Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2020 17(2): 1051-1068. **OPEN ACCESS**

Relationship between growth, fruit yield and nutritional content in Okra due to application of IAA and NAA

Ayesha Javed[1], Khalid Hussain[1,] Khalid Nawaz[1], Noshia Arshad[1], Arifa Nazeer[1], Zobia Bashir[1], Syed Saqib Ali[1], Muniza Sarfraz[1], Amna Shahzadi[1], Anam Younas[1] and Hassnaina Ghaus[1]

Department of Botany, University of Gujrat, Gujrat, **Pakistan**

***Correspondence:** khalid.hussain@uog.edu.pk **Received 12-05-2020, Revised: 06-06-2020, Accepted: 08-06-2020 e-Published: 09-06-2020**

Although, plant growth regulators mainly auxins (indole acetic acid (IAA) and naphthalene acetic acid (NAA) are used for the improvement of growth and yield of plants but not commonly used for vegetables. Okra is the mostly used and favorite summer vegetable throughout the world. Its better yield and high nutritional contents directly affect the human diet. In order to determine the growth, yield and nutritional contents of okra, experiments were carried out for three varieties of in okra i.e. NS-810, TARA-F1 and TARA-55. Different levels of IAA and NAA (separate and combinations) were applied as foliar applications. IAA and NAA increased all growth attributes (root and shoot development, foliage characteristics) and fruit yield in all varieties. Photosynthetic pigments and physiological attributes were increased due to application of IAA and NAA for rapid growth. The varieties TARA-F1 and TARA-55 were best in growth, but NS-810 had the best fruit yield and high protein and carbohydrate, potassium and phosphorus contents. Catalases (CAT) and peroxidase dismutase (POD) activities were also increased by IAA and NAA. The combined IAA+NAA applications were better than each hormone applied separately. The concentration of 200 mmol·L^{-1} (IAA+NAA) enhanced yield, and nutritional value of okra. There was a positive correlation between protein, carbohydrates, and potassium and phosphorus contents and fruit yield. The combination of IAA and NAA enhanced the growth, physiological attributes, and fruit yield and improved nutritional components of okra. Application of 200 mmol·L^{-1} of IAA+NAA can be utilized in okra to improve fruit yield and nutritional content.

Keywords: *Abelmoschus esculentus*, antioxidants, fruit yield, nutrition, physiology.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is a source of potassium, phosphorus and many important minerals. Plant growth regulators (PGRs) play a vital role in the development and growth of the plant (Singh et al., 2019). The growth regulators of plants have demonstrated intensive scientific activities for their commercial exploration. Various valuable effects of different growth regulators were examined on the number of plants, such as spinach (Akhtar et al., 2008), citrus (Nawaz et al. 2008) and tuberose (Panwar et al., 2006). These growth regulators are involved in transplantation and affect the flowering and development of plants (Naeem et al., 2004; Hayat et al., 2008). To increase productivity in okra various plant growth regulators are used, making it one of the cheapest and most widely used physical manipulators. Though plant growth regulators have great potential for growth improvement, their

applications should be appropriately planned in terms of application stage, seasons, plant specificity and its quantity and specificity (Khan et al., 2006).

Among plant growth regulators auxin are considered to be very important (Etesami et al. 2009; Anjum et al., 2011) because it plays a significant role in division and elongation of cells, in development of adventitious roots (Ahmad et al. 2008; Etesami et al., 2009). IAA has various physiological functions, with increased amounts of root hair and high development of longer roots involved in the nutrients uptake (Datta and Basu, 2000). Naphthalene acetic acid (NAA) also belongs to the family of auxins and is considered very significant in many post-harvest commercial horticultural products. NAA plays a major role in various plant processes such as development, growth, enzymatic activities of biosynthetic processes and flowering in plants. Spray of NAA on plants influences various physiological processes such as photosynthesis and respiration, and eventually accumulates dry matter, minerals and carbohydrates (Singh et al., 2017). NAA, a synthetic auxin mostly used in plants at low concentration in order to promote the cell growth, fruit setting, rooting and cell division (Srivastava, 2002 ; Sun and Hong, 2010). Application of NAA increased plant height, leaves and fruit size. In okra the quality and yield of seed, plant growth and the production of pod has been affected by the NAA (Patil, 2010).

In the literature there are many studies to find the efficacy of plant growth regulators on growth and yield of plants. So far, nutritional components and its correlations with plant growth regulators and fruit yielding in ladyfinger has not much focused. This study was designed to evaluate the relationships among fruit nutritional components with fruit yield of ladyfinger under the influence of IAA and NAA.

MATERIALS AND METHODS

Experiment was conducted at University of Gujrat, Pakistan during 2019-2020. Treatments of Indole acetic acid (IAA) and naphthalene acetic acid (NAA) were applied as foliar spray in one dose on three varieties of okra (NS 810, TARA F1 and TARA-55) after 21 days of germination. The treatments were: control (no hormones), IAA (100 mmol L^{-1}), IAA (200 mmol L^{-1}), NAA (100 mmol L^{-1}), NAA (200 mmol L^{-1}), IAA+NAA (100 mmol L^{-1}), and IAA+NAA (200 mmol L^{-1}).

The experiment was arranged in a completely randomized design with 3 replicates. Data were collected at vegetative and fruiting stages and root and shoot lengths; root and shoot dry weights; numbers of leaves; leaf area; relative growth rate (RGR); net assimilation rate (NAR); stomatal conductance; transpiration rate; photosynthetic rate; intercellular CO_2 concentration; contents of chlorophyll, carotenoids, antioxidants proteins and carbohydrates, and activities of catalase and peroxidase. The number of fruit and fruit weight were determined at fruiting stage during marketable maturity.

Leaf area was determined with portable Handheld Leaf Area Meter (CI-203 Laser scanner). RGR was calculated as:

$$RGR = \frac{1}{W} \times \frac{\Delta W}{\Delta T}$$

Where, W= Dry shoot weight at initial stage; ΔW =Dry shoot weight at final stage – Dry shoot weight at initial stage; ΔT =Number of days between initial and final stage.

Net assimilation rate (NAR) was determined by the formula:

$$NAR = \frac{W2-W1}{T2-T1} \times \frac{\log L2 - \log L1}{L2-L1}$$

Where, W1= Shoot dry weight at initial stage; W2=Shoot dry weight at final stage; L1=Leaf area at initial stage; L2=Leaf area at final stage; T1=Number of days for initial stage; T2=Number of days for final stage.

Chlorophyll a, b, and total, and carotenoids, were estimated using the method of Arnon (1949). Total carbohydrates were estimated with the Anthrone method. Soluble protein was estimated following Bradford (1976). Catalase and peroxidase activities were determined using the method of Chance and Maehly (1955). Potassium (K^+) contents were determined with a flame photometer (model PFP7, Jenway Staffordshire, UK). Phosphorus (P) content was determined with a spectrophotometer following the procedure described by Hernández et al., (2005).

Data were subjected to analysis of variance in Minitab (Version: 19.2.0, Coventry, UK). If interactions were significant, they were used to explain the results. If interactions were not significant means were separated with Tukey's Test.

RESULTS

Root development in okra:

There were highly significant ($P \leq 0.001$) effect of IAA and NAA for the enhancement of root developing attributes (Table-1). Root length was increased at vegetative and fruiting stage of okra (Fig.1A). There were highly significant interactions

among hormone, varieties and combinations. Maximum root length was found at 100mmol L^{-1} of IAA + NAA at vegetative stage in variety TARA F1 (Fig. 1A). Similarly, at fruiting stage maximum root length was noted in variety TARA F1 with the applications of 200mmol L^{-1} of IAA + NAA. Root fresh and dry weights have also significantly increased with the applications of IAA and NAA. There were highly significant results for interaction among varieties of okra and hormones (Table-1). Combine treatments of IAA+ NAA were more effective to enhance the root development in okra as compared to sole treatments. . At vegetative stage, maximum root fresh weight was noted in TARA-F1 with the applications of 200 mmol L^{-1} of NAA. There was highest root fresh weight in TARA-55 with 200 mmol L-1 of IAA + NAA application at fruiting stage (Fig. 1B). Similar pattern of root dry weight was found at vegetative stage as in the case of root fresh weight. Highest root dry weight was noted in TARA-55 with 200 mmol L^{-1} of IAA (Fig. 1C).

Table1: Analysis of variance results for root development in okra due to variety and hormones, and their interaction.

Source	df	Root length (vegetative stage)	Root length (fruiting)	Root fresh weight (vegetative stage)	Root fresh weight (fruiting)	Root dry weight (vegetative stage)	Root dry weight (fruiting)
Hormone (H)	6	25.637***	124.643***	0.7814***	7.532**	0.6734**	3.5506***
Variety (V)	2	12.341*	18.834*	0.09482**	4.463**	0.03461*	0.4284*
H ×V	12	9.145**	29.221***	0.1143***	5.324***	0.04563**	2.2638***
IAA x V	2	12.347**	22.491**	0.653*	6.408*	0.0145*	3.5641**
NAA x V	2	8.756**	11.763**	0.0482**	4.629**	0.0953**	1.2343*
IAA x NAA x V	2	24.429**	31.283**	0.903***	7.348***	0.0732***	3.3171***
Error	36	4.567	6.232	0.03612	0.459	0.0124	0.2763
Total	62						

ns= non-significant, ***= significant at P≤0.001 probability levels

Table2: Analysis of variance results for vegetation of okra due to variety and hormones, and their interaction.

Source	df	Shoot Length (vegetative stage)	Shoot length (fruiting)	Shoot fresh weight (vegetative stage)	Shoot fresh weight (fruiting)	Shoot dry weight (vegetative stage)	Shoot dry weight (fruiting)
Hormone (H)	6	493.623***	106.534***	2.3132***	285.743***	0.7423***	77.118***
Variety (V)	2	10.256***	198.356***	1.1424**	45.6275***	0.4621***	12.471***
H ×V	12	12.143***	90.478***	1.0976***	27.734***	0.1963***	6.167***
IAA x V	2	31.467**	21.452**	1.2542***	45.285**	0.2532**	8.549***
NAA x V	2	24.591**	18.934**	0.7692**	20.907**	0.4712**	6.713***
IAA x NAA x V	2	67.341***	27.384***	1.2745***	33.582**	0.8045**	12.579***
Error	36	1.231	2.129	0.0124	3.135	0.0147	5.719
Total	62						

ns= non-significant, ***= significant at P≤0.001 probability levels

Table 3: Analysis of variance results for foliage growth of okra due to variety and hormones, and their interaction.

Source	df	Number of leaves (vegetative stage)	Number of leaves (fruiting)	Leaf area (vegetative stage)	Leaf area (fruiting)
Hormone (H)	6	2.2746*	36.231**	961.142***	345.874***
Variety (V)	2	0.0543ns	5.923**	87.234***	345.691***
H ×V	12	0.2243ns	8.312**	45.762***	56.392***
IAA x V	2	0.4321*	4.392*	12.342	43.284**
NAA x V	2	0.0342*	14.523**	16.543	23.482***
IAA x NAA x V	2	0.73016*	1.286**	146.531	31.456***
Error	36	1.1256	3.412	34.157	77.578
Total	62				

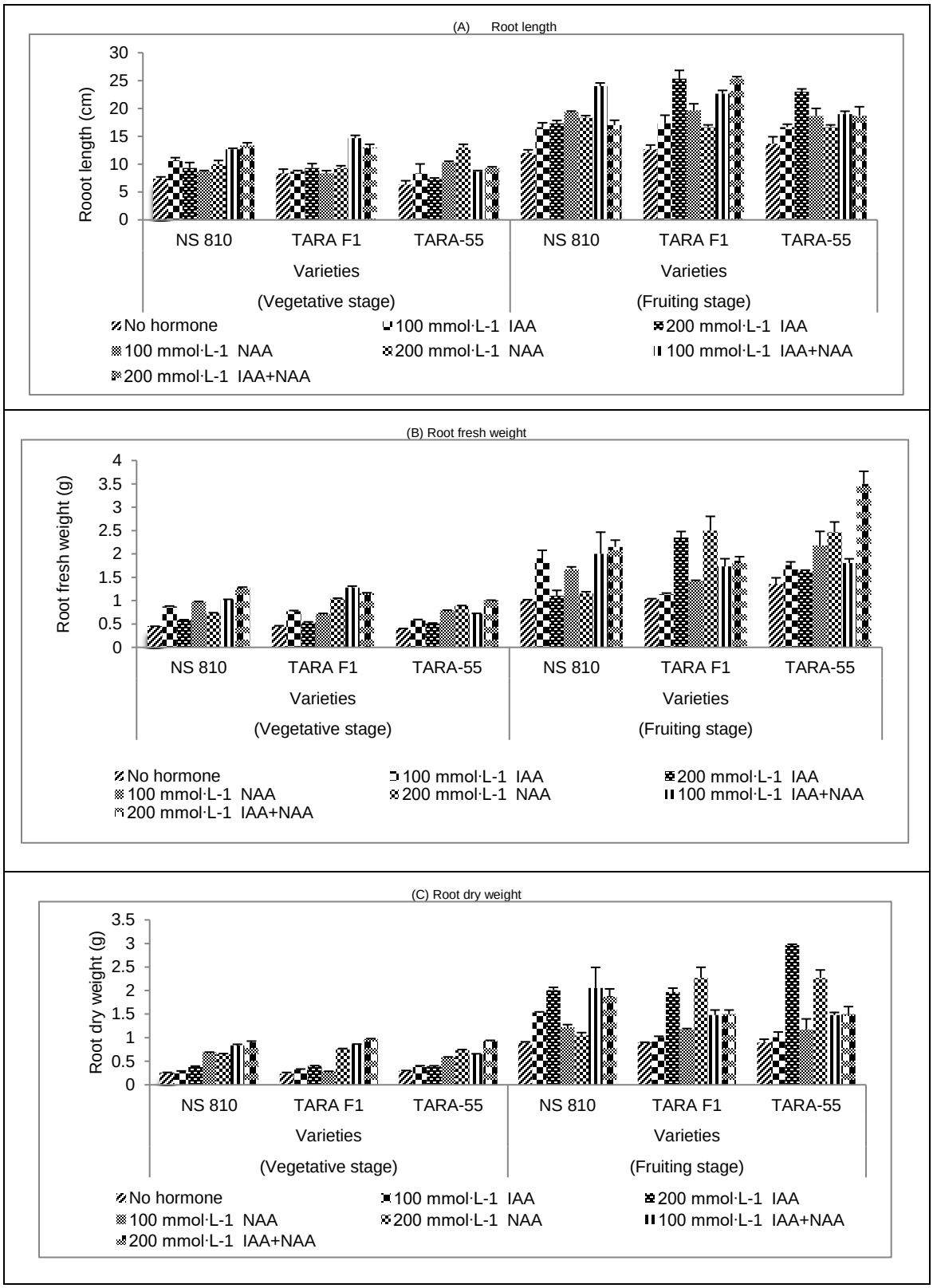

Figure 1: Effect of IAA and NAA on root development in okra

Vegetation development of okra:

Effect of IAA and NAA was highly significant effect for the development of vegetative growth of okra i.e. shoot lengths, shoot fresh and dry weights. There was a highly significant effects to increase the shoot length at vegetative and fruiting stages (Table-2). Interactions among hormones, varieties and combinations were also significant. Maximum shoot length was noted in variety TARA F1 200 mmol L^{-1} of NAA during vegetative stage, while during fruiting, maximum shoot length was present in TARA-55 with 200 mmol L^{-1} of IAA (Fig.2A). Overall, combine treatments of IAA+NAA were more effective to increase the shoot length as compared to single hormone treatment. Shoot fresh and dry weights were also significantly increased with the applications of IAA and NAA at both the stage (Table-2). There were also highly significant interactions among all the variable. At vegetative and fruiting stages, maximum shoot fresh weight was found in TARA-F1 with 200 mmol L-1 of IAA+NAA (Fig. 2B). Variety NS-810 had maximum shoot dry weight with during vegetative stage with 100 mmol L^{-1} of IAA + NAA. At fruiting stage, maximum shoot dry weight was observed in TARA-F1 with 200 mmol L^{-1} IAA+NAA (Fig. 2C).

Foliage growth of okra:

Effects of IAA and NAA was significant on number of leaves and highly significant for leaf area per plant at both vegetative and fruiting stages (Table-3). There were non-significant effects for number of leaves with IAA and NAA treatments for varieties and interaction of hormone x variety at vegetative stage. Higher number of leaves was found in NS-810 with 200 mmol L^{-1} IAA + NAA (Fig 3A). Maximum leaf area was found in TARA-F1 both at vegetative and fruiting stages with 200 mmol L^{-1} IAA + NAA (Fig. 3B).

Physiological activities and photosynthetic pigments:

Data related to relative growth rate (RGR) and net assimilation rate (NAR) is presented in Table-4. There was a highly significant effect of IAA and NAA for RGR and NAR including at the interactions among variables. RGR was increased with the applications of both hormones. Maximum RGR was found in NS-810 with the applications of 200 mmol L^{-1} of IAA (Fig.4A). Maximum NAR was notes in TARA-55 with the treatments of 200 mmol L^{-1} IAA+NAA (Fig. B).

Effect of IAA and NAA was highly significant on photosynthetic pigments in okra i.e. chl. a, b, total chlorophyll and carotenoids at vegetative as well as fruiting stage (Table-4). Photosynthetic pigments were increased with the applications of IAA and NAA. At vegetative stage, there was only significant effects for hormone and IAA interaction with variety while other variables showed non-significant effects. For Chl-a at fruiting as well as for Chl-b and carotenoids, there were highly significant effects for all the variables and its interactions. Treatments applied in combinations have more effective effects in increasing the photosynthetic pigments (Fig. 5 A-D). Maximum Chl- a, b and total contents were found in NS-810 with the treatments of 200 mmol L^{-1} of IAA+NAA at both growth stages. Similarly, there was high contents of carotenoid in NS-810 with the treatments of 200 mmol L^{-1} of IAA+NAA (Fig. 5D).

Physiological activities:

Results from Table-5 indicated that the impact of plant growth regulators (IAA and NAA) was highly significant on all physiological parameters i.e. photosynthetic and transpiration rates, intercellular CO_2 concentration and stomatal conductance. All the variables also showed highly significant responses to IA and NAA. Highest rate of photosynthesis was found in NS-810 showed highest at 200 mmol L^{-1} of IAA + NAA as compared to other varieties (Fig.6A). Maximum transpiration rate was observed in TARA-55 at 200 mmol L^{-1} of IAA + NAA (Fig. 6B). High intercellular CO_2 concentration was noted in TARA-F1 with the applications of at 200 mmol L-1 of IAA + NAA (Fig. 6C). Figure 6D revealed that TARA-F1 and TARA-55 showed the best results whereas TARA-F1 showed highest intercellular CO_2 concentration at 200 mmol L^{-1} of IAA + NAA. As compared to NS-810 and TARA-F1, variety TARA-55 showed highest stomatal conductance at 100 mmol L^{-1} of IAA + NAA (Fig. 6D). Maximum stomatal conductance was present in TARA-55 at 200 mmol L^{-1} of IAA + NAA. Overall, it was noted that the combine treatments of hormones were best as compared to separate treatment to enhance the physiological activities.

Antioxidant attributes:

Mean squares in ANOVA Table-5 showed that all the antioxidant activities like catalase (CAT) and peroxidase (POD) were significant increased at both the growth

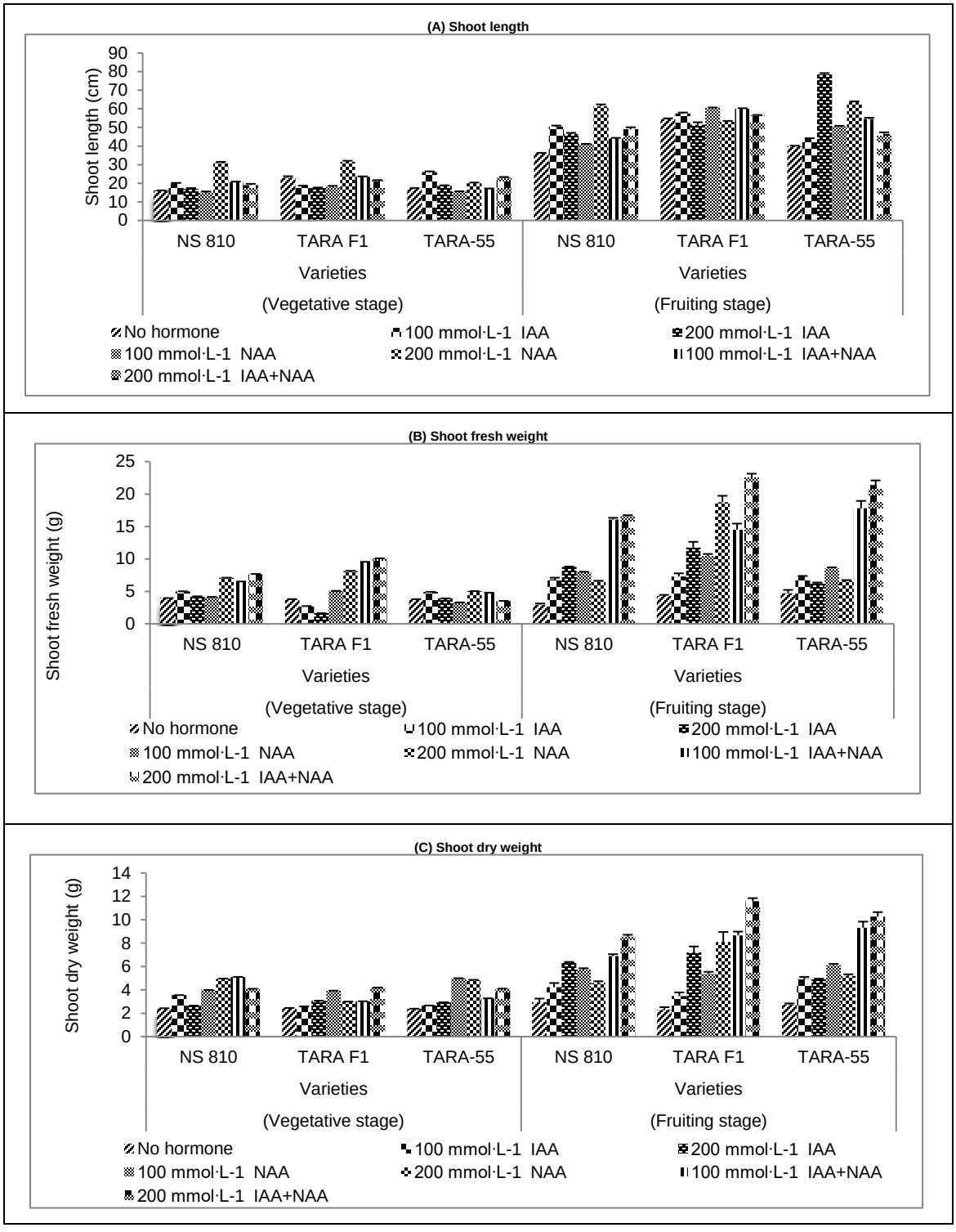

Figure 2: Effect of IAA and NAA on vegetative growth of okra

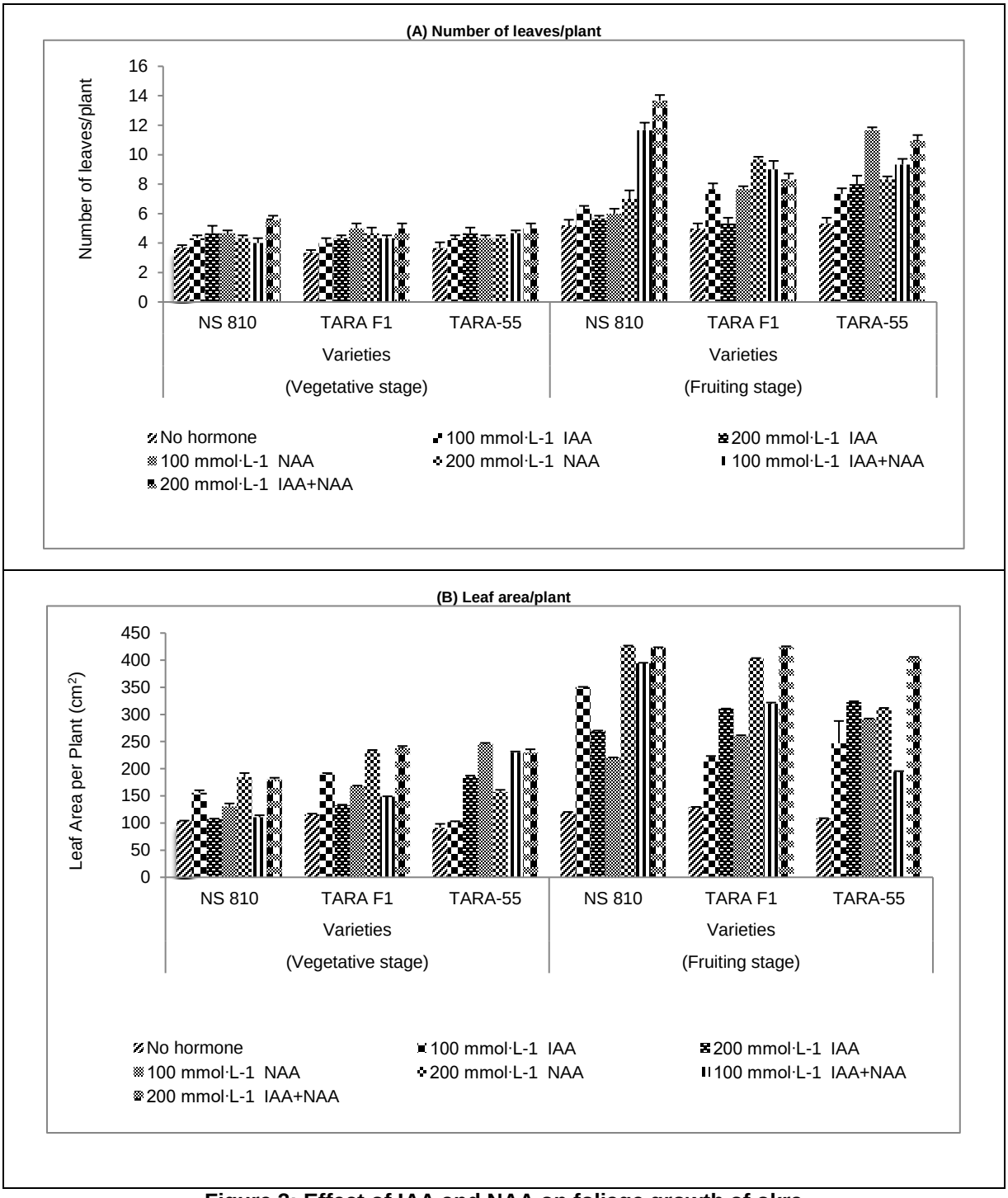

Figure 3: Effect of IAA and NAA on foliage growth of okra

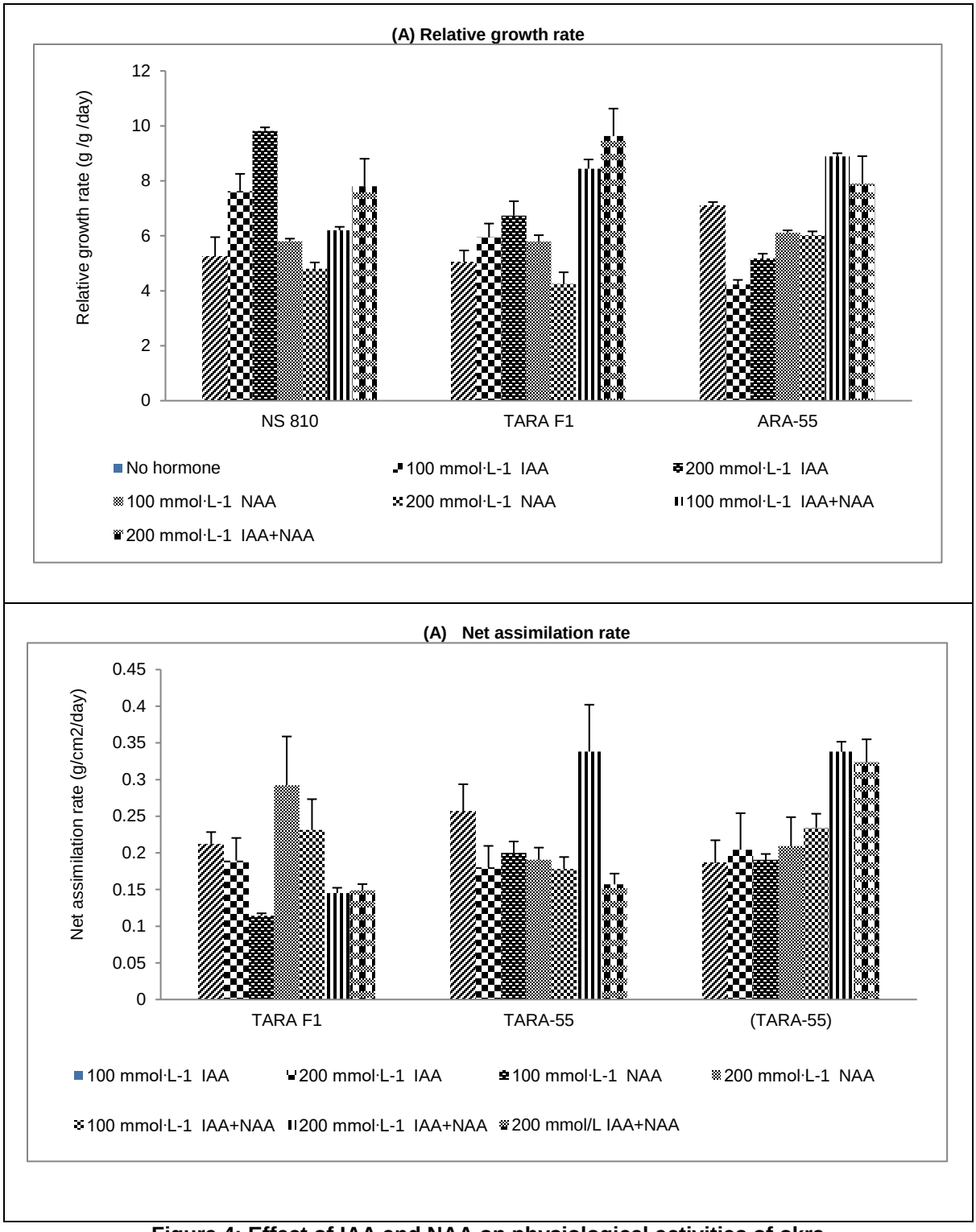

Figure 4: Effect of IAA and NAA on physiological activities of okra

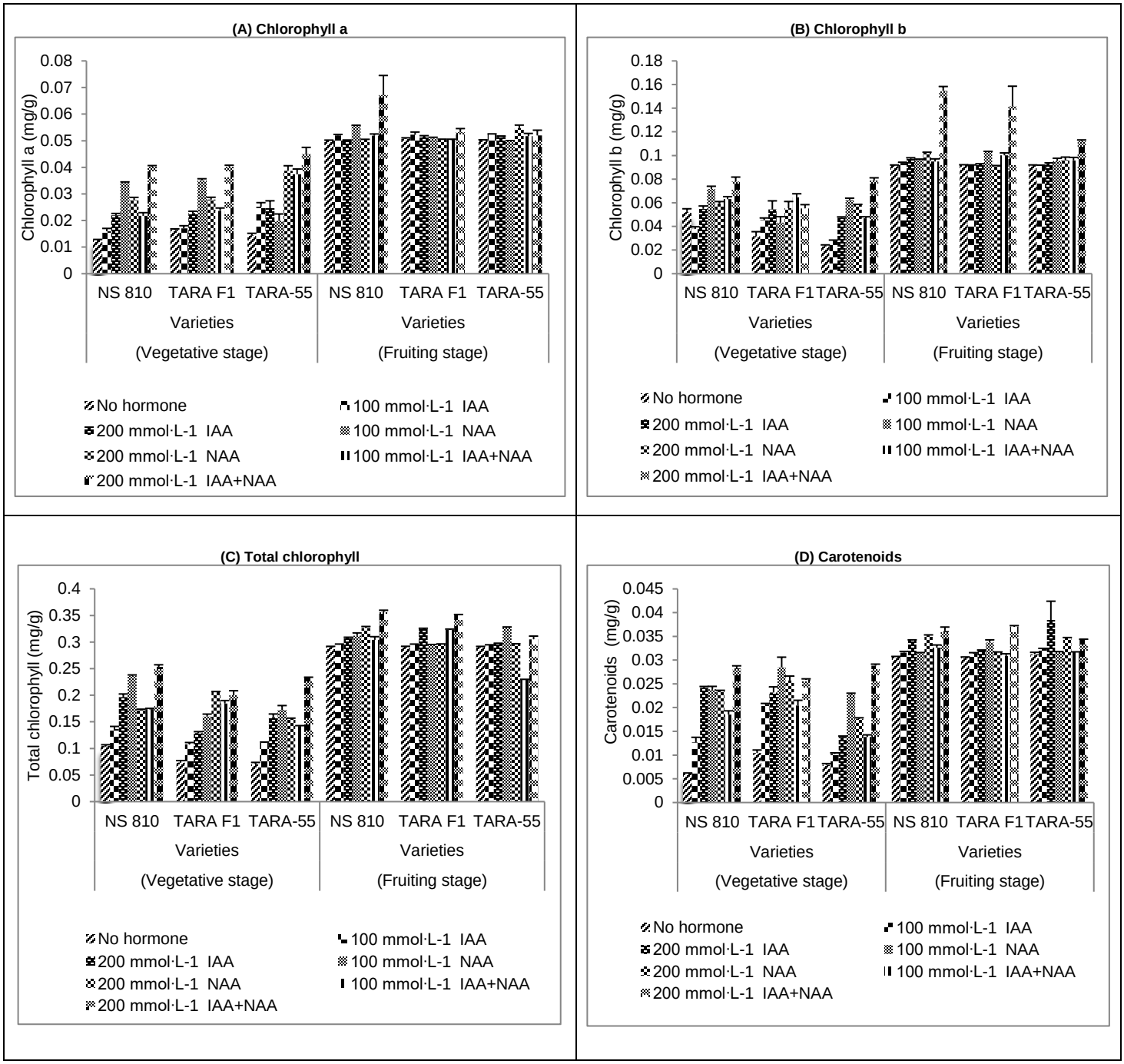

Figure 5: Effect of IAA and NAA on photosynthetic pigments of okra

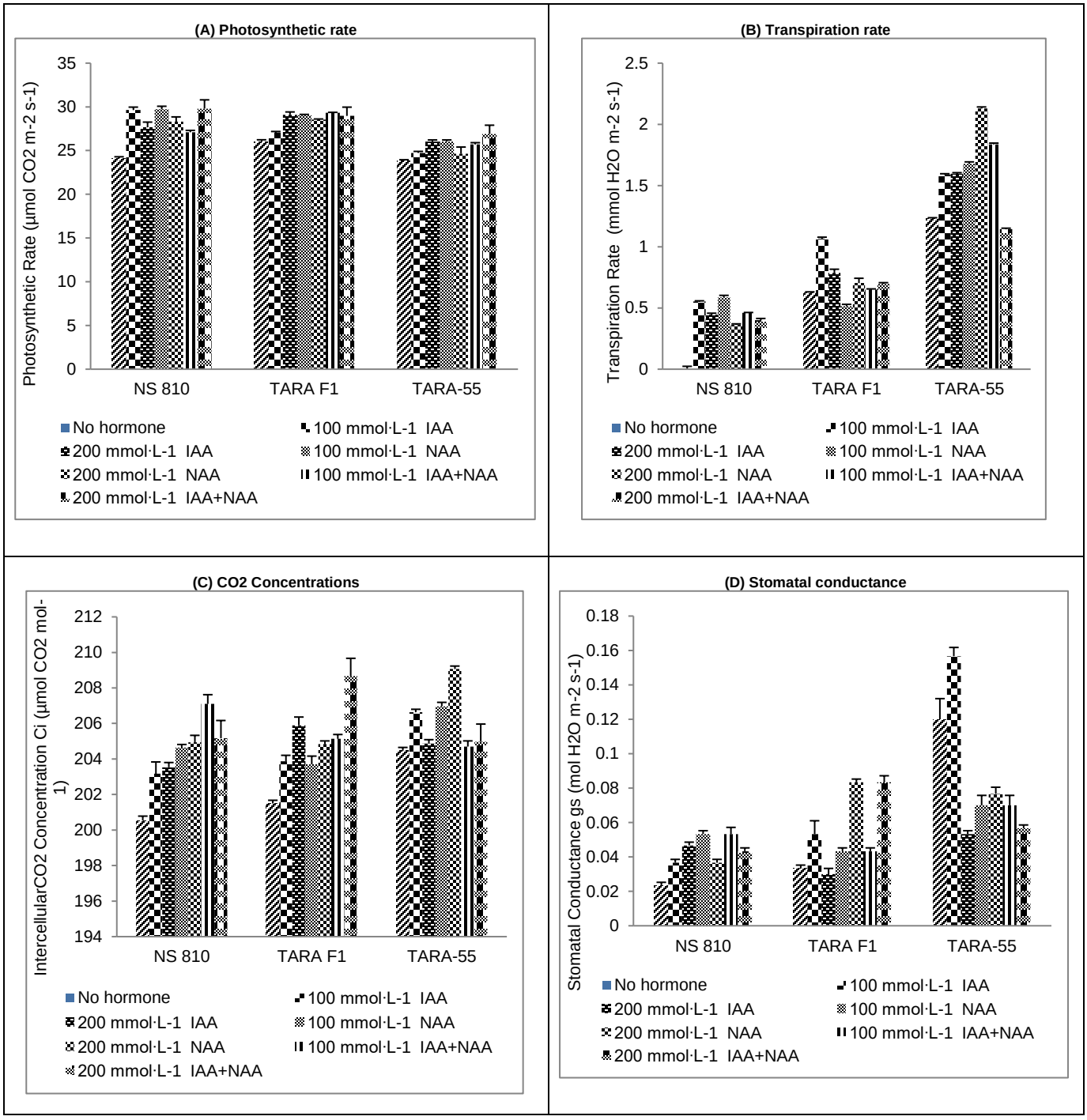

Figure 6: Effect of IAA and NAA on physiological activities of okra

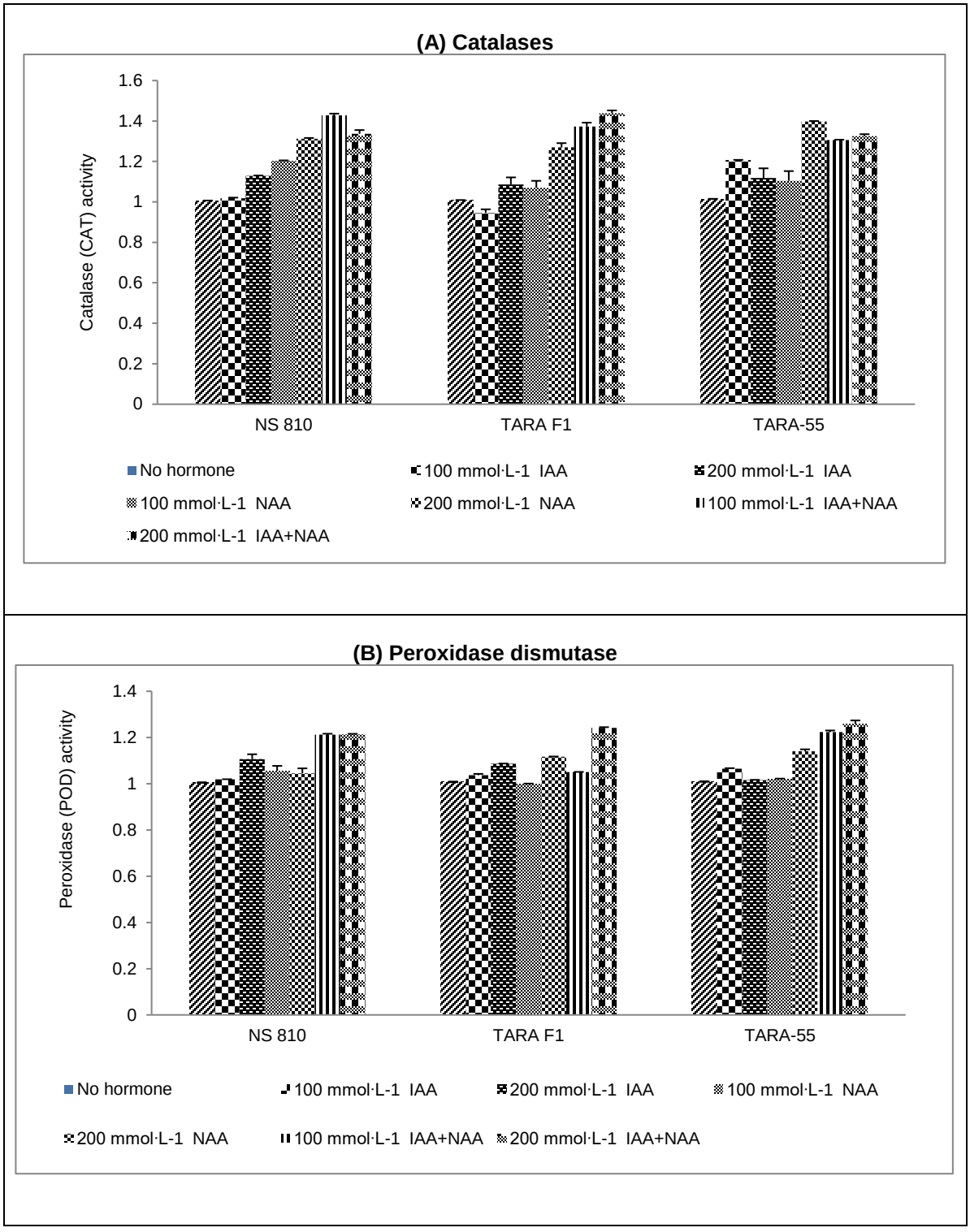

Figure 7: Effect of IAA and NAA on antioxidant activities of okra

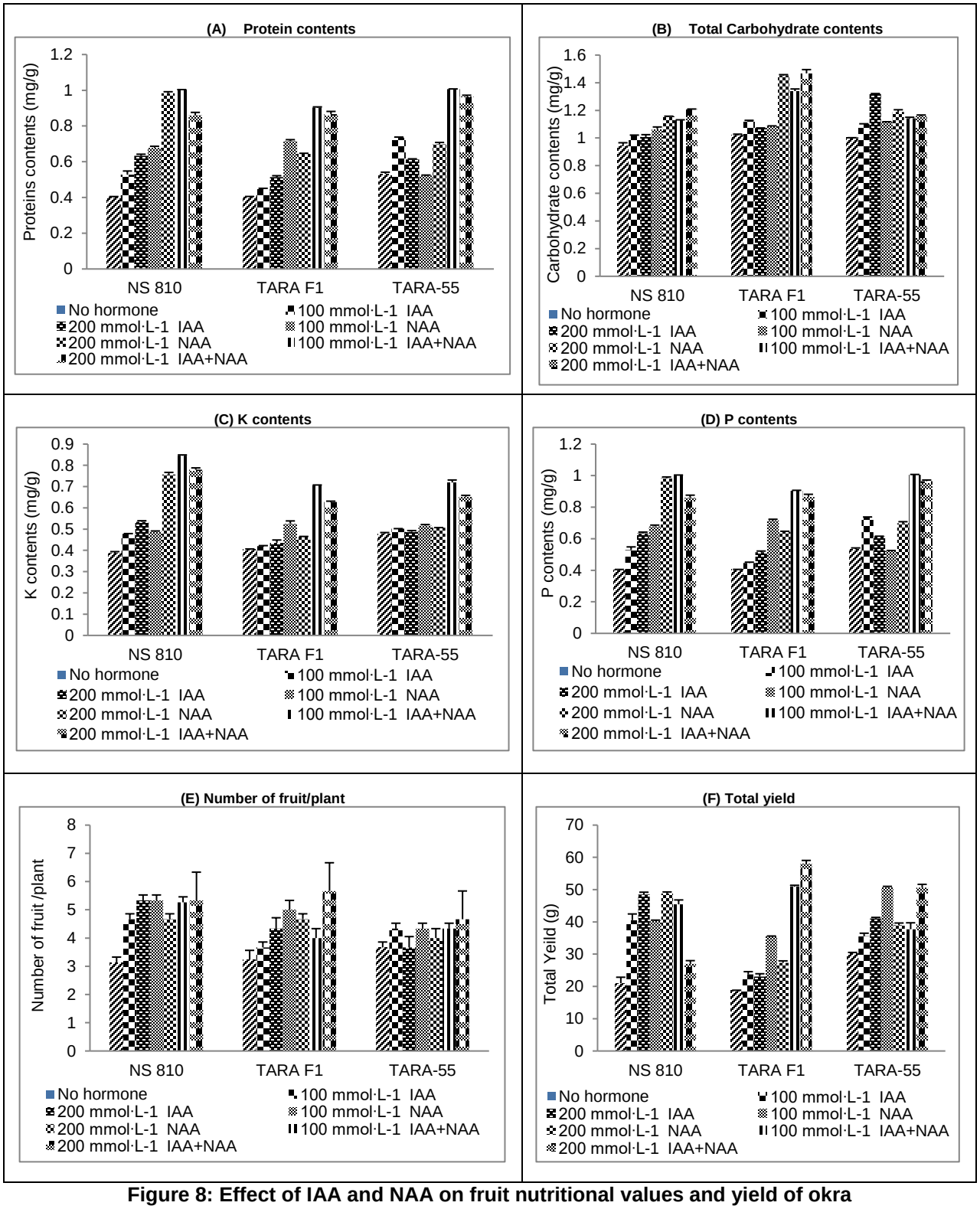

Figure 8: Effect of IAA and NAA on fruit nutritional values and yield of okra

Table 4: Analysis of variance results for physiological activity and photosynthetic pigments of okra due to variety and hormones, and their interaction.

Source	df	RGR	NAR	Chl a (vegetative stage)	Chl a (fruiting)	Chl b (vegetative stage)	Chl b (fruiting)	Total chl (vegetative Stage)	Total chl (fruiting)	Carotenoids (vegetative stage)	Carotenoids (fruiting)
Hormone (H)	6	12.153***	0.0093***	0.00723***	0.00435*	0.00432***	0.00312*	0.03451***	0.00343**	0.00461***	0.00674**
Variety (V)	2	0.523**	0.0168**	0.00155***	0.00873ns	0.00862**	0.00572*	0.08498***	0.00751**	0.00741***	0.00732**
H ×V	12	6.781***	0.0147**	0.00943***	0.00261ns	0.00761***	0.00832*	0.00835***	0.00754**	0.00754**	0.00886**
IAA x V	2	3.167**	0.0234**	0.0045**	0.00542*	0.00572**	0.00874*	0.00631***	0.00456**	0.00478***	0.00652*
NAA x V	2	4.572***	0.0428***	0.0342**	0.00762ns	0.00842**	0.00562ns	0.00943***	0.00534**	0.00631**	0.00987*
IAA x NAA x V	2	12.473***	0.4887***	0.0126***	0.0347ns	0.0765***	0.0456*	0.0251***	0.02341*	0.03451***	0.0612*
Error	36	1.036	0.00995	0.00253	0.01582	0.0347	0.0374	0.00342	0.07841	0.00763	0.0158
Total	62										

ns= non-significant, **, *** = significant at P≤0.01 and P<0.001 probability levels, respectively
RGR= relative growth rate; NAR= net assimilation rate; Chl= chlorophyll

Table 5: Analysis of Variance for physiological and antioxidant activities of okra due to variety and hormones, and their interactions.

Source	df	Photosynthetic rate	Transpiration rate	Intercellular CO_2 Concentrations	Stomatal conductance	CAT	POD
Hormone (H)	6	13.345*	0.3421***	13.345***	0.0534**	0.0564**	0.4732***
Variety (V)	2	53.573*	5.749**	14.492**	0.0573**	0.0767**	0.0872**
H ×V	12	2.1451*	1.349**	7.891**	0.0637**	0.0742**	0.0482**
IAA x V	2	11.241*	3.592**	4.691**	0.0453***	0.0649**	0.0692**
NAA x V	2	8.756*	5.392**	8.198***	0.0962*	0.0873**	0.0634**
IAA x NAA x V	2	14.592*	8.255**	5.843**	1.982**	0.0954**	0.0653*8
Error	36	1.146	0.0682	0.9811	0.0187	0.0023	0.0064
Total	62						

ns= non-significant, **, *** = significant at P≤0.01 and P<0.001 probability levels, respectively
CAT=catalases, POD=peroxidase dismutase

Table 6: Analysis of variance results for nutritional and yield of okra as affected by variety and growth regulators and their interaction.

Source	df	Protein contents	Carbohydrate Contents	K content	P content	Number fruit/plant	Total fruit yield
Hormone (H)	6	0.0432***	0.1364***	0.2093***	1.3471***	4.3243***	425.311**
Variety (V)	2	0.0321**	0.2619**	0.0192**	2.4821**	5.1954**	213.946***
H ×V	12	0.0673***	0.03134***	0.0312***	1.8435***	2.4201**	253.673**
IAA x V	2	0.0843**	0.0183***	0.0453***	2.3461***	3.8712**	45.673***
NAA x V	2	0.0943**	0.0731**	0.0652***	1.6821***	2.6327**	24.853**
IAA x NAA x V	2	0.1257***	0.0126***	0.2511***	3.7521***	4.8342***	58.391***
Error	36	0.0341	0.0231	0.0212	0.0278	0.5492	13.742
Total	62						

ns= non-significant, *** = significant at P≤0.001 probability levels

Table7: Pearson correlation coefficients for nutrition variables in of okra.

	Protein content	Carbohydrate content	K Content	P Content
Carbohydrate content	0.443347956			
K content	0.662966951	0.496384545		
P content	0.659462194	0.318713013	0.855646123	
Total yield	0.601533646	0.372842888	0.650032631	0.536492652

r value >0 shows positive correlations and r value <0 shows negative correlation.

stages with the application of IAA and NAA, Varietal response and the interactions among all the variables were also significant. Maximum CAT activity was observed at 100 mmol L^{-1} of IAA + NAA in NS-810, however at fruiting stage highest CAT activity was found in TARA-F1 at 200 mmol L^{-1} of IAA + NAA (Fig. 7A). NS-810 and TARA-55 showed maximum POD activity at vegetative stage whereas highest POD activity was observed in TARA-55 at 200 mmol L^{-1} of IAA + NAA at fruiting (Fig. 7B).

Nutritional contents in okra:

Nutritional contents such as total protein and total carbohydrate contents, ionic concentrations of potassium (K) and phosphorus (P) of okra showed highly significant results in response to IAA and NAA applications (Table-6). There were highly significant results for the interactions among variables. High contents of protein were found in all the varieties at 200 mmol L^{-1} of IAA+NAA. Varieties NS-810 and TARA-55 had maximum protein contents (Fig. 8A). Maximum carbohydrates contents were found in TARA-F1 at 200 mmol L^{-1} of IAA+NAA. It was noted the 200 mmol L^{-1} of IAA+NAA was better for the enhancement of both quality attributes (Fig. 8B). It was noted that the application applied in combination helped to increase the K contents in okra. Maximum K contents were noted in NS-810 at 100 mmol L^{-1} of IAA+NAA. It was noted that 100 mmol L^{-1} of IAA+NAA helped to increase the

K contents among all the varieties of okra (Fig. 8C). Similarly, combined treatments of IAA+NAA increased the P contents in okra more effectively as compared to separate applications (Fig.8D). Maximum P contents were noted in NS-810 at T5 (100 mmol L^{-1} of IAA+NAA).

Yield attributes:

Data regarding the yield parameters is given in Table-6. It was noted that yield attributes showed highly significant results to IAA and NAA including variable interactions. Number of fruits and total yield were increased significantly with the applications of plant hormone (Fig.8E-F). TARA-F1 and TARA-55 showed the number of fruits and highest yield as compared to NS-810. TARA-F1 showed highest number of fruit at 200 mmol L^{-1} of IAA + NAA. Similarly, maximum fruit yield was present in TARA-F1 200 mmol L^{-1} of IAA + NAA. It was noted that the application applied in combinations were more effective to enhance the fruit yield of okra.

Pearson correlations:

Correlations among all the nutritional contents and fruit yield is presented in Table-7. From correlation it was noted that all nutritional contents and fruit yield had positive correlation with each other. Protein contents had positive correlation with carbohydrates (r=0. 4433), K (r=0.6629), P (r=0.6594) and fruit yield (r=0.60153). Similarly each variable had positive correlation with each other. IAA and NAA helped to correlate all the variables positively to enhance the growth, yield, nutritional contents and fruit yield of okra.

DISCUSSION

The application of plant hormones has enhanced the growth-related characteristics, either alone or in combination. The yield and the factors leading to yield amount of pots per plants were also examined, by using different concentrations of hormones. The outcomes of the treatments indicated that the auxin category of hormones IAA and NAA have significant effect on the morphological characteristics of newly produced plants but on rooting rate it does not show any significant impact (Sevik and Guney, 2013). Ayyub et al., (2013) reported that weight and yield of seeds, content of chlorophyll elongation of stem, leaf number, number of pods and seeds, were significantly enhanced by the foliar use of different growth regulators. In tomato highest number of branches, yield and development of taller plants were obtained by the application of IAA and NAA (Pramanik and Mohapatra, 2002). In wheat height of plant was greatly enhanced by the foliar application of NAA (Jeber and Khaeim, 2019). Khalid et al. (2017) showed that the foliar application of IAA at vegetative stages of cowpea resulted increased dry weight of shoots. Jiang et al. (2015) noted that application exogenously of NAA increased the antioxidants activities like catalase (CAT) and superoxide dismutase (SOD) in tomato. Catalase activity in tomato was also significantly improved by the foliar application of Indole acetic acid (IAA). Different concentrations of IAA and NAA in tomato increased the peroxidase activity considerably relative to the control (Olaiya and Anvanwu, 2013).

Shah (2011) found that in black cumin (*Nigella sativa* L.), rate of photosynthesis, dry mass and content of protein in its leaf was increased by the foliar application of IAA. Chlorophyll content in plants as compared to control was enhanced by different chemicals and by the application of different plant growth regulators. It has been reported that in soya bean *Glycine max* L. foliar application of NAA had favorable impact on its protein content (Sivakumar et al., 2002). In plants different physiological and biochemical parameters such as stomatal conductance and content of chlorophyll were improved by the IAA application (Alenazi, 2011).

Foliar application of NAA in chili *Capsicum annum* L. considerably resulted in greater fruit yield (Gollagi et al., 2009). In white lupine plant pod and seed number, number of branches and seed yield substantially increase by the bioregulators application such as IAA and NAA. In many studies it was observed that auxin helped to improve the quality of fruits and vegetable. It was observed that starch contents were significantly increased by 20ppm NAA in maize (Zewail and Mady, 2011). In tomato, size of fruit, fresh weight and dry weight were significantly increased by the 2, 4-D application (Gemici et al. 2006). Jahan et al., (2019) identified that in mung bean *Vigna radiata* L. foliar spray of NAA significantly increased seed production and yield of its components in a favorable way. Foliar spray of NAA in bitter gourd resulted in highest yield of seed and fruit quality relative to control. By spraying NAA on groundnut the amount of pods per plant was increased.

CONCLUSION

It was concluded that there was a positive correlation between protein, carbohydrates, and

potassium and phosphorus contents and fruit yield. The combination of IAA and NAA enhanced the growth, physiological attributes and fruit yield and improved fruit nutritional components of okra. Applications of IAA and NAA can be utilized in okra for higher fruit yield and with improved nutritional contents.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

Authors would like to pay acknowledgement whole faculty and staff, Department of Botany, University of Gujrat for their support and help.

AUTHOR CONTRIBUTIONS

In this paper, AJ has conducted the field and lab experiments. KH and KN supervised the research. NA, AN and ZB helped in data collection and draft writing. SSA, MS and AS conducted statistical analysis. AY and HS facilitated for literature collection and write up.

REFERENCES

Ahmad R, Khalid M, Naveed M, Shahzad SM, Zahir ZA, Khokhar SN, 2008. Comparative efficiency of auxin and its precursor applied through compost for improving growth and yield of maize. Pakistan Journal of Botany 40: 1703-1710.

Akhtar N, Ibrar M, Aman N, 2008. The effects of different soaking times and concentrations of GA_3 on seed germination and growth of (*Spinacia oleracea* L.) Pakistan Journal of Plant Sciences 14(1): 9-13.

Alenazi MM, 2011. Improvement of Okra (*Abelmoschus esculentus*) Growth, yield and quality by using plant growth regulators in vivo and in vitro conditions. Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia. PhD dissertation.

Anjum MA, Zahir ZA, Arshad M, Ashraf M, 2011. Isolation and screening of rhizobia for auxin biosynthesis and growth promotion of mung bean (*Vigna radiata* L.) seedlings under axenic conditions. Soil and Environment 30(1):18-26.

Ayyub CM, Manan A, Pervez MA, Ashraf MI, Afzal M, Ahmed S, Shaheen MR, 2013. Foliar feeding with Gibberellic acid (GA3): A strategy for enhanced growth and yield of Okra (*Abelmoschus esculentus* L. Moench.). African Journal of Agricultural Research 8(25): 3299-3302.

Bradford MM, 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal Biochemistry 72: 248-254.

Datta C, Basu PS, 2000. Indole acetic acid production by a Rhizobium species from root nodules of a leguminous shrub, (*Cajanus cajan* L.) Microbiological Research 155(2):123-127.

Etesami H, Alikhani HA, Akbari AA, 2009. Evaluation of plant growth hormones production (IAA) ability by Iranian soils rhizobial strains and effects of superior strains application on wheat growth indexes. World Applied Science Journal 6(11): 1576-1584.

Gangopadhyay KK, Singh A, Bag MK, Ranjan P, Prasad TV, Roy A, Dutta M, 2017. Diversity analysis and evaluation of wild Abelmoschus species for agro-morphological traits and major biotic stresses under the north western agro-climatic condition of India. Genetic Research Crop Evolution 64(4): 775-790.

Gemici M, Bengü T, Kit T, 2006. Effects of 2, 4-D and 4-CPA on yield and quality of the tomato, (*Lycopersicon esculentum* L.). Miller Journal of Faculty Sciences 29: 24-32.

Gollagi SG, Hiremath SM, Chetti MB, 2009. Effects of growth regulator and nutrients on growth parameters and yield in chilli cv. Byadagi Kaddi. International Journal of Agricultural Sciences 5(1): 123-125.

Hayat MQ, Khan MA, Ahmad M, Shaheen N, Yasmin G, Akhter S, 2008. Ethnotaxonomical approach in the identification of useful medicinal flora of tehsil Pindigheb (District Attock) Pakistan. Ethnobotany Research and Applications, 6: 035-062.

Hussain MA, Mukhtar T, Kayani MZ, 2016. Reproduction of Meloidogyne incognita on

resistant and susceptible okra cultivars. Pakistan Journal of Agricultural Sciences 53(2): 319-324.

Jahan MAHS, Hossain A, Jaime A, DaSilva T, EL-Sabagh A, Rashid MH, Barutçular C, 2019. Effect of naphthaleneacetic acid on root and plant growth and yield of ten irrigated wheat genotypes. Pakistan Journal of Botany 51(2): 451-459.

Javed H, Aziz MA, Leghari RAK, 2009. Resistance in different Okra cultivars (Abelmoschus esculentus L.) against American bollworm (*Helicoverpa armigera* Huber). Journal of Agricultural Research 47: 433-438.

Jeber BA, Khaeim HM, 2019. Effect of foliar application of amino acids, organic acids, and naphthalene acetic acid on growth and yield traits of wheat. Plant Archives 19(2): 824-826.

Khalid N, Hussain K, Nawaz K, Siddiqi EH, Khan M, Shafiq SJ, Lin F, 2017. Assessment of Growth, Yield and Nutritional Values of Pea (*Pisum sativum* L.) by Foliage Applications of IAA. Pakistan Journal of Botany 49(2): 509-517.

Khan MMA, Gautam C, Mohammad F, Siddiqui MH, Naeem M, Khan MN, 2006. Effect of gibberellic acid spray on performance of tomato. Turkish Journal of Biology 30(1): 11-16.

Naeem M, Bhatti I, Ahmad RH, Ashraf MY, 2004. Effect of some growth hormones (GA3, IAA and Kinetin) on the morphology and early or delayed Initiation of bud of lentil (*Lens culinaris* Medik). Pakistan Journal of Botany 36(4): 801-809.

Nawaz MA, Ahmad W, Ahmad S, Khan MM, 2008. Role of growth regulators on preharvest fruit drop, yield and quality in kinnow mandarin. Pakistan Journal of Botany 40(5):1971-1981.

Olaiya CO, Anyanwu GO, 2013. Antistressful Action of Two Auxin Analogues on Antioxidant Enzymes and Minerals in Tomato (*Solanum lycopersicon* L.). International Journal of Biotechnology and Biochemistry 9(1):145-156.

Panwar RD, Sindhu SS, Sharma JR, Saini RS, 2006. Effect of gibberellic acid spray on growth, flowering, quality and yield of bulbs in tuberose. Haryana Journal of Horticultural Sciences 35(3/4):253-255.

Panwar S, Kumar N, Kumar A, Paul R, Sarkar SK, 2019. Analysis of trend in area, production and productivity of okra (*Abelmoschus esculentus*) in India. Current Horticulture 7(2): 56-58.

Patil DR, Patel MN, 2010. Effect of seed treatment with GA_3 and NAA on growth and yield of okra (Abmelmoschus esculentus L.) Moench cv. GO-2. Asian Journal of Horticulture 5(2): 269-272.

Pramanik K, Mohapatra PP, 2017. Role of auxin on growth, yield and quality of tomato–a review. International Journal of Current Microbiology and Applied Science 6(11):1624-1636.

Sevik H, Guney K, 2013. Effects of IAA, IBA, NAA, and GA3 on rooting and morphological features of *Melissa officinalis* L. stem cuttings. The Scientific World Journal 5: 1-5.

Shah S, 2011. Comparative effects of 4-Cl-IAA and kinetin on photosynthesis, nitrogen metabolism and yield of black cumin (*Nigella sativa* L.). Acta Botanica Croatica 70(1):91-97.

Singh J, Dwivedi AK, Ramgiry P, 2019. Effect of 2, 4-D, NAA and GA3 on Morphological, yield and quality traits in vegetable crops. International Journal of Chemical Studies 7(2):1954-1956.

Singh P, Singh D, Jaiswal DK, Singh DK, Singh V, 2017. Impact of Naphthalene Acetic Acid and Gibberellic Acid on Growth and Yield of Capsicum, (*Capsicum annum* L.) cv. Indra under Shade Net Conditions. International Journal Current Microbiology and Applied Science 6(6): 2457-2462.

Sivakumar R, Pathmanaban G, Kalarani MK, Vanangamudi M, Srinivasan PS, 2002. Effect of foliar application of growth regulators on biochemical attributes and grain yield in pearl millet. Indian Journal of Plant Physiology 7(1):79-82.

Srivastava LM, 2002. Plant Growth and Development: Hormones and Environment. Oxford Academic Press, UK. pp. 143-144.

Sun YL, Hong SK, 2010. Effects of plant growth regulators and L-glutamic acid on shoot organogenesis in the halophyte (*Leymus chinensis* Trin.). Plant Cell, Tissue Organ Culture 100(3):317-328.

Wansink B, 2002. Changing eating habits on the home front: Lost lessons from World War II research. Journal of Public Policy and Mark 21(1): 90-99.

Zewail RMY, Khder ZMA, Mady MA, 2011. Effect of potassium, some antioxidants, phosphoric acid and napthalen acetic acid (NAA) on

growth and productivity of faba bean plants (*Faba vulgaris* L.). Annals of Agricultural Science Moshtohor 49(1): 53-64.