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Effect of Biofertilizers on Vegetative Growth of Okra

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ABSTRACT: An experiment was carried out at the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh from March to July, 2001 to investigate the effect of biofertilizers on morpho-physiological characters of okra. The experiment was laid out in a randomized complete block design with four replications. There were nine treatments such as T_0 (control), T_1 (*Azotobacter* biofertilizer), T_2 (*Azospirillum* biofertilizer), T_3 (*Azotobacter*+*Azospirillum* biofertilizers), T_4 (*Azotobacter*+Cowdung 5 ton ha^{-1}), T_5 (*Azospirillum* +Cowdung 5 ton ha^{-1}), T_6 (*Azotobacter*+*Azospirillum*+Cowdung 5 ton ha^{-1}), T_7 (Cowdung 5 ton ha^{-1}) and T_8 (60% Nitrogen). The experimental results revealed that significant variations exist among the treatments regarding morphological characters e.g. plant height, number of leaves/plant, stem base diameter, tap root length, and physiological characters like, root dry weight, leaf area index and crop growth rate. Number of leaves/plant, stem base diameter, root length, root dry weight, leaf area index and crop growth rate were found higher in T_4, T_5, T_6 and T_8 than the others. In all the parameters, T_8 gave the similar result with biofertilizers in combination with cowdung treatments and T_7 showed identical with T_0 (control). Biofertilizer treatments had insignificant effect on 1000-seed weight (g). Experimental results mentioned above revealed that morpho-physioligical characters of okra could be modified by the application of biofertilizer+cowdung. However, biofertilizers+Cowdung treatments were comparable to T_8 (60% Nitrogen) in this study. This suggests that T_4 or T_6 or T_5 were more benificial in environmentally friendly okra cultivation and may be used as an alternative of inorganic nitrogen by saving cost of production and sustaining productivity.

Keywords : Biofertilizers,Vegetative growth, Okra

Okra [*Abelmoschus esculentus* (L.) Moencti] (also called ladys finger, derosh, or bhendi) is a member of the family Malvaceae. It is originated in the tropical Africa or Asia and now a days it is widely grown as vegetable crop throughout the tropics (Purseglove, 1968). Its tender green fruits are popular as vegetable among all classes of people in Bangladesh and elsewhere. The average yield of okra in Bangladesh is very low compared to those of other developed countries where the yields are as high as 7-12 t/ha (Yamaguchi, 1998).

The soils of Bangladesh are very deficient in nitrogen. So urea is being used extensively for all crops to obtain a high yield. Its extensive use has been inflicting an adverse effect on environment causing pollution of drinking water and damaging beneficial soil flora and fauna. The sources of nutrients for crops are the nutrients reserve in soils, organic manures, chemical fertilizers and biofertilizers. None of these sources is complete and therefore, no one is sufficient to sustain soil fertility and crop productivity. For that reason, combination of inorganic, organic and biofertilizers are being stressed upon now a days as integrated nutrient management approach. In this context biofertilizers may play a vital role. In recent years, biofertilizers have become an important component in integrated nutrient supply system and holds a great promise to improve crop yields through better nutrient supplies. *Azotobacter* and *Azospirillum* are the two most important non-symbiotic N_2-fixing bacteria and considered to be very important for fixation of nitrogen in non-leguminous crops. Besides N_2 fixation, *Azotobacter* synthesizes and secretes considerable amounts of biologically active substances like B vitamins, nicotinic acid, pentothenic acid, biotin, heteroxins, gibberellins etc. which enhance root growth of plants (Rao, 1986; Mishutin, 1970). Another important characteristic of *Azotobacter* association with crop improvement is excretion of ammonia in the rhizosphere in the presence of root exudates, which helps in modification of nutrient uptake by the plants (Narula and Gupta, 1986). The ability of *Azospirillum* to produce plant growth regulatory substances along with N_2-fixation stimulate growth and thereby productivity. The changes that occur in the plant roots help in transport of minerals and water (Sarig *et al.*, 1988). All these factors combined together produce positive effects on crop yield especially for cereals and vegetables.

Research work on okra with different biofertilizers have been conducted in various parts of the world. But very little

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works have been done on this crop under the agro-ecological condition of Bangladesh. Thus the present research was undertaken to see the effect of biofertilizers on vegetative growth of okra.

MATERIALS AND METHODS

The experiment was conducted at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the summer season (March to July) of 2001 to evaluate the effect of biofertilizers on morpho-physiological properties of okra. The experimental field is located at 24°75' N latitude and 90°50' East longitude at the elevation of 18m above the sea level. The topography of experimental field was Medium High Land belonging to the Sonatala Soil series of Grey Floodplain Soil type under the Agro-ecological zone Old Bramaputra Floodplain. The soil was silty loam. The experiment consisted of nine treatments like T_0 (control), T_1 (*Azotobacter* biofertilizer), T_2 (*Azospirillum* biofertilizer), T_3 (*Azotobacter*+*Azospirillum* biofertilizers), T_4 (*Azotobacter*+Cowdung 5 ton ha^{-1}), T_5 (*Azospirillum* +Cowdung 5 ton ha^{-1}), T_6 (*Azotobacter*+*Azospirillum*+Cowdung 5 ton ha^{-1}), T_7 (Cowdung 5 ton ha^{-1}) and T_8 (60% of recommended nitrogen as urea)

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 4 replications. The number of unit plots was 36 and the plot size was 12 m^2 (4 m×3 m). The experimental land was ploughed and cross ploughed six times with a power tiller and each ploughing was followed by laddering to break up the soil clods to attain good tilth. After final land preparation the experimental plot was laid out and the edge around each unit plot was raised to check run out of the materials. The plots were fertilized at the rate of 120 kg triple superphosphate (TSP) and 100 kg Muriate of Potash (MP) per ha as basal dose. Cowdung was applied at a rate of 5 tons ha^{-1}. Urea fertilizer was applied in respective plots prior to sowing at a rate of 90 kg ha^{-1}

Biofertilizers were prepared at Soil Microbiology Laboratory, Bangladesh Institute of Nuclear Agriculture (BINA) with the *Azotobacter chrococcum* (Azo-7) and *Azospirillum brasilense* (Azosp. 122) strains collected from Microbiology Division of Indian Agricultural Research Institute (IARI), New Delhi, India. Broth culture of *Azotobacter* and *Azospirillum* were prepared for seed inoculation. Jensens Broth Medium (Tilak, 1998) was used for *Azotobacter* culture preparation and Nitrogen Free Bromothymol Blue (NFB) Medium (Doeberiner *et al.* 1976) was used for *Azospirillum* biofertilizer preparation.

The okra cv. BARI Dherosh 1 seeds were soaked in *Azotobacter, Azospirillum* and mixed broth culture for half an hour so that a layer of cells could be adhered to seed coat. Seeds were sown on 31 March, 2001 in rows of raised beds. Row to row and plant to plant spacing were maintained at 60 cm and 50 cm, respectively. Three seeds were sown in each pit. Then the seeds were covered with fine soil by hand.

For more bacterial population and effectiveness, 2nd dose of *Azotobacter* and *Azospirillum* broth cultures were applied in all the pits so that it can easily be established in rhizosphere and rhizoplan of okra plant. Broth cultures of 2.1×10^7 cells/ml of *Azotobacter* and 2.7×10^7 cells/ml of *Azospirillum* culture were used in the ratio of 1:25 with tap water to inoculate rhizosphere soil.

Thinning was done after 5-6 days of emergence to keep only one healthy seedling in each pit. Three times weeding were done to keep the plots free from weeds. Stagnant water was effectively drained out at the time of heavy rain. Other cultural management practices were undertaken throughout the cropping season for proper growth and development of the okra plant. Recommended pesticides were used to control weeds, diseases and insects.

Data were collected on the following aspects: Plant height, number of leaves per plant, stembase diameter, root length, root dry weight, leaf area index (LAI) and crop growth rate (CGR). LAI and CGR were calculated using standard formulae.The collected data on different parameters under study were analysed statistically. Analysis of variance was calculated. The means for all the treatments were calculated. Co-efficients of variation were calculated to determine the precision of the experiment. The significance of difference between the pairs of treatment means was evaluated by Duncans Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Plant height

The effect of *Azotobacter, Azospirillum* biofertilizers, cowdung and nitrogen fertilizer on the plant height of okra have been presented in Table 1. The plant height ranged from 42.07 to 47.93 cm, 60.53 to 75.85 cm, 71.12 to 86.41 cm, 85.46 to 106.9 cm, 117.3 to 134.4 cm and 130.2 to 147.5 cm at 30, 45, 60, 75, 90 and 105 DAS respectively. A positive and significant effect of biofertilizers was observed on the plant height of okra. Statistically significant increase in plant height was recorded at all the growth stages except 30 DAS. *Azotobacter* (T_1) and *Azospirillum* (T_2) singly or in combination (T_3) gave higher plant height over control at different plant growth stages i.e. 45, 60, 75, 90 and 105 DAS. *Azotobacter, Azospirillum* and *Azotobacter+Azospirillum* showed better performance when applied with cowdung. T_4, T_5 and T_6 showed significantly higher plant height over control. Similar plant height to control was recorded by T_7 in all the

Table 1. Effect of biofertilizers, cowdung and nitrogenous fertilizer on plant height of okra.

Treatments	Plant height (cm)						Plant height (cm) at last matured fruit harvest i.e. at 120 DAS (Seed production)
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	
T_0	42.07	60.53b	71.12b	85.46b	117.3b	130.2b	117.7b
T_1	45.87	70.60ab	78.97ab	96.54ab	126.2ab	140.3ab	126.0ab
T_2	46.82	72.27ab	79.39ab	95.38ab	127.1ab	142.1ab	127.2ab
T_3	46.84	71.93ab	80.22ab	96.52ab	126.9ab	141.0ab	126.8ab
T_4	47.55	73.93a	83.98a	103.50a	131.5a	146.9a	130.7a
T_5	47.69	74.46a	85.03a	105.80a	133.7a	147.5a	132.2a
T_6	47.83	75.25a	84.40a	106.90a	134.4a	147.1a	130.9a
T_7	44.32	67.01ab	77.06ab	92.75ab	120.6ab	138.2ab	120.3ab
T_8	47.93	75.85a	86.41a	103.70a	134.0a	147.4a	131.4a
Level of significance	NS	**	**	**	**	**	*
CV (%)	6.07	5.92	7.10	4.74	5.11	4.25	4.88

Same letters do not differ significantly at 5% level of probability.
* = Signifciant at 5% level
** = Significant at 1% level
NS = Not significant
T_0 = Control
T_1 = *Azotobacter* biofertilizer
T_2 = *Azospirillum* biofertilizer
T_3 = *Azotobacter*+*Azospirillum* biofertilizers
T_4 = *Azotobacter*+Cowdung
T_5 = *Azospirillum*+Cowdung
T_6 = *Azotobacter*+*Azospirillum*+Cowdung
T_7 = Cowdung 5 ton ha^{-1}
T_8 = 60% Nitrogen

Table 2. Effect of biofertilizers, cowdung and nitrogenous fertilizer on number of leaves per plant at different growth stages of okra.

Treatments	Number of leaves/plant					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
T_0	7.00	12.50b	23.25c	28.50c	28.00c	27.25b
T_1	7.75	14.50ab	28.75ab	34.50ab	36.50ab	33.00ab
T_2	7.50	14.25ab	27.25ab	33.25ab	34.25ab	32.50ab
T_3	7.50	14.50ab	28.25ab	33.75ab	34.75ab	32.75ab
T_4	7.75	15.50a	30.50a	37.50a	38.75a	36.50a
T_5	7.75	15.00a	30.25a	36.25a	38.50a	35.25a
T_6	7.75	15.25a	30.25a	36.50a	38.65a	35.75a
T_7	7.00	13.75ab	25.75bc	31.75bc	32.50bc	31.50ab
T_8	8.00	16.00a	29.50ab	36.50a	37.75ab	35.50a
Level of significance	NS	*	**	**	**	**
CV (%)	11.57	9.35	7.07	5.95	7.21	8.92

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NS = Not significant
T_0 = Control
T_1 = *Azotobacter* biofertilizer
T_2 = *Azospirillum* biofertilizer
T_3 = *Azotobacter*+*Azospirillum* biofertilizers
T_4 = *Azotobacter*+Cowdung
T_5 = *Azospirillum*+Cowdung
T_6 = *Azotobacter*+*Azospirillum*+Cowdung
T_7 = Cowdung 5 ton ha^{-1}
T_8 = 60% Nitrogen

growth stages of okra except at 30 DAS. T_8 resulted significantly higher plant height than uninoculated treatment and highest at 30, 45 and 60 days after sowing. At all the growth stages this treatment showed significantly higher plant height over control. *Azotobacter* and *Azospirillum* fixed nitrogen from atmosphere and relased to soil for uptake by plant. As a

Table 3. Stem base diameter of okra as influenced by biofertilizers, cowdung and nitrogenous fertilizer at different stages of plant growth.

Treatments	Stem base diameter (cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
T_0	0.35	0.78	1.44b	1.90b	2.40b	2.63b
T_1	0.36	0.79	1.58ab	1.98ab	2.50ab	2.78ab
T_2	0.36	0.80	1.57ab	1.99ab	2.53ab	2.79ab
T_3	0.37	0.81	1.59ab	2.01ab	2.55ab	2.80ab
T_4	0.38	0.82	1.69a	2.05a	2.65a	2.94a
T_5	0.38	0.82	1.69a	2.07a	2.67a	2.95a
T_6	0.38	0.82	1.70a	2.08a	2.71a	2.98a
T_7	0.36	0.81	1.55ab	1.93b	2.47b	2.73ab
T_8	0.39	0.83	1.68a	2.05a	2.70a	2.91a
Level of significance	NS	NS	**	**	**	**
CV (%)	5.77	4.37	4.80	3.09	4.80	3.68

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NS = Not significant
T_0 = Control
T_1 = *Azotobacter* biofertilizer
T_2 = *Azospirillum* biofertilizer
T_3 = *Azotobacter*+*Azospirillum* biofertilizers
T_4 = *Azotobacter*+Cowdung
T_5 = *Azospirillum*+Cowdung
T_6 = *Azotobacter*+*Azospirillum*+Cowdung
T_7 = Cowdung 5 ton ha^{-1}
T_8 = 60% Nitrogen

result, plant height was increased. The result of present study supports the finding of Parvatham *et al.* (1989) who reported that the greatest plant height was obtained at 25 and 50 days after sowing from soil application of *Azospirillum brasilense* inoculum (at 2.5 kg/ha) followed by the growth regulator mixture treatment (1 mM each of IAA, GA and Kinetin).

Number of leaves per plant

The number of leaves/plant ranged from 7 to 8 in 30 DAS, 12.50 to 16.00 in 45 DAS, 23.25 to 30.50 in 60 DAS, 28.50 to 37.50 in 75 DAS, 28.00 to 38.75 in 90 DAS, 27.25 to 36.50 in 105 DAS respectively (Table 2). A significant variation in number of leaves per plant due to application of biofertilizers was found at different stages of plant growth except 30 DAS. The maximum number of leaves per plant was achieved from T_4, T_5, T_6, T_8 at all the stages of growth and the lowest by T_0 treatment. T_1, T_2 and T_3 showed significant increase in number of leaves/plant over control at 60, 75 and 90 DAS. *Azotobacter* or *Azospirillum* or *Azotobacter*+*Azospirillum* in combination with cowdung gave significantly higher number of leaves/plant over control in all the stages of plant growth except 30 DAS and similar with 60% Nitrogen. Seed inoculation with *Azotobacter chroococcum* was reported to increase number of green leaves/plant of maize cv. African Tall (Rohitashav *et al.*, 1993).

Stem base diameter

The observed data on stem base diameter at all the growth stages have been presented in Table 3. Stem base diameters ranged from 0.35 to 0.39 cm, 0.78 to 0.83 cm, 1.44 to 1.70 cm, 1.90 to 2.08 cm, 2.40 to 2.71 cm, 2.63 to 2.98 cm in 30 DAS, 45 DAS, 60 DAS, 75 DAS, 90 DAS and 105 DAS, respectively. From the result, it was found that up to 45 DAS, there was no significant increase in stem base diameter among the treatments. On the other hand, after 45 DAS, the effect of biofertilizer on stem base diameter was significant. All the treatments showed a similar trends at 60 to 105 DAS in respect of stem base diameter measurement. *Azotobacter* in combination with *Azospirillum* showed better performance than single application. Among the treatments, the highest result was obtained by T_6 at 60, 75, 90 and 105 DAS and the lowest by control. T_8 resulted significantly higher stem base diameter than uninoculated treatment.

Root length

The root length varied from (7.23 to 7.88), (9.73 to 11.56), (11.10 to 14.30), (14.10 to 17.88), (17.15 to 20.35) and (18.60 to 22.85) cm at 30, 45, 75, 90 and 105 DAS, respectively. The results presented in Table 4 showed that the effect of biofertilizer treatments on root length of okra was significant at all stages of growth except 30 DAS. T_1, T_2 and T_3

Table 4. Influence of biofertilizers, cowdung and nitrogenous fertilizer on root length at different growth stages of okra.

Treatments	Root length (cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
T_0	7.23	9.73b	11.10c	14.10c	17.15c	18.60b
T_1	7.53	10.65ab	13.25ab	16.58ab	19.23ab	20.89ab
T_2	7.65	10.90ab	13.65ab	16.63ab	19.38ab	20.93ab
T_3	7.60	10.73ab	13.60ab	16.75ab	19.33ab	20.91ab
T_4	7.75	11.30a	14.02a	17.65a	20.05a	22.25a
T_5	7.87	11.52a	14.30a	17.88a	20.35a	22.85a
T_6	7.80	11.50a	14.05a	17.75a	20.15a	22.45a
T_7	7.28	9.95b	12.30bc	15.30bc	18.73bc	20.80ab
T_8	7.88	11.56a	13.83a	17.60a	20.10a	21.42a
Level of significance	NS	**	**	**	**	**
CV (%)	5.92	5.49	5.05	5.19	6.41	5.46

Same letters do not differ significantly at 5% level of probability.
** = Significant at 1% level
NS = Not significant
T_0 = Control
T_1 = *Azotobacter* biofertilizer
T_2 = *Azospirillum* biofertilizer
T_3 = *Azotobacter*+*Azospirillum* biofertilizers
T_4 = *Azotobacter*+Cowdung
T_5 = *Azospirillum*+Cowdung
T_6 = *Azotobacter*+*Azospirillum*+Cowdung
T_7 = Cowdung 5 ton ha^{-1}
T_8 = 60% Nitrogen

Table 5. Root dry weight of okra as influenced by biofertilizers, cowdung and nitrogenous fertilizer at different growth stages of plant.

Treatments	Root dry weight (g/plant)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
T_0	0.75b	1.85b	4.18c	6.05b	14.40c	24.84c
T_1	0.80ab	1.99ab	4.93ab	6.84ab	15.52ab	27.60ab
T_2	0.82ab	2.00ab	4.95ab	6.89ab	15.95ab	27.61ab
T_3	0.83ab	2.01ab	4.99ab	6.95ab	15.97ab	27.98ab
T_4	0.86a	2.10a	5.35a	7.20a	16.58a	28.90a
T_5	0.87a	2.13a	5.39a	7.49a	16.65a	28.97a
T_6	0.88a	2.14a	5.42a	7.61a	16.85a	29.11a
T_7	0.79ab	1.95ab	4.47bc	6.50ab	14.90bc	25.51bc
T_8	0.88a	2.14a	5.43a	7.19a	16.00ab	27.50ab
Level of significance	*	*	**	**	**	**
CV (%)	6.10	6.08	7.89	7.15	5.63	4.29

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NS = Not significant
T_0 = Control
T_1 = *Azotobacter* biofertilizer
T_2 = *Azospirillum* biofertilizer
T_3 = *Azotobacter* + *Azospirillum* biofertilizers
T_4 = *Azotobacter* + Cowdung
T_5 = *Azospirillum* + Cowdung
T_6 = *Azotobacter* + *Azospirillum* + Cowdung
T_7 = Cowdung 5 ton ha^{-1}
T_8 = 60% Nitrogen

gave higher root length over control at 60, 75 and 90 DAS but identical at 45 and 105 DAS. *Azotobacter* or *Azospirillum* or in combination with cowdung gave significantly higher root length over control and similar to 60% Nitrogen application. T_5 gave the highest root length at 60, 75, 90 and 105 DAS and the smallest root length was observed in control at all the growth stages.

Azotobacter and *Azospirillum* biofertilizer have the affinity

to establish on root system. Both release plant growth promoting substances (Rao, 1986; Mishutin, 1970). They supply their atmospheric fixed nitrogen to root hairs and as a result root growth might be accelerated. Soil application of *Azospirillum brassilense* inoculum at 2.5 kg/ha resulted greatest root length of okra cultivar cv. Pusa Sawani (Parvatham *et al.*, 1989). Seed treatment with *Azospirillum* was also reported to produce longer and thicker roots of Radish compared to control (Sundaravela and Muthukrishnan, 1993).

Root dry weight

Data on root dry weight of okra were presented in Table 5. The root dry weight ranged from 0.75 to 0.88 g, 1.85 to 2.14 g, 4.18 to 5.43 g, 6.05 to 7.61 g, 14.40 to 16.85 g and 24.84 to 29.11 g at 30, 45, 60, 75, 90 and 105 DAS, respectively. T_1, T_2 and T_3 gave higher root dry weight over control at 60, 75, 90, 105 DAS. But these three treatments resulted significant variation over control in respect of root dry weight at 60, 90 and 105 DAS. These three treatments showed more or less similar result regarding root dry weight at all growth stages. T_4, T_5 and T_6 showed better performance at 75, 90 and 105 DAS. At 75, 90 and 105 DAS, T_6 gave the highest root dry weight. T_8 resulted significantly higher root dry weight than uninoculated treatment and highest at 30, 45 and 60 days after sowing. The results indicate that due to biofertilizer application significant increase in root dry weight was found at most growth stages. In addition to nitrogen fixation, *Azotobacter* and *Azospirillum* could secrete different biologically active substances which promoted root growth and formation of more number of lateral roots. Moreover, synergistic relationship at rhizosphere may be present between the two (Tilak, 1988). These factors combinedly helped in increased root dry weight by biofertilizer inoculated treatments.

Leaf area index

Data on leaf area index as affected by *Azotobacter* and *Azospirillum* biofertilizers, cowdung and nitrogen fertilizer have been presented in Table 6. The range of leaf area index was from 0.17 to 0.19 at 30 DAS, 1.40 to 1.61 at 45 DAS, 2.33 to 2.90 at 75 DAS, 2.46 to 3.49 at 90 DAS, 2.02 to 2.38 at 105 DAS. A positive and significant effect of biofertilizers was observed on leaf area index. T_1, T_2 and T_3 gave higher leaf area index over control during the late growth stage. T_4, T_5 and T_6 treatments showed better performances than other treatments at all growth stages except 30 DAS and 45 DAS. T_6 gave the highest leaf area index (3.49 and 2.38) at 90 and 105 DAS, respectively. On the other hand, T_4 resulted the highest leaf area index (2.90 and 4.51) at 60 and 75 DAS, respectively. Statistically similar leaf area index with control was recorded by T_7 (Cowdung) in all the growth stages of okra. T_8 (60% Nitrogen) resulted significantly higher leaf

Table 6. Leaf area index as influenced by biofertilizers, cowdung and nitrogenous fertilizer at different growth stages of okra.

Treatments	Leaf area index					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
T_0	0.17	1.40b	2.33b	3.83b	2.46c	2.02c
T_1	0.18	1.52ab	2.61ab	4.17ab	3.18ab	2.30ab
T_2	0.18	1.53ab	2.51ab	4.10ab	3.19ab	2.31ab
T_3	0.18	1.53ab	2.63ab	4.20ab	3.22ab	2.31ab
T_4	0.18	1.59a	2.90a	4.51a	3.44a	2.36a
T_5	0.19	1.60a	2.88a	4.49a	3.45a	2.37a
T_6	0.19	1.58a	2.87a	4.50a	3.49a	2.38a
T_7	0.18	1.49ab	2.54ab	4.15ab	2.83bc	2.15bc
T_8	0.19	1.61a	2.82a	4.42a	3.41a	2.34a
Level of significance	NS	**	**	**	**	**
CV (%)	5.44	4.16	5.00	7.57	7.57	3.86

Same letters do not differ significantly at 5% level of probability.
** = Significant at 1% level
NS = Not significant
T_0 = Control
T_1 = *Azotobacter* biofertilizer
T_2 = *Azospirillum* biofertilizer
T_3 = *Azotobacter*+*Azospirillum* biofertilizers
T_4 = *Azotobacter*+Cowdung
T_5 = *Azospirillum*+Cowdung
T_6 = *Azotobacter*+*Azospirillum*+Cowdung
T_7 = Cowdung 5 ton ha^{-1}
T_8 = 60% Nitrogen

Table 7. Effect of biofertilizers, cowdung and nitrogenous fertilizer on crop growth rate of okra at different growth stages.

Treatments	Crop growth rate (mg/cm^2/day)				
	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
T_0	0.55c	0.89b	0.96	0.85c	0.80
T_1	0.58bc	1.00a	1.06	0.94bc	0.94
T_2	0.58bc	1.02a	1.03	0.94bc	0.94
T_3	0.59bc	1.02a	1.15	0.94bc	0.96
T_4	0.65a	1.01a	1.09	1.04ab	1.02
T_5	0.66a	1.02a	1.07	1.05ab	0.95
T_6	0.66a	1.04a	1.05	1.04ab	1.04
T_7	0.57c	0.93ab	1.02	0.92bc	0.87
T_8	0.66a	1.02a	1.04	1.04ab	0.94
Level of significance	**	**	NS	**	NS

Same letters do not differ significantly at 5% level of probability.
** = Significant at 1% level
NS = Not significant
T_0 = Control
T_1 = *Azotobacter* biofertilizer
T_2 = *Azospirillum* biofertilizer
T_3 = *Azotobacter* + *Azospirillum* biofertilizers
T_4 = *Azotobacter* + Cowdung
T_5 = *Azospirillum* + Cowdung
T_6 = *Azotobacter* + *Azospirillum* + Cowdung
T_7 = Cowdung 5 ton ha^{-1}
T_8 = 60% Nitrogen

area index than uninoculated treatment and the highest leaf area index (0.193 and 1.61) at 30 and 45 DAS. At all the growth stages, T_8 showed significantly higher leaf area index over control.

Leaf area index depends on the capacity of the plants to generate leaves/plant. The increased leaf area index of the treated plants is related to their higher leaf area due to biofertilizer, cowdung and nitrogen application. Nitrogen fixation by *Azotobacter* and *Azospirillum* helped in increase in leaf size. Kurdikeri *et al.* (1988) reported that seed treatment with *Azotobacter* increased leaf area of cotton at 30 and 45 days after sowing, compared with seeds soaked in water. *Azotobacter*+*Azospirillum*+100% N_2 of recommended dose was reported to increase the leaf area of cauliflower cv. botrytis (Bambal *et al*,. 1998). *Azospirillum*+50% Nitrogen resulted in maximum leaf area in banana cv. Giant (Tiwary, 1998).

Crop growth rate

Crop growth rate (CGR) was estimated at 15 days interval starting from 45 and continued up to 105 days after sowing. In all treatments, CGR increased gradually with the advancement of crop growth, maximized at 75 DAS and thereafter decreased slightly (Table 7). Data revealed that a positive and significant effect of biofertilizers was observed on the CGR of okra. Significant difference in CGR was recorded at 45, 60 and 90 DAS, while there was insignificant difference on CGR among the treatments at 75 and 105 DAS. T_1, T_2 and T_3 showed higher CGR over control at 60 DAS but identical at 45 and 90 DAS. T_4, T_5 and T_6 gave significantly higher CGR over control, and similar with T_8 at 45, 60 and 90 DAS. T_7 performed identical to control and inferior to biofertilizer treatments. The highest crop growth rates obtained by biofertilizers in combination with cowdung treatments were 0.66 in 45 DAS, 1.04 in 60 DAS, 1.09 in 75 DAS, 1.05 in 90 DAS, 1.04 in 105 DAS, while the lowest crop growth rate was achieved by control treatment at all the growth stages. Due to fixation and supply of atmospheric nitrogen by *Azotobacter* and *Azospirillum* higher dry matter production was found at all the growth stages in T_4, T_5 and T_6. As a result, crop growth rate was higher than T_0.

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