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Plant Growth Regulators for Forage Yield and Quality Enhancement of Fodder Maize (*Zea mays*)

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ABSTRACT

Background: In livestock management, supply of green fodder and feed is vital to improve the productivity. In the present context, there is deficit in green and dry fodder availability. Improving the productivity and increase the area under fodder crops are the key options. This can be achieved through adopting the standard package of practises and exploring the other options. Use of plant growth regulators (PGR) have been benefited to increase the productivity in crops. PGRs helps to boost the plant metabolic rate, cellular division, cell elongation, growth and development by governing the phytohormones or other biochemical signals. Application of these PGRs in forage crops is limited and need to study its efficiency.

Methods: The study was conducted in fodder maize (*Zea mays*) crop for three successive years during *kharif* 2020-22 for growth and yield parameters at BAIFs Central Research Station, Urulikanchan in randomized block design with three replications.

Result: Results showed the significant maximum plant height of 271.30 cm and number of leaves (15.04) per plant in treatment of Mepiquat chloride @ 200 ppm whereas rest of PGR treatments were found at par. Application of Mepiquat chloride @ 300 ppm recorded significantly higher green fodder yield of 494.15 q ha^{-1} followed by application of Salicylic acid @100 ppm recorded green fodder yield of 490.75 q ha^{-1}. Maximum dry matter yield and crude protein yield of 87.17 q ha^{-1} and 6.41 q ha^{-1} respectively were recorded by the application of Salicylic acid @ 200 ppm. The treatment of Salicylic acid @100ppm recorded the highest net monetary return (Rs. 76,650 ha^{-1}) and 2.66 of benefit cost ratio.

Key words: Crude protein, Dry matter, Green fodder, Plant growth regulators.

INTRODUCTION

According to the 20th livestock census the livestock population of India was increased 4.8% (20th livestock census, Government of India Ministry of Fisheries, Animal husbandry and Dairying Department of Animal husbandry and Dairying Lok Sabha https://dahd.nic.in/sites/default/filess/LS5498.pdf). Ample source of feed and fodder is vital to improve livestock productivity. However, India suffers from constant deficit of feed and fodder, which is estimated to be 35.60% green fodder, 10.95% dry fodder and 44.00% concentrate feed ingredients as per report Vision 2050 by ICAR-IGFRI. There is limited possibility to increase area under forage cultivation and the only way is to improve the productivity of fodder crops from the inadequate land (Takawale *et al.* 2022). The other option to improve fodder resources at the farmers' level is to introduce improved varieties along with new production technologies. Among the various production technologies that help to increase the green fodder yield, use of Plant Growth Regulators (PGR) is one of them. PGR are the new-generation chemicals and are expected to play an important role in overcoming the impediments in the manifestation of biological yield (Manu *et al.,* 2021; Saini *et al*., 2016). Use of these chemicals to increase production in various agricultural/ horticultural crops is gaining pace and with encouraging results. Apart from the classical five phytohormones, auxins, cytokinins, ethylene, abscisic acid and gibberellins, the potential of a growing number of non-traditional PGRs such as Oligosaccharins, Chlormequat, Jasmonic acid, Salicylic acid, *etc.* has been noted in various crop production and quality (Kaur and Singh, 2023).

When added in small amounts, PGRs modify the growth of plant usually by stimulating or inhibiting part of the natural growth regulation. They are taken into consideration as new era of agrochemicals after fertilizers, insecticides and herbicides. PGR are capable of increasing yield by 100-200 per cent under laboratory conditions and 10-15 per cent in the field conditions. Among the different fodder crops Maize (*Zea mays* L.) is one of the most important cereal fodder crops cultivated in the worldwide and has the third important position in India after rice and wheat. Maize also has an enormous role in food and nutritional security (Kale and Takawale 2019). The earlier lot of work has been done on different field crops, vegetable and horticulture, but limited work on fodder crops.

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Khadim *et al.* (2021) studied the effect of GA3 in combination with nitrapyrin and urea and found very good results on the increase of biomass, grain yield and nitrogen uptake of maize. Golada *et al.* (2018) found that, in maize crop application of Mepiquat chloride @ 200ppm produced the highest green cob yield (5903.03 kg ha^{-1}), baby corn yield (2082.64 kg ha^{-1}) and this was comparable with application of NAA, in case of green fodder yield NAA @ 40ppm produced significantly higher green fodder yield (26.88 t ha^{-1}) over Mepiquat chloride @ 200ppm which produced lowest green fodder yield (22.13 t ha^{-1}). Considering the effects of PGR on various crops and limited work in forages the study was undertaken to find out the effect of different PGR on forage yield and forage quality of maize.

MATERIALS AND METHODS

A field experiment was conducted under All India Coordinated Research Project on Forage Crops and Utilization at BAIF's Central Research Station, Urulikanchan, Pune. The experiment was laid in Randomized Block Design with eleven treatments of plant growth regulators during *kharif* season in 2020-22. The treatments details are as, T1: Triacontanol @10 ppm, T2: Triacontanol @ 20 ppm, T3: Mepiquat chloride @ 200 ppm, T4: Mepiquat chloride @ 300 ppm, T5: Salicylic @ acid 100 ppm, T6: Salicylic acid @ 200 ppm, T7: NAA @ 20 ppm, T8: Penoxaprop-P-ethyl @ 4 g a.i./ha, T9: GA3 @ 200 ppm, T10: GA3 @ 400 ppm and T11: Control-spray of water. The irrigations were given as and when required during the season. The objective was to study the efficacy of various PGR on growth, yield and quality of fodder maize. The variety of fodder maize was 'African Tall' and was sown manually at 30 cm distance between lines. The crop management was followed as per recommended package of practices for fodder maize. The PGR were sprayed on crop at 30 DAS. The data on growth parameters, plant height, no. of leaves per plant, leaf length, leaf width, stem diameter, leaf stem ratio *etc.* and yield parameters like green fodder, dry matter and crude protein were recorded at 50% flowering stage. The plant samples at 50% flowering stage were analysed in the laboratory for dry matter and crude protein content. 500 g fresh sample from each net plot was taken to determine dry matter content. The samples were dried at 70°C±2 in hot air oven for moisture loss, grounded with a Wiley mill to pass through 1 mm screen and analyzed for quality components. Total N was determined using the Kjeldahl (digestion and distillation) method and crude protein was calculated by multiplying nitrogen per cent with 6.25 (AOAC, 1965).

RESULTS AND DISCUSSION

Effect of plant growth regulators on growth parameters

Data on growth parameters and leaf characters were recorded at 50% flowering stage and presented in Table 1 and 2 respectively. It was revealed from the tables that all the various PGR have positive response to increase the growth parameters. Among the various treatments studied, the application of Mepiquat chloride @ 200 ppm and Mepiquat chloride @ 300 ppm recorded significantly maximum plant height of 297.45 and 297.78 cm in first and second year, respectively. However, in the third-year application, salicylic acid @ 100 ppm showed a maximum plant height of 238.78 cm. Over the three years, pooled data application of Mepiquat chloride @ 200 ppm recorded significantly maximum plant height of 271.30 cm and all other PGR treatments were found at par except Salicylic acid @ 200 ppm and Fenoxaprop-p-ethyl 4g a.i./ha. Similar results were also reported by (Chandrashekhar *et al.,* 2018). He observed that the application of Mepiquat chloride @ 200 ppm exhibits the maximum plant height over the control treatment. The leaf: stem (LS) ratio was not influenced due to the application of different PGRs but maximum pooled LS ratio of 0.60 and 0.59 was observed in the treatment of application of Salicylic acid @ 200 ppm and Mepiquat chloride @ 200 ppm respectively. Nutrient sprays have significantly enhanced leaf production by stimulating the growth of new leaves while also prolonging the longevity of existing ones. This dual effect has led to a notable increase in the leaf-to-stem ratio compared to the control group, indicating that the plants treated with the nutrient sprays prioritize leaf expansion and retention. As a result, the treated plants exhibit a more robust canopy and potentially greater photosynthetic capacity, which could contribute to overall plant health and productivity. These findings are similar with the Satpal *et al.* (2024); Kaur *et al.* (2022). Significantly maximum number of leaves per plant 16.11, 15.47, 13.55 and 15.04 were recorded in the treatment of Mepiquat chloride @ 200 ppm during the first year, second year, third year and pooled mean respectively. The treatments of application of Mepiquat chloride @ 300 ppm and Salicylic acid @ 100 ppm were found at par resulting 15.34, 15.89, 12.44, 14.56 and 14.89, 14.55, 14.22, 14.55 leaves per plant during the three consequent year and pooled mean respectively. Similar findings were obtained by Chandrashekhar *et al.* (2018) in the application of Mepiquat chloride @ 200 ppm showed the highest number of leaves per plant over the control. The higher number of leaves per plant might be due to the maximum plant height recorded during the growth period. The application of Fenoxaprop-p-ethyl @ 4 g a.i./ha observed the minimum number of leaves per plant (13.00). Among the different PGRs treatments, the application of Mepiquat chloride @ 300 ppm recorded significantly maximum leaf length in the first two years and during the last year application of Salicylic acid @ 100 ppm recorded maximum leaf length of 109.56, 101.00 and 77.44 cm, respectively. Similarly, application of Mepiquat chloride @300 ppm recorded maximum leaf width (8.44 and 8.67 cm) and stem diameter (2.01 and 1.94 cm) during the first two year of the experiment and during the third year of the experiment maximum leaf width (8.11 cm) and stem diameter (1.35

Table 1: Effect of different PGR on growth parameters of fodder maize.

Treatment #	Plant height (cm)				Stem diameter (cm)				Leaf stem ratio			
	2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T1: Triacontanol @ 10 ppm	279.33	283.44	233.22	265.33	1.83	1.66	1.26	1.58	0.57	0.55	0.57	0.56
T2: Triacontanol @ 20 ppm	264.11	263.50	235.22	254.28	1.84	1.80	1.22	1.62	0.50	0.47	0.40	0.46
T3: Mepiquat chloride @ 200 ppm	297.45	285.11	231.33	271.30	1.90	1.89	1.30	1.70	0.63	0.58	0.56	0.59
T4: Mepiquat chloride @ 300 ppm	275.11	297.78	233.78	268.89	2.01	1.94	1.31	1.75	0.50	0.58	0.52	0.53
T5: Salicylic acid 100 ppm	264.78	262.67	238.78	255.41	1.60	1.84	1.35	1.60	0.52	0.41	0.66	0.53
T6: Salicylic acid 200 ppm	257.11	258.20	234.67	249.99	1.77	1.74	1.29	1.60	0.56	0.54	0.71	0.60
T7: NAA @ 20 ppm	266.11	260.20	232.45	252.92	1.60	1.67	1.24	1.50	0.56	0.54	0.44	0.51
T8: Penoxaprop-P-ethyl 4 g a.i./ha	147.11	226.67	228.00	200.59	1.88	1.82	1.35	1.68	0.57	0.54	0.48	0.53
T9: GA_3 @200 ppm	292.89	285.33	223.55	267.26	1.78	1.73	1.33	1.61	0.46	0.42	0.63	0.50
T10: GA_3 @400 ppm	273.78	278.83	224.00	258.87	1.64	1.63	1.20	1.49	0.47	0.46	0.63	0.52
T11: Control-spray of water	280.44	257.10	234.44	257.33	1.75	1.66	1.34	1.58	0.55	0.47	0.50	0.51
SE (m)±	30.55	7.75	7.24	6.56	0.11	0.07	0.07	0.06	0.05	0.05	0.09	0.05
CD at 5 %	14.54	23.03	NS	19.48	NS	NS	NS	NS	NS	NS	NS	NS
CV %	6.76	4.99	5.41	4.46	10.56	7.11	9.31	6.32	15.67	17.51	29.76	17.45

Table 2: Effect of different PGR on leaf characters of fodder maize.

Treatment #	Number of leaves/plant				Leaf length (cm)				Leaf width (cm)			
	2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T1: Triacontanol @ 10 ppm	14.67	13.67	12.67	13.67	107.34	92.89	67.33	89.19	8.28	7.50	7.34	7.71
T2: Triacontanol @ 20 ppm	14.44	12.78	13.56	13.59	101.44	93.00	75.00	89.81	8.28	8.00	8.17	8.15
T3: Mepiquat chloride @ 200 ppm	16.11	15.47	13.55	15.04	106.44	96.78	74.56	92.59	8.28	8.17	7.66	8.04
T4: Mepiquat chloride @ 300 ppm	15.34	15.89	12.44	14.56	109.56	101.00	74.56	95.04	8.44	8.67	7.94	8.35
T5: Salicylic acid 100 ppm	14.89	14.55	14.22	14.55	105.00	97.78	77.44	93.41	8.11	8.00	8.11	8.07
T6: Salicylic acid 200 ppm	13.78	13.78	12.78	13.45	97.55	91.44	75.67	88.22	7.83	7.56	7.72	7.70
T7: NAA @ 20 ppm	14.00	14.11	13.89	14.00	104.22	95.00	73.00	90.74	8.28	8.17	7.66	8.04
T8: Fenoxaprop-p-ethyl 4 g a.i./ha	13.22	13.33	12.45	13.00	95.78	92.56	67.34	85.23	8.44	7.89	7.11	7.81
T9: GA_3 @200 ppm	15.33	14.00	12.56	13.96	104.67	94.56	77.33	92.19	7.39	7.78	7.33	7.50
T10: GA_3 @400 ppm	14.00	13.50	12.89	13.46	99.56	94.56	68.89	87.67	7.56	7.78	8.05	7.80
T11: Control-spray of water	15.11	12.67	12.44	13.41	107.00	92.78	65.55	88.44	8.39	7.56	8.00	7.98
SE (m)±	0.34	0.32	0.68	0.30	3.09	3.15	3.80	2.47	0.35	0.22	0.30	0.19
CD at 5%	1.01	0.95	NS	0.90	NS	NS	NS	NS	NS	0.65	NS	NS
CV %	4.03	3.97	9.10	3.79	5.18	5.76	9.08	4.73	7.53	4.78	6.77	4.25

Table 3: Effect of different PGR on yield parameters of fodder maize.

Treatment	Green fodder yield q^{-1}				Dry matter yield q^{-1}				Crude protein yield q^{-1}			
	2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T1: Triacontanol @ 10 ppm	443.22	446.90	400.74	430.29	66.93	83.53	64.80	71.75	5.90	5.28	4.72	5.30
T2: Triacontanol @ 20 ppm	447.72	453.84	404.82	435.46	61.56	83.55	69.10	71.40	4.11	8.10	4.31	5.51
T3: Mepiquat chloride @ 200 ppm	467.32	479.58	394.61	447.17	68.88	97.79	59.78	75.48	6.25	7.95	3.86	6.02
T4: Mepiquat chloride @ 300 ppm	541.67	559.65	381.13	494.15	78.60	84.62	75.39	79.54	5.28	6.30	4.92	5.50
T5: Salicylic acid 100 ppm	507.36	503.27	461.61	490.75	70.37	106.29	77.78	84.81	6.00	8.94	4.90	6.61
T6: Salicylic acid 200 ppm	515.53	527.78	374.59	472.63	87.02	113.16	61.32	87.17	7.01	8.44	3.77	6.41
T7: NAA @ 20 ppm	471.82	488.57	409.73	456.71	62.85	72.01	72.36	69.07	5.08	6.63	4.98	5.56
T8: Fenoxaprop-p-ethyl 4 g a.i./ha	296.16	311.69	381.95	329.93	45.19	56.48	70.70	57.46	4.30	4.51	4.92	4.58
T9: GA_3 @200 ppm468.14	472.23	399.10	446.49	67.74	120.09	64.34	84.06	5.62	7.59	4.16	5.79	
T10: GA_3 @400 ppm	490.20	510.63	394.20	465.01	68.14	126.43	67.01	87.19	4.61	10.76	4.66	6.68
T11: Control-spray of water	416.67	417.49	330.89	388.35	56.29	65.00	64.34	61.88	4.30	4.92	4.12	4.45
SE(m)±	21.62	14.09	17.71	17.81	3.19	2.58	3.11	2.96	0.27	0.20	0.20	0.22
CD at 5%	64.22	41.87	52.63	52.91	9.47	7.67	9.24	8.79	0.79	0.60	0.61	0.67
CV %	8.13	5.19	7.79	7.04	8.28	4.88	7.93	7.03	8.69	8.88	7.89	8.49

cm) were observed in application of Salicylic acid @100 ppm. In pooled mean, maximum leaf width and stem diameter was recorded in the treatment of application of Mepiquat chloride @300 ppm with 8.35 cm and 1.75 cm respectively.

Effect of PGR on yield parameters

The variations due to the application of different plant growth regulators were observed in fodder maize. The year-wise data on green fodder, dry matter and crude protein yield is presented in Table 3. Among the different PGRs studied, the application of Mepiquat chloride @300 ppm at DAS was recorded significantly maximum green fodder yield of 541.67 and 559.65 qha^{-1} in the first and second year, respectively whereas in the third year, the application of Salicylic acid @100 ppm recorded a maximum green fodder yield of 461.61qha^{-1}. The pooled mean, significantly higher green fodder yield of 494.15 qha^{-1} was recorded in the treatment of application of Mepiquate chloride @300 ppm. It was found that there was 29.99, 34.13, 39.50 and 27.24% increase in the green fodder yield during the first, second, third year and pooled data over the control treatment. Whereas treatments, Salicylic acid @ 100 ppm, Salicylic acid @ 200 ppm, GA3 @ 400 ppm, NAA @ 20 ppm, Mepiquat chloride @ 200 ppm and GA3 @200 ppm were found at par with treatment of with green fodder yield of 490.75, 472.63, 465.01, 456.71, 447.17 and 446.49 qha^{-1} respectively. These results are similar to the findings of Gondaliya *et al.,* 2022. His study confirmed that application of NAA @ 40 ppm, GA3 @ 40ppm and Mepiquate chloride @ 200 ppm helps to increase the green fodder yield and it was 43.14, 41.60 and 37.78 MT ha^{-1}, respectively. According to Muthukumar *et al.* (2005), increase in fodder yield due to NAA spray might be the result of increased cell division, cell enlargement and elongation which ultimately resulted in increased plant height, leaf area index and total biomass. Similar findings were also reported by Muthukumar *et al.* (2005) in baby corn.

The dry matter yield was calculated based on dry matter content in each treatment. Significantly higher dry matter yield of 87.02 qha^{-1}, was recorded in the treatment of Salicylic acid @ 200 ppm; this was found 54.59% higher than the control-water spray treatment, followed by Mepiquat chloride @300ppm with 78.60 qha^{-1} in the first year of the study. Application of GA3 @ 400 ppm and GA3 @ 200ppm noted higher dry matter yield of 48.75% and 45.87% compared to the control-water spray treatment, respectively, during second year; however, in the third-year treatments of Salicylic acid @ 100 ppm and Mepiquat chloride @ 300 ppm recorded significantly higher yield of 77.78 and 75.39 qha^{-1}, respectively. The pooled dry matter yield of 87.19 and 87.17 qha^{-1} was recorded by the treatment of GA3 @ 400 ppm and Salicylic acid @ 200 ppm, respectively, followed by the application of Salicylic acid @100 ppm and GA_3 @ 200 ppm with dry matter yield of 84.81 and 84.06 qha^{-1} respectively. PGR helps to rise metabolization of stored food materials to the

Table 4: Effect of different PGR on crop economics of fodder maize.

Treatment #	Gross monetary return (Rs/ha)				Net monetary return (Rs/ha)				Benefit cost ratio			
	2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T1: Triacontanol @ 10 ppm	110806	111725	100185	107572	60397	61316	50659	57457	2.20	2.22	2.02	2.15
T2: Triacontanol @ 20 ppm	111929	113461	101206	108865	55927	57458	46096	53160	2.00	2.03	1.83	1.95
T3: Mepiquat chloride @ 200 ppm	116831	119895	98653	111793	68781	71844	52115	64247	2.42	2.49	2.12	2.34
T4: Mepiquat chloride @ 300 ppm	135418	139911	95283	123537	84501	88994	47705	73733	2.66	2.75	2.00	2.47
T5: Salicylic acid 100 ppm	126839	125818	115401	122686	80486	79465	70000	76650	2.74	2.71	2.54	2.66
T6: Salicylic acid 200 ppm	128882	131946	93649	118159	82249	85313	49947	72503	2.76	2.83	2.14	2.58
T7: NAA @ 20 ppm	117954	122142	102431	114176	72197	76384	57965	68849	2.58	2.67	2.30	2.52
T8: Fenoxaprop-p-ethyl 4 g a.i./ha	74041	77921	95487	82483	32070	35951	51732	39918	1.76	1.86	2.18	1.93
T9: GA_3 @200 ppm	117035	118057	99776	111623	66284	67305	50461	61350	2.30	2.33	2.02	2.22
T10: GA_3 @400 ppm	122550	127656	98551	116252	66016	71122	44013	60384	2.17	2.26	1.81	2.08
T11: Control-spray of water	104168	104372	82721	97087	59080	59284	40149	52838	2.31	2.31	1.94	2.19
SE (m)±					4953.23	3447.43	4060.3	4154	0.09	0.07	0.08	0.08
CD at 5%					14714.89	10241.51	12062.22	12340	0.26	0.21	0.23	0.23
CV %					12.96	8.70	13.79	12.00	6.55	5.11	6.41	6.02

developing sink through increase in hydrolyzing and oxidizing enzyme activities and lead to yield increases in plant reported by Gohil *et al.* (2023).

In case of crude protein yield, significantly higher yield was noted in the treatment with application of Salicylic acid @ 200 ppm, GA_3 @ 400 ppm and Salicylic acid @ 200 ppm recorded a yield of 7.01 q ha^{-1}, 10.76 q ha^{-1} and 4.90 q ha^{-1}, respectively, in three consequent years. The pooled mean showed that significantly maximum crude protein yield of 6.68 q ha^{-1} was recorded by application of GA_3 @ 400 ppm whereas application of Salicylic acid @ 200 ppm was found at par with crude protein yield of 6.61 qha^{-1}.

Effect of PGR on crop economics

Economics of different treatments of PGR were worked out and presented in Table 4. Among the various treatments, application of Salicylic acid @ 100ppm recorded significantly maximum net monetary return of Rs. 76,650 ha^{-1} and gross return of Rs. 1,22,686 ha^{-1}; however application of Mepiquat chloride @ 300 ppm and Salicylic acid @ 200 ppm were found at par with net monetary return of Rs. 73,733 and 72,503 ha^{-1} respectively. The significantly maximum benefit cost ratio of 2.66 was observed in the treatment of application of Salicylic acid @ 200 ppm whereas application of NAA @ 20ppm and Salicylic acid @100 ppm found at par and recorded benefit cost ratio of 2.52 and 2.47 respectively.

CONCLUSION

Based on the three years study, application of Mepiquat chloride @ 300 ppm or Salicylic acid @ 200 ppm is recommended for increase in green fodder, dry matter and crude protein yield in fodder maize.

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Conflict of interest

All authors declared that there is no conflict of interest.

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