available K_2O	Neutral normal ammonium acetate extract	Jackson, 1973
2	Plant Analysis		
i	Total N	Modified micro kjeldahl method	Jackson, 1973
ii	Total P	Vanadomolybdo phosphate yellow colour method by Spectronic 2000	Jackson, 1973
iii	Total K	Atomic absorption spectrophotometry	Jackson, 1973

3.4 ECONOMICS OF CULTIVATION

B : C Ratio

The economics of cultivation was worked out from the cost of cultivation and the income derived from the treatments.

$$\text{B : C ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

Considering the high initial cost of shade net, BC ratio was worked out in two sets. In the first set full cost of shade net was taken into account while the second set, cost of shade net was apportioned over five years (approximate life span of shade net) and two crops a year.

3.5 STATISTICAL ANALYSIS

The data relating to each characters were analysed using the analysis of variance technique as applied to factorial randomised block design (Snedecor and Cochran, 1967). In case where the effects were found to be significant, critical difference were calculated by using standard technique. Pooled analysis was done to test the significant difference among different shade levels.

Results

4. RESULTS

The experiment entitled ‘Performance of chilli as influenced by NK ratio, biofertilizer and shade’ was carried out at the Instructional Farm, College of Agriculture, Vellayani during the period from January to May 2003. The experimental data were subjected to statistical analysis and the results obtained are presented under the following sections.

4.1 GROWTH CHARACTERS

Observations on growth characters like plant height, number of branches, stem girth, dry matter production, leaf area index etc. were recorded and results are presented below.

4.1.1 Plant Height

The data on mean height of plants at 30 DAT is presented in Table 4.1.1.

The effect of NK ratio was found to be significant under open and 25 per cent shade. But there was no significant variation under 50 per cent shade. NK ratio (3:1) produced taller plants under open while under 25 per cent shade 2 : 1 NK ratio was significantly superior.

There was no significant difference in plant height among biofertilizer treated plots.

Except under 25 per cent shade, significant interaction in height was not observed between nutrient level and biofertilizer. Under 25 per cent shade, T_3 (2:1 NK + *Azospirillum*) registered maximum height (32.06 cm), which was on par with T_4, T_5, and T_6.

There was no significant variation among treatments for height under all shade levels. But significant difference in height was noticed among different shade levels. Overall mean for height at 30 DAT was

Table 4.1.1 Effect of NK ratio, biofertilizer and shade on the mean plant height of chilli 30 DAT, cm

Treatments	Open	25 % shade	50 % shade	Mean
F_1	24.26	26.23	30.56	27.01
F_2	27.70	30.93	31.75	30.12
F_3	29.46	30.79	33.78	31.34
CD	3.921	2.190	NS	
SE	1.244	0.695	-	
B_1	27.93	29.91	33.76	30.53
B_2	26.35	28.72	30.30	28.45
CD	-	-	-	
SE	-	-	-	
T_1	25.26	26.73	32.60	28.20
T_2	23.26	25.73	28.53	25.84
T_3	28.53	32.06	33.50	31.36
T_4	26.86	29.80	30.00	28.88
T_5	30.00	30.93	35.20	32.04
T_6	28.93	30.65	32.36	30.65
Mean	27.14	29.31	32.03	
CD (T)	-	3.097	-	
SE	-	0.983	-	
CD (Shade)	3.021			
SE	1.057			
CD (Treatments)	-			
SE	-			

27.14 cm, 29.31cm, and 32.03 cm respectively in open, 25 and 50 per cent shade levels.

The Table 4.1.2 indicates the variations in plant height at 60 DAT due to various treatments.

An increase in NK ratio resulted in significant increase in plant height under open. NK ratio of 3:1 registered maximum height of 33.50 cm which was on par with 2:1 NK ratio.

The effect of biofertilizer on plant height was not statistically significant. Significant interaction was not noticed between nutrient levels and biofertilizer.

Among the treatments under all shade levels there was no significant variation for plant height. However, there was significant difference in plant height among different shade levels. Minimum plant height of 31.71 cm was recorded in plants grown in open compared to 39.33 cm under 50 per cent shade

The data on mean plant height at 90 DAT are furnished in Table 4.1.3.

Except under 50 per cent shade there was no significant increase in plant height with increase in NK ratio. Under 50 per cent shade, 3:1 ratio recorded maximum height of 53.00 cm and 1:1 ratio registered minimum height of 44.33 cm.

There was no significant increase in plant height among biofertilizer treated plants. Significant interaction was not observed between nutrient level and biofertilizer under all shade levels.

At 90 DAT, there was significant increase in plant height from open to 50 per cent shade. Maximum overall mean for plant height was in 50 per cent shade (47.83 cm), followed by 25 per cent shade (43.91 cm), while open had minimum height of 38.67 cm.

Table 4.1.2 Effect of NK ratio, biofertilizer and shade on the mean plant height at 60 DAT, cm

Treatments	Open	25 % shade	50 % shade	Mean
F_1	28.58	34.17	38.45	33.73
F_2	33.06	38.66	38.00	36.57
F_3	33.50	39.50	41.53	38.17
CD	3.747	-	-	
SE	1.189	-	-	
B_1	32.36	38.14	40.83	37.11
B_2	31.07	36.75	37.82	35.21
CD	-	-	-	
SE	-	-	-	
T_1	29.91	34.76	39.25	34.64
T_2	27.25	33.58	37.66	32.83
T_3	33.25	39.00	39.25	37.16
T_4	32.88	38.30	36.75	35.98
T_5	33.91	40.60	44.00	39.52
T_6	33.08	38.33	39.06	36.82
Mean	31.71	37.44	39.33	
CD (T)	-	-	-	
SE	-	-	-	
Pooled data				
CD (Shade)	4.720			
SE	1.651			
CD (Treatments)	-			
SE	-			

Table 4.1.3 Effect of NK ratio, biofertilizer and shade levels on the mean plant height at 90 DAT, cm

Treatments	Open	25 % shade	50 % shade	Mean
F_1	37.56	42.46	44.33	41.45
F_2	37.93	44.41	46.18	42.84
F_3	40.52	44.86	53.00	46.12
CD	-	-	6.442	
SE	-	-	2.044	
B_1	39.26	44.93	48.91	44.36
B_2	38.08	42.90	46.76	42.58
CD	-	-	-	
SE	-	-	-	
T_1	37.93	42.96	45.40	42.10
T_2	37.20	41.96	43.26	40.81
T_3	38.36	44.76	48.06	43.73
T_4	37.50	44.06	44.30	41.95
T_5	41.50	47.06	53.26	47.27
T_6	39.50	42.66	52.73	44.98
Mean	38.67	43.91	47.83	
CD (T)	-	-	-	
SE	-	-	-	
Pooled data				
CD (Shade)	4.634			
SE	1.621			
CD (Treatments)	-			
SE	-			

Among the treatments under all shade levels there was no significant variation for plant height.

4.1.2 Number of Branches per Plant

The mean number of branches per plant at 30 DAT are shown in Table 4.2.1.

Only under 50 per cent shade, there was significant increase in mean number of branches per plant with increase in NK ratio. 3:1 NK ratio recorded more number of branches (12.80) than 1:1 NK ratio treated plants (7.65).

No significant increase in number of branches with biofertilizer treatment.

Except under 50 per cent shade, no significant interaction was observed between nutrient levels and biofertilizer. Under 50 per cent shade, T_5 registered maximum number of branches (13.20) which was on par with T_6.

There was no significant variation for number of branches among the treatments under all shade levels. But significant difference was observed between different shade levels. Maximum overall mean was in open (13.42) followed by 25 per cent shade (12.83) while 50 per cent shade had minimum number of branches (10.26).

Table 4.2.2 gives the data on mean number of branches per plant 60 DAT. Significant diffference in number of branches between NK ratio was observed under open, 25 and 50 per cent shade. 3:1 NK ratio was found to be superior to 1:1 NK ratio under all shade levels. 3:1 NK ratio recorded maximum number of branches *i.e.*, 32.16 in open, 27.85 under 25 per cent shade and 25.95 under 50 per cent shade.

There was no significant increase in number of branches with *Azospirillum* inoculation.

Table 4.2.1 Number of branches per plant at 30 DAT as influenced by NK ratio, biofertiliser and shade

Treatments	Open	25 % shade	50 % shade	Mean
F_1	12.46	11.96	7.65	10.69
F_2	13.56	12.75	10.25	12.18
F_3	14.23	13.77	12.80	13.60
CD	-	-	1.962	
SE	-	-	0.622	
B_1	13.88	13.27	10.75	12.63
B_2	12.95	12.38	9.71	11.68
CD	-	-	-	
SE	-	-	-	
T_1	12.80	12.06	8.56	11.03
T_2	12.13	11.86	6.73	10.78
T_3	13.80	13.00	10.50	12.15
T_4	13.33	12.50	10.00	12.47
T_5	15.06	14.75	13.20	14.25
T_6	13.40	12.80	12.40	12.34
Mean	13.42	12.83	10.26	
CD (T)	-	-	2.775	
SE	-	-	0.880	
Pooled data				
CD (Shade)	2.177			
SE	0.762			
CD (Treatments)	-			
SE	-			

Table 4.2.2 Number of branches per plant at 60 DAT as influenced by NK ratio, biofertiliser and shade

Treatments	Open	25 % shade	50 % shade	Mean
F_1	23.16	21.35	19.85	21.45
F_2	26.54	24.20	22.15	24.29
F_3	32.16	27.85	25.95	28.65
CD	2.095	1.784	1.345	
SE	0.665	0.566	0.427	
B_1	27.77	25.00	22.96	25.24
B_2	26.80	23.93	22.33	24.35
CD	-	-	-	
SE	-	-	-	
T_1	23.25	21.50	20.00	21.58
T_2	23.08	21.20	19.70	21.32
T_3	26.75	24.80	22.40	24.65
T_4	26.33	23.60	21.90	23.94
T_5	33.33	28.70	26.50	29.51
T_6	31.00	27.00	25.40	27.80
Mean	27.29	24.46	22.65	
CD (T)	2.963	2.523	1.903	
SE	0.940	0.801	0.604	
Pooled data				
CD (Shade)	1.458			
SE	0.510			
CD (Treatments)	2.062			
SE	0.721			

Significant interaction was noticed between nutrient level and biofertilizer. Maximum branches was recorded by plants receiving 3 : 1 NK ratio and biofertilizer under all shade levels. In open, plants treated with 3 : 1 NK ratio and biofertilizer recorded maximum number of branches (33.33) which was on par with T_6 (31.00). Under 25 per cent shade, T_5 produced significantly higher number of branches (28.70) which was on par with T_6 (27.00). Similarly under 50 per cent shade T_5 registered maximum number of branches (26.50) which was on par with T_6.

Significant difference among the treatments and between different shade levels was observed for number of branches per plant. The number of branches decreased with increase in shade. Maximum overall mean was in open (27.29), followed by 25 per cent shade (24.46) while 50 per cent shade had minimum number of branches (22.65).

Under all shade levels maximum number of branches was in T_5 with 33.33, 28.70 and 26.50 in open, 25 per cent and 50 per cent shade levels respectively. It was on par with T_6 (31.00) in open, 27.00 in 25 per cent shade and 25.40 under 50 per cent shade. Maximum pooled mean was recorded in T_5 (29.51) and minimum in T_2 (21.32).

The data on the mean number of branches per plant at 90 DAT are shown in Table 4.2.3.

There was a progressive increase in number of branches due to successive level of nitrogen and potassium upto 3:1 ratio. The higher levels of N and K tried were significantly superior to the lowest level of NK tried in the present study. 3:1 NK ratio recorded 50.13, 46.40 and 43.45 branches respectively under open, 25 and 50 per cent shade.

Application of *Azospirillum* did not influence the number of branches per plant.

Interaction between nutrient level and biofertilizer was found to be significant under open and 25 per cent shade. Under open and 25 per cent

Table 4.2.3 Number of branches per plant at 90 DAT as influenced by various treatments

Treatments	Open	25 % shade	50 % shade	Mean
F_1	43.70	42.20	40.85	42.25
F_2	46.00	43.85	39.75	43.20
F_3	50.13	46.40	43.45	46.66
CD	2.564	1.043	2.702	
SE	0.813	0.331	0.857	
B_1	47.27	44.93	42.00	44.70
B_2	45.94	43.36	40.70	43.33
CD	-	-	-	
SE	-	-	-	
T_1	44.30	42.80	41.20	42.76
T_2	43.10	41.60	40.50	41.73
T_3	46.60	44.50	40.00	43.70
T_4	45.40	43.20	39.50	42.70
T_5	50.93	47.50	44.80	47.74
T_6	49.33	45.30	42.10	45.57
Mean	46.61	44.15	41.35	
CD (T)	3.626	1.475	-	
SE	1.150	0.468	-	
Pooled data				
CD (Shade)	1.855			
SE	0.649			
CD (Treatments)	2.624			
SE	0.918			

shade, plants treated with 3:1 NK ratio and biofertilizer gave higher number of branches *i.e.,* 50.93 in open and 47.50 under 25 per cent shade T_5 was on par with T_6 under open.

Significant variation among treatments for number of branches was observed under different shade levels. The number of branches in all the treatments showed a decreasing trend with increase in shade levels and there was significant difference in number of branches among the shade levels. Minimum number of branches of 41.35 was recorded in plants grown under 50 per cent shade compared to 46.61 under open.

Among the treatments, T_5 registered maximum number of branches under open, 25 per cent and 50 per cent shade with 50.93, 47.50 and 44.80 respectively. T_5 was on par with T_6 49.33 in open, 45.30 under 25 per cent shade and 42.10 under 50 per cent shade.

T_2 recorded minimum number of branches with 43.10, 41.60 and 40.50 under open, 25 and 50 per cent shade respectively. T_2 was on par with T_1, T_3 and T_4. T_2 had the minimum pooled mean for number of branches (41.73) while T_5 (47.74) registered the maximum number of branches.

4.1.3 Stem Girth

The effect of various treatments on stem girth is given in Table 4.3. Stem girth at 30 and 90 DAT was not significantly influenced by various treatments.

Effect of nutrient ratio on stem girth was found to be significant under open and 25 per cent shade. F_3 recorded minimum stem girth of 2.41 cm and 2.10 cm under open and 25 per cent shade respectively. While F_1 registered maximum stem girth of 2.89 cm in open and 2.87 cm under 25 per cent shade.

Azospirillum inoculated plants recorded higher stem girth but was not significant.

Table 4.3 Effect of treatments on stem girth in chilli var. Jwala Sakhi, cm

Treatments	Open	25 % shade	50 % shade	Mean
F_1	2.89	2.87	2.42	2.72
F_2	2.56	2.49	2.00	2.35
F_3	2.41	2.10	1.82	2.11
CD	0.322	0.308	-	
SE	0.102	0.098	-	
B_1	2.67	2.53	2.26	2.48
B_2	2.51	2.45	1.90	2.30
CD	-	-	-	
SE	-	-	-	
T_1	2.95	2.94	2.79	2.89
T_2	2.83	2.80	2.05	2.56
T_3	2.60	2.53	2.05	2.39
T_4	2.52	2.46	1.95	2.31
T_5	2.45	2.11	1.94	2.17
T_6	2.36	2.09	1.70	2.05
Mean	2.62	2.49	2.08	
CD (T)	-	0.436	-	
SE	-	0.138	-	
Pooled data				
CD (Shade)	0.334			
SE	0.117			
CD (Treatments)	0.473			
SE	0.165			

The interaction between nutrient level and Azospirillum was significant only under 25 per cent shade. Maximum stem girth (2.94) was observed at lowest fertilizer level under 25 per cent shade. T_6 recorded minimum stem girth. T_1 was on par with T_2 and T_3.

There was significant difference among treatments for stem girth under all shade levels. A significant reduction in stem girth was noticed with increase in the shade levels. Maximum stem girth was recorded from plants grown in open condition. Overall mean stem girth due to shade level was maximum in open (2.62 cm) followed by 25 per cent shade (2.49 cm). Minimum stem girth was recorded from plants grown under 50 per cent shade (2.08 cm).

Under all shade levels, maximum stem girth was in T_1 with 2.95 cm, 2.94 cm and 2.79 cm in open, 25 per cent and 50 per cent shade level respectively. It was on par with T_2, T_3 and T_4 in open, with T_2 and T_3 under 25 per cent shade. Minimum pooled mean was recorded in T_1 (2.89 cm) and minimum in T_6 (2.05 cm).

4.1.4 Dry Matter Production

The influence of various treatments on DMP are given in Table 4.4.

Highest NK ratio (F_3) was significantly superior to F_1 and F_2. F_3 recorded maximum DMP of 42.62 in open, 50.07 under 25 per cent shade and 55.75 g plant^{-1} under 50 per cent shade.

Azospirillum inoculation registered significantly higher DMP.

At harvest, *Azospirillum* inoculation recorded a DMP of 58.91 g plant^{-1}, 45.71 g plant^{-1} and 39.78 g plant^{-1} respectively under 50, 25 per cent shade and open. Control plants recorded minimum DMP of 44.91 g plant^{-1} under 50 per cent shade, 41.94 g plant^{-1} under 25 per cent shade and 36.47 g plant^{-1} in open.

There was significant interaction between NK ratio and biofertilizer. T_5 recorded maximum and significant dry matter at open (44.81 g plant^{-1}),

Table 4.4 Influence of NK ratio, biofertilizer and shade on dry matter production in chilli, g plant^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	33.89	36.22	46.64	38.91
F_2	37.86	45.19	53.39	45.48
F_3	42.62	50.07	55.75	49.48
CD	1.609	1.781	2.078	
SE	0.510	0.565	0.659	
B_1	39.78	45.71	58.94	48.14
B_2	36.47	41.94	44.91	41.10
CD	1.314	1.454	1.696	
SE	0.417	0.461	0.538	
T_1	35.60	38.04	52.54	42.06
T_2	32.18	34.40	40.74	35.77
T_3	38.92	46.81	60.67	48.80
T_4	36.81	43.57	46.12	42.16
T_5	44.81	52.28	63.61	53.57
T_6	40.43	47.85	47.88	45.39
Mean	38.12	43.82	51.93	
CD (T)	2.276	2.519	2.938	
SE	0.722	0.799	0.932	
Pooled data				
CD (Shade)	4.329			
SE	1.499			
CD (Treatments)	6.122			
SE	2.120			

at 25 per cent shade (52.28 g plant^{-1}) and at 50 per cent shade (63.61 g plant^{-1}).

Significant variation was noticed among treatments under all shade levels. DMP under 50 per cent shade was significantly superior to open and 25 per cent shade. Maximum DMP was under 50 per cent shade (51.93 g plant^{-1}) followed by 25 per cent shade (43.82 g plant^{-1}). Minimum DMP was recorded by plants grown in open (38.12 g plant^{-1}).

T_5 registered highest DMP in open (44.81 g plant^{-1}), 52.28 g plant^{-1} under 25 per cent shade and 63.61 g plant^{-1} under 50 per cent shade. T_2 recorded minimum DMP of 31.18 g plant^{-1}, 34.40 g plant^{-1} and 40.74 g plant^{-1} under open, 25 and 50 per cent shade respectively.

T_5 recorded maximum pooled mean of 53.51 g plant^{-1}. While T_2 recorded minimum pooled mean of 35.7 g plant^{-1}.

4.1.5 Leaf Area Index

Table 4.5.1 depicts the leaf area index (LAI) at 30 DAT as influenced by shade, nutrient level and biofertilizer.

NK ratio had significant effect in leaf area index. With increasing NK ratio LAI increased. NK level 3:1 was found to be superior to 1:1 and 2:1, 3 :1 NK ratio recorded maximum LAI of 0.190 cm^2, 0.120 cm^2 and 0.307 cm^2 under open, 25 per cent shade and 50 per cent shade respectively.

Azospirillum inoculation was found to be superior to non inoculated plants. At 30 DAT, *Azospirillum* inoculation recorded maximum LAI of 0.134 cm^2 under open, 0.207 cm^2 under 25 per cent shade and 0.278 cm^2 under 50 per cent shade.

Interaction of nutrient level with biofertilizer was also significant. F_3B_1 interaction recorded highest LAI of 0.2 cm^2, 0.226 cm^2 and 0.323 cm^2 under open, 25 per cent shade and 50 per cent shade respectively.

Table 4.5.1 Effect of NK ratio, biofertilizer and shade on LAI at 30 DAT in chilli, cm^2

Treatments	Open	25 % shade	50 % shade	Mean
F_1	0.105	0.153	0.205	0.154
F_2	0.145	0.203	0.268	0.205
F_3	0.190	0.210	0.307	0.235
CD	0.018	0.029	0.023	
SE	0.005	0.009	0.007	
B_1	0.154	0.207	0.278	0.213
B_2	0.139	0.171	0.242	0.184
CD	0.014	0.024	0.019	
SE	0.004	0.007	0.006	
T_1	0.106	0.173	0.230	0.170
T_2	0.103	0.133	0.180	0.139
T_3	0.156	0.220	0.280	0.219
T_4	0.133	0.186	0.256	0.192
T_5	0.200	0.226	0.323	0.250
T_6	0.180	0.193	0.290	0.221
Mean	0.147	0.189	0.260	
CD (T)	0.025	0.041	0.033	
SE	0.008	0.013	0.010	
Pooled data				
CD (Shade)	0.020			
SE	0.007			
CD (Treatments)	0.029			
SE	0.010			

Significant difference among treatments for LAI was observed under all shade levels. There was significant difference among the shade levels. LAI was found to increase with increase in shade level also. Maximum LAI was attained under 50 per cent shade (0.260 cm^2). Open condition recorded the lowest LAI of 0.147 cm^2.

T_5 (3:1 NK + *Azospirillum*) had the maximum LAI of 0.2 cm^2, 0.226 cm^2 and 0.323 cm^2 respectively in open 25 per cent and 50 per cent shade levels. Plant receiving T_2 (1:1 NK + control) recorded least LAI of 0.103 cm^2 (open), 0.133 cm^2 (25 per cent shade) and 0.180 cm^2 (50 per cent shade). Maximum pooled mean for LAI was in T_5 (0.250 cm^2) and minimum pooled mean in T_2 (0.139 cm^2).

The effect of different NK ratios on LAI at 60 DAT (Table 4.5.2) was statistically significant. There was a progressive increase in LAI due to NK ratio upto the highest ratio tried (3:1).

Azospirillum inoculation was found to have significant effect on LAI only under open condition.

Significant interaction was observed between nutrient ratios and biofertilizer. Plants treated with high NK ratio (3:1) and *Azospirillum* recorded maximum LAI of 0.75 cm^2, 0.676 cm^2 and 0.840 cm^2 under open, 25 per cent shade and 50 per cent shade respectively.

Significant difference both among the treatments and between shade levels was observed for LAI at 60 DAT (Table 4.5.2). There was increase in LAI with increase in shade with 50 per cent shade level attaining maximum LAI (0.754 cm^2) compared to 0.672 cm^2 in open.

The treatment T_5 (3 : 1 NK + *Azospirillum*) had maximum LAI under all shade levels with 0.75 cm^2 and 0.84 cm^2 respectively in open, 25 and 50 per cent shade. Minimum LAI was in T_2 (1 : 1 NK ratio + control) in open (0.596 cm^2), 0.586 cm^2 under 25 and 0.673 cm^2 under 50 per cent

Table 4.5.2 Effect of treatments on LAI at 60 DAT of chili var. Jwala Sakhi, cm^2

Treatments	Open	25 % shade	50 % shade	Mean
F_1	0.607	0.597	0.692	0.632
F_2	0.683	0.655	0.740	0.692
F_3	0.725	0.683	0.832	0.746
CD	0.021	0.052	0.047	
SE	0.006	0.016	0.015	
B_1	0.689	0.659	0.768	0.705
B_2	0.654	0.631	0.741	0.675
CD	0.017	-	-	
SE	0.005	-	-	
T_1	0.616	0.606	0.710	0.644
T_2	0.596	0.586	0.673	0.619
T_3	0.700	0.693	0.753	0.716
T_4	0.666	0.616	0.726	0.670
T_5	0.750	0.676	0.840	0.756
T_6	0.700	0.690	0.823	0.738
Mean	0.672	0.645	0.754	
CD (T)	0.030	0.073	0.067	
SE	0.009	0.023	0.021	
Pooled data				
CD (Shade)	0.035			
SE	0.012			
CD (Treatments)	0.050			
SE	0.017			

shade. Maximum pooled mean for LAI was for T_5 (0.756 cm^2) and minimum pooled mean in T_2 (0.619 cm^2).

LAI at 90 DAT (Table 4.5.3) was more in plants treated with 3:1 NK ratio, maximum LAI for plants receiving 3:1 NK ratio is significantly superior under open (0.735 cm^2) and 50 per cent shade (0.892 cm^2).

There was significant increase in LAI in plants treated with *Azospirillum* under open (0.736 cm^2) and 50 per cent shade (0.854 cm^2).

Significant interaction was noticed between *Azospirillum* and nutrient ratio under open and 50 per cent shade. T_5 (3:1 NK + *Azospirillum*) recorded highest LAI of 0.780 cm^2, 0.793 cm^2 and 0.936 cm^2 respectively in open, 25 per cent and 50 per cent shade.

There was significant variation among treatments for LAI at 90 DAT under all shade levels. LAI in all treatments showed an increasing trend with increase in shade level and there was significant difference in LAI among the shade levels. Minimum LAI of 0.717 cm^2 was recorded in plants grown in open (0.820 cm^2) compared to those under 50 per cent shade.

Among the treatments, T_5 (3:1 NK + *Azospirillum*) registered maximum LAI under open, 25 and 50 per cent shade with a LAI of 0.780 cm^2, 0.793 cm^2 and 0.936 cm^2 respectively. Minimum LAI was in T_2 under all shade levels.

T_5 had the maximum pooled mean for LAI (0.837 cm^2) while T_2 registered the minimum (0.694 cm^2).

4.2 YIELD CHARACTERS

4.2.1 Days to Flower Initiation

The influence of graded levels of nitrogen and potassium on days for flower initiation was found to be statistically significant (Table 4.6).

Table 4.5.3 Effect of treatments on LAI at 90 DAT of chili var. Jwala Sakhi, cm^2

Treatments	Open	25 % shade	50 % shade	Mean
F_1	0.662	0.733	0.745	0.714
F_2	0.730	0.770	0.823	0.774
F_3	0.755	0.783	0.892	0.810
CD	0.038	-	0.049	
SE	0.012	-	0.015	
B_1	0.736	0.769	0.854	0.786
B_2	0.698	0.756	0.786	0.746
CD	0.031	-	0.040	
SE	0.009	-	0.012	
T_1	0.676	0.750	0.776	0.734
T_2	0.653	0.716	0.713	0.694
T_3	0.750	0.763	0.850	0.788
T_4	0.710	0.776	0.796	0.761
T_5	0.780	0.793	0.936	0.837
T_6	0.730	0.773	0.846	0.783
Mean	0.717	0.762	0.820	
CD (T)	0.054	-	0.069	
SE	0.017	-	0.022	
Pooled data				
CD (Shade)	0.038			
SE	0.013			
CD (Treatments)	0.055			
SE	0.019			

Table 4.6 Effect of treatments on days for flower initiation in vegetable chilli

Treatments	Open	25 % shade	50 % shade	Mean
F_1	26.33	25.50	27.83	26.55
F_2	29.66	27.00	32.00	29.55
F_3	32.33	31.66	33.16	32.38
CD	2.569	2.083	1.757	
SE	0.815	0.661	0.557	
B_1	27.66	26.55	29.44	27.88
B_2	31.22	29.55	32.55	31.10
CD	2.097	1.700	1.434	
SE	0.665	0.539	0.455	
T_1	24.66	24.33	26.66	25.22
T_2	28.00	26.66	29.00	27.88
T_3	27.66	25.00	30.66	27.77
T_4	31.66	29.00	33.33	31.33
T_5	30.66	30.33	31.00	30.66
T_6	34.00	33.00	35.33	34.11
Mean	29.44	28.05	31.00	
CD (T)	3.633	2.945	2.485	
SE	1.153	0.934	0.788	
Pooled data				
CD (Shade)	1.781			
SE	0.623			
CD (Treatments)	2.519			
SE	0.881			

Days for flowering was significantly delayed with increase in NK ratio. Plants supplied with 3:1 NK ratio took about 32 days in open, 31 days in 25 per cent shade and 33 days under 50 per cent shade. While plants treated with 1:1 NK ratio took only 26, 25 and 27 days respectively in open, 25 and 50 per cent shade levels.

Influence of *Azospirillum* on days to flowering was significant. *Azospirillum* inoculation decreased the days to flowering. Inoculated plants flowered in 27, 26 and 29 days respectively in open, 25 and 50 per cent shade levels.

Interaction was found to be significant under all shade levels. T_6 (3: 1 NK + control) registered maximum days for flower initiation of 34, 33 and 35 days respectively in open, 25 per cent and 50 per cent shade.

Significant variation both among treatments and between different shade levels was observed for days to flowering. An increase in number of days to flowering was observed with an increase in shade level. Overall mean for days to flowering was minimum in 25 per cent shade (28.05 days). Maximum days to flowering was registered under 50 per cent shade (31 days).

T_1 (1: 1 NK + *Azospirillum*) was earliest for flowering in open (24.66 days), 25 per cent shade (24.33 days) and 50 per cent shade (26.66 days).

T_6 (3 : 1 + control) was late in flowering in open (34 days), 25 per cent shade (33 days) and 50 per cent shade (35 days).

The lowest pooled mean was recorded by T_1 (25.22) whereas the highest pooled mean of (34.11) was recorded by T_6.

4.2.2 Days for 50 per cent Flowering

Significant variation was observed among NK ratios for days for 50 per cent flowering (Table 4.7). F_3 (3:1 NK ratio) registered higher number of days to 50 per cent flowering of 36.33, 36.33 and 35.66 days respectively in open, 25 and 50 per cent shade.

Table 4.7 Influence of NK ratio, biofertilizer and shade on days for 50 per cent flowering in chilli

Treatments	Open	25 % shade	50 % shade	Mean
F_1	30.50	29.83	31.66	30.66
F_2	33.16	31.83	35.16	33.38
F_3	36.33	36.33	35.66	36.10
CD	2.060	1.643	1.922	
SE	0.654	0.521	0.610	
B_1	31.88	31.22	33.33	32.14
B_2	34.77	34.11	35.00	34.62
CD	1.682	1.342	1.569	
SE	0.534	0.426	0.498	
T_1	29.00	29.00	30.66	29.55
T_2	32.00	30.66	32.66	31.77
T_3	31.33	29.33	35.33	32.00
T_4	35.00	34.33	35.00	34.77
T_5	35.33	35.33	34.00	34.88
T_6	37.33	37.33	37.33	37.33
Mean	33.33	32.66	34.16	
CD (T)	2.914	2.324	2.718	
SE	0.924	0.737	0.862	
Pooled data				
CD (Shade)	-			
SE	-			
CD (Treatments)	2.356			
SE	0.824			

Under all shade levels *Azospirillum* inoculation registered minimum days to 50 per cent flowering in open (31.88), 25 per cent shade (31.22) and 50 per cent shade (33.33 days).

Interaction between NK ratio and *Azospirillum* inoculation had a significant influence on days to 50 per cent flowering. T_6 (3:1 NK + control) recorded maximum days to 50 per cent flowering 37 days under all shade levels.

Significant variation was observed among treatments for days to 50 per cent flowering. But no significant variation was observed among different shade levels.

Maximum days to 50 per cent flowering under all shade levels was shown by T_6 (34.88) and T_4 (34.77). While T_1 registered minimum days to 50 per cent flowering under all shade levels with 29 days in open and 25 per cent shade and 30.66 under 50 per cent shade. Minimum pooled mean was in T_1 (29.55) and maximum in T_6 (37.33).

4.2.3 Number of flowers per plant

There was progressive increase in number of flowers produced per plant at 60 DAT with increase in NK ratio (Table 4.8.1). The highest NK ratio (3:1) was significantly superior to 1:1 ratio. F_3 recorded 85.80, 73.63 and 62.56 flowers in open, 25 per cent an 50 per cent shade.

Azospirillum inoculation was found to produce significantly higher number of flowers per plant under 25 per cent shade (71.93) and 50 per cent shade (61.31). Control plants recorded 80.31, 67.67 and 57.16 in open, 25 per cent and 50 per cent shade respectively.

As nutrient ratio increased, significant interaction was observed with *Azospirillum* for number of flowers produced per plant under all shade levels. T_5 registered highest number of flowers 86.34 (open), 76.53 (25 per cent shade) and 63.60 (50 per cent shade).

Table 4.8.1 Effect of NK ratio, biofertilizer and shade on flowers per plant 60 DAT in chilli var. Jwala Sakhi

Treatments	Open	25 % shade	50 % shade	Mean
F_1	77.71	66.95	54.83	66.49
F_2	82.46	68.81	60.31	70.52
F_3	85.80	73.63	62.56	73.99
CD	5.018	2.006	2.857	
SE	1.592	0.636	0.906	
B_1	83.68	71.93	61.31	72.30
B_2	80.31	67.67	57.16	68.38
CD	-	1.638	2.332	
SE	-	0.519	0.740	
T_1	80.20	68.53	57.63	68.78
T_2	75.20	65.36	52.03	64.21
T_3	84.50	70.73	62.70	72.64
T_4	80.43	66.90	57.93	68.42
T_5	86.34	76.53	63.60	75.49
T_6	85.26	70.73	61.53	72.51
Mean	81.96	69.80	59.23	
CD (T)	7.096	2.837	4.040	
SE	2.252	0.900	1.282	
Pooled data				
CD (Shade)	2.868			
SE	1.003			
CD (Treatments)	4.056			
SE	1.419			

Significant variation both among treatments and between different shade levels was observed for number of flowers per plant. A decrease in number of flowers per plant was observed with increase in shade levels. Maximum number of flowers per plant was observed in plants grown under open (81.96) followed by 25 per cent shade (69.80). Minimum number of flowers per plant was recorded by plants under 50 per cent shade (59.23).

Among the treatments, T_5 recorded maximum flowers in open (86.34), 25 per cent shade (76.53) and 50 per cent shade (63.60). While T_2 registered minimum number of flowers under all shade levels. Maximum pooled mean for number of flowers was in T_5 (75.49) which was on par with (72.51) and T_3 (72.64). Minimum pooled mean was in T_2 (64.21).

Similar trend was seen at 90 DAT (Table 4.8.2). F_3 registered highest number of flowers under all shade levels (77.14). *Azospirillum* inoculation was found to produce significantly higher number of flowers per plant under all shade levels with values 90.20 (open), 73.04 (25 per cent shade) and 61.53 (50 per cent shade). Significant interaction was also noted at all shade levels. T_5 recorded maximum number of flowers in open (96.86), 25 per cent shade (77.63) and 50 per cent shade (64.23). While T_2 noted lowest number of flowers plant^{-1}.

There was significant difference both among treatments and between different shade levels for number of flowers per plant at 90 DAT. Maximum overall mean was recorded in plants grown under open (86.15) and least in 50 per cent shade (59.60).

Among the treatments, T_5 registered higher number of flowers in open (96.86), 25 per cent shade (77.63) and 50 per cent shade (64.23). While T_2 noted least number of flowers under all shade levels. Maximum pooled mean for number of flowers at 90 DAT was in T_5 (79.57) and minimum in T_2 (66.76).

Table 4.8.2 Effect of NK ratio, biofertilizer and shade on number of flowers per plant 90 DAT

Treatments	Open	25 % shade	50 % shade	Mean
F_1	81.70	68.73	55.71	68.71
F_2	88.40	69.93	60.55	72.96
F_3	94.36	74.55	62.53	77.14
CD	2.530	2.131	1.643	
SE	0.803	0.676	0.521	
B_1	90.20	73.04	61.53	74.92
B_2	86.11	69.10	57.66	70.95
CD	2.066	1.740	1.342	
SE	0.655	0.552	0.425	
T_1	83.10	70.36	58.53	70.66
T_2	80.30	67.10	52.90	66.76
T_3	90.60	71.13	61.83	74.53
T_4	86.10	68.73	59.26	71.38
T_5	96.86	77.63	64.23	79.57
T_6	91.86	71.46	60.88	74.72
Mean	88.15	71.07	59.60	
CD (T)	3.578	3.014	2.324	
SE	1.135	0.956	0.737	
Pooled data				
CD (Shade)	2.038			
SE	0.718			
CD (Treatments)	2.883			
SE	1.008			

4.2.4 Number of Fruits per Plant

Perusal of the data presented in Table 4.9.1 showed that number of fruits per plant varied significantly due to NK ratio. Among different NK ratios tried, 3:1 ratio recorded the highest number of fruits per plant of 63.86, 51.01, 44.91 in open, 25 per cent and 50 per cent shade respectively.

Azospirillum inoculation also exerted significant influence in number of fruits per plant. B_1 recorded highest number of fruits 63.22, 51.75 and 43.33 on open, 25 per cent and 50 per cent shade respectively. It was significantly superior to control treatment.

The interaction effect between nutrient ratio (3:1) *Azospirillum* (T_5) was most effective in increasing the number of fruits under all shade levels. The treatment combination T_5 (3:1 NK + *Azospirillum*) was found to be on par with T_3 (2:1 NK + *Azospirillum*) under 25 per cent shade. The treatment combination T_2 recorded lowest number of fruits under open and 25 shade. Under 50 per cent shade T_4 recorded lowest number of fruits per plant which was on par with T_2, T_1 and T_6.

There was significant variation both among treatments and between different shade levels for number of fruits per plant at 90 DAT. Maximum overall mean was recorded in open (61.84) and least in 50 per cent shade (41.01).

Among the treatments T_5 registered highest number of fruits per plant in open (66.06), 25 per cent shade (53.80) and 50 per cent shade (49.23). While T_2 noted the least number of fruits per plant both under open and 25 per cent shade.

Maximum pooled mean for number of fruits per plant at 90 DAT was in T_5 (56.36) and minimum in T_2 (46.78).

4.2.5 Total Yield of Chillies per Plot

The different NK ratios tried had no significant impact on yield (Table 4.10).

Table 4.9.1 Influence of treatments on fruits per plant in chilli var. Jwala Sakhi

Treatments	Open	25 % shade	50 % shade	Mean
F_1	60.17	46.88	38.31	48.45
F_2	61.49	48.15	39.80	49.81
F_3	63.86	51.01	44.91	53.26
CD	1.581	2.425	3.031	
SE	0.502	0.769	0.962	
B_1	63.22	51.75	43.33	52.76
B_2	60.46	45.61	38.68	48.25
CD	1.291	1.980	2.475	
SE	0.409	0.628	0.785	
T_1	61.38	50.26	38.76	50.13
T_2	58.96	43.51	37.86	46.78
T_3	62.23	51.20	42.00	51.81
T_4	60.75	45.10	37.60	47.81
T_5	66.06	53.80	49.23	56.36
T_6	61.66	48.23	40.60	50.16
Mean	61.84	48.68	41.01	
CD (T)	2.237	3.430	4.287	
SE	0.710	1.088	1.360	
Pooled data				
CD (Shade)	2.118			
SE	0.741			
CD (Treatments)	2.996			
SE	1.048			

Table 4.10 Yield of vegetable chilli var. Jwala Sakhi as influenced by NK ratio, biofertilizer and shade, t ha^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	8.71	6.76	5.08	6.85
F_2	9.18	8.75	6.55	8.16
F_3	11.12	10.52	7.57	9.73
CD	-	-	-	
SE	-	-	-	
B_1	9.84	10.86	7.26	9.32
B_2	9.50	6.49	5.54	7.17
CD	-	3.052	-	
SE	-	0.968	-	
T_1	9.16	9.21	6.06	8.14
T_2	8.27	4.31	4.11	5.56
T_3	9.14	10.33	6.64	8.70
T_4	9.23	7.16	6.46	7.62
T_5	11.23	13.04	9.09	11.12
T_6	11.01	8.01	6.05	8.35
Mean	9.67	8.68	6.40	
CD (T)	-	-	-	
SE	-	-	-	
Pooled data				
CD (Shade)	2.538			
SE	0.888			
CD (Treatments)	-			
SE	-			

Azospirillum inoculation recorded significantly higher yield only under 25 per cent shade (10.86 t ha^{-1}).

There was no significant interaction between nutrient ratio and Azospirillum as far as yield is concerned.

No significant variation among treatments for yield was observed under all shade levels. No significant difference was observed between open and 25 per cent shade for yield. Overall mean yield in open (9.67 t ha^{-1}) was on par with that at 25 per cent shade (8.68 t ha^{-1}). But there was significant reduction in yield under 50 per cent shade. Under 50 per cent shade the overall mean yield was (6.40 t ha^{-1}).

4.2.6 Number of Harvest

As depicted in Table 4.11, the different NK ratio tried had no significant impact on number of harvest. However it varied significantly due to *Azospirillum* inoculation under open and 25 per cent shade. B_1 recorded higher number of harvest 3.66 in open and 4.55 under 25 per cent shade.

There was no significant interaction between NK ratio and *Azospirillum*.

No significant difference was observed for number of harvest among treatments and between different shade levels.

4.3 QUALITY CHARACTERS

4.3.1 Shelf Life

Of the different NK ratios tried, the 1:1 NK ratio was significantly superior for shelf life (Table 4.12) to all other treatments under open (3.33) and 50 per cent shade (5.16).

The treatment involving *Azospirillum* showed significant increase on shelf life under 25 and 50 per cent shade (4.55).

Table 4.11 Number of harvest in chilli as influenced by various treatments

Treatments	Open	25 % shade	50 % shade	Mean
F_1	3.16	3.50	4.16	3.60
F_2	3.33	4.00	4.16	3. 83
F_3	3.50	4.50	4.66	4.22
CD	-	-	-	
SE	-	-	-	
B_1	3.66	4.55	4.44	4.21
B_2	3.00	3.44	4.22	3.55
CD	0.635	0.878	-	
SE	0.201	0.278	-	
T_1	3.66	4.00	4.33	4.00
T_2	2.66	3.00	4.00	3.22
T_3	3.33	4.66	4.33	4.11
T_4	3.33	3.33	4.00	3.55
T_5	4.00	5.00	4.66	4.55
T_6	3.00	4.00	4.66	3.88
Mean	3.33	4.00	4.33	
CD (T)	-	-	-	
SE	-	-	-	
Pooled data				
CD (Shade)	-			
SE	-			
CD (Treatments)	-			
SE	-			

Table 4.12 Effect of treatments on shelf life in chilli var. Jwala Sakhi

Treatments	Open	25 % shade	50 % shade	Mean
F_1	3.33	4.33	5.16	4.27
F_2	2.33	4.00	3.50	3.27
F_3	1.83	3.16	2.66	2.55
CD	1.174	-	1.212	
SE	0.372	-	0.384	
B_1	2.77	4.55	4.55	3.95
B_2	2.22	3.11	3.00	2.77
CD	-	0.857	0.990	
SE	-	0.272	0.314	
T_1	3.33	5.00	6.33	4.88
T_2	3.33	3.66	4.00	3.66
T_3	2.66	5.00	4.00	3.88
T_4	2.00	3.00	3.00	2.66
T_5	2.33	3.66	3.33	3.11
T_6	1.33	2.66	2.00	2.00
Mean	2.50	3.83	3.77	
CD (T)	-	1.485	1.715	
SE	-	0.471	0.544	
Pooled data				
CD (Shade)	0.959			
SE	0.335			
CD (Treatments)	1.356			
SE	0.474			

There was significant interaction between nutrient ratio and *Azospirillum* under 25 per cent and 50 per cent shade. T_1 registered maximum shelf life under 25 per cent shade (5 days) and 50 per cent shade (6.33 days) while T_6 (3 : 1 NK + control) noted least shelf life with values 2.66, 2.00 under 25 and 50 per cent shade respectively.

Significant difference was observed for shelf life among treatments under all shade levels. Significant difference existed between different shade levels too. Overall mean shelf life was maximum 25 per cent shade (3.83) followed by 50 per cent shade (3.77 days). Minimum overall mean shelf life was recorded under open (2.50 days).

T_1 (1 : 1 NK + *Azospirillum*) had maximum shelf life with 3.33, 5.00 and 6.33 respectively in open, 25 and 50 per cent shade levels. Minimum shelf life in open, 25 per cent shade and 50 per cent shade was in T_6 with 1.33, 2.66 and 2.00 days respectively.

Highest pooled mean for shelf life was in T_1 (4.88 days) and least in T_6 (2.00 days).

4.3.2 Ascorbic Acid

The different NK ratio and *Azospirillum* tried had a significant effect on ascorbic acid content (Table 4.13) with 3:1 NK ratio recording significantly higher value of 133.70 mg 100 g^{-1} (25 per cent shade) and 135.15 mg 100 g-1 (50 per cent shade), while 1:1 NK ratio recorded significantly inferior values.

Azospirillum inoculation registered significantly higher vitamin C content 132.50 mg 100 g^{-1} (open) 132.02 mg 100 g^{-1} (25 per cent shade) and 133.86 mg 100 g^{-1} (50 per cent shade) while control plants recorded significantly inferior values.

Significant difference was observed for ascorbic acid content among treatments under all shade levels. No significant difference was observed for ascorbic acid content between shade levels.

Table 4.13 Influence of NK ratio, biofertilizer and shade on vitamin C in chilli, mg 100 g^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	120.40	117.63	117.13	118.38
F_2	137.41	136.18	138.75	137.44
F_3	133.70	132.86	135.15	133.90
CD	2.614	2.831	5.664	
SE	0.829	0.898	1.797	
B_1	132.50	132.02	133.86	132.79
B_2	128.51	125.76	126.82	127.03
CD	2.134	2.312	4.624	
SE	0.677	0.733	1.467	
T_1	122.30	121.76	120.80	121.62
T_2	118.50	113.50	113.46	115.15
T_3	140.10	139.10	141.56	140.25
T_4	134.73	133.26	135.93	134.64
T_5	135.10	135.20	139.23	136.51
T_6	132.30	130.53	131.06	131.30
Mean	130.50	128.89	130.34	
CD (T)	3.697	4.004	8.010	
SE	1.173	1.271	2.542	
Pooled data				
CD (Shade)	-			
SE	-			
CD (Treatments)	4.605			
SE	1.611			

T_3 had maximum vitamin C content with 140.10 mg 100 g^{-1} 139.10 mg 100 g^{-1}, 141.56 mg 100 g^{-1} respectively in open, 25 and 50 per cent shade levels. Minimum vitamin C content was noted in T_2 with 118.50, 113.50, 113.46 mg 100 g^{-1} respectively in open, 25 per cent and 50 per cent shade.

Highest pooled mean for vitamin C was in T_3 (140.25 mg 100 g^{-1}) and minimum in T_2 (115.15 mg 100 g^{-1}).

4.3.3 Proline

The lowest NK ratio recorded the maximum proline content under all shade levels and it was superior to all other NK ratios (Table 4.14). F_1 registered 1.99 µg g^{-1} in open, 1.84 µg g^{-1} under 25 per cent and 1.55 µg g^{-1} under 50 per cent shade. F_1 was on par with.

Azospirillum inoculated plants recorded significantly higher values under all shade levels than uninoculated plants.

Interaction between NK ratio and *Azospirillum* was significant under all shade levels. T_1 registered maximum proline content with 2.44 µg g^{-1}, 2.13 µg g^{-1} and 1.73 µg g^{-1} respectively in open, 25 per cent and 50 per cent shade. While plants treated with T_6 (3 : 1 NK + control) recorded least proline content with 1.31 µg g^{-1}, 0.81 µg g^{-1} and 0.83 µg g^{-1} respectively in open, 25 per cent and 50 per cent shade.

Significant difference among treatments for proline content was observed under all shade levels. There was also significant difference among shade levels. Proline content was found to decrease with increase in shade. Highest proline content was recorded from plants grown in open (1.82 µg g^{-1}) while plants under 50 per cent shade noted least proline content (1.26 µg g^{-1}).

T_1 had the maximum proline content of 2.44, 2.13, 1.73 µg g^{-1} respectively in open, 25 per cent and 50 per cent shade levels. T_1 was on par with T_3 under (1.74 µ g^{-1}) 25 per cent and 50 per cent shade (1.46 µg g^{-1}).

Table 4.14 Proline content of chilli under different treatments, µg g^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	1.99	1.84	1.55	1.79
F_2	1.82	1.56	1.26	1.54
F_3	1.65	0.95	0.96	1.18
CD	0.268	0.279	0.238	
SE	0.085	0.088	0.075	
B_1	2.16	1.65	1.42	1.74
B_2	1.48	1.25	1.09	1.27
CD	0.219	0.228	0.194	
SE	0.069	0.072	0.061	
T_1	2.44	2.13	1.73	2.10
T_2	1.55	1.54	1.38	1.49
T_3	2.04	1.74	1.46	1.75
T_4	1.60	1.38	1.06	1.35
T_5	1.98	1.09	1.09	1.39
T_6	1.31	0.81	0.83	0.98
Mean	1.82	1.45	1.26	
CD (T)	0.379	0.394	0.337	
SE	0.120	0.125	0.107	
Pooled data				
CD (Shade)	0.229			
SE	0.080			
CD (Treatments)	0.324			
SE	0.113			

Minimum proline content under all shade levels was on T_6 with 1.31, 0.81 and 0.83 μg g^{-1} respectively in open, 25 per cent and 50 per cent shade levels.

Maximum pooled mean for proline content was in T_1 (2.10 μg g^{-1}). Minimum pooled mean was in T_6 (0.98 μg g^{-1}).

4.3.4 Capsaicin

Table 4.15 shows the superiority of 2:1 NK ratio in increasing the capsaicin under all shade levels. F_2 recorded 0.78 per cent (open), 1.14 per cent (25 per cent shade) and 1.27 per cent (50 per cent shade). F_1 registered least capsaicin content.

Capsaicin content was significantly influenced by Azospirillum inoculation. B_1 noted highest capsicum content of 0.74 per cent, 1.08 per cent and 1.16 per cent under open, 25 per cent and 50 per cent shade respectively.

There was significant variation both among treatments and between different shade levels for capsaicin content. Maximum overall mean was recorded under 50 per cent shade (1.09 per cent) and minimum in open (0.63 per cent).

Among treatments, T_3 (2 : 1 NK + *Azospirillum*) registered highest capsaicin content with 0.92 per cent (open) 1.20 per cent (25 per cent shade) and 1.33 per cent (50 per cent shade) while T_2 (1 : 1 NK + control) recorded least capsaicin content.

Maximum pooled mean for capsaicin was in T_3 (1.15 per cent) and least in T_2 (0.59 per cent).

4.3.5 Pest and Disease Scoring

Incidence of wilt was observed under open and 25 per cent shade. But under 50 per cent shade there was severe reduction in the incidence of wilt. Hence, the data was not statistically analysed.

Table 4.15 Capsaicin content of chilli as influenced by NK ratio, biofertilizer and shade, %

Treatments	Open	25 % shade	50 % shade	Mean
F_1	0.47	0.73	0.85	0.68
F_2	0.78	1.14	1.27	1.06
F_3	0.63	1.13	1.14	0.96
CD	0.097	0.093	0.138	
SE	0.030	0.029	0.043	
B_1	0.74	1.08	1.16	0.99
B_2	0.51	0.92	1.01	0.81
CD	0.079	0.076	0.113	
SE	0.025	0.024	0.035	
T_1	0.58	0.84	0.93	0.78
T_2	0.37	0.63	0.77	0.59
T_3	0.92	1.20	1.33	1.15
T_4	0.64	1.08	1.21	0.97
T_5	0.73	1.21	1.24	1.06
T_6	0.53	1.05	1.05	0.88
Mean	0.63	1.00	1.09	
CD (T)	0.137	1.32	0.195	
SE	0.043	0.042	0.062	
Pooled data				
CD (Shade)	0.095			
SE	0.033			
CD (Treatments)	0.135			
SE	0.047			

Data presented in Table 4.16 shows incidence of leaf curl was significant with respect to NK ratio and biofertilizer. NK ratio (3 : 1) was significantly superior to both ratios under all shade levels.

Azospirillum inoculation recorded significantly low scoring than control and recorded 1.55 (open), 1.47 (25 per cent shade) and 1.24 (50 per cent shade).

The interaction between nutrient ratio and *Azospirillum* was significant under all shade levels. T_6 (3 : 1 NK + control) recorded highest incidence of leaf curl with 1.64, 1.58 and 1.39 in open, 25 per cent and 50 per cent shade respectively.

Significant difference both among the treatments and between different shade levels was observed for incidence of leaf curl. There was decrease in leaf curl incidence with increase in shade with 50 per cent shade levels scoring lowest value of 1.28 compared to 1.58 in open.

The lowest score was registered by T_1 under 50 per cent shade, T_3 under open and 25 per cent shade.

The minimum pooled mean was recorded by T_1 (1.37) which was on par with T_3 and T_2 whereas, the maximum pooled mean was shown by T_6 (1.54) which was on par with T_5 (1.51).

4.3.6 *Azospirillum* Population Count

As indicated in Table 4.17, the effect of NK ratio was significant under all shade levels. F_2 was significantly superior to F_1 and F_3. F_2 recorded maximum *Azospirillum* count of 8.00 x 10^5, 7.33 x 10^5 and 6.33 x 10^5 in open, 25 per cent and 50 per cent shade respectively.

Azospirillum inoculation recorded significantly higher count. B_1 recorded *Azospirillum* count of 6.88 x 10^5, 6.89 x 10^5 and 4.66 x 10^5 in open, 25 per cent and 50 per cent shade respectively.

Table 4.16 Effect of NK ratio, biofertilizer and shade on leaf curl incidence in chilli

Treatments	Open	25 % shade	50 % shade	Mean
F_1	1.59	1.52	1.13	1.41
F_2	1.54	1.46	1.30	1.43
F_3	1.62	1.54	1.40	1.52
CD	0.034	0.024	0.049	
SE	0.010	0.007	0.015	
B_1	1.55	1.47	1.24	1.42
B_2	1.61	1.54	1.32	1.49
CD	0.028	0.019	0.040	
SE	0.009	0.006	0.012	
T_1	1.56	1.49	1.06	1.37
T_2	1.61	1.54	1.20	1.45
T_3	1.50	1.42	1.24	1.38
T_4	1.59	1.51	1.36	1.48
T_5	1.60	1.51	1.41	1.51
T_6	1.64	1.58	1.39	1.54
Mean	1.58	1.51	1.28	
CD (T)	0.049	0.034	0.070	
SE	0.015	0.108	0.022	
Pooled data				
CD (Shade)	0.083			
SE	0.028			
CD (Treatments)	0.117			
SE	0.040			

Table 4.17 *Azospirillum* count in chilli as influenced by various treatments, 10^5 $cfug^{-1}$

Treatments	Open	25 % shade	50 % shade	Mean
F_1	7.50	7.16	3.66	6.10
F_2	8.00	7.33	6.33	7.22
F_3	4.66	3.50	2.16	3.44
CD	2.223	2.177	1.604	
SE	0.705	0.691	0.509	
B_1	6.88	6.89	4.66	6.14
B_2	6.55	5.11	3.44	5.03
CD	1.815	1.778	-	
SE	0.576	0.564	-	
T_1	7.33	7.00	4.00	6.11
T_2	7.66	7.33	3.33	6.11
T_3	8.66	9.00	7.33	8.33
T_4	7.33	5.66	5.33	6.11
T_5	4.66	4.66	2.66	4.00
T_6	4.66	2.33	1.66	2.88
Mean	6.72	6.00	4.05	
CD (T)	-	3.080	2.268	
SE	-	0.977	0.720	
Pooled data				
CD (Shade)	1.661			
SE	0.581			
CD (Treatments)	2.349			
SE	0.822			

The interaction effect of the factors had significant impact on *Azospirillum* count under 25 per cent and 50 per cent shade. T_3 (2:1 NK + *Azospirillum*) registered maximum count of 9 x 10^5 (25 per cent) and 7.33 x 10^5 (50 per cent) while T_6 recorded least *Azospirillum* count.

There was significant variation both among treatments and between different shade levels. Maximum overall mean was recorded on par (6.72 x 10^5) and minimum under 50 per cent (4.05 x 10^5).

Among the treatments T_3 registered higher *Azospirillum* count in open (8.66 x 10^5), 25 per cent (9 x 10^5) and 50 per cent shade (7.33 x 10^5). T_6 was significantly inferior to all other treatments.

Maximum pooled mean for *Azospirillum* count was in T_3 (8.33 x 10^5) and least in T_6 (2.88 x 10^5).

4.4 PLANT UPTAKE OF NUTRIENTS

4.4.1 Nitrogen Uptake of Crop

The data presented in Table 4.18.1 reveal that 3:1 NK ratio was significantly higher than other NK ratios under all shade levels. The 1:1 NK ratio recorded lowest value, which was significantly inferior to all other treatments.

Azospirillum inoculated plants was significantly superior to control under all shade levels.

The factor interaction under all light intensities was significant with T_5 (3:1 NK ratio + *Azospirillum*) registered significantly higher values than all other interactions. While interaction T_2 (1:1 NK + control) recorded the lowest N content, which was significantly inferior to all other interactions.

Significant variation among treatments for N uptake was observed under all shade levels. There was also significant difference among the shade levels. N content was found to increase with shade. Highest N

Table 4.18.1 Effect of shade levels, NK ratio and biofertilizer on the uptake of nitrogen in chilli, kg ha^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	50.55	55.60	58.10	54.75
F_2	57.63	61.85	67.00	62.16
F_3	60.70	66.45	70.43	65.86
CD	2.715	1.089	0.955	
SE	0.861	0.345	0.303	
B_1	58.33	64.16	68.00	63.49
B_2	54.25	58.43	62.35	58.34
CD	2.216	0.889	0.780	
SE	0.703	0.282	0.247	
T_1	52.90	58.40	61.80	57.70
T_2	48.20	52.80	54.40	51.80
T_3	59.50	64.60	69.60	64.56
T_4	55.76	59.10	64.40	59.75
T_5	62.60	69.50	72.60	68.23
T_6	58.80	63.40	68.26	63.48
Mean	56.29	61.30	65.17	
CD (T)	3.839	1.540	1.351	
SE	1.218	0.488	0.428	
Pooled data				
CD (Shade)	1.503			
SE	0.525			
CD (Treatments)	2.125			
SE	0.743			

content was recorded from plants grown under 50 per cent (65.17 kg ha^{-1}) while least N content under open (56.29 kg ha^{-1}).

T_5 had maximum N content under all shade levels while T_2 recorded least. Maximum pooled mean for N content was on T_5 (68.23 kg ha^{-1}) and minimum in T_2 (51.80 kg ha^{-1}).

4.4.2 Phosphorus Uptake of Crop

2:1 NK ratio recorded highest P content (Table 4.18.2) under all shade levels and it was superior to F_1 and F_3.

Among biofertilizer treatment, *Azospirillum* treatment recorded significantly higher values under all shade levels (10.58, 11.06 and 11.87 kg ha^{-1}). Interaction between NK ratio and *Azospirillum* was significant under all shade levels. T_3 (2:1 NK + *Azospirillum*) registered significantly higher values than all other interactions. T_3 was on par with T_4. T_2 was significantly inferior to all other interactions.

There was significant difference both among treatments and between different shade levels. Maximum overall mean was recorded on 50 per cent shade (11.39 kg ha^{-1}) and minimum under open 10.20 kg ha^{-1}).

Among treatments, T_3 recorded higher P content with 11.38, 11.84 and 12.82 in open, 25 per cent and 50 per cent shade respectively. While T_2 recorded least P content under all shade levels.

Maximum pooled mean for P content was in T_3 (12.01) and least in T_2 (8.56 kg ha^{-1}).

4.4.3 Potassium Uptake of Crop

2:1 NK ratio recorded very high K content (Table 4.18.3). Which was on par with F_3 under open and 50 per cent shade

Significant interaction between NK ratio + *Azospirillum* under all shade levels. T_3 registered maximum K content of 34.70 (open), 36.70

Table 4.18.2 Influence of NK ratio, biofertilizer and shade on the uptake of phosphorus, kg ha^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	8.63	9.26	10.17	9.35
F_2	11.30	11.59	12.66	11.85
F_3	10.66	10.95	11.34	10.98
CD	0.417	0.700	0.761	
SE	0.132	0.222	0.241	
B_1	10.58	11.06	11.87	11.17
B_2	9.82	10.14	10.90	10.28
CD	0.340	0.571	0.622	
SE	1.08	0.181	0.197	
T_1	9.54	10.18	10.72	10.15
T_2	7.73	8.35	9.62	8.56
T_3	11.38	11.84	12.82	12.01
T_4	11.22	11.35	12.50	11.69
T_5	10.83	11.17	12.09	11.36
T_6	10.52	10.74	10.60	10.62
Mean	10.20	10.60	11.39	
CD (T)	0.590	0.990	1.077	
SE	0.187	0.314	0.341	
Pooled data				
CD (Shade)	0.542			
SE	0.189			
CD (Treatments)	0.767			
SE	0.268			

Table 4.18.3 Effect of shade levels, NK ratio and biofertilizer on the uptake of potassium by chilli, kg ha^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	29.30	32.40	34.25	31.98
F_2	34.36	36.36	38.60	36.44
F_3	33.35	35.40	38.25	35.66
CD	1.287	0.944	1.391	
SE	0.408	0.299	0.441	
B_1	32.56	34.93	37.30	34.93
B_2	32.11	34.51	36.76	34.46
CD	-	-	-	
SE	-	-	-	
T_1	29.50	32.60	34.50	32.20
T_2	29.10	32.20	34.00	31.76
T_3	34.70	36.70	38.90	36.76
T_4	34.03	36.03	38.30	36.12
T_5	33.05	35.50	38.50	33.83
T_6	33.20	35.30	38.00	33.50
Mean	32.33	34.72	37.03	
CD (T)	1.820	1.336	1.967	
SE	0.577	0.424	0.624	
Pooled data				
CD (Shade)	0.979			
SE	0.342			
CD (Treatments)	1.381			
SE	0.484			

(25 per cent shade) and 38.90 (50 per cent shade) while T_2 recorded least K content under all shade levels.

Both among treatments and between different shade levels there was significance.

Maximum overall mean was recorded in 50 per cent shade (37.03 kg ha^{-1}) and minimum under open 32.33 kg ha^{-1}).

4.5 POST HARVEST SOIL NUTRIENT STATUS

A perusal of the data on available N (Table 4.19.1) revealed that there was significant difference between 3:1 NK ratio and other treatments. Available soil nitrogen increased progressively with increase in NK ratio and other treatments. F_3 registered highest available N 234.86 (open), 224.65 (25 per cent shade) and 201.20 (50 per cent shade).

Azospirillum inoculation significantly decreased available N (196.67) compared to control (205.02 kg ha^{-1}) under all shade levels.

Significant interaction was observed between factors on available N status. T_6 registered maximum available N content of 238.83, 228.90, 208.01 kg ha^{-1} in open, 25 per cent and 50 per cent shade respectively.

Both among treatments and between shade levels there was significant variation. A decrease in available N was noted with increase in shade. Maximum overall mean was registered in open (226.85 kg ha^{-1}) and minimum available N in 50 per cent shade (174.18 kg ha^{-1}).

Under all shade levels, T_6 was significantly superior to all other treatments with values 238.83, 229.90 and 208.01 in open, 25 per cent and 50 per cent shade respectively. T_1 recorded minimum available N under all shade levels.

Maximum pooled mean for available N was registered by T_6 (225.25 kg ha^{-1}) while T_1 recorded minimum pooled mean (182.30 kg ha^{-1}).

Table 4.19.1 Effect of NK ratio and biofertilizer on available soil nitrogen under different shade levels, kg ha^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	218.10	185.05	153.10	185.41
F_2	227.60	194.83	168.25	196.89
F_3	234.86	224.65	201.20	220.23
CD	1.132	0.948	3.209	
SE	0.359	0.301	1.018	
B_1	224.20	197.90	167.93	196.67
B_2	229.51	205.12	180.43	205.02
CD	0.924	0.774	2.620	
SE	0.293	0.245	0.831	
T_1	216.40	182.00	148.50	182.30
T_2	219.80	188.10	157.70	188.53
T_3	225.30	191.30	160.90	192.50
T_4	229.90	198.36	175.60	201.28
T_5	230.90	220.40	194.40	215.23
T_6	238.83	228.90	208.01	225.25
Mean	226.85	201.51	174.18	
CD (T)	1.601	1.341	4.538	
SE	0.508	0.425	1.440	
Pooled data				
CD (Shade)	9.660			
SE	3.345			
CD (Treatments)	13.661			
SE	4.730			

Available P (Table 4.19.2) was maximum in F_2 (2:1 NK) with 51.33, 49.66 and 47.59 kg ha^{-1} under open 25 per cent and 50 per cent shade.

Under 25 and 50 per cent shade, *Azospirillum* inoculation was significantly inferior to control, with respect to available P.

Significant interaction between factors was observed under 25 and 50 per cent shade. T_4 registered highest available P with 52.93 (open), 50 30 (25 per cent shade) and 48.98 kg ha^{-1} (50 per cent shade). While T_1 (1: 1 NK + *Azospirillum*) noted least available P.

Both among treatments and between shade levels there was significant variation. Maximum available mean was in open (49.98 kg ha^{-1}) (50 per cent shade). While T_1 (1:1 NK + *Azospirillum*) noted least available P.

Both among treatments and between shade levels there was significant variation. Maximum overall mean was on open (49.97 kg ha^{-1}) and minimum under 50 per cent shade (44.68 kg ha^{-1}).

Maximum pooled mean for available P was in T_4 (50.74) and minimum pooled mean in T_1 (44.41 kg ha^{-1}).

The data on available K (Table 4.19.3) shows significant variation with NK ratio. F_2 (2 : 1 NK) registered maximum available K (76.62 kg ha^{-1}) under all shade levels.

Azospirillum treated plants were significantly inferior to control.

Significant interactions between biofertilizer and NK ratio was observed under all shade levels. T_4 registered maximum available K under all shade levels and value recorded under the three conditions were 85.40 (open), 79.73 (25 per cent) and 72.80 (50 per cent shade) respectively while T_1 noted least variation among treatments and between different shade levels. Maximum overall mean was open (76.80 kg ha^{-1}) and least under 50 per cent shade (67.45 kg ha^{-1}).

Table 4.19.2 Effect of shade levels, NK ratio and biofertilizer on available soil phosphorus, kg ha^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	49.75	45.40	40.82	45.32
F_2	51.33	49.66	47.59	49.52
F_3	48.84	46.84	45.63	47.10
CD	1.955	1.516	1.535	
SE	0.620	0.481	0.487	
B_1	49.23	46.05	43.37	46.21
B_2	50.72	48.55	45.99	48.42
CD	-	1.238	1.253	
SE	-	0.393	0.397	
T_1	49.06	44.10	40.07	44.41
T_2	50.45	46.70	41.56	46.23
T_3	49.73	49.01	46.20	48.31
T_4	52.93	50.30	48.98	50.74
T_5	48.90	45.04	43.85	45.93
T_6	48.78	48.64	47.41	48.28
Mean	49.97	47.30	44.68	
CD (T)	-	2.144	2.171	
SE	-	0.680	0.689	
Pooled data				
CD (Shade)	1.625			
SE	0.568			
CD (Treatments)	2.298			
SE	0.804			

Table 4.19.3 Effect of NK ratio, biofertilizer and shade on available potassium status of the soil after experiment, kg ha^{-1}

Treatments	Open	25 % shade	50 % shade	Mean
F_1	70.90	64.46	61.50	65.62
F_2	82.55	76.28	71.05	76.62
F_3	76.95	73.41	69.80	73.38
CD	0.881	2.850	1.004	
SE	0.279	0.904	0.318	
B_1	74.81	69.31	66.23	70.11
B_2	78.78	73.46	68.66	73.63
CD	0.719	2.327	0.819	
SE	0.228	0.738	0.260	
T_1	69.33	63.60	60.90	64.61
T_2	72.46	65.33	62.10	66.63
T_3	79.70	72.83	69.30	73.94
T_4	85.40	79.73	72.80	79.31
T_5	75.40	71.50	68.50	71.80
T_6	78.50	75.33	71.10	74.97
Mean	76.80	71.38	67.45	
CD (T)	1.246	4.031	1.420	
SE	0.395	1.279	0.450	
Pooled data				
CD (Shade)	1.607			
SE	0.562			
CD (Treatments)	2.273			
SE	0.795			

Among treatments T_4 registered maximum available K while T_1 noted least available K.

Maximum pooled mean for available K was in T_4 (79.31 kg ha^{-1}) and minimum pooled mean in T_1 (64.61 kg ha^{-1}).

4.6 ECONOMICS OF CULTIVATION

The data on economics of cultivation is presented in Table 4.20. Owing to the high initial investment of shade, economics was worked out in two sets. Statistical analysis was not done. It was found that T_5 higher NK ratio and *Azospirillum* inoculation recorded maximum BC ratio of 2.24 under open condition. Lowest nutrient ratio and control under 50 per cent shade recorded the least BC ratio of 0.22. In general, open condition was found to be better than shaded situation.

When the cost of shade net was apportioned over five years and two crops a year, BC ratio increased from 0.50 to 1.50 under 25 per cent shade and 0.33 to 1.10 under 50 per cent shade.

Table 4.20 Economics of cultivation

Treatments	BC ratio				
	Open	25 % shade		50 % shade	
		Total cost taken	1/10th cost of net taken	Total cost of net taken	1/10th cost of net taken
T_1	2.05	0.54	1.63	0.32	1.04
T_2	1.86	0.25	0.76	0.22	0.70
T_3	2.00	0.60	1.83	0.35	1.14
T_4	2.06	0.42	1.27	0.34	1.11
T_5	2.44	0.76	2.14	0.48	1.56
T_6	2.44	0.47	1.42	0.32	1.04
Mean	2.14	0.50	1.50	0.33	1.10

Discussion

5. DISCUSSION

Light plays a pivotal role in determining the economic produce of a crop. Shading of crop plants at various stages of growth influences the plant growth, yield and quality of produce. Though chilli is one of the popular vegetables of Kerala, its requirement is mostly met by the supply from neighbouring states. Limited availability of land, high temperature and humidity leads to this situation.

Effect of light intensity as influenced by NK ratio and biofertilizer in chilli was investigated by conducting three separate experiments with NK ratio and biofertilizer as treatments. The results of the experiments are discussed in this chapter.

5.1 GROWTH CHARACTERS

5.1.1 Plant Height

The results revealed that NK ratio had significant effect on plant height under all shade levels. Increase in plant height is attributable to enhanced vegetative growth due to nitrogen. This is in confirmity with the results obtained by John (1989) and Sherly (1996).

Biofertilizer treatments could exhibit no significant difference in all the growth stages and all shade levels. This may be due to the insufficient nitrogen addition by bioinoculants.

Interaction effect was found to be significant only under 25 per cent shade at 30 DAT. Plants treated with 3:1 NK ratio and *Azospirillum* recorded maximum height at all stages of observation. Nutrients when associated with *Azospirillum* enhanced vegetative growth. Similar result was obtained by Anitha (1997).

Present study indicated that shading has marked influence on plant height. Effect of low light intensity on crop growth and development is its impact on photosynthesis, as light is the essential requirement for photosynthesis.

From the pooled analysis, we could infer that treatment combination had got an effect in increasing the plant height under low light intensities in all the three growth stages. High rate of transpiration and respiration in open lead to deficiencies of water and carbohydrate which resulted in retarded height in open (Meyer *et al*., 1973). This was also corraborated by Sreelathakumary (2000) and Smitha (2002).

5.1.2 Number of Branches per Plant

There was increase in number of branches due to NK ratio in all the stages but significant difference was noticed only in 60 and 90 DAT. No significant effect on number of branches during the establishment stage may be attributed to the crops poor ability to absorbs more nitrogen and potassium due to less developed root system. During 60 and 90 DAT, crop reaches reproductive phase, then the requirement of major nutrients is relatively high and the higher NK ratio applied exhibited significant influence on number of branches per plant. Similar result of increased branching at higher level of nutrient has been reported by Sherly (1996).

As in the case of plant height, *Azospirillum* has got no significant impact on increasing the number of branches. Significant interaction was noticed for number of branches per plant between NK ratio and biofertilizer at 60 and 90 DAT. This might be due to the significantly higher uptake of nitrogen.

From pooled analysis, it was observed that treatment combination had got significant difference in number of branches due to different shade levels. More number of branches was produced in open when compared to shaded

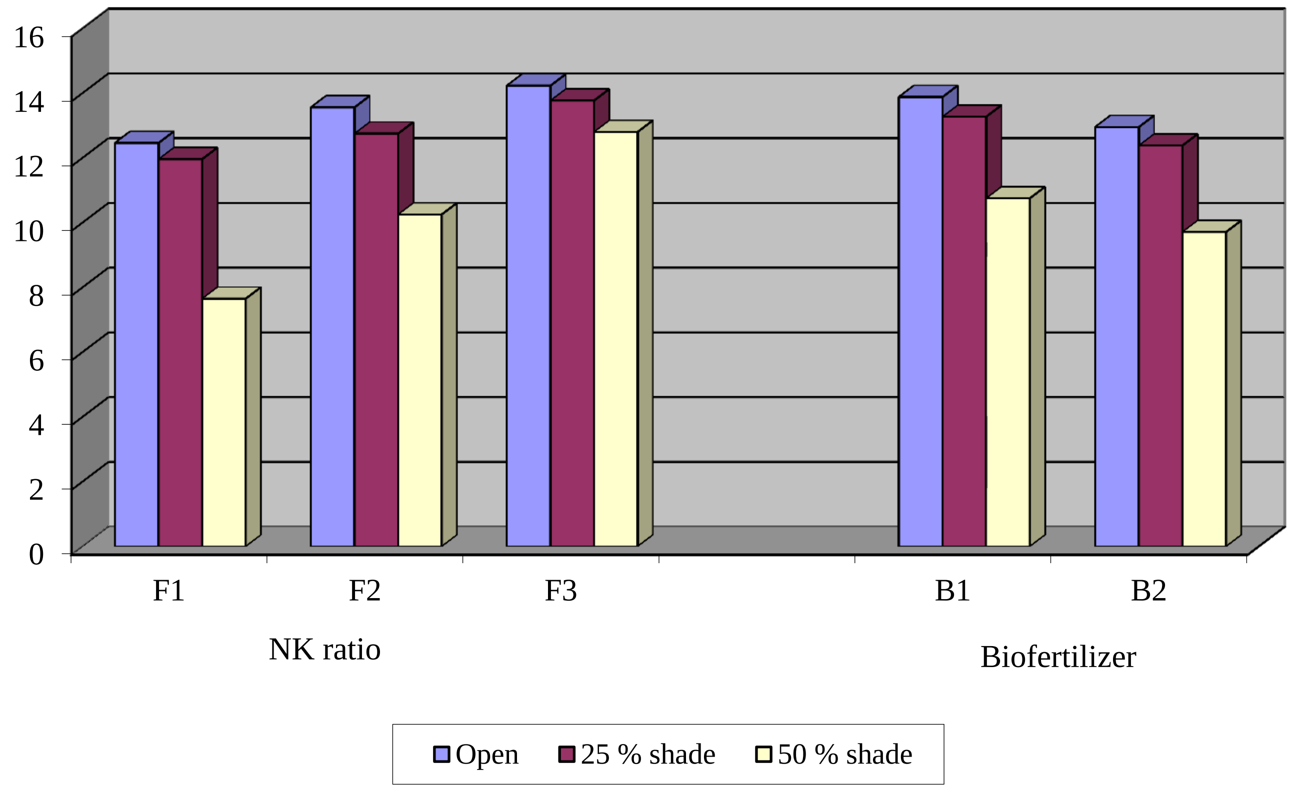

Fig. 3. Effect of NK ratio and biofertilizer on number of branches per plant under different shade levels

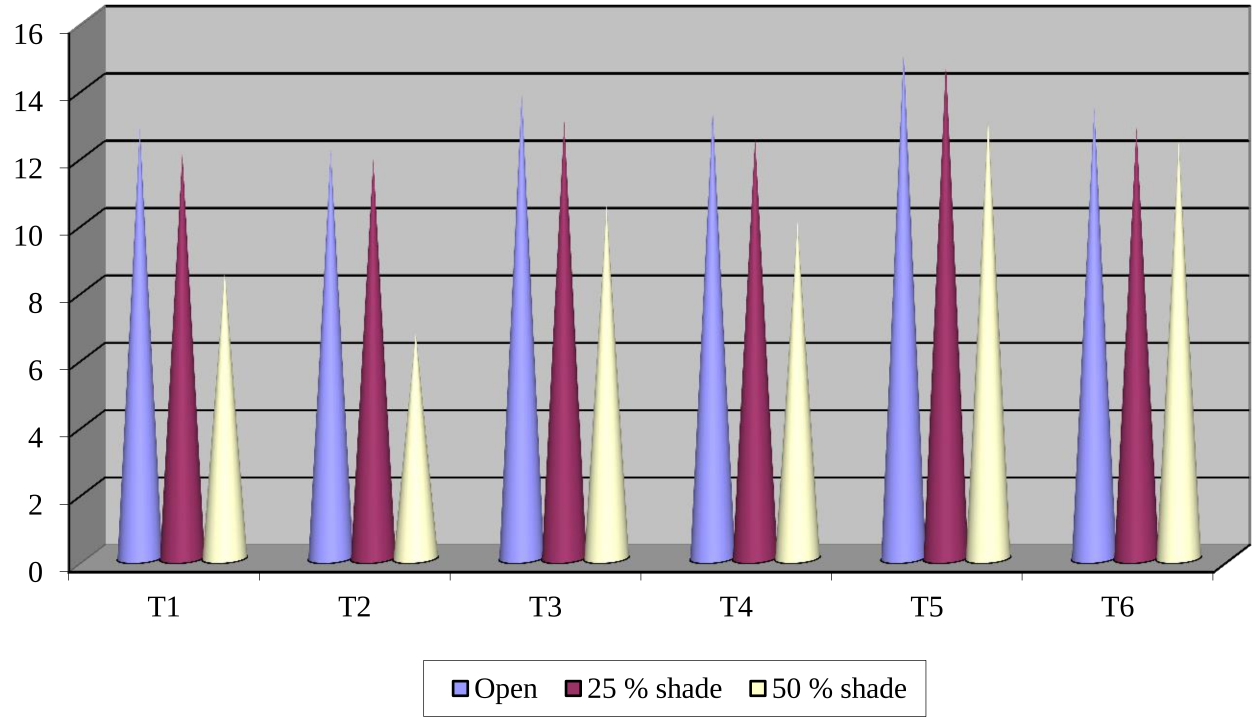

Fig. 4. Interaction effect of NK ratio and biofertilizer on number of branches per plant under different shade levels

condition. This was clearly contradicting the effect on plant height. Reduced plant height under open is compensated by increased number of branches by the treatment combinations. It is evident that more photosynthates produced by the increased absorption of nutrient is diverted to produce more number of branches under open and translocated to the branches. This is in confirmity with the result obtained by Smitha (2002).

5.1.3 Stem Girth

Stem girth was found to be significantly reduced by the higher NK ratio in open and 25 per cent shade. Normally, stem girth is a function related to plant height. As higher NK ratio produced increased height in open and 25 per cent shade which in turn reduced the stem girth.

Plants inoculated with *Azospirillum* showed no significant variation on stem girth.

There was significant interaction for stem girth under 25 per cent shade between NK ratio and *Azospirillum*. Plants treated with lowest NK level and *Azospirillum* registered maximum stem girth (2.94 cm). *Azospirillum* inoculation with fertilizers in lower level had resulted in increased plant growth. This might be due to nitrogen fixation and growth hormone produced by *Azospirillum* (Barea and Brown, 1974).

As stem girth has got inverse relationship with plant height, there is significant reduction in stem girth under shaded condition due to treatment combination. While plant height increased significantly under shaded condition. However, this reduction in stem girth due to shade is significant only at 60 DAT, which is the stage when more number of branches were produced and it coincides with reproductive phase.

This reduction in stem girth may be due to etiolation effect of shade. It is inferred that when light is cut off, there is more availability of auxin, which will help to increase the cell elongation. Moreover there would be more parenchymatous cells available due to lack of oxidation of polyphenol, which will result in suberization (Thangam, 1998). This result is in confirmity with findings of Smith *et al.* (1984) and Sreelathakumary (2000).

From the above result, it is also evident that low levels of nitrogen and potassium could register maximum stem girth under open. It shows that light and other environmental factors have got more role than the nutrients on getting study stem and more branches.

5.1.4 Dry Matter Production

3:1 NK ratio produced maximum DMP and was significantly superior to other ratios in all the three shade levels. This might be due to the profound influence of nitrogen in increasing vegetative growth which was reflected in increased growth parameters like height, number of branches etc. Similar result was reported in chilli by Joseph (1982), John (1989) and Sherly (1996).

DMP was significantly influenced by *Azospirillum* under all shade levels. Though *Azospirillum* could not produce effect in the early growth stages of plant, it has got an effect in the later stages. Maximum DMP was produced in 50 per cent shade. This shows that microbial fertilizers performed well under shade than in open. It might be due to more N fixed by *Azospirillum* under shaded situation. This is also evident from the data on N uptake at 50 per cent shade. Similar result was corraberated by Pandey *et al.* (1992) and Anitha (1997).

Significant interaction between nutrient ratio and *Azospirillum* was obtained for DMP. Plants treated with 3:1 NK ratio and *Azospirillum* registered highest DMP under all shade levels.

From the pooled data, it was observed that DMP had significantly increased under shaded condition by the treatment combination. And maximum dry matter was produced under 50 per cent shade and it is due to the better availability of nitrogen with enhanced application of N and *Azospirillum*. The positive influence of different growth parameters like plant height, number of branches and leaf area might have reflected in DMP of the plant. Similar increase in dry matter was reported in ginger under shaded condition by Ravisankar and Muthuswamy (1988) and Joseph (1982).

Very high light intensity under open condition may cause stomatal closure preventing entry of carbon dioxide for assimilation as reported Hardy (1958). This lead to drastic reduction of DMP under open.

5.1.5 Leaf Area Index

NK ratio has got a significant influence on LAI during early stages and 3:1 produced significantly higher LAI than other ratios. During later stages, 3:1 NK could produce more leaf area in all shade levels but it was not significant in 25 per cent shade. This result is a reflection of the statement of Russel (1973) who reported that as the nitrogen supply increases, the extra protein produced allows the plant leaves to grow larger and hence to have more surface area available for photosynthesis.

Unlike other growth parameters, *Azospirillum* has got significant influence on LAI in the later stages also. It might be due to better N supply by the biological N fixation which increased the number of leaves per unit area due to increased height in shaded condition and increased branching in open.

Interaction between nutrient ratio and azosprillum was found to be significant. Plants treated with 3:1 NK + *Azospirillum* registered more. LAI under all shade levels. This might be due to extraprotein synthesis as a result of increased N availability which promoted production of more number of leaves and leaves to grow larger (Jayakrishnan, 1986).

There was significant increase in LAI due to treatment combination under shaded condition. This can be attributed to the influence of light intensity on cell enlargement and differentiation which thus influenced the growth and leaf size of plants (Thompson and Miller, 1963).

This effect was in confirmity with increased height of plants and better vegetative growth characters under to shaded situation. Attridge (1990) reported that under shade, plants produced more leaves and leaf area as an adaptation to expose larger photosynthetic surface under limited illumination. Under shade, plants tend to adjust to the specific environment by increasing the area of light interception so that the available light energy is utilised more efficiently.

The above finding is in line with that of Heuvelink and Marcells (1996) in tomato and Yinhua and Jianzhen (1998) in capsicum.

Among the treatments, T_5 (3:1 NK + *Azospirillum*) registered maximum LAI while T_2 (1:1 NK + control) recorded least LAI. It might be due to the increased availability and absorption of N as a result of higher N application and bioinoculants.

5.2 FLOWERING CHARACTERS

5.2.1 Days for Flower Initiation

Higher NK ratio (3:1) had significantly delayed flower initiation under all shade levels. N at higher dose has a tendency to prolong the vegetative phase and delay the maturity of chilli (Joachum and Paul, 1939).

Normally increased nitrogen has an influence in increasing the physiological maturity and promotes early flowering. However delay in this case might be attributed to low K and resulting imbalance of major nutrients.

Azospirillum treated plants flowered earlier than uninoculated plants under all shade levels. Here, nitrogen influence in advancing the flower initiation is clearly exhibited.

Similar effect was also reflected in the interaction effect between NK ratio and *Azospirillum*. Better availability and absorption of N resulted in earliness and this effect is in confirmity with observations of Sajitharani

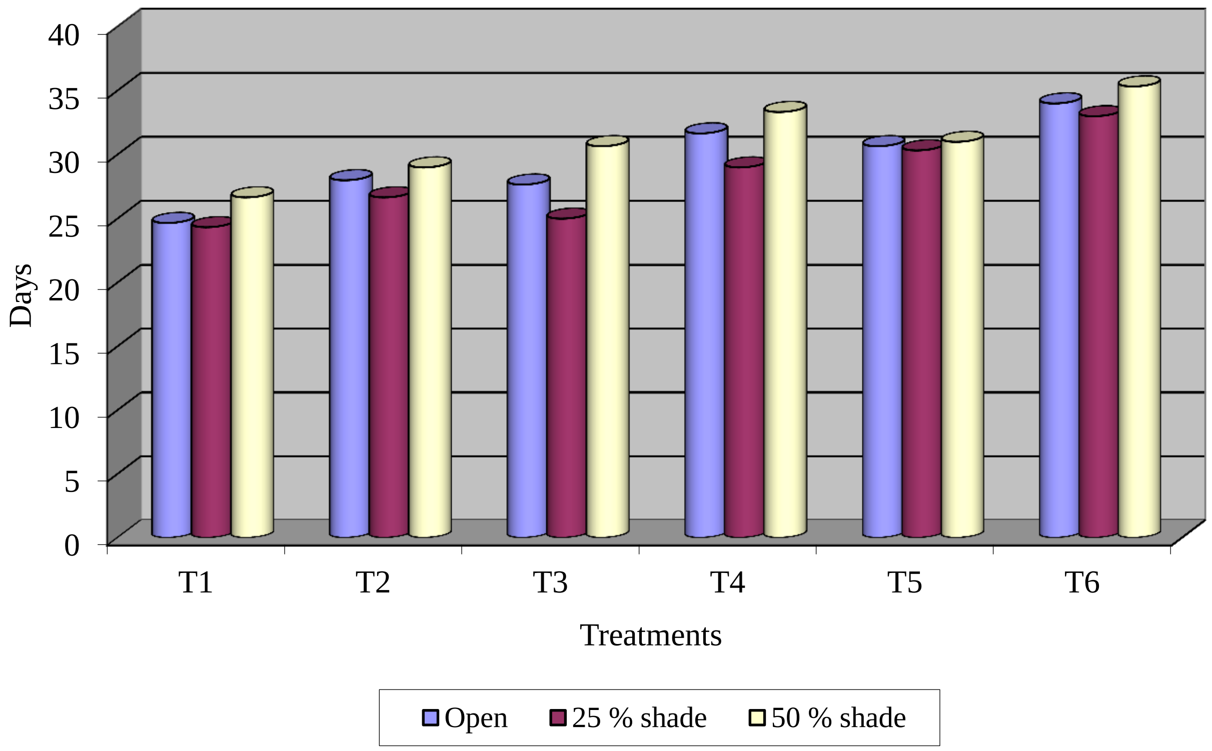

Fig. 5. Days for flower initiation due to interaction effect of NK ratio and biofertilizer under different shade levels

(1993) who found that higher nitrogen levels reduced the days for flower initiation.

From pooled anlaysis, it was observed that there was significant increase in number of days for flower initiation under shaded condition. This can be due to the adaptation of chilli to delay flowering under shaded situation. Delayed flowering is not at all beneficial from production point of view in seasonal crops. From this, we can infer that light and temperature are crucial for the reproductive phase and it influences the yield attributes of vegetable crops.

Delay in flowering due to shade in tomato was also reported by El-Gizawy *et al*. (1993 a) and Thangam (1998). In chilli also there were reports of prolonged vegetative phase resulting in delayed flowering under shade (Jeon and Chung, 1982; Sreelathakumary, 2000).

Under shading, there is a prolonged vegetative phase. Shading might have reduced the net photosynthesis or interfered with the light controlled plant morphogenesis, favouring vegetative development (Logendra *et al.*, 1990). Moreover, under shade there is reduced rate of transpiration and respiration compared to open, which favours vegetative growth (Schoch, 1972).

5.2.2 Days for 50 per cent Flowering

With regard to this parameter, same trend as in the case of days for flower initiation was noticed but days for 50 per cent flowering under shaded condition was not significant. It might be due to the treatment effect under open which was not sufficient to over come the drastic effects of shade. Similar increase in time for 50 per cent flowering with increase in nutrients was noted by John (1989) and Sherly (1996).

There was significant interaction between NK ratio and *Azospirillum* in time taken for 50 per cent flowering. T_6 (3:1 NK + control) took maximum days for 50 per cent flowering. Under high N levels, *Azospirillum* inoculation could not influence the days taken for 50per cent flowering due to low K levels. Imbalance of nutrients is one of the reason for the above result.

5.2.3 Number of Flowers per Plant

Number of flowers per plant increased significantly with increase in nutrients. 3:1 NK ratio registered highest number of flowers plant^{-1} which is significantly superior to other ratios under all shade levels. Increase in nutrients increased photosynthetic surface area and more production, translocation and assimilation of photosynthates to growing points thereby indicating more number of flowers plant^{-1}. This is in confirmity with findings obtained by Shukla *et al*. (1987) and Sherly (1996).

Azosprillum treated plants were significantly superior to control plants in producing more number of flowers per plant under 25 and 50 per cent shade. This shows that favouruable microclimatic condition for bioinoculants to exhibit its potential was under cooler condition.

Interaction effect of NK ratio and Azosprillum was significant in all shade intensities. Among the treatments, T_5 (3:1 NK + *Azospirillum*) recorded highest number of flowers per plant. This might be due to profound influence of applied nitrogen and fixed N in producing more number of flowers per plant.

With regard to the effect of shade, open condition was significantly superior in producing more number of flowers per plant. Eventhough plants grown under shade adapted in increasing the height, number of leaves, delayed flowering etc they were not able to produce more number of flowers. So, temperature and light plays a crucial role in yield attributes.

Carbohydrate shortage under conditions of low light intensity might have resulted in reduced flower production under shade. Wien and Turner

(1989) opined that shading reduces the sugar concentration in flower buds with an increase in ethylene production. This leads to flower bud abscission under shade. This may be the reason for reduced number of flowers under shade. This is in conformity with findings of Sreelathakumary (2000).

5.3 YIELD CHARACTERS

5.3.1 Number of Fruits per Plant

There was significant effect on number of fruits per plant due to NK ratio and bioinoculants. Maximum number of fruits were recorded at 3:1 NK ratio and it was significantly superior to other ratios. Increased nutrients in turn increased production, translocation and assimilation of photosynthates to growing points thereby stimulating plants to produce more flowers per plant and subsequently more fruits per plant. Similar results were reported by Kaminwar and Rajagopal (1993) and Sherly (1996).

Plants inoculated with *Azospirillum* produced significantly higher number of fruits plant^{-1} than control under all shade levels. *Azospirillum* inoculation helps in the release of various growth hormones like IAA, GA in addition to nitrogen fixed which leads to higher number of fruits plant^{-1}. This result is in confirmity with the findings of Anitha (1997).

Significant interaction between NK ratio and *Azospirillum* was observed in number of fruits produced per plant. Under all shade levels, T_5 registered significantly superior number of fruits per plant than all other combinations under all light intensities.

From pooled data, it was observed that there was significant difference in number of fruits produced per plant by different treatments among three light intensities. With increase in shade level, number of fruits per plant reduced. These showed that chilli requires higher light and temperature during its flowering phase to exhibit better yield attributes like number of fruits per plant. It was noticed that there was flower drop under

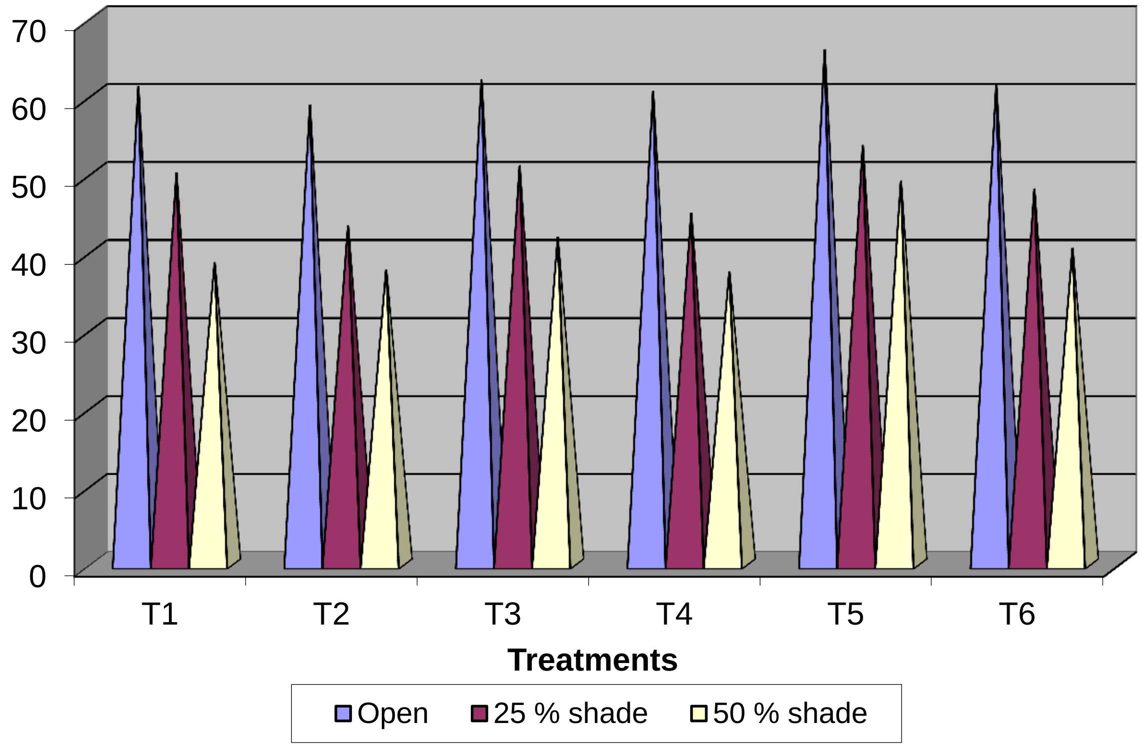

Fig. 6. Interaction effect of NK ratio and biofertilizer on number of fruits per plant under different shade levels

shaded condition than open which may also have contributed to less number of fruits uunder shade and this finding was corraberated by Picken (1989) and Thangam (1998) in tomato. Hence, reduction in number of fruits per plant under heavy shade may be due to reduction in flower production, high flower drop and low fruit set.

5.3.2 Yield per Plot

There was no significant difference due to NK ratio under all shade levels. While *Azospirillum* inoculation has exhibited significant effect in producing yield per plot only under 25 per cent shaded condition. From this we can infer that partially shaded condition as provided by 25 per cent shade might have provided optimum micro climatic condition for the microbes to efficiently fix N and increase its availability. The ability of *Azospirillum* for showing better growth might be due to the activities of plant growth regulators (Tien *et al*., 1979).

Interaction effect due to NK ratio and biofertilizer was found to be non significant. There was significant variation in yield due to different shade levels.

Open condition recorded maximum yield of chilli (9.67 t ha^{-1}) which is on par with 25 per cent shade. However under 50 per cent shade yield was reduced considerably and it was significantly inferior to other two conditions. From this, we can infer that chilli is a crop which is less adapted to shaded situation and partial shade recorded an yield comparable with open. Considering quality and reduced incidence of pests and diseases, partial shade can be considered as an optimum condition. Minimum requirement of light and temperature is crucial for chilli to express its potential in terms of yield and yield attributes. Similar result was reported by Sreelathakumary (2000) and Smitha (2002).

Though shaded condition recorded higher growth parameters and healthy plants it was not able to reflect it in better crop productivity.

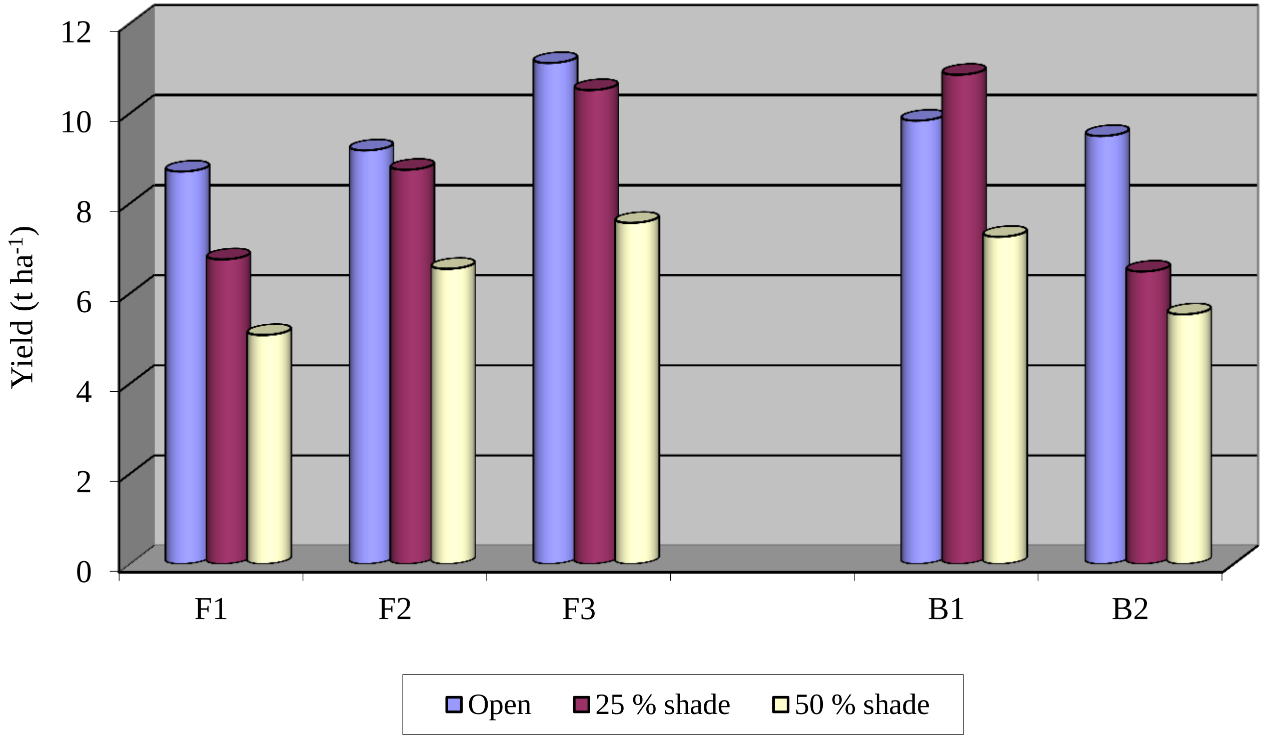

Fig. 7. Effect of treatments on yield per plot under different shade levels

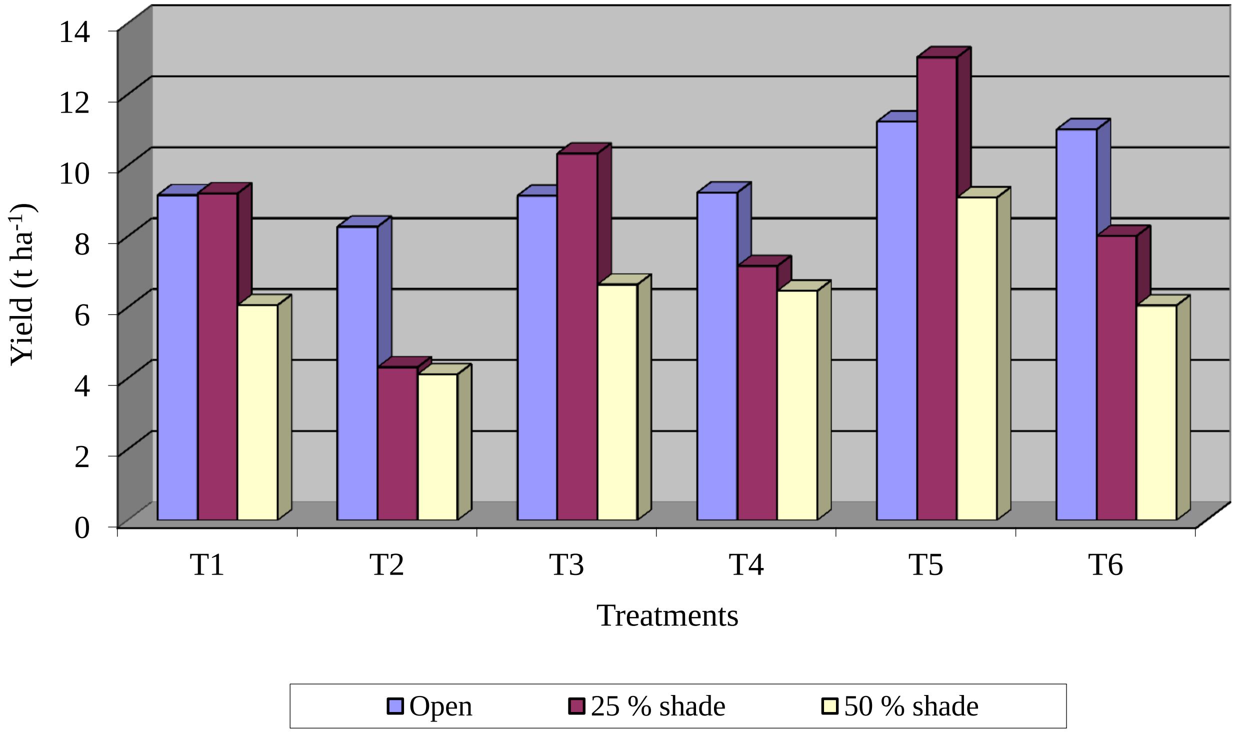

Fig. 8. Interaction effect of NK ratio and biofertilizers on yield per plot under different shade levels

C_3 plants are more efficient in dim to intermediate light intensities, whereas C_4 plants are more efficient in bright light than in dim light (Lawler, 1987). This explains the tolerance of C_3 plants like chilli to mild shade.

Higher yield in open is also explained by early flowering, better yield attributes like more flowers per plant more number of fruits per plant etc. Under heavy shade light acts as major limiting factor for photosynthesis. Only small amount of light reaches the leaf surface, which impairs the photosynthetic activity. Increased yield under open in chilli was reported by Shukla, 1997.

There was no significant effect between treatment combinations and shade intensities. The treatments selected were having little role in influencing the yield level under different shade intensities.

From the results, it was evident that though the treatment selected has got some effect on yield when they are considered as individual experiment. However, they don't have much influence on yield when their yield level was taken collectively for all shade levels. One of the reason might be inadequacy of evenly higher levels of N applied and N fixed by *Azospirillum*.

5.3.3 Number of Harvest

Only *Azospirillum* inoculation had significant effect on number of harvest. Since this effect was not reflected in yield or other characters, this effect cannot be entirely explained by effect of *Azospirillum*.

Significant effect was not noticed between open and shaded condition with respect to number of harvest and interaction effect between treatment combinations and shade.

5.4 QUALITY CHARACTERS

5.4.1 Shelf Life

There was significant difference in shelf life by different NK ratios in all shade levels except 25 per cent shade. Maximum shelf life was recorded

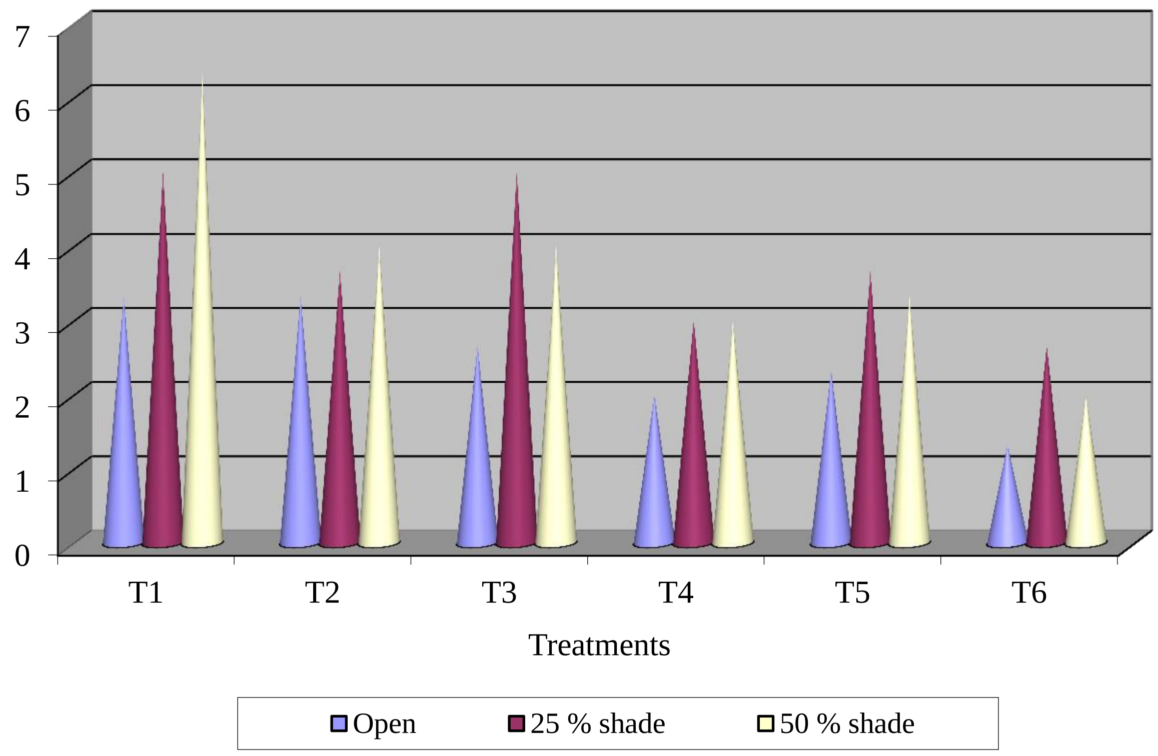

Fig. 9. Interaction effect of NK ratio and biofertilizer under different shade levels on shelf life

by lowest NK ratio which was significantly superior to other 2 levels. It is evident that higher N reduces the quality. This is also explained by low K and high N which leads to imbalance. So, K which is a quality element when applied in limited quantity reduces the quality of fruit.

Similarly *Azospirillum* which supplies organic N also enhances fruit quality. Interaction effect between NK ratio and *Azospirillum* also found to be significant under 25 and 50 per cent shade. Here also low NK ratio, which means less N and balanced fertilization along with *Azospirillum* rendered better storage life.

From pooled data, it was observed that there was significant effect in different shade intensities with respect to shelf life. With increase in shade level, shelf life increased. Shelf life of 3.77 (50 per cent shade) which is significantly superior than open which was on par with 25 per cent shade.

Effect of treatment between shade was found to be significant. T_1 (1:1 NK + *Azospirillum*) under 50 per cent shade registered significantly superior shelf life than all other treatment combination.

5.4.2 Ascorbic Acid

There was significant effect in ascorbic acid content with increase in nutrients. Increase in ascorbic acid content might be due to increase in protein synthesis and enhancement of enzymatic activates for amino acid synthesis at higher nutrient level which is instrumental in improving the fruit quality.

Plants inoculated with *Azospirillum* were significantly superior in ascorbic acid content than those without *Azospirillum*. Similar finding was reported by Balakrishnan (1988). Increase in ascorbic acid could be due to the increased ability of microbial inoculants to fix atmospheric nitrogen and secrete growth promoting substances which accelerated the physiological process like carbohydrate synthesis.

There was significant interaction between NK ratio and biofertiliser in all shade intensities and T_3 (2:1 NK ratio + Azosprillum) registered maximum Vitamin C content.

From pooled data, it was observed that there was significant difference among the treatment combination for ascorbic acid content. T_3 recorded significantly higher ascorbic acid content. There was no significant effect due to shade.

5.4.3 Proline

Proline content of leaf was significantly influenced by NK ratio, *Azospirillum* under all shade levels.

Low level of N and balanced fertilization had a profound positive effect to increase the proline content which helps to combat the adverse effect of moisture stress and acts as drought tolerance in plants.

Similarly *Azospirillum* inoculation increased the proline content due to production of growth promoting substances and increased level of organic N in soil.

From pooled data, maximum proline was in open which was significantly superior to other shade levels. The reason for this might be that crop which was exposed to high temperature and light as an adaptive mechanism produces more proline to mitigate the ill effects of shade. Sreelathakumary (2000) in chilli and Smitha (2002) also reported similar findings.

Here also low N content and balanced N and K recorded maximum proline content which is significantly superior to other treatment combinations.

5.4.4 Capsaicin

Significant effect was noticed by different NK ratio under all shade levels and 2:1 NK ratio recorded maximum capsaicin content. Pungency is

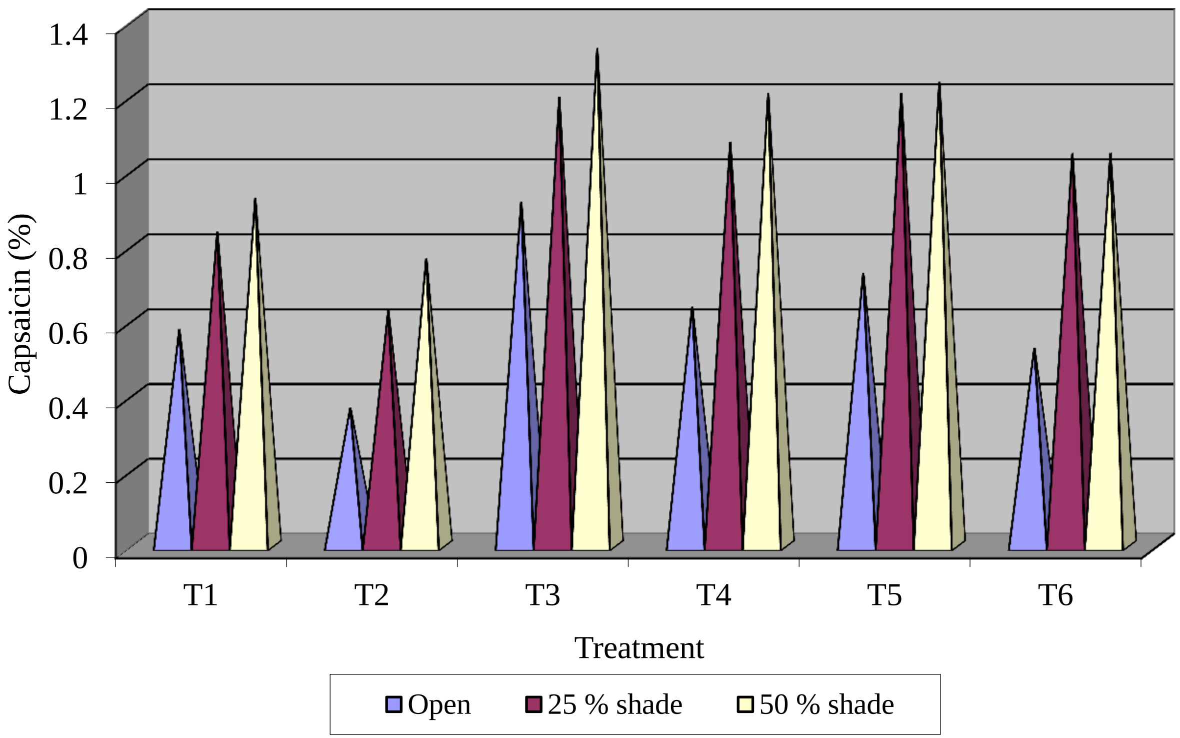

Fig. 10. Interaction effect of NK ratio and biofertilizer on capsaicin content under different shade levels

considered as the most important quality trait in chilli. Capsaicin is the condensation product of 3- hydroxy, 4-methoxy benzylamine and decylenic acid. Optimum nitrogen content is considered to be essential for the production of this chemical.

From pooled analysis, the different shade exhibited significant effect on production of capsaicin and 50 per cent shade recorded significant effect on capsaicin content which is on par with 25 per cent shade.

T_3 (2:1 NK + *Azospirillum*) under 50 per cent shade produced maximum capsaicin content. So, from the quality point of view, integrated supply of nutrients under shaded condition was a winner though the yield level was found to be low.

5.4.5 Pest and Disease Scoring

Leaf curl and bacterial wilt are the two major pest and disease incidence noticed in the experimental plot. With regard to bacterial wilt, though there was severe symptoms in open condition, practically crops in shaded condition were disease free irrespective of treatments. Since, scoring and statistical analysis were practically not meaningful it was not carried out. Anyhow, from the observation it was found that crops under shade was naturally protected from disease attack and it was reflected in reduced cost of cultivation due to reduced plant protection cost.

With regard to leaf curl due to mite attack, scoring was done, statistical scrutiny revealed that there was significant difference among the different treatments. Among the different NK ratios, mite incidence was maximum at wider NK ratio (3:1) which is significantly different from other two NK ratios, mite incidence was maximum at wider NK ratio (3:1) which is significantly different from other two NK ratios under all shade levels. This explains the role of N and imbalance of fertilizer in harbouring more pest and disease incidence. Higher nitrogen levels and lower K levels harbours more pest and reduces the resistance to pest.

Azospirillum inoculated crops defends themselves better against mite attack under all shaded condition when compared to non inoculated plants. Interaction due to NK ratio and *Azospirillum* was also found to be significant in the incidence of mite attack T_6 (3:1 NK ratio + control) found to be infested with higher mite attack.

From pooled data it was observed that mite attack was maximum under open which was significantly different from other two shade levels. The interaction effect due to shade and treatment was also found to be significant and T_6 (3:1 NK + no *Azospirillum*) under open has got significantly heavier incidence of mite. From this it was evident that temperature and light influenced the pest incidence as is the case of excess N. However, it can be observed that this was not reflected in the yield. So, there should be optimum light and temperature for optimum yield and healthy plants. Finally we can infer that if pesticide residue free produce fetch better market price, we can opt for 25 per cent shade though with lesser yield.

5.4.6. *Azospirillum* Count

NK ratio has got significant influence on *Azosprillum*. Obviously low NK ratio has provided better environmental condition for multiplication of bioinoculants in soil and its performance. This was also corroborated by Wam and Konde (1986). According to them, performance of *Azospirillum* was better at lower doses of N.

Similarly there was significant increase in *Azospirillum* count in *Azospirillum* inoculated plots than in control. Since the native bioinoculum was found to be low in the experiment site.

Regarding the light intensities low *Azospirillum* count was recorded in 50 per cent shade and was significantly inferior to open and 25 per cent shade. Though maximum *Azospirillum* count was recorded in open, it is on par with 25 per cent shade. Since the maximum count in open is not reflected in other parameters, we can infer that 25 per cent shade provides optimum condition for microbial growth if all other factors are taken into consideration. This was evident from the fact that interaction effect due to treatment combination was found to be significant and highest count was recorded by T_3 (2:1 NK + *Azospirillum*) under 25 per cent shade. So, optimum N with microbial fertilizer is the optimal microclimatic condition including light and temperature where the favourable factors for microbial multiplication and better performance.

5.5 PLANT UPTAKE OF NUTRIENTS

Higher NK ratio (3:1) has recorded higher uptake of N than other ratios. Increased supply of N might have lead to the development of better root system and better absorption of other nutrients like P and K. Efficient uptake of P had been associated with increased root growth which greatly increased root proliferation and extensive exploitation of soil nutrients. The beneficial effects of higher levels of nutrients on the increase uptake of nitrogen have been reported by John (1989) and Sherly (1996).

Nitrogen uptake was favourably influenced by *Azospirillum* inoculation. *Azospirillum* has the ability for better root induction in inoculated plants mainly due to the production of plant growth hormones like IAA and GA. As a result of this, such plants are capable of absorbing more and more available nutrients from the soil, which in turn results in better establishment of plant and subsequent growth (Tien *et al*., 1979).

P and K uptake where maximum at 2:1 and was significantly superior to other 2 ratios. Balanced fertilization by optimum N and K results in better tolerance to water stress, water intake and stomatal closure leading to better establishment, better root growth and better nutrient uptake.

Significant influence was noticed with regard to P and K uptake in shaded condition when compared to open. 50 per cent shade recorded

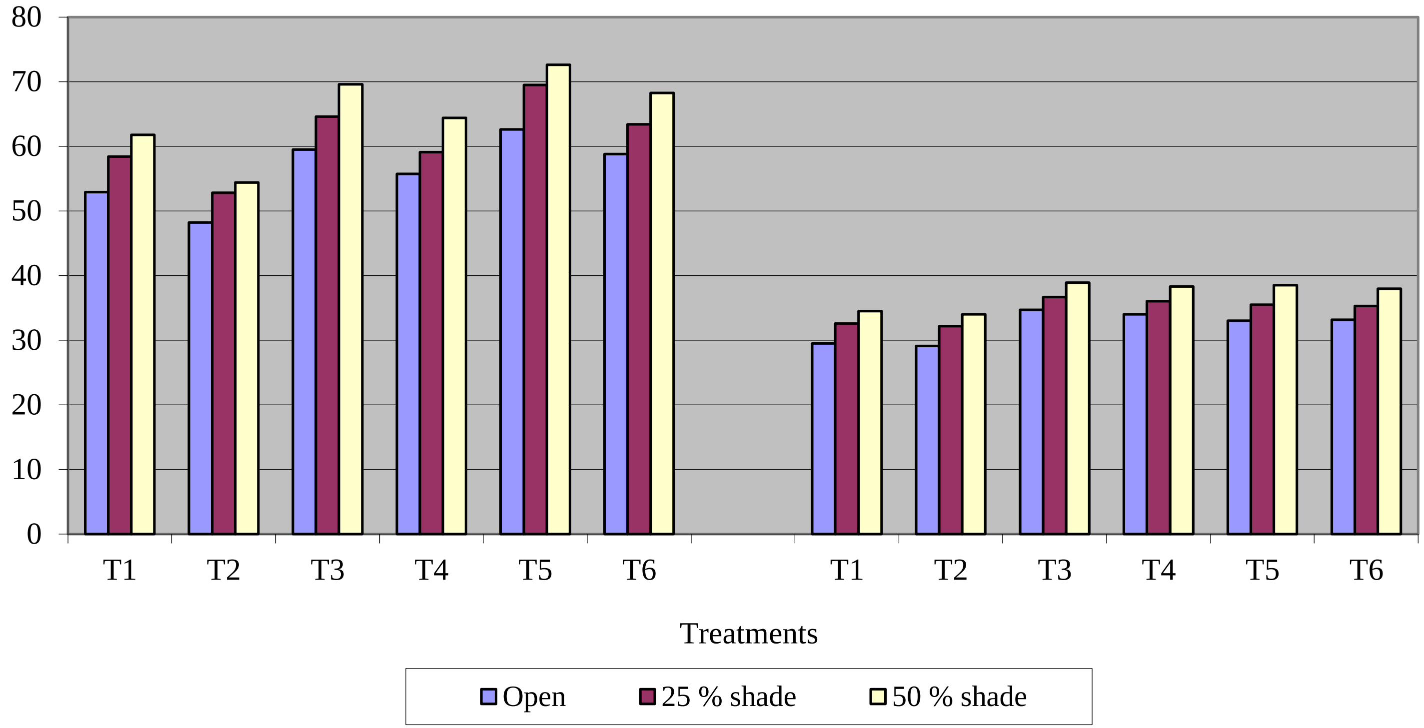

Fig. 11. Interaction effect of NK ratio and biofertilizer on uptake of N and K under different shade levels

maximum P and K uptake. However, the absence of improvement in yield and yield attributes was obvious. From this we can infer that rather than nutrient factor, climatic factor plays very important role in influencing the yield.

The interaction effect due to shade and treatment was highest under 50 per cent shade. Though N uptake was maximum in T_5 (3:1 NK + *Azospirillum*) in 50 per cent shade, P and K uptake was maximum in T_3 (2:1 NK + *Azospirillum*) and under 50 per cent shade. Although shaded situation enhanced uptake of N, P and K, yield was found to be lower.

5.6 SOIL NUTRIENT STATUS

With regard to soil nutrient status, NK ratio and *Azospirillum* has exhibited significant effect which is similar to that of uptake of nutrients ie maximum soil N was recorded in 3:1 which is significantly superior to other two ratios. However soil P and K was found superior to 2:1 ratio. This clearly shows that liberal supply of N has resulted in more soil N enrichment. But at the same time, relative proportion of N and K has got significant effect on soil P and K status. This may be due to the release of fixed P and K due to the better soil physical, chemical and biological environment.

Unlike in the uptake of nutrients soil N, P and K content was significant higher in open condition than shaded situation. Healthier plants remove maximum nutrients under shaded condition which result in less soil nutrient status than in open condition. Another reason for low soil nutrient status might be moisture condition in shaded situation is more which increases the absorption of nutrients and loss of nutrients due to leaching.

From pooled data, it was observed that soil nutrient status (N, P, K) was significantly higher in open and treatment combination. T_6 (3:1 + control) recorded maximum N content in soil under 50 per cent shade. While T_4 recorded maximum P and K content in soil.

5.7 ECONOMICS

T_5 recorded maximum BC ratio in both sets of economics worked out. Similarly open condition recorded maximum BC ratio in both sets when compared to all other shade levels.

From the economic point of view, T_5 (3:1 NK + biofertilizer) recorded profitable treatment and the least profitable treatment was 50 per cent shade without biofertilizer even after computing expenditure towards shade net as $1/10^{th}$ of total cost. Thus, we can conclude that chilli is a crop highly adapted to the high light and temperature (open condition) in terms of yield and economics. However quality wise if the produce fetches remunerative price, the economics of 25 per cent shade can also be considered to be a better treatment.

Summary

6. SUMMARY

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from January 2003 to May 2003 to study the effects of NK ratio and biofertilizer under different shade levels on the growth, yield, quality and nutrient uptake of vegetable chilli, cv. Jwala Sakhi.

The experiments were laid out in factorial randomised block design with three replications. The treatments consisted of three levels of NK ratio (1:1, 2:1 and 3:1) and two levels of biofertilizer (*Azospirillum* and control) thereby forming six treatment combinations. Three separate experiments were carried out in 25 and 50 per cent shade levels along with open condition. Data were analysed for three experiments individually and pooled analysis was done to analyse the data statistically. The salient findings of the experiments are summarized below.

1. The height of plant at 30 DAT was significantly influenced by NK ratio under open and 25 per cent shade. At 30 DAT, NK ratio of 3:1 recorded significantly superior plant height. AT 60 DAT similar trend was noted for plant height in open, whereas at 90 DAT, NK ratio of 3:1 registered significantly higher plant height only in 50 per cent shade.

   Azospirillum had no significant influence on the plant height at all growth stages. The treatment combinations of biofertilizer and NK ratio recorded significantly superior plant height only under 25 per cent shade at 30 DAT. The height of plants increased with increase in shade levels. 50 per cent shade recorded significantly superior plant height.

2. The number of branches produced per plant increased significantly with increased NK ratio at 60 DAT and 90 DAT. Only under 50 per cent shade, 3:1 NK ratio recorded significantly higher number of branches per plant at 30 DAT.

   Azospirillum inoculation had no significant increase in number of branches at all growth stages. Maximum number of branches per plant was observed in T_5 (3:1 NK + *Azospirillum*) at 60 DAT. The number of branches decreased with increase in shade level indicating that shading reduces the production of branches.

3. Significant influence of NK ratio on stem girth was observed under open and 25 per cent shade. *Azospirillum* inoculation had no significant increase in stem girth. Stem girth varied significantly among different shade levels. Stem girth were maximum in open. There was significant variation for stem girth among the treatments under all shade levels. T_1 (1:1 NK + *Azospirillum*) recorded maximum stem girth.

4. The DMP was significantly influenced by levels of NK ratio, *Azospirillum* and shade. NK ratio of 3:1, use of *Azospirillum* recorded an appreciable increase in DMP over other levels. The interaction between NK ratio and biofertilizer influenced the DMP at harvest and the ratio 3:1 and *Azospirillum* produced an increase in DMP.

   DMP was observed to be significantly higher under 25 and 50 per cent shade compared to open. NK ratio of 3:1 and *Azospirillum* resulted in significantly higher DMP under all shade levels.

5. An increase in NK ratio resulted in increase leaf area index and the application of 3:1 NK ratio recorded the maximum LAI index under all shade levels. *Azospirillum* inoculation was found to be significantly superior than control.

There was significant interaction between nutrient ratio and *Azospirillum* at all growth stages under all shade levels. LAI increased with increase in shade level. Maximum leaf area index was in T_5 (3:1 NK + *Azospirillum*) under all shade levels.

6. Days for flower initiation and days for 50 per cent flowering was significantly influenced by NK ratio, *Azospirillum* and shade. Number of days taken for flower initiation and 50 per cent flowering increased with increase in NK ratio. While plants treated with *Azospirillum* recorded earlier flowering than control.

   There was significant variation both among the treatments and between shade levels for number of days to flowering and days to 50 per cent flowering. It was found that shading delayed flowering. The treatment T_1 (1:1 NK + *Azospirillum*) was earliest in flowering in open, 25 and 50 per cent shade.

7. Flowers per plant varied significantly among NK ratio, *Azospirillum* and shade. With increase in NK ratio, number of flowers per plant increased. Influence of *Azospirillum* was found to be significantly superior to control. Plants treated with 3:1 NK ratio and *Azospirillum* recorded maximum number of flowers per plant. Flowers per plant varied significantly both among treatment and between shade levels. Heavy shade of 50 per cent markedly reduced number of flowers per plant. The treatment T_5 (3:1 NK + *Azospirillum*) produced highest number of flowers per plant.

8. Number of fruits per plant significantly increased with NK ratio and *Azospirillum* inoculation. Higher NK ratio (3:1) and *Azospirillum* inoculation registered maximum fruits per plant.

   Fruits per plant varied significantly among treatments and between shade levels. It was found that shading reduced number of fruits per plant. Among treatments, T_5 (3:1 NK + *Azospirillum*) recorded maximum fruits per plant under all shade levels.

9. Yield of chilli was not significantly influenced by NK ratio under all shade levels. While *Azospirillum* inoculation recorded maximum yield of (10.86 t ha^{-1}) only under 25 per cent shade.

   In the present study, the yield of chilli under mild shade (25 per cent shade) was on par with that in open condition. However under heavy shade of 50 per cent, yield was reduced considerably. It indicates that dense shade affects the performance of chilli.

10. Number of harvest was significantly influenced by *Azospirillum* only under 25 per cent shade. Interaction due to NK ratio and shade had no significant variation on number of harvest.

11. Shelf life was significantly influenced by NK ratio, *Azospirillum* and shade. Plant treated with *Azospirillum* and 1:1 NK ratio registered maximum shelf life under all shade levels. Shading has a marked positive effect on shelf life and 25 per cent shade recorded maximum shelf life.

12. Ascorbic acid content was significantly increased by plants treated with 2:1 NK ratio and *Azospirillum*. There was no significant variation for ascorbic acid content between shade levels but significant difference was noted for ascorbic acid content among treatments under all shade levels.

13. Significant influence was observed on proline with NK ratio, *Azospirillum* and shade. *Azospirillum* inoculation and 1:1 NK ratio recorded maximum proline. Significant variation in proline content was observed both among treatments and between the shade levels. Maximum accumulation of proline was recorded in open.

14. Plants treated with 2:1 NK ratio and *Azospirillum* was found to be significantly superior in capsaicin content than other treatments. Significant difference both among treatments and between shade was observed for capsaicin content. Capsaicin was found to increase with increase in level of shade.

15. Incidence of leaf curl was reduced due to shade, lower NK ratio and *Azospirillum* inoculation. As the shade level increased, there was less incidence of disease probably due to reduced insect activity under higher shade levels.

16. *Azospirillum* count varied significantly with *Azospirillum* inoculation, NK ratio and shade. There was reduction in *Azospirillum* count with increase in shade levels. *Azospirillum* count under open and 25 per cent shade was on par. Plants treated with 2:1 NK + *Azospirillum* registered maximum *Azospirillum* count.

17. The total uptake of nitrogen was significantly increased by plants treated with 3:1 NK ratio and *Azospirillum* inoculation. Shading has a marked positive effect on N uptake.

18. *Azospirillum* inoculation and 2:1 NK ratio treated plants recorded maximum phosphorus uptake by plant. Phosphorus uptake increased with increase in shade levels.

19. Potassium uptake by plants was higher under *Azospirillum* inculcation and 2:1 NK ratio. With respect to shade, potassium uptake was maximum at 50 per cent shade.

20. Soil nitrogen and soil potassium was significantly influenced by NK ratio, *Azospirillum* and shade.

21. Soil phosphorus differed significantly in plots treated with 2:1 NK and control. Soil phosphorus decreased with increase in shade levels.

22. The highest BCR of 2.24 was noticed at T_5 under open condition. However, economic yield was obtained in shade intensity upto 25 per cent.

References

7. REFERENCES

Achhireddy, N.R., Fletcher, J.S. and Beevers, L. 1982. The influence of shade on the growth and nitrogen assimilation of developing fruits on bell pepper. *Hort. Sci.* 17 : 635-637

Ahmed, M.K. 1984. Optimum plant spacing and nitrogen fertilization of sweet pepper in Sudan Gizura. *Acta Hort.* 143 : 305-310

Ahmed, N. and Tanki, M.I. 1991. Response of chilli (*capsicum annuum* L.) to nitrogen and phosphorus. *Haryana J. Hort. Sci*. 20 : 114-118

Amritalingam, S. 1988. Studies on the effect of Azospirillum, nitrogen and NAA on growth and yield of chilli (*Capsicum annuum* L.) cv. K-1. *S. Indian Hort.* 36 : 218

Ancy, J. 1992. Nutrient requirement of ginger under shade. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 109

Anitha, V. 1997. Nitrogen management in vegetable chilli grown in pots with modified drip irrigation system. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 138

Anu, A. and Peter, K.V. 2000. The chemistry of paprika. *Indian Spices* 37 : 15-18

Anu, S. 2001. Nutrient management of upland rice (*Oryza sativa* L.) varieties in coconut garden. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.99

Arora, S.K. and Pandita, M.L. 1982. Studies on performance of tomato varieties under high temperature conditions. *Haryana agric. Univ. J. Res*. 12 : 376-379

Asif, M.I. and Greig, J.K. 1972. Effect of N, P and K fertilization on fruit yield, macro and micronutrient levels and nitrate accumulation on okra (*Abelmoschus esculentus* (L.) Moench). *J. Am. Soc. Hort. Sci.* 97 : 440-442

Attavar, M. 2000. Tool for productivity gains. *The Hindu Survey of Indian Agriculture.* p. 145-149

Attridge, T.H. 1990. *Light and Plant Responses.* Edward Arnold, A Division of Hodder and Stoughtton Ltd., London, p. 148

Babu, P. 1993. Effect of shade and mulch on yield of ginger (*Zinger officinale* R.) M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 112

Bai, L.E.K. 1981. Shade response of common rainfed intercrops of coconut. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 161

Baki, A.A.A. 1991. Tolerance of tomato cultivars and selected germplasm to heat stress. *J. Am. Soc. Hort. Sci.* 116 : 1113-1116

Balakrishnan, R. 1988. Effect of Azospirillum, nitrogen and NAA on growth and yield of chilli. *S. Indian Hort.* 36 : 218

Balasimha, D. 1982. Leaf growth and associated physiological changes in six cocoa accessions under water stress. *Proceedings PLACROSYM.* Indian Society for Plantation Crops, Kasargode, Kerala, *Abstract* : 227-230

Balasubramani, P. and Pappiah, C.M. 1995. Effect of nitrogen and Azospirillum inoculation on the yield and quality of bhindi. *National Symposium on Organic Farming*. October, 27-28, 1995. Tamil Nadu Agricultural University, Madurai, *Abstract*: 164-169

Baldani, D. and Doberiner, J. 1980. Host plant specificity in the infection of cereals with *Azospirillum* sp. *Soil Biol. Biochem.* 12 : 433-439

Barea, J.M. and Brown, M.E. 1974. Effect of plant growth produced by *Azotobacter paspali* related to synthesis of plant growth regulating substances. *J. Appl. Biocontrol* 40 : 586-593

Bashan, Y., Singh, H. and Levanomy, H 1989. Contribution of *A. brasilense* cd. to growth of tomato seedlings is not through nitrogen fixation. *Canadian J. Botany* 67 : 2429-2434

*Belichki, I. 1988. Mineral fertilization of *Capsicum annuum* for early field production. *Rasteneiv "dni Nauki* 25 (6) : 56-61

*Bigotti, P.G. 1974. Revista della ortoflow fruthi kultura. *Italiana* 58 : 187-193

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* 54 : 464-465

Bray, A.H. and Kurtz, L.O. 1945. Determination of total, organic and available forms of phosphorus in soils. *Curr. Sci.* 59 : 39-45

Calvert, A. and Slack, C.I. 1980. Effect of light dependent control of day temperature on the yields of early sown tomato. *J. Hort. Sci.* 55 : 7-13

Chadha, K.L. 1999. Horticulture – new advances for growth. *The Hindu Survey of Indian Agriculture*, p. 155-160

Chougule, A.B. and Mahajan, P.R. 1979. Effect of varying levels of plant population, N, P and K on growth and yield of chilli. *Veg. Sci.* 6 : 73-80

Cockshull, K.E., Graves, C.J. and Cave, C.R.J. 1992. The influence of shading on yield of glasshouse tomatoes. *J. Hort. Sci.* 67 : 11-24

Cohen, E.Y., Okon, J.K., Nair, I. and Henis, Y. 1980. Increase in dry weight and total nitrogen content in *Zea mays* and *Setaria italica* associated with nitrogen fixing *Azospirillum* spp. *Pl. Physiol.* 66 : 746-749

Damke, M.M., Kawarkhe, V.J. and Patil, C.V. 1988. Effect of P and K on growth and yield of chilli. *PKV Res. J.* 12 : 110-114

Dart, P.J. 1986. Nitrogen fixation associated with non-legumes in agriculture. *Pl. Soil* 90 : 303-304

Deli, Y. and Tiessen, H. 1969. Interaction of temperature and light intensity on flowering of *Capsicum frutescens* var. *grossum* cv. California Wonder. *J. Am. Soc. Hort. Sci.* 94 : 349-351

Dhanalakshmi, P. and Pappiah, C.M. 1995. *National symposium on organic farming*. October 27-28, Tamil Nadu Agricultural University, Madurai, *Abstract* : 122-124

Dod, V.N., Joshi, A.T., Kale, P.B. and Kulwal, L.V. 1983. Effect of different levels of nitrogen in split doses on yield and quality of red ripe chilli (*Capsicum annuum* L.) cv. G.3. *Proceedings National Seminar Production Tecchnology Chillies and Tomato*, Tamil Nadu Agricultural University, Coimbatore, pp. 152-153

*Dolkova, M., Petronv, K.H. and Rankov, V. 1984. Nutrient uptake from fertilized soil by capsicum crop. *Grad. Loz. Nau.* 21 (8) : 51-57

El-Aidy, F. 1986. Tomato production under simple protective tunnels in Egypt. *Acta Hort.* 190 : 511-514

El-Gizawy, A.M., Abdullah, M.M.F., Gomaa, H.M. and Mohamed, S.S. 1993a. Effect of different shading levels on tomato plants 2. Yield and fruit quality. *Acta Hort.* 323 : 349-354

El-Gizawy, A.M., Gomaa, H.M., El-Habbasha, K.M., Mohamed, S.S., Abou-Haded, A.F. and Smith, A.R. 1993b. Effect of different shading levels on tomato plants growth, flowering and chemical composition. *Acta Hort.* 323 : 341-347

Everett, P.H. and Subramanya, R. 1984. Pepper production as influenced by plant spacing and nitrogen – potassium rates. *Citrus Veg. Mag.* 48 (4) : 42-47

FAI. 1994. Harnessing biofertilizer potential. *Fert. News.* 39 (4) : 9-10

FIB. 2002. *Farm Guide 2002.* Farm Information Bureau, Government of Kerala, Thiruvananthapuram, p. 96

Francescangeli, N., Ferrato, J. Rosania, A. and Marcozz, P. 1994. Green house shading. Effects on greenhouse environment and blossom end rot incidence in spring-summer tomato. *Hort. Argentina* 13 (33) : 65-70

George, B.E. 1992. Evaluation of ginger cultivars for shade tolerance. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 153

Gulati, J.M.L., Mishra, M.M., Paul, J.C. and Sahu, G.S. 1995. Production potential of chilli (*Capsicum annuum* L.) under levels of irrigation and nitrogen. *Indian J. Agron.* 40 : 145-146

Hadas, R. and Okon, Y. 1987. Effect of *Azospirillum brasilense* inoculation on root morphology and respiration in tomato seedlings. *Biol. Fertil. Soils* 5 : 241-247

Hardy, F. 1958. The light relation of cocoa. *Cocoa Manual. Inter. Am. Inst. agric. Sci*. Turrialha, Costa Rica, pp. 85-94

Hegde, D.M. 1987. Growth analysis of bell pepper (*Capsicum annuum* L.) in relation to soil moisture and nitrogen fertilization. *Sci. Hort.* 33 : 179-187

Hegde, D.M. 1988. Irrigation and nitrogen requirement of bell pepper. *Indian J. agric. Sci.* 58 : 669-672

Heuvelink, E. and Marcelis, L.F.M. 1996. Influences of assimilate supply of leaf formation in sweet pepper and tomato. *J. Hort. Sci.* 71 : 405-414

Hou, G.Q., Chen, D.S. and Liu, B.Z. 1987. The microclimate and ecophysiological effects of shading and pinching on capsicums. *Acta Hort.* 14 : 251-256

Jackson, M.L. 1973. *Soil Chemical Analysis*. Second edition. Prentice Hall of India Ltd., New Delhi, p. 498

Jayakrishnan, K.V. 1986. Water management in relation to split application of nitrogen on bhindi [*Abelmoschus esculentus* (L.) Moench]. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 92

Jayaraman, S. and Balasubramanian, R. 1991. Effect of different levels of potassium and nitrogen on yield of irrigated chilli. *Madras agric. J.* 78 : 519-520

Jeon, H.J. and Chung, H.D. 1982. Chilli and capsicum. *J. Korean Soc. Hort. Sci.* 23 : 3-6

Jha, R.K. and Mishra, S. 1999. Effect of *Azospirillum* inoculation on nitrogen fixation and growth of sweet potato. *J. Appl. Biol.* 9 : 49-57

Jinadasa, D.M., Eavis, B.W., Bolton, F.R. and Thenabadu, M.W. 1987. Nitrogen and water balance studies in relation to farmyard manure and nitrogen fertilizer applications to Sri Lankan Luvisols. *Trop. Agric.* 64 : 49-54

Joachim, A.W.R. and Paul, W.R.C. 1939. Manurial experiments with chillies. *Trop. Agric.* 91 : 217-230

John, S. 1989. Nutrient management in vegetable chilli (*Capsicum annuum* L.) var. Jwalasakhi. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 90

Joseph, P.A. 1982. Effect of nitrogen, phosphorus and potassium on the growth and yield of chilli, var. Pant C-1. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 108

Joseph, P.A. and Pillai, P.B. 1985. Effect of nitrogen, phosphorus and potassium on the growth and yield of chilli, var. Pant C-1. *Agric. Res. J. Kerala* 23 : 75-82

*Jung, H.B., Ito, T. and Maruo, T. 1994. Effects of shading and NO_3 : NH_4 ratio in the nutrient solution on the growth and yield of pepper plants in nutrient film technique culture. *J. Jap. Soc. Hort. Sci.* 63 : 371-377

Kadam, D.D., Deore, B.P., Wattamvar, M.J. and Pawar, B.B. 1991. The influence of environment on dry matter accumulation and yield in tomato (*Lycopersicon esculentum* Mill.) Pusa Ruby. *Maharashtra J. Hort.* 2 : 60-63

Kamaruddin, S.W. 1988. The effect of shade on growth of tomato caused by fruit borer. *Indian J. agric. Sci.* 54 : 341-343

Kaminwar, S.P. and Rajagopal, V. 1993. Fertilizer response and nutrient requirements of rainfed chillies in Andhra Pradesh. *Fert. News* 38 (7) : 23-26

Kanaujia, S.P., Rastogi, K.B and Sharma, S.K. 1997. Effect of P, K and Rhizobium inoculation on growth, yield and quality of pea. cv. Lincokin. *Veg. Sci*. 24: 91-94

Kapulnik, Y., Sarij, S., Nier, I., Okon, Y. and Kigel, J. 1981. Yield increase in summer cereal crops in Israeli fields inoculated with Azospirillum. *Exp. Agri.* 17 : 179-187

Karthikeyan, M. 1981. Effect of Azospirillum inoculation on rice under graded levels of nitrogen. M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, p. 93

KAU. 2002. *Package of Practices Recommendations, 'Crops'*, 2002. Directorate of Extension, Kerala Agricultural University, Thrissur, p.278

Kavitha, K. 2001. Management of damping off and improvement of growth in chilli (*Capsicum annuum* L.) with native species of Arbuscular Mycorrhizae and Azospirillum. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 79

Kumar, A. and Thakral, K.K. 1993. Effect of herbicides and nitrogen fertilization on growth and yield of chilli (*Capsicum frutiscens* L.). *Proceedings of Indian Society Weed Science.*, *International Symposium,* Hisar, India May 20 –22, 1993 (ed. Girish, M.A.) pp. 3 : 206-208

*Lakatos, M. 1982. Studies on dry matter accumulation and nutrient uptake by capsicum cv. Sorokasi in water culture experiments. *Kert. Egy. Koz.* 45 (13) : 23-25

Lakshmikumari, M., Kavimandan, S.K. and Rao, S.N. 1976. Occurrence of nitrogen fixing *spirillum* in roots of rice, sorghum, maize and other plants. *Indian J. Exp. Biol*. 14 : 638-639

Lata, S. and Singh, R.P. 1993. Effect of nitrogen level and growth regulators on growth, yield and quality of chilli (*Capsicum annuum* L.) var. Plant C-1. *Veg. Sci.* 20 (1) : 40-43

Lawler, D.W. 1987. *Photosynthesis : Metabolism, Control and Physiology.* Longman Scientific and Technical, England, p.

Lehri, L.K. and Mehrotia, C.L. 1972. Effect of *Azospirillum* inoculation on the yield of vegetable crops. *Indian J. agric. Res.* 9 : 201-204

Leskovar, D.I., Canttiffe, D.J. and Stoffella, P.J. 1989. Pepper (*Capsium annuum* L.) root growth and its relation to shoot growth in response to nitrogen. *J. Hort. Sci*. 64 : 711-716

Logendra, S., Putnana, J.D. and Janos, H.W. 1990. The influence of light period on carbon partitioning, translocation and growth on tomato. *Scient. Hort.* 42 : 75-83

Magalhaes, J.R. and Wilcox, G.E. 1983. Tomato growth and mineral composition as influenced by nitrogen forms and light intensity. *J. Pl. Nutr.* 6 : 847-862

Maliphant, G.K. 1959. Manurial and cultural experiments on cocoa. VII River Estate, Trinidad. Shade, spacing, time and rates of fertilizer application experiment. Regional Research Centre, ICTA, Trinidad. *Report on Cocoa Research* (1955-58), p. 83-86

Manchanda, A.K. and Singh, B. 1987. Effect of plant density and nitrogen on yield and quality of bell pepper (*Capsicum annuum* L.). *Indian J. Hort.* 44 : 250-252

Mary, S.S. and Balakrishnan, R. 1990. Effect of irrigation, nitrogen and potassium on pod characters and quality in chilli (*Capsicum annuum* L.) cv. K-2. *S. Indian Hort.* 38 : 86-89

Mathew, A.G., Nambudiri, E.S., Ananthakrishna, S.M., Krishnamurthy, N. and Lewis, Y.S. 1971. An improved method for estimation of capsaicin in capsicum oleoresin. *Laboratory Practice* 1 : 23-26

Meena, N. and Peter, K.V. 1990. Organic, inorganic fertilizers and their combination on yield and storage life of hot chilli. *Veg. Sci.* 17 (1) : 7-10

Meyer, B.S., Anderson, D.B., Bohning, H.R. and Fratianne, D.G. 1973. *Introduction to Plant Physiology*. D Von Nostrand Company, London, p. 565

Minami, M., Toyoto, M., Inoue, T., Nemato, K. and Ujihara, A. 1998. Changes of capsaicin content during maturing stage in chilli pepper (*Capsicum* spp.). *J. Faculty Agric.* 35 : 45-49

Monteith, J.L. 1969. Light interception and radio active exchange on crop stands. In : *Physiological aspects of Crop yield* (eds. Eastin, J.O., Haskins, F.A., Sullivan, C.Y. and Van Bavel, C.H.M.) Longman Scientific and Technical, Wisconsin, pp. 89-110

Nair, R.V. 1991. Shade response of few tropical vegetable crops. In : *Recent Advances in Tropical Vegetable Production.* (eds. Peter, K.V., Joesph, S. and Indira, P.). Kerala Agricultural University, Thrissur, p. 762

Narasappa, K., Reddy, E.N. and Reddy, V.P. 1985. Effect of nitrogen fertilization on chilli (*Capsicum annuum* L.) cv. Sindur. *S. Indian Hort.* 33 : 158-162

Narasimhan, V. and Alagianagalingam, M.N. 1986. Potassium in the management of chilli mosaic disease. *J. Potss. Res.* 2 : 59-64

Narayanan, S.S., Hegde, S., Sadananda, A.R. and Chelliah, S. 1999. Commerce and utility considerations in chillies. *Kissan Wld.* 26 (5): 73-75

Nasiruddin, K.M., Sharfuddin, A.F.M. and Begum, R. 1995. Effect of different shading treatments on growth, yield and quality of tomato cv. Roma VF and Marglobe. *Punjab Veg. Grower* 30 : 35-44

Nasreen, S. and Islam, M.S. 1989. Response of chilli to nitrogen, phosphorus, potassium and sulphur fertilization. *Bangladesh Hort.* 17 (2) : 5-9

Natarajan, S. 1990. Standardization of nitrogen application for chilli (*Capsicum annuum* L.) grown under semi-dry condition. *S. Indian Hort.* 38 : 315-318

Okon, Y. 1985. The physiology of Azospirillum in relation to its utilization as inoculum for promoting growth of plants. *Nitrogen Fixation and Carbon dioxide metabolism* (eds. Ludden, P.W. and Burris, J.E.). Elsevier, New York, U.S.A. pp.165-174

*Pandev, S., Stanev, V. and K"Drev, T. 1980. Effect of major element deficiency in the nutrient medium in the photosynthetic productivity of *C. annuum Fizi. Rast.* 6 (4) : 46-55

Pandey, A. and Kumar, S. 1989. Potenital of Azospirillum as biofertilizers for upland agriculture. *J. Sci. Ind. Res.* 48 : 134-144

Pandey, D.P., Singh, S.B. and Singh, S. 1992. Effect of nitrogen levels and row spacings on growth and yield of autumn-winter chilli (*Capsicum annuum* L.) *Narendra Deva J. agric. Res.* 7 : 58-61

Panwar, J.D.S. and Singh, O. 2000. Response of Azospirillum and Bacillus on growth and yield of wheat under field conditions. *Indian J. Plant Physiol.* 5 : 108-110

Papadopoulos, A.P. and Tissen, H. 1983. Root and air temperature effects on the flowering and yield of tomato. *J. Am. Soc. Hort. Sci.* 108 : 805-809

Parvatham, A., Viajayan, K.P. and Nazar, A. 1989. Effect of Azospirillum on growth and nutrient uptake of Pusa Swani bhindi (*Abelmoschus esculentus* L. Moench). *S. Indian Hort.* 37 : 227-229

Patra, A.K., Samui, R.C. and Tripathi, S.K. 1996. Effect of variety, potassium and planting method on growth and yield of rainy season groundnut (*Arachis hypogaea*) *Indian J. Agron*. 41 : 433-437

Peit, M.M., Wilitis, D.H. and Gardner, R. 1996. Response on post pollen production process in male sterile tomatoes to chronic, sub-acute high temperature stress. *J. Exp. Bot.* 48 : 101-111

Picken, A.J.E. 1989. A review of pollination and fruit set in the tomato. *J. hort. Sci.* 89 : 1-13

Prabhakar, B.S., Srinivas, K. and Shukla, V. 1987. Growth and yield response of green chilli to nitrogen and phosphorus fertilization. *Indian Cocoa Arecanut Spices J.* 10 (1) : 12-14

Prabhakar, M. and Naik,.L.B. 1993. Effect of irrigation and nitrogen fertilization on growth, yield, nitrogen uptake and water use of chilli (*Capsicum annuum* L.) grown for green fruits. *Golden Jubilee Symposium on Horticultural Research* – Changing Scenario, May 24-28, 1993. Bangalore, *Abstract* : 185

Prameela, P. 1990. Screening of different morphotypes of colocasia (*Colocasia esculenta*) for shade tolerance. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.62

Prasad, B. and Singh, S.K. 1984. Nutrient recycling through crop residue management for sustainable rice and wheat production in calcareous soil. *Fert. News* 40 (1) : 11-25

Premanathan, T. 1981. Studies on the phyllosticta leaf spot of ginger. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 94

Purushothaman, D. 1988. Upland rice responses to biofertilizer. *Madras agric. J.* 75 : 149-150

Pushpakumari, R. and Sasidhar, V.K. 1996. Dry matter production and uptake of nutrients by yam and aroids as influenced by shade intensities. *Tropical Tuber Crops : Problems, Prospects and Future Strategies.*(eds. Kurup, G.T., Palaniswami, M.S., Potty, U.P., Padmaja, G., Kabeerathummam, S. and Santha, V.P.) Oxford and IBH Publishing Company Ltd., New Delhi, pp. 247-249

Rajasekhar, C.M., Pappiah, C.M. and Sambanthamoorthy, S. 1995. Studies on the effect of FYM, Azospirillum phosphobacteria and inorganic fertilization in bhindi. *National symposium on organic farming,* October 27-28, 1995. Tamil Nadu Agricultural University, Madurai, *Abstract* : 42-44

Rajasekhar, R., Cox, S. and Sathyanarayana, N. 1988. Evaluation of certain morphological factors in tea cultivars under water stress. *Proc. PLACROSYM* VIII October 23-26, 1988 (ed. Sathyanarayan). Indian Society for Plantation Crops, Kasargode, Kerala, India, p. 204-210

Ramachandran, S. and Subbiah, K.K. 1981. Studies on the effect of plant density and graded levels of nitrogen on yield and yield component of chillies (*Capsicum annuum* L.). *S. Indian Hort.* 29 : 178-181

Ramachandran, S. and Subbiah, K.K. 1982. Effect of plant density and graded levels of nitrogen on growth attributes of chillies (*Capsicum annuum* L.) cv. MDU-1. *S. Indian Hort.* 30 : 266-267

*Rankov, V., Oimitrov, G. and Stoyanova, I. 1983. Nitrogen, phosphorus and potassium uptake during early capsicum growth at different levels of mineral fertilization. *Fizi.Rast.* 9 (1) : 22-31

Rao, E.H. and Gulshanlal. 1986. Response of chilli (*Capsicum annuum* L.) var. Pant C-1 to varying levels of nitrogen and spacing. *Veg. Sci.* 13 (1) : 17-21

Rao, R.Y., Bhavaji, J.N. and Murthy, N.S.R. 1988. Studies on nitrogen nutrition of chilli in relation to potassium under rainfed condition. *Indian Cocoa Arecanut Spices J*. 11 : 90-93

Rao, S.W.V.B., Mann, H.S., Pal, N.B. and Mathur, R.S. 1963. Bacterial inoculation experiments with special reference to Azotobacter. *Indian J. agric. Sci.* 33 : 279-290

Ravi, V. and Indira, P. 1999. Crop physiology of sweet potato (ed. Jules Janic). *Hort. Rev.* 23 : 277-338

Ravisankar, C. and Muthuswamy, S. 1988. Influence of light and temperature on leaf area index, chlorophyll content and yield of ginger. *J. Maharashtra agric. Univ.* 13 : 216-217

*Roman, L. 1982. Studies on mineral nutrition with nitrogen, phosphorus and potassium of capsicum growth under high plastic tunnels. *Anale, Inst. Cer. Pent. Leg. Flori.* Vidra 6 : 191-196

Romano, D. and Leonardi, C. 1994. The response of tomato and egg plant to different minimum air temperatures. *Acta Hort.* 366 : 57-63

Russel, E.W. 1973. *Soil Conditions and Plant Growth*. Tenth edition. Longman group, London, p. 573

Russo, V.M. 1991. Effects of fertilizer rate, application timing, plant spacing on yield and nutrient content of bell pepper. *J. Pl. Nutr.* 14 : 1047-1056

Rylski, I. 1986. Improvement of pepper fruit quality and timing of harvest by shading under high solar radiation conditions. *Acta Hort.* 191 : 221-228

Rylski, I. and Aloni, B. 1994. Flowering, fruit set, fruit development and fruit quality under different environmental conditions in tomato and pepper crops. *Acta Hort.* 366 : 45-55

Rylski, I. and Spigelman, M. 1986a. Use of shading to control the time of harvest of red ripe pepper fruits during the winter season in a high radiation desert climate. *Sci. Hort.* 29 : 37-45

Rylski, I. and Spigelman, M. 1986b. Effect of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of high temperature and radiation. *Sci. Hort.* 29 : 31-35

Sadasivam, S. and Manickam, A. 1992. *Biochemical Methods for Agricultural Sciences.* Wiley Eastern Ltd., Madras, p. 246

*Sagi, A., Rylski, I. and Fuchs, M. 1979. Influence of solar radiation intensity (SRI) on flowering, fruit set and fruit development in tomatoes. *Pamphlet,* Volcani Center 208 : 75

Saigal, O. 2001. Food processing industry, current scene and prospects. *Employ. News* 20-26. January, p. 3-8

Sajitharani, T. 1993. Standardisation of fertilizer schedule for export oriented production of bhindi (*Abelmoschus esculentus* (L.) Moench). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 151

Santiago, C.L. and Goyal, M.R. 1985. Nutrient uptake and solute movement in drip irrigated summer peppers. *J. agric. Univ*., Puerto Rico 69 : 63-38

Schoch, P.G. 1972. Effect of shading on structural characteristic of the leaf and yield of fruit in *Capsicum annuum* L. *J. Am. Soc. Hort. Sci.* 97 : 461-464

Sharma, N.K. and Tiwari, R.S. 1993. Effect of shade on soil temperature, light intensity, number and quality of tomato fruits cv. Pusa Ruby. *Prog. Hort.* 25 : 56-59

Sherly, C.M. 1996. Response of vegetable chilli to graded levels of nitrogen and potassium under varying soil moisture levels. M.Sc. (Ag.) thesis. Kerala Agricultural University, Thrissur, p. 110

Shin, C.W., Yoon, J.H., Rhee, K.M., Park, J.K. and Roh, T.H. 1988. Soil chemical properties of representative farmer's field for hot pepper and yield response to nitrogen, phosphorus and potassium fertilizers. *Research Report, Rural Development Administration, Soil Fertilizer,* Korea Republic 30 : 76-83

Shinde, S.T., Aple, R.G. and Singh, T. 1977. Influence of *Azospirillum* on germination of rice and cotton seeds. *Curr. Sci.* 46-675

Shukla, B. and Kundu, B.S. 1986. Ammoniacal nitrogen fixation quoted from Yadav, K. *Role of biofertilizers in nutrient economics on integrated nutrient management for sustainable agriculture.* (eds. Prasad, B.), pp. 258-277

Shukla, N., Tiwari, D.N., Kashyap, R.L. and Sharma, R.N. 1997. Effect of subabul canopy on vegetable yield over the year. *Adv. Pl. Sci.* 10 : 41-44

Shukla, V., Srinivas, K. and Prabhakar, B.S. 1987. Response of bell pepper to nitrogen, phosphorus and potassium fertilization. *Indian J. Hort*. 44 : 81-84

Singh, K. and Srivastava, B.K. 1988. Effect of various levels of nitrogen and phosphorus on growth and yield of chilli (*Capsicum annuum* L.). *Indian J. Hort.* 45 : 319-324

Singh, P., Sharma, P.P. and Arya, P.S. 1986. Studies on the effect of nitrogen and potassium on growth, fruit yield and quality of chilli. *Indian Cocoa Arecanut Spices J.* 9 (3) : 67-69

Smith, I.E., Savage, M.L. and Mills, P. 1984. Shading effects on greenhouse tomatoes and cucumbers. *Acta Hort.* 148 : 491-500

Smith, R.L., Sehak, S.C., Bontan, J.H. and Qusenberry, K.H. 1978. Yield increase of tropical grasses after inoculation with *Azospirillum lipoferum*. *Ecol. Bull.* 26 : 380-385

Smitha, K. 2002. Performance of bacterial wilt tolerant tomato (*Lycopersicon esculentum* Mill.) genotypes under shade. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 95

Snedecor, G.W. and Cochran, W.G. 1967. *Statistical Methods* (Sixteenth ed.). Oxford and IBH Publishing Co., Calcutta, p.139

Song, S.J. 1987. Studies on the time of applying nitrogen fertilizer to capsicum. *Acta Hort. Sinica* 14 : 185-191

Soohyun, K., Younghyun, K., Zeewon, L. and Kwinso, H. 1998. Analysis of chemical constituents of fruits of red pepper (*C. annuum* L.) cv. Burgary. *J. Korean Soc. Hort. Sci.* 186 : 49-53

Splittstoesser, W.E. and Gerber, J.M. 1986. Response of bell pepper to high rates of side dressed nitrogen. *Proceedings of International American Society on Tropical Horticulture.* 30 : 171-176

Sreelathakumary, I. 2000. Genetic analysis of shade tolerance in chilli (*Capsicum* spp.). Ph.D. thesis, Kerala Agricultural University, Thrissur, p. 153

Srinivas, K. 1983. Response of green chilli to nitrogen and phosphorus fertilization. *S. Indian Hort.* 31 : 37-39

Srinivas, K. and Prabhakar, B.S. 1982. Response of capsicum to nitrogen fertilization. *Veg. Sci.* 9 (2) : 71-74

Stevens, M.A. and Ruchid, J. 1978. Genetic potential overcoming physiological limitations on adaptability, yield and quality of tomato. *Hort. Sci.* 13 : 673-678

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* 25 : 259-260

Subbiah, K. 1990. Nitrogen and Azospirillum interaction on fruit yield and nitrogen use efficiency in tomato. *S. Indian Hort.* 38 : 342-344

Subbiah, K. 1991. Studies on the effect of nitrogen and Azospirillum on okra. *S. Indian Hort.* 39 : 37-44

Subbiah, K. 1993. Effect of biofertilizer in the presence of nitrogen and potassium on yield in chilli and bellary onion. *Golden Jubilee Symposium on Horticultural Research.*, Changing Scenario, May 24-28, 1993, Bangalore, *Abstract* : 129

Subbiah, K. 1994. Effect of nitrogen, potassium and biofertilizers on yield and nutrient uptake in chilli and bellary onion. *Madras agric. J.* 81 (5) : 277-279

Subbiah, K., Helkiah, J., Ravikumar, V. and Rajagopal, C.K. 1982. Effect of combined application of organic and inorganic fertilizer on yield and nutrient uptake of MDU-1 chilli. *S. Indian Hort.* 30 : 45-47

Subhani, P.M., Ravisankar, C. and Narayana, N. 1990. Effect of graded levels and time of application of nitrogen and potassium on flowering, fruiting and yield of irrigated chilli. *Indian Cocoa Arecanut Spices J.* 14 (2) : 70-73

Sundstrom, F.J., Thomas, C.H., Edwards, R.L. and Baskin, G.R. 1984. Influence of nitrogen and plant spacing on mechanically harvested Tabasco pepper. *J. Am. Soc. Hort.* 109 : 642-645

*Surlekov, P. and Rankov, V. 1989. The effect of fertilization on capsicum productivity and soil agrochemical and biological properties in monoculure. *Poch. Agro.* 24 (2) :17-23

Thangam, M. 1998. Effect of shade on growth, yield and quality of certain tomato (*Lycopersicon esculentum*) genotypes. M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, p. 144

Thangaraj, M. and Sivasubramanian, V. 1990. Effect of low light intensity on growth and productivity of irrigated rice grown in Kavery delta region. *Madras agric. J.* 77 : 220-224

Thomas, M.B. and Leong, A.G.B. 1984. The effect of shade and nitrogen on production of container grown ornamental peppers (*Capsicum annuum* L.). *Ann. J. Royal New Zealand Ins. Hort.* 12 : 57-67

Thomas, U.C. 2000. Response of seed priming nutrient management and irrigation in upland rice (*Oryza sativa* L.) M.Sc (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 95

Thompson, B.F. and Miller, P.M. 1963. The role of light in histogenesis and differentiation in the shoot of *Pisum III* the internode. *Am. J. Botany* 50 : 219-227

Tien, T.M., Gaskins, M.H. and Hubbel, D.H. 1979. Plant growth substances produced by *Azospirillum brasilience* and their effect on the growth of pearl millet (*Pennisetium americanum*). *Appl. Enviorn. Micorbiol.* 37 : 1016-1024

Tisdale, S.L., Nelson, W.L. and Beaton, J.D. 1995. *Soil Fertility and Fertilizers*. Fifth edition. Mc Millian Publishing Co., New York, p. 733

Uddin, M.M. and Begum, S. 1990. Effect of fertilizer on vitamin C content of green chilli (*Capsicum* sp.). *Bangladesh J. Scient. Ind. Res.* 25 : 1-4

Varughese, S. 1989. Screening of varieties of ginger and turmeric for shade tolerance. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.81

*Vasudeva, N., Venkataraman, D., Raju, K.I. and Rategeri, M.C. 1981. Preliminary studies on the pattern of accumulation of proline in coffee cultivars during drought. *Turrialba* 31 : 388-390

Voleti, S.R., Kasturibai, K.V., Rajagopalan, V. and Sivasankar, S. 1990. Relative water content and proline accumulation in coconut genotypes under moisture stress. *J. Plantation Crops* 18 : 88-95

Wallace, D.H. and Enriquiz, G.A. 1980. Day length and late maturing beans. *J. Am. Soc. Hort. Sci.* 105 : 583 - 591

Wam, P.V. and Konde, B.K. 1986. A study on Azospirillum a review. *J. Maharashtra Univ.* 11 : 203

Wani, S.P. 1990. Inoculation with associative nitrogen fixing bacteria; Role in cereal grain production improvement. *Indian J. Microbiol.* 30: 363-393

Wankhade, B.N. and Morey, D.K. 1986. Effect of levels of irrigation, nitrogen and potassium on growth and yield of chilli (*Capsicum annuum* L.). *PKV Res. J.* 8 : 22-25

Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. *Ann. Bot.* 22 : 37-54

Wien, H.C. and Turner, A.D. 1989. Hormonal basis for low light intensity induced flower bud abscission of pepper. *J. Amer. Soc. Hort. Sci.* 114 : 981-985

Yanagi, T., Ueda, Y., Sato, H., Hirai, H. and Oda, Y. 1995. Effect of shading and fruit set order on fruit quality in shade truss tomato. *J. Jap. Soc. Hort. Sci.* 64 : 291-297

*Yao, Y.G., Shi, X.H., Yang, J.G., Wang, S.Y. and Liu, Y. 1998. Study on physiological and biochemical indices of heat tolerance of pepper leaves. *J. Hunan agric. Univ.* 24 : 119-122

Yahiya, M., Samiullah, T.K. and Hayat, S. 1996. Influence of potassium on growth and yield of pigeon pea. *Indian J. Agron*. 41 : 416-419

*Yinghua, C. and Jianzhen, J. 1998. The effects of light intensity on photosynthetic character, growth and development in pepper (*Capsicum annuum*). *Acata agric. Shanghai* 14 : 46-50

Yoshida, S. and Parao, F.T. 1976. Climatic influence on yield and yield components of lowland rice in the tropics. *Climate and Rice* IARI, Philippines, p.471-479

*Zayed, E.A., Eh-Zawily, A.I. and Nofal, E.S. 1985. Studies on growth, productivity and some physiological aspects of hot pepper (*Capsicum annuum* L.) var. Red cherry. I. Effects of interaction between morphactin, gibberlic acid and nitrogen, phosphorus and potassium fertilization. *J. agric. Sci. Mansouria Univ* 10 : 191-198

Zhong, L.F. and Kato, T. 1988. The effect of sunlight intensity on growth, yield and chemical composition of system exudates on solanaceous fruits. *Agric. Sci.* 37 : 39-40

*Zuieli, Y. Gamliel, B., Golan, R., Zabari, Y., Teitel, M., Shikarji, A., Chen, R. and Mezarfi, E. 1993. Growing pepper in screen house. *Hassadeh* 74 : 35-40

---

* Originals not seen

PERFORMANCE OF CHILLI (*Capsicum annuum* L.) AS INFLUENCED BY NK RATIO, BIOFERTILIZER AND SHADE

SREEJA. M.

Abstract of the
thesis submitted in partial fulfilment of the requirement
for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2003

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695522

ABSTRACT

The experiments on the 'Performance of chilli (*Capsicum annuum* L.) as influenced by NK ratio, biofertilizer and shade' was conducted at the Instructional Farm, College of Agriculture, Vellayani during January to May 2003.

The experiment was laid out in factorial RBD with two factors, in six treatment combinations and replicated thrice. The factors included were NK ratio *viz*., 1:1, 2:1 and 3:1 and biofertilizer treatment *viz*., *Azospirillum* inoculation and control. Three separate experiments were carried out in open, 25 and 50 per cent shade. Artificial shade was provided using high density polyethylene shade nets.

Results of the experiment revealed that the NK ratio as well as *Azospirillum* inoculation had positive influence on plant height, number of branches, stem girth, DMP and leaf area index. The growth parameters showed an increasing trend with increase in level of shade, while stem girth reduced with shade.

Yield parameters like number of flowers plant^{-1}and number of fruits plant^{-1} vary significantly with NK ratio and *Azospirillum* inoculation. With regard to days for flower initiation and 50 per cent flowering, higher NK ratio hastened this phyto phase. Shading prolonged vegetative phase and delayed flowering.

Yield in open and 25 per cent shade were on par but NK ratio did not significantly influence the yield.

Quality parameters of chilli significantly improved as a result of *Azospirillum* inoculation and shade. Plants treated with 2:1 NK ratio and *Azospirillum* was found to be significantly superior in ascorbic acid and

capsaicin. There was significant reduction in incidence of leaf curl and wilt under shade.

The nutrient uptake showed a significant increase with increase in dose of NK, *Azospirillum* inoculation and shade.

Combined application of biofertilizer with higher NK ratio increased the N and K status of soil after the experiment while P status of soil decreased with increase in shade.

Lower levels of shade with higher dose of nitrogen and potassium registered highest benefit cost ratio. However upto 25 per cent shade economic yield was obtained.

APPENDIX

APPENDIX – I

Weather parameters during the cropping period (January to May 2003)

Standard weeks	Maximum temperature	Rainfall (mm)	RH (%)	Minimum temperature	Evaporation (mm)
3	31.16	0.23	72.21	21.11	3.89
4	31.59	0.00	77.79	21.57	3.64
5	31.94	7.43	76.79	23.06	3.92
6	32.06	2.16	79.00	23.34	3.49
7	31.16	0.00	77.64	21.97	3.97
8	31.94	0.19	76.14	22.83	4.11
9	32.54	0.00	75.21	23.70	4.41
10	32.77	1.24	79.29	23.59	4.29
11	31.93	14.14	77.79	24.37	3.79
12	32.63	0.64	77.86	24.57	4.37
13	32.53	4.29	79.71	24.91	4.17
14	33.24	0.01	77.00	25.24	4.14
15	32.87	2.00	83.21	24.56	3.76
16	33.03	2.86	78.50	25.21	3.91
17	32.30	6.73	78.93	25.56	2.97
18	32.74	16.31	76.86	25.80	3.38
19	32.47	0.57	77.40	26.00	3.30
20	32.51	0.00	80.04	23.46	4.50
21	32.00	2.00	81.22	24.00	4.00
22	30.96	6.90	84.00	24.23	3.23
23	29.66	10.79	82.93	24.17	3.80