Effect of Plant Growth Promoters and Herbicides on Growth, Yield Attribute and Yield of *Kharif*Hybrid Maize (*Zea mays* L.)

Abstract

A field experiment was conducted during two consecutive *kharif*seasons 2022 and 2023at Students' Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (U.P.) - 208002 India.The experiment was laid out in split plot design with three replications. Threeplant growth promoters [*viz*. Gibberellic acid (P_1), Cytokinin + Enzymes (P_2) and Amino acid + Humic acid + Sea weed extract (P_3)] were allocated in main plots; whereas sixherbicidal treatments[*viz.*Weedy check (W_1), Tembotrione 42%SC @ 120g a.i./ha (W_2), Halosulfuron methyl 75% WG @ 72g a.i./ha (W_3), Topramezone 33.6 SC @ 25.2g a.i./ha (W_4), Atrazin 50%WP @ 1kg a.i./ha (W_5) and Mesotrione 2.27%W + Atrazin 22.7%SC @ 750 ml a.i./ha (W_6)] were setup in sub plots.On the pooled basis of two years experimental results showed that, application of Amino acid + Humic acid + Sea weed extract (P_3)recorded significantly highest value of plant height (208.22cm), crop growth rate (47.54 and 9.96 g m^{-2} day^{-1} at 60 - 90 DAS and 90 DAS - harvest stage, respectively), relative growth rate (0.1029, 0.1052 and 0.0825 g g^{-1} day^{-1} at 30 - 60 DAS, 60 - 90 DAS and 90 DAS - harvest stage, respectively), length of cob (18.56cm), number of grains cob^{-1}(574.01), grain yield (6835.95 kg ha^{-1}) and harvest index (34.26). However, among herbicidal treatments, Tembotrione 42%SC @ 120g a.i./ha (W_2) was recorded significantly maximum weed control efficiency (85.86% at 75 DAS) plant height (216.59cm), leaf area (5226cm^2)crop growth rate (43.45, 48.77 and 10.26 g m^{-2} day^{-1} at 30 - 60 DAS, 60 - 90 DAS and 90 DAS - harvest stage, respectively), relative growth rate (0.1037. 0.1053 and 0.0829 g g^{-1} day^{-1} at 30 - 60 DAS, 60 - 90 DAS and 90 DAS - harvest stage, respectively) and net assimilation rate (5.65 g m^{-2} day^{-1} at 30 - 60 DAS), length of cob (18.56cm), number of grains cob^{-1}(574.01), grain yield (6835.95 kg ha^{-1}) and harvest index (34.26).

Key words: *Growth, plant growth promoters, herbicide, maize and yield.*

INTRODUCTION

Maize (*Zea mays* L.) is a wonder crop due to high yield potential and known as the "Queen of Cereals". It ranks third among cereals worldwide, following rice and wheat. Globally during 2022-23 around 200.53 million hectares area is under maize along with 1157.53 million tonnes production and 5772.3 kg ha^{-1} productivity. In India around 10.74 million hectares area is under maize along with 38.09 million tonnes production and 3546.5 kg ha^{-1} productivity in 2022-23 (USDA, 2024). Maize serves as a staple for human consumption, livestock and fish feed, and is used in various industrial applications. Maize kernels and sweeteners are increasingly important as a key feedstock for ethanol production, which is utilized as a biofuel. Maize grains contain about 10 % proteins, 4 % oil, 70 % carbohydrates, 2.3 % crude fibre, 10.4 % albuminoids, and 1.4 % ash. Vitamin A, nicotinic acid, phosphorus, riboflavin, and vitamin E are also present in large amounts in maize grain.

The application of plant growth promoters has shown promising results in augmenting maize growth parameters such as shoot length, root development, leaf area, and ultimately, yield (Etesami and Maheshwari 2018). Plant Growth Promoters have been shown to significantly improve nutrient uptake efficiency, particularly for nitrogen, phosphorus, and potassium, which are essential for maize growth. Moreover, they help maize better withstand abiotic stresses such as drought, salinity, and extreme temperatures, enhancing its resilience in challenging environmental conditions. (Iqbal *et al. 2023*).

Rainy season maize suffers from severe weed competition depending upon the intensity, nature, stages and duration of weed infestation and yield losses varied from 28-100 per cent (Patel *et al.* 2006). A wide-spaced crop has high weed infestation as a result of its initial slow development, especially during the *kharif* season. Weeds consume a significant portion of the fertilizer applied to the soil, reducing its availability to crops and leading to a loss of 30-40% of the nutrients. This limits the effectiveness of fertilizer in promoting crop growth. Herbicides represent a cornerstone in modern weed management strategies, offering efficient and cost-effective solutions to suppress weed growth and enhance crop yields. Herbicides play a crucial role in weed suppression by targeting specific weed species while minimizing adverse effects on maize plants (Abbas *et al.* 2018). Understanding the effectiveness of different herbicides, their application methods, and dosage regimes is imperative for devising tailored weed management strategies that optimize maize productivity and economic returns (Norsworthy *et al.* 2012).

MATERIALS AND METHODS

The field experiment was carried out during *kharif* seasons of 2022 and 2023 at Students' Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (U.P.) - 208002 India, which is situated 26.4148^{0} North latitude, 80.2321^0 East longitude and at the 125.9 meters above sea level in the alluvial tract of Indo - Gangetic Plain zone of central part of Uttar Pradesh. The irrigation facilities are sufficiently available on this farm. The experiment was laid out in Split Plot Design and allocated plant growth promoters in main plots and herbicides in sub plots with eighteen treatment combinations were replicated three times. The experimental setup included three plant growth promoters *viz,* Gibberellic acid (P_1), Cytokinin + Enzymes (P_2) and Amino acid + Humic acid + Sea weed extract (P_3) along with six herbicides *viz,* Weedy check (W_1), Tembotrione 42%SC @ 120g a.i./ha (W_2), Halosulfuron methyl 75% WG @ 72g a.i./ha (W_3), Topramezone 33.6 SC @ 25.2g a.i./ha (W_4), Atrazin 50%WP @ 1kg a.i./ha (W_5) and Mesotrione 2.27%W + Atrazin 22.7%SC @ 750 ml a.i./ha (W_6). The seeds of maize variety DKC-9144 was sown 5 cm depth @ 25 kg ha^{-1} at 50 cm × 20 cm spacing by seed drill. The crop was sown on 7th July during 2022 and 17th July during 2023. The mean weekly maximum and minimum temperature during the crop growth period ranged from 29.3 °C to 37.7°C and 16.0°C to 28.5 °C, during 2022 and 31.4 °C to 35.6°C and 14.5°C to 28.9 °C during 2023, respectively. The crop availed maximum relative humidity 94%, 93% against minimum 42% and 37% during 2022 and 2023, respectively. Total rainfall of 984.90 mm and 424.4 mm was received during crop period 2022 and 2023, respectively. During the crop growing period, the mean weekly highest and lowest total rainfall recorded ranging from 0.0 mm to 159 mm and 0.0 mm to 128 mm and evaporation ranged from 2.60 to 7.94 mm day^{-1} and 2.01 to 4.86 mm day^{-1} during 2022 and 2023, respectively. Soil of the experimental field was silty loam in texture having 0.37 and 0.34% organic carbon, 179.5 and 152.20 kg ha^{-1} available N, 12.5 and 13 kg ha^{-1} available P_2O_5, 142.0 and 139.0 kg ha^{-1} available K_2O and soil pH 7.7 and 7.7 in 2022 and 2023, respectively. The crop was harvested at the fully ripe stage on October 25th in 2022 and November 2nd in 2023.

All the growth and yield attributing characters were recorded with the standard methodology at different growth stages of the crop. Various growth indices were estimated with the formulae as per mentioned below-

Crop growth rate (CGR)

$$\text{CGR (g m}^{-2}\text{ day}^{-1}) = \frac{W2 - W1}{t2 - t1} \times \frac{1}{A}$$

Where, W_1 and W_2 are dry weight (gm^{-2}) at first and second taken at times t_1 and t_2 respectively.

Relative growth rate (RGR)

$$\text{RGR (g g}^{-1}\text{ day}^{-1}) = \frac{\log W2 - \log W1}{t2 - t1}$$

Where, W_1 and W_2 are dry weight (g m^{-2}) at times t_1 and t_2 respectively.

Net assimilation rate

$$\text{NAR (g m}^{-2}\text{day}^{-1}) = \frac{W2 - W1}{t2 - t1}\left(\frac{\log L2 - \log L1}{L2 - L1}\right)$$

Where, W_1 and W_2 are dry weight (g m^{-2}) at times t_1 and t_2 respectively. L_1 and L_2 are Leaf area at times t_1 and t_2 respectively.

Harvest Index

$$\text{Harvestindex (\%)} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

Where, Economic yield = Grain yield (kg ha^{-1}), Biological yield = Grain yield + straw yield (kg ha^{-1}).

Weed control efficiency (%)

$$\text{Weed Control Ef iciency}(\%) = \frac{Wo - Wt}{Wo} \times 100$$

Where,

W_0 = weed dry weight of weedy check plot (g m^{-2})
W_t= weed dry weight of treated plot (g m^{-2})
Recorded data was analyzed using appropriate method of ‘Analysis of Variance (ANOVA)’ given by Gomez and Gomez (1984).Pooled analysis data of two consecutive *kharif* seasons 2022 and 2023 has been given in table.1,2 and 3.

RESULTS AND DISCUSSION

Effect of treatments on growth characters of *kharif* maize

Pooled data result showed significant effect of application of various plant growth promoters and herbicides on growth characters (Table.1and 2). Application of Amino acid + Humic acid + Sea weed extract was recorded significantly maximum plant height 208.22cm at harvest stage, crop growth rate 47.54 and 9.96 g m^{-2} day^{-1} at 60 - 90 DAS and 90 DAS - harvest stage, respectively, and relative growth rate 0.1029, 0.1052 and 0.0825 g g^{-1} day^{-1} at 30 - 60

DAS, 60 - 90 DAS and 90 DAS - harvest stage, respectively. It might be due to the combination of amino acid, humic acid and sea weed extract enhance chlorophyll synthesis, improving photosynthesis and energy production. They also help reduce transpiration and improve stomatal conductance, ultimately promoting increased plant growth. Such findings have been earlier reported by Al-Shaheen and Soh (2018), Noor *et al.* (2017),and Ghorbani *et al.* (2010).

Among herbicidal treatments, the application of Tembotrione 42%SC @ 120g a.i./ha in *kharif* maize was recorded significantly maximum plant height 216.59cm, leaf area 5226 cm^2 at harvest stage, crop growth rate 43.45, 48.77 and 10.26 g m^{-2} day^{-1} at 30 – 60 DAS, 60 - 90 DAS and 90 DAS - harvest stage, respectively, relative growth rate 0.1037 , 0.1053 and 0.0829 g g^{-1} day^{-1} at 30 - 60 DAS, 60 - 90 DAS and 90 DAS - harvest stage, respectively, and net assimilation rate 5.65 g m^{-2} day^{-1} at 30 - 60 DAS and its found at par with Mesotrione 2.27%W + Atrazin 22.7%SC @ 750 ml a.i./ha, Topramezone 33.6 SC @ 25.2g a.i./ha and Atrazin 50%WP @ 1kg a.i./ha. The minimum growth characters were recorded under weedy check treatments at all growth stages of the crop(Table.1and 2). It might be due to the improvements appear to result from the direct impact of reduced crop-weed competition. Tembotrione, a selective post-emergence herbicide, targets broadleaf and grassy weeds that compete with maize for essential nutrients, water, and sunlight. This reduction in crop-weed competition creates more favourable conditions for crop growth, leading to an increased growth character. Similar result has been also reported by Sachan *et al.* (2024)and Umesha and Sridhara (2015).

Effect of treatments on yield attributing characters of *kharif* maize

The application of various plant growth promoters resulted in significant differences in all yield attributing characters of maize (Table.3). Amino acid + Humic acid + Sea weed extract recorded enhancement in length of cob 5.94%, number of grains cob^{-1} 16.36% and 100 grains weight 1.90% as compared to Gibberellic acid. Amino acids act as essential building blocks for protein synthesis, promoting robust vegetative growth and enhancing enzymatic activities that are crucial for nutrient uptake and stress tolerance. They create a synergistic effect that maximizes the growth potential of maize, ultimate this combination improved yield attributes of maize. Such finding has been also reported by earlier Eryigit andHusamalddin (2023)and Singh *et al.* (2018).

The herbicides, Tembotrione 42%SC @ 120g a.i./ha recorded significantly better yield attribute varied the tune in length of cob 28.63%, number of grains cob^{-1} 72.82% and 100 grains weight 9.97% compared to Weedy check. When applied Tembotrione 42%SC @ 120g a.i./ha act as inhibiting the enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD), which is crucial for carotenoid biosynthesis in weeds. This leads to the bleaching and eventual death of weeds, thereby reducing competition for the maize plants. This resulted weed control successfully and allows maize plants to access more nutrients and light, promoting better growth and development of yield attributes. Similar findings were corroborated by Sachan *et al.* (2024), Gupta *et al.* (2023)and Ghrasiram*et al.* (2020).

Effect of treatments on yield of *kharif* maize

Under the application of various plant growth promoters in *kharif* maize, Amino acid + Humic acid + Sea weed extract recorded maximum grain yield 5.28%, stover yield 3.94%and harvest index 0.91% compared to Gibberellic acid (Table. 3). Yield of crop can be considered as the final expression of physiological and metabolic activities of plants and is governed by various climatic and plant metabiotic factors. Seaweed extracts enhance the source-sink relationship and the translocation of photo assimilates, improving plant's photosynthetic ability, which significantly improved in growth and yield attributing characters were ultimately reflected in higher yield. Similar result had been also reported by Aalipour*et al.* (2023) andHegab*et al.* (2020),

In herbicidal application, Tembotrione 42%SC @ 120g a.i./ha recorded increment in grain yield which varied to the tune of 86.96%, stover yield 53.34%and harvest index 14.14% compared to Weedy check. However, application of Mesotrione 2.27%W + Atrazin 22.7%SC @ 750 ml a.i./ha was also increased to the tune of 84.08, 52.64and 13.33% grain yield, stover yieldand harvest index, respectively, Topramezone 33.6 SC @ 25.2g a.i./ha 82.34, 51.72 and 13.07% grain yield, stover yieldand harvest index, respectively, and Atrazin 50%WP @ 1kg a.i./ha 80.63, 51.03and 12.69% grain yield, stover yieldand harvest index, respectively, over Weedy check treatments and found at par with Tembotrione 42%SC @ 120g a.i./ha. To improve the yield of maize, the application of Tembotrione 42%SC @ 120g a.i./ha can be highly effective. Tembotrione targets broadleaf and grassy weeds, which compete with maize for essential nutrients, water, and light. By controlling these weeds, the maize plants can grow more robustly and access resources more efficiently. For optimal results, application of herbicide during the early post-emergence stage of the maize crop, when weeds are actively growing but before they become established found successful. This strategy helps in minimizing competition and maximizing the maize crop yield potential. Similar findings were also reported by Sahoo *et al.* (2024) and Gupta *et al.* (2023).

Effect of treatments on weed control efficiency

The effect of plant growth promoters on weed control efficiency was found non-significant. Among herbicidal treatment, application of Tembotrione 42% SC at 120 g a.i./ha was recorded significantly maximum weed control efficiency 85.86% at 75 DAS, while the minimum weed control efficiency 27.49% at 75 DAS recorded under Halosulfuron methyl 75% WG @ 72g a.i./ha treatment (Table 3). Reducing weed density and biomass through the application of Tembotrione 42% SC at 120 g a.i./ha was an effective approach in managing weeds in crops. Similar findings were also reported by Kumar and Chawla (2019) and Mali *et al.* (2019).

CONCLUSION:

On the basis of above findings of result, can be concluded that, the application of Amino acid + Humic acid + Sea weed extract observed better growth and yield attributes and grain yield (6835.95 kg ha^{-1}) over other treatments. While among herbicides, Tembotrione 42% SC at 120 g a.i./ha exhibited maximum weed control efficiency and recorded superior growth and yield attributes, grain yield (7600.45 kg ha^{-1}) and harvest index (35.27%) in *kharif* maize.

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Table.1: Effect of treatments on growth parameters of *kharif* maize

Treatments	Plant height at harvest(cm)	Leaf area (cm^2)	Crop growth rate (g m^{-2} day^{-1})			
			0 - 30 DAS	30 - 60 DAS	60 - 90 DAS	90 DAS-harvest stage
A. Plant Growth Promoters						
Gibberellic acid (P_1)	200.36	4901	3.78	39.35	44.97	9.15
Cytokinin + Enzymes (P_2)	204.96	5011	3.90	39.71	46.57	9.65
Amino acid + Humic acid + Sea weed extract (P_3)	208.22	5061	3.77	40.71	47.54	9.96
SE(d) ±	1.49	46	0.05	0.41	0.46	0.18
C.D at 5%	4.24	NS	NS	NS	1.30	0.52
B. Herbicide						
Weedy check (W_1)	174.80	4505	3.79	33.95	42.42	8.57
Tembotrione 42%SC @ 120g a.i./ha (W_2)	216.59	5226	3.95	43.45	48.77	10.26
Halosulfuron methyl 75% WG @ 72g a.i./ha (W_3)	198.27	4914	3.72	37.02	45.82	9.27
Topramezone 33.6 SC @ 25.2g a.i./ha (W_4)	212.56	5103	3.80	41.63	46.11	9.76
Atrazin 50%WP @ 1kg a.i./ha (W_5)	210.32	5039	3.68	40.67	47.14	9.68
Mesotrione 2.27%W + Atrazin 22.7%SC @ 750 ml a.i./ha (W_6)	214.52	5160	3.96	42.81	47.88	9.98
SE(d) ±	3.48	137	0.12	1.35	1.37	0.23
C.D at 5%	7.14	280	NS	2.78	2.80	0.48
Interaction						
A × B						
SE(d) ±	5.07	221	0.20	2.18	2.21	0.41
C.D at 5%	NS	NS	NS	NS	NS	NS
B × A						
SE(d) ±	6.03	237	0.21	2.35	2.37	0.40
C.D at 5%	NS	NS	NS	NS	NS	NS

Table.2: Effect of treatments on growth parameters of *kharif* maize

Treatments	Relative growth rate (g g^{-1} day^{-1})			Net assimilation rate (g m^{-2} day^{-1})	
	30 - 60 DAS	60 - 90 DAS	90 DAS – harvest stage	30 - 60 DAS	60 - 90 DAS
A. Plant Growth Promoters					
Gibberellic acid (P_1)	0.1024	0.1043	0.0812	5.54	3.52
Cytokinin + Enzymes (P_2)	0.1024	0.1047	0.0820	5.50	3.61
Amino acid + Humic acid + Sea weed extract (P_3)	0.1029	0.1052	0.0825	5.57	3.73
SE(d) ±	0.0002	0.0003	0.0004	0.03	0.34
C.D at 5%	0.0004	0.0007	0.0008	NS	NS
B. Herbicide					
Weedy check (W_1)	0.1004	0.1035	0.0802	5.43	3.35
Tembotrione 42%SC @ 120g a.i./ha (W_2)	0.1037	0.1053	0.0829	5.65	4.04
Halosulfuron methyl 75% WG @ 72g a.i./ha (W_3)	0.1017	0.1047	0.0814	5.29	3.39
Topramezone 33.6 SC @ 25.2g a.i./ha (W_4)	0.1031	0.1050	0.0822	5.61	3.60
Atrazin 50%WP @ 1kg a.i./ha (W_5)	0.1028	0.1049	0.0821	5.59	3.52
Mesotrione 2.27%W + Atrazin 22.7%SC @ 750 ml a.i./ha (W_6)	0.1037	0.1051	0.0825	5.65	3.80
SE(d) ±	0.0004	0.0004	0.0004	0.06	0.23
C.D at 5%	0.0008	0.0009	0.0007	0.12	NS
Interaction					
A × B					
SE(d) ±	0.0003	0.0004	0.0004	0.10	0.50
C.D at 5%	NS	NS	NS	NS	NS
B × A					
SE(d) ±	0.0004	0.0004	0.0004	0.10	0.41
C.D at 5%	NS	NS	NS	NS	NS

Table.3: Effect of treatments on yieldattribute, yield and weed control efficiency of *kharif* maize

Treatments	Length of cob (cm)	No. of grains cob^{-1}	100 seed weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)	Weed control efficiency (%)
A. Plant Growth Promoters							
Gibberellic acid (P_1)	17.52	493.30	26.33	6492.88	12501 .74	33.95	57.25
Cytokinin + Enzymes (P_2)	18.07	547.88	26.62	6679.87	12727.14	34.20	57.74
Amino acid + Humic acid + Sea weed extract (P_3)	18.56	574.01	26.83	6835.95	12994.66	34.26	57.63
SE(d) ±	0.25	12.82	0.31	58.56	148.58	0.36	1.75
C.D at 5%	0.71	36.54	NS	166.93	NS	NS	NS
B. Herbicide							
Weedy check (W_1)	15.02	364.22	24.98	4065.14	9102.89	30.90	0.00
Tembotrione 42%SC @ 120g a.i./ha (W_2)	19.32	629.48	27.47	7600.45	13958.57	35.27	85.28
Halosulfuron methyl 75% WG @ 72g a.i./ha (W_3)	17.11	443.32	25.93	6113.37	11931.38	33.86	27.49
Topramezone 33.6 SC @ 25.2g a.i./ha (W_4)	18.91	600.50	27.07	7412.02	13811.42	34.94	77.92
Atrazin 50%WP @ 1kg a.i./ha (W_5)	18.77	585.93	26.86	7343.22	13747.58	34.82	72.11
Mesotrione 2.27%W + Atrazin 22.7%SC @ 750 ml a.i./ha (W_6)	19.17	606.92	27.26	7483.22	13895.24	35.02	82.45
SE(d) ±	0.34	20.00	0.36	127.82	320.25	0.45	1.24
C.D at 5%	0.69	41.08	0.74	262.30	657.20	0.93	2.55
Interaction							
A × B							
SE(d) ±	0.59	34.15	0.65	210.41	527.71	0.80	2.63
C.D at 5%	NS	NS	NS	NS	NS	NS	NS
B × A							
SE(d) ±	0.59	34.67	0.62	221.39	554.69	0.79	2.15
C.D at 5%	NS	NS	NS	NS	NS	NS	NS