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Study on the impact of foliar application of bioregulators and nutrients on the reproductive parameters of Okra (*Abelmoschus esculentus* (L.) Moench) Cultivation

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Abstract
A field experiment was conducted during the years 2011 and 2012 on okra cv. Parbhani Kranti to ascertain the influence of foliar application of plant growth regulators (PGRs) and nutrients with different concentrations on yield and its contributing characters. The field experiment was carried out at Horticulture Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. The experiment consisted of two growth regulators and four nutrients in different concentrations. The different treatment concentration tested were NAA (25, 50 and 75ppm), GA_3 (25, 50 and 75ppm), $MnSO_4$ (2000 and 4000 ppm), $FeSO_4$ (2000 and 4000 ppm), $MgSO_4$ (2500 and 5000 ppm), $CuSO_4$ (1000 and 2000 ppm) and Control (water spray). All variables parameters regarding yield attributes were significantly influenced by different concentrations of the growth regulators and nutrients. Results revealed that among all the treatments, the foliar application of GA_3 (75 ppm) registered significantly higher reproductive aspects viz., number of flower per plant (22.88), number of pod per plant (20.68), fruit setting (90.34 %), pod length (20.63 cm), pod diameter (1.77 cm) and green pod yield (15.23 t/ha) over NAA and other treatments. While among the nutrients foliar application $FeSO_4$ @ 4000 ppm had more positively effects on reproductive parameter as compare to other nutrient treatment.

Keywords: foliar application, bioregulators, nutrients and Okra (Abelmoschus esculentus (L.) Moench) Cultivation

Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) is the only vegetable crop of significance in the Malvaceae family and as an important economically vegetable crop grown in tropical and sub-tropical parts of the world. Okra prefers warm-moist season and thrives successfully both in the plain and hill areas. It is a short duration crop and grown as spring-summer and rainy season crop in northern India. In south India, where winter is mild and frost free, it is possible to grow okra throughout the year. In the production system, it is considered as a cash crop. The leading okra producing countries in the world are China, South Africa, America and Turkey. It is an oligo purpose crop, but it is usually consumed for its green tender fruits as a vegetable in a variety of ways. Almost all parts of okra plant are consumed, like fresh okra fruits are used as vegetable, roots and stem are used for clearing the cane juice (Chauhan, 1972) [4]. Okra is a popular health food due to its high fiber, vitamin C, and folate content. Okra is also known for being high in antioxidants. The green fruits are rich sources of vitamins; calcium, potassium and other minerals. Since the entire plant is edible, the leaves are also eaten raw in salads and also beneficial in cases of spermatorrhoea (Nadkarni, 1927) [12]. Okra is also a desirable vegetable for direct marketing to local restaurants, where chefs are often willing to pay a premium for smaller sizes of okra. Beside these, bhendi has a vast a potential as one of the foreign exchange earning crops which accounts for about 60 per cent of the export of fresh vegetables. Among all the cultivars of okra the cultivar ‘Parbhani Kranti’ has high export potential (Pandey, 1998) [14].

The foliar application of plant growth regulators and nutrients becomes more vital; these provide an immediate effect on crop growth & development and are less time consuming. Although the quantity of nutrients absorbed by the plant leaf during foliar application may be small, it is compensated by a higher efficiency of nutrient uptake than applying the same quantity of nutrients to the soil. Plant growth regulators considered as a new generation of agrochemicals. Plant Growth Regulators in olericulture provides professionals and researchers with the information needed to effectively tap these versatile resources to enhance crop production. The growth regulators have been known to be one of the quick means of increasing production. Exogenous application of GA_3 can enhance the productivity of crops affecting the vital physiological process (Bora and Sarma, 2006) [3]. NAA has both stimulatory and inhibitory effect on different yield parameters, and it depends on several factors including the varietal difference and concentration of the hormones (Adam and Jahan, 2011) [1]. Iron is an importance element in crops, because it is essential for many important enzymes, including cytochrome that is involved in electron transport chain, synthesize chlorophyll, maintain the structure of chloroplasts, and enzyme activity to increase biomass and yield (Ziaeian and Malakouti, 2006) [22]. Magnesium used in large amount by plants for their growth and reproductive success (Williams and Salt 2009) [21]. Singh *et al*. (1999) [17] and Patil (2004) [15] reported significant improvement in growth and yield of okra due to the foliar application of PGRs and nutrients. Higher production through breeding is a continuous endeavor of mankind. But, these methods are however, not only time consuming but also costly. Hence, the present investigation was carried out to find out the suitable growth regulators and micronutrients to increase the vegetative growth of okra.

Material and Methods

The field experiment was conducting at Horticulture Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during 2011 and 2012 to find out the impact of foliar application of plant growth regulators and nutrients. Geographically, experimental field is located at 29^0 01' North latitude, 77^0 45' East longitudes and at an altitude of 237.75 meter above the mean sea level. The experimental field was laid out in a randomized block design with three replications. The seeds of okra cultivar 'Parbhani Kranti' were sown in the experimental field with the all recommended package of practices. Fifteen treatments comprising of two plant growth regulators viz., GA_3 (25, 50 and 75ppm), NAA (25, 50 and 75ppm) and four nutrients viz., MnSO4 (2000 and 4000 ppm), FeSO4 (2000 and 4000 ppm), MgSO4 (2500 and 5000 ppm), CuSO4 (1000 and 2000 ppm) and Control (Water spray) were used as foliar spray at 30 and 60 days after seed sowing. The data on yield and its attributing characters namely; number of flower per plant, number of pod per plant, fruit setting, pod length, pod diameter, pod yield per plant and green pod yield per hectare were recorded and subjected for statistical analysis.

Result and discussion

The results revealed that there is a significant and promotive influence of foliar application of plant growth regulators (GA_3 and NAA) and nutrients ($MnSO_4$, $FeSO_4$, $MgSO_4$ and $CuSO_4$) with different concentrations (as compare to control treatment) on the reproductive characteristics of okra plants during the both years of investigation (table-1&2). Although flower production is depends on genotype of plant and environmental condition of the particular location (Craita and Tom, 2013) [6]. But, the flower initiation is significantly enhanced by the foliar application of bioregulators and nutrients. The maximum number of flower per plant (22.88) and pod per plant (20.68) was recorded with foliar application of GA_3 over NAA. While, in case of nutrients plant treated under $FeSO_4$ had more number of flower (18.97) and pod per plant (16.55) as compare to MgSO4. These results also confirm with the findings of Surendra *et al.* (2006) [19]. This might be because of the fact that GA_3 and NAA are known to increase the metabolization of photosynthetes and also reduce sugar thereby bringing a change in the membrane permeability (Shukla *et al.*, 1997) [16]. Iron application improved the flower initiation possibly due to the fact that it acts as enzyme catalyst and therefore accelerates metabolic activity in plant and also increase cytochrome and flavoprotien content in plants because iron acts as oxygen carrier which ultimately increase the fruit set and finally pod formation.

Fruit set mainly depends on the viable and compatible features of male and female organs (Jennifer and Carol, 2007) [9]. The results obtained from the present investigations have shown remarkable improvement in fruit setting of okra. Between the both growth regulators (GA_3 and NAA), the foliar spray of GA_3 @75ppm had maximum fruit setting (90.34 %). All the treatments of varying doses of NAA and GA3 improved the fruit setting significantly than control, which implies that, the application of growth regulators have immense scope in improving the fruit setting. Dhage *et al.* (2011) [7] also recorded maximum per cent fruit set with GA_3 when applied as foliar spray after 30 days of sowing in okra cultivar Akola Bahar. The per cent fruit set as affected by various treatments varied from 83.09 per cent (control) to 90.34 per cent (75 ppm GA_3) during both the years of study. Of the nutrient treatments applied in the present study, $FeSO_4$ application was found to be most effective in improving the fruit set percentage (86.18 %). Surendra *et al.* (2006) [19], who recorded significant improvement in fruit set with the foliar application of $FeSO_4$. The increase in fruit set by GA_3 and $FeSO_4$ is possibly due to the fact that these substances are reported to increase functional male and female organs and compatibility besides reducing the embryo abortion in plants. The applications of plant growth regulators have been found ineffective against the fruit drop (Ericson, 1951) [8]. After successful pollination followed by fertilization the ovary of the flower develops into fruit and the ovules into seed. In the absence of pollination, the ovary abscises and falls. Therefore, pollination supplies the necessary stimulus for the development of ovary. The stimulus is in the form of auxin. At the outset pollen grains, they constitute a source of auxin. The amount of auxin supplied by pollination, however, is quite small and it is barely sufficient for future fruit development. At this stage if auxins are supplied exogenously they help in normal fruit setting and development. The significant reduction in fruit setting by foliar application of GA_3 can be owed to role of exogenous GA_3 in inhibition of ethylene production (Cooper and Henry, 1973) [5] and higher endogenous level of gibberellin probably counteract the effect of endogenous ABA which has been ascribed to cause fruit drop in several fruits (Martin and Nishizima, 1972) [11]. GA_3 also have great role in the fast increase of ovaries growth and reduction magnitude of abscission the peak (Agusti *et al.*, 1982) [2].

Okra pods having 6 – 9 cm length are most desirable from the market and export point of view. However, for higher seed production, the larger pods are preferred. Experimental data clearly indicate that the maximum pod length (20.63 cm) and pod diameter (1.77 cm) was noticed with the foliar application of GA_3 (75 ppm). The findings obtained here have confirmed the findings of Subramanyam and Bhatia (1993) [18]. Syed *et al*. (1997) [20] who reported that foliar application of GA_3 @ 150 ppm increased pod size of okra in terms of length and diameter. In case of nutrients; FeSO4 @4000 ppm had maximum pod length (16.90 cm) and pod diameter (1.59 cm) as compare to other nutrient treatments. The stimulative effect of GA_3 on pod size may be due to the fact that bioregulators particularly gibberellins are known to influence both cell division and cell enlargement (Kamijima, 1981) [10]. The iron has a role in chlorophyll synthesis and mobalization of food material.

Fruit weight is the most important yield contributing character for all the plant species. The individual fruit weight has direct path effects on cumulative yield. The okra plants subjected to the foliar application of GA_3 @75ppm exhibits maximum pod weight per plant (276.89 g) and green pod yield (15.23 t/ha) followed by NAA. However, control treatment had minimum pod yield. These findings are in agreement with the findings of Naruka and Paliwal, 2000 [13]. While among the nutrients treatments FeSO4 (4000 ppm) treated plants produced maximum pod weight per plant (219.07 g) and green pod yield (12.05 t/ha) followed by $MgSO_4$. Patil (2004) [15] was also obtained maximum pod yield through the foliar spray of FeSO4 in okra cv. Arka Anamika. This may be attributed to the increased supply of photosynthetic materials and its efficient mobilization in plants giving rise to increased stimulation of fruit growth ultimately resulting in increased fruit weight. GA_3 and NAA have been found to enhance photosynthetic and enzymatic activity and also chlorophyll biosynthesis which could be the possible reason for higher green pod yield of okra. Further, gibberellins have a unique ability to promote cell division and fruit set so their application not only enhanced fruit set but also increased the pod yield. On the other hand, micronutrients have a role in chlorophyll synthesis and photosynthesis and also influence metabolic enzymatic activation. Iron and magnesium are essential for chlorophyll and starch bio synthesis. Iron is essential for translocation the carbohydrate, cellular differentiation and cell division.

Table 1: (Effect of foliar application of bioregulators and nutrients on the number of flowers and pods per plant, fruit setting and pod length of okra (*Abelmoschus esculentus* (L.) moench**)**

Treatments	Number of flowers/ plant		Avg. number of flowers/ plant	Number of pods/ plant		Avg. number of pods/ plant	Fruit set (%)		Avg. fruit set (%)	Pod length (cm)		Avg. pod length (cm)
	2011	2012		2011	2012		2011	2012		2011	2012	
NAA (25 ppm)	20.68	19.66	20.17	18.50	17.29	17.89	89.44	87.91	88.67	18.27	17.03	17.65
NAA (50 ppm)	20.97	19.79	20.38	18.76	17.48	18.12	89.91	88.30	89.10	18.53	18.20	18.36
NAA (75 ppm)	21.69	20.35	21.02	19.50	18.10	18.80	89.97	88.81	89.39	18.64	18.38	18.51
GA_3 (25 ppm)	21.65	20.29	20.97	19.48	18.02	18.75	89.94	88.78	89.36	19.56	19.11	19.33
GA_3 (50 ppm)	22.56	21.46	22.01	20.45	19.15	19.80	90.64	89.21	89.92	20.47	19.91	20.19
GA_3 (75 ppm)	23.72	22.05	22.88	21.61	19.76	20.68	91.09	89.60	90.34	20.93	20.33	20.63
$MnSO_4$ (2000 ppm)	18.80	17.48	18.14	16.06	14.60	15.33	85.41	83.54	84.47	15.92	15.65	15.78
$MnSO_4$ (4000 ppm)	18.87	17.53	18.33	16.19	14.90	15.54	85.78	84.98	85.38	16.14	15.87	16.00
$FeSO_4$ (2000 ppm)	19.33	18.08	18.70	16.78	15.37	16.07	86.56	84.77	85.66	16.87	16.53	16.70
$FeSO_4$ (4000 ppm)	19.61	18.33	18.97	17.25	15.86	16.55	86.92	85.44	86.18	17.06	16.74	16.90
$MgSO_4$ (2500 ppm)	18.90	17.79	18.34	16.26	14.98	15.62	86.02	84.50	85.26	16.46	16.18	16.32
$MgSO_4$ (5000 ppm)	19.10	18.09	18.59	16.48	15.30	15.89	86.09	85.20	85.64	16.62	16.30	16.46
$CuSO_4$ (1000 ppm)	18.50	17.46	17.98	15.77	14.49	15.13	84.89	83.39	84.14	15.56	15.28	15.42
$CuSO_4$ (2000 ppm)	18.58	17.61	18.09	15.85	14.75	15.30	85.34	83.80	84.57	15.81	15.49	15.65
Control (water spray)	17.59	16.51	17.05	14.81	13.53	14.17	84.16	82.02	83.09	15.08	14.83	14.95
CD at 5%	0.49	0.45		0.45	0.43		1.05	0.89		0.65	0.43	
SEm(±)	0.17	0.15		0.15	0.15		0.35	0.30		0.22	0.15	

Table 2: (Effect of foliar application of bioregulators and nutrients on the pod diameter, pod weight per plant and green pod yield of okra (*Abelmoschus esculentus* (L.) moench**)**

Treatments	Pod diameter (cm)		Average pod diameter (cm)	Pod weight / plant (g)		Average pod weight/ plant (g)	Yield (t/ha)		Average yield (t/ha)
	2011	2012		2011	2012		2011	2012	
NAA (25 ppm)	1.67	1.63	1.65	246.89	227.23	237.06	13.63	12.45	13.04
NAA (50 ppm)	1.69	1.65	1.69	249.66	230.83	240.24	13.84	12.71	13.27
NAA (75 ppm)	1.73	1.70	1.71	257.81	241.64	249.72	14.23	13.22	13.72
GA_3 (25 ppm)	1.75	1.71	1.73	270.42	239.55	247.80	14.18	13.19	13.68
GA_3 (50 ppm)	1.78	1.72	1.75	273.69	255.02	264.35	15.10	13.98	14.54
GA_3 (75 ppm)	1.81	1.74	1.77	288.89	264.89	276.89	15.97	14.50	15.23
$MnSO_4$ (2000 ppm)	1.50	1.46	1.48	209.56	192.56	201.06	11.57	10.55	11.06
$MnSO_4$ (4000 ppm)	1.52	1.48	1.50	213.62	196.45	205.03	11.80	10.67	11.18
$FeSO_4$ (2000 ppm)	1.59	1.55	1.57	221.94	202.77	212.35	12.26	11.11	11.68
$FeSO_4$ (4000 ppm)	1.60	1.58	1.59	227.66	210.49	219.07	12.57	11.54	12.05
$MgSO_4$ (2500 ppm)	1.54	1.51	1.52	215.00	197.33	206.16	11.87	10.81	11.34
$MgSO_4$ (5000 ppm)	1.57	1.53	1.55	217.88	201.72	209.80	12.01	11.08	11.54
$CuSO_4$ (1000 ppm)	1.47	1.43	1.45	207.67	190.84	199.25	11.47	10.46	10.96
$CuSO_4$ (2000 ppm)	1.50	1.45	1.47	209.97	193.64	201.80	11.59	10.61	11.10
Control (water spray)	1.44	1.39	1.41	189.97	176.47	186.22	10.57	9.76	10.16
CD at 5%	0.04	0.03		11.29	10.16		0.35	0.31	
SEm(±)	0.01	0.01		3.77	3.39		0.12	0.11	

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