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Effect of foliar application of plant growth regulators on yield and yield attributes of okra in western arid region of Rajasthan

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Abstract
A field experiment was carried out to evaluate the effects of BAP (6-benzylaminopurine), GA3 (Gibberellic Acid) and NAA (Naphthalene acetic acid) on yield and yield attributes of okra (*Abelmoschus esculentus* L. Moench) cv. Arka Anamikaat the Instructional farm, Agricultural Research Station, Jodhpur Rajasthan during *kharif*, 2020. Three treatments each of BAP @ T_1-25, T_2-50, and T_3-75 (ppm), GA3 @ T_4-25, T_5-50, and T_6-75 (ppm) and NAA @ T_7-25, T8-50, and T_9-75 (ppm) were used besides controls i.e. T0 with water spray. These three growth regulators were found to enhanced early fruiting and yield. Other yield parameters were also found to be increased by treatments with plant growth regulators in okra. Among the yield parameters, earliest (46.60 DAS) fruit picking, Broadest fruit diameter (1.72 cm), heaviest fruit weight (14.9 g), maximum number of fruits per plant (27.38), maximum number of marketable fruits per plant (25.70), highest fruit yield per plant and estimated fruit yield per hectare (369.65 g and 13.21 t/ha, respectively) were recorded with NAA @ 75 ppm. The fruit length (11.67 cm) observed with GA3@ 75 ppm was significantly higher as compared to control and rest of the treatments.

Keywords: Fruiting, GA3, NAA, BAP, okra, plant growth regulators

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench, 2n=2x=130] is a herbaceous warm season vegetable grown in subtropical and tropical parts of the world (Balock, 1994) [5]. It is popularly known as lady's finger and belongs to the family Malvaceae (Brouk, 1975) [6]. The cultivated okra is native of Ethiopia (Vavilov, 1951) [20]. It is cultivated from ancient times and is disseminated from Asia to Africa, Southern Europe and America (Ariyo, 1993 and Oyelade *et al.*, 2003) [2, 17]. Okra is presently grown in many countries including India, Turkey, Iran, Western Africa, Bangladesh, Afghanistan, Burma, Pakistan, Malaysia, Japan, Brazil, Cyprus, Ethiopia, Ghana and United States of America. India is the largest okra producing country in the world with 5.19 lac hectare area and 63.71 lac MT production (Anonymous, 2020) [1]. In Rajasthan area and production of okra is 4.15 thousand ha and 21.39 thousand metric tonnes, respectively (Anonymous, 2020) [1]. It is a rich source of dietary fiber, magnesium, potassium, manganese, vitamin C (30mg/100g), vitamin K, foliate (1.5mg/100g) and vitamin B_1 and B_6. Fully ripe fruits and stems containing crude fiber are used in the paper manufacturing industry. Dry seeds of okra possess 20-23% crude protein and 18-20% oil and seed oil of okra is found to be rich in unsaturated fatty acids like linoleic acid which is essential in human nutrition. Okra is found to have beneficial health effects on diabetes and some kinds of cancers (Aykroud, 1963) [4]. Okra growth and yield are influenced by a variety of factors, including seed quality, nutrition, climatic conditions and cultural practices (Kusvuran, 2012) [13]. Recently, the researchers have paid considerable attention to the concept of controlling plant growth as an important factor for improving growth, yield and quality.

Plant growth regulators are designated as new generation agrochemicals having potential of altering the phenotype of plant by affecting physiological efficiency of plants including growth, photosynthesis and accretion of assimilates. Ascribed to their significant role in numerous physiological phenomena, plant growth regulators are utilized in fruit thinning, artificial induction of seed lessness, fruit set and size improvement and controlling pre-harvest fruit drop. They serve as metabolic sink, diverting metabolic energy from one portion of the plant to another, primarily towards developing fruits. Solaimalai *et al.* (2001) [19] reported that the productivity of crops is increased by stimulating the translocation of photo assimilates by plant growth regulators. Naphthalene acetic acid (NAA) is a synthetic auxin that is involved in cell elongation, cell division, vascular tissue, differentiation, root initiation, apical dominance, fruit abscission, fruit setting ratio, fruit dropping prevention. (El-Otmani *et al.*, 2000 and Davies, 1987)[10, 7]. NAA is said have potential to upsurge crop yield and increase productivity. Gibberellin causes cell lengthening and the formation of follicles. It increases the size and number of fruits. BAP (6-benzylaminopurine) is a first generation synthetic cytokinin that stimulates cell division to induce fruit richness. Plant growth regulators have high potential of improving the plant growth and yield but their application has to be planned quite sensibly in terms of optimum dose, stage of application, crop and season specificity (Khan and Chaudhary, 2006) [11].

Materials and Methods

The experiment was carried out at Instructional Farm, Agriculture Research Station, Jodhpur Rajasthan which is situated at $26^0 15$" N to $26^0 45$" North latitude and $73^0 00$" E to $73^0 29$" East longitude, at an altitude of 231 metres above mean sea level. Jodhpur falls under agro-climatic zone Ia (Arid Western Plains) of Rajasthan which is typically arid climate with hot summers and dry mild cool winters. The soil in the experimental area was loamy sand in texture, mildly alkaline in reaction, low in organic carbon (0.13%), nitrogen (171.0 kg/ha), available phosphorus (23.2 kg/ha) and medium in available potassium (319.0 kg/ha). The crop was fertilized with 2.5 kg/m^2 FYM along with NPK@ 120:60:50 kg/ha. recommended dose was supplied through urea, single super phosphate (SSP), muriate of potash (MOP). At the time of sowing applied full dose of SSP, MOP and half dose of urea and remaining half dose of urea was applied as top dressing at 30 days after sowing. Cultural operations and plant protection measures were implemented uniformly in all treatments as and when required. The experiment was conducted on okra var. Arka Anamika with application of plant growth regulators *viz.*, NAA, GA_3 and BAP each at three levels (25, 50 and 75 ppm) as spray application. The plant growth regulator solutions were prepared fresh on the day of spray application of the treatments. The first spray was done at 20 DAS (days after sowing) followed by second spray at 40 DAS and third spray at 60 DAS. The observations of various yield and yield attributes were recorded on five randomly selected and labelled plants in each treatment plot. The data on yield and yield attributes like Number of days to first fruit harvest, Fruit length (cm), Fruit diameter (cm), Fruit weight (g), Number of fruits per plant, Number of marketable fruits per plant, Fruit yield per plant (g), Fruit yield per hectare (t) were recorded. The observed data for different studied characters were statistic analysed using the Analysis of Variance technique for Randomized Block Design (RBD), for interpretation of results and comparison of the treatments. On the basis of the null hypothesis, the treatment variations were investigated using the F-test at 5% level of significance. In each case, the acceptable standard error of mean (S.E.m±) was determined and the Critical Difference (C.D.) at a 5% level of likelihood was calculated to compare the treatment means, where the treatment results were significant under the F-test.

Results and Discussion

Effect of BAP, GA3 and NAA on fruiting time and fruiting traits of Okra

The application of plant growth substances significantly improved fruiting and fruiting related traits. Generally, it is considered good if fruiting starts from lower nodes (3.94), here it is seen that NAA @75 ppm (T_9) shows fruiting at a significantly lower, whereas the upper most node for first fruit seen in control (6.68). Days to first fruit harvest is prominent parameter attributing yield, treatment with NAA@ 75 ppm showed earliest (46.60 DAS) fruit picking, whereas the control (51.88 DAS) was lastest for picking (Table 1). The fruit length (11.67 cm) observed with GA3@ 75 ppm was significantly higher as compared to control and rest of the treatments. Broadest fruit diameter (1.72 cm) was recorded in NAA @ 75 ppm treatment which was at par with NAA @ 50 ppm whereas the narrowest fruit diameter (1.08 cm) was in control. The heaviest fruit weight (14.9 g) was recorded in NAA @75 ppm (T_9), while the lightest fruit weight (9.8 g) was recorded in control (T_0). The maximum number of fruits per plant (27.38) and maximum number of marketable fruits per plant (25.70) was produced in NAA @75 ppm (T_9). The highest fruit yield per plant and estimated fruit yield per hectare (369.65 g and 13.21 t/ha, respectively) were produced in NAA @75 ppm (T_9) which was at par to BAP @ 75 ppm, GA_3 @ 50 ppm and NAA @ 50 ppm, while the minimum fruit yield per plant and estimated fruit yield per hectare (242.10 g and 9.29 t/ha, respectively) were recorded in the control (T_0).

The increase in fruit length with use of GA_3, NAA and BAP could be due to increased supply of photosynthates and their efficient mobilization in plants giving rise to increased stimulation of fruit growth by rapid cell division and increased elongation and enlargement of individual cells under the influence of applied plant growth regulator which might have ultimately resulted in increased length of okra fruits. Similar outcomes have been reported by Mehraj *et al.* (2015) [15], Dev *et al.* (2017) [8]. The production of most thick fruits with application of NAA could be due to comparatively higher mobilization of photosynthates towards the sink along with enhanced cellular activity. It could be also ascribed to NAA increasing the permeability of the fruit cell wall for water and dissolved materials to enter the cells of fruits, resulting in increased fruit size. These findings are in conformity with earlier reports of Askr *et al.* (2018) [3]. Application of NAA recorded higher number of fruits per plant as compared to GA_3 and BAP. It might be attributed to the fact that application of NAA led to more number of fruits per plant due to improvement in fruit set. Moreover, NAA accelerates the metabolic activities of the plant by increasing the meristematic activities which in turn increase the vegetative growth and photosynthesis and higher mobilization of photosynthates ultimately leading to increased flowering and fruiting. These findings are in compliance with results reported by Durrani *et al.* (2010) [9], Mandal *et al.* (2012) [14]. The increase in yield with the application of NAA might be due to increased plant metabolic activities, resulting in enhancement of reproductive phase and higher fertility rate of reproductive organ due to creation of favourable balance of hormones and more fruit setting. These results are in conformation with the reports by Kokare *et al.* (2006) [12]. In okra, the yield of fruit is much dependent on better vegetative growth, number of fruits per plant, length and girth of fruit and weight of fruit. As application of NAA revealed most prominent effect, compared to other growth regulator, hence resulted in maximum fruit yield per plant and estimated fruit yield per hectare. The results are in agreement with the earlier findings of Mandal *et al.* (2012) [14], Singh *et al.* (2017) [18] and Nisar *et al.* (2021) [16].

Table: Effect of Foliar Application of Plant Growth Regulators on Yield and Yield Attributes of Okra

Treatment	Node on which first fruit harvested	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits per plant	Number of marketable fruits per plant	Fruit yield per plant (g)	Fruit yield per hectare (t)
Control (T_0)	6.68	8.10	1.08	9.80	23.29	19.40	242.10	9.29
BAP @ 25 ppm (T_1)	6.52	8.44	1.10	10.68	24.10	21.10	280.17	10.53
BAP @ 50 ppm (T_2)	6.19	9.12	1.22	11.98	25.66	22.80	319.20	11.75
BAP @ 75 ppm (T_3)	5.92	10.28	1.36	13.10	26.92	23.92	344.80	12.57
GA_3 @ 25 ppm (T_4)	6.20	8.98	1.12	10.90	23.90	20.88	278.44	9.69
GA_3 @ 50 ppm (T_5)	5.92	10.34	1.27	12.55	26.70	22.90	340.50	11.66
GA_3 @ 75 ppm (T_6)	5.18	11.67	1.39	13.80	24.98	21.76	316.20	11.05
NAA @ 25 ppm (T_7)	5.82	8.78	1.14	11.10	24.30	21.40	283.66	10.63
NAA @ 50 ppm (T_8)	4.96	9.96	1.48	13.28	25.90	23.76	328.50	11.99
NAA @ 75 ppm (T_9)	3.94	11.10	1.72	14.90	27.38	25.70	359.48	13.21
S.E.m ±	0.32	0.60	0.10	0.77	0.88	1.21	18.05	0.73
CD ($p = 0.05$)	0.95	1.78	0.30	2.29	2.60	3.60	53.64	2.17

Conclusion

From the above results it may be concluded that plant growth regulators i.e. BAP, gibberellic acid and NAA have significant effect in increasing yield of okra The enhancement in the fruiting parameters by BAP, GA3 and NAA due to their effect on cell enlargement, cell growth, cell division, biochemical properties of protoplasm, transportation of photosynthates, accumulation of metabolites, respiration and nucleic acid metabolism, etc It could be concluded that fruiting and yield traits of okra plant were significantly affected by the application of BAP, GA3 and NAA at different suitable concentrations each which ultimately increased the yield. Amongst the different plant growth regulator treatments, NAA@75ppm (T_{10}) was found to be the best.

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