Agronomy Journal of Nepal. 9(1): 44-54
ISSN: 2091-0649 (Print)
DOI: https://doi.org/10.3126/ajn.v9i1.90903

Effect of Different Weed Management Practices on Weed Dynamics, Growth and Yield of Maize (*Zea Mays* L.) in Lalitpur, Nepal

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Received: May 15, 2025
Revised: August 11, 2025
Published: December 31, 2025

Publisher: Agronomy Society of Nepal (ASoN)

OPEN ACCESS

ABSTRACT

A field experiment was conducted in Godawari municipality-11, Tahakhel, Lalitpur, Nepal during April to August, 2024 to evaluate the effect of different weed management practices on weed dynamics, growth and yield of maize. The experiment was carried out in randomized complete block design (RCBD) comprising of seven treatments with three replications. Mankamana-4 maize variety was used in the experiment. Data on crop growth, weed dynamics and yields were recorded and analyzed. The data tabulation was done in MS-EXCEL and analysis of data was done by using R. The experiment results revealed application of atrazine 50% WP @1kg a.i/ha as Pre emergence (PE) treatment resulted in highest grain yield (7.35 mt/ha) which was statistically at par with the treatment pendimethalin 30% EC @0.5 kg a.i/ha + atrazine 50% WP @0.5 kg a.i/ha as PE (7.31 mt/ha) and followed by the hoeing at 25 DAS (7.17 mt/ha).Different weed species belonging to 8 families were identified. The total weed density and weed dry weight were found significantly ($p<0.05$ and $p<0.01$ value) lower with application of atrazine 50% WP @1kg a.i/ha as PE compared to other treatments. Similarly, application of atrazine 50% WP @1kg a.i/ha as PE resulted in maximum weed control efficiency of 60.56%, 71.37% and 95.71% at 30, 60 DAS and at harvest, respectively. Likewise, in growth parameters, highest plant height (245.29 cm) was also obtained in atrazine 50% WP @1kg a.i/ha as PE treatment at all observations. Similarly, the shortest days to silking (75 days) was also observed in the same treatment, while the longest days to silking (80 days) was observed in weedy check. Significantly shortest days to 50% tasseling (71 days) was observed in the treatment pendimethalin 30% EC @1kg a.i /ha as PE. The highest B:C ratio (1.18) was observed in atrazine 50% WP @1kg a.i/ha as PE treatment.

Keywords: Atrazine, growth, maize, weed management, yield

How to cite this article:
Karki JB and H Giri. Effect of Different Weed Management Practices on Weed Dynamics, Growth and Yield of Maize (*Zea Mays L.*) in Lalitpur, Nepal. Agronomy Journal of Nepal **9**(1): 44-54. DOI: https://doi.org/10.3126/ajn.v9i1.90903

INTRODUCTION

Maize also known as "Queen of Cereals" is the most significant cereal crop cultivated globally, which was originated from Mexico and belongs to the family Poaceae. It ranks among the world's most important cereal crops, grown on 193.7 million ha and producing 1147.7 million mt (FAOSTAT 2020) and it is grown on 0.916 million hectors in Nepal, producing 3.19 million mt (MoALD 2023/24). Among cereals, it has the highest production volume of over 1.14 billion mt cultivated in 193.74 million ha area worldwide (FAO 2018). The global average productivity of maize is about 5.9 t/ha with highest productivity of 11.8 mt/ha in USA (FAO 2018), whereas in Nepal the productivity of maize is only 3.49 mt/ha (MoALD 2023/24). Conventional method of manual weed control requires huge number of laborers (Shrestha and Marasaini 2021) which are being scarce because of migration to foreign countries as well as in urban areas in non-agriculture sector and also costly because of increased wages of manual workers (Jaquet and Schwilch 2019). Various chemical and mechanical methods of weed management have been used all over the world. However, the effective and economic control of weeds in maize cultivation can be achieved through the efficient and right use of pre and post emergence herbicides (Sharma et al 2022).

Throughout the maize growing area in Nepal, the constraints of weed during the growing season is vital (Bhattarai et al 2022). At the early stage of growth, maize crop is highly susceptible to weed competition, so

application of both pre and post emergence herbicides help to reduce the problem (Shrestha et al 2019). Maize plants are more sensitive to the competition by neighboring weedy plants during critical period of weed control (Cerrudo and Tollenaa 2012). Due to lack of application of effective weed management method results in reduced growth and yield of crop (Dhakal and Sah 2021). Up to 48% grain yield losses due to weeds in the hills of Nepal (Karki and Shrestha 2015). Application of suitable pre-emergence followed by post-emergence herbicides for effective control of weeds in maize, which is beneficial even than the manual weeding (Marahattha 2019). Integrated weed management makes use of different forms of weed control methods for the objective of allowing producers the best chance of controlling problematic weeds and also reducing the chances of the development of herbicide resistance (Kumar et al 2017).

The absence of efficient weed management strategies poses a significant challenge in the maize cultivation regions of our nation. The Lalitpur district, situated in the mid-hill area, has been grappling with ineffective weed management practices affecting maize crops. Addressing this issue is essential for maize growers in the Lalitpur district. Although a few growers have implemented certain cultural practices, the majority remain uninformed. Nevertheless, there appears to be a lack of genuine interest among farmers in cultivating maize for commercial purposes. The specific objectives of this experiment included assessing the impact of various weed management strategies on weed dynamics, growth parameters, yield parameters and the economic returns of maize crop.

MATERIALS AND METHODS

Experiment site

The experiment was conducted in Godawari municipality-11, Tahakhel, Lalitpur, Bagmati province, Nepal. It is located in mid hills with subordinates 27.55°N and 85.33°E and an elevation of 1350 msl.

Agro-meteorological data

During the experimental period from March to August in 2024, the highest rainfall occurred in July (8.45mm/day) and the least amount in April (1.39 mm/day). Highest temperature, was observed in April (31.7°C), while the lowest temperature was recorded in August (19.03°C).

Planting materials and sowing

The Manakamana-4 (developed by the NRMP of the NARC) variety of maize was used as the planting material for the experiment. Manakaman-4 is the variety which is recommended for the mid-hill region of the country. Seed rate was used at the rate of 25 kg/ha and seed was sown in 8th April, 2024 with spacing 60×30 cm (row to row 60 cm and plant to plant 30 cm).

Research design and treatment details

The experiment was conducted in randomized complete block design (RCBD) with seven treatments and three replications. The experimental plot size measured 6 m², with length of 3m and breadth 2m, and comprised of four rows with 10 plants per row. The total research area covered was 192 m², with inter-plot spacing of 50 cm, block-to-block spacing of 1m, and a border width of 15 cm. Data were collected from the randomly selected five plants of each plot. Treatment details are as follows.

Weed management practices	Symbol
Weedy Check	T_1
Hand Weeding	T_2
Hoeing at 25 DAS	T_3
Pendimethalin 30% EC @1kg/ha as pre-emergence	T_4
Atrazine 50% WP @ 1kg a.i/ha as pre-emergence	T_5
Pendimethalin 30% EC @0.5 kg a.i/ha + Atrazine 50% WP @0.5kg a.i/ha as pre-emergence	T_6
Butachlor 5% G @1kg a.i/ha as pre-emergence fb Atrazine 50% WP @1kg a.i/ha as post emergence	T_7

Cultural practices

Field was ploughed three times before seed sowing to make field free from large soil clods and weeds. Land preparation was done by manually (using mini tiller) and removal of stubbles of previous crops then followed by planking. The recommended dose of FYM at the rate of 15 ton/ha and the dose of fertilizers N: P2O5:K2O @120:60:40 kg/ha was applied in field in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP). Full dose of phosphorus and potassium were applied as basal dose and nitrogen was applied in

three equal splits at the time of sowing, 35 DAS and 65 DAS respectively. Harvesting was done manually after 140 days of sowing.

Data collection
The data was collected for the following trait.

Plant height: Plant height was measured from each sample plant and average was calculated at 30, 60 and 90 days after sowing respectively.

Number of leaves per plant: The number of leaves per plant was counted from each sample plant and average was calculated at 30, 60 and 90 days after sowing respectively

Leaf area index (LAI): The leaf area index of maize plant was calculated from each sample plant and average was calculated at 30, 60 and 90 days after sowing (DAS) respectively.

Days to 50% tasseling: Data was collected through inspection during tasseling period.

Days to 50% silking: Data was collected through inspection during silking period.

Weed density: Weed density was determined though weed count at 30 DAS, 60 DAS, 90 DAS and at harvest from $1m^2$ area of each plot.

Weed dry weight: Weed dry weight was calculated after the completion of count and oven dry.

Weed control efficiency (WCE): The weed control efficiency was determined after the completion of weed count. It was calculated by comparing the population of weeds from different treatments to that from the control plot using the given formula (Mishra et al 2020).

$$WCE = \frac{(WPWC - WPTP)}{WPWC} \times 100 \quad \ldots\ldots\ldots\ldots\ldots 1)$$

WCE: Weed control efficiency (%)
WPWC: Weed population(no/m^2) in weedy check
WPTP: weed population(no/m^2) in treated plot

Weed control index (WCI): The weed control index was calculated after oven drying of sample weeds. It was determined by comparing the dry weight of weeds from different treatments to that from the control plot by using the following formula (Mishra et al 2020).

$$WCI = \frac{(DWWC - DWTP)}{DWWC} \times 100 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

WCI: Weed control index (%)
DWWC: Dry weight of weeds (g) in weedy check
DWTP: Dry weight of weeds (g) in treated plot

Yield attributing traits: These traits (number of cobs per plant, cob length, cob weight, number of kernel row per cob, number of kernels per row, number of kernels per cob, grain yield per cob, grain yield per plot, stover yield per plot, shelling percentage and harvest index) were evaluated in five sample plants taken from each plot.

Statistical analysis
Microsoft Excel 2019 was used for data entry. Statistical analysis was performed by using R Studio version 4.2.1.

RESULTS AND DISCUSSION

Plant height
The different treatment showed significant difference in plant height. Significantly taller plant height was recorded in atrazine 50% WP @1kg a.i/ha as PE treated plot with 14 cm, 116.80 cm and 245.29 cm height at 30, 60 and 90 DAS respectively (Table 1). This could be due to better controlled of weeds by the application of herbicides which allow plants to grow freely without competition with weeds. As no weed control measures

were applied, Weedy check resulted in lower plant height at various DAS of observation. The results are in accordance with (Nandaji 2019) that the application of atrazine as pre-emergence resulted higher plant height.

Table 1. Effect of different weed management practices on plant height of maize in Lalitpur, Nepal in 2024

Weed management practices	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
Weedy Check	9.86[b]	88.80[b]	210.96[b]
Hand Weeding	12.38[ab]	115.33[a]	229.84[ab]
Hoeing at 25 DAS	10.96[ab]	109.13[ab]	242.52[ab]
Pendimethalin 30%EC as PE	13.08[ab]	116.80[a]	245.29[a]
Atrazine 50%WP as PE	14.00[a]	131.70[a]	253.34[a]
Pendimethalin + Atrazine as PE	12.00[ab]	126.46[a]	241.88[ab]
Butachlor as PE fb Atrazine as PoE	13.55[ab]	130.86[a]	238.34[ab]
SEM (±)	1.2	8.255	10.446
LSD (0.05)	3.7	25.438	32.188
F-test	*	*	*
CV (%)	16.861	12.22	7.619
Grand mean	12.33	117.01	237.45

DAS = Days after sowing, means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability *=significant at 5% probability level, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Number of leaves per plant

The number of leaves per plant in the experiment was significantly influenced by weed management practices at all dates of observation (Table 2). It was generally higher in butachlor 5% G @1kg a.i/ha as PE fb atrazine 50% WP @1kg a.i/ha as PoE treated plot at 30 DAS (5.66). At 60 DAS the maximum number of leaves per plant (9.66) was obtained in pendimethalin 30% EC @ 0.5kg a.i/ha + atrazine 50% WP @0.5kg a.i/ha as PE. At 90 DAS the higher number of leaves per plant (13.00) was obtained in both atrazine 50%WP @1kg a.i/ha as PE and hoeing and minimum number of leaves per plant was obtained in weedy check plot. This could be due to the effective management of weeds through the application of herbicides and the manual removal of weeds, which enables plants to thrive without competition from weeds (Bista et al 2023).

Table 2. Effect of different weed management practices on number of leaves per plant of maize in Lalitpur, Nepal in 2024

Weed management practices	Number of leaves per plant		
	30 DAS	60 DAS	90 DAS
Weedy Check	3.66[b]	6.00[c]	9.00[b]
Hand Weeding	4.66[ab]	7.33[bc]	12.66[a]
Hoeing at 25 DAS	4.00[b]	7.66[b]	13.00[a]
Pendimethalin 30% EC as PE	4.66[ab]	8.33[ab]	12.33[a]
Atrazine 50% WP as PE	4.66[ab]	9.66[a]	13.00[a]
Pendimethalin + Atrazine as PE	4.66[ab]	7.00[bc]	12.66[a]
Butachlor as PE fb Atrazine as PoE	5.66[a]	8.33[ab]	12.33[a]
SEM (±)	0.506	0.655	0.767
LSD (0.05)	1.559	2.01	2.363
F-test	*	*	*
CV (%)	19.175	14.441	10.942
Grand mean	4.57	7.85	12.14

DAS = Days after sowing, means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Leaf area index

The LAI in the experiment was significantly affected by weed management strategies at all observation (Table 3). It was generally higher in herbicide applied plots and significantly lower in weedy check treatment. At 30 DAS, LAI was higher in atrazine 50%WP @1kg a.i/ha as PE, pendimethalin 30% EC @1kg a.i /ha as PE and butachlor 5% G @1kg a.i/ha as PE fb atrazine 50% WP @1kg a.i/ha as PoE treated plots (0.03). At 60 DAS, LAI was obtained higher in butachlor 5% G @1kg a.i/ha as PE fb atrazine 50% WP @1kg a.i/ha as PoE (0.33). Similarly, at 90 DAS, LAI was maximum in atrazine 50%WP @1kg a. i/ha as PE treatments (0.51). The lower LAI in weedy check. It might be because of limited supply of nutrients like NPK to the crop due to higher crop-weed competition that reduced plant growth. (Shrestha and Marasaini 2021) also reported lower leaf area index in all weedy check plots of maize.

Table 3. Effect of different weed management practices on leaf area index of maize in Lalitpur, Nepal in 2024

Weed management practices	Leaf area index		
	30 DAS	60 DAS	90 DAS
Weedy Check	0.01[b]	0.24[b]	0.44[a]
Hand Weeding	0.02[b]	0.28[ab]	0.48[ab]
Hoeing at 25 DAS	0.02[ab]	0.29[ab]	0.48[ab]
Pendimethalin 30% EC as PE	0.03[a]	0.29[a]	0.48[ab]
Atrazine 50%WP as PE	0.03[a]	0.31[a]	0.51[a]
Pendimethalin + Atrazine as PE	0.02[ab]	0.31[a]	0.49[ab]
Butachlor as PE fb Atrazine as PoE	0.03[a]	0.33[a]	0.49[ab]
SEM (±)	0.005	0.016	0.013
LSD (0.05)	0.007	0.05	0.04
F-test	**	**	**
CV (%)	18.116	9.607	4.649
Grand mean	0.02	0.29	0.48

DAS = Days after sowing, Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability *=significant at 5% probability level, **= significant at 1% probability level, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Days to 50% tasseling

The result showed the significant effect of weed management practices on days to tasseling (Table 4). Significantly shortest days to tasseling (71 days) was observed under the treatment pendimethalin 30% EC @1kg a.i /ha as PE. While the longest days to tasseling (74.66 days) was observed under the treatment weedy check. The minimum days to tasseling was recorded in the chemical weed management practice compared to manual and weedy check which could be due to minimum crop-weed competition imposed throughout growth period of maize resulting in optimum utilization of nutrients. (Bista et al 2023) also reported shortest days to tasseling in herbicide (pendimethalin) applied plots.

Days to 50% silking

Significantly shortest days to silking (75 days) was observed under the treatment atrazine 50%WP @1kg a.i/ha as PE while the longest days to silking (80 days) was observed under weedy check treatment (Table 4). This outcome may be attributed to reduced crop-weed competition throughout the maize growth period, which facilitated optimal utilization of nutrients, light, and moisture. (Bista et al 2023) also observed shortest period to silking in chemical weed management practices as compare to other manual weeding.

Table 4. Effect of different weed management practices on days to 50% tasseling and silking of maize in Lalitpur, Nepal in 2024

Weed Management Practices	Days to 50% tasseling	Days to 50% silking
Weedy Check	74.66[a]	80.00[a]
Hand Weeding	72.00[bcd]	75.33[b]
Hoeing at 25 DAS	73.33[ab]	75.66[ab]
Pendimethalin 30% EC as PE	71.00[d]	76.33[ab]
Atrazine 50%WP as PE	73.00[bc]	75.00[ab]
Pendimethalin + Atrazine as PE	72.33[bcd]	75.66[ab]
Butachlor as PE fb Atrazine as PoE	71.66[cd]	76.33[ab]
SEM (±)	0.538	1.058
LSD (0.05)	1.66	3.262
F-test	*	*
CV (%)	1.285	2.329
Grand mean	72.57	78.14

DAS = Days after sowing, Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Weed flora

Twenty different weed species belonging to eight families were identified in the research field (Table 5). *Bidens pilosa, Digitaria spp, Chenopodium album, Ageratum conyzoides, Cynodon dactylon, Cyperus rotundus* were the major weed species identified in the research fieldShrestha and Marasaini 2021) also reported 16 major species of weed including *Cynodon dactylon, Digitaria ciliaris, Cyperus rotundus, Ageratum conyzoides* etc. in spring maize at Dhading Besi of Nepal.

Table 5. Weeds observed in experimental field of maize in Lalitpur, Nepal in 2024

Common name	Scientific name	Weed category	Family
Bermuda grass	*Cynodon dactylon (L.)*	GW	Poaceae
Crowfoot grass	*Dactyloctenium aegyptium (L.)*	GW	Poaceae
Para grass	*Brachiaria reptans (L.)*	GW	Poaceae
Annual bluegrass	*Poa annua*	GW	Poaceae
Hairy crabgrass	*Digitaria sanguinalis*	GW	Poaceae
Purple nutsedge	*Cyperus rotundus L*	SW	Cyperaceae
Rice flat sedge	*Cyperus iria (L.)*	SW	Cyperaceae
Lamb's quarter	*Chenopodium album*	BLW	Amarantheaceae
Marijuana	*Cannabis sativa (L.)*	BLW	Cannabaceae
Crofton weed	*Ageratina adenophora*	BLW	Asteraceae
Whitetop weed	*Parthenium hysterophorus*	BLW	Asteraceae
False amaranth	*Digera arvensis (L.)*	BLW	Amaranthaceae
Black nightshade	*Solanum nigrum (L.)*	BLW	Solanaceae
Goat weed	*Ageratum conyzoides (L.)*	BLW	Asteraceae
Tropical spiderwort	*Commelina benghalensis*	BLW	Commelinaceae
Broadleaf woodsorrel	*Oxalis latifolia*	BLW	Oxalidaceae
Creeping woodsorrel	*Oxalis dilleni*	BLW	Oxalidaceae
Beggar ticks	*Bidens pilosa*	BLW	Asteraceae
Tropical soda apple	*Solanum viarum*	BLW	Solanaceae
Common mugwort	*Artimisia vulgaris*	BLW	Asteraceae

BLW= Broad leaf weed, GW= Grassy weed, SW= Sedge weed

Weed density

The weed density in the experiment was significantly affected by weed management practices at all dates of observation (Table 6) and found significantly higher under weedy check at all observations. At 30 DAS, lower number of weeds per metre area found in pendimethalin 30% EC @1kg a.i /ha as PE treatment (125.33 /m^2) while higher under weedy check (341.33/m^2). At 60 and 90 DAS, lower number of weeds found in atrazine 50% WP @1kg a.i/ha as PE (86.67/m^2) and pendimethalin 30% EC @0.5 kg a.i/ha + atrazine 50% WP @0.5kg a.i/ha as PE treatment (110.67 /m^2) respectively. At harvest, lower weed density was observed in the atrazine 50% WP 1kg a.i./ha as a PE treatment (127.33/m^2). The lower weed density in the herbicide application plot was due to their action against the germination, growth, and development of weeds. The fewer weed in maize due to the use of pendimethalin was also observed by (Shaba et al 2015).

Table 6. Effect of different weed management practices on weed density in Lalitpur, Nepal in 2024

Weed management practices	Weed density (number/m^2)			
	30 DAS	60 DAS	90 DAS	At harvest
Weedy Check	18.43^{a}(341.3)	17.75^{a}(316)	15.25^{a}(236)	16.73^{a}(280)
Hand Weeding	13.39^{b}(181.3)	13.7^{ab}(192)	13.66^{ab}(188)	14.0^{ab}(196)
Hoeing at 25 DAS	13.16^{b}(173.3)	10.8^{bc}(134)	11^{bc}(121.33)	14.0^{ab}(198)
Pendimethalin 30%EC as PE	10.95^{b}(125.3)	12.7^{bc}(153)	11.81^{bc}(141)	11.88^{b}(141)
Atrazine 50% WP as PE	11.14^{b}(128.0)	9.00^{c}(86.67)	10.29^{c}(113)	11.28^{b}(127)
Pendimethalin + Atrazine as PE	11.57^{b}(134.6)	10.9^{bc}(113)	10.20^{c}(110)	14.1^{ab}(201)
Butachlor as PE fb Atrazine as PoE	13.10^{b}(172.0)	12.27(150)	11.92^{bc}(142)	11.42^{b}(130)
SEM (±)	0.994	1.331	0.937	1.122
LSD $_{(0.05)}$	3.063	4.103	2.890	0.159
F-test	**	**	*	**
CV (%)	13.135	18.66	13.513	14.339
Grand mean	13.10	12.35	12.021	13.15

DAS = Days after sowing, Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, **= significant at 1% probability level,SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Data in the parenthesis are the original values. Data were transformed by using the square root transformation method. This method helps to reduce skewness and stabilizes variance.

Square root transformation method = $\sqrt{x}$

Where x = initial data

Weed dry weight

Weed dry weight differed among the different treatment significantly (Table 7). At 30 DAS, lower dry weight was observed in atrazine 50%WP @1kg a.i/ha as PE treated plot (3.48 g/m^2), at 60 DAS and at harvest lower

weed dry weight was observed in hoeing treatment (9.85 g/m^2) and atrazine 50%WP @1kg a.i/ha as PE treatment (15.20 g/m^2) while higher weed dry weight was observed under weedy check at all observations (Table 7). Higher weed dry weight in weedy check was due to uncontrolled weeds germination and growth in comparison to all weed control treatments. (Gurung et al 2019) also reported significantly higher weed dry weight was observed in weedy check.

Table 7. Effect of different weed management practices on weed dry weight in Lalitpur, Nepal in 2024

Weed management practices	Weed dry weight (g/m^2)			
	30 DAS	60 DAS	90 DAS	At harvest
Weedy Check	4.07^a(16)	7.00^a(50)	11.48^a(134)	17.36^a(301.73)
Hand Weeding	1.93^b(8.3)	5.43^{ab}(29)	4.52^{bc}(20.6)	7.43^b(55.33)
Hoeing at 25 DAS	2.06^b(4.2)	3.12^c(9)	4.00^c(17.1)	4.58^c(21.07)
Pendimethalin 30% EC as PE	2.16^b(4.7)	4.24^{bc}(18)	7.02^{bc}(50)	8.53^b(72.93)
Atrazine 50%WP as PE	1.80^b(3.4)	4.28^{bc}(18)	7.27^{bc}(55)	3.89^c(15.20)
Pendimethalin + Atrazine as PE	2.44^b(7.2)	4.52^{bc}(21)	6.43^{bc}(44.8)	8.27^b(68.40)
Butachlor as PE fb Atrazine as PoE	2.36^b(5.7)	4.50^{bc}(21)	8.33^b(70.3)	6.69^b (44.80)
SEM (±)	0.274	0.580	0.984	2.331
LSD $_{(0.05)}$	0.847	1.787	3.033	143.504
F-test	*	*	*	**
CV (%)	19.799	18.250	17.327	3.354
Grand mean	2.40	4.72	7.00	8.11

DAS = Days after sowing, Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, **= significant at 1% probability level, g= gram, m^2= metre square, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Weed control efficiency

Weed control efficiency also affected by different weed management practices (Table 8). At all dates of observations highest and lowest weed control efficiency were observed in atrazine 50% WP @1kg a.i/ha as PE and hand hoeing respectively. But, at 30 DAS, highest WCE was recorded in pendimethalin 30% EC @1kg a.i /ha as PE application (61.12%). This might be due to suppress of weed species by herbicides. (Kumar et al 2017) also observed highest weed control efficiency in atrazine 50% WP @1kg a.i/ha as PE.

Table 8. Effect of different weed management practices on weed control efficiency in Lalitpur, Nepal in 2024

Weed management practices	Weed control efficiency (%)			
	30 DAS	60 DAS	90 DAS	At harvest
Weedy Check	-	-	-	-
Hand Weeding	6.88^b(47.41)	6.283^b(40)	5.59^b(18)	9.18^a(84)
Hoeing at 25 DAS	6.93^a(48.39$^)$	7.44^{ab}(61)	6.66^a(45)	9.18^a(93)
Pendimethalin 30% EC as PE	7.69^a(60.12)	7.08^a(50)	6.94^a(39)	8.89^b(79.1)
Atrazine 50% WP as PE	7.65^a(60.56)	8.53^a(73.3)	6.30^a(51)	9.78^a(95.7)
Pendimethalin + Atrazine as PE	7.76^a(60.42)	8.01^a(64.3)	6.97^a(52)	8.97^a(80.4)
Butachlor PE fb Atrazine as PoE	6.91^a(48.43)	7.54^a(59.9)	6.26^a(39)	9.33^a(87)
SEM (±)	0.488	13.322	0.662	0.012
LSD (0.05)	1.538	2.643	2.081	0.038
F-test	*	*	*	**
CV (%)	11.57	19.419	17.771	0.227
Grand mean	7.30	7.48	6.45	9.30

DAS = Days after sowing, Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, **= significant at 1% probability level, g= gram, m^2= metre square, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Weed control index

Data showed that (Table 9) at 30 DAS, 60 DAS and at harvest, significantly lowest weed control index was observed in weedy check while highest WCI in atrazine 50%WP @1kg a.i/ha as PE as statistically par with pendimethalin 30% EC @0.5kg a.i/ha + atrazine 50%WP @0.5kg a.i/ha as PE and hoeing treatment. This could be due to the action of chemical herbicide in contradiction of growth and development of weeds. (Kumar et al 2017) also reported lowest weed control index in weedy check.

Table 9. Effect of different weed management practices on weed control efficiency and weed control index in Lalitpur, Nepal in 2024

Weed management practices	Weed control index (%)			
	30 DAS	60 DAS	90 DAS	At harvest
Weedy Check	-	-	-	-
Hand Weeding	8.81^{a}(70.2)	6.72^{b}(46)	9.17^{a}(84)	9.03^{bc}(81)
Hoeing at 25 DAS	8.63^{a}(74.5)	8.69^{a}(76.2)	9.21^{a}(85.1)	9.64^{a}(93)
Pendimethalin 30% EC as PE	8.46^{b}(71)	7.97^{ab}(63)	7.90^{ab}(62)	8.70^{c}(75)
Atrazine 50% WP as PE	8.92^{a}(80)	7.67^{ab}(59)	8.37^{ab}(71)	9.43^{ab}(89)
Pendimethalin + Atrazine as PE	7.67^{b}(60)	8.68^{a}(76.1)	7.81^{ab}(64)	8.78^{bc}(77)
Butachlor PE fb Atrazine as PoE	8.01^{a}(73)	7.47^{ab}(56)	6.23^{b}(42)	9.22^{ab}(85)
SEM (±)	0.496	0.591	0.729	0.141
LSD (0.05)	1.565	1.863	2.298	0.445
F-test	*	**	*	**
CV (%)	10.218	13.013	15.560	2.681
Grand mean	8.42	7.87	8.12	9.13

DAS = Days after sowing, Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, **= significant at 1% probability level, g=gram, m^2= metre square, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Number of cobs per plant

The number of cobs per plant were significantly influenced by weed management practices (Table 10). Higher number of cobs per plant were observed in atrazine 50% WP @1kg a.i/ha as PE, butachlor 5% G 1kg a.i/ha as PE fb atrazine 50% WP 1kg a.i/ha as PoE (1.66) and hoeing treatment while lower number of cobs per plant was observed in weedy check (1.00). The highest number of cobs may result from the absence of competition between weeds and maize for water, nutrients, and space. Similar results of higher number of cobs per plant was also observed by (Kumar et al 2017).

Cob length

Cob length differed among the different treatment significantly (Table 10). The highest cob length was obtained in pendimethalin 30% EC @1kg a.i /ha as PE treatment (18.11 cm) while minimum cob length was observed in weedy check (15.06 cm). This could be due to competition between weeds and maize for water. Lack of sufficient water during the silking and grain-filling stages might negatively impact cob length. (Kumar et al 2017) also reported lowest cob length in weedy check treatment among rest treatments.

Cob weight

Cob weight varied among the different treatment significantly (Table 10). The highest cob weight was obtained in atrazine 50%WP 1kg a.i/ha as PE treatment (258.87 g) while lowest cob weight was obtained in weedy check (175.16 g). Similar finding was reported, lowest cob weight in weedy check by (Kumar et al 2017). This was due to some fast-growing weeds compete with maize plant for essential nutrients and limit their access for proper growth and development.

Number of kernels per row

The number of kernels per row was significantly influenced by weed management practices (Table 10). The maximum number of kernel per row was obtained in atrazine 50%WP 1kg a.i/ha as PE and pendimethalin 30% EC @0.5kg a.i/ha + atrazine 50%WP @0.5kg a.i/ha as PE treatment (39.66) while minimum number of kernels per row was obtained in weedy check (31.66). (Kumar et al 2017) also observed lowest number of kernels per row in control (weedy check) treatment. This could be due to release of allelopathic chemicals by some weed species into the soil, which can inhibit maize growth and development, including kernel formation.

Number of kernel row per cob

The number of kernel row per cob was also significantly affected by different weed management practices (Table 10). The higher number of kernel row per cob was found in atrazine 50%WP @1kg a.i/ha as PE (15.66) while lower number of kernel row per cob was found in control plot (12). This might be due to the suppress of weed species by the action of weedicide. (Kumar et al 2017) also obtained higher number of kernel row per cob in atrazine as PE treatment while lower in weedy check.

Number of kernels per cob

The number of kernels per cob was significantly influenced by weed management practices (Table 10). The maximum number of kernels per cob was found in atrazine 50%WP @1kg a.i/ha as PE (619) while minimum number of kernels per cob was found in weedy check treatment (455). (Shrestha and Marasaini 2021) also

reported highest number of kernels per cob in atrazine as a PE treatment. This could be due to the suppress of weed species by the effect of weedicide and plant grow freely without any disturbance.

Table 10. Effect of different weed management practices on yield parameters of maize in Lalitpur, Nepal in 2024

Weed management practices	No of cobs per plant	Cob length (cm)	Cob weight (g)	No of kernel per row	No of kernel row per cob	No of kernel per cob
Weedy check	1.00[b]	15.06[b]	175.16[b]	31.66[b]	12.00[b]	455.00[b]
Hand Weeding	1.33[ab]	17.58[a]	237.35[a]	36.66[ab]	14.66[a]	544.00[ab]
Hoeing at 25 DAS	1.66[ab]	17.07[a]	214.20[ab]	35.66[ab]	15.00[a]	529.00[ab]
Pendimethalin 30% as PE	1.33[ab]	18.11[a]	254.13[a]	39.33[a]	15.33[a]	586.66[a]
Atrazine 50% WP as PE	1.66[ab]	17.63[a]	258.87[a]	39.66[a]	15.66[a]	619.00[a]
Pendimethalin + Atrazine as PE	2.00[ab]	17.45[a]	247.41[a]	39.66[a]	15.33[a]	583.33[a]
Butachlor PE fb Atrazine as PoE	1.66[ab]	17.64[a]	224.70[ab]	35.66[ab]	15.00[a]	536.66[ab]
SEM (±)	0.263	0.399	16.696	1.834	0.431	36.377
LSD $_{(0.05)}$	0.813	1.231	51.446	5.651	1.923	126.286
F-test	*	**	*	*	*	*
CV (%)	30	4.026	12.559	8.608	7.347	11.444
Grand mean	1.52	17.22	230.26	36.9	14.71	550.52

Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, **= significant at 1% probability level, cm=centimeter, g=gram, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

Thousand grain weight

The 1000 grain weight was significantly influenced by different weed management practices (Table 11). The highest 1000 grain weight was obtained in hand hoeing treatment (322.20 g) while the lowest 1000 grain weight was obtained in weedy check plot (267.37 g). (Shrestha and Marasaini 2021) also observed the lowest 1000 grain weight in weedy check plot. This could be due to the insufficient nutrient uptake by the maize plants throughout their growth and reproductive stages.

Grain yield

Grain yield was significantly influenced by different weed management practices (Table 11). The highest grain yield was obtained in atrazine 50 % WP @1kg a.i/ha as PE treatment (7.35 mt/ha) as statistically par with pendimethalin 30 % EC @1kg a.i /ha as PE and pendimethalin 30 % EC 0.5 kg a.i/ha + atrazine 50% WP @0.5kg a.i/ha as PE treatment while the lowest yield was obtained in weedy check plot (5.05 mt/ha). This might be due to the sufficient uptake of essential nutrients by the maize crop throughout the growth and reproductive period. Bhattarai et al (2022) also reported highest grain yield in atrazine and pendimethalin as PE treatments. Same result of higher grain yield per cob was also obtained by (Bista et al 2023).

Stover yield

The stover yield of the different compared treatments ranged from 6.23 mt/ha to 8.12 mt/ha (Table 11). The highest stover yield was found in pendimethalin 30% EC 0.5kg a.i/ha + atrazine 50% WP 0.5kg a.i/ha as PE treatment (8.12 mt/ha) as statistically par with atrazine 50% WP 1kg a.i/ha as PE treatment (8.08 mt/ha) while the lowest stover yield was found in weedy check treatment (6.23 mt/ha). There was significant difference among the treatment in the stover yield. This could be due to constant competition with weeds can stress maize plants, making them less effective in converting energy into biomass production. This stress can lead to a decrease in overall plant vigor, reducing both grain and stover yield. (Gurung et al 2019) also observed lowest stover yield in weedy check treatment.

Shelling percentage

The shelling percentage was also significantly affected by different weed management practices (Table 11). The higher shelling percentage was obtained in atrazine 50%WP @1kg a.i/ha as PE (79.63 %) while the lower in weedy check (65.66%). This was because of weeds introduced pests or diseases that influenced the maize crop, more reducing kernel quality and size, ultimately lowering the shelling percentage. (Bista et al 2023) also reported similar findings as highest and lowest shelling percentage in herbicides (atrazine as PE) and weedy check respectively.

Harvest index

The harvest index was significantly influenced by weed management practices (Table 11). The higher harvest index was found in atrazine 50% WP 1kg a.i/ha as PE treatment (0.48) while lower in weedy check treatment (0.44). This could be due to the effect of weeds which reduces the economic yield of maize and this results lower harvest index. Similar finding was also reported by (Bista et al 2023).

Table 11. Effect of different weed management practices on yield parameters of maize in Lalitpur, Nepal in 2024

Weed Management Practices	Grain yield per cob (g)	1000 grain weight (g)	Grain yield (mt/ha)	Stover yield (mt/ha)	Shelling percentage (%)	Harvest index (HI)
Weedy Check	127.98^{b}	267.37^{b}	5.05^{b}	6.23^{b}	65.66^{b}	0.43^{b}
Hand Weeding	183.47^{ab}	322.20^{a}	6.98^{a}	7.80^{a}	75.40^{ab}	0.46^{a}
Hoeing at 25 DAS	164.50^{ab}	321.15^{a}	7.17^{a}	7.82^{a}	73.58^{ab}	0.47^{a}
Pendimethalin 30% as PE	193.17^{a}	315.53^{a}	7.08^{a}	7.84^{a}	75.45^{ab}	0.46^{a}
Atrazine 50% WP as PE	198.82^{a}	317.96^{a}	7.35^{a}	8.06^{a}	79.63^{a}	0.48^{a}
Pendimethalin + Atrazine as PE	186.11^{a}	318.00^{a}	7.31^{a}	8.12^{a}	75.85^{ab}	0.47^{a}
Butachlor fb Atrazine as PoE	167.95^{ab}	321.80^{a}	7.08^{a}	7.72^{a}	73.43^{ab}	0.47^{a}
SEM (±)	15.528	13.313	0.383	0.342	2.366	0.007
LSD $_{(0.05)}$	45.776	41.023	1.14	1.019	7.293	0.022
F-test	*	**	**	**	*	**
CV (%)	14.739	7.39	9.706	7.757	5.528	2.691
Grand mean	174.57	312	6.85	7.68	74.1	0.46

Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, *=significant at 5% probability level, **= significant at 1% probability level, SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

ECONOMIC ANALYSIS

The cost of production of the different treatments were NRs 87553.33 to 92519.67 (Table 12). The lowest cost was incurred in the control and the highest cost was recorded in pendimethalin 30% EC @1kg a.i /ha as PE. The economic analysis revealed that (Table 12) application of atrazine 50% WP @1kg a.i/ha as PE resulted in the highest return of NRs 108668.33 and B:C ratio 1.18, statistically par with pendimethalin 30% EC @1kg a.i/ha as PE NRs 103094.67 and B:C ratio of 1.11. This was due to the effective control of weed species thereby plants got maximum nutrients, space and other essentials for their growth and development. (Patel et al 2018) also reported highest B:C ratio in atrazine as PE application treatment.

Table 12. Effect of different weed management practices on economics of maize in Lalitpur, Nepal, 2024

Weed management practices	Cost of cultivation (NRs)	Gross return (NRs)	B:C Ratio
Weedy Check	87553.33	83641.67^{c}	0.95^{b}
Hand Weeding	88526.67	95286.67^{b}	1.07b
Hoeing at 25 DAS	89623.33	95168.67^{b}	1.06^{ab}
Pendimethalin 30% EC as PE	92281.33	103094.67^{ab}	1.11^{ab}
Atrazine 50% WP as PE	91911.67	108668.33^{a}	1.18^{a}
Pendimethalin + Atrazine as PE	92519.67	102180^{ab}	1.10^{ab}
Butachlor fb Atrazine as PoE	91148.00	100168.67^{ab}	1.10^{ab}
SEM (±)	-	3272.744	0.033
LSD $_{(0.05)}$	-	10084.33	0.098
F-test	-	**	**
CV (%)	-	5.765	5.311
Grand mean	90509.14	98315.43	1.085

Means followed by the same letter(s) in a column are not significantly different by DMRT at 5% level of probability, **= significant at 1% probability level, NRs = Nepali Rupees, the local market price of maize grain was NRs 50 per kg was assumed. SEM=Standard error of mean, LSD=Least significant difference, CV=Coefficient of variation

CONCLUSION

Different weed management practices used in the study showed significant variation in growth and yield attributes and weed biomass. This was because of differences in the mode of action of herbicides. It is concluded that among the seven treatments atrazine 50% WP @1kg a.i/ha as PE is the most economical management practices due to highest value of plant height (245.29 cm), highest number of leaves per plant (13) and shortest days to 50% silking (75 days). Also, it showed highest yield (7.5 mt/ha) and B:C ratio (1.11). Similarly, butachlor 5%G @1kg a.i/ha as PE fb atrazine 50% WP @1kg a.i/ha as PoE and pendimethalin 30% EC @0.5kg a.i/ha + atrazine 50% WP @0.5 kg a.i/ha as PE also found to be potential practices for weed management.

ACKNOWLEDGEMENT

Author wants to acknowledge Agriculture and Forestry University, Rampur, Chitwan for this wonderful opportunity. I would like to express my gratitude to my major supervisor Assoc. prof. Dr. Homnath Giri, principal Anish Lamichhane sir, Shovit Khanal sir and Prashant Dahal sir and Rajendra Kumar Bhattarai sir for their valuable guidance throughout the research. Author also thankful to Kedar Dulal, the farmer, for providing field for the experiment.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding publication of this manuscript.

AUTHORS' CONTRIBUTION

The experiment was carried out, data was collected and analysed and the manuscript was prepared by Jiwan Bahadur Karki. The manuscript was edited and supervised by another author.

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