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Research Article

Effect of Different Herbicides and Mulches on Yield and Yield Components of Maize Cultivars

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Abstract | Reducing invasive weeds to enhance crop productivity is a major challenge in agriculture. A field study was conducted at the Agricultural Research Institute (ARI), Tarnab, Peshawar, Pakistan, during the 2023 Kharif season to evaluate different weed management strategies. The experiment followed a Randomized Complete Block Design (RCBD) with a split-plot arrangement and three replications. The local maize cultivars (Iqbal, Jalal, and Kaptan) were assigned to main plots, while subplots included weed control treatments: Preclude 58% SE (mesotrione + acetochlor + atrazine), Drigan 55% SC (mesotrione + atrazine), Forum 4% OD (nicosulfuron), sawdust, white plastic mulch, wheat straw mulch, hand weeding once at (30 & 45 days), and a weedy check. Data were collected on weed density (m^{-2}), fresh and dry weed biomass (kg ha^{-1}), plant height (cm), biological yield (kg ha^{-1}), grain yield (kg ha^{-1}), harvest index (%), and cost-benefit ratio (CBR). Results showed that hand weeding once at 30 & 45 days after transplanting (DAT) recorded the lowest weed density (13 m^{-1}), fresh (734 kg ha^{-1}), and dry weed biomass (327 kg ha^{-1}), followed by mesotrione + acetochlor + atrazine herbicide. Among maize cultivars, Kaptan exhibited the least weed density (26 m^{-2}) and highest biological (8220 kg ha^{-1}) and grain yield (3564 kg ha^{-1}). The highest economic return (CBR: 1:3.5) was observed with mesotrione + acetochlor + atrazine, followed by mesotrione + atrazine (1:3.4), nicosulfuron (1:3.2), and hand weeding (1:2.8). Overall, weed management strategies significantly improved yield and economic returns compared to the weedy check. Herbicide application proved cost-effective, while hand weeding remained efficient but labor-intensive. The study recommends timely hand weeding or herbicide application at recommended rates for effective weed control and improved maize yield.

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Introduction

Maize (*Zea mays L.*), a member of the Poaceae family, is an annual, cross-pollinated, short-day plant widely cultivated in temperate and subtropical regions around the world. In Pakistan, it ranks as the third most economically important cereal crop, following wheat and rice. While maize is highly adaptable to diverse soil types and climates, it struggles under extremely hot or arid conditions (PARC, 2017). Maize is a staple food for humans and a highly nutritious feed for livestock, playing a crucial role in global food security. Its grains are rich in essential nutrients, with modern compositional data indicating that maize kernels typically contain 72–73% starch (carbohydrates), 7.6–8.8% protein, 3.6–4.1% fat, 2.3–2.6% crude fiber, and 1.2–1.4% ash (mineral content) (INRAE-CIRAD-AFZ, 2024). These nutritional values highlight maize's importance in both human nutrition and livestock feeding strategies, especially in regions where maize is a dietary staple. Due to its economic significance and versatility, maize is often referred to as the "queen of cereals."

Maize is grown on more than 188 million hectares worldwide, yielding roughly 1,214.47 million metric tonnes with an average productivity of 5.63 tonnes per hectare (USDA, 2022-2023). Compared to the previous year's production of 1,154.99 million tonnes, this year's output is 59.48 million tonnes higher, representing a 5.15% increase in worldwide maize production. "The United States is the world's largest maize producer, producing 370.96 million tonnes from 33.4 million hectares of land, placing first among 176 countries. Other major maize producers are China, Brazil, the European Union, and Argentina. Pakistan produces the 14th most maize in the world. In Pakistan, maize agriculture accounts for 3.5% of total agricultural value added and 0.7% of GDP (PGE, 2025). According to recent reports, maize cultivation increased by 1.0% to 1,419 thousand hectares from 1,405 thousand hectares the previous year. Furthermore, maize production increased by 7.5%, reaching 8.467 million tonnes, compared to the previous year's production of 7.883 million tonnes (Pakistan Economic Survey, 2022-2023). Enhanced area, access to superior seed varieties, and higher financial returns were the primary factors of enhanced maize productivity. Khyber Pakhtunkhwa (KPK) province produced 887.8 thousand tonnes of maize on 475.3 thousand hectares, with an average yield of 1868 kg ha-1 (MNFSR, 2018).

Weeds compete with crops for essential resources such as water, light, nutrients, and carbon dioxide, leading to significant reductions in crop productivity (Korav, 2018). In addition to lowering grain production, they degrade grain quality. Weed infestations, particularly by the invasive Parthenium hysterophorus, pose a significant biological threat to maize cultivation in Pakistan, including the Khyber Pakhtunkhwa (KPK) region, leading to substantial reductions in crop productivity (Hussain *et al*., 2024). Weeds have been observed in maize fields across Khyber Pakhtunkhwa and other regions of Pakistan, encompassing both irrigated and rainfed areas. A diverse array of weed species is commonly encountered in agricultural settings, including broadleaf weeds such as field bindweed (*Convolvulus arvensis L.*), black pigweed (*Trianthema portulacastrum*), and puncture vine (*Tribulus terrestris*) (Anwar *et al*., 2020). Furthermore, grassy weeds like Bermuda grass (*Cynodon dactylon L. Pers*), Egyptian crowfoot grass (*Dactyloctenium aegyptium L.*), barnyardgrass (*Echinochloa crus-galli L. Beauv*), purple nutsedge (*Cyperus rotundus L.*), and yellow nutsedge (*Cyperus esculentus L.*) have been identified as significant contributors to reduced maize productivity in Pakistan (Anwar *et al*., 2020). Recent surveys have documented approximately 93 weed species in maize and wheat crops within Tehsil Sarai Naurang, Khyber Pakhtunkhwa, indicating varying levels of infestation (Ahmad *et al*., 2024).

Weeds present a considerable obstacle to obtaining optimal agricultural production, primarily because they compete for important resources with crops (Kubiak *et al*., 2022). Weed infestations can have a significant impact on maize yields, generating losses ranging from 20% to 40% (Ali *et al*., 2011). Weed infestations can significantly reduce maize yields in Pakistan, with losses ranging from 25% to 50% under typical field conditions. In severe cases, yield reductions may reach up to 70% (Ahmad *et al*., 2021). Effective weed management reduces yield losses and boosts crop productivity. Integrated approaches combining cultural, biological, mechanical, and chemical methods are essential. Although herbicides have largely replaced labor-intensive methods, their overuse raises concern about environmental impact and herbicide resistance (Chauhan & Mahajan, 2014). They increase maize yield by 100–150% and eradicate 65–90% of weeds (Nadeem *et al*., 2006). Weed infestation has increased in Pakistan as a result of sparse pesticide application.

Mulching is a non-chemical weed management approach that involves covering the soil with various materials to prevent weed growth (Ramakrishna *et al*., 2006). Mulch can be organic, such plant leaves, tree bark, and pasture trimmings that help retain nutrients, or inorganic. Polyethylene sheets, stones, gravel, wheat straw and rice husk are good mulching materials for weed control in field crops (Kluepfel, 2010). Mulching not only controls weeds, but it also improves soil health, moisture retention, and biological activity (Rossi *et al.*, 2024). Plastic mulch improves crop yields by 18–52%, enhances soil moisture retention by 30–45%, and suppresses weed growth by up to 90% compared to bare soil (Kasirajan & Ngouajio, 2012; USDA-ARS, 2023; FAO, 2021).

While herbicides are effective for weed control, their excessive use raises environmental concerns. Overreliance on herbicides can lead to the development of herbicide-resistant weed species, soil and water contamination, and adverse effects on non-target organisms, including beneficial insects and soil microorganisms. These issues underscore the importance of adopting integrated weed management practices that combine chemical, cultural, and mechanical methods to ensure sustainable agriculture (Kaur *et al.*, 2024).

This study aimed to examine the effects of various weed management techniques, such as herbicides and mulching, on maize productivity and economic returns. It further evaluated the interaction between weed control methods and maize varieties to identify the most effective and sustainable combination. Ultimately, the goal was to support the development of an integrated weed management strategy that enhances yield while preserving soil health and ecological balance.

Materials and Methods

Experimental site and design

A field experiment entitled "Effect of Different Herbicides and Mulches on Yield and Yield Components of Maize Cultivars" was undertaken at the Agricultural Research Institute (ARI), Tarnab, Peshawar, Pakistan (34.0039892° N, 71.975449° E) during the Kharif season of 2023. The study was set up as a split-plot experiment using a Randomized Complete Block (RCB) design with three replications. Weed management treatments were applied to subplots, while maize cultivars were assigned to the main plots. The subplots measured 5 × 2.5 m^2, with 75 cm row spacing and 25 cm plant-to-plant distance. Standard agronomic practices were maintained consistently throughout the growing season. The climatic conditions during the research period are shown in Figure:1.

Herbicide and mulch treatments

This study was carried out to assess how various mulching treatments and herbicides affected the growth and production of spring maize (*Zea mays L.*). The three varieties of maize employed in the study were Iqbal (V1), Jalal (V2), and Kaptan (V3). Iqbal is known for its high grain yield and drought tolerance; Jalal exhibits robust performance under rainfed conditions and moderate disease resistance; while Kaptan is an early-maturing hybrid with good standability and adaptability to varied agro-ecological zones. Among the herbicide and mulch treatments were Pre-Clude 58% SE (Mesotrione + Acetochlor +

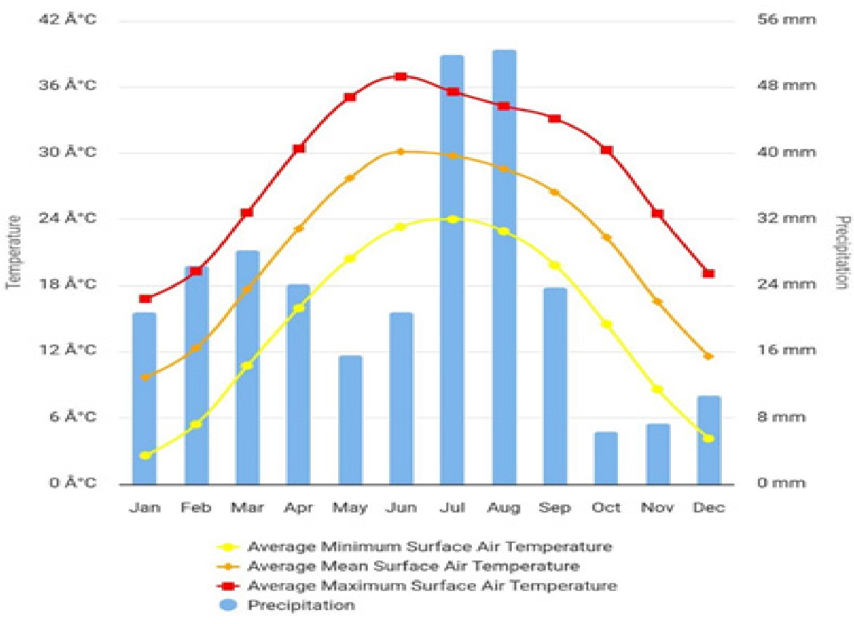

Figure 1: *Climate of the study area during research. Fresh weed biomass (kg ha-1)*

Atrazine) applied at 2.5 L ha^{-1} (T1), Drigan 55% SC (Mesotrione + Atrazine) applied at 1.8 L ha^{-1} (T2), and Forum 4% OD (Nicosulfuron) applied at 1.25 L ha^{-1} (T3) as a post-emergence treatment. Additionally, different mulching techniques were tested, including sawdust mulch (Siouxland Cottonwood) (T4), white plastic mulch (T5), wheat straw mulch (T6), and hand weeding once after (30 & 45 DAT) (T7), along with a weedy check (control) (T8).

The study aimed to determine the most effective combination of maize cultivar, herbicide, and mulch for improved weed control and yield performance.

Crop establishment and management practices

Three widely grown maize cultivars have been obtained from the Cereal Crop Research Institute (CCRI) in Pirsabaq, District Nowshera. Herbicides, plastic mulch, and sawdust were obtained from local Pesticides shop in Peshawar. On June 15, 2023, a hand drill was used to sow the maize cultivars during the Kharif season. Standard agronomic methods were followed, including applying nitrogen (60 kg ha^{-1}) and phosphorus (90 kg ha^{-1}) to the soil before planting. Before the crop reached maturity, it received an additional equivalent dose of nitrogen. The crop was irrigated as needed during its growing cycle. Following seeding, mulch was added, and all herbicides were sprayed at the approved amount. To compare the effectiveness of the treatments, a weedy check treatment was maintained with no weed management techniques. When the maize crop reached maturity, it was manually harvested with a sickle.

Data collection and recorded parameters

Weed density (m^{-2}) was determined by counting weeds in three randomly placed quadrats (50 × 50 cm) per treatment, averaging the values, and converting them to m^2. Fresh weed biomass (kg ha^{-1}) was collected from each quadrat, weighed using an electronic digital balance, and converted to kg ha^{-1}. Dry weed biomass (kg ha^{-1}) was obtained by oven-drying fresh samples at 70°C for 48 hours until a constant weight was achieved. Plant height (cm) at maturity was measured from ten randomly selected plants in each treatment, from the soil surface to the plant tip, and the mean height was recorded.

Biological yield (kg ha^{-1}) was determined by harvesting two middle rows per treatment at crop maturity (90 days) and using the formula:

$$\text{Biological yield (kg ha}^{-1}) = \frac{\text{Biological weight (kg)}}{\text{Area harvested (m}^2)} \times 10000 \text{ m}^2$$

Grain yield (kg ha^{-1}) was recorded after harvesting and shelling cobs from each subplot, calculated using:

$$\text{Grain yield (kg ha}^{-1}) = \frac{\text{Grain yield from net plot (kg)}}{\text{Area harvested (m}^2)} \times 10000 \text{ m}^2$$

The harvest index was recorded by using the following equation:

$$HI = \frac{\text{Grain yield of all field (kg ha}^{-1})}{\text{Biological yield of all field (kg ha}^{-1})} \times 100$$

Cost benefit ratio was computed by using the following formula:

$$CBR = \frac{\text{Added income}}{\text{Added cost}}$$

All measurements were systematically recorded, analyzed, and converted into standard agronomic units for statistical analysis.

Statistical analysis

The data were analyzed using analysis of variance (ANOVA) technique in Statistix 8.1 software. Means were separated using Fisher's the protected LSD test at a 5% probability level, following the procedure described by Steel and Torrie (1980). A P-value of less than 0.05 was considered statistically significant.

Results and Discussion

Weed density (m^{-2})

Data on weed density (m^{-2}) after the application of weed management treatments are presented in Table 1. Two-time hand weeding recorded the lowest weed density (13 m^{-2}), followed by Pre-Clude 58% SE herbicide (18 m^{-2}) and white plastic mulch (19 m^{-2}). Other treatments, including Drigan 55% SC, Forum 4% OD, sawdust, and wheat straw mulch, resulted in weed densities ranging from 21 to 35 m^{-2}. The highest weed density (75 m^{-2}) was observed in the weedy check. Among the maize cultivars, Kaptan had the minimum weed density (26.1 m^{-2}), while Iqbal and Jalal had maximum densities (29.9 and 31.8 m^{-2}, respectively). The interaction between maize cultivars and weed management treatments was also significant (Fig. 2). The least weed density (11 m^{-2}) was noted in the hand-weeding treatment with Kaptan and Iqbal cultivars, while the greatest weed density (82 m^{-2}) was recorded in the control plots with Iqbal. These findings indicate that hand weeding was the most effective method for controlling weeds, followed by Pre-Clude 58% SE herbicide and white plastic mulch. These results align with Bist *et al.* (2023), who reported that manual weeding and herbicide applications effectively reduced weed density and improved maize yield. Similarly, Nandaji (2019) and Yaseen *et al.* (2015) found hand weeding to be more efficient than other methods. Additionally, herbicides and mulches provided effective weed suppression, as demonstrated by Megersa *et al.* (2018).

Table 1: *Influence of various weed control strategies on weed density (m–^{2}) in maize cultivars.*

Treatments	Maize cultivars			Treatments means
	Iqbal	Jalal	Kaptan	
Pre-clude 58% SE	19 jkl	21 ijk	15 m	18 e
Drigan 55% SC	24 hi	21 ij	18 klm	21 d
Forum 4% OD	26 gh	24 hi	18 lm	22 d
Saw dust	28 fg	31 f	27 g	29 c
White plastic	18 jkl	19 jkl	19 jkl	19 e
Wheat straw	28 fg	42 d	35 e	35 b
Hand weeding	11 n	17 lm	11 n	13 f
Weedy check	82 a	78 b	63 c	75 a
Cultivars means	29.9 b	31.8 a	26.1 c	

$LSD_{0.05}$ for cultivars = 1.1854, $LSD_{0.05}$ for treatments = 1.6759, $LSD_{0.05}$ for interaction = 2.4967

Fresh weed biomass (kg ha^{-1})

The results indicated that fresh weed biomass was significantly influenced by maize cultivars, weed management treatments, and their interaction (Table 2). Hand weeding resulted in the minimum fresh weed biomass (734 kg ha^{-1}, followed by Pre-Clude 58% SE and white plastic mulch (844 and 862 kg ha^{-1} respectively), which were statistically similar. Other treatments, including Drigan 55% SC, Forum 4% OD, sawdust, and wheat straw mulches, led to fresh weed biomass ranging from 877 to 1,056 kg ha^{-1}The maximum biomass (1,669 kg ha^{-1}) was recorded in the weedy check treatment. Among the cultivars, Kaptan exhibited the lowest fresh weed biomass (918.9 kg ha^{-1}), while Iqbal and Jalal showed higher values (1,027.8 and 1,043.4 kg ha^{-1} respectively). The interaction (Fig. 3) showed that the combination of hand weeding and the Kaptan cultivar produced in the lowest fresh weed biomass (679 kg ha^{-1}), while the highest biomass (1,840 kg ha–^{1}) was found in the weedy check with Iqbal. These results demonstrate that effective weed management, such as hand weeding and herbicide treatments, significantly reduces fresh weed biomass. Similar findings were reported by Awan *et al.* (2018), Iqbal *et al.* (2020), and Hossain *et al.* (2019), emphasizing the role of timely weed control in minimizing weed biomass. Furthermore, Kaptan superior growth may contribute to its ability to suppress weeds and reduce biomass effectively.

Table 2: *Influence of various weed control strategies on fresh weed biomass (kg ha^{-1}) in maize cultivars.*

Treatments	Maize cultivars			Treat-ments means
	Iqbal	Jalal	Kaptan	
Pre-clude 58% SE	865 ijk	870 ijk	798 kl	844 c
Drigan 55% SC	873 ij	932 ghi	827 jkl	877 c
Forum 4% OD	906 hi	934 ghi	815 jkl	885 c
Saw dust	1050 ef	1123 d	956 gh	1043 b
White plastic	869 ijk	909 hi	808 jkl	862 c
Wheat straw	1060 def	1116 de	991 fg	1056 b
Hand weeding	756 l	767 l	679 m	734 d
Weedy check	1840 a	1692 b	1474 c	1669 a
Cultivars means	1027.8 a	1043.4 a	918.9 b	

$LSD_{0.05}$ for cultivars = 26.024, $LSD_{0.05}$ for treatments = 42.241, $LSD_{0.05}$ for interaction = 73.163

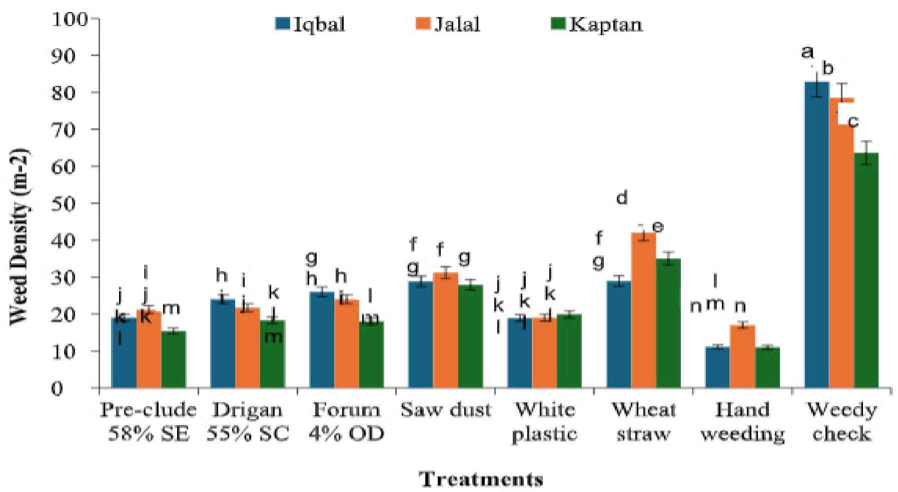

Figure 2: *Interaction of maize cultivars and treatments on weed density (m^{-2}).*

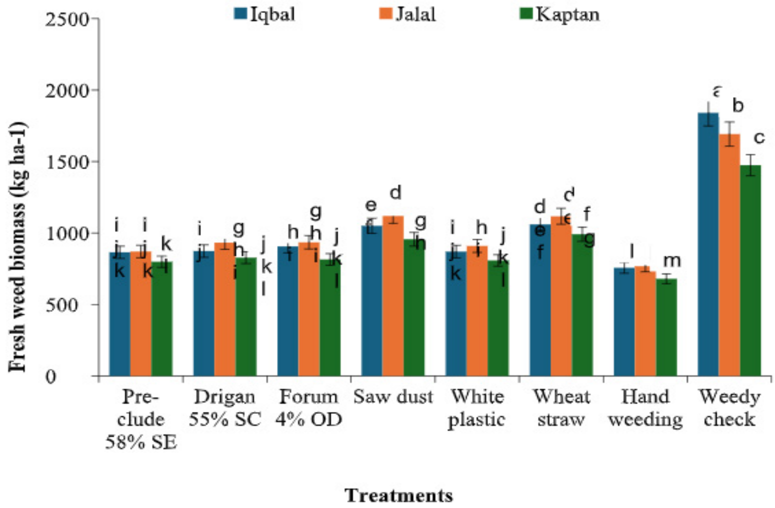

Figure 3: *Interaction of maize cultivars and treatments on fresh weed biomass (kg ha^{-1}).*

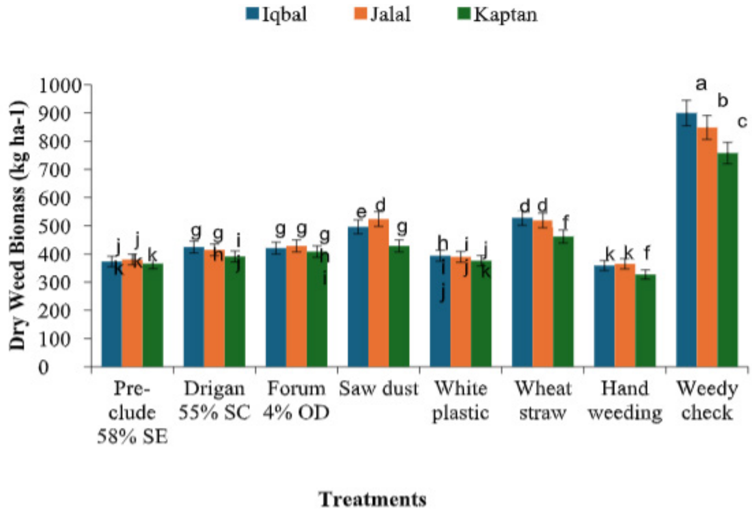

Figure 4: *Interaction of maize cultivars and treatments on dry weed biomass (kg ha^{-1}).*

Dry weed biomass (kg ha^{-1})

Statistical analysis of variance showed significant differences in dry weed biomass among control measures, maize cultivars, and their interactions (Table 3). Hand weeding produced the lowest biomass (350 kg ha^{-1}), followed by Pre-Clude 58% SE herbicide (373 kg ha^{-1}) and white plastic mulch (386 kg ha^{-1}).

The weedy check had the highest biomass (835 kg ha^{-1}). Among cultivars, Kaptan showed the minimum biomass (439.4 kg ha^{-1}), while Iqbal and Jalal had maximum values (486.5 kg ha^{-1}and 483.4 kg ha^{-1}, respectively). The interaction between cultivar and treatment (Figure 4) revealed the lowest biomass in hand-weeded Kaptan (327 kg ha^{-1}) and the highest in the weedy check for Iqbal (899 kg ha^{-1}).

These results suggest that hand weeding and Pre-Clude 58% SE herbicide effectively minimized weed biomass, aligning with previous studies (Awan *et al*., 2018; Triveni *et al*., 2017; Idziak *et al*., 2020; Khatam *et al*., 2013). The higher biomass in the weedy check and Iqbal cultivar was due to uncontrolled weed growth and poor weed competition, respectively. This highlights the importance of effective weed control and selecting cultivars with higher weed suppression for better maize yield potential.

Table 3: *Influence of various weed control strategies on dry weed biomass (kg ha^{-1}) in maize cultivars.*

Treatments	Maize cultivars			Treatments means
	Iqbal	Jalal	Kaptan	
Pre-clude 58% SE	373 jk	380 jk	365 k	373 e
Drigan 55% SC	424 g	414 gh	390 ij	409 d
Forum 4% OD	420 g	428 g	408 ghi	419 d
Saw dust	495 e	523 d	428 g	482 c
White plastic	393 hij	389 ij	375 jk	386 e
Wheat straw	528 d	518 d	461 f	502 b
Hand weeding	358 k	364 k	327 l	350 f
Weedy check	899 a	848 b	757 c	835 a
Cultivars means	486.8 a	483.5 a	439.4 b	

$LSD_{0.05}$ for cultivars = 6.3724, $LSD_{0.05}$ for treatments = 13.495, $LSD_{0.05}$ for interaction = 22.710

Plant height (cm)

The analysis revealed significant differences in plant height among maize cultivars and weed management techniques (Table 4). The tallest plants (211.5 cm) were observed in hand-weeded plots, followed by Pre-Clude 58% SE herbicide (193.8 cm) and white plastic mulch (193.9 cm), which were statistically similar. Other treatments, such as Drigan 55% SC, Forum 4% OD, sawdust, and wheat straw, resulted in intermediate plant heights (172.4 to 191.4 cm). The lowest plant height (159.0 cm) was recorded in the weedy check. Among cultivars, Kaptan had the highest plants (189.2 cm), while Iqbal and Jalal were shorter (181.7 cm and 184.9 cm, respectively). The interaction between cultivars and treatments was non-significant, though the tallest plant height (215.9 cm) was observed in hand-weeded Kaptan, and the shortest (156.8 cm) was noted in the weedy check with Iqbal. Despite differences in biomass among treatments, plant height showed less variation likely due to the genetic potential of the cultivars limiting height growth, and because treatments mainly influenced biomass allocation rather than vertical growth. These findings indicate that hand weeding, Pre-Clude 58% SE herbicide, and white plastic mulch positively impacted plant height, likely by reducing competition for resources.

Table 4: *Influence of various weed control strategies on plant height (cm) in maize cultivars.*

Treatments	Maize cultivars			Treatments means
	Iqbal	Jalal	Kaptan	
Pre-clude 58% SE	190.8	193.7	197.1	193.8 b
Drigan 55% SC	189.0	190.3	195.0	191.4 b
Forum 4% OD	179.6	183.6	188.0	183.7 c
Saw dust	172.2	176.6	180.4	176.4 d
White plastic	189.7	193.4	198.5	193.9 b
Wheat straw	167.9	172.0	177.2	172.4 e
Hand weeding	207.6	211.0	215.9	211.5 a
Weedy check	156.8	158.5	161.7	159.0 f
Cultivars means	181.7 c	184.9 b	189.2 a	

$LSD_{0.05}$ for cultivars = 3.2158, $LSD_{0.05}$ for treatments = 3.5593, $LSD_{0.05}$ for interaction = NS

Biological yield (kg ha^{-1})

The biological yield of maize significantly varied under different weed management practices and cultivars (Table 5). Hand weeding resulted in the maximum biological yield (8937 kg ha^{-1}), followed by Pre-Clude 58% SE (8281 kg ha^{-1}) and Drigan 55% SC (8227.6 kg ha^{-1}). The weedy check had the minimum yield (6967 kg ha^{-1}). Among cultivars, Kaptan produced the highest biological yield (8220 kg ha^{-1}), while Iqbal and Jalal showed lower yields (7864 and 7965 kg ha^{-1}, respectively). The interaction of cultivars and treatments was significant (Fig. 5), with the highest yield (9128 kg ha^{-1}) noted in hand-weeded Kaptan, and the lowest (6778 kg ha^{-1}) in the weedy check with Iqbal. Kaptan likely performed better due to its early vigor and favorable canopy architecture, which enhance light interception and nutrient uptake, giving it a competitive advantage over weeds. Additionally, Kaptan's genetic traits may contribute to more efficient biomass production under effective weed control.

These results suggest that hand weeding and Pre-Clude 58% SE herbicide were most effective in increasing biological yield, likely due to effective weed control. In contrast, the weedy check led to reduced yields due to competition for nutrients, light, and space. Our findings align with Shrestha *et al.* (2018), Kumar *et al.* (2017) and Lukangila *et al.* (2024), who observed that hand weeding and herbicides significantly reduced weed populations and improved maize yield.

Grain yield (kg ha^{-1})

The data in Table 6 show a significant effect of weed management practices and maize cultivars on grain yield. Hand weeding noted in the greatest grain yield (4273 kg ha^{-1}), followed by Pre-clude 58% SE (3976 kg ha^{-1}) and white plastic mulch (3886 kg ha^{-1}).

Table 5: *Influence of various weed control strategies on biological yield (kg ha^{-1}) in maize cultivars.*

Treatments	Maize cultivars			Treat-ments means
	Iqbal	Jalal	Kaptan	
Pre-clude 58% SE	8125 hij	8181 gh	8538 d	8281 b
Drigan 55% SC	8080 ijk	8240 fg	8362 e	8227 c
Forum 4% OD	8002 l	8056 jkl	8309 ef	8122 d
Saw dust	7661 n	7672 n	8005 kl	7779 e
White plastic	8106 hij	8149 hi	8357 e	8204 c
Wheat straw	7408 p	7549 o	7874 m	7610 f
Hand weeding	8752 c	8933 b	9128 a	8937 a
Weedy check	6778 s	6940 r	7185 q	6967 g
Cultivars means	7864 c	7965 b	8220 a	

$LSD_{0.05}$ for cultivars = 52.670, $LSD_{0.05}$ for treatments = 37.876, $LSD_{0.05}$ for interaction = 79.944

Other treatments like Drigan 55% SC, Forum 4% OD herbicide, wheat straw, and sawdust mulch produced intermediate yields (2847 to 3792 kg ha^{-1}), while the weedy check produced the smallest yield (2394 kg ha^{-1}). Among cultivars, Kaptan produced the highest grain yield (3564 kg ha^{-1}), while Iqbal and Jalal produced the lowest yields (3380 and 3465 kg ha^{-1}, respectively).

The interaction between cultivars and treatments was significant, with the maximum grain yield (4384 kg ha^{-1}) recorded in hand-weeded Kaptan, and the minimum (2306 kg ha^{-1}) in the weedy check x Iqbal interaction (Fig. 6). Effective weed management, particularly hand weeding and herbicide application, reduced weed competition, allowing maize to absorb nutrients and resources more efficiently, resulting in higher grain yield. These results are consistent with Olubunmi *et al.* (2023), Tanveer *et al.* (2015), and Sharma *et al.* (2018), who found that weed control significantly enhanced maize productivity. The weedy check, with uncontrolled weed growth, led to reduced yield, as noted by Khan *et al.* (2012b).

Table 6: *Influence of various weed control strategies on grain yield (kg ha^{-1}) in maize cultivars.*

Treatments	Maize cultivars			Treat-ments means
	Iqbal	Jalal	Kaptan	
Pre-clude 58% SE	3874 f	3938 e	4117 c	3976 b
Drigan 55% SC	3720 i	3813 gh	3842 fgh	3792 d
Forum 4% OD	3586 k	3650 j	3725 i	3654 e
Saw dust	2866 no	2920 mn	3018 l	2935 f
White plastic	3792 h	3866 fg	4000 d	3886 c
Wheat straw	2760 p	2842 o	2938 m	2847 g
Hand weeding	4133 c	4304 b	4384 a	4273 a
Weedy check	2306 s	2386 r	2490 q	2394 h
Cultivars means	3380 c	3465 b	3564 a	

$LSD_{0.05}$ for cultivars = 18.041, $LSD_{0.05}$ for treatments = 35.200, $LSD_{0.05}$ for interaction = 59.622

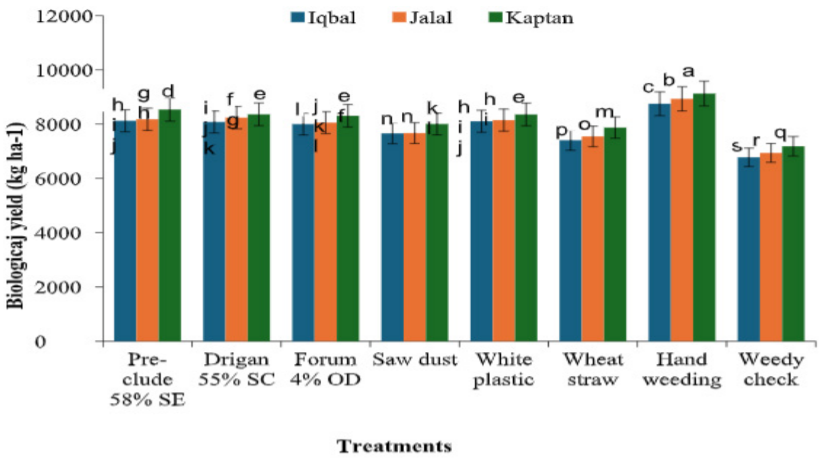

Figure 5: *Interaction of maize cultivars and treatments on biological yield (kg ha^{-1}).*

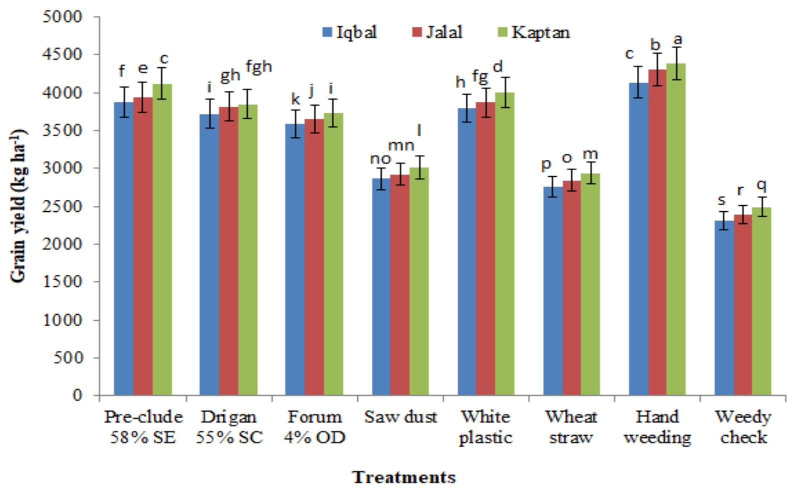

Figure 6: *Interaction of aize cultivars and treatments on grain yield (kg ha^{-1}).*

Harvest index (%)

According to Table 7, the harvest index (%) was significantly influenced by weed management treatments and maize cultivars. The lowest harvest index (34%) was observed in the weedy check treatment, followed by wheat straw and sawdust mulch (37%), which were statistically similar. Intermediate harvest indices (44 to 47%) were recorded for Drigan 55% SC, Forum 4% OD herbicide, white plastic mulch, and hand weeding, with the highest value (48%) noted in the Pre-clude 58% SE herbicide treatment. Among cultivars, Jalal and Kaptan recorded the maximum harvest index (43%), while Iqbal had the minimum (42%). The interaction of cultivars and treatments was non-significant, with the least harvest index (34%) observed in the weedy check x Iqbal, Jalal, and Kaptan cultivars, and the highest (47%) in Pre-clude 58% SE and hand weeding x Jalal and Kaptan. The results highlight the significant impact of hand weeding and herbicide treatments on the harvest index, as both effectively managed weeds and enhanced crop productivity. These findings align with Megersa *et al.* (2018), who reported that effective weed control, including hand weeding and herbicide application, improved plant growth and harvest index. Additionally, white plastic mulch also increased the harvest index compared to wheat straw and sawdust mulches, consistent with Asif *et al.* (2020).

Table 7: *Influence of various weed control strategies on harvest index (%) in maize cultivars.*

Treatments	Maize cultivars			Treatments means
	Iqbal	Jalal	Kaptan	
Pre-clude 58% SE	47	48	48	48 a
Drigan 55% SC	46	46	45	46 c
Forum 4% OD	44	45	44	44 d
Saw dust	37	38	37	37 e
White plastic	46	47	47	47 b
Wheat straw	37	37	37	37 e
Hand weeding	47	48	48	47 ab
Weedy check	34	34	34	34 f
Cultivar means	42 b	43 a	43 a	

$LSD_{0.05}$ for cultivars = 0.2969, $LSD_{0.05}$ for treatments = 0.5101, $LSD_{0.05}$ for interaction = 0.8747

Cost-benefit ratio

The cost-benefit ratio (CBR) of various weed management techniques, including herbicides, mulches, hand weeding, and the weedy check, was calculated. Table 8 summarizes the results, which demonstrate that all approaches significantly influenced crop production and varied in cost. Pre-Clude 58% SE herbicide reported the greatest CBR (1:3.5), followed by Drigan 55% SC (1:3.4) and Forum 4% OD herbicide (1:3.2), as well as hand weeding twice (1:2.8). The minimum CBR (1:1.4) was observed in white plastic mulch (Table 9). The use of herbicides and manual weeding increased farmer income, whereas mulches, despite their cost, negatively affected maize output. The highest gross income (Rs 285,175) was obtained from the Kaptan cultivar, followed by Jalal (Rs 277,224) and the smallest (Rs 270,400) from Iqbal. The highest CBR (1:3.2) for maize cultivars was noted with Drigan 55% SC, Pre-Clude 58% SE, and Forum 4% OD herbicides, followed by manual weeding (1:2.3) in Kaptan cultivar (Table 10). The least CBR (1:1.2) was found in white plastic mulch with Iqbal cultivar (Table 11). The economic analysis suggests that herbicide treatments and hand weeding are more cost-effective than mulching for weed management. These findings align with Megersa *et al.* (2018), Ehsas *et al.* (2016), and Iqbal *et al.* (2020), who emphasized the cost-effectiveness of herbicides and hand weeding in maize weed management.

Table 8: *Influence of various weed control strategies on maize yield cost-benefit ratio ha^{-1}.*

Treatments	Gross income	Added cost	Net profit	CBR
	(Rs)	(Rs)	(Rs)	
Pre-clude 58% SE	318152	88500	229652	1 : 3.5
Drigan 55% SC	303360	87250	214860	1 : 3.4
Forum 4% OD	292336	88750	203586	1 : 3.2
Saw dust	234808	133706	101102	1 : 1.7
White plastic	310896	220333	90563	1 : 1.4
Wheat straw	227760	131400	96360	1 : 1.7
Hand weeding	341904	119000	222904	1 : 2.8
Weedy check	191576	83000	108576	1 : 2.3

Table 9: *Influence of various weed control strategies on iqbal maize cultivar yield cost-benefit ratio ha^{-1}.*

Treatments	Gross income (Rs)	Added cost (Rs)	Net profit (Rs)	CBR
Pre-clude 58% SE	270400	88500	181900	1 : 3.0
Drigan 55% SC	270400	87250	183150	1 : 3.0
Forum 4% OD	270400	88750	181650	1 : 3.0
Saw dust	270400	133706	136690	1 : 2.0
White plastic	270400	220333	50067	1 : 1.2
Wheat straw	270400	131400	139000	1 : 2.0
Hand weeding	270400	119000	151400	1 : 2.2

Table 10: *Influence of various weed control strategies on jalal maize cultivar yield cost-benefit ratio ha^{-1}.*

Treatments	Gross income (Rs)	Added cost (Rs)	Net profit (Rs)	CBR
Pre-clude 58% SE	277224	88500	188724	1 : 3.1
Drigan 55% SC	277224	87250	189974	1 : 3.1
Forum 4% OD	277224	88750	188474	1 : 3.1
Saw dust	277224	133706	143518	1 : 2.0
White plastic	277224	220333	56891	1 : 1.2
Wheat straw	277224	131400	145824	1 : 2.1
Hand weeding	277224	119000	158224	1 : 2.3

Table 11: *Influence of various weed control strategies on kaptan maize cultivar yield cost-benefit ratio ha^{-1}.*

Treatments	Gross income (Rs)	Added cost (Rs)	Net profit (Rs)	CBR
Pre-clude 58% SE	285176	88500	196676	1 : 3.2
Drigan 55% SC	285176	87250	197926	1 : 3.2
Forum 4% OD	285176	88750	196426	1 : 3.2
Saw dust	285176	133706	151470	1 : 2.1
White plastic	285176	220333	64843	1 : 1.2
Wheat straw	285176	131400	153776	1 : 2.1
Hand weeding	285176	119000	166176	1 : 2.3

Correlation coefficients

The correlations between variables, including weed density, fresh and dried weed biomass, biological yield, grain yield, and harvest index, are depicted in this correlation matrix. Red ellipses represent positive correlations, whereas blue ellipses indicate negative correlations (Figure 7). The correlation strength is reflected in the ellipse form and color intensity. The strong positive correlation (around 1.0) between weed density and fresh and dry weed biomass indicates that these variables rise in proportion. However, there are significant negative relationships between weed-related metrics and harvest index, grain yield, and biological yield, suggesting that increased weed biomass or density harms crop productivity.

Grain yield correlates well with the harvest index (0.98), while biological yield and grain yield have a strong positive correlation (0.96) among agricultural productivity metrics. Due to the significant inhibitory effects of weed presence on biological and grain yields and harvest index, the overall pattern emphasizes the importance of reasonable weed control.

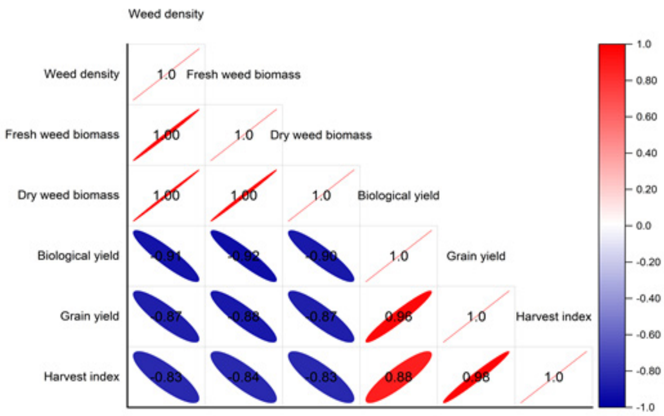

Figure 7: *Correlation coefficients (Pearson's correlation) of the studied observations.*

Conclusions and Recommendations

The findings of this study suggest that herbicides, particularly Pre-Clude 58% SE and Drigan 55% SC, were among the most effective weed control strategies under the conditions tested, leading to improved maize grain yield and favorable cost-benefit ratios. While hand weeding also demonstrated strong performance in suppressing weeds and enhancing productivity, it was comparatively less economical due to its labor-intensive nature.

Among the maize cultivars evaluated, Kaptan exhibited the highest productivity and economic returns, indicating its potential suitability for regions with similar agro-climatic conditions. Mulching methods, especially white plastic mulch, also contributed to weed suppression and yield improvements, though their higher cost may limit widespread adoption when compared to chemical or manual control methods.
Overall, this study highlights that integrated weed

management approaches combining effective herbicide use or manual weeding with suitable maize cultivars can improve productivity and profitability in maize cultivation. Under the conditions of this experiment, Pre-Clude 58% SE, Drigan 55% SC, and the Kaptan cultivar appear to offer promising options. However, further multi-season trials and broader field evaluations are recommended to confirm these findings and enhance their applicability across different environments.

Novelty Statement

This study evaluates several weed control strategies, such as herbicides, mulches, and hand weeding, among maize cultivars, focusing on their impact on yield, harvest index, and cost-benefit ratio. It shows the efficacy of herbicides such as Pre-Clude 58% SE and Drigan 55% SC, as well as the Kaptan cultivar, and provides practical recommendations for increasing maize productivity and economic returns.

Author's Contribution

Muhammad Saddique: Conducted the experiment, collected and analyzed the data, prepared visualizations, and wrote the manuscript.
Ijaz Ahmad Khan: Conceived, planned, and supervised the research.
Muhammad Fawad: Reviewed and edited the manuscript for clarity and structure.
Meher Ali: Assisted in data analysis and contributed to the interpretation of the results.

Conflict of Interest
No conflict of interest exists.

References

Ahmad, M., H.U. Jan, K. Raina, N. Shafiq, S.M. Shah, M. Ibrahim, S. Buddin and G. Parveen. 2024. Ethnobotanical profile of diverse weed flora in maize and wheat crops of Tehsil Sarai Naurang, Khyber Pakhtunkhwa, Pakistan. Pak. J. Weed Sci. Res., 30(2): 75-85.

Ahmad, H., M. Shafi, W. Liaqat, M.F. Jan, S. Ahmad and M. Farooq. 2021. Weeds performance in maize crop against different tillage and weed management practices. Pak. J. Weed Sci. Res., 27(1): 51–66. https://doi.org/10.28941/pjwsr.v27i1.892

Ali, K., F. Munsif, Z. Husain, I.A. Khan and N. Khan. 2011. Effect of different weed control methods on weeds and maize grain yield. Pak. J. Weed Sci. Res., 17(4): 313-21.

Anwar, M., N. Akhtar, S. Khalid and H. Zeb 2020. Eco-floristic study of weed flora of maize crop in district Swabi, Khyber Pakhtunkhwa, Pakistan. Pak. J. Weed Sci. Res., 26(4): 421-429. https://doi.org/10.28941/pjwsr.v26i4.815

Asif, M., M.A. Nadeem, M.A. Aziz, M.E. Safdar, M. Adnan, A. Ali and B. Abbas. 2020. Mulching improves weeds management, soil carbon and productivity of spring planted maize (*Zea mays L.*). Int. J. Bot. Stud., 5(2): 57-61.

Awan, D.A., F. Ahmad and S. Ashraf. 2018. Effective weed control strategy in tomato kitchen gardens–herbicides, mulching or manual weeding. Curr. Sci., 114(6): 1325-1329 https://doi.org/10.18520/cs/v114/i06/1325-1329.

Bist, D., K. Somai, S. Acharya, P. Acharya, S. Adhikari, U. Tiwari and M. Regmi. 2023. Effect of different weed management practices on production of spring maize in Dang, Nepal. Arch. .Agric. Environ. Sci., 8(2): 150-156. https://doi.org/10.26832/24566632.2023.080209

Chauhan, B.S and G. Mahajan. 2014. Recent advances in weed management. Springer., https://doi.org/10.1007/978-1-4939-1019-9

Ehsas, J., L.J. Desai, N.B. Ahir and J.R. Joshi. 2016. "Effect of integrated weed management on growth, production, and production attributes and weed parameters on summer maize (*Zea mays L.*) under South Gujarat condition," Int. J. Sci. Environ. Technol., 5(4): 2050–2056.

FAO. 2021. Assessment of agricultural plastics and their sustainability: A call for action. www.fao.org

Hussain, I., M.I.U. Qaisrani, A.A Khakwani, Z. Hasnian, U.K Saddozai, M. Naeem, H. Gul and M. Abbass. 2024. Response of maize (*Zea mays L.*) to Parthenium hysterophorus mixed soil under climatic condition of Dera Ismail Khan, KP, Pakistan. Pak. J. Weed Sci. Res., 30(1): 01-06.

Hossain, A., M.T. Islam, M.S. Islam, S. Ahmed, K.K. Sarker and M.K. Gathala. 2019. Chemical weed management in maize (*Zea mays L.*) under conservation agricultural systems: An Outlook of the Eastern Gangetic Plains in South-Asia

[Online First]. In Maize - Production and Use. IntechOp., pp 1-14. https://doi.org/10.5772/intechopen.89030

Idziak, R. and Z. Woznica. 2020. Efficacy of reduced rates of soil applied dimethenamid-P and pendimethalin mixture followed by post emergence herbicides in maize. Agric., 10: 163.

INRAE-CIRAD-AFZ, 2024. Feed tables: Composition and nutritive values of feeds for cattle, sheep, goats, pigs, poultry, rabbits, horses and salmonids. Feedipedia, a programme by INRAE, CIRAD, AFZ and FAO. Retrieved from https://www.feedtables.com/ https://doi.org/10.3390/agriculture10050163

Iqbal, S., S. Tahir, A. Dass, M.A. Bhat and Z. Rashid. 2020. Bio-efficacy of pre-emergent herbicides for weed control in maize: a review on weed dynamics evaluation. Int. J. Exp. Agric., 42(8): 13–23. https://doi.org/10.9734/jeai/2020/v42i830565

Kaur, A., G. Singh, S. Menon and K. Kumari. 2024. Integrated Weed Management: A Comprehensive Review of Conventional, Non-Conventional, and Emerging Strategies for Sustainable Agriculture. J. Advan. Biol. Biotechnol., 27:156-167. https://doi.org/10.9734/jabb/2024/v27i81130

Kasirajan, S. and M. Ngouajio. 2012. Polyethylene and biodegradable mulches for agricultural applications: A review. Agron. Sustain. Develop., 32: 501-529. https://doi.org/10.1007/s13593-011-0068-3

Khan, N., N.W. Khan, S.A. Khan, M.A. Khan and K.B. Marwat. 2012b. Combined effect of nitrogen fertilizers and herbicides upon maize production in Peshawar. J. Anim. Plant Sci., 22(2): 12-7.

Khatam, A., M.Z. Khan, K. Nawab, I.A. Mian and W. Ahmad. 2013. Effect of various herbicides and manual control yield, yield components and weeds of maize. Pak. J. Weed Sci. Res. 19(2): 209-216.

Kluepfel, M. 2010. http://www.savvygardener.com/Features/mulch.html.

Kubiak, A., A. Wolna-Maruwka, A. Niewiadomska and A.A. Pilarska. 2022. The Problem of Weed Infestation of Agricultural Plantations vs. the Assumptions of the European Biodiversity Strategy. Agron., 12(8): https://doi.org/10.3390/agronomy12081808

Kumar, B., S. Prasad, D. Mandal and R. Kumar. 2017. "Influence of integrated weed management practices on weed dynamics, productivity and nutrient uptake of rabi maize (*Zea mays L.*)," Int. J. Current Microbi. Appl. Sci., 6(4): 1431–1440. https://doi.org/10.20546/ijcmas.2017.604.175

Korav, S. 2018. A study on crop weed competition in field crops. J. Pharmacogn. Phytochem., 7(3), 123-127

Lukangila, M.A.B., H.I. Tabu, D.B. Mugisho, A.K. Lubobo and A.K.M. Wa Mbombo. 2024. Evaluating the effects of manual hoeing and selective herbicides on maize (*Zea mays* L.) productivity and profitability. Heliyon, 10(13): e33294. https://doi.org/10.1016/j.heliyon.2024.e33294.

Nadeem, M.A., M.S. Tufail and M. Tahir. 2006. Effect of different herbicides on growth and yield of spring maize (*Zea mays L.*). Proceedings of the International Symposium on Sustainable Crop Improvement and Integrated Management, Faisalabad: University of Agriculture, pp. 72-76.

Megersa K., B. Gudeta and A. Fufa. 2018 "Integration of glyphosates and hand weeding for weeds management in maize (*Zea mays. L*)," Agri. Res. Technol., 18(5): 55-60 https://doi.org/10.19080/ARTOAJ.2018.18.556075

MNFSR, 2017-2018. Agricultural Statistics of Pakistan. Ministry of National Food Security and Research (Economic Wing), Government of Pakistan, Islamabad., pp. 18-19.

Nandaji, J.J. 2019. Efficacy of Different Pre and Post Emergence Herbicides on Weed Control in Maize (*Zea mays L.*). Department of Agronomy. Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra.

Olubunmi, A., O. Amosun, O. Julius, D. Adewumi and K. Odunaye. 2023. Increasing Array of Herbicides for Post-emergence Weed Control and Seed Yield in Maize (*Zea mays L*). Int. J. Exp. Agric., 45: 1-8. https://doi.org/10.9734/jeai/2023/v45i62120

PARC, 2017. Pakistan Agricultural Research Council, Islamabad. http://www.pakistan.com.allabout/crops/maize

PES, 2022-2023. Pakistan Economic Survey, Islamabad. https://www.pbs.gov.pk/ content/agriculture-statistics.

Pakistan Gulf Economist, 20, January. 2025. Pakistan agriculture grows 6.25% in

FY2023–24. Retrieved from https://www.pakistangulfeconomist.com/2025/01/20/pakistan-agriculture-grows-6-25-in-fy2023-24

Ramakrishna, S., H.M. Tam, S.P. Wani and T.D. Long. 2006. Effect of mulch on soil temperature, moisture and weed infestation and yield of groundnut in Northern Vietnam. Field Crop. Res., 95(2-3): 115-125 https://doi.org/10.1016/j.fcr.2005.01.030

Rossi, G., C. Beni and U. Neri. 2024. Organic Mulching: A Sustainable Technique to Improve Soil Quality. Sustain.,16(23): 10261. https://doi.org/10.3390/su162310261

Sharma, S., S. Marahattha, S.K. Sah and T.B. Karki. 2018. Efficacy of different tillage and weed management practices on phenology and yield of winter maize (*Zea mays L.*) in Chitwan, Nepal. Inte. J. Plant Soil Sci., 26(2): 1-11. https://doi.org/10.9734/IJPSS/2018/44398

Shrestha, A., R.B. Thapa, M. Devkota and R. Subedi. 2018. Comparative Efficiency of Different Weed Management Practices on Yield and Economic in Summer Maize in Dang. Advan. Crop Sci. Technol., 6(02): 41-72

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach. 2nd Ed. McGraw Hill Book Co. Inc. New York., pp. 232-251.

Tanveer., A., S. Ahmad, R.N. Abbas, M. Zafar, H.H. Ali and M. Buriro. 2015. Field validation of ammonium sulphate as an activator adjuvant on bromoxynil+ MCPA+ metribuzin efficacy against maize weeds. Pak. J. Weed Sci. Res., 20(2): 283-293.

Triveni, U., Y.S. Rani, T. Patro and M. Bharathalakshmi. 2017. Effect of different pre and post-emergence herbicides on weed control, productivity and economics of maize. Ind. J. Weed Sci., 49(3): 231-235. https://doi.org/10.5958/0974-8164.2017.00061.2

USDA-ARS 2023. Plasticulture research and its impact on crop production. www.ars.usda.gov

USDA, 2022-2023. Unit. State. Depart. Agric., http://www.worldagriculturalproduction.corn

Yaseen, T., W. Ullah, M. Ahmad, K. Ali and M. Amin. 2015. Effect of tillage and weed control methods on weeds density and tomato (*Lycopersicon esculentum*) productivity. Pak. J. Weed Sci. Res., 21(2): 105-113.