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Paclobutrazol increases pod yield of okra by altering plant architecture: A case of a growth retardant that outperformed the growth promoters

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Abstract

Plant growth regulators offer a brilliant scope to customize the plant physiology of crops in favor of our objectives. This experiment in Okra involving the classical PGRs (GA_3, NAA), new generation PGRs (triacontanol, brassinosteroid), and plant growth retardants (CCC, paclobutrazol) revealed the superiority of the plant growth retardant, paclobutrazol, through higher chlorophyll content, more number of branches, more number of pods plant^{-1} and thus yield plant^{-1}. Besides, this paper explicates the ability of paclobutrazol to impart short stature and narrow frame to the okra plants that would favor closer spacing so that more number of plants can be grown hence realizing of higher yield.

Keywords: Okra, PGRs, paclobutrazol, modified plant architecture, planting density, maximizing yields

Introduction

Though the cereals and grains are the staple food of the Indian diet, the essential nutrients and minerals are acquired from the vegetables. Okra is an Oligo-purpose crop that is being used in various industries namely textiles, food fortification, etc. It is a frequently consumed vegetable, in India, owing to its richness in dietary fiber, folate, magnesium, manganese, potassium, vitamin K, vitamin C, vitamin B1, B6 contents and it holds an average nutritional value (ANV) of 3.21, which is superior to that of cucurbits (except bittergourd) eggplant and tomato (Grubben, 1977) [13]. India's okra production is 63,71,000 MT from an area of 5,19,000 ha (NHB, 2020). The growing population demands a rapid increase in production and productivity of the vegetables, which is not always possible only by the crop improvement that is naturally long. The plant growth regulators offer a shortcut to increase production apace through manipulating the plant physiological processes, to confirm the growing need for vegetable production.

In Okra, a crop wherein the vegetative and reproductive phases occur simultaneously as well as a long reproductive phase, the plant growth regulators have many scopes to take over the physiological modification towards novel changes in growth and yield.

Many studies have reported positive stimulus of various growth regulators on growth, development, yield and quality of okra plants and pods. The plant growth regulators tend to improve yield by manipulating endogenous hormone levels, improving source sink relations, water and nutrient uptake, biomass buildup, etc. (Gelmesa *et al.*, 2013; Ravat *et al.*, 2015; Meena *et al.*, 2017; Zhang *et al.*, 2014) [11, 27, 18, 15], however the role of plant growth regulators on altering the plant architecture as an yield maximizing strategy is seldom reported. Moreoever, the positive effect on growth and yield of okra were pronounced by only few plant hormones. Our investigation is unique in its kind as it spotlights how the plant growth regulators especially growth retardants could increase the yield by altering the plant architecture in okra.

Materials and Methods

The present investigation was conducted in okra cv. Arka Anamika, which is a product of the interspecific cross between *Abelmoschus esculentus* (IIHR 20-31) x *Abelmoschus manihot* spp. *tetraphyllus* developed by the backcross method.

The Western block of the Horticulture farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal was the site of the experiment, located at 10º 49' and 11º 01' North latitude and 79º 52' East longitude with an altitude of 4 m above the mean sea level. The Karaikal region of Puducherry Union Territory is the representation of the eleventh agro-climatic zone spanning the east coast plains and hills and placed under the PC-2 coastal deltaic alluvial plain zone.

The experiment was laid out in a Randomized Block Design with ten treatments of three replications each. The plant growth regulators used were gibberellic acid (GA_3) 50 ppm (Cryzib 90 per cent a.i.), Naphthalene acetic acid (NAA) 200 ppm (Planofix 4.5 per cent SL), Triacontanol (TRIA) 1ppm (Vipul 0.1 per cent EW), Brassinosteroid (BR) 0.1 and 0.2 ppm (Double 0.04 per cent), Cycocel (CCC) 400 ppm (Lihocin 50 per cent SL) and Paclobutrazol (PBZ) 400 ppm (Cultar 23 per cent a.i.), in their respective commercially available formulations. All the growth regulators, except paclobutrazol, were applied as foliar spray on 30 and 45 days after sowing, while paclobutrazol was soil drenched to the plant rhizosphere at two different growth stages *viz.*, 7 and 14 days after sowing and 15 and 30 days after sowing, in such a way that each plant in the plot received 10 ml of 400 ppm paclobutrazol solution.

Five plants were randomly selected, tagged, and numbered from each plot and the following observations were recorded from these plants.

Growth traits

The average number of days from sowing to first flowering is expressed as days to first flowering. The node which the first flower appeared at, from the base of the stem upward, is marked as the node of the first flower. The plant height at first harvest (cm) and final harvest (cm) was measured from the base of the plant to the growing tip, at the time of first harvest and final harvest, respectively. The number of primary branches from the main stem at first flowering and final harvest were counted and recorded. The distance between the fifth and sixth nodes on the main stem was measured on the 75th day after sowing and the mean value was expressed in centimeter (Venkadeswaran, 2013) [36]. The stem diameter (cm) was measured during the final harvest.

Physiological traits

The leaf area plant^{-1} at 60 DAS was estimated by a leaf area meter (Systronics Leaf Area Meter - 211). The leaf area index was worked out using the method given by Williams (1946) [38]. The relative water content (RWC) was estimated from the fourth fully developed mature leaf from the tip (Slatyer, 1967) [33]. The total chlorophyll (mg g^{-1}) was spectrophotometrically analyzed from the fourth fully developed mature leaf from the tip, by following the standard procedure (Sadasivam and Manicham, 1996) [29].

Yield traits

The individual pod length (cm) and girth (cm) were expressed as the mean value of the measured length from the stalk end to the tip; and the girth at the broadest point of the pod at harvestable maturity, respectively. The sum total of weight of the pods harvested from first to final harvest from a particular plant denotes the yield plant^{-1}.

Statistical analysis

The statistical analysis was carried out using R and the ANOVA for the parameters under study was analysed with Randomized Block Design (RBD). The standard error of means and critical differences were tested at the level of significance of $P \leq 0.05$.

Results and Discussion

1. Growth Traits

In this investigation, the early flowering was observed with NAA 200 ppm. The tallest and the shortest plants as well as internodal length were obtained with the treatments of GA_3 and paclobutrazol respectively. The highest number of primary branches was recorded with the paclobutrazol treatment. The maximum stem diameter was observed in the foliar application of BR 0.2 ppm. Moreover, the node of the first flower was found insignificant (Table 1 & 2) across treatments.

The earliness in flowering defines the period required for the outset of monetary returns and thus a desirable trait for commercial production. The earliness in flowering induced by the exogenous NAA application might be attributed to the enhanced auxin activity and its transport to the axillary buds that would have resulted in a faster mobilization of assimilates to the sink. Therefore, the early transformation from vegetative to reproductive phase was hit (Sanodiya *et al.*, 2017) [32]. The present results were found in line with that of Meena *et al.* (2017) [18].

The plant height is an important morphological trait strongly associated with life span, time of maturity and carbon storage capacity of the plants. The increased plant height by the foliar GA_3 application is due to the cell enlargement, internodal elongation and stimulated RNA and protein synthesis, thereby leading to enhanced growth and development. It is also reported that the GA_3 increases cell wall plasticity and stimulates the cells to elongate more due to the increased water uptake (Ravat and Makani, 2015) [27]. Similar results were reported by Kalariya *et al.* (2016) and Verma *et al.* (2016) [16, 37] in okra.

The least plant height was brought in by the paclobutrazol 400 ppm (soil drenched on 7th and 14th DAS), which might be due to the inhibitory effect of paclobutrazol on gibberellic acid activity in the plant, therefore giving rise to plants with shorter internodes and plant height. There are reports that the paclobutrazol is an effective GA_3 biosynthesis inhibitor that inhibits the oxidation process in the transformation of kaurene to kaurenoic acid, in the biosynthetic pathway of GA_3. Particularly, its mode of action depends on the interaction with kaurene oxidase (a cytochrome P-450 oxidase) and restrain the oxidation of kaurene, kaurenal and kaurenol (Megbo, 2010) [19]. Similar reports on plant height reduction by paclobutrazol were made by Benjawan *et al.* (2007) [3], Megbo (2010) [19] in okra and Almeida *et al.* (2016) [2] in common bean.

Moreover, it is also noticed that paclobutrazol 400 ppm applied to the soil on 15th and 30th DAS had resulted in the lowest plant height at first harvest while the same applied on the 7th and 14th DAS exhibited shortest plants at the time of final harvest. In this context, it is evident that the paclobutrazol application during early stages of plant growth is efficient in regulating the plant height. The early stage application of paclobutrazol possibly have arrested the gibberellic acid activity inside the plant cell, thus reducing the length of stem. The efficacy of the early application of paclobutrazol on plant height was also studied by Berova and Zlatev (2000) [4] in pepper, Benjawan *et al*. (2007) [3] in okra, Almeida *et al.* (2016) [2] in common bean and Mabvongwe *et al.* (2016) [17] in potato. Furthermore, the internodal length lies in association with the plant height.

The internodal length is governed by the number of nodes present on the stem. In okra, the lesser the internodal length more is the number of nodes, as proposed by Bhagure and Tambe (2013) [5]. Pods of okra are borne at nodes and hence studying of internodal length in okra assumes greater significance. As shorter internodes are related to more number of productive nodes, the minimum internodal length is highly appreciable. The internodal length was found to be the shortest in paclobutrazol 400 ppm (soil drenched on 7th and 14th DAS). In the same way, Hafeez-Ur-Rahman *et al.* (1989) [14] and Rai *et al.* (2003) [26] noted that reduction in internodal length can be achieved through paclobutrazol application in pepper and bottle gourd, respectively. The probable reason for the reduction in internodal length might be the anti-gibberellic activity of paclobutrazol that checks the cell division and enlargement. Interestingly, the reduction in the internodal length is linked with the increase in pod number plant^{-1} and thereby the yield.

The number of primary branches plant^{-1} has a positive indirect effect on pods plant^{-1} (Tunçtürk and Çiftçi, 2007) [35]. Paclobutrazol 400 ppm applied as soil drenching on 7th and 14th DAS registered its superiority over other plant growth regulators by producing the maximum number of primary branches, both at the time of first flowering and final harvest. This is in accordance with the findings of Rai *et al.* (2003) [26] in bottle gourd and Hua *et al*. (2014) [15] in canola. Besides being an anti-gibberellin, paclobutrazol has a secondary role in promoting the biosynthesis of cytokinin too. This was probably achieved through the diversion of reactions into the biosynthetic pathway of cytokinin since they have the same intermediate precursor (Adil *et al.*, 2011) [1]. The paclobutrazol-induced cytokinin synthesis might have attributed to the induction of lateral branches by liberating axillary buds from apical dominance (Rai *et al*., 2003) [26].

2. Physiological traits

The leaf area plant^{-1} and the leaf area index were the maximum when treated with BR 0.2 ppm whereas the minimum of the same was noticed under PBZ 400 ppm (soil drenched on 7th and 14th DAS). The total chlorophyll content was found to be the highest under CCC 400 ppm. The relative water content was found to be insignificant (Table 2).

Leaves are considered very important as they are the site of photosynthesis, carbon accumulation and water movement regulation. Brassinosteroid 0.2 ppm outperformed the other treatments by recording the highest leaf area plant^{-1} and leaf area index which is comparable to the findings of Samancioglu *et al.* (2016) [30] in pepper and Girisha (2010) [12] in black gram. This increase in leaf area plant^{-1} could be due to the dual role of brassinosteroid in cell enlargement and its proliferation, as suggested by Nakaya *et al.* (2002) [21]. The increased leaf area might have attributed to the increase in the leaf area index.

In the present study, it is quite interesting that the plants with minimum leaf area index were noticed with the maximum pod yield. Minimum values for the above leaf parameters were rendered by the soil application of paclobutrazol 400 ppm on the 7th and 14th DAS. In addition to this, reduced leaf length and breadth, petiole length and shoot length were also noticed, which were in agreement with the observation of Rai *et al.* (2003) [26] and might be due to the anti-gibberellic action of paclobutrazol (Megbo, 2010) [19].

This contrast in the relationship between minimum leaf area and maximum pod yield can be well described by the product of the factors *viz.*, leaf characteristics, intercepted radiation and radiation use efficiency. Leaf characteristics are important factors in understanding plant growth, as they determine the amount of intercepted radiation, at given radiation characteristics.

The better display of leaves in a canopy is one of the pivotal determinants of efficiency of the photosynthetic conversion of available light into assimilates. In the present investigation, the higher plant yield coincided with the lowest leaf area index that was produced by the paclobutrazol. This could be substantiated by the fact that the paclobutrazol has altered the plant architecture in such a way that facilitated more light interception leading to higher photosynthetic assimilate accumulation.

The leaf angle is an important trait associated with light interception and photosynthesis. Paclobutrazol is reported to decrease the leaf angle (Dwyer *et al*., 1995) [10] making the leaves erect. It is well known that the plants with erect leaves are efficient in the light interception and can capture more light for photosynthesis, carbon gain and enable more dense plantings, all of which contribute to increased yield (Zhang *et al*., 2014) [39]. The reduced petiole length and increased leaf angle also cut down the shading effect while, the brassinosteroid treated plants were observed with a self-shading effect by overlapping of lower and upper leaves, due to the bigger size of the leaves. The plant architecture that is altered by paclobutrazol includes smaller erect leaves with narrow leaf angle, short petioles, short branches and narrow plant canopythat tend to ease the accommodation of higher number of plants per unit area, thereby maximizing the yield.

The chlorophyll is the vital photosynthetic pigment, which allows the plants to absorb energy from light. It is proposed that the triazole compounds, like paclobutrazol, stimulate the cytokinin synthesis that enhances chloroplast biosynthesis and differentiation and hence prevent the chlorophyll degradation (Zhou and Leul, 1998 [40]; Berova and Zlatev, 2000 [4])

Moreover, paclobutrazol stimulate the periclinal division (Baluska *et al.*, 1999) and increase the cell number and thickness of leaf parenchyma (Rodrigues *et al*., 2016) [28]. This improvement in the spatial aspect of leaf parenchyma might have enabled the leaf to contain more chlorophyll pigments. Due to the above reasons, the leaves of paclobutrazol treated plants appeared greener and thicker and the same was noted by Tekalign *et al*. (2005) [34] in potato.

3. Yield traits

The maximum pod length and number of seeds pod^{-1} were observed with GA_3 50 ppm. The maximum pod girth was noted under CCC 400 ppm. The number of pod plant^{-1}, yield plant^{-1} and estimated yield ha^{-1} were recorded with PBZ 400 ppm (soil drenched on 7th and 14th DAS). The pod weight was found insignificant (Table 3).

The pod characters influence the okra pod marketability, particularly the characteristic pod length (Narkar, 2016) [22]. The resulted maximum pod length with GA_3 application might be the result of GA_3 induced rapid cell division and multiplication in the reproductive organs (Bharti *et al*., 2017) [6] of the okra flowers. The built-up of adequate photosynthates and its efficient mobilization in plants giving rise to increased stimulation of pod growth ultimately have resulted in the increased pod length (Prasad *et al*., 2013) [25]. Further, Gelmesa *et al*. (2013) [11] indicated that after the cell division and during the cell expansion, an increase in cell volume may contribute to the final size of the pods, as observed in this study.

Regarding pod girth, our results confirm with the reports of Pateliya *et al*. (2008) [24], whose study on okra proposed that the increase in pod girth could have been brought about by the diversion of the flow of food material to the growing sink by the application of CCC.

The increased seed number pod^{-1} might be the result of improved translocation of photosynthates from the source to the sink. This heavier buildup of abundant food reserves in the growing pods and seeds, due to spraying of GA_3 (Sanjeevkumar *et al*., 2016) [31] might be the reason behind increased seed number pod^{-1}. Moreover, the sole function of fertilized ovules or seed is to synthesize one or more hormones that initiate and maintain metabolic gradient along with food from one part of the plant towards the pods. The transportation and accumulation of food material could have associated with increased length of pods when treated with GA_3 (Desai *et al*., 2012) [8]. In this context, the positive association with the number of seeds pod^{-1} and pod growth; and also the effect of GA_3 on the above parameters were well evinced.

The highest number of pods plant^{-1} was found with the Paclobutrazol 400 ppm soil drenched on 7th and 14th DAS (30.47) (Table 3). Similarly, Almeida *et al.* (2016) [2] had also witnessed an increased number of pods plant^{-1} in common bean. This favor over the number of pods plant^{-1} could be attributed to the shortened internodes that might have increased the number of productive nodes (Narkar, 2016) [22], realized as increased number of pods plant^{-1}. Besides, the increased number of branches has also contributed to the highest number of pods plant^{-1}.

The highest yield plant^{-1}, so the highest estimated yield ha^{-1} were recorded in the okra plants that were subjected to soil application of paclobutrazol 400 ppm on 7th and 14th DAS (Fig. 1). In the present study, it is apparent that the increase in yield was directly driven by the tremendous hike in the number of pods plant^{-1} since the individual pod weight was found to be insignificant. The production of more number of pods plant^{-1} was the effect of shortened internodes that could have resulted in increased pods plant^{-1}. The striking feature of the present investigation is that the highest number of pods plant^{-1}, which is 61.43 per cent higher than that of the control, was observed under the treatment with a plant growth retardant, paclobutrazol. The increased number of pods plant^{-1} registered by the paclobutrazol treatment affirm its effect on enhanced flowering and fruiting, which might have resulted from the inhibition of gibberellin biosynthesis, thereby changed the sink source relationship by reallocation of carbohydrate to other organs of the plants than the shoot apex (Rai *et al*., 2003) [26].

In addition to these direct effects, the higher total chlorophyll content is also likely to promote photosynthesis. The stimulated chlorophyll synthesis, accelerated RuBisCo activity and increased capacity for electron transport were some probable reasons for enhanced photosynthesis (Boogaard, 1994) [7]. The increased content of photosynthetic pigments is a precondition for enhanced photosynthesis (Berova and Zlatev, 2000) [4]. Thus, yield improvement after the paclobutrazol application was attributed to the enhanced leaf photosynthesis and accumulation of photosynthetic pigments (Hua *et al*., 2014) [15].

It is also plain that the paclobutrazol is able to delay the senescence of the plants probably by increasing the photosynthetic efficiency that is considered to sustain the activity of enzymes RuBisCo and phosphoenol carboxylase during plant senescence (Rai *et al*., 2003) [26]. The higher yield under paclobutrazol application might also be caused by rapid carbohydrate production and its quicker accumulation in plant organs, demanding rapid unloading of assimilates (Benjawan *et al*., 2007) [3].

A well-known fact is that the plant height is an index of plant vigor. However, the tallest plants observed did not give a higher yield than the shorter plants noticed in the study. The positive effect of gibberellin on plant height is well recognized in okra and other vegetable crops. In okra, GA_3 increases plant height by increasing internodal length and was well studied through the present experiment but it has no role on the number of nodes plant^{-1}. In a crop like okra, where the flowers are solitarily born at each node (Dhingra, 2009) [9], there is no effect of GA_3 on flower induction in okra (Mohammadi *et al*., 2014) [20]. In contrast, paclobutrazol treated plants that were with altered architecture were found to produce increased yields (Fig.1).

In this study, the high yielding treatment did not stand for a high leaf area and leaf area index. This reveals that in okra, source is not the limitation. If sink strength is increased, a higher yield might be obtained without altering the source. Moreover, higher leaf area index might be obtained by decreasing the spacing with altered architecture to exploit the source and sink relationship.

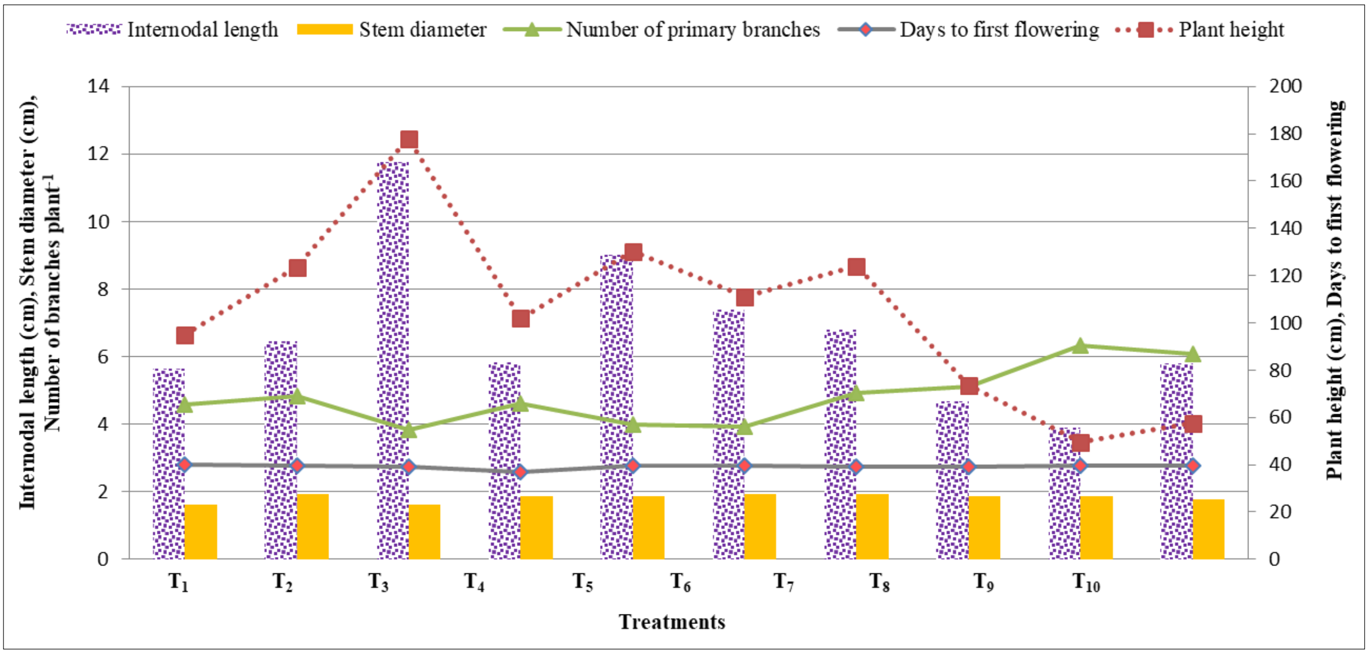

Fig 1: Effect of PGRs on growth traits

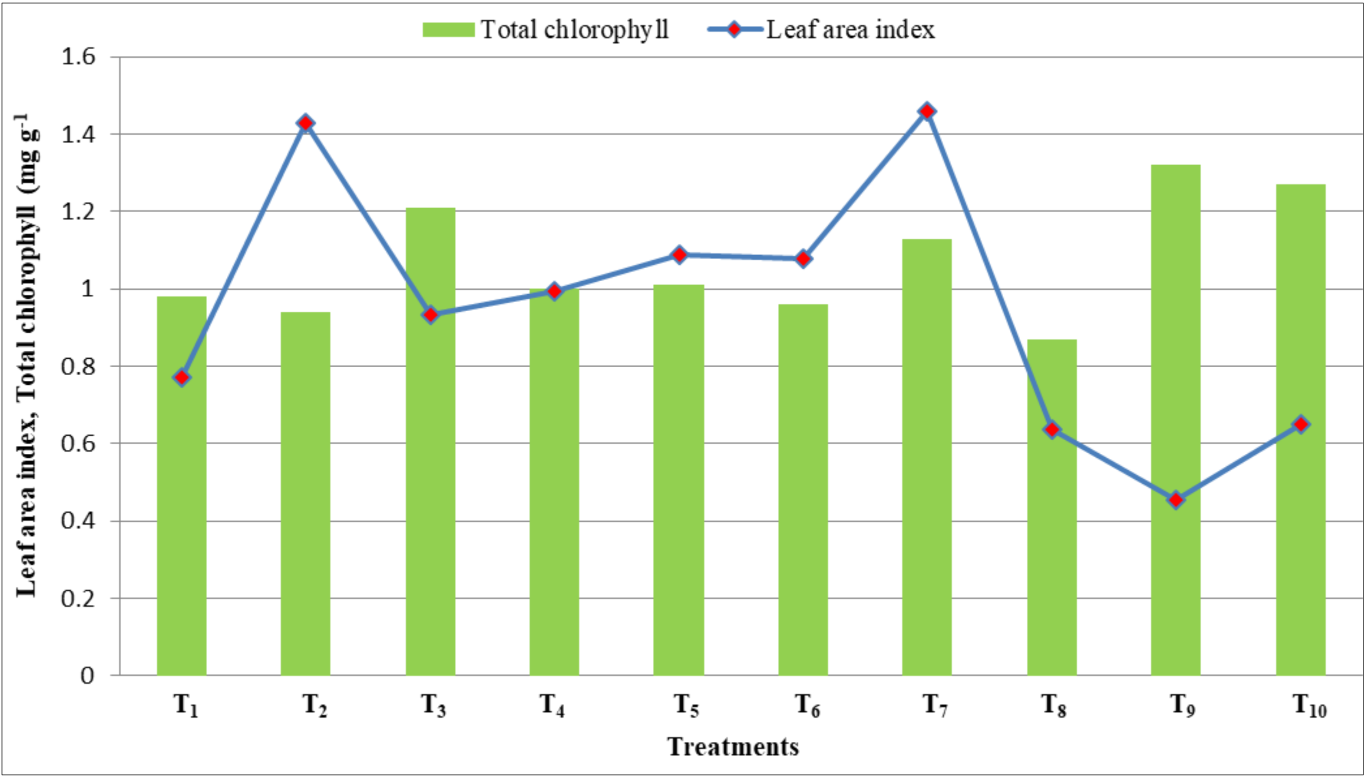

Fig 2: Effect of PGRs on physiological traits

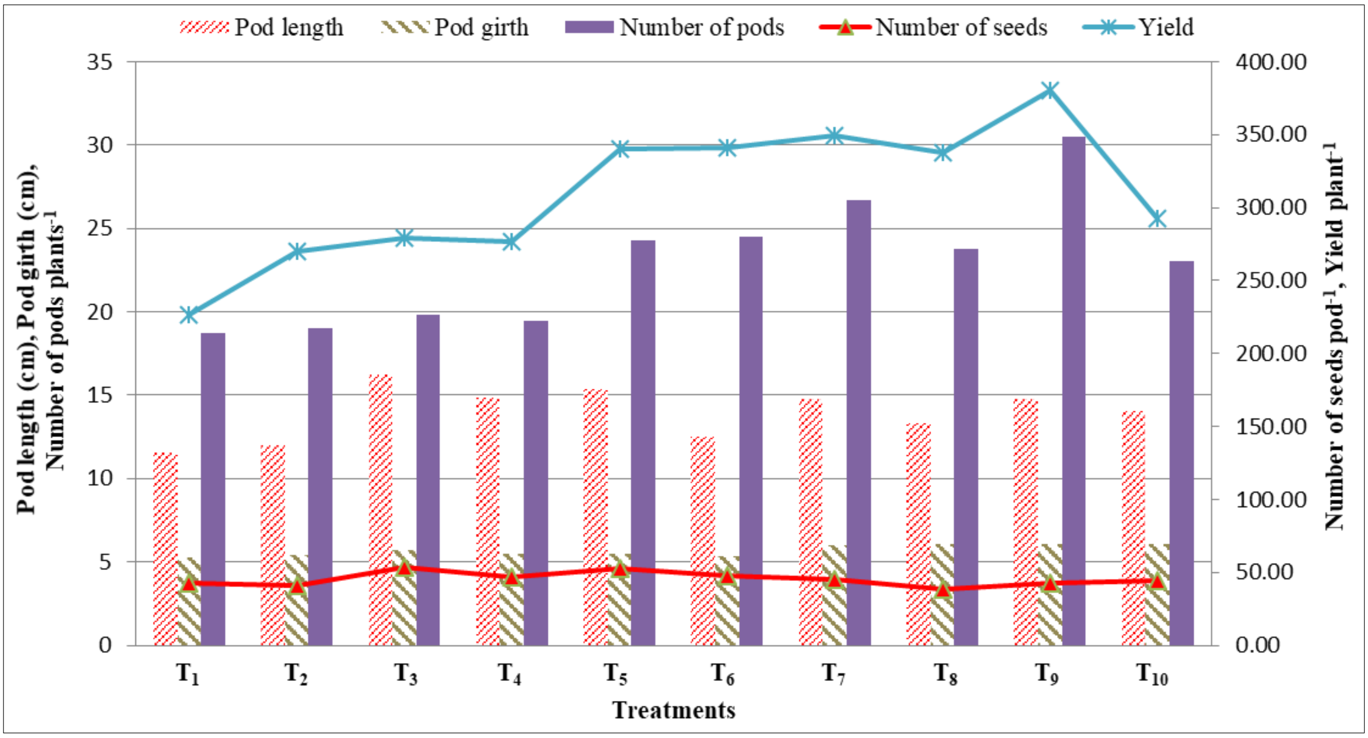

Fig 3: Effect of PGRs on yield traits

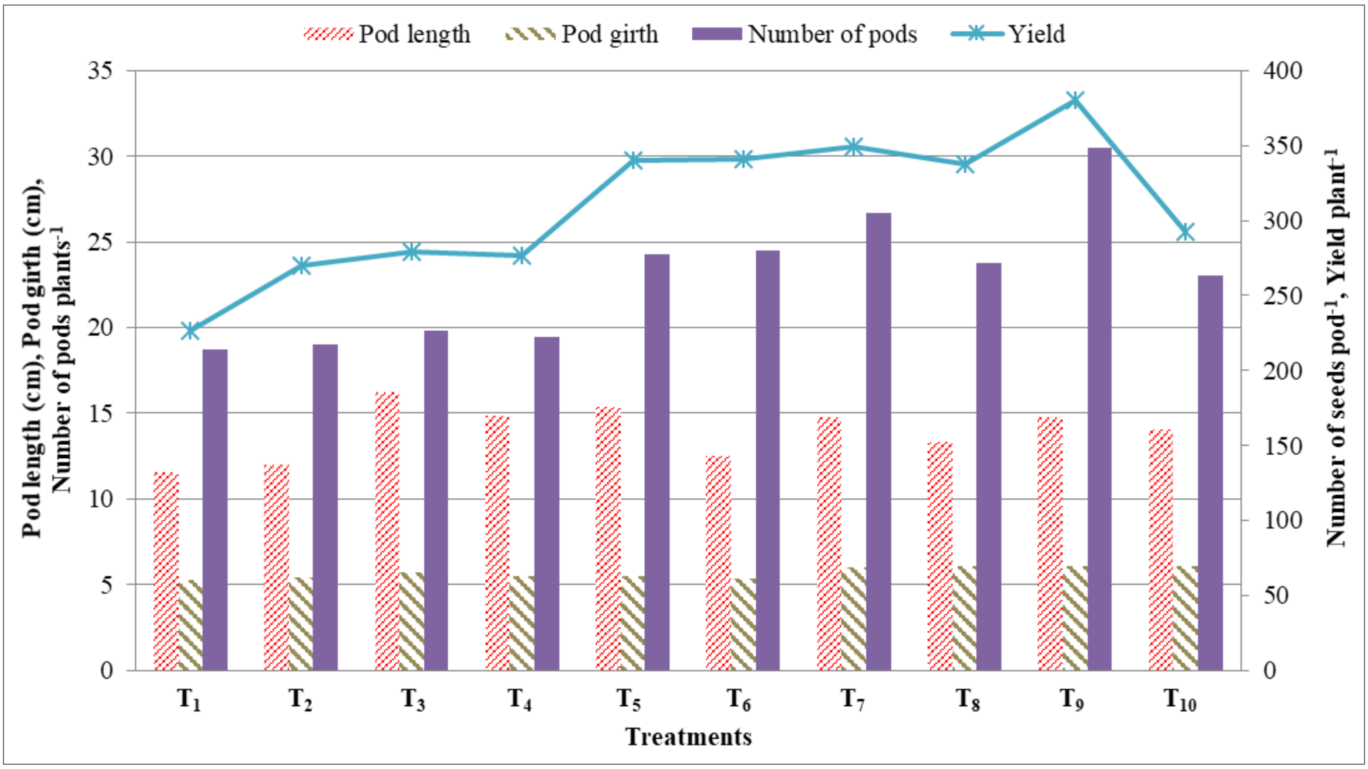

Fig 4: Effect of PGRs on yield traits

Table 1: Effect of PGRs on plant height, flowering and primary branches

Treatments	Days to first flowering	Node of first flower	Plant height at first harvest (cm)	Plant height at final harvest (cm)	Number of primary braches at first harvest	Number of primary braches at final harvest
Absolute control (T_1)	40.23^{a}	4.00	34.46^{e}	95.03^{cd}	1.62^{c}	4.58^{cdef}
Control (T_2) (water spray on 30 & 45 DAS)	39.58^{ab}	4.00	35.14^{de}	123.41^{bc}	2.58^{b}	4.83^{cde}
GA_3 50 ppm (T_3) (foliar spray on 30 & 45 DAS)	39.32^{ab}	4.00	54.10^{a}	177.89^{a}	1.62^{c}	3.83^{f}
NAA 200 ppm (T_4) (foliar spray on 30 & 45 DAS)	37.12^{c}	3.92	41.19^{c}	101.79^{bcd}	2.07^{c}	4.62^{cdef}
Triacontanol 1 ppm (T_5) (foliar spray on 30 & 45 DAS)	39.48^{ab}	4.00	49.82^{b}	130.21^{b}	1.92^{c}	4.00^{def}

Brassinosteroid 0.1 ppm (T_6) (foliar spray on 30 & 45 DAS)	39.67^{ab}	4.00	37.63^{d}	110.98^{bc}	2.80^{b}	3.93^{ef}
Brassinosteroid 0.2 ppm (T_7) (foliar spray on 30 & 45 DAS)	39.31^{ab}	4.00	36.00^{de}	123.97^{bc}	1.82^{c}	4.93^{cd}
CCC 400 ppm (T_8) (foliar spray on 30 & 45 DAS)	39.07^{b}	3.92	29.80^{f}	73.52^{de}	3.32^{a}	5.12^{bc}
Paclobutrazol 400 ppm (T_9) (soil drench on 7th and 14th DAS)	39.55^{ab}	4.00	29.19^{f}	49.62^{e}	3.48^{a}	6.32^{a}
Paclobutrazol 400 ppm (T_{10}) (soil drench on 15th and 30th DAS)	39.50^{ab}	4.00	24.94^{g}	57.47^{e}	3.47^{a}	6.07^{ab}
Mean	39.28	3.98	37.23	104.39	2.47	4.82
S.Ed	0.47	0.05	1.48	14.10	0.24	0.45
CD (0.05)	0.99	NS	3.12	29.63	0.51	0.95

In a column, values followed by common letters are not significantly different by DMRT at 5 per cent
Bold values indicate the highest mean value: Underlined values indicate the least mean value

Table 2: Effect of PGRs on growth and physiological traits

Treatments	**Internodal length (cm)**	**Stem diameter (cm)**	**Leaf area plant^{-1} (cm^2)**	**Leaf area index**	**Relative water content (per cent)**	**Total chlorophyll (mg g^{-1})**
Absolute control (T_1)	5.65^{e}	1.61^{b}	1042.43^{d}	0.772^{d}	59.13	0.98^{bc}
Control (T_2) (water spray on 30 & 45 DAS)	6.44^{d}	1.93^{a}	1928.57^{a}	1.429^{a}	53.96	0.94^{c}
GA_3 50 ppm (T_3) (foliar spray on 30 & 45 DAS)	11.76^{a}	1.62^{b}	1261.27^{c}	0.934^{c}	47.35	1.21^{ab}
NAA 200 ppm (T_4) (foliar spray on 30 & 45 DAS)	5.82^{e}	1.86^{a}	1343.77^{c}	0.995^{c}	57.92	1.00^{bc}
Triacontanol 1 ppm (T_5) (foliar spray on 30 & 45 DAS)	9.01^{b}	1.86^{a}	1469.37^{b}	1.088^{b}	51.53	1.01^{bc}
Brassinosteroid 0.1 ppm (T_6) (foliar spray on 30 & 45 DAS)	7.39^{c}	1.93^{a}	1455.33^{b}	1.078^{b}	55.14	0.96^{bc}
Brassinosteroid 0.2 ppm (T_7) (foliar spray on 30 & 45 DAS)	6.81^{d}	1.94^{a}	1967.80^{a}	1.458^{a}	53.96	1.13^{abc}
CCC 400 ppm (T_8) (foliar spray on 30 & 45 DAS)	4.67^{f}	1.86^{a}	858.20^{e}	0.636^{e}	61.60	0.87^{c}
Paclobutrazol 400 ppm (T_9) (soil drench on 7th and 14th DAS)	3.91^{g}	1.86^{a}	613.47^{f}	0.454^{f}	61.46	1.32^{a}
Paclobutrazol 400 ppm (T_{10}) (soil drench on 15th and 30th DAS)	5.81^{e}	1.78^{ab}	876.63^{e}	0.649^{e}	54.34	1.27^{a}
Mean	6.73	1.83	1281.68	0.949	55.64	1.07
S.Ed	0.77	0.10	49.21	0.037	6.38	0.12
CD (0.05)	0.51	0.21	103.39	0.079	NS	0.26

In a column, values followed by common letters are not significantly different by DMRT at 5 per cent
Bold values indicate the highest mean value: Underlined values indicate the least mean value

Table 3: Effect of PGRs on yield and yield related traits

Treatments	**Average pod length (cm)**	**Average pod girth (cm)**	**Average pod weight (g)**	**Number of seeds pod^{-1}**	**Number of pods plant^{-1}**	**Yield plant^{-1} (g)**	**Estimated yield (t ha^{-1})**
Absolute control (T_1)	11.59^{f}	5.29^{c}	12.44	43.00^{cde}	18.72^{d}	226.81^{f}	16.80^{f}
Control (T_2) (water spray on 30 & 45 DAS)	12.03^{ef}	5.40^{c}	12.45	40.66^{de}	19.00^{d}	269.70^{ef}	19.98^{ef}
GA_3 50 ppm (T_3) (foliar spray on 30 & 45 DAS)	16.23^{a}	5.71^{b}	15.14	53.66^{a}	19.83^{cd}	278.97^{cdef}	20.66^{cdef}
NAA 200 ppm (T_4) (foliar spray on 30 & 45 DAS)	14.82^{b}	5.51^{bc}	12.62	46.66^{bc}	19.42^{cd}	276.40^{def}	20.47^{def}
Triacontanol 1 ppm (T_5) (foliar spray on 30 & 45 DAS)	15.39^{b}	5.51^{bc}	16.08	52.33^{ab}	24.28^{bc}	340.22^{abcd}	25.20^{abcd}
Brassinosteroid 0.1 ppm (T_6) (foliar spray on 30 & 45 DAS)	12.53^{e}	5.32^{c}	14.35	48.00^{abc}	24.48^{bc}	341.32^{abc}	25.28^{abc}
Brassinosteroid 0.2 ppm (T_7) (foliar spray on 30 & 45 DAS)	14.81^{b}	5.99^{a}	13.75	45.33^{cd}	26.67^{ab}	349.36^{ab}	25.88^{ab}
CCC 400 ppm (T_8) (foliar spray on 30 & 45 DAS)	13.30^{d}	6.10^{a}	15.13	38.33^{e}	23.78^{bcd}	337.46^{abcd}	25.00^{abcd}
Paclobutrazol 400 ppm (T_9) (soil drench on 7th and 14th DAS)	14.79^{bc}	6.06^{a}	13.61	42.33^{cde}	30.47^{a}	379.90^{a}	28.14^{a}
Paclobutrazol 400 ppm (T_{10}) (soil drench on 15th and 30th DAS)	14.05^{c}	6.04^{a}	13.06	44.66^{cd}	23.00^{bcd}	292.82^{bcde}	21.69^{bcde}
Mean	13.95	5.69	13.86	45.50	22.97	309.29	22.91
S.Ed	0.35	0.13	1.31	2.78	2.49	30.40	2.25
CD (0.05)	0.75	0.27	NS	5.83	5.22	63.87	4.73

In a column, values followed by common letters are not significantly different by DMRT at 5 per cent
Bold values indicate the highest mean value: Underlined values indicate the least mean value

Conclusion and future outlooks

Through this investigation, the potentials of paclobutrazol on growth, development and yield of okra are debunked. Though yield maximization through plant architecture modification is a well-established area of research in fruit crops, it is a seldom studied concept in vegetable crops. The paclobutrazol treated okra plants are evidently high yielding and additionally offers an advantage of closer spacing for accommodating more number of plants unit area^{-1}, through its short stature and narrow frame. Through this paper, we show that the paclobutrazol could be an effective candidate for commercial okra production aiming higher yields. Our results indicate a new direction in the breeding of okra that higher yield could be achieved through the development of lines having short plant stature with more number of nodes and branches.

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