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Enhancing Maize Productivity in Nepal's Terai Region through Integrated Weed Management Practices

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ABSTRACT

Weeds pose a major challenge to crop productivity, significantly impacting maize (*Zea mays* L.), which is Nepal's second-most important staple crop. Although attainable yield 5.8 t ha^{-1}, the national average is only 3.15 t ha^{-1}, largely due to issues like weed competition that can lead to yield losses of up to 48%. This study, carried out during the winter season at the National Maize Research Program in Rampur, Chitwan, evaluated nine different weed management treatments, weedy check, weed free, green polythene mulching, clear polythene mulching, cowpea co-culture, black polythene mulching, atrazine + one hand weeding @ 30 DAS, silver black polythene mulch and *Lantana camara* as mulch in a randomized complete block design with four replications. The results showed that mulching methods, particularly silver-black polythene mulch, significantly enhanced growth parameters, grain yield (4,537.5 kg ha^{-1}) and stover yield (6,500 kg ha^{-1}). Furthermore, mulching facilitated earlier tasseling (73.19 DAS) and silking (85.31 DAS), while also improving soil moisture retention, and weed suppression. Both clear and black polythene mulches had beneficial effects on growth and yield. Similarly, grain yield in *Lantana camara* as mulch and Atrazine @ 0.75 kg ha^{-1} + one hand weeding also remain same with clear polythene mulch.

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KEYWORDS: Atrazine, Black polythene mulch, Clear polythene mulch, Green polythene mulch, *Lantana camara* mulch, Silver black mulch, Weed check and Weed free.

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1. INTRODUCTION

Weeds are among the most significant biotic factors affecting crop production, causing substantial yield losses across agro-ecosystems. Their impact is particularly pronounced in maize (*Zea mays* L.), the second most important staple food crop in Nepal after rice, contributing significantly to national food security and the agricultural economy. Maize accounts for 7.04% of Nepal's agricultural gross domestic product (AGDP) and 2.2% of the national GDP (MoF Economic Survey, 2016). Despite its high yield potential—reaching up to 12 t ha^{-1} under optimal conditions (Haarhoff, & Swanepoel, 2018)—the average maize yield in Nepal is only about 3.15 t ha^{-1} (MoALD, 2023), far below the attainable yield of 5.8 t ha^{-1} (Bhandari et al., 2021; MoALD, 2022).

Weeds play a crucial role in this yield gap, competing with maize plants for nutrients, water, and light, and often serving as alternate hosts for pests and diseases. Maize is cultivated across diverse agro-climatic zones in Nepal ranging from the Terai and Inner Terai (below 900 m) to the mid-hills (900–1800 m) and high-hills (above 1800 m) covering 985,565 hectares and yielding 3,106,397 tons annually (MoALD, 2023). However, weed infestation remains a persistent challenge, exacerbating the already low productivity. Addressing weed management effectively is therefore crucial to improving maize yields and meeting the growing demand for food grains driven by Nepal's annual population growth rate of 1.28% (CBS, 2014).

In maize, the critical period for weed control is 1 to 8 weeks after emergence, spanning the V1 to V10 growth stages (Ghosheh et al., 1996; Evans et al., 2003; Page et al., 2012). Weeds compete for resources like space, light, water, and nutrients, causing yield losses ranging from 28–100%, depending on weed intensity and duration of infestation (Retta et al., 1991; Patel et al., 2006). In Nepal, weed infestation can reduce maize yields by up to 48%, particularly in hill regions (Karki & Mishra, 2010). The weed problem varies with seasons, being more pronounced in the first 20–30 days after emergence in rainy-season maize, while in winter maize, weeds typically emerge after the first irrigation. The need to enhance maize yield necessitates improved crop management, including effective weed control strategies tailored to specific crops, times, and locations. Cultural weed control methods, though traditional, are labor-intensive, time-consuming, and increasingly costly, making sole reliance on them impractical (Nadeem et al., 2010). Chemical control, particularly herbicides, offers a quick and effective alternative, saving time and labor (Ahmad et al., 2004). However, continuous use of a single herbicide can lead to herbicide-resistant weeds and shifts in weed flora (Thakur & Sharma, 1996). Physical methods like polythene mulch and biological options like *Lantana camara* mulch are gaining popularity for conserving soil moisture, regulating temperature, and suppressing weeds (Mihajlov et al., 2014). This study aimed to evaluate integrated weed management approaches, including herbicides, cowpea brown manuring, biological mulching, and plastic mulching, alongside traditional hand weeding, for optimal maize production in the central Terai of Nepal during the winter season.

2. MATERIAL AND METHODS

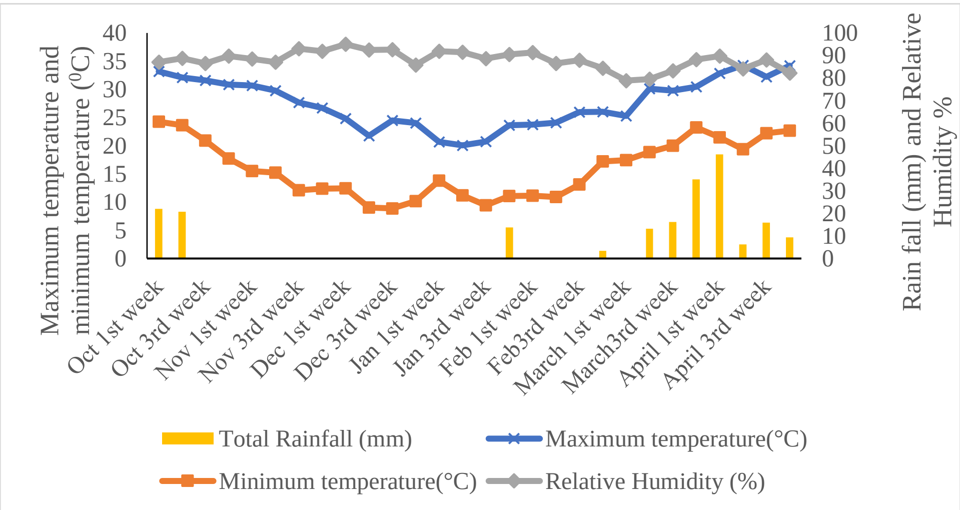
Field research was conducted in the research block of NMRP (National Maize Research Program) Rampur, Chitwan during the winter season from October to April. The area is situated in the Central terai of Nepal which lies at $27^{0}37'$ North latitude and $84^{0}25'$ East longitude with the elevation of 256 m above mean sea level. The soil of experimental plot was sandy loam in texture. Similarly, all other chemical properties from 0-15 cm depth of soil such as organic matter (3.23%), available potassium (207.15kg ha^{-1}) were found medium, total nitrogen (0.07%) was low while available phosphorus (229.30 kg ha^{-1}) was found high and soil pH was found slightly acidic (pH 5.58) . Similarly, from 15-30 cm depth of soil such as organic matter (3.16%), available potassium (178.42kg ha^{-1}) were found medium, total nitrogen (0.07%) was low while available phosphorus (122.36 kg ha^{-1}) was found high and soil pH was found slightly acidic (pH 5.59) based on soil rating chart given by (Khatri Chetri, 1991) and (Jaishy, 2000).

Experiment was laid out in Randomized Completely Block Design with three replication and nine treatments constituting 36 plots. The experiments consist following treatments weedy check, Weed free, Green Polythene mulching, Clear Polythene mulching, Cowpea co-culture, Black Polythene mulching, Atrazine +one hand weeding @30 DAS, Silver black Polythene mulching and *Lantana camara* mulching. The field was ploughed 15 days prior to sowing using tractor. In Polythene mulch treatment plot plastic were laid down on field and hole was made. Seeds of Deuti were planted by jab planter in furrows at spacing of 25 cm opened 75 cm apart with the help of tractor drawn furrow opener. In case of control plot, weeds were allowed to grow along with the maize crop throughout the crop cycle. In the weed free treatment, weeding was done manually to keep the plots free from weeds throughout the crop cycle. The crop was raised under irrigated condition as per the recommended package of practices.

Density and dry weight of weeds were recorded at 30, 60, 90 and at harvest. These data were subjected to square root transformation before analysis. Growth and yield characters were recorded as per standard procedures and calculated using standard formulas. Weed control efficiencies were also calculated for each treatment. Density and dry weight of weeds were recorded at 30, 60, 90 DAS and at harvest. These data were subjected to square root transformation before analysis. Growth and yield characters were recorded as per standard procedures and calculated using standard formulas. Weed control efficiencies were also calculated for each treatment. The analysis of variance of all parameters was determined using Gen STAT software program and the analyzed data were subjected to DMRT for the mean separation.

CLIMATIC CONDITION DURING EXPERIMENTATION

Weekly average data on different weather parameters i.e., maximum and minimum temperatures, total rainfall, and relative humidity, recorded during the maize growing season at NMRP are presented in Figure 1.



(**Source:** NMRP)

Figure 1. Weather conditions during experimentation at NMRP, Rampur, Chitwan, Nepal

3. RESULTS AND DISCUSSION

3.1 Phenological stages of maize

3.1.1 Tasseling, Silking, Tasseling Silking Interval and Physiological Maturity

Table 1. evaluates the impact of various treatments on crop growth stages, including tasseling, silking, tasseling silking interval (TSI), and physiological maturity (PM), measured in days after sowing (DAS). The weedy check treatment exhibited the longest durations across all parameters, indicating delayed development. At the same time, clear polythene mulch achieved the shortest tasseling (70.75 DAS) and silking (82.19 DAS) times, promoting earlier crop maturity. Other treatments, such as weedy free, silver black mulch, and black polythene, significantly reduced TSI and PM compared to the control. The phenological stage of maize was influenced considerably by weed management practices, earlier tasseling and silking appearance was recorded in clear polythene mulch treated plot as polythene mulch increases the soil temperature and prevents the loss of nutrients and develops soil microclimate favorable for growth, development, and early maturity of the crop (Pinjari et al., 2009). Finding was supported by the result of (Aguyoh et al., 1999) who reported that sweet corn grown under clear plastic mulch shortened the time to maturity by 10 days. Results align with Mirshekari et al. (2012) where black plastic mulch advanced days from planting to silking and harvest relative to control treatment (2-6 days). Similarly, Iqbal et al. (2009) also support this finding.

Table 1. Phenological stages of maize as influenced by weed management practices during winter at NMRP, Rampur, Chitwan.

	Phenological stages			
Treatment	Tasseling (DAS)	Silking (DAS)	TSI (DAS)	PM
Weedy check	83.81[a]	102.32[a]	18.51[a]	[a]
Weedy free	72.92[cd]	86.28[ef]	13.37[b]	[bc]
Green polythene	77.08[bc]	91.66[cd]	14.57[b]	[bc]
Clear polythene	70.75[d]	82.19[f]	11.44[b]	[bc]
Cowpea co-culture	83.11[a]	97.41[b]	14.30[b]	[a]
Black polythene	75.25[bcd]	87.82[de]	12.57[b]	[bc]
Atrazine + one hand weeding	79.81[ab]	93.31[bc]	13.50[b]	[b]
Silver black mulch	73.19[cd]	85.31[ef]	12.13[b]	[c]
Lantana camara mulch	78.87[ab]	93.71[bc]	14.85[b]	[bc]
SEm (±)	1.58	1.36	1.11	
LSD (=0.05)	4.61	3.96	3.23	
CV, %	4.10	3.00	15.90	
Grand mean	77.20	91.11	13.91	

Note: Atrazine 0.75 kg a.i ha^{-1} Mean separated by DMRT and columns represented with the same letter (s) is non-significant at 5% level of significance, DAS, days after sowing; TSI=Tasseling silking interval: PM=Physiological Maturity ; ns, non-significant

3.2 Biometrical Observation

3.2.1 Plant Height, Leaf Area Index and Total Dry matter of maize

Table 2. Plant height (cm), Leaf Area Index and Total dry matter (TDM) of maize in 90 DAS as influenced by weed management practices during winter at NMRP, Rampur, Chitwan.

	PH	LAI	TDM
Weedy check	129.45[c]	1.01[c]	313.9[c]
Weed free	210.60[b]	2.23[a]	761.7[a]
Green polythene	209.45[b]	2.64[a]	940.7[a]
Clear polythene	208.75[b]	2.55[a]	862.5[a]
Cowpea co-culture	134.30[c]	1.19[c]	350.8[c]

Black polythene	248.85^{a}	2.56^{a}	857.6^{a}
Atrazine+1 HW	185.35^{b}	1.33^{bc}	425.8^{bc}
Silverblack mulch	248.75^{a}	2.88^{a}	955.0^{a}
Lantana camara mulch	188.85^{b}	2.16^{ab}	714.2^{ab}
SEm (±)	11.92	0.29	100.5
LSD (=0.05)	34.79	0.8	293.2
CV, %	12.2	28	29.2
Grand mean	195.95	2.06	686.9

Atrazine @ 0.75 kg a.i. ha^{-1} + 1 hand weeding ; Mean separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% significance level, DAS, days after sowing; PH= Plant Height; LAI= Leaf Area Index; TDM= Total Dry Matter.

Table 2 highlights the impact of weed management practices on maize growth parameters plant height (PH), leaf area index (LAI), and total dry matter (TDM) at 90 days after sowing (DAS) during winter at NMRP, Rampur, Chitwan. The weedy check recorded the lowest values for all parameters (PH: 129.45 cm, LAI: 1.01, TDM: 313.9 g), indicating poor growth under uncontrolled weed conditions. In contrast, mulching practices, especially silver black mulch**,** and black polythene produced the tallest plants (248.75 cm and 248.85 cm, respectively). *Lantana camara* mulch performed moderately well, though its results were slightly lower than the top-performing mulches. Overall, mulching, particularly silver black mulch, and black plastic mulch proved to be the most effective strategy for enhancing maize growth and productivity during winter. With the reduction of temperature with the onset of winter, the mulch is favored for better plant growth by creating a better microenvironment and better retention of soil moisture and also by enhancing the increase in soil temperature. (Kahangi et al., 2014) also supported this finding, who recorded maximum plant height (247cm) in polythene mulching followed by hand weeding treatment. Underhand weeding could be attributed to the reduced crop weed competition. A similar finding was supported by (Rajablariani, & Sheykhmohamady, 2015). (Rajablariani, & Sheykhmohamady, 2015) also found similar results, recording the highest plant height (162 cm) and stem diameter (28.4 mm) in white on black plastic, which remains at par with black plastic, clear plastic, blue plastic, and control. Kulkarni et al. (1998) reported that maize plant height at harvest improved considerably and significantly under black polythene mulch as compared to paddy straw mulch and no mulch treatment. Pinjar (2007) reported that plant height was significantly superior under polythene mulch over no mulch at all the crop growth stages during both the years (2005-06 and 2006-07) and in the mean of two years. Silver black mulch recorded the highest TDM 955.0 g, with LAI values exceeding 2.88, demonstrating their effectiveness in promoting growth and biomass production. Other treatments, such as black polythene, green polythene**,** clear polythene, and weed-free conditions, also showed significant improvements in LAI and TDM compared to the control. Plastic mulch and biological mulch might be attributed to control weed, thus providing favorable conditions and have potential to accelerate the vegetative growth. Finding supported by (Rajablariani, & Sheykhmohamady, 2015) reported the highest LAI on white on black plastic (2.8), black plastic (2.7) and blue plastic (2.6). Gul et al. (2009) reported the highest leaf area per plant and leaf area index in the hand weeding and black plastic mulch applied treatment.

3.3 Yield and Yield Attributing Character

Table 3. Yield and Yield attributes of maize as influenced by weed management practices during winter at NMRP, Rampur, Chitwan.

Treatment	plants population per ha	Ear harvested per ha	No. of kernel rows per ear	No. of kernels per row	TWG	GY(kg ha^{-1})	SY (Kg ha^{-1})	HI (%)
Weedy check	50625.00^{bc}	24183.42^{e}	8.53^{c}	9.93^{c}	229.57^{b}	718.18e	1293.37d	29.5
Weedy free	53333.33^{abc}	47500.0^{bc}	12.18^{a}	19.18^{a}	291.87^{a}	3222.74abc	3818.99c	37.6
Green polythene	54166.67^{abc}	51750^{ab}	12.90^{a}	21.10^{a}	309.62^{a}	3834.84abc	4972.75b	36.38
Clear Polythene	57708.33^{ab}	56458.33^{a}	12.65^{a}	22.55^{a}	293.74^{a}	4065.22ab	4453.73bc	40.94
Cowpea co-culture	38541.67^{d}	27569.44^{e}	10.55^{b}	14.85^{b}	269.1^{a}	1073.05de	1682.67d	31.89

Black polythene	60416.67^{a}	49958.33^{b}	12.25^{a}	21.93^{a}	304.43^{a}	4068.20ab	6365.60a	30.86
Atrazine + 1HW	50000.00^{c}	37436.11^{d}	12.00^{a}	19.43^{a}	300.93^{a}	2356.13cd	3783.27c	33.98
Silver black mulch	58125.00^{a}	50625.00^{ab}	13.35^{a}	22.38^{a}	304.81^{a}	4537.50a	6500.00a	38.25
Lantana camera mulch	53958.33^{abc}	43208.33^{cd}	12.55^{a}	20.95^{a}	296.35^{a}	2705.16bc	3637.41c	35.08
SEm (±)	2196.4	2042.8	0.42	1.31	12.35	495.3	284.2	3.35
LSD (=0.05)	6410.8	5962.4	1.24	3.83	36.04	1445.6	829.6	Ns
CV, %	8.3	9.5	7.1	13.7	8.5	33.5	14	19.1
Grand mean	52986.11	43187.66	11.88	19.14	288.94	2953	4056	34.9

Note: Atrazine @ 0.75 kg a.i ha^{-1};TGW (Thousand Grain Weight), GY (Grain Yield), SY (Stover Yield), and HI (Harvest Index) were analyzed using DMRT, and columns represented by the same letter(s) are not significantly different at the 5% level of significance. DAS refers to days after sowing, and ns indicates non-significance

The results revealed significant variations among treatments, with mulching techniques showing superior outcomes compared to weedy and co-culture practices. In (table 3) shows the highest plant population (60,416.67 plants/ha) was recorded under Black Polythene Mulch, followed by Silver Black Mulch (58,125.00 plants/ha) and Clear Polythene Mulch (57,708.33 plants/ha). The increased plant population under these treatments can be attributed to better soil moisture retention, temperature regulation, and weed suppression provided by mulches, which promote germination and seedling establishment. Similar findings have been reported by Sharma et al. (2018), who noted enhanced plant populations under mulching due to improved micro environmental conditions. Conversely, the lowest plant population (38,541.67 plants/ha) was observed under Cowpea Co-culture, likely due to competition for light, water, and nutrients.

In terms of yield components, Clear Polythene Mulch recorded the highest number of kernels per row (22.55) and a high number of kernel rows per ear (12.65), closely followed by Silver Black Mulch (22.38 kernels, 13.35 rows). Mulching provides consistent soil moisture and reduces abiotic stress, which positively influences kernel development (Kara, & Atar, 2013). In contrast, Weedy Check showed the lowest kernel rows per ear (8.53) and kernels per row (9.93), underscoring the adverse impact of uncontrolled weed growth on reproductive performance.

The highest grain yield (4,537.50 kg/ha) was achieved with Silver Black Mulch, followed by Black Polythene Mulch (4,068.20 kg/ha) and Clear Polythene Mulch (4,065.22 kg/ha). The superior performance of these treatments is likely due to the combined effects of improved water-use efficiency, nutrient availability, and reduced weed competition, as also noted by (Gul et al., 2011; Rajablariani, & Sheykhmohamady, 2015). On the other hand, the Weedy Check treatment produced the lowest grain yield (718.18 kg/ha), demonstrating that unchecked weed pressure can drastically reduce yield by competing for critical resources.

The harvest index (HI) was highest for Clear Polythene Mulch (40.94%), followed by Silver Black Mulch (38.25%), indicating efficient partitioning of biomass into grain yield. The lowest HI was observed in the Weedy Check (29.5%), which aligns with its lower grain and stover yields as studied by Shah et al. (2013). The findings support the critical role of effective weed management and mulching in achieving optimal yield and resource use efficiency.

These results collectively emphasize the importance of adopting mulching practices, particularly Silver Black Mulch, to enhance crop productivity. Weed management through mulching not only suppresses weed growth but also improves microclimatic conditions, promoting better crop performance (Sharma et al., 2018). While co-culture systems, such as Cowpea Co-culture, may provide some agronomic benefits, they may not be ideal for maximizing yield in this specific cropping system.

WEED FLORA OBSERVED IN THE EXPERIMENTAL FIELD IN WINTER MAIZE

Weed flora dominating throughout the research were grasses includes: *Cynodon dactylon*, *Digitaria ciliaris*, *Eluesine indica, Echinochloa colonum*, sedges include *Cyperus rotundus, Fimbristylis miliacea*; broad leaf includes *Ageratum conyzoides, Chenopodium album, Brassica tourneforti*, *Amaranthus spinosus, Oxalis corniculata*, *Polygonum plebeium*, *Solanum nigrum*, *Tridex percumbens.* Mean density of weed continue to decrease up to 90 DAS and again increase at harvest while dry weight of weed decreased at 60 DAS and again increased up to harvest.

3.4 Weed Control Efficiency and Weed Control Index

Table 4. Weed Control Efficiency and Weed Control Index as influenced by weed management practices in winter maize at different dates of observations at NMRP, Rampur, Chitwan, Nepal.

	Weed Control Efficiency		Weed Control Index	
Treatment	30 DAS	60 DAS	30 DAS	60 DAS
Green polythene	8.50^{ab} (71.79)	7.72^{a} (60.03)	8.50abc (72.21)	8.46ab (72.41)
Clear polythene	8.48^{ab} (71.85)	6.73^{ab} (47.25)	7.38abc (57.16)	7.42b (55.52)
Cowpea co-culture	4.49^{c} (24.48)	4.52^{bc} (24.43)	2.86d (11.02)	7.07bc (49.51)

Black polythene	9.83a (96.21)	9.52a (90.10)	9.76a (94.79)	9.68a (93.28)
Atrazine+ one hand weeding	6.39bc (42.25)	8.39a (72.67)	6.82bc (48.05)	8.13ab (67.04)
Silverblack mulch	9.78a (95.12)	8.55a (76.86)	9.47ab (89.25)	9.06a (82.57)
Lantana camera mulch	7.84ab (62.21)	2.94c (17.34)	5.92c (39.0)	5.67c (34.64)
SEm (±)	0.676	0.915	0.85	0.5
LSD (=0.05)	2.007	2.72	2.51	1.49
CV, %	17.1	26.5	23.3	12.7
Grand mean	7.9	6.91	7.24	7.93

Note: DAS, Days after sowing; Atrazine 0.75 kg a.i ha^{-1} . Data subjected to square-root (√X+0.5) transformation, and figures in the parenthesis are original values. Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance, ns, non-significant.

Black polythene mulch recorded the highest Weed Control Efficiency (WCE) and Weed Control Index (WCI) values at both 30 and 60 Days After Sowing (DAS), achieving 96.21% (WCE) and 94.79% (WCI) at 30 DAS, and 90.10% (WCE) and 93.28% (WCI) at 60 DAS (Table 4). Similarly, silver-black mulch demonstrated high efficacy, with values of 95.12% (WCE) and 89.25% (WCI) at 30 DAS, 76.86% (WCE), and 82.57% (WCI) at 60 DAS. The above results of this study align with Barche et al. (2015); Mahadeen (2014). Black polythene and silver black mulch works primarily by blocking light, preventing weed seed germination and growth, and has been consistently reported to achieve high levels of weed suppression in various crops. In contrast, *Lantana camara* mulch exhibited moderate weed control at 30 DAS, with 62.21% (WCE) and 39.0% (WCI), but its effectiveness declined significantly by 60 DAS to 17.34% (WCE) and 34.64% (WCI). Similarly, Cowpea co-culture showed the lowest performance at 30DAS and 60 DAS, recording 24.48% (WCE) and 11.02% (WCI) at 30 DAS, and 24.43% (WCE) and 49.51% (WCI) at 60 DAS. *Lantana camara* mulch and cowpea co-culture showed much lower weed suppression, especially as the growing season progressed. *Lantana camara* mulch exhibited only moderate weed control at 30 DAS, with its effectiveness declining sharply by 60 DAS, which is consistent with (Jha et al., 2018), who noted that plant-based mulches such as *Lantana camara* lose their effectiveness over time as they decompose and provide reduced soil coverage. Atrazine combined with one-hand weeding showed moderate weed control, with 42.25% (WCE) and 48.05% (WCI) at 30 DAS, which improved to 72.67% (WCE) and 67.04% (WCI) at 60 DAS. The combination of atrazine and one-hand weeding provided moderate weed control, with a noticeable improvement in efficacy from 30 to 60 DAS, supporting findings by Ibade (2020), who observed that herbicide use, when combined with manual weeding, is more effective than either method alone.

3.5 Weed Persistence Index and Crop Resistance Index

Table 5. Weed Persistence Index and Crop Resistance Index as influenced by weed management practices in winter maize at different dates of observations at NMRP, Rampur, Chitwan, Nepal.

	Weed Persistence Index		Crop Resistance Index	
Treatment	30 DAS	60 DAS	30 DAS	60 DAS
Green polythene	1.21b (0.97)	1.12 (0.85)	2.76b (7.27)	4.54b (22.39)
Clear polythene	1.41ab (1.52)	1.35 (1.61)	2.62b (6.96)	3.22bc (9.97)
Cowpea co-culture	1.31b (1.22)	1.09 (0.70)	1.36b (1.36)	1.78c (2.67)
Black polythene	1.43ab (1.58)	1.11 (0.76)	5.55a (33.03)	8.91a (82.05)
Atrazine + one hand weeding	1.18b (0.91)	1.79 (3.23)	1.84b (3.21)	3.03bc (11.26)
Silver black mulch	1.65a (2.22)	1.29 (1.24)	5.41a (37.76)	7.40a (62.50)
Lantana camera mulch	1.44ab (1.59)	1.22 (1.11)	1.80b(3.11)	2.18c(4.35)
SEm (±)	0.08	0.18	0.75	0.73
LSD (=0.05)	0.24	Ns	2.22	2.18
CV, %	12	30.8	49	33.1
Grand mean	1.37	1.28	3.05	4.44

Note: DAS, Days after sowing; Atrazine 0.75 kg a.i ha^{-1}. Data subjected to square-root (√X+0.5) transformation and figures in the parenthesis are original values. Mean separated by DMRT and columns represented with the same letter (s) are non-significant at a 5% level of significance, ns, non-significant.

The results (Table 5.) showed significant variations in the Weed Persistence Index (WPI) and Crop Resistance Index (CRI) among treatments. At 30 DAS, Silver-black mulch had the highest WPI (1.65), while Atrazine + one hand weeding recorded the lowest (1.18), demonstrating superior early-stage weed suppression. By 60 DAS, differences in WPI among treatments were not significant, but the lowest WPI was observed for Cowpea co-culture (1.09). These findings align with previous studies by Gupta et al. (2019); Garko et al. (2020), which reported similar trends in weed suppression through shading and resource competition.

For CRI, Black polythene and Silver-black mulch consistently outperformed others, with Black polythene achieving the highest CRI values at both 30 DAS (5.55, 33.03%) and 60 DAS (8.91, 82.05%), followed by Silver-black mulch (5.41, 37.76% at 30 DAS and 7.40, 62.50% at 60 DAS). In contrast, Cowpea co-culture recorded the lowest CRI at both time points (1.36, 1.36% at 30 DAS and 1.78, 2.67% at 60 DAS), indicating minimal resistance to weed competition.

4. CONCLUSION

The study highlighted the important role of weed management practices, especially the use of plastic and biological mulches, in improving weed suppression and maize productivity in Chitwan, Nepal. Among the various treatments, silver-black polythene mulch was found to be the most effective, leading to the highest grain yield of 4,537.50 kg ha^{-1}. This success can be attributed to its ability to regulate soil temperature, retain moisture, and create a favorable microclimate for crop growth. Both black polythene mulch and silver-black polythene mulch demonstrated excellent weed control efficiency during the critical growing season (1-8 weeks). Additionally, the black and silver-black mulches showed a higher crop resistance index. Integrated weed management, which included atrazine and hand weeding at 30 days after sowing, produced results comparable to those of the mulch treatments, suggesting it could serve as a viable alternative.

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