PHYSICAL, CHEMICAL AND BIOLOGICAL REGULATION OF FRUIT CHARACTERS AND YIELD IN OKRA (*Abelmoschus esculentus* L. *Moench*).

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

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Kerala Agricultural University

Department of Olericulture
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DECLARATION

I hereby declare that this thesis entitled "Physical, Chemical and Biological Regulation of Fruit Characters and Yield in Okra (Abelmoschus esculentus L. Moench)" is a bonafide record of research work done by me during the course of research and this 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 to me.

18.10.1990

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CERTIFICATE

Certified that this thesis entitled "Physical, Chemical and Biological Regulation of Fruit Characters and Yield in Okra (Abelmoschus esculentus L. Moench)" is a record of research work done independently by **Miss. Rukmani, R.** 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.

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Dr. K.V. Peter,
Chairman,
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CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss. Rukmani, R. a candidate for the degree of Master of Science in Horticulture agree that this thesis entitled "Physical, Chemical and Biological Regulation of Fruit Characters and Yield in Okra (*Abelmoschus esculentus* L. Moench)" may be submitted by Miss. Rukmani, R. in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

Every year, about 14 lakh tonnes of vegetables are required to meet the needs of home consumption in Kerala. We are producing only 1.45 lakh tonnes per annum and about Rs.90 crores flow every year to neighbouring states, Tamil Nadu, Karnataka and Andhra Pradesh for purchase of vegetables alone (Anon, 1989a). Intensification of vegetable cultivation in Kerala assumes utmost importance and significance in this background.

Okra (Abelmoschus esculentus L. Moench) is a member of Malvaceae family and is considered of African or Asiatic origin (De Candolle, 1883). It occupies an important place among vegetables on account of its tender green fruits. Further, it is one of the choicest vegetables grown extensively in India in kitchen and market gardens. Its quick growth habit, short duration and easiness in culture enable the farmers to cultivate this crop under wide range of growing conditions. Okra is grown mainly during kharif. In summer, it is cultivated under irrigated conditions.

In addition to its role as a choice vegetable, okra has nutritional, economic and medicinal importance too (CSIR, 1959). The fruits are canned, dehydrated or frozen alone, and used in soups and stews. They are relished for their high mucilage content. The ripe seeds, flowers and tender leaves also find use in human diet. Use of mucilaginous extracts of roots and stems as clarifier in manufacture of jaggery, leaf mucilage as substitute for detergents and mature fruits and stems containing crude fibre in paper industry are a few of the other commercial uses of this crop. Nadkarni (1927) reported that okra has emollient, demulcent, diuretic, cooling and aphrodisiac action and is found serviceble in fevers, catarrhal attacks, dysentry and spermatorrhoea.

Vegetables cover an area of 16,211 ha producing 1.62 lakh t/year in Kerala (Anon, 1989b). Out of this, 6,312 tonnes of vegetables costing Rs.11.96 crores were exported during 1988-89 to Kuwait, Saudi Arabia, Republic of Arabia and Maldives (Anon, 1989a). The percentage share of okra out of this total quantity of vegetables exported is hardly 0.5-1% and the reason attributed is the preference for small to medium sized fruits (< 10 cm) in Gulf countries (Anon, 1990c). The trend in export of vegetables is also encouraging recording an increase from 4747 metric tonnes worth Rs.9.50 crores during 1986-87 to 6312 metric tonnes worth Rs.11.96 crores during 1988-89 (Anon, 1989a). Local preferences for length of marketable fruits vary even within the country. Processing industries prefer shorter fruits of manageable size. Uniformity in fruit size is also an important criterium for scoring okra pods for canning and dehydration (Indian Standards Institution, 1977). The present study was conducted with the objective of regulating fruit characters and yield using different agents; physical, chemical and biological.

Maintenance of optimum plant population is important for exploiting maximum physiological yield capacity of a crop. Spatial arrangement of crops has a direct effect on yield, on the absorption of radiant energy and on evaporation. Uniformity of fruit size is one of the outcomes of high density planting.

Potentialities of an existing genotype can be brought to light through careful utilisation of specific growth substances. Triacontanols are of recent introduction consisting of a group of long chain fatty alcohols. They stimulate crop growth through increased uptake and translocation of nutrients and activation of enzymes involved in the metabolism. Possibility of their utilization is emphasised in a number of vegetables, but remains untapped in okra.

Naphthalene acetic acid is a growth regulator already found successful in okra for better fruit set and yield. Its efficiency is to be worked out in relation to the array of new chemicals. 2,4-D is another synthetic growth regulator which at low concentration, is proved to be giving growth promotory effect in many crops. Reports on its effects on okra are seen contradictory. Improved plant growth and development under conditions of high temperature and severe soil moisture stress have led to the utilisation of anti-transpirants. Cycocel reduces plant size, thereby limiting the area of transpiration. They also regulate closure of stomata thus enhancing effective utilization of available water.

Chemically fixed 'N' is a non-renewable resource and the largest and costly fossil energy dependent input in agriculture (Rao, 1982). For non-leguminous crops, Azotobacter is used as a dependable 'N' fixing candidate. However, its restricted population in the soil and rhizosphere compared to other soil bacteria together with high demand of energy for N fixation have made us sceptical in its use. It is in this context, Azospirillum is found as an ideally suited microbial inoculant under tropical conditions exhibiting high efficiency of N fixation combined with lower energy requirement, easy establishment in plant roots and tolerance of high soil temperature (Govindan, 1976). Dart and Wani (1982) calculated that increasing associative N fixation by 10 kg N/ha replaces fertilizers worth $53.3 million to Indian farmers. Azospirillum provides much scope to be used as a biofertilizer in vegetables.

Pronounced vegetation effect and requirement of specific ecology for nitrogenous activity demand isolation and development of suitable strains. Hence local strain of

Azospirillum was also raised to test the efficacy in relation to the commercially available culture, in promoting growth and development in okra.

The present work was taken up with the following specific objectives:

1. To find out effect of physical, chemical and biological agents on earliness and its components, vegetative characters, fruit characters and fruit yield and incidence of malformed fruits.

2. To find out effect of biological agents on seed germination and seedling vigour and

3. To estimate gross returns and heat units requirement.

Review of Literature

REVIEW OF LITERATURE

Production of vegetables of marketable size and weight are equally important objectives as high yield for getting remunerative returns. Okra is one of the most important warm season fruit vegetables grown as a garden crop in the tropical and subtropical countries. Fruit colour, size and weight are the three more important characters governing market price of this crop. There is preference for small fruited okra in an export market. Attainment of small fruitedness is the main objective of the present study.

Chauhan (1979) reported that summer okra yields 5.6 to 6.5 t/ha while during kharif, it yields 7.99 to 11.2 t/ha. Choudhary (1983) reported a fruit yield of about 5 t/ha during summer to 10 t/ha during kharif. According to Dutta (1985), pod yield ranges from 7 to 12 t/ha. Yawalker (1985) reported that a good crop yields 10 t/ha during kharif and 6 to 7 t/ha during summer. Thakkur and Arora (1986) suggested, on an average, okra yield varies from 6.5 to 7.5 t of green fruits/ha during spring-summer and 11.5 to 12.5 t during kharif. Nath et al. (1987) recorded 5.4 to 6 t/ha during summer and 8-9.2 t/ha during kharif.

High yielding varieties of okra yield 10-12 t/ha during summer and 15-20 t/ha during kharif and hybrid okra yields upto 25 t/ha (Balakrishnan, 1988). He also reported that under the present practices of cultivation, the realised yield is well below 10 t/ha and attempts to boost up present day yield of okra need actual transformation of technologies to the field conditions.

Rao and Ramu (1975) and Kaul _et al_. (1978) reported that pod yield was influenced chiefly by pods/plant. Singh and Singh (1979) reported that pod yield had a positive and significant association with pods/plant, pod length and plant height. Elangovan _et al_. (1980) observed that fruits/plant, fruit length, fruit width and number of branches were the preliminary yield determining components in okra. Sheela (1986) reported fruits/plant, number of branches, length, girth and weight of single fruit, total number of flowers, fruiting phase, seeds/fruit and stem girth as the important contributing characters of yield.

Spatial arrangements and plant density are manipulated to regulate fruit characters and yield in many vegetables. Okra is a direct sown crop. Broadcasting, spaced line sowing and dibbling are followed in many parts of the country. They are sown broadcasted or in rows either in flat beds or on ridges or on furrows depending on soil type, season and irrigation facilities available. The vegetative growth during summer is relatively slow and a closer spacing is given. Under Kerala conditions, the recommended spacing is 60 cm x 30 cm during summer and 60 cm x 45 cm during _kharif_ (KAU, 1986).

Under Tamil Nadu conditions, Kamalanathan *et al*. (1970) recommended a spacing of 60 cm x 20 cm for higher yield. Dutta (1985) recommended a spacing of 50 cm x 50 cm under Bangalore conditions. In North India, Chouhan (1979) recommended a spacing of 30 cm x 30 cm in summer and 45 cm x 45 cm on *kharif*. A spacing of 30 cm x 15 cm is recommended for spring-summer crop and 45-60 cm x 25-30 cm for *kharif* crop (Thakkur and Arora, 1986). Nath *et al*. (1987) reported that in summer, the spacing is 30 cm x 13-15 cm and in *kharif* 60 cm x 30 cm.

Plant growth substances are used to control different developmental phases, so as to improve seed germination (Hsuch and Lou, 1947; Choudhary and Singh, 1960; Adlakha and Verma, 1965), to induce plant vigour (Choudhary and Singh, 1960), to induce earliness in flowering and fruiting (Zimmerman and Hitchcock, 1944; Leopold and Scott, 1952; Gopalakrishnan and Choudhary, 1978) and to increase yield (Singh and Choudhary, 1966; Verma and Choudhary, 1980).

In attempts to regulate fruit characters like fruit length and girth and yield attributes in terms of number and weight of pods in okra, almost all groups of plant growth substances were used. Among the various auxins tried, naphthalene acetic acid (NAA) gave promising results in terms of fruit and yield contributing characters. Application of plant growth substances decreased the ascorbic acid content and increased crude fibre and ash contents of cv. Pusa Sawani (Gowda, 1983).

Beneficial effects of triacontanol, a recently introduced plant stimulant, were demonstrated by a number of workers in many vegetables (Lim (1981), Mamat et al. (1983), Mini Raj (1985), Rajamani (1987) and Usha (1988) in Chilli, Gunasekharan and Shanmugavelu (1983) in tomato, Jyothi and Shanmugavelu (1985) in brinjal, Zheng et al. (1986) in beans and Knight and Mitchell (1987) in lettuce). Reports on their use in okra are very limited.

Growth retardants like daminozide, chlormequat (CCC) (500-1000 ppm) (Seemanthini, 1970), chlormequat (1000-5000 ppm and chlorphonium (100-1000 ppm) (Shukla and Tewari, 1973), morphactin (300 ppm) (Gujar and Srivastava, 1972, Bhatnagar and Sareen, 1983) were effective in okra.

Various growth substances and nutrient sprays, either in combination or individually were tried recently in okra. An increase in yield of 3.37 to 3.55 kg/12 m^2 plot as compared to 2.4 to 4.2 kg/plot was obtained on treating okra seeds with CCC (250 ppm) + proline (100 ppm) in sucrose by El-Beheidi (1979). Suryanarayana and Rao (1981) reported that gibberelic acid (50 ppm) + Agromin (0.3%) or NAA (25 ppm) + Agromin (0.3%) accelerated yield in okra (6.42 t/ha). Foliar spray of okra with ethylene (10^{-5M}) increased pods/plant (Saxena et al., 1987).

The ever increasing cost of the nitrogenous fertilizers has emphasised the need for full exploitation of biological nitrogen fixation. In case of non-leguminous crops; an associative symbiotic N fixing bacterium; Azospirillum is found useful in increasing yield attributes. The effect of Azospirillum on seed germination was first reported by Dhanpal *et al.* (1978).

A. Physical regulation

Reeve and Schmidt (1952) reported significant increase in early and total yield of canning tomatoes from closer spacings. They observed a definite trend towards smaller fruit size with closer spacing without influencing quality of tomatoes. The yield/unit area increased at a decreasing rate with increase in plant density in four vine types of tomato (Fery and Janick, 1970). Significant increase in marketable weights and number of cabbage heads and reduction in average head size with closer spacing was reported by Csizinsky and Schuster (1985). The highest yield of marketable fruits in brinjal and chilli were obtained at the closest spacing (Abutiate, 1987; Stofellá, 1988).

1. Seed rate

Seed rate depends upon season, method of sowing and variety. For summer crop, the recommended seed rate is

8.5 kg/ha and for *kharif*, 7 kg/ha (KAU, 1986). Growth being restricted during summer, a higher seed rate is given. Under Bangalore conditions, the recommended seed rate is 10 kg/ha during summer and 20 kg/ha during *kharif* (Dutta, 1985). According to Choudhary (1983) and Nath *et al*. (1987), okra requires 18 to 22 kg/ha of seeds during summer and 8 to 10 kg/ha during *kharif*. Chouhan (1979) recommended 9 to 15 kg/ha in summer and 7 to 9 kg/ha in *kharif*. Sundaraj *et al*. (1965) reported that 56 g of seed contain about 1000 seeds with an average germination of 50-60%.

2. Regulation of yield and fruit characters

Randhawa (1967) studied influence of row spacing on growth and development in okra and found that increasing width of rows increased number of flowers and fruits/plant and decreased yield/ha. Kamalanathan *et al*. (1970) recommended the closest spacing of 60 cm x 20 cm for maximum economic returns. Fruits/ha increased by 1,57,300 and 80,400 in 60 cm x 20 cm spacing over, 60 cm x 40 cm and 60 cm x 30 cm spacings respectively. Regarding yield/ha, the increase in 60 cm x 20 cm spacing were 2209 kg and 1346 kg over 60 cm x 40 cm and 60 cm x 30 cm spacings respectively. The number and weight of fruits/plant decreased with decrease in spacing, recording a mean of 9.8 fruits/plant weighing 137 g under the closest spacing compared to 12.4 fruits/plant weighing 186 g under the widest spacing. The higher Bartlett rates Index was recorded by the closest spacing (0.6062). Pandey et al. (1976) obtained maximum pods/plant under 45 cm x 45 cm as compared to 30 cm x 30 cm and 60 cm x 60 cm spacings. The linear increase of yield/unit area with increase in plant density was repeatedly confirmed by Sutton and Albregets (1970), Alberegts and Howard (1974), Gupta et al. (1981), Lan Chow Wing and Rajkomar (1982), Abasar and Siddique (1982), Arajuo (1982), Gowda and Gowda (1983) and Shrestha (1983). Zanin and Kimoto (1980), Arajuo (1982) and Shrestha (1983) supported the observation of reduction in individual plant yield with reduction in spacing. Gowda (1983) reported more number and weight of okra pods at narrow inter-row spacings.

Mc Ferran et al. (1963) and Kamalanathan et al. (1970) suggested reduction in lateral branch as the reason for reduction in yield/plant in closely spaced plants. Gowda (1983) observed shorter internodes, minimum dry weight of stem (%) and maximum dry weight of leaves (%) with wider inter-row spacing. Khan and Jaisawal (1988) attributed increased availability of light and food material/unit plant area under wider spacing, for its better individual performance. According to Gupta (1990), higher number of plants/ha under closer spacing, resulted in higher yield/unit area.

Individual pod size decreased with increase in density (Thamburaj, 1972; Alberegts and Howard, 1974). Gupta et al. (1981) studied effect of plant spacing on plant height, fruit size and yield in okra. Fruit yield/ha decreased with increase in spacing, significantly. Plant height and fruit size increased with increase in spacing, though not significantly. A medium spacing of 45 cm x 30 cm favourably influenced plant height (48.5), fruits/plant (4.25) and fruit length (14.93 cm) compared to higher (45 cm x 45 cm) and lower (45 x 15 cm) spacings (Pandey and Singh, 1979). In 1990, Gupta recorded increase in fruits size with increase in spacing with the 60 cm x 20 cm spacing giving the biggest fruit size (12.6 g) and 50 cm x 10 cm spacing, the smallest (11.6 g). Plant height at 60 cm x 20 cm spacing (122.4 cm) was statistically at par with plant height at 60 cm x 10 cm (123.6 cm) and 50 cm x 20 cm spacings (128.3 cm) but higher than plant height at 50 cm x 10 cm spacing (118.4 cm).

B. Chemical regulation

Reports on effects of NAA, 2-4 dichlorophenoxy acetic acid (2,4-D), triacontanol and CCC on okra are consolidated below.

1. Auxin (NAA and 2, 4-D)

The most important effect of auxin is cell elongation. Leopold (1958) stated prescence of a large amount of growth hormones at fruit set. Synthetic auxins, even substitute for pollination suggesting that auxin itself is responsible for fruit set. Auxin compounds delay senescence through maintenance of RNA synthesis and increased carbohydrate synthesis (Osborne, 1963). The auxin directed transport of nutrients, hormones and photosynthesis favour increased fruit set by their application (Krishnamoorthi, 1981).

The supra optimal concentrations of 2,4-D causes a number of undesirable effects. Relatively high concentration of auxin may result in inhibitory effect as a result, some of the auxin molecules secure all free positions in the protein component of the enzyme molecule, (Mayer and Anderson, 1955). The reduction in the rate of photosynthesis as a result of its action of closing stomata also might be contributing to these effects (Mansfield, 1967).

Singh and Upadhyay (1967) obtain the highest significant increase in plant height, stem diameter, number and weight of pods on applying NAA (15 ppm) in okra. Beyond 15 ppm, the pod number was reduced. Nandpuri et al. (1969) compared influence of GA, indole acetic acid (IAA), phenoxy acetic acid (PAA) and 2,4-D. IAA (10 ppm) and PAA (50 ppm) increased plant height next to GA (100 and 200 ppm). Application of GA (100 and 200 ppm), IAA (10 and 20 ppm) and PAA (50 and 100 ppm) also increased the total plant growth whereas, 2,4-D (5 and 10 ppm) depressed it. All the treatments, except 2,4-D (10 ppm) increased fruit set, though not significantly.

GA (200 ppm) and PAA (50 ppm) significantly increased fruit length. Treatments with NAA (25 ppm) + Agromin (0.3%) gave higher yield of 6.42 t/ha compared to 5.76 t/ha in control (Suryanarayana and Rao, 1981). The longest pod was obtained with IAA (50 ppm) seed treatment and plant spray (100 ppm) on Pusa Sawani (Rattan, et al., 1987).

Thompson (1970) discovered that in okra, auxin applied at the apical end of an isolated internode was able to replace the stimulus responsible for formation of tracheary elements in intact plants. Thus basipetally moving IAA met the necessary requirement for morphological activity in isolated stem systems.

According to Bhandari (1957), 2,4-D (2 ppm) sprayed at the freshly open flower stage, increased yield by 27.8% over control. When sprayed at 10 ppm, 2,4-D reduced fruit set, average fruit weight and yield by 56%, 7% and 49% respectively from control. Sundararajan and Muthukrishnan (1974) reported increase in fruit length by spraying 2,4-D (1 and 2 ppm).

2. Triacontanol

Triacontanol is a plant stimulant, getting popular now-a-days. This was first isolated from lucerne wax by Chibnall et al. (1933) and from Alfalfa by Ries et al. (1977). A rapid increase in water uptake by plants treated with triacontanol indicates that it affects transpiration. Slatyer and Bierbuizen (1964) studied influence of several transpiration suppressants on transpiration, photosynthesis and water use efficiency of cotton leaves. He observed that leaf temperature of cotton was raised by 4°C only when the transpiration was suppressed by 50%. Similar observations in many other cases led Gale and Robert (1966) to conclude that only under extreme conditions of high incident radiation and very low wind velocity, would leaf temperature be significantly raised by reduction of transpiration. He also suggested that transpiration could be at least halved without harmful effects on leaf temperature and mineral nutrition except under the most extreme conditions. This suggested effective use of anti-transpirants especially under stress situations when transpiration exceeded water uptake.

Response of crops to triacontanol was positively correlated with temperature during germination and early growth (Ries, 1978). Average increase of growth of tomato, carrot and wheat over control, changed from about 20% at the lowest temperature to 80% at the highest temperature. Later on, Ries et al. (1983) discovered that triacontanol, a 30 carbon primary alcohol was more effective when formulated as a colloidal suspension than as a suspension in chloroform or NAA or $CaCl_2$. They observed positive correlation between temperature of the growth chamber environment one hour before spraying and response to triacontanol, but temperature one hour after, had no effect on triacontanol activity.

Hongarter et al. (1978) accounted increased water uptake and cell enlargement for the growth promotion role of triacontanol. Influence of triacontanol on ion uptake and transport was first reported by Ramani and Kannan (1980) and they observed a differential effect on ion uptake in the drought resistant and susceptible sorghum varieties. Triacontanol superimposed over NPK treatment at 0.1 mg/litre recorded increased nutrient uptake values and ascorbic acid in tomato fruits (Subbiah et al., 1980). Henry and Gordon (1980) reported an increase in peroxidase activity in peas treated with triacontanol alone or in combination with IAA or GA. Cheng et al. (1982) reported improvement of plasmalemma permeability of leaf cells, phosphorylation in chloroplast, accumulation of ATP and assimilation of CO_2 in *Astragalus sinicus* sprayed with triacontanol (0.1 ppm). Phosphorylation activity of nitrate reductase and N concentration in leaves of treated plants were 30 to 44.3%, 7.1% and 8.4% respectively higher than control. Stem thickness, fresh and dry weight of the root system and fresh weight of the aerial part increased by 12%, 62.7% and 21.6% and 10% respectively. Triacontanol increased total chlorophyll and carotenoid content (Devlin et al., 1984). Vijayaraghavan and Balakrishnan (1985) observed increase in the NPK content of leaves while a decrease in the shoots of tea on applying triacontanol.

In field trials of Tabasco chilli, triacontanol (1.25 mg/litre) applied as soil drench at 25 ml/plant, at transplanting, significantly increased early ripening, fruit number and total yields (Mamat et al., 1983). Gunasekharan and Shanmugavelu (1983) opined that triacontanol sprayed twice (1 ppm) enhanced fruit quality and yield/plant of tomato. The same effects were reported in brinjal by Jyothi and Shanmugavelu (1985) on applying triacontanol (2 ppm) 15 days after transplanting and again at flowering. The cost benefit ratio was 1:8.5 as against 1:4.5 under control. Yield/plant (1.71 kg) as against 0.92 kg in control was obtained. Mixtalol (2 ppm), a formulation of triacontanol in combination with 2,4-D (1 ppm) and Boron (2 ppm) increased fruit characters of chilli; length, breadth, mean fruit weight, single plant yield and per plot yield (Mini Raj, 1985). Plant height and capsaicin content in dry fruit of chilli increased on spraying triacontanol (2.5 ppm) as reported by Rajamani (1987). Knight and Mitchell (1987) reported increased plant fresh weight, dry weight, leaf area and mean relative growth rate of hydroponic lettuce seedlings applied with 10^{-7M} of triacontanol.

3. CCC

Growth retardants control transpiration, as the total surface area exposed to the atmosphere is reduced when plant growth is checked, CCC, a growth retardant used as an anti-transpirant probably acts through its interference with biosynthesis of GA (Wittwer and Tolbert, 1960). A reduced level of GA in treated plants would result in reduced stomatal opening and a lowered transpiration (Halvey and Kessler, 1963).

Cathey (1964) observed that CCC was effective in reducing cell division, cell expansion and synthesis of diffusable endogenous growth substance. The histological studies of the treated leaves showed reduced cell size in the cortical region compared to untreated plants. Increased carbohydrate (Szopa, 1960) and total N (Mathan, 1968) content on treated plants are other physiological effects. Sutti (1969) suggested that the increased chlorophyll content of ashgourd leaves treated with CCC increased photosynthetic and net assimilation rate. Seemanthini (1970) obtained an increase from 4.5 to 10.5 in respect of number of pods and from 45.93 g to 106.06 g in respect of pod weight over the control, on treating okra with CCC (500 ppm). The increase in pod yield/plot over check amounted to 33%. The increase in yield was attributed to high C/N ratio. Reduced vegetative growth in terms of internodal length, petiolar length and laterals suggested the channeling of increased accumulation of nutrients for fruit production rather than growth promotion. The pod length increased to a slight degree. Reduction in plant height and days to flowering, increase in number and weight of fruits/plant, increase in mean length and breadth of fruits and ascorbic acid content were observed on treating tomato with Alar and CCC each at 1500 ppm and 3000 ppm respectively (Irulappan, 1972). Shukla and Tewari (1973) obtained increased fruit length and fresh weight on applying chlorphonium (100 and 1000 ppm) and CCC (500 ppm) in okra. They accounted increased number and size of seeds for the increased fruit size. Okra cv. Pusa Sawani treated with CCC (1000 ppm) produced short plants of 36.56 cm height as compared to control plants of 64.13 cm height (Chooknkar et al., 1977). But they could obtain maximum pod number, yield/plant as well as yield/ha when treated with CCC. CCC (125 ppm) yielded the highest (12.98 t/ha) as compared to control (11.8 t/ha). They accounted, the reaction between CCC and GA or IAA oxidase and lower levels of diffusable auxin, for the suppressed vegetative growth. Godfrey et al. (1978) reported similar reduction in plant height (171.5 cm and 167.5 cm), increase in number (47 and 46.6) weight of pods/plant (74.81 g and 61.28 g) and pod length (46.59 cm and 48.74 cm) on applying Alar twice at 4000 and 6000 ppm respectively in okra. Mangal et al. (1984) recorded beneficial effect of cycocel in inducing salt tolerance in the cv. Pusa Sawani. CCC (500 ppm) improved fruit yield at 6 mmhos/cm^{3}Ec as compared to other treatments. Appreciable reduction in plant height and shoot dry weight was reported by Abdul et al. (1985) on treating okra with chlormequat but they could not obtain any significant effect on yield. When the cv. Clemson Spineless of okra was treated with CCC at concentrations ranging from 500 to 1500 mg/litre, there was reduction in stem length, number of days to flower, increase in the number, length of branches and number of leaves/plant, pods/plant, early and total yields and leaf pigment content (Zayed et al., 1986). They suggested spraying of CCC (1000 ppm) to increase pods/plant and total yield.

C. Biological regulation

In recent years, there is an increasing use of biofertilisers to boost up production. Many micro-organisms, without human efforts, have been helping in crop production by biological N fixation and these have become the target of exploitation. Beijerinck (1925) described a N fixing bacterium under the name Azotobacter spirillum and later on renamed as spirillum lipoferum. After a spell of half a century, Doberenier and Day (1976) rediscovered this organism and its N fixing efficiency in digita grass. Subsequently, this organism was assigned to a new genus, Azospirillum (Tarrand et al., 1978). Azospirillum lives in close association with the root system of plants and treated as associative symbiotic. Decreased O_2 supply 0.005-007 atm of dissolved O_2, temperature ranging between 32 and 36°C, pH between 5.6 and 7.2 and high soil moisture favour activity of Azospirillum. Its association with cereals was established since its rediscovery. But in vegetable crops, occurrence in the rhizosphere of chilli, radish and tomato was reported by Amer et al. (1977). Later on Mohandas (1987) reported

N fixation in intact tomato plants in the field and could detect prescence of Azospirillum species in the endorhizosphere. Further, isolation of phytohormones from the pure culture of this organism (Tien, et al., 1979 and Govindan and Nair, 1986) paved way to its new use as biofertiliser in vegetables.

Lower levels of N induce nitrogenous activity. Balandreau et al. (1975) accounted increased root exudation for the enhancement of nitrogenous activity in lower levels of N. Such induction manifested by better yield response was reported in amaranthus (Udayasuryan and Oblisami, 1980) okra (Subbiah et al., 1988), chilli (Veeraraghavathatham et al., 1988) and onion (Gurubatham, 1989). The greatest positive effect of Azospirillum inoculation in conjunction with N fertiliser strongly suggests a predominantly N acquisition role for the bacteria than N fixation function.

Azospirillum inoculation induces better germination and seedling vigour as reported by Dhanpal et al. (1978) and Balasubramani (1988) in okra and Subbiah et al. (1988) in tomato. This effect is attributed to the synthesis of auxin like substances as identified by Tien et al. (1979) and Govindan and Purushothaman (1984) from pure culture of pearl millet roots. Gunasekharan and Vlassak (1986) noted increased activity of GA, IAA and dihydrozeatin in Azospirillum inoculated chicory plants. A further still unidentified substance, in addition to IAA, GA and cytokinin, twice as active as IAA was reported to increase the wet weight when grown in *Azospirillum brasilense* medium (Zimmer and Bothe, 1988).

Improvement of vegetative growth by enhancing growth components like plant height, leaf area, root length and width by *Azospirillum* were reported in sweet potato (Musmade and Konde, 1986) tomato (Hadas and Okon, 1987), okra (Balasubramani, 1988), and onion (Gurubatham, 1989). Nair (1981) reported colonisation in root elongation zone and bases of root hairs, proliferation in the inner-most layer of cortex and conducting vessels in addition to epidermal and other cortical cells in sorghum inoculated with *Azospirillum brasilense.*

The increased nutrient absorbing surfaces resulting from promoted root hair development and root branching increase growth of aerial plant parts. Increase in active surface for mineral uptake by softening of the middle lamellae of root cortex cells by pectin enzymes as reported by Linweet *et al.* (1983) might be another possible mechanism. Such increased N uptake from 55 to 65 kg/ha in okra (Subbiah *et al.*, 1988), 60-90 kg/ha in chilli (Veeraraghava-thatham *et al.*, 1988) and 50-54 kg/ha in sweet potato (Palnisami, 1985) were recorded by treating with *Azospirillum*.

Hadas and Okon (1987) found that, the energy spent for dry matter accumulation was significantly lower in case of tomato seedlings inoculated with Azospirillum brasilense, though there was significant increase in root, shoot length and leaf area.

Balasubramani (1988) studied in detail, effect of Azospirillum on the various growth and yield characters in okra var. Pusa Sawani. Seed treatment with Azospirillum resulted in 91.65% germination, significantly superior to control. The increase in plant height was highly significant (184.87 cm as compared to 81.92 cm) upon soil and seed treatment. There was significant increase in mean number of leaves (22.6), leaf area (233.85 cm^2), root length (24.58 cm), root width (18.23 cm), dry weight of plants (205.93 g) as compared to 16.67, 148.67 cm^2, 18.65 cm, 17.45 cm and 171.69 g respectively in control. The seed and soil treatment with Azospirillum recorded the highest number of fruits/plant (24.62) against 19.78 fruits/plant in control. The same trend was shown for fruit weight/plant (0.280 kg against 0.221 kg). The per plot yield was the highest (13.73 kg) when seeds and soil were treated than under control (9.91 kg). Qualitative characters, high fruit length and girth (15 cm and 6.86 cm), low crude fibre content (6.29%) and high ascorbic acid content (7.96 mg/100 g) were also recorded against 11.35 cm and 6.13 cm, 6.88% and 6.62 mg/100 g respectively under control.

The treatment effects on the leaf N, chlorophyll b and total chlorophyll content were also higher significantly. Significant increase in uptake of N and P and available K were also recorded as an effect of seed and soil treatment with Azospirillum.

The seed and soil treatment of Azospirillum and application of nitrogen at 30 kg/ha resulted in greatest profit by recording the highest net return of Rs.13,430 with cost: benefit ratio of 1:4.2 as compared to control with 1:2.5 ratio. Similar economic benefit on applying Azospirillum was reported in chilli (Rs.6565/ha) by Veeraraghavathatham et al. (1988).

Heat units requirement

Okra is included as warm season crop requiring long growing season and high temperature above 70°F (Mac Gillivary, 1953). Thamburaj (1972) observed that higher maximum temperature of 34.5°C ± 1 and higher minimum temperature of 23°C ± 0.5 and longer days of 9 to 4 hours prevailing in the months of March, April and May are congenial for realising a higher percentage of germination, imparting earliness in flowering and fruit production, improving vigour of plants, production of large number of flowers and fruits and to get maximum yields both in terms of number and weight of pods. He also recorded negative correlation between time taken for the appearance of first flowers and higher temperature and day length. Increased yields in April sown crops as reported by Venkataramani (1945) and Randhawa (1967) are also attributed to the higher temperature and longer days available during this period compared to the other periods. Gupta *et al* (1981) also observed less than 50% reduction in yield when sown on dates after July 5th upto November. The yield was the highest when crop was sown on 25th May which got reduced with delay in sowing. Temperature and day length which prevailed during both vegetative and reproductive phase was reported to have positive and significant correlation with fruits/plant, seeds/fruit and seed weight (Palnisamy and Ramasamy, 1985).

Materials and Methods

MATERIALS AND METHODS

The present studies were conducted to find out effects of spacings, growth regulators and biofertiliser Azospirillum on fruit characters and yield in okra var. Pusa Sawani (Abelmoschus esculentus).

A. Experimental sites

The experimental sites were at Vegetable Research Plots, College of Horticulture, Vellanikkara, Thrissur. This place is located at an altitude of 23 m above MSL and is situated at 10° 32' N latitude and 76° 16' E longitude. This region enjoys a typical warm humid tropical climate.

B. Seasons and weather conditions

The experiments were conducted during four seasons; March-June 1989 (Summer), September-November 1989 (Late kharif) December 1989-March 90 (Spring) and March-May 1990 (Summer). The meteorological data during periods of experimentation are furnished in Appendix I.

C. Soil characteristics

A portion of the experimental site was dug to a depth of 120 cm and to a width of 90 cm, to study soil fertility status (N, P_2O_5 and K_2O) before and after every cropping season from all replications. The data are furnished in Appendix II.

D. Experimental materials

1. Okra var. Pusa Sawani

Okra var. Pusa Sawani was used for the experiment. The seeds of this variety were collected from the Vegetable Seed Production Centre of the Department of Olericulture, College of Horticulture, Vellanikkara for the two summer seasons and from NSC Sales Depot, Coimbatore for the other two seasons.

2. Azospirillum culture

Culture of Azospirillum collected from the Department of Microbiology, TNAU, Coimbatore was used during all seasons. Local strain of Azospirillum was also cultured and used for seed and soil treatment during all seasons except summer 1989.

Roots were collected from ten okra plants at random, from the Vegetable Research Plots. They were cut into pieces of 10 cm length, surface sterilised using chloromine T (1%) solution for 15 minutes followed by washing in sterilised water and phosphate buffer of p^H 7, several times. These washed root bits were then planted in semisolid nitrogen free malate medium (Table 1) and incubated at 37°C for 72 hours. Growth of Azospirillum was indicated by the formation of white pellicle 2-4 mm below the surface of the medium. A loopfull of this was then transferred into malate semisolid medium in screw capped tubes. It was repeated three times, streaked on solid medium (Table 1) and then incubated at 37°C for 3 days. Single colonies were picked from the streaks, purified further and identified as Azospirillum under the microscope by the spirillar movement and rod shape. The best strain among the samples was then selected based on the nitrogen fixing efficiency of the culture in nitrogen free malate medium estimated by micro-kjeldahl method (Table 2). These were then maintained by streaking on slants.

Mass multiplications of these isolates were done at the required time by inoculating the maintained colonies into liquid medium and incubating at 37°C for 72 hrs. It was incorporated with mixture of soil and sand as carrier material prior to seed and soil treatments.

3. Design and layout

The experimental design was a randomised block design with four replications. Each plot of net size 22.68 sq m was divided into 9 rows except for broadcasting and seeds dibbled in each row as per the treatment specifications. Seeds at the rate of 10 kg/ha were broadcasted after digging and levelling the plot in case of the treatment, broadcasting. During the

Table 1 Composition of semisolid and solid media to culture *Azospirillum*

Semisolid medium		Solid medium	
Malic acid	- 5 g	Malic acid	- 6.0 g
KH_2PO_4	- 0.4 "	KH_2PO_4	- 4.0 "
K_2HPO_4	- 0.1 "	K_2HPO_4	- 6.0 "
$Mg\ SO_4$	- 0.2 "	$Mg\ SO_4$	- 0.2 "
NaCl	- 0.1 "	NaCl	- 0.1 "
$CaCl_2$	- 0.02 "	$CaCl_2$	- 0.02 "
$FeCl_3$	- 0.01 "	NH_4Cl	- 3.0 "
Sodium molybdate	- 0.002 g	Na OH	- 3.0 "
Bromothimol blue (0.5% alcohol solution)	- 5 ml	Yeast extract	- 0.1 "
		$FeCl_3$	- 0.01 "
Agar	- 1.75 g	Sodium molybdate	- 2 mg
Distilled water	- 100 ml	$MnSO_4$	- 2.1 g
p^H	- 6.8	Boric acid	- 2.8 "
		Cu $(NO_3)_2$	- 0.24 mg
		Bromothimol blue (in 0.5% alcohol solution)	- 2 ml
		Agar	- 18 g

Table 2 Nitrogen fixing efficiency of different strain samples

Strain samples	mg of N/100 g of carbon source
1	2.41
2	3.86
3	3.05
4	1.96
5	3.05
6	3.92
7	3.08
8	2.80
9	3.36
10	3.40

The strain No.6 was used for the study

cropping period, cultural operations and application of manures and fertilizers were carried out as per package of practices recommendations of Kerala Agricultural University (KAU, 1986). Twenty five tonnes of farm yard manure/ha were applied at the time of land preparation. A fertilizer dose of 50 kg N, 8 kg P_2O_5 and 30 kg K_2O/ha were applied. Half of nitrogen, full phosphorus and full potassium were applied as basal dose. The remaining quantity of nitrogen was applied 30 days after sowing. Earthing up of ridges was done after each fertilizer application. Intercultural operations to control weeds were done as and when necessary. Irrigation was carried out on alternate days to ensure sufficient moisture, during summer.

4. Details of treatments

The experimental treatments fell under three heads; physical regulation, chemical regulation and biological regulation (Table 3).

There were ten treatments during summer 1989 and eleven during all other reasons.

Seeds were mixed with the Azospirillum culture using rice gruel to form a thin coating and then shade dried for half an hour and dibbled. For soil treatments, the Azospirillum culture was mixed with soil and applied along the ridges followed by a light raking.

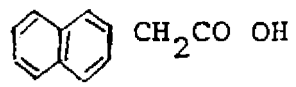
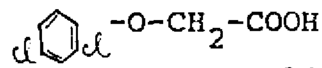
The chemical names and formulae of various chemical regulants used in the experiment are given in Table 4.

The spray solutions at desired concentrations were prepared taking into consideration the concentration of the active ingredient in the formulations and the quantity required for the treatment. A spray volume of 0.06 litres/m^2 was used.

Table 3 Details on treatments

Treatments	Units/quantity
a) Physical regulation	
(i) Broadcasting	10 kg/ha
(ii) Dibbling	
Spacing	(i) 60 cm x 60 cm
	(ii) 60 cm x 45 cm (control)
	(iii) 60 cm x 30 cm
	(iv) 60 cm x 15 cm
b) Chemical regulation (spacing 60 cm x 45 cm)	
(i) Growth regulators	
	(i) NAA (15 ppm)
	(ii) 2,4-D (5 ppm)
(ii) Growth stimulant	
	(i) Triacontanol (0.25 ppm)
(iii) Anti transpirant	
	(i) Cycocel (1000 ppm)
All chemicals were sprayed once at 2nd node stage.	
c) Biological regulation	
(i) *Azospirillum* seed and soil treatment	400 g/kg of seed and then 2 kg/ha of soil
(ii) *Azospirillum* local strain seed and soil treatment	400 g/kg of seed and then 2 kg/ha of soil

Table 4 Chemical names and formulae of various chemical regulants

Common name	Chemical name	Chemical structure
Vipul	1 hydroxytriacontanol	$CH_3\ (CH_2)_{28}\ CH_2OH$
NAA	Naphthaleneacetic acid	
2,4-D	2,4-Dichlorophenoxyacetic acid	
CCC	2-Chloroethyl trimethyl ammonium chloride	$\left[H_3C - \overset{CH_3}{\underset{CH_3}{N}} - C_2H_4Cl \right]^{+} Cl^{-}$

5. Observations recorded

a) Germination (%) and seedling vigour (cm)

Seeds treated with <u>Azospirillum</u> and local strain were sown along with untreated seeds in potting mixture and observations recorded on germination (%) and seedling height (cm) 7 and 14 DAS.

b) Days to first fruit set

Number of days from sowing, to the time when 50% of the plants in each plot set fruit first were recorded.

c) Days to first harvest

Number of days from sowing to the first harvesting in each plot were recorded.

d) Plant height (m)

Five plants were randomly tagged from each plot and height measured from ground level.

e) Index to earliness (I)

$$I = \frac{a_1 + a_2 + \ldots\ldots\ldots\ldots an}{c_1 + c_2 + \ldots\ldots\ldots\ldots cn}$$

where,

a_i - yield of treated plot on ith day

c_i - yield of control plot on ith day

n = 5

f) Number of harvests

g) Fruit/plant and per plot

Five plants were randomly tagged from each plot and fruits/plant recorded at each harvest and their total found out. The total fruits from the plot were taken at each harvest and added up.

h) Yield/plant and per plot (g)

Five plants were randomly tagged from each plot and yield/plant recorded at each harvest and their total found out. The bulk yield of the plot was taken at each harvest and added up.

i) Fruit length (cm)

Average fruit length of 10 fruits/harvest from each plot was measured from 5th to 15th harvest.

j) Fruit girth

Average girth of 10 fruits/harvest from each plot was measured from 5th to 15th harvest from middle of the fruit.

k) Observations on fruit malformation

(i) Number and weight of curled fruits/plot at each harvest and added up.

(ii) Number and weight of crinkled fruits/plot at each harvest and added up.

l) Ascorbic acid content

Fresh edible fruit samples were subjected to visual titration method based on reduction of 2, 6-dichlorophenol indophenol to estimate ascorbic acid (AOAC, 1960).

Observations were also made during summer 1990 for average tap root length (cm), root diameter (cm), number of lateral roots, fresh weight (g) and dry weight (g) of five sample plants at random from each plot after the final harvest.

6. Statistical analysis

Analysis of variance was done as for a randomised block design (Panse and Sukhatme, 1985) separately for all quantitative characters for all seasons.

Correlation and regression analyses were done to establish relation between spacings and yield/plot and spacings and fruit characteristics.

Calculations were also made to find out

1. Heat units - Heat units availability in all the four seasons were worked out using the formula.

$$\sum_{i=1}^{t} \frac{a_i + b_i}{2} - 10°C$$

where,

a_i = maximum temperature on ith day

b_i = minimum temperature on ith day

$\sum_{i=1}^{t}$ = period from sowing date till the last date of harvesting

2. Estimation of gross returns - Gross returns due to application of various treatments during all seasons were worked out taking into consideration costs of various inputs, cost of application and setting premium price for small fruitedness (Appendix III).

3. Best growing season - The best growing season was found out by taking into consideration the highest yield/season.

4. Best treatment - The best treatment was found out by ranking the treatments for characters viz., average fruit length, fruit girth, ascorbic acid content, pods/plant, pods/plot, yield/plant and yield/plot.

Results

RESULTS

Results of the present study to elucidate effects(s) of spacings, growth regulators and biofertiliser on okra are presented under the following heads.

A. Effect of physical, chemical and biological agents on earliness and its components

B. Effect of physical, chemical and biological agents on vegetative characters.

C. Effect of physical, chemical and biological agents on fruit characters and fruit yield

D. Effect of physical, chemical and biological agents on the incidence of malformed fruits

E. Effect of biological agents on seed germination and seedling vigour

F. Effect of physical, chemical and biological agents on root characters

G. Heat units availability

H. Estimation of gross returns

A. Effect of physical, chemical and biological agents on earliness and its components

1. Days to first fruit set

The treatments were significantly different during summer 1989, spring 1989-90 and summer 1990 (Table 5). During

Table 5 Effect of physical, chemical and biological agents on days to first fruit set in okra var. Pusa Sawani

Treatments	Cropping seasons				Pooled mean over	Pooled mean over
	SE_1	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$	$SE_1+SE_2+SE_3+SE_4$
Physical						
Broadcasting (T_1)	39.8	44.0	44.0	40.5	42.8	42.1
60 cm x 60 cm spacing (T_2)	37.5	45.0	43.3	41.5	43.3	41.8
60 cm x 45 cm spacing (T_3) (control)	37.5	44.3	42.0	40.0	42.1	40.9
60 cm x 30 cm spacing (T_4)	38.0	42.8	41.8	39.0	41.2	40.4
60 cm x 15 cm spacing (T_5)	37.8	42.0	42.3	39.3	41.2	40.3
Chemical						
NAA (15 ppm) (T_6)	36.0	45.0	40.8	39.5	41.8	40.3
2,4-D (5 ppm) (T_7)	37.0	44.3	42.8	40.8	42.2	40.9
Triacontanol (0.25 ppm) (T_8)	37.0	43.3	42.5	39.8	42.2	40.9
Cycocel (1000 ppm) (T_9)	36.5	43.5	43.0	39.8	42.1	40.7
Biological						
Azospirillum (T_{10})	38.5	43.0	41.0	39.8	41.3	40.6
Azospirillum L. (T_{11})		41.5	41.3	40.5	41.1	
F test	*	NS	*	*	NS	*
C.D (p=0.05)	1.7	--	1.8	1.1	--	0.6
Interaction (Treatments x seasons)					NS	NS

SE_1 = March-June 1989 (summer 1989), SE_2 = Sept.-Nov. 1989 (late *kharif* 1989), SE_3 = Dec. 1989-March 90 (spring 1989-90), SE_4 = March- May 1990 (summer 1990)

NS = Non significant

late *kharif* 1989, the treatments did not differ significantly. Treatment means pooled over the four seasons were significantly different. During summer 1989, the plants under 60 cm x 45 cm spacing (control) and 60 cm x 60 cm spacing were the first to set fruits among the physical treatments (37.5 DAS). Broadcasted plants set first fruit 39.8 DAS. Among the chemical treatments, the effect of NAA (15 ppm) was the most conspicuous in inducing earliness (36.0 DAS). The rest of the chemical treatments, 2,4-D (5 ppm), triacontanol (0.25 ppm) and CCC (1000 ppm) were on par (37.0 DAS). *Azospirillum* treated plants set fruits 39.0 DAS. During spring 1989-90, 60 cm x 30 cm spaced plants set fruits first (41.8 DAS) and broadcasted plants were delayed by 2 days (44.0 DAS). NAA (15 ppm) was effective to induce early fruit set among the chemical treatments (40.8 DAS). The remaining chemical treatments were on par (43.0 DAS). Both strains of *Azospirillum* induce fruit set 41 DAS. During summer 1989, 60 cm x 30 cm spaced plants were the first to set fruits (39 DAS) and 60 cm x 60 cm spaced plants (41.5 DAS) were the last among the physical treatments. The effects of NAA (15 ppm), triacontanol (0.25 ppm) and CCC (1000 ppm) were on par (40.0 DAS). 2,4-D treated plants were delayed by one day (41.0 DAS). *Azospirillum* treated plants were on par with control (40.0 DAS) whereas local strain of *Azospirillum* delayed fruit set by one day. Over the four seasons, 60 cm x 15 cm spaced plants and NAA (15 ppm) treated plants set fruits the earliest (40.3).

2. Days to first harvest

The treatments were significantly different during summer 1989 and 1990 (Table 6). During the remaining seasons, late *kharif* 1989 and spring 1989-90, there were no significant difference among the treatments. Treatment means pooled over the seasons were also not significantly different. During summer 1989, among the physical treatments, the plants under control were harvested the earliest (40 DAS). Plants broadcasted were delayed by 3 days (42.5 DAS). Among the chemical treatments, NAA (15 ppm) sprayed plants were harvested on 39.0 DAS. Other chemical treatments, 2,4-D (5 ppm), triacontanol (0.25 ppm) and CCC (1000 ppm) were on par (39.5 DAS). *Azospirillum* treated plants were harvested 41.0 DAS. During summer 1990, the earliest harvest was made from plants spaced 60 cm x 30 cm (41.5 DAS).

3. Index to earliness

During spring 1989-90 and summer 1990, the treatments differed significantly (Table 7). In late *kharif* 1989, there was no significant difference among the treatments. Treatment means pooled over the three seasons were also not significantly different. Among the physical treatments during spring 1989-90, 60 cm x 15 cm spaced plants were the earliest (1.6) and 60 cm x 60 cm spaced plants, the latest (0.6). Among the chemical treatments, triacontanol (0.25 ppm) was the

Table 6 Effect(s) of physical, chemical and biological agents on days to first harvest to okra

Treatments	Cropping seasons				Pooled mean over	Pooled mean over
	SE_1	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$	$SE_1+SE_2+SE_3+SE_4$
Physical						
Broadcasting (T_1)	42.5	47.3	46.0	43.0	45.4	44.7
60 cm x 60 cm spacing (T_2)	40.3	47.3	45.3	43.8	45.4	44.1
60 cm x 45 cm spacing (T_3) (control)	40.0	46.8	43.8	42.0	44.2	43.1
60 cm x 30 cm spacing (T_4)	40.5	46.3	44.5	41.5	44.1	43.2
60 cm x 15 cm spacing (T_5)	40.3	45.5	44.5	42.0	44.0	43.1
Chemical						
NAA (15 ppm) (T_6)	39.0	47.3	43.8	42.0	44.3	43.0
2,4-D (5 ppm) (T_7)	39.5	47.3	46.3	42.0	45.2	43.8
Triacontanol (0.25 ppm) (T_8)	39.5	46.0	43.8	43.5	44.4	43.2
Cycocel (1000 ppm) (T_9)	39.5	47.8	44.5	42.5	44.9	43.6
Biological						
Azospirillum (T_{10})	41.0	46.0	43.0	42.0	43.7	43.0
Azospirillum L. (T_{11})	--	45.0	47.0	43.0	45.0	--
F test	*	NS	NS	*	NS	NS
C.D (p=0.05)	1.8	--	--	1.3	--	--
Interaction (Treatments x seasons)					NS	NS

SE_1 = March-June 1989, SE_2 = Sept.-Dec. 1989, SE_3 = Dec. 1989-March 90, SE_4 = March-May 1990

NS = Non significant

Table 7 Effect of physical, chemical and biological agents on index to earliness in okra

Treatments	Cropping seasons			Pooled mean over
	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$
Physical				
Broadcasting (T_1)	1.7	0.8	0.7	1.1
60 cm x 60 cm spacing (T_2)	0.7	0.6	0.5	0.6
60 cm x 45 cm spacing (T_3) (Control)	1.0	1.0	1.0	1.0
60 cm x 30 cm spacing (T_4)	3.3	1.3	1.7	2.1
60 cm x 15 cm spacing (T_5)	2.5	1.6	2.5	2.2
Chemical				
NAA (15 ppm) (T_6)	0.6	0.9	1.0	0.9
2,4-D (5 ppm) (T_7)	1.1	0.8	0.5	0.8
Triacontanol (0.25 ppm) (T_8)	1.1	1.1	0.9	1.1
Cycocel (1000 ppm) (T_9)	1.3	0.8	0.9	1.0
Biological				
Azospirillum (T_{10})	1.1	1.4	1.1	1.2
Azospirillum L. (T_{11})	5.4	0.1	0.8	2.1
F test	NS	*	*	NS
C.D (p=0.05)	-	0.7	0.9	-
Interaction (Treatments x seasons)				NS

SE_2 = Sept.-Nov. 1989, SE_3 = Dec. 1989-March 90, SE_4 = March-May 1990

NS = Non significant

most effective in inducing earliness (1.1). 2,4-D (5 ppm) and CCC (1000 ppm) were on par (0.8). Azospirillum treated plants recorded a higher value (1.4) whereas local strain of Azospirillum a lower value (0.1) as compared to control (1.0). During summer 1990 also, 60 cm x 15cm spaced plants recorded the highest value (2.5) and 60 cm x 60 cm spaced plants the lowest (0.5) among the physical treatments. Among the chemical treatments, all except NAA (15 ppm) recorded a lower value than control. Azospirillum treated plants recorded a higher value (1.1) whereas Azospirillum (local strain), a lower value (0.8) as compared to control.

B. Effect of physical, chemical and biological agents on vegetative characters

1. Plant height

The treatments differed significantly in all seasons except spring 1989-90 (Table 8). Treatment means pooled over all seasons and over last three seasons also differed significantly. During summer 1989, among the physical treatments, 60 cm x 60 cm spaced and 60 cm x 45 cm spaced (control) plants were the tallest (1.2 m). Significant reduction in plant height was observed in broadcasted (0.7 m) and 60 cm x 15 cm spaced (0.9 m) plants. Among the chemical treatments, NAA (15 ppm) and 2,4-D (5 ppm) recorded the highest value and CCC (1000 ppm), the lowest (1.0m). Azospirillum treated plants

Table 8 Effect of physical, chemical and biological agents on plant height (m) in okra

Treatments	Cropping seasons				Pooled mean over	Pooled mean over
	SE_1	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$	$SE_1+SE_2+SE_3+SE_4$
Physical						
Broadcasting (T_1)	0.7	0.3	0.4	0.6	0.5	0.5
60 cm x 60 cm spacing (T_2)	1.2	0.4	0.6	1.1	0.7	0.9
60 cm x 45 cm spacing (T_3) (control)	1.2	0.5	0.5	1.0	0.7	0.8
60 cm x 30 cm spacing (T_4)	1.1	0.6	0.5	1.0	0.7	0.8
60 cm x 15 cm spacing (T_5)	0.9	0.5	0.5	0.9	0.6	0.7
Chemical						
NAA (15 ppm) (T_6)	1.3	0.4	0.6	1.1	0.7	0.9
2,4-D (5 ppm) (T_7)	1.3	0.5	0.5	0.9	0.6	0.8
Triacontanol (0.25 ppm) (T_8)	1.2	0.5	0.5	1.0	0.7	0.8
Cycocel (1000 ppm) (T_9)	1.0	0.4	0.4	0.8	0.5	0.6
Biological						
Azospirillum (T_{10})	1.2	0.6	0.7	1.2	0.8	0.9
Azospirillum L. (T_{11})	-	0.7	0.5	1.1	0.8	-
F test	*	*	NS	*	*	*
C.D (p=0.05)	0.2	0.2	-	0.1	0.1	0.1
Interaction (Treatments x seasons)					NS	*
C.D (p=0.05)					-	0.3

SE_1 = March-June 1989, SE_2 = Sept.-Nov. 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990

NS = Non significant

were on par with control. During late *kharif* 1989, 60 cm x 30 cm spaced plants were the tallest among the physical treatments (0.6 m) and broadcasted plants the dwarfest (0.3 m). Among the chemical treatments, effects of 2,4-D (5 ppm) and triacontanol (0.25 ppm) were on par (0.5 m). Plant height got reduced on applying NAA (15 ppm) and CCC (1000 ppm) (0.4 m). Plant height got increased significantly on applying local strain of *Azospirillum* (0.7 m). During summer 1990, among the physical treatments, significant increase in plant height was observed under 60 cm x 60 cm spacing (1.1 m) and significant decrease under 60 cm x 15 cm spacing (0.9 m) and broadcasting (0.6 m) over control (1.0 m). Among the chemical treatments, NAA (15 ppm) treated plants were significantly superior (1.1 m) and triacontanol (0.25 ppm) treated plants were on par with control. Increase in plant height over control was significant on applying both strains of *Azospirillum* (1.2 and 1.1 m respectively). Over all seasons, *Azospirillum* was the most effective in increasing plant height (0.9 m) among all treatments.

2. Plant fresh weight

Among the physical treatments, 60 cm x 60 cm spacing recorded maximum plant fresh weight, (220.0g) (Table 9) significantly higher than control (132.0g) and broadcasting the minimum weight (35.5 g). Among the chemical treatments, 2,4-D (5 ppm) treated plants recorded the highest value (201.0g) and

Table 9 Effect of physical, chemical and biological agents on plant fresh/dry weight (g) in okra.

	Treatments												
	T_1 Broad-casting	T_2 (60 cm x 60 cm spacing)	T_3 (60 cm x 45 cm spacing)	T_4 (60 cm x 30 cm spacing)	T_5 (60 cm x 15 cm spacing)	T_6 NAA (15 ppm)	T_7 2,4-D (5 ppm)	T_8 Tria-con-tanol (0.25 ppm)	T_9 Cyco-cel (1000 ppm)	T_{10} Azos-piri-llum	T_{11} Azos-piri-llum L.	F test	C.D (p= 0.05)
Fresh weight (g)	35.5	222.0	132.0	111.5	75.5	182.5	201.0	141.0	167.5	168.0	177.0	*	69.1
Dry weight (g)	8.6	42.5	24.8	21.3	15.6	33.1	22.8	27.8	28.5	29.6	31.9	*	11.6

triacontanol (0.25 ppm) treated plants the lowest (141·0g). The plant freshweight was higher than control for both strains of Azospirillum.

3. Plant dry weight

Among the physical treatments, 60 cm x 60 cm spacing increased plant dry weight significantly (42.5 g) (Table 9) and broadcasting decreased dry weight significantly (8.6 g) as compared to control (24.8 g). Among the chemical treatments, the plant dry weight was higher than control for all treatments except 2,4-D (5 ppm) with NAA (15 ppm) recording the maximum (33.1 g) and triacontanol (0.25 ppm) the minimum (27.8 g). Both strains of Azospirillum recorded a higher value than control.

C. Effect of physical, chemical and biological agents on fruit characters and fruit yield

1. Fruit characters

a. Fruit length

The treatments differed significantly during all seasons except late kharif 1989 (Table 10). Treatment means pooled over the last three seasons and all seasons also differed significantly. During summer 1989, among the physical treatments, 60 cm x 60 cm spaced plants recorded

Table 10 Effect of physical, chemical and biological agents on average fruit length (cm) in okra

Treatments	Cropping seasons SE_1	SE_2	SE_3	SE_4	Pooled mean over $SE_2+SE_3+SE_4$	Pooled mean ove[r] $SE_1+SE_2+SE_3+SE_[4]$
Physical						
Broadcasting (T_1)	12.3	10.2	8.1	10.1	9.5	10.2
60 cm x 60 cm spacing (T_2)	15.3	12.0	9.4	14.9	12.1	12.9
60 cm x 45 cm spacing (T_3) (control)	14.8	11.5	10.3	13.4	11.7	12.5
60 cm x 30 cm spacing (T_4)	14.8	12.0	9.3	12.9	11.4	12.3
60 cm x 15 cm spacing (T_5)	14.5	11.4	9.3	12.2	11.0	11.9
Chemical						
NAA (15 ppm) (T_6)	15.1	12.8	10.4	15.1	12.8	12.3
2.4-D (5 ppm) (T_7)	15.0	11.5	9.5	12.7	11.3	12.2
Triacontanol (0.25 ppm) (T_8)	14.5	12.8	10.5	14.8	12.7	12.1
Cycocel (1000 ppm) (T_9)	14.8	10.7	9.8	12.2	10.6	11.6
Biological						
<u>Azospirillum</u> (T_{10})	15.5	13.0	10.9	16.1	13.3	13.9
<u>Azospirillum</u> L. (T_{11})	--	13.7	10.9	15.5	13.3	--
F test	*	NS	*	*	*	*
C.D (p=0.05)	0.9	--	1.0	1.0	0.5	0.5
Interaction (Treatments x seasons)					NS	NS

SE_1 = March-June 1989, SE_2 = Sept.-Nov. 1989, SE_3 = Dec. 1989-March 90, SE_4 = March-May 1990

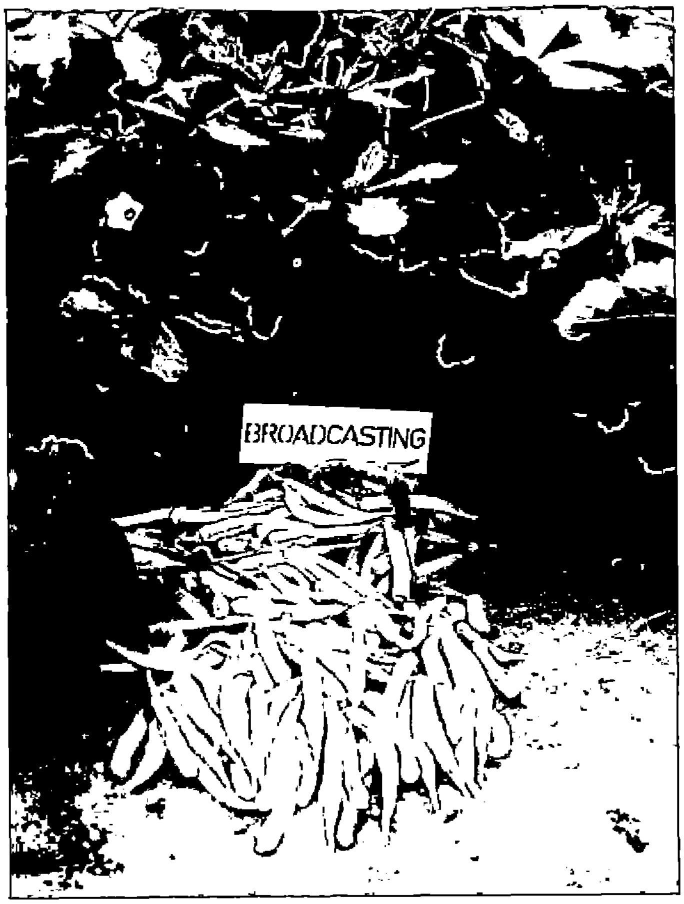
NS = Non significant

maximum fruit length (15.3 cm) and broadcasted plants, the minimum (12.4 cm). The decrease over control (14.8 cm) was significant in broadcasting. Among the chemical treatments, NAA (15 ppm) treated plants recorded maximum fruit length (15.1 cm) and triacontanol (0.25 ppm) the minimum (14.5 cm). Azospirillum treated plants recorded the highest fruit length (15.5 cm). During spring 1989-90, 60 cm x 45 cm spaced plants recorded the highest value (10.3 cm) and broadcasted plants the lowest (8.1 cm) among the physical treatments. The decrease over control was significant under 60 cm x 15 cm spacing (9.3 cm) and broadcasting. Among the chemical treatments, triacontanol (0.25 ppm) recorded maximum fruit length (10.5 cm) and CCC (1000 ppm) the minimum (8.8 cm). Increase in fruit length for both strains of Azospirillum were on par. During summer 1990, among the physical treatments, the longest pods were obtained under 60 cm x 60 cm spacing (14.9 cm) significantly superior to control (13.4 cm) (Plate 1). The decrease over control was significant under 60 cm x 15 cm spacing (12.2 cm) and broadcasting (10.1 cm) (Plate 2). Among the chemical treatments, NAA (15 ppm) and triacontanol (0.25 ppm) increased fruit length over control significantly (15.1 and 14.8 cm respectively). CCC (1000 ppm) recorded significant reduction in fruit length (12.2 cm). Both strains of Azospirillum recorded significant increase in fruit length (16.1 cm and 15.5 cm respectively) (Plate 3). Over all seasons, Azospirillum was the most effective in increasing fruit length (13.9 cm) among all treaments.

Plate 1 Effect of wider spacing (60 cm x 60 cm) on fruit length

Plate 2 Effect of closer spacing (broadcasting) on fruit length


SPACING 60X60


BROADCASTING


SPACING 60X60


BROADCASTING

Plate 1 Effect of wider spacing (60 cm x 60 cm) on fruit length

Plate 2 Effect of closer spacing (broadcasting) on fruit length

Plate 1 Effect of wider spacing (60 cm x 60 cm) on fruit length

Plate 2 Effect of closer spacing (broadcasting) on fruit length

Plate 3 Effect of *Azospirillum* L. on fruit length


AZOSPIRILLU
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b. Fruit girth

There were significant differences among the treatments in all the seasons except late *kharif* 1989 (Table 11). Treatment means pooled over the last three seasons and over all seasons were also significantly different. During summer 1989, among the physical treatments, 60 cm x 60 cm spaced plants recorded maximum fruit girth (6.6 cm) and broadcasted plants the minimum (5.5 cm) which was significantly lower than control (6.5 cm). Among the chemical treatments, NAA (15 ppm) was the most effective (6.6 cm), 2,4-D (5 ppm) and triacontanol (0.25 ppm) were on par (6.5 cm) while CCC (1000 ppm) reduced fruit girth (6.3 cm). *Azospirillum* increased fruit girth (6.6 cm). During spring 1989-90, among the physical treatments, 60 cm x 45 cm spaced plants (control) recorded maximum girth (5.2 cm). The decrease over control was significant in 60 cm x 60 cm, 60 cm x 15 cm spaced and broadcasted plants (4.9 cm, 4.9 cm and 4.5 cm respectively). Among the chemical treatments, maximum value was recorded by NAA (15 ppm) treated plants and minimum by CCC (1000 ppm) (4.9 cm). The other two treatments were on par. Significant increases in fruit girth were recorded by both strains of *Azospirillum* (5.5 and 5.6 cm respectively). During summer 1990, among the physical treatments, 60 cm x 60 cm spaced plants recorded significant increase in fruit girth (6.1 cm) over control (5.6 cm). The decrease over control was

Table 11 Effect of physical, chemical and biological agents on average fruit girth (cm) in okra

Treatments	Cropping seasons				Pooled mean over	Pooled mean over
	SE_1	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$	$SE_1+SE_2+SE_3+SE_4$
Physical						
Broadcasting (T_1)	5.5	3.9	4.5	4.8	4.4	4.7
60 cm x 60 cm spacing (T_2)	6.6	4.3	4.9	6.1	5.1	5.5
60 cm x 45 cm spacing (T_3) (control)	6.5	4.2	5.2	5.6	4.9	5.4
60 cm x 30 cm spacing (T_4)	6.4	4.5	5.1	5.6	5.1	5.4
60 cm x 15 cm spacing (T_5)	6.4	4.3	4.9	5.3	4.8	5.2
Chemical						
IAA (15 ppm) (T_6)	6.6	4.5	5.2	6.0	5.2	5.6
2,4-D (5 ppm) (T_7)	6.5	3.8	5.1	5.2	4.7	5.1
Triacontanol (0.25 ppm) (T_8)	6.5	5.3	5.1	5.9	5.4	5.7
Cycocel (1000 ppm) (T_9)	6.3	4.5	4.9	5.9	5.1	5.4
Biological						
Azospirillum (T_{10})	6.6	5.1	5.5	6.2	5.6	5.8
Azospirillum L. (T_{11})	-	5.2	5.6	6.0	5.6	-
F test	*	NS	*	*	*	*
C.D (p=0.05)	0.3	-	0.3	0.4	0.2	0.2
Interaction (Treatments x seasons)					NS	NS

SE_1 = March-June 1989, SE_2 = Sept.-Nov. 1989, SE_3 = Dec. 1989-March 90, SE_4 = March-May 1990

NS = Non significant

significant in broadcasted plants recording the minimum value (4.8 cm). Among the chemical treatments NAA (15 ppm) significantly increased fruit girth (6.0cm). CCC (1000 ppm) and triacontanol (0.25 ppm) were on par (5.9 cm) whereas 2,4-D (5 ppm) decreased fruit girth significantly (5.2 cm). Both strains of Azospirillum increased fruit girth significantly and the highest value was recorded by Azospirillum (6.2 cm). Over all seasons, Azospirillum was the most effective in increasing fruit girth (5.8 cm) among all treatments.

c. Ascorbic acid content

Among the physical treatments, broadcasted plants recorded significant increase in ascorbic acid content (12.3 mg/100 g) over control fruits (10.2 mg/100 g) (Table 12). Among the chemical treatments, triacontanol (0.25 ppm) recorded the maximum value (12.6 mg/100 g) followed by NAA (15 ppm) (12.1 mg/100 g) significantly superior to control. 2,4-D (5 ppm) and CCC (1000 ppm) were on par (10 mg/100 g). The increases in content on treating with both strains of Azospirillum were highly significant (14.3 and 15.0mg/100 g respectively) recording the maximum values among all the treatments.

d. Number of harvests

The treatments differed significantly during summer 1989 and spring 1989-90 (Table 13). There was no significant

Table 12 Effect of physical, chemical and biological agents on ascorbic acid content (mg/100 g) in okra

	Treatments												
	T_1 Broad-casting	T_2 (60 cm x 60 cm spacing)	T_3 (60 cm x 45 cm spacing)	T_4 (60 cm x 30 cm spacing)	T_5 (60 cm x 15 cm spacing)	T_6 NAA (15 ppm)	T_7 2,4-D (5 ppm)	T_8 Tria-con-tanol (0.25 ppm)	T_9 Cyco-cel (1000 ppm)	T_{10} Azos-piri-llum	T_{11} Azos-piri-llum L.	F test	C.D (p= 0.05)
Vit. C content (mg/ 100 g)	12.3	11.1	10.2	10.2	9.1	12.1	10.0	12.6	10.0	14.3	15.0	*	1.8

Table 13 Effect of physical, chemical and biological agents on number of harvest in okra

Treatments	Cropping seasons				Pooled mean over	Pooled mean ove
	SE_1	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$	$SE_1+SE_2+SE_3+SE_4$
Physical						
Broadcasting (T_1)	21.8	7.8	15.5	15.5	12.9	15.1
60 cm x 60 cm spacing (T_2)	24.0	7.8	16.5	15.3	13.2	15.9
60 cm x 45 cm spacing (T_3) (control)	23.8	8.8	17.0	16.0	13.9	16.4
60 cm x 30 cm spacing (T_4)	23.3	8.8	16.8	16.0	13.8	16.2
60 cm x 15 cm spacing (T_5)	23.5	9.0	16.3	16.0	13.8	16.2
Chemical						
NAA (15 ppm) (T_6)	24.3	7.5	16.8	16.0	13.4	16.1
2,4-D (5 ppm) (T_7)	24.3	8.3	14.8	13.3	12.1	15.1
Triacontanol (0.25 ppm) (T_8)	23.8	8.8	16.8	15.3	13.6	16.1
Cycocel (1000 ppm) (T_9)	23.5	8.0	16.0	15.5	13.2	15.8
Biological						
<u>Azospirillum</u> (T_{10})	23.3	9.0	17.0	16.0	14.0	16.3
<u>Azospirillum</u> L. (T_{11})	--	9.0	11.5	15.3	11.9	--
F test	*	NS	*	NS	NS	*
C.D. (p=0.05)	1.0	--	1.60	--	--	0.5
Interaction (Treatments x seasons)						NS

SE_1 = March-June 1989, SE_2 = Sept.-Dec. 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990

NS = Non significant

difference among the treatments during late *kharif* 1989 and summer 1990. Treatment means pooled over the four seasons were significantly different. During summer 1989, among the physical treatments, 60 cm x 60 cm spaced plants, recorded maximum number of harvests (24.0). The decrease over control was significant in broadcasted plants (21.8). Among the chemical treatments, NAA (15 ppm) and 2,4-D (5 ppm) were effective in increasing the number of harvests (24.3) over control (23.8). Triacontanol (0.25 ppm) was on par with control and CCC (1000 ppm) recorded reduction in number (23.5). *Azospirillum* treatment reduced the number (23.3). During spring 1989-90, among the physical treatments, 60 cm x 45 cm spaced plants (control) recorded the highest value (17.0) and broadcasted plants the lowest (15.5). Among the chemical treatments, NAA (15 ppm) and triacontanol (0.25 ppm) were the most effective (16.8) and 2,4-D (5 ppm) decreased the number (14.8) significantly over control. *Azospirillum* was on par with control while local strain of *Azospirillum* decreased the number significantly. Over the four seasons, *Azospirillum* was the most effective (16.3).

e. Fruits/plant

The treatments differed significantly during spring 1989-90 and summer 1990 (Table 14). There was no significant difference among the treatments in other two seasons. Treatment means pooled over the last three reasons and all

Table 14 Effect of physical, chemical and biological agents on fruits/plant in okra

Treatments	Cropping seasons				Pooled mean over	Pooled mean over
	SE_1	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$	$SE_1+SE_2+SE_3+SE_4$
Physical						
Broadcasting (T_1)	14.8	2.8	5.8	13.5	7.3	9.2
60 cm x 60 cm spacing (T_2)	23.8	4.3	11.3	14.5	10.0	13.4
60 cm x 45 cm spacing (T_3) (control)	22.0	6.0	15.3	17.8	13.0	15.3
60 cm x 30 cm spacing (T_4)	21.8	6.0	13.5	18.5	12.7	14.9
60 cm x 15 cm spacing (T_5)	19.5	5.5	15.5	20.5	13.8	15.3
Chemical						
NAA (15 ppm) (T_6)	24.8	4.3	15.5	18.0	12.6	15.6
2,4-D (5 ppm) (T_7)	26.3	4.0	9.5	5.8	6.4	11.4
Triacontanol (0.25 ppm) (T_8)	22.8	6.5	14.5	17.0	12.7	15.2
Cycocel (1000 ppm) (T_9)	28.5	5.8	10.3	19.5	11.8	16.0
Biological						
Azospirillum (T_{10})	19.0	6.8	17.8	19.8	14.8	15.8
Azospirillum L. (T_{11})	--	7.3	4.5	18.3	10.0	--
F test	NS	NS	*	*	*	*
C.D ($p=0.05$)	--	--	5.5	5.4	3.4	2.3
Interaction (Treatments x seasons)					NS	NS

SE_1 = March-June 1989, SE_2 = Sept.-Nov. 1989, SE_3 = Dec. 1989-March 90, SE_4 = March-May 1990

NS =Non significant

four seasons were significantly different. During spring 1989-90, among the physical treatments, 60 cm x 15 cm spaced plants gave the maximum number (15.5). The decrease over control was significant in broadcasted plants (5.8). Among the chemical treatments, NAA (15 ppm) recorded the highest fruit number (15.5). The decrease over control (15.3) was significant in 2,4-D (5 ppm) treated plants (9.5). Azospirillum treated plants produced the maximum number (17.8) while the local strain reduced the fruit number significantly (4.5) over control. During summer 1990, among the physical treatments, 60 cm x 15 cm spaced plants recorded the maximum value (20.5) and broadcasted plants the minimum (13.5). Among the chemical treatments, CCC (1000 ppm) was the most effective in increasing fruits/plant (19.5) (Plate 4) followed by NAA (15 ppm) (18.0)(Plate 5). The decrease over control was significant in 2,4-D (5 ppm) treated plants (5.8). Azospirillum (19.8) and Azospirillum (local strain) (18.3) increased fruits/plant. Over the four seasons CCC (1000 ppm) was the most effective (16.0) and over the four seasons excluding summer 1989, Azospirillum was the most effective (14.8) (Plate 6).

f. Fruits/plot

The treatments differed significantly in spring 1989-90 and summer 1990 (Table 15). During late kharif 1989, there was no significant difference between treatments. Treatment

Plate 4 Effect of CCC (1000 ppm) on fruits/plant

Plate 5 Effect of NAA (15 ppm) on fruits/plant


CCC 1000ppm


NAA 15ppm

Plate 6 Effect of *Azospirillum* on fruits/plant


AZOSPIRILLUM·
BRASILENSE

Table 15 Effect of physical, chemical and biological agents on fruit/plot ($5.4 \times 4.2\ m^2$) in okra

Treatments	Cropping seasons			Pooled mean over
	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$
Physical				
Broadcasting (T_1)	11.3	261.0	904.8	426.3
60 cm x 60 cm spacing (T_2)	88.8	321.5	648.0	352.8
60 cm x 45 cm spacing (T_3) (control)	194.0	437.0	1027.8	552.9
60 cm x 30 cm spacing (T_4)	267.0	456.8	1332.8	685.5
60 cm x 15 cm spacing (T_5)	322.8	509.8	1803.0	878.5
Chemical				
NAA (15 ppm) (T_6)	82.3	441.5	1028.0	517.3
2,4-D (5 ppm) (T_7)	111.8	307.8	249.5	223.0
Triacontanol (0.25 ppm) (T_8)	156.8	434.8	939.5	510.3
Cycocel (1000 ppm) (T_9)	121.5	309.0	960.0	463.5
Biological				
<u>Azospirillum</u> (T_{10})	146.3	551.8	1104.8	600.9
<u>Azospirillum</u>+L. (T_{11})	245.8	147.3	924.5	439.2
F test	NS	*	*	NS
C.D. (p=0.05)	--	182.3	365.4	--
Interaction (Treatments x seasons)				NS

SE_2 = Sept.-Nov. 1989, SE_3 = Dec. 1989-March 90, SE_4 = March-May 1990, NS = Non significant means pooled over the three seasons were also not significantly different. During spring 1989-90, among the physical treatments, 60 cm x 15 cm spaced plot had the highest number (509.8) and broadcasted plot, the lowest (261.0). Among the chemical treatments, only NAA (15 ppm) increased the number. The decrease over control was maximum in 2,4-D (5 ppm) treated plots (307.8). Azospirillum treated plots produced the maximum number (551.8) among all treatments while local strain of Azospirillum reduced the number significantly (147.3). During summer 1990, among the physical treatments, 60 cm x 15 cm spaced plots recorded the highest number (1803.0)(Plate 7) significantly superior to control (1027.8) (Plate 8). 60 cm x 30 cm spaced plot also recorded increase in fruit number over control (Plate 9). The decrease over control was significant in 60 cm x 60 cm spaced plot, recording the minimum value (648.0)(Plate 10). Among the chemical treatments, only NAA (15 ppm) was effective in increasing fruits/plot (1028.0). The decrease over control was maximum for 2,4-D (5 ppm) (249.5) which was significantly inferior. Both strains of Azospirillum recorded lower number compared to control (1104.8 and 924.5 respectively).

g. Fruit weight/plant

During spring 1989-90 and summer 1990, the treatments differed significantly (Table 16). During summer 1989 and late kharif 1989 the differences among the treatments were not

Plate 7 Effect of spacing (60 cm x 15 cm) on fruits/plot

Plate 8 Fruits/plot under control (60 cm x 45 cm spacing)


SPACING


CONTROL60X45

Plate 9 Effect of spacing (60 cm x 30 cm) on fruits/plot

Plate 10 Effect of spacing (60 cm x 60 cm) on fruits/plot


SPACING 60X60


SPACING 60X30

Table 16 Effect of physical, chemical and biological agents on fruit weight/plant (g) in okra

Treatments	Cropping seasons				Pooled mean over	Pooled mean over
	SE_1	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$	$SE_1+SE_2+SE_3+SE_4$
Physical						
Broadcasting (T_1)	316.3	27.5	55.5	236.3	106.4	158.9
60 cm x 60 cm spacing (T_2)	578.8	38.0	144.5	331.0	171.2	273.1
60 cm x 45 cm spacing (T_3) (control)	561.0	53.5	185.0	396.0	211.5	298.9
60 cm x 30 cm spacing (T_4)	556.8	45.8	175.0	406.5	209.1	296.0
60 cm x 15 cm spacing (T_5)	465.5	50.0	166.8	422.5	213.1	276.2
Chemical						
NAA (15 ppm) (T_6)	588.5	43.8	207.0	395.8	215.5	308.8
2,4-D (5 ppm) (T_7)	636.0	35.0	114.5	155.8	101.8	235.3
Triacontanol (0.25 ppm) (T_8)	579.8	66.0	180.5	363.3	203.3	297.4
Cycocel (1000 ppm) (T_9)	650.5	52.3	122.8	398.8	191.3	306.1
Biological						
Azospirillum (T_{10})	470.3	62.0	225.0	421.5	236.2	294.7
Azospirillum L. (T_{11})	--	88.5	52.5	402.0	181.0	--
F test	NS	NS	*	*	NS	NS
C.D. (p=0.05)	--	--	73.8	108.7	--	--
Interaction (Treatments x seasons)					NS	NS

SE_1 = March-June 1989, SE_2 = Sept.-Nov. 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990

NS = Non significant

significant. Treatment means pooled over the last three seasons and all the four seasons were also not significantly different. During spring 1989-90, among the physical treatments, 60 cm x 45 cm spaced plants recorded the maximum fruit weight (185·0g). The decrease in broadcasted plants (55.5 g) was significantly different from control (185·0g) Among the chemical treatments, only NAA (15 ppm) recorded higher value (207·0g) over control. The decrease over control was maximum for 2,4-D (5 ppm) (114.5 g). Azospirillum increased fruit weight/plant (225·0g) whereas local strain decreased it (52.5 g) over control. During summer 1990, 60 cm x 15 cm spaced plants recorded maximum weight/plant (422.5 g) followed by 60 cm x 30 cm spaced plants (396·0g). The decrease over control was maximum in broadcasting (236.3 g) and was significant. Among the chemical treatments, only CCC (1000 ppm) increased fruit weight/plant (398.8 g) over control. The decrease over control was maximum in 2,4-D (5 ppm) treated plants (155.8 g). Both strains of Azospirillum increased fruits/plant compared to control (421.5 g and 402·0g respectively).

h. Fruit weight/plot

During spring 1989-90 and summer 1990, the treatments differed significantly (Table 17). In late kharif 1989, there was no significant difference among the treatments. Treatment means pooled over three seasons also did not differ

Table 17 Effect of physical, chemical and biological agents on fruit weight/plot (5.4 x 4.2 m^2) (kg) in okra

Treatments	Cropping seasons			Pooled mean over
	SE_2	SE_3	SE_4	$SE_2+SE_3+SE_4$
Physical				
Broadcasting (T_1)	1.2	1.8	11.4	4.8
60 cm x 60 cm spacing (T_2)	0.8	3.2	10.4	4.8
60 cm x 45 cm spacing (T_3) (control)	1.7	4.4	16.6	7.6
60 cm x 30 cm spacing (T_4)	2.7	4.3	20.9	9.3
60 cm x 15 cm spacing (T_5)	2.8	4.4	26.9	11.4
Chemical				
NAA (15 ppm) T_6)	0.7	4.8	15.9	7.1
2,4-D (5 ppm) (T_7)	0.9	3.0	4.1	2.7
Triacontanol (0.25 ppm) (T_8)	1.4	4.4	14.9	6.9
Cycocel (1000 ppm) (T_9)	1.1	3.0	16.3	6.8
Biological				
Azospirillum (T_{10})	1.3	5.8	17.7	8.3
Azospirillum L. (T_{11})	3.0	1.5	14.3	6.2
F test	NS	*	*	NS
C.D (p=0.05)	-	1.8	6.1	-
Interaction (Treatments x seasons)				NS

SE_2 = Sept.-Nov. 1989, SE_3 = Dec.-1989-March 90, SE_4 = March-May 1990, NS = Non significant significantly. In spring 1989-90, among the physical treatments, the highest value was recorded in 60 cm x 15 cm spaced plots and 60 cm x 45 cm spaced plots (control) (4.4 kg). The decrease over control was significant in broadcasted plot (1.8 kg). Among the chemical treatments, only NAA (15 ppm) increased fruit weight (4.8 kg) over control. 2,4-D (5 ppm) and CCC (1000 ppm) decreased the weight over control (3.0kg). Azospirillum increased fruit weight recording the maximum among all treatments (5.8 kg). Local strain of Azospirillum decreased fruit weight significantly over control recording the minimum value (1.5 kg). During summer 1990, among the physical treatments, increase in fruit weight/plot was highly significant in 60 cm x 15 cm spaced plot (26.9 kg) over control (16.6 kg). 60 cm x 30 cm spacing also increased fruit weight/plot (20.9 kg). The decrease over control was significant in 60 cm x 60 cm spaced plot (10.4 kg) recording the minimum value. Among the chemical treatments, none was effective in increasing fruit weight/plot. Among the treatments, CCC (1000 ppm) recorded the highest value (6.3 kg) and the decrease over control was significant in 2,4-D (5 ppm) treated plot (4.1 kg). Azospirillum treatment increased the weight (17.7 kg) over control.

D. Effect of physical, chemical and biolcgical agents on the incidence of malformed fruits

1. Curled fruits/plot

The treatments differed significantly during spring 1989-90 and summer 1990 (Table 18). During summer 1989,

Table 18 Effects of physical, chemical and biological agents on curled fruits/plot ($5.4 \times 4.2\ m^2$) in okra

Treatments	Cropping seasons			Pooled mean over
	SE_1	SE_3	SE_4	$SE_1+SE_3+SE_4$
Physical				
Broadcasting (T_1)	35.5	17.5	5.3	19.4
60 cm x 60 cm spacing (T_2)	38.5	16.0	4.3	19.6
60 cm x 45 cm spacing (T_3) (control)	36.0	28.5	9.0	24.5
60 cm x 30 cm spacing (T_4)	35.8	33.3	4.5	24.5
60 cm x 15 cm spacing (T_5)	37.5	31.5	10.5	26.5
Chemical				
NAA (15 ppm) (T_6)	50.0	30.3	12.0	30.8
2,4-D (5 ppm) (T_7)	45.0	29.8	12.3	29.0
Triacontanol (0.25 ppm) (T_8)	34.8	28.8	15.0	26.2
Cycocel (1000 ppm) (T_9)	42.8	32.5	15.0	30.1
Biological				
Azospirillum (T_{10})	34.3	22.8	8.0	21.7
Azospirillum L. (T_{11})	--	8.0	6.5	--
F test	NS	*	*	NS
C.D (p=0.05)	--	14.0	6.2	--
Interaction (Treatments x seasons)				NS

SE_1 = March-June 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990, NS = Non significant there was no significant difference among the treatments. Treatment means pooled over the three seasons also did not differ significantly. During spring 1989-90, among physical treatments, 60 cm x 30 cm spaced plot recorded maximum number of curled fruits (33.3) followed by 60 cm x 15 cm spaced plot (31.5). The decrease over control (28.5) was maximum in 60 cm x 60 cm spaced plot (16.0). All the chemical treatments increased the number of curled fruits over control, the maximum being for CCC (1000 ppm) (32.5). Azospirillum treatment decreased the number (22.8) and the effect of local strain was significant in reducing the number of curled fruits (8.0). During summer 1990, among the physical treatments, 60 cm x 15 cm spacing increased the number (10.5) over control (9.0) and the decrease over control was maximum under 60 cm x 60 cm spacing. All the chemical treatments increased the number of curled fruits over control with CCC (1000 ppm) and triacontanol (0.25 ppm) recording the maximum (15.0). Both strains of Azospirillum reduced the incidence of curled fruits over control.

2. Curled fruit weight/plot

The treatments differed significantly during spring 1989-90 and summer 1990 (Table 19). In summer 1989, there was no significant difference among the treatments. Treatment means pooled over all the three seasons did not differ significantly. During spring 1989-90, among the physical

Table 19 Effect of physical, chemical and biological agents on curled fruit weight/plot (5.4 x 4.2 m^2) (g) in okra

Treatments	Cropping seasons			Pooled mean over
	SE_1	SE_3	SE_4	$SE_1+SE_3+SE_4$
Physical				
Broadcasting (T_1)	587.3	150.0	70.0	269.1
60 cm x 60 cm spacing (T_2)	810.3	201.3	78.8	363.4
60 cm x 45 cm spacing (T_3) (control)	758.0	320.0	205.0	427.7
60 cm x 30 cm spacing (T_4)	794.0	321.3	90.0	401.8
60 cm x 15 cm spacing (T_5)	799.0	276.3	241.3	438.8
Chemical				
NAA (15 ppm) (T_6)	971.3	356.3	261.3	529.6
2,4-D (5 ppm) (T_7)	946.8	297.5	237.5	493.9
Triacontanol (0.25 ppm) (T_8)	774.5	326.3	316.3	472.3
Cycocel (1000 ppm) (T_9)	938.0	336.3	367.5	547.3
Biological				
Azospirillum (T_{10})	716.8	270.0	198.8	395.2
Azospirillum L. (T_{11})	--	82.5	161.3	--
F test	NS	*	*	NS
C.D (p=0.05)	--	149.4	139.0	--
Interaction (Treatments x seasons)				NS

SE_1 = March-June 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990 NS = Non significant treatments only 60 cm x 30 cm spaced plot recorded higher weight (321.3 g) over control (320.0g). The decrease over control was significant in broadcasted plot (150.0g) recording the minimum value. Among the chemical treatments, all except, 2,4-D (5 ppm) (297.5 g) recorded higher weight of curled fruits over control and the maximum weight (356.3 g) by NAA (15 ppm). Both strains of Azospirillum reduced the weight of curled fruit over control and the decrease was significant in treatment with local strain of Azospirillum (82.5 g). During summer 1990, among the physical treatments, 60 cm x 15 cm spaced plot recorded the maximum value (241.3 g) and the weight was less than control (205.0g) in all other cases. Broadcasted plot recorded the minimum value. Among the chemical treatments, the weight of curled fruits was higher than control in all cases with CCC (1000 ppm) recording the maximum weight (367.5 g). Both strains of Azospirillum reduced the weight of curled fruits over control.

3. Crinkled fruits/plot

The treatments differed significantly only during spring 1989-90 (Table 20). During summer 1989 and 1990 there were no significant differences among the treatments. Treatment means pooled over the three seasons did not differ significantly. During spring 1989-90, among the physical treatments, 60 cm x 15 cm spaced plot recorded the highest number of crinkled fruits/plot (6.3) significantly higher than

Table 20 Effect of physical, chemical and biological agents on crinkled fruits/plot ($5.4 \times 4.2\ m^2$) in okra

Treatments	Cropping seasons SE_1	SE_3	SE_4	Pooled mean over $SE_1+SE_3+SE_4$
Physical				
Broadcasting (T_1)	11.8 (3.5)	1.3 (1.4)	2.3 (1.7)	5.1 (2.2)
60 cm x 60 cm spacing (T_2)	12.5 (3.6)	0.8 (1.3)	4.0 (2.1)	5.8 (2.3)
60 cm x 45 cm spacing (T_3) (control)	9.3 (3.1)	1.0 (1.4)	2.0 (1.7)	4.1 (2.1)
60 cm x 30 cm spacing (T_4)	18.5 (4.4)	3.0 (1.9)	1.5 (1.5)	7.7 (2.6)
60 cm x 15 cm spacing (T_5)	17.5 (4.3)	6.3 (2.7)	2.0 (1.7)	8.6 (2.9)
Chemical				
NAA (15 ppm) (T_6)	18.8 (4.4)	3.5 (2.0)	1.5 (1.6)	7.9 (2.7)
2,4-D (5 ppm) (T_7)	13.0 (3.6)	2.5 (1.7)	1.8 (1.6)	5.8 (2.3)
Triacontanol (0.25 ppm) (T_8)	13,0 (3.7)	5.3 (2.4)	3.5 (2.1)	7.9 (2.7)
Cycocel (1000 ppm) (T_9)	17.5 (4.2)	5.0 (2.4)	4.5 (2.3)	9.0 (3.0)
Biological				
Azospirillum (T_{10})	22.8 (4.8)	3.3 (1.9)	1.8 (1.6)	9.3 (2.8)
Azospirillum L. (T_{11})	--	1.0 (1.3)	1.0 (1.4	
F test	NS	*	NS	
C.D (p=0.05)	--	0.9	--	
Interaction (Treatments x seasons)				NS

SE_1 = March-June 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990, () = $\sqrt{X}$ transformed values

NS = Non significant

control (1.0). The number was less than control only under 60 cm x 60 cm spacing (0.8). All the chemical treatments increased the number of crinkled fruits over control with triacontanol (0.25 ppm) (5.3) and CCC (1000 ppm)(5.0) recording significant increase (Plate 11). Azospirillum increased the number (3.3) while local strain of Azospirillum was on par with control.

4. **Crinkled fruit weight/plot**

The treatment differed significantly only during spring 1989-90 (Table 21). During summer 1989 and 1990, there was no significant difference among the treatments. Treatment means pooled over the three seasons did not differ significantly. During spring 1989-90, among the physical treatments, 60 cm x 15 cm spaced plot recorded significant increase in crinkled fruit weight (30.0g) over control (8.8 g). Crinkled fruit weight/plot decreased over control under broadcasting (7.5 g). All the chemical treatments increased weight of crinkled fruits over control with triacontanol (0.25 ppm) (52.5 g) and CCC (1000 ppm) (61.3 g) recording significant increase. Azospirillum increased the weight of crinkled fruits (35.0g) while local strain of Azospirillum decreased it.

E. **Effect of biological agents on seed germination (%) and seedling vigour (cm)**

Germination was maximum on treating Azospirillum (79.3%) followed by local strain of Azospirillum (72.7%)


CONTROL 60X45
TRIA 0·25 ppm

Table 21 Effect of physical, chemical and biological agents on crinkled fruit weight/plot (5.4 x 4.2 m^2) in okra

Treatments	Cropping seasons SE1	SE3	SE4	Pooled mean over SE1+SE3+SE4
	SE_1	SE_3	SE_4	$SE_1+SE_3+SE_4$
Physical				
Broadcasting (T_1)	174.0 (12.9)	37.5 (2.5)	37.5 (5.4)	73.0 (6.9)
60 cm x 60 cm sapcing (T_2)	264.3 (15.4)	10.0 (2.7)	85.0 (7.0)	119.8 (8.4)
60 cm x 45 cm spacing (T_3) (control)	189.3 (13.2)	8.8 (2.6)	50.0 (6.3)	82.7 (7.4)
60 cm x 30 cm spacing (T_4)	306.0 (17.4)	30.0 (5.4)	37.5 (5.5)	124.5 (9.4)
60 cm x 15 cm spacing (T_5)	300.0 (17.3)	58.7 (7.6)	60.0 (6.9)	139.6 (10.6)
Chemical				
NAA (15 ppm) (T_6)	371.3 (19.2)	42.5 (5.9)	41.3 (6.3)	151.7 (10.4)
2,4-D (5 ppm) (T_7)	275.3 (15.5)	27.5 (4.0)	65.0 (8.0)	122.6 (9.1)
Triacontanol (0.25 ppm) (T_8)	262.5 (15.9)	52.5 (7.1)	87.5 (8.9)	134.1 (10.6)
Cycocel (1000 ppm) (T_9)	420.0 (20.1)	61.3 (7.8)	140.0 (11.4)	207.1 (13.1)
Biological				
Azospirillum (T_{10})	446.3 (20.9)	35.0 (5.1)	45.0 (6.0)	175.4 (10.6)
Aozspirillum L. (T_{11})	--	5.0 (1.9)	20.0 (4.1)	--
F test	NS	*	NS	
C.D (p=0.05)	--	3.61	--	
Interaction (Treatments x seasons)				NS.

SE_1 = March-June 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990, () = $\sqrt{X}$ transformed values

NS = Non significant

(Table 22). The increase over control was not significant. Seedling height increased significantly on treating with Azospirillum (14.0cm) and local strain of Azospirillum (14.7 cm) over control (11.0cm) (Plate 12).

F. Effect of physical, chemical and biological agents on root characters

1. Tap root length (cm)

Among the physical treatments, significant increase in root length was recorded under 60 cm x 60 cm spacing (31.1 cm) over control (24.1 cm) (Table 23). Root length decreased over control in all other cases with 60 cm x 15 cm spaced (17.4 cm) and broadcasted plants (15.2 cm) recording significant reduction in length. Among the chemical treatment, root length was higher than control only on applying NAA (15 ppm) (29.6 cm). Azospirillum treatment increased root length significantly (28.2 cm). Local strain of Azospirillum also increased root length (24.7 cm) over control.

2. Tap root diameter (cm)

Among the physical treatments 60 cm x 60 cm spaced plants recorded higher root diameter (15.6 cm) over control (14.4 cm) (Table 23). Root diameter decreased significantly in all other cases with broadcasting recording the minimum diameter (7.0cm). Among the chemical treatments, root diameter

Table 22 Effect of *Azospirillum* on seed germination (%) and seedling vigour/height (cm) in okra

	Treatments				
	Azospirillum	*Azospirillum* L.	Control	F test	C.D (p=0.05)
Germination (%)	79.3	72.7	51.3	NS	-
Seedling height (cm)	14.0	14.7	11.0	*	1.8

Table 21 Effect of physical, chemical and biological agents on crinkled fruit weight/plot ($5.4 \times 4.2\ m^2$) in okra

Treatments	Cropping seasons			Pooled mean over
	SE_1	SE_3	SE_4	$SE_1+SE_3+SE_4$
Physical				
Broadcasting (T_1)	174.0 (12.9)	37.5 (2.5)	37.5 (5.4)	73.0 (6.9)
60 cm x 60 cm sapcing (T_2)	264.3 (15.4)	10.0 (2.7)	85.0 (7.0)	119.8 (8.4)
60 cm x 45 cm spacing (T_3) (control)	189.3 (13.2)	8.8 (2.6)	50.0 (6.3)	82.7 (7.4)
60 cm x 30 cm spacing (T_4)	306.0 (17.4)	30.0 (5.4)	37.5 (5.5)	124.5 (9.4)
60 cm x 15 cm spacing (T_5)	300.0 (17.3)	58.7 (7.6)	60.0 (6.9)	139.6 (10.6)
Chemical				
NAA (15 ppm) (T_6)	371.3 (19.2)	42.5 (5.9)	41.3 (6.3)	151.7 (10.4)
2,4-D (5 ppm) (T_7)	275.3 (15.5)	27.5 (4.0)	65.0 (8.0)	122.6 (9.1)
Triacontanol (0.25 ppm) (T_8)	262.5 (15.9)	52.5 (7.1)	87.5 (8.9)	134.1 (10.6)
Cycocel (1000 ppm) (T_9)	420.0 (20.1)	61.3 (7.8)	140.0 (11.4)	207.1 (13.1)
Biological				
Azospirillum (T_{10})	446.3 (20.9)	35.0 (5.1)	45.0 (6.0)	175.4 (10.6)
Aozspirillum L. (T_{11})	--	5.0 (1.9)	20.0 (4.1)	--
F test	NS	*	NS	
C.D (p=0.05)	--	3.61	--	
Interaction (Treatments x seasons)				NS.

SE_1 = March-June 1989, SE_3 = Dec.1989-March 90, SE_4 = March-May 1990, () = $\sqrt{X}$ transformed values

NS = Non significant

(Table 22). The increase over control was not significant. Seedling height increased significantly on treating with Azospirillum (14.0cm) and local strain of Azospirillum (14.7 cm) over control (11.0cm) (Plate 12).

F. Effect of physical, chemical and biological agents on root characters

1. Tap root length (cm)

Among the physical treatments, significant increase in root length was recorded under 60 cm x 60 cm spacing (31.1 cm) over control (24.1 cm) (Table 23). Root length decreased over control in all other cases with 60 cm x 15 cm spaced (17.4 cm) and broadcasted plants (15.2 cm) recording significant reduction in length. Among the chemical treatment, root length was higher than control only on applying NAA (15 ppm) (29.6 cm). Azospirillum treatment increased root length significantly (28.2 cm). Local strain of Azospirillum also increased root length (24.7 cm) over control.

2. Tap root diameter (cm)

Among the physical treatments 60 cm x 60 cm spaced plants recorded higher root diameter (15.6 cm) over control (14.4 cm) (Table 23). Root diameter decreased significantly in all other cases with broadcasting recording the minimum diameter (7.0cm). Among the chemical treatments, root diameter

Table 22 Effect of *Azospirillum* on seed germination (%) and seedling vigour/height (cm) in okra

	Treatments				
	Azospirillum	*Azospirillum* L.	Control	F test	C.D (p=0.05)
Germination (%)	79.3	72.7	51.3	NS	-
Seedling height (cm)	14.0	14.7	11.0	*	1.8

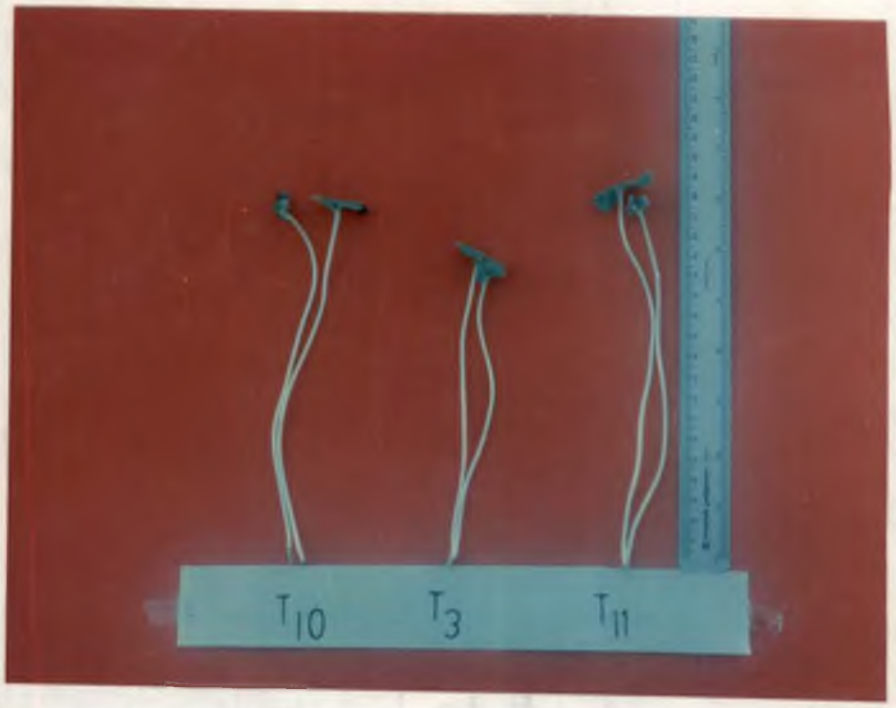
T10
T3
T11

Table 23 Effect of physical, chemical and biological agents on tap root length (cm), tap root diameter (cm) and lateral root number in okra

	Treatments												
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	F test	C.D (p=0.05)
Tap root length (cm)	15.2	31.1	24.1	20.3	17.4	29.6	20.1	23.0	22.1	28.2	24.7	*	6.2
Tap root diameter (cm)	7.0	15.6	14.4	11.5	10.6	14.9	22.7	14.8	15.7	17.4	16.9	*	2.6
Lateral root number	12.3	21.5	17.5	16.8	15.5	16.0	12.5	18.8	19.8	26.5	18.8	*	5.4

was higher than control in all cases with 2,4-D (5 ppm) recording significant increase (22.7 cm). Azospirillum increased root diameter significantly (17.4 cm). Root diameter was higher than control on treating with local strain of Azospirillum (16.9 cm).

3. Number of lateral roots

Among the physical treatments, 60 cm x 60 cm spacing increased the lateral root number (21.5) over control (17.5). The number decreased over control in all other cases with minimum value recorded under broadcasting (12.3). Among the chemical treatments, lateral root number increased on applying triacontanol (0.25 ppm) (18.8) and CCC (1000 ppm) (19.8). The increase in number of lateral roots was highly significant on applying Azospirillum (26.5). Local strain of Azospirillum also increased lateral root number though not significantly.

G. Heat units availability

During summer 1989, heat units of 1635.84 were available. During late kharif 1989 and spring 1989-90, 1103.45 and 1545.15 heat units were recorded respectively. Heat units of 1434.05 was available during summer 1990.

H. Gross returns due to application of physical, chemical and biological agents

Among the physical treatments, 60 cm x 15 cm spacing recorded maximum increase over control during all seasons