EFFECT OF FOLIAR APPLICATION OF GIBBERELLIC ACID ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF OKRA (*Abelmoschus esculentus* L.)

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF FOLIAR APPLICATION OF GIBBERELLIC ACID ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF OKRA (Abelmoschus esculentus L.)"** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE** in **AGRICULTRUL BOTANY**, embodies the result of a piece of bonafide research work carried out by **G. M. RABBANE**, Registration No. **12-04965** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

June, 2018

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Dedicated to
My
Beloved Parents

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The Author

EFFECT OF FOLIAR APPLICATION OF GIBBERELLIC ACID ON MORPHO-PHYSIOLOGICAL CHARACTERS AND YIELD OF OKRA (*Abelmoschus esculentus* L.)

ABSTRACT

The experiment was carried out in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to August 2018 to study the effect of foliar application of gibberellic acid on morpho-physiological characters and yield of okra. The experiment considered of two factors. Factor A – two okra variety; V_1 = BARI dheros-1 and V_2 = Lal teer hybrid dheros and Factor B: Gibberellic acid (GA_3) - 4 levels; G_0 = Control (0 ppm GA_3), G_1 = 50 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 150 ppm GA_3 and G_4 = 200 ppm GA_3. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield components and yield of okra were recorded. Different growth and yield parameters were significantly influenced by variety and GA_3 and also with their combinations. Results showed that the variety V_2 (Lal teer hybrid dheros) gave highest yield and yield contributing parameters compared to V_1 (BARI dheros-1). Again, regarding, GA_3 effect, the treatment G_2 (100 ppm GA_3) it gave the best performance on yield and yield contributing parameters. Considering treatment combination of variety and GA_3, the highest SPAD value (68.35 at 50 DAS), length of fruit (11.70 and 14.90 cm at 60 and 90 DAS, respectively), diameter of fruit (1.86 and 1.92 cm at 60 and 90 DAS, respectively), number of fruits plant^{-1} (24.60), fresh weight of fruits plant^{-1} (348.20 g), fruit yield plot^{-1} (6.26 kg) and fruit yield ha^{-1} (17.88 t) was obtained from the treatment combination of V_2G_2 whereas the lowest SPAD value (40.65 at 50 DAS), length of fruit (6.67 and 8.87 cm at 60 and 90 DAS, respectively), diameter of fruit (1.34 and 1.42 cm at 60 DAS and 90 DAS, respectively) number of fruits plant^{-1} (24.60), fresh weight of fruits plant^{-1} (198.70 g), fruit yield plot^{-1} (3.47 kg) and fruit yield ha^{-1} (9.92 t) were observed from the treatment combination of V_1G_O. These results suggested that gibbrellic acid increased the yield of okra.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
ppm	=	Parts per million
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is a popular vegetable belongs to the family Malvaceae and locally known as “Dherosh” or “Bhindi”. It is also known as Lady’s finger. It is an annual vegetable crop grown from seed in tropical and sub-tropical parts of the world (Tahkur and Arora, 1986). It is well distributed throughout the Indian sub-continent and East Asia (Rashid, 1990). Okra is specially valued for its tender and delicious edible pods which is rich source of vitamins and minerals. Tender green pods of okra contains approximately 2.2% protein, 0.2% fat, 9.7% carbohydrate, 1.0% fibre and 0.8% ash (Purseglove, 1987). The pods have some medicinal value with mucilaginous preparation which may used as plasma replacement or blood volume expander (Savello *et al.,* 1980). In Bangladesh, vegetable production is not uniform round the year and it is plenty in winter but less in quantity in the summer season. Therefore, as vegetable okra can get an importance in *kharif* season as well as summer season in our country context.

In Bangladesh the total production of okra is about 246 thousand tons which was produced from 7287.5 hectares of land in the year 2010 with average yield about 3.38 t/ha which is very low (BBS, 2011) compared to that of other developed countries where the yield is as high as 7.0-12.0 t/ha (Yamaguchi, 1998). The reduction in the productivity and yield in okra is mainly due to lack of location specific varieties or hybrids tolerant to insects and diseases high fruit bearing habit, length and weight of fruit etc. Hence it is of practical importance to develop a high yielding hybrid or variety coupled with resistance/tolerance to the disease and also higher production ability. High yield and quality of vegetables depends on high seeds quality of improved cultivars, in addition to the optimum cultural practices. Okra seed production is not organized. The main supply of seeds is from unreliable sources.

The farmers after a number of market picks of the commercial crop reserve the late pods for seeds. Such seeds are usually of low quality (Ahmed, 1994). Plant growth regulators like auxins, gibberellins and cytokinins are used in the agriculture for better growth and yield responses ultimately affecting crop production (Briant, 1974; Srivastava and Sachan, 1971). Gibberellins (GAs) mediate many responses in plants from seed germination to the senescence (Davies, 1995). The most widely available compound is a gibberellic acid (GA_3) which induces stem and internode elongation, seed germination, enzyme production during germination, and fruit setting and growth (Dijkstra and Kuiper, 1989; Ross *et al.*, 1990; Davies, 1995). GA_3 is a natural growth hormone and is a part of a type of plant hormones called gibberellins. It promotes cell division and a number of plant development mechanisms and encourages numerous desirable effects such as plant height, uniform flowering, reduced time to flowering and increased flower number and size (Srivastava and Srivastava, 2007). Foliar application of gibberellic acid modified also plant growth and pod characteristics of okra (Asghar *et al*., 1997).

Gibberllic acid (GA_3) has potentiality to control growth and flowering process also its application increase petiole length, leaf area (Mehraj *et al*., 2013), delayed petal abscission (Khan, 2006 and Emongor, 2004) and yield also (Islam, 2014) that used in agriculture since long ago (Naeem, 2001). Gibberellin induces cell elongation, development of fruit and flowering. It increase the size and number of fruit and break the dormancy of seed, buds and underground organ like bulb, tuber, corm, etc. It increases the size and number of flower and growth of stem in light, i.e. revival of light inhibited stem growth and increase the size of leaves (Islam, 2014).

Under the above circumstances, the present research was undertaken to study the effect of gibbrellic acid on the growth and yield of okra. Considering the above facts, the present research was under taken with the following objectives:

1. To know the varietal performance of okra
2. To determine the effect of gibberellic acid on growth and yield of okra
3. To find out the combined effect of gibberellic acid and variety on growth and yield of okra

CHAPTER II

REVIEW OF LITERATURE

There is very few information about performance of okra with different variety or cultivars available at present in Bangladesh. However, some information is available on the effect of variety and GA_3 management on the performance of okra production. So there is a brief review of the available literature has been furnished in this section.

2.1 Effect of variety

Rajesh *et al*. (2018) conducted an investigation for the evaluation of Okra [*Abelmoschus esculentus* (L.) Moench] hybrids for yield and yield attributes was carried out at Allahabad region with 11 hybrids and 3 check varieties during kharif -2014. The data was recorded for sixteen quantitative characters *viz*., days to 50% germination, plant height(cm), number of leaves/plant, number of branches/plant, inter nodal length(cm), days to first flower appears, days to emergence of 50% blooming, first pod (fruit) occurring node, length of fruit (cm), fruit girth (cm), fresh weight of fruit (g), number of seeds per fruit, number of fruits per plant, fruit yield per plant (g), fruit yield per hectare (t) and per cent incidence of YVMV to obtain and estimate the best hybrid for yield (quantitative) attributes and YVMV resistance. Fruit yield was ranged from 14.7 tonnes (OKHYB-12) to 24.5 tonnes (OKHYB-15) with an average of 18.5 tonnes and YVMV infestation on plants (%) was ranged from 0% (OKHYB-6, OKHYB-7 and OKHYB-13) to 64.17% (OKHYB-12) with an average of 28.9%. It is concluded that based on the mean performance of all the sixteen yield attributes, hybrids OKHYB-15, OKHYB-10 and OKHYB-4 were found superior and resistant to YVMV in performances than check varieties (Arka Anamika, Pusa Sawani and HOK-152).

Elhag and Ahmed (2014) conducted this study during two consecutive years (2008/2009) at the Experimental farm, College of Agricultural Studies, Sudan University of Science and Technology. The effects of three sowing dates, 1st and 20th of July and 10th of August on seed yield of two okra cultivars (Khartoumia and Wad Gammer) were studied. Both vegetative growth (50% flowering) and seed yield (after pod drying) were evaluated. The results showed that almost similar negative response of both cultivars to late sowing. It could be concluded that both okra growth and seed yield were significantly negative affected by late sowing (last week of July or later). Although no significant differences were noticed between the two cultivars in their response to sowing date okra cultivars might differ in their response to sowing date. The variety Khartoumia performed better than Wad Gammer in respect of yield and yield contributing parameters.

Iyagba *et al*. (2012) conducted field studies at the Federal University of Technology, Owerri, Nigeria to determine the influence of weed interference on the growth and yield of three okra (*Abelmochus esculentus* (L) Moench) varieties. Three varieties of okra (NHAe47-4, Lady's finger and V35) were weeded using five weeding regimes (weedy check, unweeded till 5 weeks after sowing (WAS), weeding once each at 3 WAS and 4 WAS and weed free). The treatment combinations were laid out in a randomized complete block design with three replications. Plant height for okra varieties was in the decreasing order of Lady's finger < NHAe47-4 < V35 while leaf area was in the increasing order of NHAe47-4>V35> lady's finger in both years. More flowers/plant was obtained from NHAe47-4 while the least number of flowers aborted were obtained from the Lady's finger.

2.2 Effect of GA_3

The Gibberellic acid (GA_3) is widely used phytohormone in horticulture and food industry. Gibberellins enhance biological activity in stimulating cell division or

cell elongation, early flowering, fruit set, fruit growth, and seed germination etc. today 72 forms of gibberellins are known and commercialy available gibberellins are GA_3, GA_4, GA_7 (Taiz, 2010).

Sanodiya *et al.* (2017) conducted an investigation entitled, "Effect of growth regulator on growth, yield and seed quality parameters of okra (*Abelmoschus esculentus* L.) cv. Utkal Gaurav.". Foliar spray two growth regulator like GA_3, NAA were spray at different concentration and 20^{th}, 40^{th}, 60^{th} day after sowing. Result revealed foliar spray is significantly positive impact on growth regulator in growth parameters i.e. T_4 (NAA 50 @ ppm at 20days spray) was first flowering (31.47 days), 50 percent flowering (40.40 days), first harvesting (37.02 days), minimum days to fruit maturity (66.02 days), yield parameter T_5 (NAA 50 ppm at 40 days spray) maximum fruit weight (16.47 gm.), dry fruit weight (5.61 gm.), fruit length (16.58 cm), fruit girth (6.46 cm), fruit yield per plot (4.83 kg), yield per hectare (96.63 q/ha.), and seed quality parameter T_6 (NAA @ 50 ppm spray at 60 DAS) recorded maximum root length (9.40cm), fresh seedling weight (6.43 g), dry seedling weight (26.77mg) and Vigour index type-I and II (2210.29 and 22.58) and as compare to other treatment and T_9 (control).

Chormule *et al*. (2017) conducted an investigation entitled "Effect of spacing and plant growth regulators on plant growth parameters, seed yield and its attributes of okra [*Abelmoschus esculentus* (L.) Moench]" with two consecutive seasons (kharif 2015 and kharif 2016). Seeds of okra variety GJO-3 were treated with aqueous solution of growth regulators *viz*., GA_3, IBA and NAA, each at 50, 100 and 150 ppm concentrations and without growth regulators (water soaking) and with three plant spacing (S_1 : 45 cm × 30 cm, S_2 : 60 cm × 30 cm and S_3 : 60 cm × 45 cm). All plant growth parameters, seed yield and its attributes studied were significantly influenced by different plant spacing and application of different plant growth regulators. Interactions effects of spacing and seed treatments (S x T) with growth regulators were found significant for field emergence, number of

branches per plant, fruit length and fruit thickness during kharif 2015; for fruit length and fruit thickness during kharif 2016; and for field emergence in pooled over years. A combination of wider plant spacing 60 cm x 45 cm and GA_3 @ 150 ppm was found best suited combination, as it has good field emergence and produced significantly and/or comparatively the maximum plant height, stem diameter, number of branches per plant, number of fruits per plant, fruit length, fruit thickness, number of seeds per fruit and seed yield per plant.

Singh *et al*. (2017) conducted a field experiment during the kharif season to study the effect of GA_3 and NAA on yield and quality of Okra. Yield parameters like number of fingers harvested per plant, average weight of finger, yield per plant, yield per plot and yield per hectare and quality parameters like total number of pickings, thickness of finger and length of finger were analyzed. The experiment consisted of 16 treatments combination involving two growth regulators with four levels each (0, 25, 50 and 75 ppm). GA_3 and NAA (75 ppm) was found to be the most effective in increasing more number of fingers harvested per plant (15.10), total number of pickings (9.33) and thickness of finger (1.54 cm). Treatment combinations of (GA_3 75 and NAA 50 ppm) increased average weight of finger (16.28 g) and yield per plant (0.232 g). Maximum length of finger (15.82 cm) was found treatment combinations of (GA_3 and NAA 50 ppm each).

Tomar *et al.* (2016) showed that the combinatorial use of GA_3, NAA and 2, 4- D at specific concentration (GA_3 at 30 ppm, NAA at 30 ppm and 2, 4-D at 5 ppm) considerably increase the weight of fruit and significantly increases total yield up to 523 q/h in tomato.

Chandiniraj *et al*. (2016) reported that maximum plant height (75.60 cm), plant spread in north-south direction (46.53 cm), number of days to flowering (47.56) and maximum fruit diameter (1.24 cm) were recorded in GA3 60 ppm treated plants in chilli.

Krishnaveni *et al.* (2016) revealed maximum yield attributes like number of pods per plant, length of pod and seed yield per plant were recorded with single pinching at 25 DAS and application of GA3 50 ppm in fenugreek.

Thomson *et al.* (2015) examined the effect of plant growth substances on growth, flowering, yield and economics of garden pea, *(Pisum sativum)* L cv. Bonneville. Plants were sprayed with treatments *viz* control, NAA at (25 and 50 ppm), GA3 at (50 and 100 ppm), the results revealed that the plant growth substance GA3 at (100 ppm) showed highest growth parameters. Days to first flowering ranged between 48.97 and 52.75. The minimum days (48.97) to first flowering were taken by the treatment GA_3 at (100 ppm) and all other treatments were *statistically at par* for the days taken to first flowering.

Bello (2015) revealed that the okra seeds were pre-soaked GA_3 at (100 ppm) for 3-4 hours observed that increase the plant height, number of leaves, leaf Area and dry matter (yield) in okra.

Rathod *et al.* (2015) reported that the maximum plant height (34.53 cm), plant spread (31.46 cm), number of leaves per plant (15.73) and number of branches per plant (7.66) in treatment where GA_3 at 200 ppm was applied, while minimum plant height (25.93 cm), plant spread (24.70 cm), number of leaves per plant (11.66) and number of branches per plant (5.20) respectively observed in the treatment in Cycocel 200 ppm, in French bean.

Njogu *et al.* (2015) reported that foliar application of GA_3 causes significant increase in subsequent germination, enhances vegetative growth, average number of stems, leaflets number and more yields in potato.

Ravat and Makani (2015) reported that among the different treatments GA_3 @ 100 ppm was the best for growth characters *viz*., plant height (cm), number of leaves, number of internodes per plant, days to flower initiation and days to 50 (%) flowering. While the start sprayed with thiourea @ 500 ppm yielded the best

for growth characters ***viz.*** leaf area (cm^2), leaf area index and total dry weight of the plant. Ravat and Makani (2015) also reported that among the different treatments GA_3 @ 50 ppm was the best for seed quality traits ***viz.,*** average pod weight, 100 seed weight, while the plants sprayed with thiourea @ 500 ppm best for fruit yield traits viz., number of pods per plant, length of pod, number of seeds per pod, seed yield per plant and seed yield per hectare.

Mehraj *et al.* (2015) found that the tallest plant (89.0 cm), longest petiole (29.0 cm), number of leaves (49.0 per plant), leaf area (29.7 cm^2), number of branches (5.5 per plant), fresh weight (84.5 g/plant) and dry weight (10.9 g/plant) was from G_1 (GA_3 50 ppm) which was statistically identical with G_2 (NAA 50 ppm) while minimum from G_0 (control fresh water). The maximum number of pods (33.4/plant), pod length (17.5 cm), pod diameter (1.7 cm) and fruit yield (338.1 g/plant, 2.9 kg/plot and 16.4 t/ha) were also recorded from G_1 (50 ppm GA_3) which was statistically identical with G_2 (50 ppm NAA) while minimum from control. GA_3 and NAA have the potentiality to increase the yield of okra but GA_3 was found to be most effective in the present study.

Samapika *et al.* (2015) reported that the treatment of GA_3 20 ppm + NAA 100 ppm was significantly superior in terms of growth parameters ***i.e.*** vine length (cm), number of primary branches per plant and number of leaves per plant as compared to control and other applied treatments in cucumber. Treatment GA_3 20 + NAA 100 ppm was also produced highest fruit yield of cucumber as compared to control.

Prajapati and Varma (2014) reported that application of GA3 at 50 ppm to the maximum number of branches (5.52) and minimum days taken for initiation of flower (48.50 day) in sweet pepper.

Chowdhury *et al.* (2014) reported that the combined use of 100 ppm GA_3 and 11.5 t/ha poultry manure produced the tallest plants in okra. Both the growth regulators

and organic manures enhanced early flowering. The highest fruit yield (16.67 t/ha) was recorded from 100 ppm GA_3 followed by 1000 ppm miraculan (16.49 t/ha). The highest yield (18.03 t/ha) of okra was found from poultry manure, closely followed by vermicompost (17.59 t/h). Considering the treatment combinations, the highest yield was harvested from 100 ppm GA_3 + poultry manure (19.62 t/ha) followed by 100 ppm GA_3 + vermicompost (19.01 t/h), 1000 ppm miraculan + vermicompost (18.42 t/h) and 1000 ppm + poultry manure (18.30 t/h), respectively.

Mohammadi *et al.* (2014) found that GA_3 application increased okra plant height irrespective of cultivar and GA_3 concentration (50 and 100 mg per liter), but without increasing flower induction or pod set. He also concluded that the germination was promoted, inhibited or not affected by GA_3. It was also found that GA_3 had no effect on pod dimensions or more than 100 seed weight. Similarly, GA_3 application did not consistently affect seed moisture content, but it did however, increase the number of seeds per pod. Overall, pod and seed characteristics were affected more by harvest time then by GA_3 application.

Moniruzzaman *et al.* (2014) reported that the GA_3 (Gibberellic acid) and NAA (Naphthalene acetic acid) had no significant effect on plant height and stem diameter at the end of the crop period and days to 100% flowering. NAA 40 ppm produced highest percentage of long and medium styled-flower, leaf photosynthesis and Fv/Fm (efficiency of photosystem II). The variety BARI Begun-5 was earlier to 100% flowering which took 44 days after transplanting which out yielded BARI Begun-10. NAA 40 ppm coupled with BARI Begun-5 gave the maximum Fv/Fm and long-styled flower percent.

Kumar *et al.* (2014) studied that gibberellic acid plants treated with the application of GA_3 @ 50 ppm showed an increased plant height, number of leaves, number of fruits, fruit weight, ascorbic acid and total soluble solids in tomato.

Shahid *et al*. (2013) conducted an experiment with different concentrations (0, 50, 100 & 200 ppm) of gibberellic acid (GA_3) and naphthalene acetic acid (NAA), alone or in different combinations were sprayed on okra plants at 2-true leaf stage, to ascertain their impact on plant growth, pod production, seed yield and seed quality. All variables regarding vegetative and reproductive growth were significantly influenced by different concentrations of the growth regulators except number of days taken to flowering. Growth regulators were less effective when applied individually as compared to their combined use; however, performance of plants treated with individual PGR was better than the untreated plants. The number of leaves plant^{-1} and plant height was higher in plants when sprayed with GA_3 and NAA @ 200+100 ppm as well as with GA_3 and NAA @ 200+200 ppm. The number of pods plant^{-1}, pod length, pod fresh and dry weight, seed yield and seed quality (in terms of germination percentage and 1000-seed weight) was maximum in plants receiving foliar spray of both GA_3 and NAA @ 200+200 ppm. These results signify the role of GA_3 and NAA in okra pod production for fresh consumption as well as for seed yield.

Ayyub *et al.* (2013) revealed that the increase in number of foliar application of GA_3 (100 mg/kg) substantially improved the vegetative growth of okra comparing to control plants. It was found that application at different growth stages of okra predominantly boosted the stem elongation and number of leaves per plant, number of pods per plant, number of seeds per pod, seed weight and seed yield. Therefore it can be concluded that foliar application of GA_3 may be an effective strategy for maximizing the growth and yield of okra.

Prasad *et al.* (2013) found that there was a linear increase in growth parameters like plant height and number of branches per plant with increasing level of GA_3 and NAA. The maximum plant height was recorded as 85.3 cm and 82.3 cm with the application of GA_3 @ 80 ppm and NAA @ 100 ppm, respectively after 60 days of transplanting in tomato. The maximum fruit yield (483.6 q/ha and 472.2

q/ha) was obtained with the use of 80 ppm GA_3 and 100 ppm NAA, respectively in tomato.

Shahid *et al.* (2013) reported that growth regulators were less effective when applied individually as compared to their combined use however performance of plant treated with individual PGR was the better than untreated plants. The numbers of pods per plant, pod length, pod fresh and dry weight, seed yield and seed quality (in terms of germination percentage and 1000 seed weight) was maximum in plants receiving foliar spray of both GA_3 and NAA @ 200+200 ppm. These results signify the role of GA_3 and NAA in okra pod production for fresh consumption as well as for seed yield.

Choudhury *et al.* (2013) observed that maximum plant height at 60 DAT (86.01cm), number of flowers cluster per plant (10.60), number of flowers per plant (39.69), number of fruits per plant (36.54), single fruit weight (74.01 g) and yield (28.40 t/ha) were found the minimum for all the parameters in tomato were found in control.

Sure *et al.* (2012) observed that the spraying with GA3 at 25 ppm in four leaf stage at trellis method could be a suitable for enhancing growth and yield in medicinal pumpkin.

Singh *et al.* (2012) found that the Application of 160 ppm GA3 resulted in minimum number of days of first flowering (37.13) and days to 50% flowering (41.33) in okra .

Dhage *et al.* (2011) found that significant effect for plant height (107.74 cm) and intermodal length (3.1 cm) in treatment GA_3 at 150 ppm whereas, numbers of branches (3.53) were found maximum in the treatment IAA at 100 ppm. However, significantly minimum numbers of days required for first flowering (39.67 days) were recorded in treatment GA_3 at 150 ppm in okra. Significant effect for minimum number of days required for first harvesting (44.67 days) were also

recorded in treatment GA_3 at 150 ppm in okra. The significantly maximum parentage of fruit set (74.79) and fruit yield per hectare were observed in same treatment.

Bhagure and Tambe (2011) observed application of GA_3 (50 and 100 ppm) at 30 and 45 days after sowing increase the height of plant, number of leaves, number of internodes, induce early flowering, increase number of flowers, fruit set, number of fruits, and high yield per plant in okra.

Hilli *et al.* (2010) reported the spraying of GA3 @ 50 ppm at four leaves stage, flower stage and fruit initiation stage significantly improved the vine length and Maximum vine length and number of branches recorded in ridge gourd.

Unamba *et al.* (2010) reported that the effect of low concentrations (0,1,5,10,20 and 30 ppm) of gibberellic acid on the growth of *Abelmoschus esculentus* (dwarf) and showed that gibberellic acid significantly stimulated internode elongation, plant height, number of leaves and caused a reduction in the petiole length in both treatment methods. Gibberellic acid also stimulated earlier flowering. The foliar spray application was found to have a significant effect on the plant height when compared with the seed soaking application technique. Although GA_3 stimulated internode elongation, it had no effect on the number of internodes in both the treated plants and the control indicating that dwarfism of this variety of Okra may be due to the absence of adequate endogenous gibberellic acid.

Patil and Patel (2010) reported that GA_3 at 15 mg/l produce the highest percentage of seed germination, stem girth, number of branches, number of leaves per plant and early flowering in okra while GA_3 at 45 mg/l found to be beneficial with respect to plant height, number of internodes and intermodal length. GA_3 at 15 mg/L recorded maximum fruit girth, fruit length, fruit weight, fruit yield per plant and fruit yield per hectare in okra. However, GA_3 at 30 mg/L produced maximum

number of fruits per plant. From the economics point of view, NAA 10 mg/L was found to be profitable as compared to rest of treatments.

Fathima and Balasubramanian (2006) reported that the effect of plant growth regulators like gibberelic acid (GA) and naphthalene acetic acid (NAA) on the quality of best fibres in *A. esculentus.* The fibre quality was best in GA100 + NAA 50 micro gram per ml treatment. Fibre macerate studies showed an increase in fibre length and the slenderness ratio was also high. Proximate analysis of retted fibres re-vealed lower moisture and ash content and an increase in wax content. The physico-mechanical properties showed considerable improvement of fibre quality. Considering the above criteria, GA100 + NAA 50 micro gram per mL treatment brought about advantageous changes for improving the quality of fibers.

Surendra *et al.* (2006) revealed that the growth regulators and micronutrients used in this experiment significant increased the plant height. However, among the growth regulators significant increase in plant height was noticed with GA_3 (25 and 50 ppm) and among micronutrients $FeSO_4$ (0.5%) has shown significant increase in plant height. Among the growth regulators and micronutrients the foliar application of GA_3 (25 and 50 ppm) and $FeSO_4$ (0.5%) at 60 days after sowing (DAS) registered significantly higher fresh fruit yield over other treatments. The increase is due to increase in yield attributing components ***viz.,*** total number of flowers, fruits per plant, fruit length, number of seeds per fruit, seed weight and harvest index. The benefit: cost ratio was higher with application of GA_3 (50 ppm) over all other treatments. It was also indicated that the increase in fruit yield was significantly higher in GA_3 (25 and 50 ppm) as compared to other treatments and was found lowest in control.

Sharma (2006) reported in Brinjal cultivar of Pusa Purple Long produced significantly higher yield at 40 ppm NAA than at GA_3 at 10 ppm and 30 ppm BAP while, the yields at other treatments were at par.

Mohammadi *et al.* (2014) reported that exogenous GA_3 on culture medium was used to increase height of *Dyckia maritima* shoots to facilitate In vitro manipulation. Grapevine fruits (Thompson seedless) treated with GA_3 had increased its size and production. Results revealed that foliar application of GA_3 and nutrients had improved the productivity and quality of lily cut flowers. Stimulation of the enzyme protein synthesis by GA_3 stimulates the overall protein synthesis.

Kumar *et al.* (2014) was conducted with the objective to determine the effects of Gibberellic acid (GA_3) on growth, fruit yield and quality of tomato. The experiment consisted of one tomato variety Golden, and six treatments with five levels of gibberellic acid (GA_3-10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm),. The highest plant height, number of leaves, number of fruits, fresh fruit weight, ascorbic acid and total soluble solid (TSS) was found from GA_3-350 ppm.

Akter *et al.* (2007) conducted an experiment in pot house at BINA, Mymensingh, Bangladesh to evaluate the effects of Gibberellic Acid (GA_3) on growth, and yield of mustard *var*. Bina sarisha-3. Four concentrations *viz*., 0, 25, 50 and 75 ppm of GA_3 were sprayed on canopy at 30 days after sowing. Results revealed that GA_3 at 50 ppm significantly increased plant height, number of fertile siliqua/plant, number of flowers/plant, setting of siliqua/plant (%), dry matter yield, number of seeds/siliqaua, and harvest index, while the number of flowers/plant was significantly increased with the application of 75 ppm GA_3. The highest seed yield/plant was recorded from the application of 50 ppm GA_3 at optimum harvest date. The seed yield/plant was positively correlated with plant height, number of seeds/siliqua, number of fertile siliqua/plant and % of setting siliqua/plant.

Bora and Sarma (2006) carried out a study on the effect of Gibberellic acid (GA_3) and Cycocel on growth, yield and protein content of pea (*cv*. Aparna and Azad-P-1). GA_3 irrespective of concentrations was most effective in promoting shoot

growth while cycocel at all concentrations tried reduced shoot growth. Number of branches per plant was increased with both the hormones. In both the varieties chlorophyll contents were decreased by higher concentrations of GA_3 while cycocel increased it. Both the hormones significantly affected the yield characteristics. GA_3 at 250 pg mL-1 produced maximum number of pods per plant,seed yield, seed index and protein content in seeds in both the varieties. Their study clearly showed that judicious application of GA_3 and cycocel can increase yield and protein content in seeds of pea.

Hoque, *et al.* (2002) investigated two varieties of Mungbean to study the effects of seed treatment and foliar application of GA_3 at 0, 50, 100 and 200 ppm on the growth, yield and yield contributing characters. Seed treatment with GA_3 at 50 ppm increased plant height, number of leaves, fresh and dry weight. Foliar application of GA3at 200 ppm had higher plant height and number of leaf, while that at 100 ppm greater number of pods, higher fresh and dry weight of pod, number of seeds whereas 50 ppm GA_3 resulted higher pod length and ultimately seed yield. The mungbean variety V_2 performed better than V_2 with foliar application of GA_3. This study indicates high potentiality to increase yield of mungbean in Bangladesh by the application of GA_3.

Chaudhary *et al*. (2017) carried out this investigation with ten treatments *viz*., T_1 (Control), T_2 (GA_3 10 ppm), T_3 (GA_3 20 ppm), T_4 (GA_3 30 ppm), T_5 (Ethrel 50 ppm), T_6 (Ethrel 100 ppm), T_7 (Ethrel 150 ppm), T_8 (Ethrel 25 ppm), T_9 (NAA 50 ppm) and T_{10} (NAA 100 ppm). The results revealed that, the maximum length of main vine at 60 and 90 DAS (225.07 and 268.21 cm), respectively, and number of leaves per plant at 60 and 90 days after sowing (205.78 and 332.17) and produced the maximum number of male flower (228.56) were recorded with treatment (T_4) GA3 30 ppm. Treatment (T_7) Ethrel 150 ppm proved to be most effective for produced the minimum number of sub-vine at 60 and 90 DAS (7.78 and 9.22), lower node number at which first female flower appears (5.60), lower node

number per plant at main vine (24.11), lower internodal length (9.56 cm), maximum total leaf area per plant (92.39 cm2), number of female flower (45.78) and fruit set percent (66.18), numbers of fruits (28.78), fruit weight (68.00 g/fruit), fruit yield per plant (2.59 kg), fruit yield per plot (18.14 kg) and higher fruit yield per hectare (129.33 q/ha). The lowered sex ratio was recorded in treatment (T6) Ethrel 100 ppm i.e. (1: 4.06).

Roy and Nasiruddin (2011) conducted a research work to study the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3, viz., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was recorded with 50 ppm GA_3 and 50 ppm GA_3 gave the highest diameter (23.81 cm) of cabbage head while the lowest diameter (17.89 cm) of cabbage head was found in control (0 ppm GA_3) treatment. The application of different concentrations of GA_3 as influenced independently on the growth and yield of cabbage. Significantly the highest yield (45.22 kg/plot and 104.66 t/ha) was found from 50 ppm GA_3.

Shafeek *et al*. (2016) conducted a study to survey the reply of squash plants (*Cucurbita peop* L.) to foliar exercise of several bio-regulators (GA_3) at several concentrations (15, 30, 45 and 60 mg/L) or Ethereal at the levels of (150, 200 and 250 mg/L) and foliar spraying with water (control) to the effect of impact plant growth sex expression, proportion of fruit set, fruits yield and nutritional supplement of squash fruits c.v. Eskandarani. The concise outcome gained from this field research that, mounting the concentrations of growth regulators (GA_3 or Ethereal) fulfilled tallest plant, highest number of leaves and branches, heaviest fresh and dry weight of leaves, branches, leaf area /plant and fruit set percentage as well as total yield and highest values of the percentage of N, protein, dry matter, TSS and vitamin C (mg/100g F.W.) in squash fruit tissues.

Dalai *et al*. (2015) conducted an experiment to assess the effect of various doses of GA_3, NAA and their combined dose. Total eight treatments were tried in RBD with three replications. Out of these, a dose of GA_3 20 ppm + NAA100 ppm was found significantly superior in terms of growth parameters i.e. Vine length plant^{-1} (cm), Number of primary branches plant^{-1}, Number of leaves plant^{-1}, as compared to control and other applied treatment. Similarly, a positive effect was also reported in various flowering, yield and yield attributing characters with GA3 20 + NAA100 ppm. In context of yield a dose of GA_3 20 + NAA100 ppm was produced highest yield of cucumber as compared to control and other treatments during experimentation.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out during the period from March to August 2018. The materials and methods that were used for conducting the experiment have been presented in this chapter.

3.1 Location of the experimental site

The experiment was carried out at the Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 24°09′N latitude and 90°26′E longitudes. The altitude of the location was 8 m from the sea level**.** The location of the experimental field is presented in Appendix I.

3.2 Climatic condition

Experimental location is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of March to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment were collected and presented in Appendix II.

3.3 Soil characteristics of the experimental site

Selected land of the experimental field was medium high land in nature with adequate irrigation facilities and remained utilized for crop production during the previous season. The soil is belongs to the Modhupur Tract under AEZ No. 28. The soil texture of the experimental soil was sandy loam. The nutrient status of the farm soil under the experimental plot with in a depth 0-20 cm were collected and analyzed in the Soil Resources Development Institute (SRDI) Dhaka, and result have been presented in Appendix III.

3.4 Planting materials

The test crop used in the experiment were BARI Dherosh-1 and Lal teer hybrid dheros.

3.5 Collection of seeds

The seeds of okra variety BARI Dherosh-1 was collected from BARI (Bangladesh Agricultural Research Institute), Joydebpur, Gazipur, Bangladesh and seeds of okra variety Lal teer hybrid dheros was collected from Siddique Bazar, Dhaka.

3.6 Treatment of the experiment

Two factors experiment was initiated for the present study which was as follows:

Factor A: Variety – 2 varieties

1. V_1 = BARI dheros-1
2. V_2 = Lal teer hybrid dheros

Factor B: Gibberellic acid (GA_3) - 4 levels

1. G_0 = Control (0 ppm GA_3)
2. G_1 = 50 ppm GA_3
3. G_2 = 100 ppm GA_3
4. G_3 = 150 ppm GA_3
5. G_4 = 200 ppm GA_3

Treatment combinations: 10 treatment combinatios

V_1G_0, V_1G_1, V_1G_2, V_1G_3, V_1G_4, V_2G_0, V_2G_1, V_2G_2, V_2G_3, V_2G_4.

3.7 Land preparation

The plot selected for conducting the experiment was opened march 17, 2018 before one week of seed sowing in the field with a power tiller, and left exposed to the sun. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil was obtained for sowing okra seeds. The soil was treated with insecticides (cinocarb 3G @ 4 kg/ha) at the time of final land preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.8 Application of manure and fertilizers

Urea, Triple super phosphate (TSP) and Muriate of Potash (MP) were used as source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers that were applied to the experimental plot presented as follows.

Fertilizers	Dose/ha
Cowdung	10 t/ha
Urea	150 kg/ha
TSP	100 kg/ha
MP	150 kg/ha

Source:Fertilizer Recommendation Guide, BARC, 2012

The total amount of cowdung, TSP and MP was applied as basal dose at the time of final land preparation. Urea was applied at 15, 30 and 45 days after sowing (DAS).

3.9 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area was divided into three equal blocks. Each block was divided into 10 plots where 10 treatments combination were allotted at random. There were 30 unit plots altogether in the experiment. The size

of the each plot was 2.4 m × 1.5 m. The distance maintained between two blocks and two plots were 0.5 m and 0.5 m, respectively. The spacing was at 60 cm × 50 cm. The layout of the experimental plot is shown in Appendix IV.

3.10 Seeds sowing

The okra seeds were sown in the main field at march 23, 2018 as per treatment. Seeds were treated with Bavistin @ 2ml/L of water before sowing the seeds to control the seed borne diseases. The seeds were sown in rows having a depth of 2-3 cm with maintaining distance from 40 cm and 60 cm from plant to plant and row to row , respectively.

3.11 Collection, preparation and application of GA_3

GA_3 was collected from 33/2 Hatkhola Road,Tikatuly, Dhaka-1203 . A 1000 ppm stock solution of GA_3 was prepared by dissolving 1 g of it in a small quantity of ethanol prior to dilution with distrilled water in one liter of volumetric flask.The stock solution was used to prepare the required concentration for the different GA_3 solution of 50, 100, 150 and 200 ppm concentration were prepared by dissolving 50, 100, 150 and 200 mg/litre GA_3, respectively. At the time of preparation of GA_3 solution small quantity of ethanol was mixed to dissolve properly. Distilled water was used as control solution (0 ppm). Gibberellic acid was applied in the field with hand sprayer.

3.12 Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the okra seedlings.

3.12.1 Gap filling

The seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after germination and such seedling were replaced by new seedlings Replacement was done with healthy seedling in the afternoon having a ball of earth which was also planted on the same date by the side of the unit plot. The seedlings were given watering for 7 days starting from germination for their proper establishment.

3.12.2 Weeding

The weeding was done by nirani with roots at 15, 30 and 45 days after sowing to keep the plots free from weeds.

3.12.3 Irrigation

Light watering was given by a watering cane at every morning and afternoon and it was continued for a week for rapid and well establishment of the germinated seedlings.

3.12.4 Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedings in the field. In spite of Cinocarb 3G applications during final land preparation few young plants were damaged due to attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some discolored and yellowish diseased leaves were also collected from the plant and removed from the field.

3.13 Harvesting

Fruits were harvested at 5 days interval based on eating quality at soft and green condition. Harvesting was started at eating quality level regarding sowing time.

3.14 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of plots, which was recorded plot wise. Data were collected in respect of the growth, yield attributes and yields as affected by different treatments of the experiment.

3.14.1 Plant height (cm)

Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest stem of five plants and mean value was calculated. Plant height was also recorded at 30 days interval starting from 30 days after sowing (DAS) up to 90 days to observe the morphological rate of plants.

3.14.2 Number of leaves per plant

The total number of leaves per plant was counted from each selected plant. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot from 30 DAS to 90 DAS at 30 days interval.

3.14.3 Leaf area (cm^2)

Leaf area (cm^2) was recorded with the instrument of LAI-2200C Plant Canopy Analyzer. It was measured at 60 DAS from each replication.

3.14.4 SPAD value

SPAD value was measured from okra leaves from each replication with the help of SPAD meter and it was measured at 50 DAS.

3.14.5 Length of fruit (cm)

The length of fruit was measured with a meter scale from the neck of the fruit to the bottom of 10 selected marketable fruits from each plot and there average was taken and expressed in cm.

3.14.6 Diameter of fruit (cm)

Diameter of fruit was measured at the middle portion of 10 selected marketable fruit from each plot with a digital calipers-515 (DC-515) and average was taken and expressed in cm.

3.14.7 Number of fruits per plant

The number of fruits per plant was counted from the sample plants for the whole growing period and the average number of fruits produced per plant was recorded and expressed as number of fruits per plant.

3.14.8 Fresh weight of fruits/plant (g)

The weight of fresh fruits was measured with a digital weighing machine from 5 selected plants from each selected plots and there average was taken and expressed in gram.

3.14.9 Yield per plot

Yield of okra per plot was recorded as the whole fruit per plot by a digital weighing machine for the whole growing period and was expressed in kilogram.

3.14.10 Yield per hectare

Yield per hectare of okra fruits was estimated by converting the weight of plot yield into hectare and was expressed in ton.

3.15 Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C software to find out the significance of the difference on growth and yield of okra. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the means of treatment combinations was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The research work was accomplished to investigate the effect of foliar application of gibberellic acid on morpho-physiological characters and yield of okra. Some of the data have been presented and expressed in tables and others in figures for easy discussion, comparison and understanding. The analysis of variance of data respect of all the parameters has been shown in Appendix. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under following headings.

4.1 Growth parameters and morphological parameters

4.1.1 Plant height (cm)

Effect of variety

Different variety had significant influence on plant height at different growth stages (Fig.1 and Appendix V). Results revealed that the highest plant height (43.58, 81.55 and 110.34 cm at 30, 60 and 90 DAS, respectively) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest plant height (40.40, 75.22 and 104.73 cm at 30, 60 and 90 DAS, respectively) was observed from the variety V_1 (BARI dheros-1). Rajesh *et al*. (2018) also found similar result which justify the present study.

Effect of GA_3

There was a significant variation on plant height influenced by different levels of GA_3 application at different growth stages (Fig.2 and Appendix V). The highest plant height (50.37, 92.80 and 120.90 cm at 30, 60 and 90 DAS, respectively) was obtained from the treatment, G_4 (200 ppm GA_3) which was significantly different from all other treatments followed by G_3 (150 ppm GA_3). The lowest plant height

(cm at 30, 50 and 70 DAS, respectively) was observed from the control treatment G_0 (0 ppm GA_3). The results obtained from the present study was similar with the findings of Chormule *et al*. (2017) and Chandiniraj *et al*. (2016).

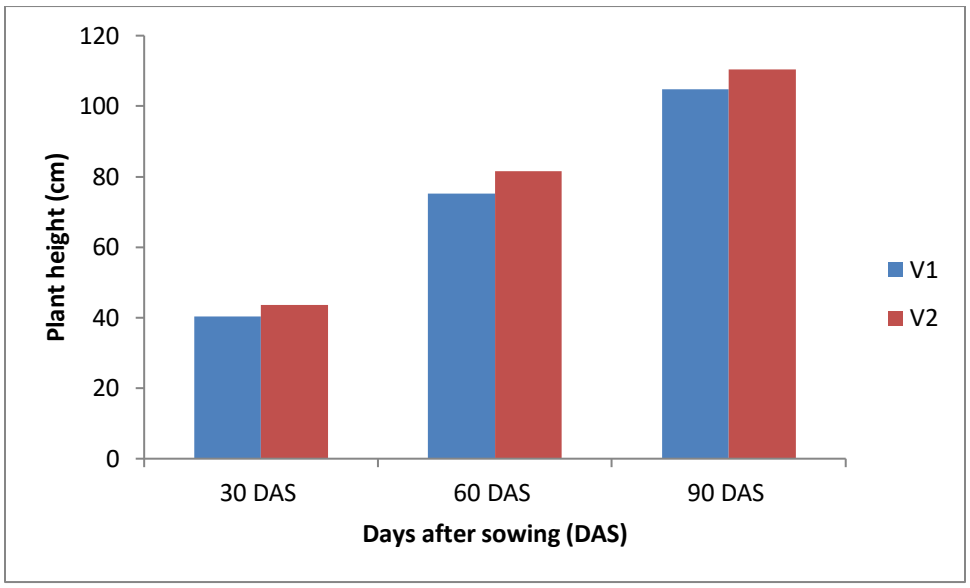

Fig. 1. Plant height of okra influenced by variety

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

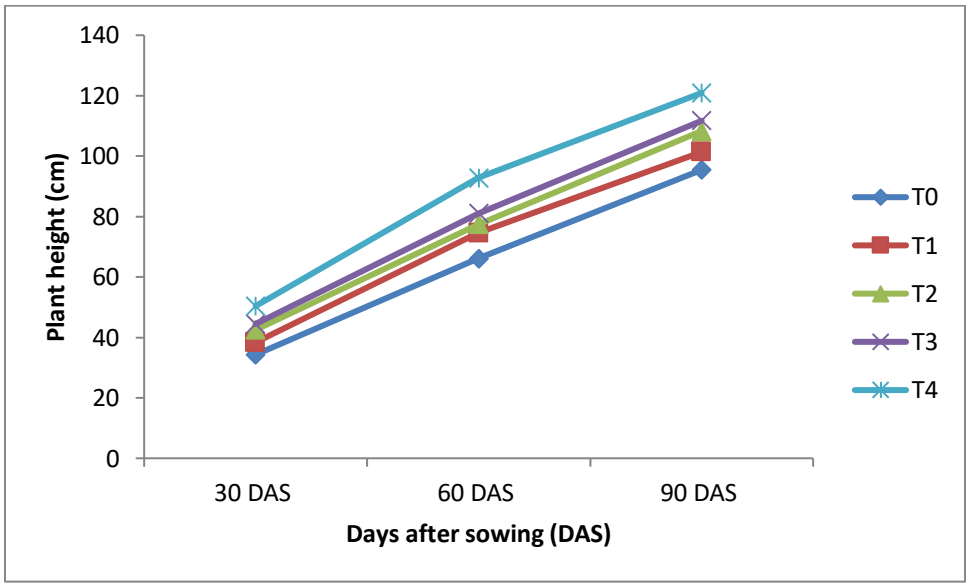

Fig. 2. Plant height of okra influenced by gibberellic acid

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

Combined effect of variety and GA_3

Plant height was significantly influenced by combined effect of variety and GA_3 at different growth stages (Table 1 and Appendix V). The highest plant height (54.53, 101.10 and 127.50 cm at 30, 60 and 90 DAS, respectively) was obtained from the treatment combination of V_2G_4 followed by the treatment combination of V_1G_4. The lowest plant height (33.73, 61.43 and 91.53 cm at 30, 60 and 90 DAS, respectively) was observed from the treatment combination of V_1G_0 which was also significantly different from all other treatment combinations.

Table 1. Plant height of okra influenced by variety and gibberellic acid at different growth stages

Treatment	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
V_1G_0	33.73 e	61.43 g	91.53 g
V_1G_1	36.80 e	73.57 ef	99.53 f
V_1G_2	41.67 cd	76.10 de	107.2 d
V_1G_3	43.60 bc	80.50 c	111.1 bc
V_1G_4	46.20 b	84.50 b	114.3 b
V_2G_0	34.85 e	70.77 f	99.33 f
V_2G_1	39.93 d	75.57 de	103.2 e
V_2G_2	43.33 bc	78.70 cd	109.4 cd
V_2G_3	45.27 b	81.63 bc	112.3 bc
V_2G_4	54.53 a	101.1 a	127.5 a
$LSD_{0.05}$	2.987	3.133	3.531
CV(%)	8.366	10.922	9.634

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3
G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

4.1.2 Number of leaves plant^{-1}

Effect of variety

Significant variation was not observed on number of leaves plant^{-1} at different growth stages influenced by different variety (Fig.3 and Appendix VI). However, the highest number of leaves plant^{-1} (17.34, 23.12 and 27.29 at 30, 60 and 90 DAS, respectively) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest number of leaves plant^{-1} (16.66, 22.07 and 26.65 at 30, 60 and 90 DAS, respectively) was observed from the variety V_1 (BARI dheros-1).

Effect of GA_3

Number of leaves plant^{-1} was significantly varied due to different levels of GA_3 application at different growth stages (Fig.4 and Appendix VI). The highest number of leaves plant^{-1} (22.94, 27.14 and 30.42 at 30, 60 and 90 DAS, respectively) was obtained from the treatment, G_4 (200 ppm GA_3) which was significantly different from all other treatments followed by G_2 (100 ppm GA_3) and G_3 (150 ppm GA_3). The lowest number of leaves plant^{-1} (12.77, 18.33 and 22.87 at 30, 60 and 90 DAS, respectively) was observed from the control treatment G_0 (0 ppm GA_3) which was significantly different from all other treatments. The results obtained from the present study was similar with the findings of Bello (2015), Rathod *et al.* (2015) and Ravat and Makani (2015).

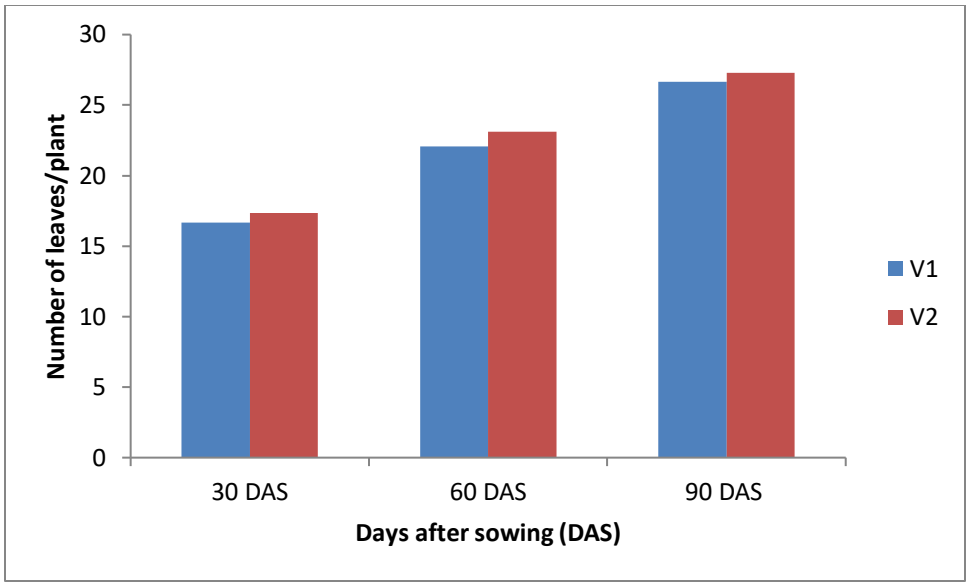

Fig. 3. Number of leaves plant^{-1} of okra influenced by variety

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

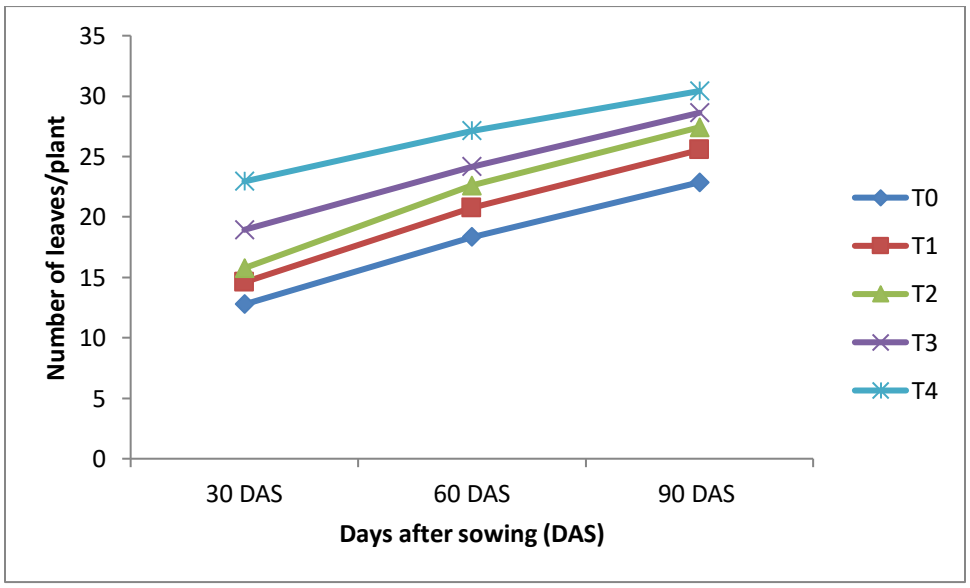

Fig. 4. Number of leaves plant^{-1} of okra influenced by gibberellic acid

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

Combined effect of variety and GA_3

Remarkable variation was observed on number of leaves plant^{-1} at different growth stages influenced by combined effect of variety and GA_3 (Table 2 and Appendix VI). The highest number of leaves plant^{-1} (23.10, 27.87 and 31.30 at 30, 60 and 90 DAS, respectively) was obtained from the treatment combination of V_2G_4 which was significantly different from all other treatment combinations. The lowest number of leaves plant^{-1} (12.37, 17.73 and 22.70 at 30, 60 and 90 DAS, respectively) was observed from the treatment combination of V_1G_0 which was statistically identical with the treatment combination of V_2G_0 at 90 DAS.

Table 2. Number of leaves plant^{-1} of okra influenced by variety and gibberellic acid at different growth stages

Treatment	Number of leaves plant^{-1}		
	30 DAS	60 DAS	90 DAS
V_1G_0	12.37 f	17.73 f	22.70 f
V_1G_1	14.50 de	20.20 de	25.20 e
V_1G_2	15.10 cd	21.93 cd	27.30 cd
V_1G_3	18.57 b	24.07 b	28.53 bc
V_1G_4	22.27 a	26.40 a	29.53 b
V_2G_0	13.17 ef	18.93 ef	23.03 f
V_2G_1	14.70 cde	21.27 d	25.87 de
V_2G_2	16.43 c	23.29 bc	27.53 cd
V_2G_3	19.30 b	24.27 b	28.70 bc
V_2G_4	23.10 a	27.87 a	31.30 a
$LSD_{0.05}$	1.660	1.699	1.665
CV(%)	5.376	8.524	10.731

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

4.1.3 Leaf area (cm^2) at 60 DAS

Effect of variety

Significant influence was noted on leaf area (cm^2) affected by different variety (Fig.5 and Appendix VII). The highest leaf area index at 60 DAS (256.54) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest leaf area index at 60 DAS (245.62) was observed from the variety V_1 (BARI dheros-1).

Effect of GA_3

Leaf area (cm^2) varied significantly due to different levels of GA_3 application (Fig. 6 and Appendix VII). The highest leaf area (cm^2) at 60 DAS (298.98) was obtained from the treatment, G_3 (150 ppm GA_3) which was significantly different from all other treatments followed by G_2 (100 ppm GA_3) and G_4 (200 ppm GA_3) where the lowest leaf area index at 60 DAS (213.66) was observed from the control treatment G_0 (0 ppm GA_3). Ravat and Makani (2015) also found similar results with the present study.

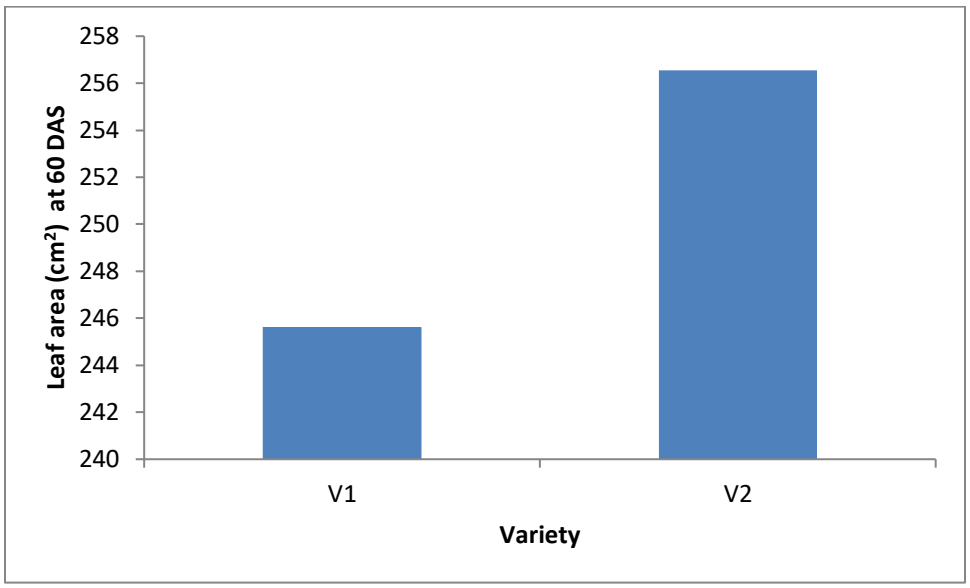

Fig. 5. Leaf area (cm^2) of okra at 60 DAS influenced by variety

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

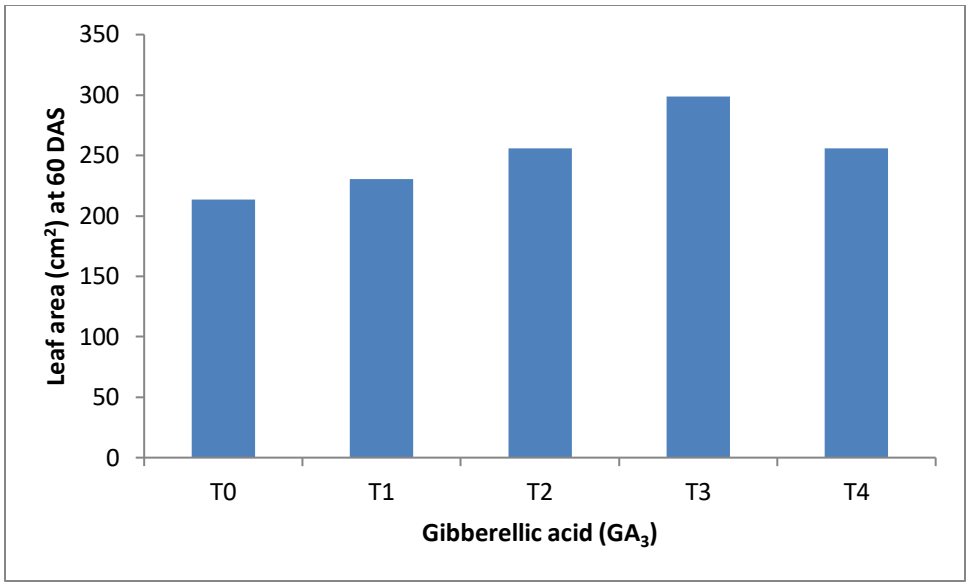

Fig. 6 Leaf area (cm^2) of okra at 60 DAS influenced by gibberellic acid

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3
G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

Combined effect of variety and GA_3

Significant variation was remarked on leaf area (cm^2) as influenced by combined effect of variety and GA_3 (Table 3 and Appendix VII). The highest leaf area index at 60 DAS (310.00) was obtained from the treatment combination of V_2G_3 which was significantly different from all other treatment combinations followed by V_1G_3. The lowest leaf area index at 60 DAS (207.80) was observed from the treatment combination of V_1G_0 which was also significantly different from all other treatment combinations followed by V_1G_1.

Table 3 Leaf area (cm^2) of okra at 60 DAS influenced by variety and gibberellic acid

Treatment	Leaf area (cm^2) at 60 DAS
V_1G_0	207.80 g
V_1G_1	225.20 f
V_1G_2	244.90 de
V_1G_3	287.90 b
V_1G_4	262.30 c
V_2G_0	219.50 f
V_2G_1	236.20 e
V_2G_2	266.90 c
V_2G_3	310.00 a
V_2G_4	250.00 d
$LSD_{0.05}$	9.449
CV(%)	10.522

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

4.1.4 SPAD value **at 50 DAS**

Effect of variety

SPAD value was significant with the effect of different variety (Fig. 7 and Appendix VIII). Results revealed that the highest SPAD value at 50 DAS (55.40) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest SPAD value at 50 DAS (52.18) was observed from the variety V_1 (BARI dheros-1).

Effect of GA_3

Variation on SPAD value was noted influenced by different levels of GA_3 application (Fig. 8 and Appendix VIII). It was observed that the highest SPAD value at 50 DAS (65.62) was obtained from the treatment, G_2 (100 ppm GA_3) which was significantly different from all other treatments whereas the lowest

SPAD value at 50 DAS (42.23) was observed from the control treatment G_0 (0 ppm GA_3) which was also significantly different from all other treatments. Bora and Sarma (2006) also found similar results which supported the present study.

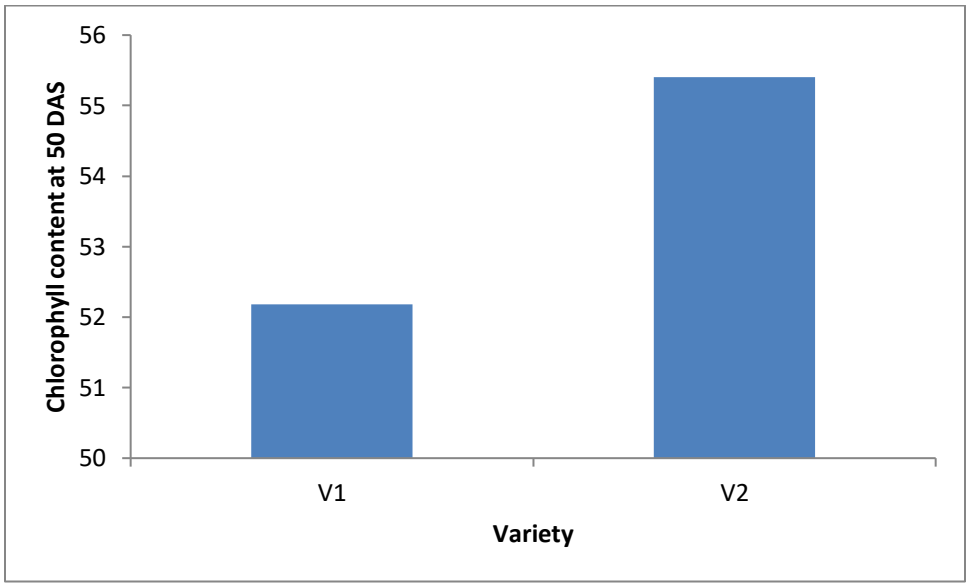

Fig. 7 SPAD value of okra leaves at 50 DAS influenced by variety

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

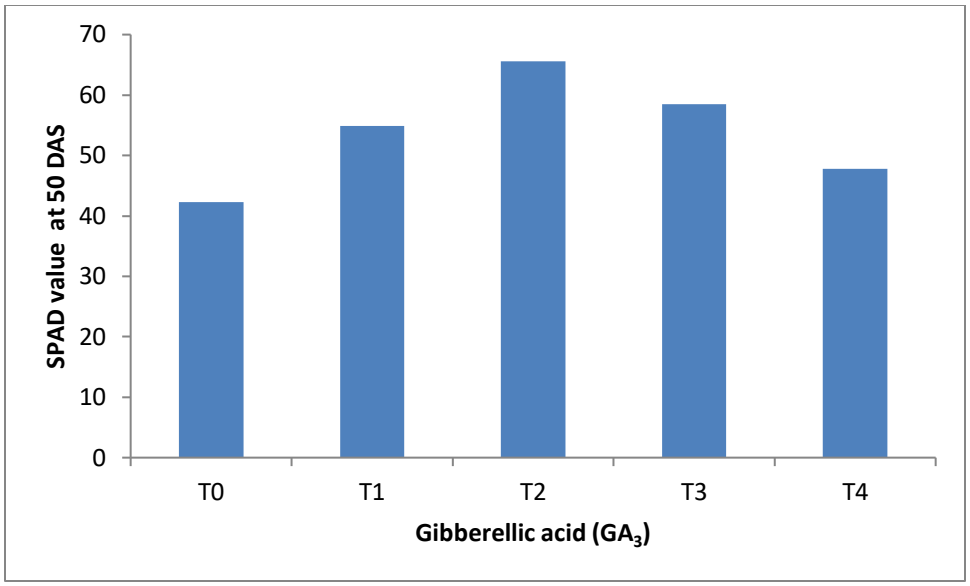

Fig. 8. SPAD value of okra leaves influenced by gibberellic acid

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3
G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

Combined effect of variety and GA_3

SPAD value of okra leaves affect by combined effect of variety and GA_3 was significant (Table 4 and Appendix VIII). The highest SPAD value at 50 DAS (68.35) was obtained from the treatment combination of V_2G_2 which was significantly different from all other treatment combinations followed by V_1G_2 whereas the lowest SPAD value at 50 DAS (40.65) was observed from the treatment combination of V_1G_0 followed by V_1G_4.

Table 4. SPAD value of okra leaves at 50 DAS influenced by variety and gibberellic

Treatment	SPAD value at 50 DAS
V_1G_0	40.65 g
V_1G_1	54.01 de
V_1G_2	62.88 b
V_1G_3	57.91 cd
V_1G_4	45.44 f
V_2G_0	43.80 fg
V_2G_1	55.69 cd
V_2G_2	68.35 a
V_2G_3	59.00 bc
V_2G_4	50.14 e
$LSD_{0.05}$	4.541
CV(%)	3.68

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

4.2 Yield contributing parameters and yield

4.2.1 Length of fruit (cm)

Effect of variety

The recorded data on length of fruit was not significant with the effect of different variety (Table 5 and Appendix IX). However, the highest length of fruit (9.27 and 11.86 cm at 60 and 90 DAS, respectively) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest length of fruit (8.73 and 11.39 cm at 60 and 90 DAS, respectively) was observed from the variety V_1 (BARI dheros-1). Similar result was also observed by Rajesh *et al*. (2018) which supported the present study.

Effect of GA_3

Considerable influence was observed on length of fruit affected by different levels of GA_3 application (Table 5 and Appendix IX). The highest length of fruit (11.00 and 14.70 cm at 60 and 90 DAS, respectively) was obtained from the treatment, G_2 (100 ppm GA_3) which was significantly different from all other treatments followed by G_3 (150 ppm GA_3) at all growth stages. The lowest length of fruit (7.00 and 9.20 cm at 60 and 90 DAS, respectively) was observed from the control treatment G_0 (0 ppm GA_3) which was also significantly different from all other treatments followed by G_1 (50 ppm GA_3). The results obtained from the present study was similar with the findings of Sanodiya *et al*. (2017) and Chormule *et al*. (2017).

Combined effect variety and GA_3

Remarkable variation was recorded on length of fruit due to the combined effect of variety and different levels of GA_3 application (Table 5 and Appendix IX). The highest length of fruit (11.70 and 14.90 cm at 60 and 90 DAS, respectively) was obtained from the treatment combination of V_2G_2 which was statistically identical with the treatment combination of V_1G_2 whereas the lowest length of fruit (6.67 and 8.87 cm at 60 and 90 DAS, respectively) was observed from the treatment combination of V_1G_0 which was also statistically identical with the treatment combination of V_2G_0 at 90 DAS.

Table 5. Yield contributing parameters regarding fruit length of okra influenced by variety and gibberellic acid

Treatment	Length of fruit (cm)	
	60 DAS	**90 DAS**
Effect of variety		
V_1	8.73	11.39
V_2	9.27	11.86
$LSD_{0.05}$	NS	NS
CV(%)	6.731	8.289
Effect of GA_3		
G_0	7.00 d	9.20 d
G_1	8.84 b	11.14 c
G_2	11.00 a	14.70 a
G_3	9.85 b	12.56 b
G_4	8.33 c	10.53 c
$LSD_{0.05}$	0.856	0.642
CV(%)	6.731	8.289
Combined effect variety and GA_3		
V_1G_0	6.67 g	8.87 e
V_1G_1	8.67 de	10.87 d
V_1G_2	10.30 b	14.50 a
V_1G_3	9.70 c	12.20 bc
V_1G_4	8.33 e	10.53 d
V_1G_0	7.33 f	9.53 e
V_2G_1	9.00 d	11.40 cd
V_2G_2	11.70 a	14.90 a
V_2G_3	10.00 bc	12.92 b
V_2G_4	8.33 e	10.53 d
$LSD_{0.05}$	0.4882	0.9442
CV(%)	6.731	8.289

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

4.2.2 Diameter of fruit (cm)

Effect of variety

Significant influence was not found on diameter of fruit affected by different variety (Table 6 and Appendix X). However, the highest diameter of fruit (1.58 and 1.70 cm at 60 and 90 DAS, respectively) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest diameter of fruit (1.55 and 1.64 cm at 60 and 90 DAS, respectively) was observed from the variety V_1 (BARI dheros-1). The results obtained from the present study was similar with the findings of Rajesh *et al*. (2018).

Effect of GA_3

Diameter of fruit varied significantly due to different levels of GA_3 application at 90 DAS, but fruit length at 60 DAS was not significant (Table 6 and Appendix X). However, the highest diameter of fruit (1.84 and 1.90 cm at 60 and 90 DAS, respectively) was obtained from the treatment, G_2 (100 ppm GA_3) and the lowest diameter of fruit (1.36 and 1.43 cm at 60 and 90 DAS, respectively) was observed from the control treatment G_0 (0 ppm GA_3). The results obtained from the present study was similar with the findings of Sanodiya *et al*. (2017) and Chormule *et al*. (2017).

Combined effect variety and GA_3

Significant variation was remarked on diameter of fruit as influenced by combined effect of variety and GA_3 at 90 DAS but at 60 DAS it was not significantly influenced (Table 6 and Appendix X). However, the highest diameter of fruit (1.86 and 1.92 cm at 60 and 90 DAS, respectively) was obtained from the treatment combination of V_2G_2 which was statistically identical with the treatment combination of V_1G_2 at 90 DAS. The lowest diameter of fruit (1.34 and 1.42 cm at 60 and 90 DAS, respectively) was observed from the treatment combination of

V_1G_0 which was statistically similar with the treatment combination of V_2G_0 at 90 DAS.

Table 6. Yield contributing parameters regarding diameter of fruit of Okra influenced by variety and gibberellic acid

Treatment	Diameter of fruit (cm)	
	60 DAS	**90 DAS**
Effect of variety		
V_1	1.55	1.64
V_2	1.58	1.70
$LSD_{0.05}$	NS	NS
CV(%)	4.22	5.036
Effect of GA_3		
G_0	1.36	1.43 d
G_1	1.51	1.69 b
G_2	1.84	1.90 a
G_3	1.67	1.77 b
G_4	1.47	1.57 c
$LSD_{0.05}$	NS	0.114
CV(%)	4.22	5.036
Combined effect variety and GA_3		
V_1G_0	1.34	1.42 f
V_1G_1	1.49	1.65 cd
V_1G_2	1.81	1.88 a
V_1G_3	1.65	1.75 b
V_1G_4	1.45	1.52 e
V_2G_0	1.37	1.44 ef
V_2G_1	1.52	1.72 bc
V_2G_2	1.86	1.92 a
V_2G_3	1.69	1.78 b
V_2G_4	1.48	1.62 d
$LSD_{0.05}$	NS	0.093
CV(%)	4.22	5.036

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

4.2.3 Number of fruits plant^{-1}

Effect of variety

Number of fruits plant^{-1} was not significantly affected with the effect of different variety (Table 7 and Appendix XI). However, the highest number of fruits plant^{-1} (20.21) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest number of fruits plant^{-1} (19.34) was observed from the variety V_1 (BARI dheros-1). Rajesh *et al.* (2018) also found similar result which supported the present study.

Effect of GA_3

Variation on number of fruits plant^{-1} was found influenced by different levels of GA_3 application (Table 7 and Appendix XI). The highest number of fruits plant^{-1} (24.25) was obtained from the treatment, G_2 (100 ppm GA_3) which was significantly different from all other treatments whereas the lowest number of fruits plant^{-1} (15.72) was observed from the control treatment G_0 (0 ppm GA_3). The results obtained from the present study was similar with the findings of Chormule *et al*. (2017) and Ravat and Makani (2015).

Combined effect variety and GA_3

Number of fruits plant^{-1} was affected significantly by combined effect of variety and GA_3 (Table 7 and Appendix XI). The highest number of fruits plant^{-1} (24.60) was obtained from the treatment combination of V_2G_2 which was statistically similar with the treatment combination of V_1G_2. The lowest number of fruits plant^{-1} (24.60) was observed from the treatment combination of V_1G_0 which was statistically similar with the treatment combination of V_1G_4 and V_2G_0.

4.2.4 Fresh weight of fruits plant^{-1} (g)

Effect of variety

The recorded data on fresh weight of fruits plant^{-1} was not significant with the effect of different variety (Table 7 and Appendix XI). However, the highest fresh weight of fruits plant^{-1} (273.90 g) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest fresh weight of fruits plant^{-1} (268.85 g) was observed from the variety V_1 (BARI dheros-1). Rajesh *et al*. (2018) also found similar result which supported the present study.

Effect of GA_3

Considerable influence was observed on fresh weight of fruits plant^{-1} influenced by different levels of GA_3 application (Table 7 and Appendix XI). The highest fresh weight of fruits plant^{-1} (333.60 g) was obtained from the treatment, G_2 (100 ppm GA_3) which was significantly different from all other treatments whereas the lowest fresh weight of fruits plant^{-1} (184.30) was observed from the control treatment G_0 (0 ppm GA_3). The results obtained from the present study was similar with the findings of Chormule *et al*. (2017) and Ravat and Makani (2015).

Combined effect variety and GA_3

Remarkable variation was found on fresh weight of fruits plant^{-1} due to the combined effect of variety and GA_3 (Table 7 and Appendix XI). Results revealed that the highest fresh weight of fruits plant^{-1} (348.20 g) was obtained from the treatment combination of V_2G_2 which was significantly different from all other treatment combinations followed by the treatment combination of V_1G_2 and V_2G_3. The lowest fresh weight of fruits plant^{-1} (198.70 g) was observed from the treatment combination of V_1G_0 which was statistically identical with the treatment combination of V_1G_4.

Table 7. Yield contributing parameters mentioned as number of fruits plant^{-1} and fresh weight of fruits plant^{-1} influenced by variety and combined effect of variety and gibberellic acid on okra

Treatment	Yield contributing parameters	
	Number of fruits plant^{-1}	Fresh weight of fruits plant^{-1} (g)
Effect of variety		
V_1	19.34	268.85
V_2	20.21	273.90
$LSD_{0.05}$	NS	NS
CV(%)	8.269	10.352
Effect of GA_3		
G_0	15.72 e	184.30 e
G_1	19.30 c	262.45 d
G_2	24.25 a	333.60 a
G_3	22.01 b	303.30 c
G_4	17.60 d	230.95 b
$LSD_{0.05}$	0.781	4.651
CV(%)	8.269	10.352
Combined effect variety and GA_3		
V_1G_0	15.10 e	198.70 f
V_1G_1	19.12 c	258.50 de
V_1G_2	23.90 ab	319.00 b
V_1G_3	21.88 b	291.60 c
V_1G_4	16.70 de	206.30 f
V_2G_0	16.34 de	184.30 g
V_2G_1	19.48 c	266.40 d
V_2G_2	24.60 a	348.20 a
V_2G_3	22.14 b	315.00 b
V_2G_4	18.50 cd	255.60 e
$LSD_{0.05}$	2.126	9.541
CV(%)	8.269	10.352

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

4.2.5 Fruit yield plot^{-1}

Effect of variety

Significant influence was noted on fruit yield plot^{-1} affected by different variety (Table 8 and Appendix XII). It was found that the highest fruit yield plot^{-1} (5.09 kg) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest fruit yield plot^{-1} (4.83 kg) was observed from the variety V_1 (BARI dheros-1). Rajesh *et al*. (2018) also found similar result which supported the present study.

Effect of GA_3

Fruit yield plot^{-1} varied significantly due to different levels of GA_3 application (Table 8 and Appendix XII). The highest fruit yield plot^{-1} (6.20 kg) was obtained from the treatment, G_2 (100 ppm GA_3) which was statistically identical with G_3 (150 ppm GA_3) whereas the lowest fruit yield plot^{-1} (3.51 kg) was observed from the control treatment G_0 (0 ppm GA_3). The results obtained from the present study was similar with the findings of Chormule *et al*. (2017) and Ravat and Makani (2015).

Combined effect variety and GA_3

Significant variation was remarked on fruit yield plot^{-1} as influenced by combined effect of variety and GA_3 (Table 8 and Appendix XII). The highest fruit yield plot^{-1} (6.26 kg) was obtained from the treatment combination of V_2G_2 which was statistically identical with the treatment combination of V_1G_2 and statistically similar with the treatment combination of V_2G_3. The lowest fruit yield plot^{-1} (3.47 kg) was observed from the treatment combination of V_1G_0 which was statistically identical with the treatment combination of V_2G_0.

4.2.6 Fruit yield ha^{-1}

Effect of variety

Fruit yield ha^{-1} was significant with the different varietal performance (Table 8 and Appendix XII). Results revealed that the highest fruit yield ha^{-1} (14.53 t) was obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest fruit yield ha^{-1} (13.79 t) was observed from the variety V_1 (BARI dheros-1). Rajesh *et al*. (2018) also found similar result which supported the present study.

Effect of GA_3

Significant variation on fruit yield ha^{-1} was noted as influenced by different levels of GA_3 application (Table 8 and Appendix XII). The highest fruit yield ha^{-1} (17.70 t) was obtained from the treatment, G_2 (100 ppm GA_3) which was statistically identical with G_3 (150 ppm GA_3) whereas the lowest fruit yield ha^{-1} (10.03 t) was observed from the control treatment G_0 (0 ppm GA_3). The results obtained from the present study was similar with the findings of Chormule *et al*. (2017) and Ravat and Makani (2015).

Combined effect variety and GA_3

Fruit yield ha^{-1} was affected significantly by treatment combination of variety and GA_3 (Table 8 and Appendix XII). The highest fruit yield ha^{-1} (17.88 t) was obtained from the treatment combination of V_2G_2 which was statistically similar with the treatment combination of V_1G_2. The lowest fruit yield ha^{-1} (9.92 t) was observed from the treatment combination of V_1G_0 which was statistically identical with V_2G_0.

Table 8. Yield parameters regarding fruit yield plot^{-1} and fruit yield ha^{-1} influenced by variety and gibberellic acid

Treatment	Yield parameters	
	Fruit yield plot^{-1} (kg)	Fruit yield ha^{-1} (t)
Effect of variety		
V_1	4.83 b	13.79 b
V_2	5.09 a	14.53 a
$LSD_{0.05}$	0.113	0.536
CV(%)	5.289	7.884
Effect of GA_3		
G_0	3.51 d	10.03 d
G_1	5.00 b	14.29 b
G_2	6.20 a	17.70 a
G_3	5.76 a	16.44 a
G_4	4.33 c	12.37 c
$LSD_{0.05}$	0.486	1.291
CV(%)	5.289	7.884
Combined effect variety and GA_3		
V_1G_0	3.47 f	9.92 g
V_1G_1	4.84 cd	13.84 de
V_1G_2	6.13 a	17.52 ab
V_1G_3	5.64 b	16.10 c
V_1G_4	4.05 e	11.58 f
V_2G_0	3.55 f	10.14 g
V_2G_1	5.16 c	14.73 d
V_2G_2	6.26 a	17.88 a
V_2G_3	5.87 ab	16.77 bc
V_2G_4	4.60 d	13.15 e
$LSD_{0.05}$	0.376	0.9943
CV(%)	5.289	7.884

V_1 : BARI dheros-1

V_2 : Lal teer hybrid dheros

G_0 : Control (0 ppm GA_3) G_1 : 50 ppm GA_3 G_2 : 100 ppm GA_3

G_3 : 150 ppm GA_3 G_4 : 200 ppm GA_3

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to August 2018 to study the effect of foliar application of gibberellic acid on morpho-physiological characters and yield of okra. The experiment considered of two factors. Factor A – two okra variety; V_1 = BARI dheros-1 and V_2 = Lal teer hybrid dheros and Factor B: Gibberellic acid (GA_3) - 4 levels; G_0 = Control (0 ppm GA_3), G_1 = 50 ppm GA_3, G_2 = 100 ppm GA_3, G_3 = 150 ppm GA_3 and G_4 = 200 ppm GA_3. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield components and yield of okra were recorded. Different growth and yield parameters were significantly influenced by variety and GA_3 and also with their combinations.

Results revealed that in terms of growth parameters, variety had no significant effect on number of leaves plant^{-1} at all growth stages. However, the highest plant height (43.58, 81.55 and 110.34 cm at 30, 60 and 90 DAS, respectively) and number of leaves plant^{-1} (17.34, 23.12 and 27.29 at 30, 60 and 90 DAS, respectively) were obtained from the variety, V_2 (Lal teer hybrid dheros). where the lowest plant height (40.40, 75.22 and 104.73 cm at 30, 60 and 90 DAS, respectively) and number of leaves plant^{-1} (16.66, 22.07 and 26.65 at 30, 60 and 90 DAS, respectively) were observed from the variety V_1 (BARI dheros-1). Again, the highest leaf area (cm^2) at 60 DAS (256.54) and SPAD value at 50 DAS (55.40) were obtained from the variety, V_2 (Lal teer hybrid dheros) and the lowest leaf area (cm^2) at 60 DAS (245.62) was observed from the variety V_1 (BARI dheros-1) and SPAD value at 50 DAS (52.18) were observed from the variety V_1 (BARI dheros-1). In terms of yield contributing parameters and yield of okra affected by variety, the highest length of fruit (9.27 and 11.86 cm at 60 and 90

DAS, respectively), diameter of fruit (1.58 and 1.70 cm at 60 and 90 DAS, respectively), number of fruits plant^{-1} (20.21), fresh weight of fruits plant^{-1} (273.90 g), fruit yield plot^{-1} (5.09 kg) and fruit yield ha^{-1} (14.53 t) was obtained from the variety, V_2 (Lal teer hybrid dheros). Here, it can be mentioned that length of fruit, diameter of fruit, number of fruits plant^{-1} and fresh weight of fruits plant^{-1} were not significantly affected by variety. The lowest length of fruit (8.73 and 11.39 cm at 60 and 90 DAS, respectively) diameter of fruit (1.55 and 1.64 cm at 60 and 90 DAS, respectively), number of fruits plant^{-1} (19.34), fresh weight of fruits plant^{-1} (268.85 g), fruit yield plot^{-1} (4.83 kg) and fruit yield ha^{-1} (13.79 t) were observed from the variety V_1 (BARI dheros-1).

Regarding, GA_3 effect, the highest plant height (50.37, 92.80 and 120.90 cm at 30, 60 and 90 DAS, respectively) and number of leaves plant^{-1} (22.94, 27.14 and 30.42 at 30, 60 and 90 DAS, respectively) were obtained from the treatment, G_4 (200 ppm GA_3) but the highest leaf area (cm^2) at 60 DAS (298.98) was obtained from the treatment, G_3 (150 ppm GA_3) and the highest SPAD value at 50 DAS (65.62) was obtained from the treatment, G_2 (100 ppm GA_3). The lowest plant height (34.29, 66.10 and 95.43 cm at 30, 60 and 90 DAS, respectively), number of leaves plant^{-1} (12.77, 18.33 and 22.87 at 30, 60 and 90 DAS, respectively), leaf area (cm^2) at 60 DAS (213.66) and SPAD value at 50 DAS (42.23) were observed from the control treatment G_0 (0 ppm GA_3). Again, the highest length of fruit (11.00 and 14.70 cm at 60 and 90 DAS, respectively), diameter of fruit (1.84 and 1.90 cm at 60 and 90 DAS, respectively), number of fruits plant^{-1} (24.25), fresh weight of fruits plant^{-1} (333.60 g), fruit yield plot^{-1} (6.20 kg) and fruit yield ha^{-1} (17.70 t) were obtained from the treatment, G_2 (200 ppm GA_3) whereas the lowest length of fruit (7.00 and 9.20 cm at 60 and 90 DAS, respectively), diameter of fruit (1.36 and 1.43 cm at 60 and 90 DAS, respectively), number of fruits plant^{-1} (15.72), fresh weight of fruits plant^{-1} (184.30), fruit yield plot^{-1} (3.51 kg) and fruit yield ha^{-1} (10.03 t) was observed from the control treatment G_0 (0 ppm GA_3).

In case of combined effect of variety and GA_3, highest plant height (54.53, 101.10 and 127.50 cm at 30, 60 and 90 DAS, respectively) and number of leaves plant^{-1} (23.10, 27.87 and 31.30 at 30, 60 and 90 DAS, respectively) were obtained from the treatment combination of V_2G_4 but the highest leaf area (cm^2) at 60 DAS (310.00) was obtained from V_2G_3 and the highest SPAD value at 50 DAS (68.35) was obtained from the treatment combination of V_2G_2. Likewise, the highest length of fruit (11.70 and 14.90 cm at 60 and 90 DAS, respectively), diameter of fruit (1.86 and 1.92 cm at 60 and 90 DAS, respectively), number of fruits plant^{-1} (24.60), fresh weight of fruits plant^{-1} (348.20 g), fruit yield plot^{-1} (6.26 kg) and fruit yield ha^{-1} (17.88 t) was obtained from the treatment combination of V_2G_2. The lowest plant height (33.73, 61.43 and 91.53 cm at 30, 50 and 70 DAS, respectively), number of leaves plant^{-1} (12.37, 17.73 and 22.70 at 30, 60 and 90 DAS, respectively), lowest leaf area (cm^2) at 60 DAS (207.80) and lowest SPAD value at 50 DAS (40.65) were observed from the treatment combination of V_1G_0. Similarly, the lowest length of fruit (6.67 and 8.87 cm at 60 and 90 DAS, respectively), diameter of fruit (1.34 and 1.42 cm at 60 and 90 DAS, respectively), number of fruits plant^{-1} (24.60), fresh weight of fruits plant^{-1} (198.70 g), fruit yield plot^{-1} (3.47 kg) and fruit yield ha^{-1} (9.92 t) were also observed from the treatment combination of V_1G_0.

Considering the results of the present experiment, it may conclude that variety and GA_3 positively influenced the entire physiology, growth and yield of okra. In all stage of growth and yield the variety, Lal teer hybrid dheros (V_2) gave better result. On the other hand GA_3 at the rate of 100 ppm (G_2) produced the highest growth and yield. So, it may be recommended that V_2 (Lal teer hybrid dheros) with G_2 (100 ppm GA_3) was better (V_2G_2) for growth and yield of okra.

The experiment was done only one growing season, for more confirmation of the result such type of experiment is required before recommendation. Considering

the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performance
2. Another okra variety and GA_3 levels may be used for identifying more accurate doses
3. Different fertilizers may be included for attaining better results

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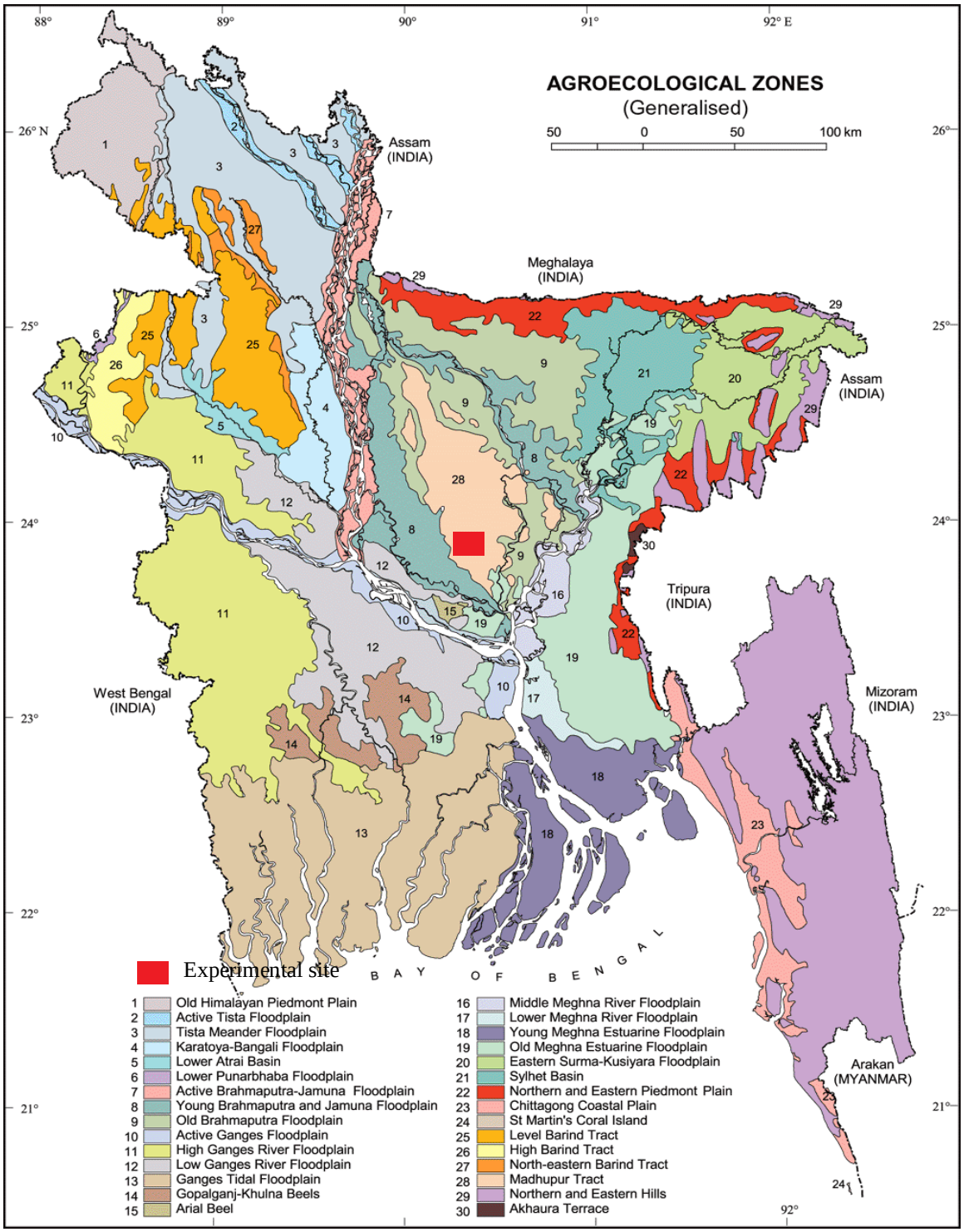
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from March to August 2018

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	March	35.20	21.00	28.10	52.44	20.4
2018	April	34.70	24.60	29.65	65.40	165.0
2018	May	32.64	23.85	28.25	68.30	182.2
2018	June	27.40	23.44	25.42	71.28	190
2018	July	30.52	24.80	27.66	78.00	536
2018	August	31.00	25.60	28.30	80.00	348

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

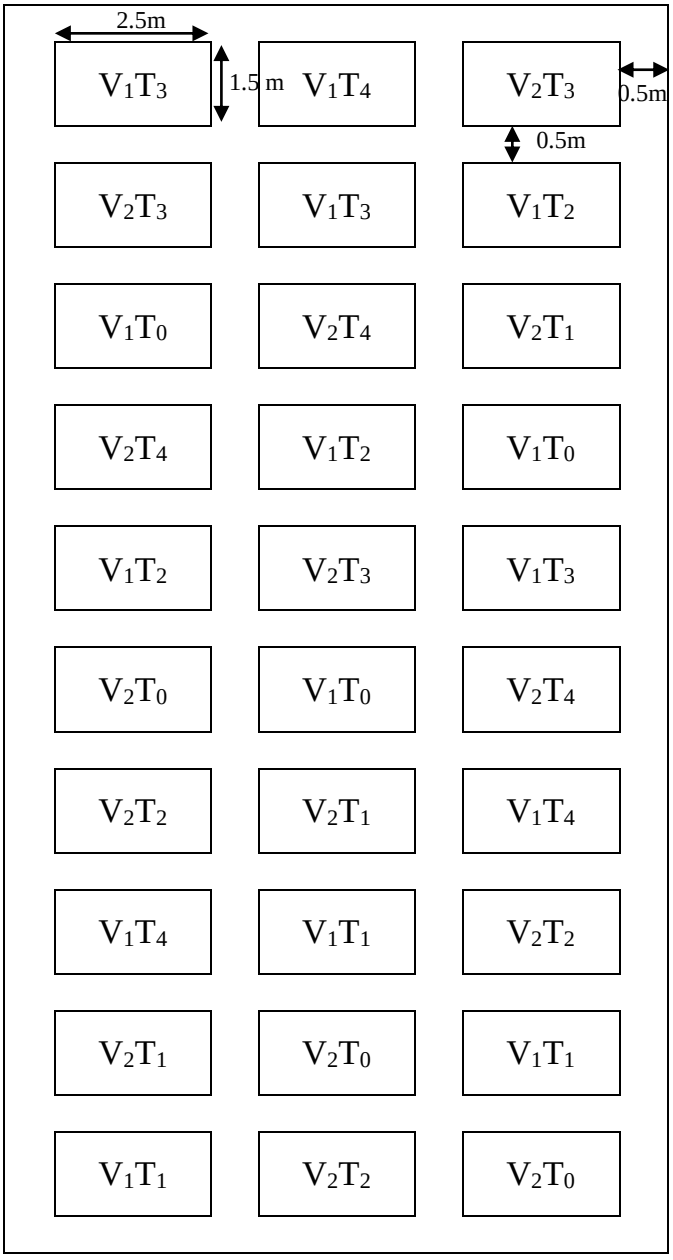
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field



Legend:

Factor A: Variety – 2 varieties

1. V_1 = BARI dheros-1
2. V_2 = Lal teer hybrid dheros

Factor B: GA_3 - 4 levels

1. T_0 = Control (0 ppm GA_3)
2. T_1 = 50 ppm GA_3
3. T_2 = 100 ppm GA_3
4. T_3 = 150 ppm GA_3
5. T_4 = 200 ppm GA_3

Fig. 9. Layout of the experimental plot

Appendix V. Plant height of okra influenced by variety and gibberellic acid at different growth stages

Sources of variation	Degrees of freedom	Plant height (cm)		
		30 DAS	60 DAS	90 DAS
Replication	2	0.401	1.214	1.526
Factor A	1	7.78*	12.87*	16.502*
Factor B	4	22.68*	26.48*	37.336*
AB	4	11.79*	9.690*	11.819*
Error	20	1.302	1.522	1.507

Appendix VI. Number of leaves plant^{-1} of okra influenced by variety and gibberellic acid at different growth stages

Sources of variation	Degrees of freedom	Number of leaves plant^{-1}		
		30 DAS	60 DAS	90 DAS
Replication	2	0.724	1.326	3.025
Factor A	1	NS	NS	NS
Factor B	4	13.157	18.85*	42.53**
AB	4	6.245**	6.638**	12.52*
Error	20	1.171	1.053	2.057

Appendix VII. Leaf area index of okra at 60 DAS influenced by variety and gibberellic acid

Sources of variation	Degrees of freedom	Leaf area index at 60 DAS
Replication	2	5.052
Factor A	1	164.50*
Factor B	4	288.29*
AB	4	104.46*
Error	20	10.178

Appendix VIII. Chlorophyll content of okra leaves at 50 DAS influenced by variety and gibberellic

Sources of variation	Degrees of freedom	Chlorophyll content at 50 DAS
Replication	2	3.403
Factor A	1	22.41*
Factor B	4	38.72**
AB	4	16.06*
Error	20	2.274

Appendix IX. Yield contributing parameters regarding fruit length of okra influenced by variety and gibberellic acid

Sources of variation	Degrees of freedom	Length of fruit (cm)	
		60 DAS	80 DAS
Replication	2	1.122	1.246
Factor A	1	NS	NS
Factor B	4	16.107*	21.29*
AB	4	6.161**	12.38*
Error	20	0.402	1.412

Appendix X. Yield contributing parameters regarding diameter of fruit of okra influenced by variety and gibberellic acid

Sources of variation	Degrees of freedom	Diameter of fruit (cm)	
		60 DAS	80 DAS
Replication	2	0.002	0.003
Factor A	1	NS	NS
Factor B	4	NS	7.35**
AB	4	NS	3.76*
Error	20	0.034	0.072

Appendix XI. Yield contributing parameters mentioned as number of fruits plant^{-1} and fresh weight of fruits plant^{-1} influenced by variety and gibberellic acid

Sources of variation	Degrees of freedom	Yield contributing parameters	
		Number of fruits plant^{-1}	Fresh weight of fruits plant^{-1} (g)
Replication	2	1.431	6.346
Factor A	1	NS	NS
Factor B	4	37.456**	204.88*
AB	4	13.291*	47.525*
Error	20	2.052	8.365

Appendix XII. Yield parameters regarding Fruit yield plot^{-1} and Fruit yield ha^{-1} influenced by variety and gibberellic acid

Sources of variation	Degrees of freedom	Yield parameters	
		Fruit yield plot^{-1} (kg)	Fruit yield ha^{-1} (t)
Replication	2	0.102	1.513
Factor A	1	4.367**	11.26*
Factor B	4	9.289*	17.15*
AB	4	6.106**	7.064*
Error	20	0.357	1.318

Fig. 10. Layout preparation of the experiment field