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Assessing Impact of Naphthalene Acetic Acid on the Growth and Yield of Okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract. This study assessed the impact of naphthalene acetic Acid (NAA) on the growth and yield of Okra cv. Sabz Pari at Agricultural Research Institute, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan. A field experiment was set out in randomised complete block design with NAA application as a main factor. Different NAA concentrations were obtained by dissolving NAA in distilled water at the rate of 0 (control), 10, 30, 50, 70, 90 and 110 mg/L. NAA treatments along with control were foliar applied to okra plants after 30 days of sowing. Lower concentration of NAA (30-50 mg/L) stimulated maximum increase in plant height (59.5-57.2%), number of leaves/plant (50.4-45.5%,), total plant leaf area (113.9-119.4%), internodes/plant (72.5-61.6%), internode length (53.2-44.5%), pod diameter (53.5-49.9%), pod fresh weight (126.8-111.8%), pod yield (271.2-255.8%) compared to control (0 mg NAA/L). NAA at higher concentrations (>50 mg/L) had a supressing effect on most parameters. It was inferred that yield production in okra is influenced by multiple yield-determining component traits and their mutual interactions which could be manipulated by the application of NAA. Foliar application of NAA (30-50 mg/L) have a beneficial impact on plant characters and yield of Okra, hence recommended in Okra cultivation.

Keywords: *Abelmoschus esculentus*, NAA, component traits, foliar application, growth, pod yield

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a monetarily critical crop, indeterminate in nature and widely grown in tropical and subtropical regions of the world (Gemede *et al*., 2015). The crop is produced for tender pods (fruits) which can be harvested over multiple times. It is far more nutritious than tomato, brinjal, and several other cucurbits with average nutritive value of 3.21 (Adelakun and Oyelade, 2011). The pods are highly nutritious and a very good source of dietary fibre, protein, phosphorus, potassium, zinc, copper, calcium, magnesium, manganese, and fair amount of vitamins *viz*., thiamine, riboflavin, niacin, ascorbic acid, etc., (USDA Nutrient Database for Standard Reference, 2018). The immature pods (fresh or dried) are consumed as boiled or fried vegetables, as soup thickeners as well as used in salads and stews (Yadev and Dhankhar, 2002). Hence, Okra is a worthful crop ensuring excellent means of livelihood to small-scale farmers.

Okra is mostly grown in areas with plentiful sunlight throughout the day. It prefers loamy to sandy loam soils, however, heavier soils with good drainage capacity can produce well. It can tolerate a wide range of soil pH, but prefers soil with a pH ranging between 6.0-6.8. Soil-based NPK fertilizer application has been reported to ensure good yield in Okra (Babatola, 2006).

Despite the wider production and numerous uses of Okra, there are many constraints contributing to the lower yields, some major ones include soil infertility, limited irrigation resources, adverse environmental conditions leading to unwanted abscission of floral bud and/or developing fruit (Iderawumi *et al*., 2017), etc. For normal growth an production, Okra crop need a temperature between 24 °C and 28 °C (Benchasri, 2012). Seed germination is delayed and decreased, at higher temperatures beyond 38 °C to 42 °C, flowers may parch and drop, causing yield loss. Despite its considerable tolerance to drought, the crop requires good availability of soil water for optimum growth. High yield reduction has been shown in the water stressed plants (Gunawardhana and de-Silva, 2011). In such situations, exogenous application of plant growth regulators (PGRs) have been found to be effective and useful (Husen *et al*., 2016; Liu *et al*., 2014), if applied in suitable forms and at appropriate concentrations.

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The PGRs are known to modify and regulate many growth and physiological processes in plants (Raddadi *et al*., 2008). They can improve the physiological efficiency of plants such as enhancing the photosynthetic ability of plants as well as stimulating the translocation of photo-assimilates to yield related plant components due to better source-sink relationships and, thereby increasing the overall crop productivity (Dawood and Sadak, 2008). The PGRs have therefore, been known to be one of the quick means of increasing production (Maity *et al*., 2016).

Auxins are considered an important group of PGRs (Anjum *et al*., 2011) which play a vital role in cell multiplication and enlargement, adventitious roots formation (Majda and Robert, 2018), apical dominance (Abdoli *et al*., 2013), and inducing flowering (Malik, 1999). Naphthalene acetic acid (NAA) is among one of the most beneficial PGRs in auxin family. Studies have shown that NAA plays a key function in improving the growth, yield as well as quality of the produce (Singh *et al*., 2017).

Although, PGRs have great potential, their application, optimal concentration, and plant species specificity have not been fully assessed in important vegetable crops and particularly in Okra. Along these lines, taking into account the positive role of PGRs, this study was designed to determine the impact of exogenous application of NAA on the pod yield including pod quality attributes by optimizing the concentration of NAA.

Materials and Methods

Plant material. A certified Okra cv. "Sabz Pari" was used in this study. It is early maturing (< 90 days) with light green pod colour (Fatima *et al*., 2019; Khan *et al*., 2013).

Field experiment. The field experiment was conducted to assess yield formation in aforementioned Okra variety in two consecutive growing seasons (March-July) of 2014 and 2015 referred to as GS_1 and GS_2, respectively throughout the text. The experimental site was under the auspices of Agricultural Research Institute, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan and situated between latitude 31º 52' N, longitude 70º 53' E with altitude of 182 m from sea level.

The experiment was set out in a randomised complete block design with different NAA treatments replicated thrice. Six NAA solutions were obtained by dissolving NAA in distilled water using concentrations of 10, 30, 50, 70, 90, and 110 mg/L along with control (0 mg NAA/L) having distilled water only. Ethanol (10 mL) was used to facilitate the dissolution process.

The experimental site was assessed for basic physico-chemical soil properties prior to execution of the experiment (Table 1). Soil samples were air-dried, ground in a mortar and pestle and screened through $\geq$ 2 mm mesh for measuring the soil texture (Koehler *et al*., 1984). Soil pH was assessed by hand-held pH meter (JENWAY-3020). Electrical conductivity (EC) was evaluated *via* conductivity meter (inoLab). Soil organic matter (OM) content (Nelson and Sommers, 1982), ammonium-N, nitrate-N, total N (Keeney and Nelson, 1982), phosphorus (Olsen and Sommers, 1982), and potassium (Knudsen *et al*., 1982) contents were also ascertained. Soil properties did not vary considerably between the two growing seasons. The soil was a clay-loam, marginally alkaline (pH: 7.15-7.51), salt-free (EC: 140-170 µS/cm), short in OM (0.93-1.01 %), appropriate regarding ammonium-N (9.21-9.37 mg/Kg), nitrate-N (7.89-8.05 mg/Kg), total N (0.089-0.096%), potassium (157-163 mg/Kg) contents and rich in phosphorus (43.64-45.13 mg/Kg).

Standard cultivation practices were used in seedbed preparation. N (120 Kg/ha), phosphorus (90 Kg/ha), and potassium (60 Kg/ha) were incorporated before seed sowing as urea, single super phosphate (SSP), and

Table 1. Pre-planting physical and chemical properties of the soil.

Parameters	Unit	GS_1†	GS_2‡
AB-DTPA extractable phosphorus (P_2O_5)	mg/Kg	45.13	43.64
Ammonium acetate extractable potassium (K_2O)	mg/Kg	163	157
Ammonium nitrogen (NH_4-N)	mg/Kg	9.37	9.21
Nitrate nitrogen (NO_3-N)	mg/Kg	8.05	7.89
Total nitrogen	%	0.096	0.089
Organic Matter (OM)	%	1.01	0.93
pH	-	7.15	7.51
Electrical Conductivity (EC)	µS/cm	170	140
Texture class	-	Clay-loam	Clay-loam

† = Growing season of 2014; ‡ = Growing season of 2015.

sulphate of potash (SOP), respectively. Nitrogen was given in two equal split doses, first at time of planting and second at the onset of flowering. Seeds were pre-soaked in distilled water before sowing for 24 h to ensure consistent germination. The pre-germinated seeds were planted on ridges 60 cm apart and maintaining 30 cm intra-row spacing. Each block consisted of seven plots of afore-mentioned treatments making total of 21 plots across the three replicates. There were 4 ridges per treatment plot each possessing 10 plants thereby constituting the net plot size of 7.2 m^2 (2.4×3 m) with a total of 40 plants.

NAA treatments along with control were applied to each plot after 30 days of sowing by foliar application with the help of atomizer (Unamba *et al*., 2009). An adhesive Tween-20 (0.1%) was added to each solution according to Roy *et al*. (1991). Control plots were treated only with distilled water. Crop was managed well to avoid any kind of plant stress.

Meteorological temperature and precipitation data were collected from a local weather station during both the growing seasons (Fig. 1). The average monthly air temperature in GS_1 (March-July) was 18.0 to 33.0 °C, whereas it ranged from 19.0 to 32.5 °C in GS_2. The total precipitation was 248.5 and 156.5 mm during the growing season GS_1 and GS_2, respectively. This clearly indicated that the weather during GS_1 was comparatively wetter than GS_2.

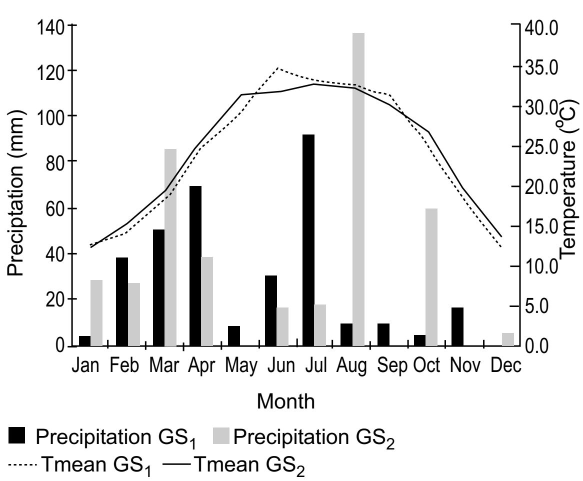

Fig. 1. Meteorological trends during two growing seasons of Okra (*i.e.*, GS_1 = 2014; GS_2 = 2015).

Measurements. Data were compiled on a range of parameters shaping vegetative and reproductive growth, pod characteristics and yield during the crop cycle in two growing seasons. Plant height (cm), leaves/plant, total plant leaf area (cm^2), internodes/plant, and internode length (cm) were noted at time of first flowering. The onset of first flowering was estimated at commencement of 50% plants' flowering. Pod length (cm), pod diameter (mm), and pod fresh weight (g) was noted at every picking and mean value was estimated. Total pods/plant and pod yield (t/ha) were estimated from the summation of all pickings made. Standard rules developed by the International Union for the Protection of New Varieties of Plants (UPOV, 2018) and The International Plant Genetic Resources Institute (IPGRI, 1991) were adopted for all parameters measuring.

Statistical analysis. Recorded data were analysed statistically in Genstat (Payne *et al*., 2009). A preliminary analysis of data indicated non-significant differences between the two growing seasons (data not shown). Therefore, a general one-way analysis of variance (ANOVA) technique for each growing season was followed to test the extent and significance of variations among NAA treatments. Differences among treatments means were compared through Fisher's multiple comparison test using 5% probability level. Pearson correlations were quantified to appraise the inter-relationships among the parameters.

Results and Discussion.

Assessing impact of NAA on vegetative growth of Okra. Various concentrations of NAA had highly significant ($P \leq 0.001$) impact on parameters determining the vegetative growth of Okra in both growing seasons (*i.e.* GS_1 and GS_2). In GS_2, NAA at 30 mg/L produced the maximum plant height (84.0 cm), leaves/plant (29.1), total plant leaf area (13818 cm^2), internodes/plant (22.2), and internode length (8.0 cm) (Table 2). Values of most parameters remained statistically at par with 50 mg/L NAA. Data obtained in GS_2 indicated almost similar trend with 30 and 50 mg/L NAA producing the maximum plant height (78.5 and 77.4 cm) leaves/plant (24.4 and 23.0), total plant leaf area (10946 and 10038 cm^2), internodes/plant (19.8 and 18.5), and internode length (5.6 and 5.2 cm, accordingly) and remained statistically alike with each other for most parameters. Data also indicated that the maximum concentration of NAA (110 mg/L) led to reduced plant height (50.7 and 45.1 cm), leaves/plant (18.4 and 14.5), total plant leaf area (5048 and 4529 cm^2), internodes/plant (16.4 and 14.0), and internode length (5.2 and 4.3 cm) in GS_1 and GS_2, respectively. However, results were statistically alike at control (0 mg NAA/L) for most parameters. Data pooled over two growing seasons indicated gain in most parameters determining vegetative growth in response to certain NAA concentration (mostly up to 30 mg/L). Additional rise in NAA concentration (> 30 mg/L) had a supressing effect on most of parameters. This was also apparent from a quadratic relationship between plant height, leaves/plant, total plant leaf area, internodes/plant, internode length and NAA concentrations with R^2 ranging from 80 to 98% (Fig. 2a-e).

Assessing impact of NAA on reproductive growth of Okra. NAA application induced a highly significant ($P \leq 0.001$) impact on earliness to flowering in both the growing seasons. Days required to first flowering ranged between 53.0–72.7 in GS_1 and 51.1–70.7 in GS_2 (Table 3). The plants without NAA application (*i.e*., control) exhibited delayed onset of first flowering significantly and took 60.0 and 58.0 days, whereas earlier start of flowering (53.0, 51.1 days) was recorded with 10 mg/L NAA concentration in GS_1 and GS_2, respectively. NAA applied at 30 mg/L appeared second most influential concentration in initiating early flowering (55.8 and 52.6 days) in plants during both the seasons. Data further indicated a strong quadratic link (R^2 = 96%) between days required to first flowering and NAA concentrations (Fig. 2f). In conclusion, onset of first flowering advanced with lowest NAA concentration and gradually delayed with increase in NAA concentration till 110 mg/L and produced maximum delay in first flowering in GS_1 and GS_2, respectively.

Assessing impact of NAA on pod characteristics. Parameters determining the pod characteristics were significantly ($P \leq 0.001$) influenced by NAA application in both seasons. Maximum pod length (11.0 and 12.3 cm) was noted with the foliar application of 30 mg NAA/L among the treatments apart from 10 mg NAA/L (10.7 and 12.0 cm) and 50 mg NAA/L (10.1 and 11.4 cm) in GS_1 and GS_2, respectively (Table 3). Similarly, NAA concentration (30–50 mg/L) exhibited major increase in pod diameter and pod fresh weight and ranged between 14.3–16.0 mm and 15.2–17.6 g, respectively across both the seasons. However, statistically both NAA treatments were alike. The absence of NAA application (control) produced minimum pod length (8.9 and 10.2 cm), pod diameter (9.3 and 10.6 mm), and pod fresh weight (6.8 and 8.1 g) in GS_1 and GS_2, respectively. Data also indicated that higher concentration of NAA (70–110 mg/L)

Table 2. Effect of naphthalene acetic acid (NAA) concentrations on the vegetative growth of Okra during two growing seasons.

NAA (mg/L)	Plant height (cm)	Leaves/ plant	Total plant leaf area (cm^2)	Internodes/ plant	Internode length (cm)
GS_1†					
0	52.5 e	18.8 d	6161 cd	13.4 d	4.9 f
10	73.0 c	23.9 c	10102 b	18.1 abc	7.7 b
30	84.0 a	29.1 a	12314 ab	22.2 a	8.0 a
50	82.8 a	28.5 ab	13818 a	20.9 ab	7.6 b
70	78.0 b	23.6 bc	10661 b	19.8 abc	7.0 c
90	67.0 d	19.7 cd	7361 c	17.2 bcd	5.9 d
110	50.7 e	18.4 d	5048 d	16.4 cd	5.2 e
LSD ($P \leq 0.05$)	4.0	5.0	2313.6	4.1	0.13
GS_2‡					
0	49.3 d	15.7 d	4715 c	11.0 d	4.0 f
10	69.8 b	20.1 bc	7734 b	15.8 bc	5.3 b
30	78.5 a	24.4 a	10946 a	19.8 a	5.6 a
50	77.4 a	23.0 ab	10038 a	18.5 ab	5.2 bc
70	71.3 b	21.0 b	7934 b	17.4 abc	5.0 c
90	59.2 c	17.4 cd	5842 c	14.8 bc	4.7 d
110	45.1 e	14.5 d	4529 c	14.0 cd	4.3 e
LSD ($P \leq 0.05$)	3.4	3.3	1663.5	3.7	0.20

Means with unlike letter(s) are significantly different; † = Growing season of 2014; ‡ = Growing season of 2015.

Table 3. Effect of naphthalene acetic acid (NAA) concentrations on the reproductive growth, pod characteristics and yield of Okra during two growing seasons

NAA (mg/L)	Onset of first flowering	Pod length (cm)	Pod diameter (mm)	Pod fresh weight (g)	Total pods/plant	Pod yield (t/ha)
GS1†						
0	60.0 c	8.9 c	9.3 e	6.8 f	11.5 g	5.8 f
10	53.0 f	10.7 a	13.0 c	12.7 d	22.3 a	15.7 d
30	55.8 e	11.0 a	14.7 a	16.3 a	21.5 b	20.8 a
50	57.0 de	10.1 ab	14.3 a	15.2 ab	19.9 c	19.8 b
70	59.1 cd	9.6 bc	13.5 b	14.3 bc	18.3 d	18.0 c
90	67.0 b	9.5 bc	13.1 bc	13.5 cd	14.0 e	14.8 d
110	72.7 a	9.1 c	11.8 d	10.5 e	13.3 f	10.7 e
LSD ($P \leq 0.05$)	2.6	0.97	0.51	1.4	0.67	1.0
GS2‡						
0	58.0 c	10.2 c	10.6 e	8.1 f	10.3 f	5.0 e
10	51.1 e	12.0 a	13.0 d	14.0 d	19.7 a	15.0 c
30	52.6 e	12.3 a	16.0 a	17.6 a	18.9 b	19.0 a
50	53.3 de	11.4 ab	15.6 ab	16.5 ab	18.5 b	18.4 a
70	56.0 cd	10.9 bc	14.8 bc	15.6 bc	17.3 c	16.7 b
90	63.5 b	10.4 bc	14.4 c	14.8 cd	13.4 d	14.1 c
110	70.7 a	10.0 c	13.1 d	11.8 e	12.8 e	9.0 d
LSD ($P \leq 0.05$)	3.4	1.0	0.79	1.2	0.60	1.5

Means with unlike letter(s) are significantly different; † = Growing season of 2014; ‡ = Growing season of 2015.

negatively affected the pod length, diameter and fresh weight among all the treatments in both the growing seasons. The combined data from two growing seasons further indicated a strong quadratic relationship between pod length, diameter, fresh weigh and NAA concentration with R^2 ranging from > 63% to 90% (Fig. 2g-h & Fig. 3a). In other words, all these parameters increased positively with NAA application up to certain concentration (30 mg/L) and reduced with further rise in NAA concentration. These results indicated that higher concentration of NAA ($\geq$ 70 mg/L) may induce a negative effect on pod characteristics. However, NAA application is still better than control (0 mg NAA/L) which overall resulted into minimum values of these parameters.

Assessing impact of NAA on yield formation in Okra. The reposted data showed significant ($P \leq 0.001$) effect of NAA application on the yield formation in Okra. The significantly greater (22.3 and 19.7) pods/plant were observed in treatments receiving 10 mg/L NAA followed by 30 mg/L NAA producing 21.5 and 18.9 pods/plant in GS_1 and GS_2, respectively (Table 3). On the other hand, foliar application of 30 and 50 mg/L NAA produced maximum pod yields during both the seasons and ranged from 18.4 to 20.8 t/ha. However, results were statistically alike in GS_2 between these two NAA treatments. The control treatment (0 mg NAA/L) exhibited lowest (11.5 and 10.3) pods/plant and minimum pod yield (5.8 and 5.0 t/ha) in GS_1 and GS_2, respectively among all the treatments. Data showed the quadratic relationship between pods/plant, pod yield and different concentration of NAA (R^2 = 86–93%) as illustrated by Fig. 3b-c. The results overall suggested that pod production enhanced with lower NAA concentrations (10–30 mg/L). Further concentration of NAA induced a gradual declination in pod yield.

Assessing correlations between yield and yield-contributing parameters of Okra. Data revealed significant ($P \leq 0.001$) inter-relationships among the parameters (Fig. 4). There existed positive very strong correlations ($r \geq 0.70$) between plant height and leaves/plant, total plant leaf area, internodes/plant, internode length, pod fresh weight, and pods/plant (r = 0.77–0.88), between leaves/plant and total plant leaf area, internodes/plant, internode length, and pods/plant (r = 0.72–0.96), between total plant leaf area and internodes/plant, internode length, and pods/plant (r = 0.77–0.80), between internodes/plant and internode length (r = 0.73), between pod diameter and pod fresh weight (r = 0.93), between pods/plant and internode length (r = 0.72).

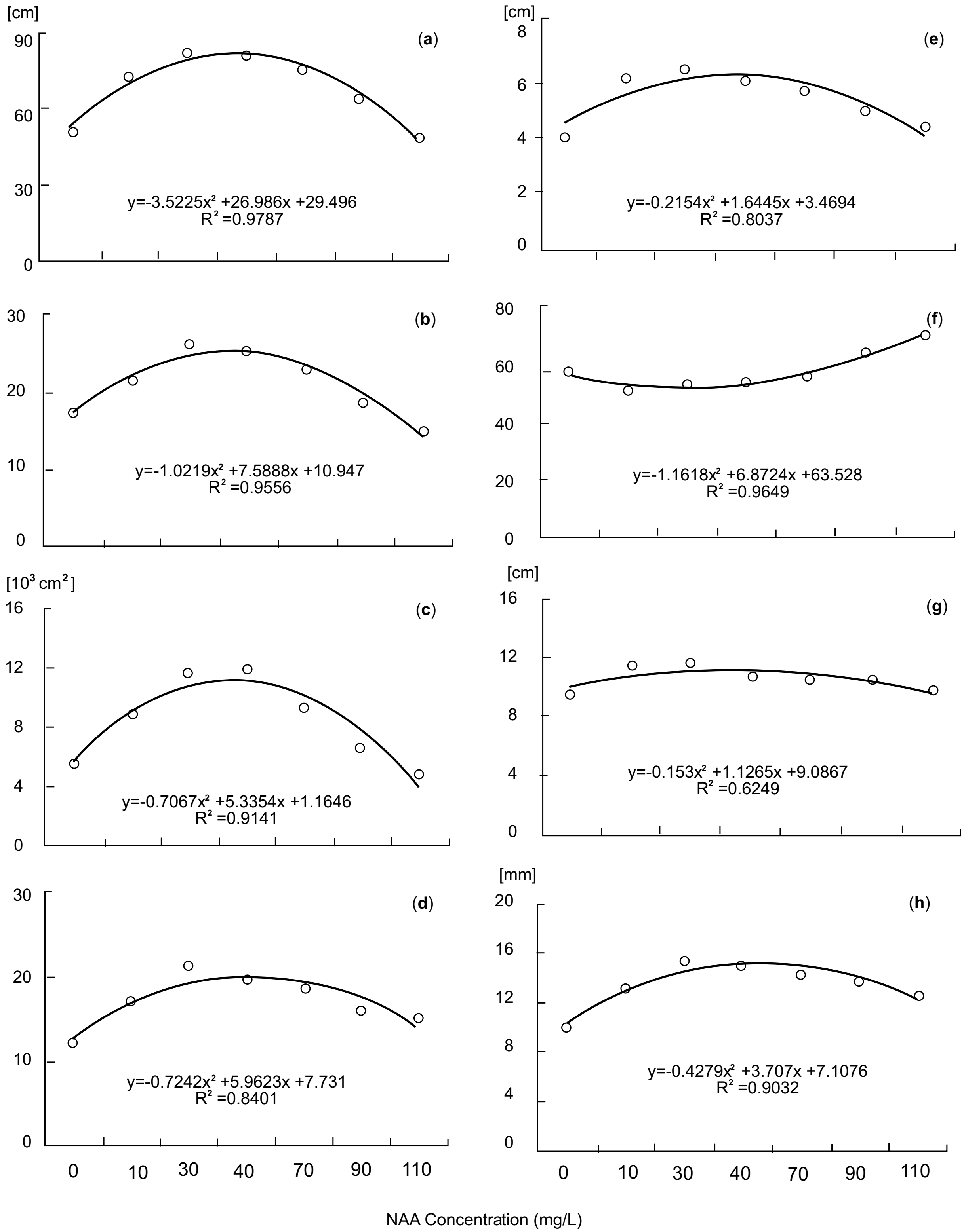

Fig. 2. Effect of different concentrations of naphthalene acetic acid (NAA) on (**a**) plant height, (**b**) leaves/plant, (**c**) total plant leaf area, (**d**) internodes/plant, (**e**) internode length, (**f**) onset of first flowering, (**g**) pod length, (**h**) pod diameter.

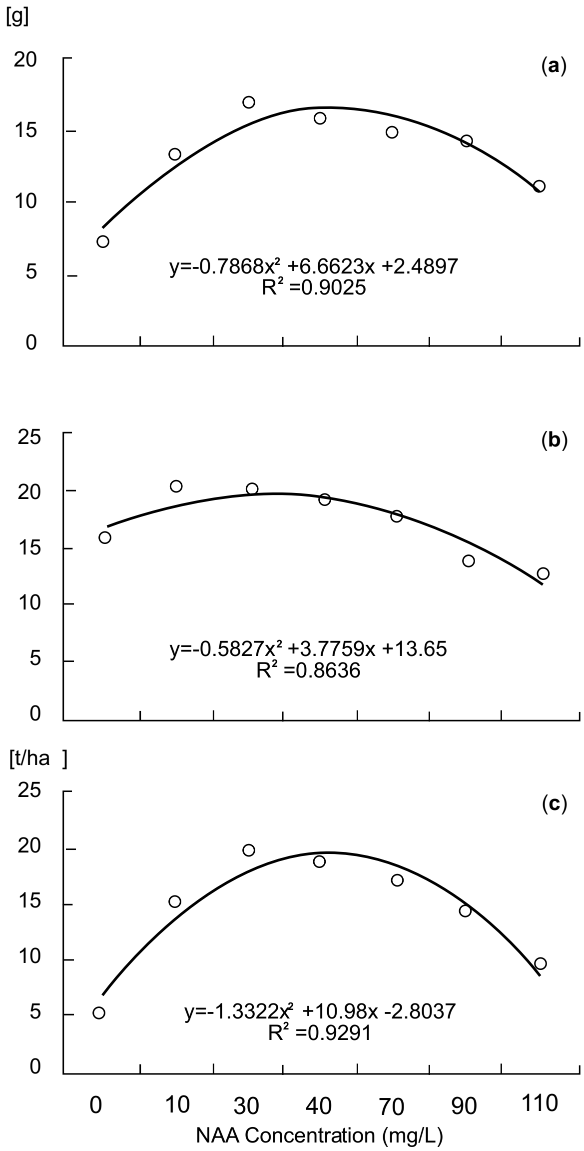

Fig. 3. Effect of different concentrations of naphthalene acetic acid (NAA) on (**a**) pod fresh weight, (**b**) total pods/plant, (**c**) pod yield.

Furthermore, fairly strong positive correlations ($0.40 \leq r \leq 0.70$) existed between plant height and pod length, pod diameter (r = 0.47-0.68); between leaves/plant and pod diameter, pod fresh weight (r = 0.47–0.53), between total plant leaf area and pod diameter, pod fresh weight, pods/plant (r = 0.60–0.64), between internodes/plant and pod diameter, pod fresh weight (r = 0.47–0.53), between internode length and pod fresh weight (r = 0.42), between pod length and pod diameter, pod fresh weight, pods/plant (r = 0.43–0.65), between pod fresh weight and pods/plant (r = 0.45).

Data also exposed very strong negative correlations (r = - 0.80) between pods/plant and onset of first flowering. There existed fairly strong negative correlations ($-0.40 \leq r \leq -0.70$) between onset of first flowering and plant height, leaves/plant, total plant leaf area, pod length, pod fresh weight with "r" values ranging from - 0.40 to - 0.67.

Data further revealed very strong positive correlations ($r \geq 0.70$) between pod yield and most of the parameters including plant height, leaves/plant, total plant leaf area, internodes/plant, pod diameter, pod fresh weight with value of r ranging between 0.70 to 0.92 (Fig. 4). Data also showed reasonably strong positive correlations ($0.40 \leq r \leq 0.70$) between pod yield and pod length, pods/plant ($r \leq 0.48 – 0.64$). Pod yield indicated strong negative relationship (r = - 0.51) with the onset of first flowering amongst the rest of parameters.

This study aimed to assess the influence of NAA on the growth and yield production in Okra. Foliar application of NAA positively affected the parameters determining the vegetative, reproductive and yield formation in Okra. Lower concentration of NAA (30–50 mg/L) induced maximum plant height, leaves/plant, total plant leaf area, internodes/plant, internode length, pod length, pod diameter, pod fresh weight, and pod yield. Furthermore, results indicated the mean increase in plant height (59.5 and 57.2 %), number of leaves/plant (50.4 and 45.5 %,), total plant leaf area (113.9 and 119.4 %), internodes/plant (72.5 and 61.6 %), internode length (53.2 and 44.5 %), pod diameter (53.5 and 49.9 %), pod fresh weight (126.8 and 111.8 %), and pod yield (271.2 and 255.8 %) with the application of 30 and 50 mg/L NAA, respectively, over control (0 mg NAA/L). However, NAA concentration of 10 and 30 mg/L increased the pod length up to 19.0 and 21.07 %, and pods/plant up to 31.1 and 27.9 %, respectively over control (0 mg NAA/L).

The increase in vegetative growth could be due to stimulated cell multiplication and elongation of internodes (Dhage *et al*., 2011). Studies by Abdo and Abdel-Aziz (2009) and Kumar *et al*. (2018) also revealed that exogenous application of NAA up to 50 mg/L improved the overall vegetative growth and leaf area of the plant. Furthermore, more pod yield with lower NAA concentrations (30 and 50 mg/L) might be due to

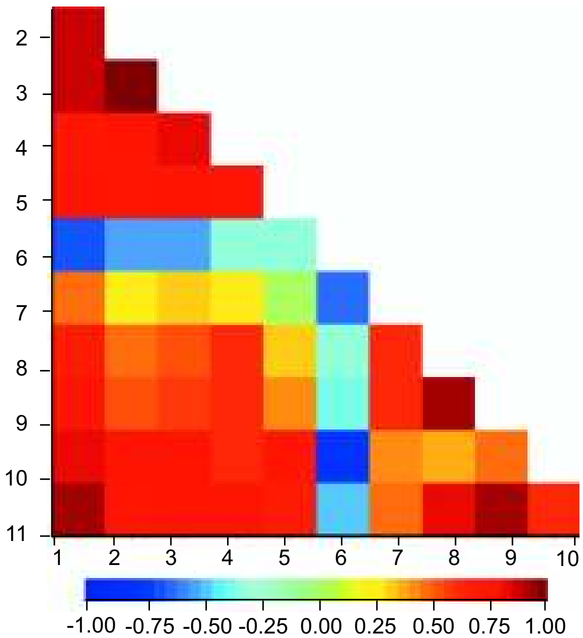

Fig. 3. A colour heat map exposing correlations among growth and yield-determining parameters of Okra, where:

1 = Plant height; 2 = Leaves/plant; 3 = Total plant leaf area; 4 = Internodes/plant; 5 = Internode length; 6 = Onset of first flowering; 7 = Pod length; 8 = Pod diameter; 9 = Pod fresh weight; 10 = Total pods/plant; 11 = Pod yield. Colour bars represent the strength of the Pearson's correlation coefficient "r".

better translocation of photo-assimilates to the developing pods and seeds (Ravat and Makani, 2015). This could also be due to enhanced source sink relationship initiated by exogenous NAA application that in turn stimulated the heavier build-up of sufficient food reserves thereby helping in effective pod development and ultimately enhancing the pod yield (Huang *et al*., 2018). Various studies have reported the effectiveness of NAA towards inducing pod production in other crops including lablab bean (Uddin *et al*., 1994), pigeonpea (Rao and Narayan, 1997), and chickpea (Karim, 2005). Our results were supported by Meena (2015) and Singh *et al*. (2017), who also accounted increase in most of the growth traits, yield-components and overall pod yield in Okra with the application of NAA.

Furthermore, it was observed that application of NAA at higher concentrations (> 50 mg/L) had a supressing effect on most of parameters. This was also apparent from a quadratic relationship between most of parameters and NAA concentrations. For instance, the onset of first flowering became 7 and 5 days earlier with the application of lower rates of NAA (10 and 30 mg/L, respectively) and gradually delayed with rise in NAA concentration till the maximum level (110 mg/L) and produced maximum delay (12.7 days) in the start of first flowering over control (0 mg NAA/L) (Mustafa *et al*., 2016). This could be associated with suppression of metabolic pathways responsible for early flowering at higher NAA concentration (Huang *et al*., 2018). It was interesting to note that results of NAA (110 mg/L) and control (0 mg NAA/L) were statistically alike for most parameters. However, NAA application was still better than control (0 mg NAA/L) which overall led to minimum vegetative growth and pod yield. This was evident from the fact that different NAA concentrations (10, 30, 50, 70, 90, 110 mg/L) increased the pod yield in the range of 185.8, 271.2, 255.8, 224.3, 169.7 and 83.6 %, respectively over control (0 mg NAA/L).

Analysis of correlation coefficients revealed strong and positive inter-relationships between most of the parameters (Fatima *et al*., 2019). Highly strong association between pod yield and growth parameters *viz*., plant height, leaves/plant, total plant leaf area, internodes/plant, internode length and yield-components such as pod diameter, pod fresh weight, and number of pods/plant revealed that these are the vital yield determinants in Okra (Falusi *et al*., 2012). Negative association between pod yield and the onset of first flowering suggested that a delay in flowering might have a detrimental impact on yield production in Okra mainly due to shortening of the reproductive growth period influenced by uncongenial environmental conditions (Bruns, 2009). It was inferred that yield constitution in Okra is influenced by multiple yield-contributing traits and their mutual inter-associations. Selecting for such traits would assist in formulating an indirect selection criterion for yield improvement in Okra (Fatima *et al*., 2019).

Conclusion

This study clearly indicated that foliar application of NAA had a marked impact on parameters determining the vegetative, reproductive, and yield formation in

Okra. Overall, application of NAA in the range of 30–50 mg/L appeared the best levels for increased pod yield. Results concluded that yield-contributing characters and pod yield of Okra could be manipulated by the application of NAA. Therefore, foliar application of NAA at the rate of 30-50 mg/L may be recommended for ensuring better Okra yield.

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Conflict of Interest. The authors declare no conflict of interest.

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