

Original Research Article

Influence of Different Herbicides on the Growth, Growth Attributes and Yield of Maize (*Zea mays* L.) under Central Plains Zone of Uttar Pradesh

Comment [Ek1]: Reduce this section to: Growth and yield of maize

Abstract

The field experiment was carried out at Agriculture Research Farm, Integral University, Lucknow, Uttar Pradesh, India during Kharif, 2021. The experiment was aimed at studying the effect of herbicides on the growth, growth attributes and yield of maize crop. The experiment was laid down in the RBD with 12 treatments replicated three times. The highest plant height was observed in weed-free treatment (T₁₁) due to weed free environment all over the maize growth period but among the herbicides, treatments the treatment (T₈) Atrazine 0.5 kg a.i ha⁻¹ PE followed by Tembotrione 0.120 kg a.i ha⁻¹ PoE at 20 DAS showed highest plant height of 115.2 cm, 173.63 cm and 226.29 cm at 40 DAS, 60 DAS and at harvest stage, respectively. The same treatments (T₈) also resulted in the highest number of leaves per plant. The highest cob weight plant⁻¹, grain weight cob⁻¹, number of seed cob⁻¹ and test weight of 219.23 g, 144.1 g, 579.23 and 27.43 g, respectively was observed in the same herbicide treatments (T₈). The highest grain yield (5199 kg ha⁻¹) was observed in the weed free treatment (T₁₁) but among the herbicidal treatments, Atrazine followed by Tembotrione the treatment T₈ obtained the highest grain yield of 4803 kg ha⁻¹ and was at par with Atrazine followed by 2,4-D sodium salt the treatment (T₇) Atrazine 0.5 kg ha⁻¹ fb 2,4 D sodium salt 0.5 kg ha⁻¹ PoE at 30 DAS bearing grain yield of 4723 kg ha⁻¹. Among the herbicidal treatments, the treatment (T₈) also resulted in the highest biological yield (12042 kg ha⁻¹) and Harvest index (39.89%) which was at par with the treatment T₇.

Comment [Ek2]: Did you mean RCBD?

Comment [Ek3]: Delete – reasons are expected in the main text

Comment [Ek4]: Actual treatment

Comment [Ek5]: Actual treatment

Keywords: Harvest index, biological yield, fb (followed by), PE (pre-emergence), PoE (Post emergence)

Introduction

Maize (*Zea mays* L.) stands as a pivotal cereal and versatile crop within the *Poaceae* family. Its significance spans across diverse applications, encompassing human dietary needs,

animal and poultry feed, and industrial utilization for the production of maize starch, dextrose, maize syrup, and maize flakes (Gul *et al.*, 2021). Thriving in a broad spectrum of soil and climatic conditions, maize exhibits a remarkable capacity to extract more nutrients compared to other crops, including small-grain cereals and grain legumes. The cultivation of maize serves various purposes, ~~eatering to~~including the production of animal feed, both in the form of silage and grains, as well as meeting the dietary requirements of **poultry** through maize grains. Additionally, it contributes to **pig feed** by providing grains. Moreover, maize plays a pivotal role in human consumption, presenting itself in various forms such as grains, sweet maize, and grain maize.

Comment [Ek6]: Poultry falls under animal feeds

Comment [Ek7]: Also animal feed!

Recognized as the "Queen of Cereals" for its prolific yield, maize, or corn, holds the esteemed position of being the third most extensively cultivated crop globally, trailing only wheat and rice. In terms of both area under cultivation and maize production, India secures the third position. Corn crops on a global scale play a vital role in sustaining food production for both human and animal consumption, as highlighted by Erenstein *et al.* (2022). Maize stands out as a rich source of diverse nutrients, including carbohydrates, proteins, minerals, vitamins, iron, and more, offering notably high energy content at 365 Cal/100g.

Originating from central Mexico, maize has become one of the most extensively cultivated crops globally. Globally, around 1147.7 million metric tonnes of maize is produced from 193.7 million hectare with an average yield of 5.75 tonnes/hectare⁻¹ in 170 countries (Meena and Nirupma, 2021). In India, it ~~spans an impressive~~ cultivation ~~covers area of~~ 9.63 million hectares, ~~with yielding~~ an annual production of 25.90 million metric tons, ~~with and~~ an average productivity of 2.69 metric tons per hectare. Its cultivation is widespread across ~~diverse habitats throughout~~ the country, with major production ~~hubs areas~~ situated in Karnataka, Andhra Pradesh, Telangana, Maharashtra, Bihar, Punjab, Rajasthan, and Haryana ~~(as reported by Malleh et al. (2023))~~.

Prakash and Venkataramana (2023) reported that at present, 47 percent of the maize produced in India finds its primary utilization in the feed industry, with an additional 13 percent dedicated to animal feed. Maize holds a significant role in the starch industry, constituting approximately 14 percent of its consumption. Furthermore, various other industries rely on maize as a key raw material, encompassing starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceuticals, cosmetics, films, textiles, gums, packaging, and paper production, among others. Over the past decade, the direct consumption of maize as

food has notably diminished, currently standing at around 13 percent. However, there is ~~andiscernible~~ upward trend in utilizing maize for processed food, contributing to approximately 7 percent of the annual maize consumption in the country. The emergence of specialty corns, such as sweet corn, baby corn, and popcorn, represents a recent development where maize cultivation intertwines with rural entrepreneurship and agro-business. Considering these ~~multifaceted-multiple~~ applications, maize stands out as the ideal crop to support the government's objective of doubling farmer's income.

Success of crop depends largely on effective weed control under weed management strategy. ~~e~~Cultivation is effective but cost and ~~labour-intensive~~labour-intensive. Chemical weed control is an alternative method that may be less expensive but ~~with risk associated with herbicides resistance and unwarranted negative effects on~~ riskier because of weeds becoming herbicides resistant and because of concerns about unwanted side effects on soil microflora. Improved weed control practices that include chemical weed control with newer formulations and herbicide mixtures and integrated cultivation need to be developed and refined. The hypothesis is that weeds can be controlled efficiently having no adverse effect on soil microflora and yield can be maintained at a lower rate of input practice by bettering the weed management strategy. Also used newly released herbicide having new mode of action, which can control narrow as well as broad spectrum weed in maize. Similarly, combination of herbicide may result in effective weed control.

~~Furthermore, t~~The increased need for labour during peak seasons, combined with its limited availability, underscores the necessity of resorting to herbicides as an efficient approach to weed management. Considering that chemical weed management demands less labour, it is advised as a means to overcome this constraint as reported by Sachan et al. (2023).

MATERIALS AND METHODS

Experimental site

The experiment was carried out at Agriculture Research Farm, Integral University, Lucknow, Uttar Pradesh, India during Kharif, 2021. The city of Nawabs, Lucknow lies in the coordinates 26°51'N 80°57'E. Lucknow has a humid subtropical climate with hot, sunny summers from March to May. ~~From June to October, t~~The city receives an average of 827.2 millimetres of rainfall from the southwest monsoon winds ~~between June to October~~. Summers are very hot with temperatures rising ~~into the~~ 40 to 45 °C (104 to 113 °F) range.

Comment [Ek8]: Long sentence - rephrase

Comment [Ek9]: Meaning? Rephrase

The hypothesis of this study was,

Comment [Ek10]: Not necessary

Comment [Ek11]: Meant for a conclusion based on results. This statement is not for introduction

Edaphic condition

Soil samples were collected from different locations of the field at a depth of 0–20 cm before sowing and analysed for physio-chemical characteristics in the Agriculture Laboratory, Faculty of Agriculture, Integral University, Lucknow. The soil in the experimental field was clayey in texture and slightly alkaline with pH of (7.4). Organic carbon in the soil was 0.39% which was estimated by rapid titration method given by **Walkley and Black (1934)**. The available Nitrogen in the soil was 143 kg ha⁻¹, which was estimated by the Alkaline permanganate method given by **Subbiah and Asija (1956)**. The available Phosphorus was 15.3 kg ha⁻¹ estimated by Olsen's method given by **Jackson (1967)**. The available K was 261.3 kg ha⁻¹ which was estimated by the Flame photometer method according to given by **Jackson (1967)**.

Experimental design and treatment details

The experiment was designed as Randomized block design (RBD) with 12 Treatments replicated thrice. The treatment was allocated randomly in each block. The details of the treatment are as follows: - (T1) *Atrazine* @ 1.0 kg a.i ha⁻¹ PE (Pre-emergence); (T2) *Pendimethalin* @ 1.0 kg a.i ha⁻¹ PE; (T3) *Metribuzin* 0.35 kg a.i ha⁻¹ PE; (T4) *Atrazine* 0.5 kg a.i ha⁻¹ + *Pendimethalin* 0.5 kg a.i ha⁻¹ PE; (T5) 2,4-D sodium salt 0.8 kg a.i ha⁻¹ PoE (Post-emergence) at 30 DAS (Days after sowing); (T6) *Tembotrione* 0.120 kg a.i ha⁻¹ PoE at 20 DAS; (T7) *Atrazine* 0.5 kg a.i ha⁻¹ PE followed by 2,4-D sodium salt 0.8 kg a.i ha⁻¹ PoE at 30 DAS; (T8) *Atrazine* 0.5 kg a.i ha⁻¹ PE followed by *Tembotrione* 0.120 kg a.i ha⁻¹ PoE at 20 DAS; (T9) *Topramezone* 0.0252 kg a.i ha⁻¹ PoE at 20 DAS; (T10) *Halosulfuron methyl* 0.05 kg a.i ha⁻¹ PoE at 20 DAS; (T11) Weed free; and the treatment (T12) was Weedy check.

Comment [Ek12]: There is no such design in scientific experiments: it is Randomized complete block design – RCBD

Preparation of the experimental field and application of fertilizers

The initial ploughing involved using a Disc harrow drawn by a tractor, and the field was levelled using a tractor-drawn leveller. Subsequently, a seed bed was prepared by ploughing with a rotavator. The field was then manually laid out according to the plan, and *Pioneer 3396* Hybrid seeds were sown at a rate of 25 kg ha⁻¹ with a spacing of 60 cm × 20 cm. Prior to the first irrigation, plants were thinned to one plant per hill. The first irrigation was administered within a week after seeding, followed by subsequent irrigations every two weeks throughout the growth season. Urea (46% N) was applied in split doses, while DAP (46% P₂O₅) and MOP (60% K₂O) were uniformly applied as a basal application across all treatments.

Application of chemical herbicides

The chemical herbicides were sprayed as per plan with the help of Knapsack sprayer with the regular flat-fan nozzle. Some herbicides were applied as pre-emergence and some as post-emergence. Pre-emergence (PE) herbicides were applied just day after sowing while post-emergence as per plan.

RESULTS AND DISCUSSION

Plant Height (cm) as influenced by weed management treatments

The periodical data on plant height (cm) of maize as influenced by different weed management treatments are presented in Table 1.

Table 1: - Plant height (cm) as influenced by different weed management treatments

Treatment	Plantheight(cm)				
	20 DAS	40 DAS	60 DAS	80 DAS	Atharvest
T1	28.43	112.67	168.20	184.37	220.34
T2	25.47	93.31	139.20	154.52	197.45
T3	28.17	94.50	151.00	157.23	199.58
T4	27.63	100.83	150.45	165.39	207.22
T5	26.47	98.03	147.96	162.97	204.96
T6	26.73	101.48	153.47	167.81	211.74
T7	27.13	114.17	170.73	187.89	223.51
T8	28.33	115.20	173.63	191.08	226.29
T9	25.93	103.93	155.80	170.61	215.21
T10	26.10	95.93	144.29	159.83	202.96
T11	29.87	117.27	175.44	193.06	228.64
T12	24.77	82.33	132.47	145.78	169.97
SE(M)±	0.99	2.20	3.08	3.22	2.61

Comment [Ek13]: Insert the treatment - Atrazine

Comment [Ek14]: Replace T2 with Pendimethalin

Comment [Ek15]: Replace with Metribuzin

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C.D. at 5%	NS*	6.46	9.01	9.44	7.66
GM	27.09	102.47	155.22	170.05	208.99

Comment [Ek17]: Should remove Table grids and use lines for heading and below the Table as conventionally done

Plant height was gradually increased with advancement in crop age up to harvest stage. The rate of increase in plant height was rapid during early vegetative growth stage. The various weed control treatments significantly influenced plant height at all growth stages except stage of 20 DAS where the treatment differences were statistically not significant. From 40 DAS up to harvest Weed free (T11) was recorded significantly higher plant height over rest of the herbicidal treatments. The treatment *Atrazine* 0.5 kg a.i ha⁻¹ PE followed by *Temboatrione* 0.120 kg a.i ha⁻¹ PoE at 20 DAS (T8), were found highly superior over rest of the treatments, which are at par with atrazine followed by 2,4-D (the treatment (T7) and the lowest plant height was noticed in the preemergence application of *Pendimethalin* @ 1kg a.i ha⁻¹ (T2) and Weedy check (T12) treatments.

Comment [Ek18]: Re-write for clarity

Significant reduction in plant height was noticed in unweeded control treatment at all the growth stages of the crop. Decrease in plant height might be due to the fact that weeds suppressed the vegetative growth of plants by the competition between crop and weeds for soil moisture, plant nutrients, solar radiation and space during active growth period. Almost similar results were reported by *Walia et al. (2007)*, *Shantveerayya and Agasimani (2012)* and *Triveni et al. (2017)*.

Number of leaves plant⁻¹ as influenced by different weed management treatments

Number of leaves of maize as influenced by different weed management treatments are presented in Table 2. The leaves of plant increase up to 60 DAS and afterwards up to maturity stage of crop number of leaves were decreased. The various weed control treatments significantly influenced leaves number at all growth stages except at 20 DAS where the treatment differences were statistically not significant. Treatment weed free (T₁₁) recorded significantly maximum number of leaves from 20 DAS up to harvest. From rest of the herbicidal treatments, the treatment (T₈), were found highly superior over rest of the treatments, which was at par with the treatment (T₇). The minimum number of leaves was noticed in pre-emergence application of *Pendimethalin* (T₂) and Weedy check (T₁₂). Similar results were reported by *Shinde et al. (2001)* and *Birendra et al. (2013)*.

Comment [Ek19]: Meaning? The sentence lack meaning

Table 2: - Number of leaves plant⁻¹ as influenced by different weed management treatments

Treatment	Number of leaves plant ⁻¹				
	20 DAS	40 DAS	60 DAS	80 DAS	Athar vest
T1	7.53	11.20	12.60	13.05	12.85
T2	7.40	9.67	10.07	10.24	10.19
T3	7.05	10.27	11.00	11.31	11.23
T4	7.47	10.80	12.33	12.57	12.47
T5	6.27	10.00	10.40	10.67	10.53
T6	7.13	10.40	11.40	11.69	11.59
T7	8.13	11.33	12.93	13.12	13.02
T8	8.27	11.87	13.07	13.40	12.64
T9	6.00	10.60	11.93	12.19	12.11
T10	6.40	10.20	10.67	10.89	10.74
T11	8.33	12.47	13.40	13.81	13.63
T12	5.60	8.87	9.73	9.93	9.09
SE(M)±	0.36	0.62	0.74	0.31	0.27
C.D. at 5%	NS*	1.82	2.18	0.91	0.81
GM	7.13	10.64	11.63	11.91	11.67

Comment [Ek20]: Remove Table grids
Replace T with actual treatments

Cob weight plant⁻¹ (g)

Comment [Ek21]: per plant

The data pertaining to cob weight plant⁻¹ (g) is given in Table 3. Among all the weed management practices, significantly maximum cob weight plant⁻¹ was obtained with Weed free treatment (T₁₁) and which was statistically at par with treatment T₈. However Weedy check (T₁₂) plot recorded significantly least cob weight plant⁻¹. The similar type of result with

chemical and mechanical measures of weed control were also reported by Pandey et al. (2000), Walia et al. (2007) and Triveni et al. (2017).

Comment [Ek22]: Did you mean to write: These results are similar to those reported by ,,,,,

Grain weight cob⁻¹(g)

The data pertaining to grain weight per cob⁺(g) is given in table-Table3. Research data revealed that grain weight per cob⁺ recorded was highest in treatment the Weed free treatment (T₁₁) and was statistically at par with Atrazine followed by Tembotrione treatment (T₈). Weedy check (T₁₂) plot recorded significantly least grain weight per cob⁺. Similar results were also obtained by Rao et al. (2016) and Gantoli et al. (2013).

Number of seed cob⁻¹

The data pertaining to the Number of seed per cob⁺ is given in table-Table3. Research data showed that number of seed cob⁻¹ recorded maximum in treatment T₁₁ followed by T₈. Treatment Weedy check (T₁₂) recorded minimum number of seed cob⁻¹. The similar types of results were also reported by Pandey et al. (2000), Walia et al. (2007) and Triveni et al. (2017).

Comment [Ek23]: per cob – only use cob⁻¹ in the Table

Test weight (g)

The data pertaining to test weight(g) is given in table-Table 3. Among the herbicidal treatments the highest test weight(27.43 g) was observed in the treatment T₈.

Comment [Ek24]: Re-phrase

Comment [Ek25]: What is Test wt?

Table 3: -Cob weight plant⁻¹ (g), Grain weight cob⁻¹ (g), Number of seed cob⁻¹ and Test weight (g) as influenced by different weed management treatments

Treatment	Cob weight plant ⁻¹ (g)	Grain weight cob ⁻¹ (g)	Number of seed cob ⁻¹	Test weight (g)
T1	214.41	140.47	572.17	27.13
T2	185.71	113.6	547.3	25.89
T3	197.59	131.73	560.18	26.59
T4	200.5	132.13	561.67	26.97
T5	187.67	127.97	544.9	26.19
T6	195.06	130.1	555.13	26.34
T7	216.15	141.13	577.33	27.27
T8	219.23	144.1	579.23	27.43
T9	199	130.6	559.08	26.73

Comment [Ek26]: What is Test weight?

T10	179.28	115.7	552.6	26.07
T11	225.83	147.83	581.9	27.96
T12	132.35	78.3	438.27	22.67
SE (M)±	4.01	2.64	6.64	0.29
C. D. at 5 %	11.74	7.72	19.43	0.87
GM	196.06	127.81	552.48	26.44

Comment [Ek27]: Remove Table grides and use lines for heading and one below

Grain yield, Biological Yield and Harvest Index

The data pertaining to Grain yield (kg ha^{-1}), Biological Yield (kg ha^{-1}) and Harvest Index (%) is given in Table 4. Among the weed control treatments, sequential application of Atrazine $0.5 \text{ kg a.i ha}^{-1}$ PE followed by Tembotrione $0.120 \text{ kg a.i ha}^{-1}$ PoE at 20 DAS (T₈) and Atrazine $0.5 \text{ kg a.i ha}^{-1}$ PE followed by 2,4-D sodium salt $0.8 \text{ kg a.i ha}^{-1}$ PoE at 30 DAS (T₇) the higher grain yield in this treatment could be attributed to improved yield components such as higher cob weight at harvest (g), grain weight cob^{-1} , number of seed cob^{-1} , and test weight (g). This could be attributed to the effective control of weeds during the germination phase through the pre-emergence application of herbicides. Substantial reduction in later growth stages occurred as late germinating weeds were managed by Tembotrione and 2,4-D, leading to a diminished competition with the crop for essential growth factors like light, space, and nutrients. This, in turn, facilitated efficient photosynthetic activity, upon which cob weight, grain weight, test weight, and the number of grains depend. These results are in conformity with the findings of Kamble *et al.* (2005) and Tesfay *et al.* (2014).

Table 4: - Grain yield (kg ha^{-1}), Biological Yield (kg ha^{-1}), Harvest Index (%) as influenced by different weed management treatments

Treatment	Grain yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest Index (%)
T1	4596	11684	39.34
T2	3574	10096	35.4
T3	4115	11028	37.31
T4	4223	11235	37.59
T5	3872	10681	36.25
T6	3984	10862	36.68

T7	4723	11862	39.81
T8	4803	12042	39.89
T9	4105	11100	36.98
T10	3746	10445	35.86
T11	5199	12761	40.76
T12	2345	8110	28.91
SE (M)±	206	487	37.06
C. D. at 5 %	605	1426	--
GM	4107	10992	--

Comment [Ek28]: Remove grides and instead use lines for the headings and below the Table

CONCLUSION

Hence, it is recommended that farmers in the Central plains zone of Uttar Pradesh consider applying *Atrazine* at a rate of 0.5 kg a.i. ha⁻¹ as a pre-emergence herbicide, followed by *Tembotrione* at 0.120 kg a.i. ha⁻¹ as a post-emergence herbicide. The utilization of *Atrazine* and *Tembotrione* herbicides has proven to be highly effective in weed control within maize fields, contributing to increased crop yields by mitigating crop-weed competition.

Comment [Ek29]: Conclusion or recommendation?

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