Research Article

Management of Wild Onion (*Asphodelus tenuifolius* Cav.) in Chickpea Crop at District Karak

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Abstract | The study aims to investigate the management of noxious weed (*Asphodelus tenuifolius* Cav.) in chickpea growing areas of District Karak, Khyber Pakhtunkhwa-Pakistan. A Randomized Complete Block (RCB) design with three replicates and various weed management practices were implemented. The treatments include; different herbicides (Pendimethalin, dual gold and fenxaprop-p-ethyl), mulches (Black polythene, white polythene and available weed biomass) and allelopathic weed extracts (*Asphodelus tenuifolius* Cav., *Convolvulus arvensis* L. and *Lathyrus* sp.) compared with control treatment. The study parameters include; weed density (m^{-2}) before and after application, fresh and dry weight (m^{-2}) of *A. tenuifolius* Cav., plant height (cm), number of nodes and branches $plant^{-1}$, leaf area index (LAI), number of pods $plant^{-1}$, number of grains pod^{-1}, 500 seed weight (g), biological yield ($kgha^{-1}$), grain yield ($kgha^{-1}$) and cost benefit ratio (%).The data analysis revealed that the herbicide Pendimethalin showed the lowest *A. tenuifolius* Cav. density (6.10 m^{-2}), fresh weight (1.30 kgm^{-2}) and dry weight (0.43 kgm^{-2}) , while the control plots had the highest density, fresh weight and dry weight of *A. tenuifolius* Cav. Data regarding chickpea parameters, Pendimethalin showed the maximum plant height (46.66 cm), number of nodes (32.33 $plant^{-1}$), number of branches (10.33 $plant^{-1}$), leaf area index (1.85), number of pods (31.66 $plant^{-1}$, number of grains (2.00 pod^{-1}), 500 seed weight (165.46 g), biological yield (4532.9 $kgha^{-1}$), grains yield (1438.2 $kgha^{-1}$), and cost benefit ratio (1:3.1). Whereas, the lowest values for these parameters were observed in the control plots. Based on the results, it can be concluded that Pendimethalin herbicide was the most effective in controlling *A. tenuifolius* Cav. that has significantly increased the yield and yield components of chickpea. Fenoxaprop-p-ethyl also showed positive effects on weed control and chickpea yield, although to a lesser extent than Pendimethalin. The study highlights the importance of using appropriate weed control methods to enhance crop productivity and reduce weed competition in chickpea cultivation. However, it is essential to consider factors like herbicide resistance, environmental impacts, and sustainability while formulating weed management strategies in agricultural practices. Further research may be needed to optimize the application of different treatments and to explore additional weed management techniques to maintain effective weed control in the long term.

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Introduction

Chickpea (*Cicer arietinum* L.), also known as gram, is a crop that is cultivated in subtropical and warm climate regions worldwide. It is one of the most important pulse crops and is considered the second-largest crop grown among pulses globally (Pang *et al*., 2017). It is highly nutritious and is a staple food for large populations in many countries. Chickpea is recognized for its nutritional value and is a rich source of proteins, carbohydrates, minerals, vitamins, and dietary fibers. It is particularly valued for its high protein content, which makes it an important source of plant-based protein for vegetarians. The protein content in chickpea ranges from 15% to 24%, depending on the variety. (Muehlbauer and Sarker, 2017; USDA, 2021). In addition to their nutritional value, chickpea also play a significant role in the sustainability of agroecosystems. One of the key contributions of chickpea is their ability to fix atmospheric nitrogen (Dutta *et al*., 2022).

More than 50 countries are growing chickpea on an area of 13.98 million hectares with 13.73 metric tonnes production with major production share from India (66.3%), followed by Australia (6.2%), Pakistan (5.7%), Turkey (3.9%) and Burma (3.7%) (FAOSTAT, 2021). Pakistan is one of the top three contributors to chickpea production globally. In Pakistan, chickpeas are cultivated on a significant area of 936.2 thousand hectares. Among the provinces in Pakistan, Punjab plays a major role in chickpea cultivation. During the 2020-2021 cropping season, Punjab alone accounted for 855 thousand hectares of chickpea cultivation, which is approximately 91% of the total chickpea area grown in the country. The province Khyber Pakhtunkhwa produced 18.6 thousand tonnes of chickpeas on 29 thousand hectares of land, with an average grain yield of 643 kg ha^{-1} (Pakistan Bureau of Statistics, 2020).

For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. Certainly, Khyber Pakhtunkhwa is an important region in Pakistan for chickpea cultivation, and chickpeas are one of the significant pulse crops grown there. However, the average yield of chickpea in Pakistan is relatively low compared to other chickpea-producing countries worldwide, and one of the main reasons for this is weed infestation. Weeds pose a significant challenge to chickpea productivity in Pakistan. Chickpeas have a slow growth rate and limited leaf area development during the early stages of crop growth, making them poor competitors against weeds (Merga and Alemu, 2019). Yield losses in chickpea due to weed competition can be significant, and studies have shown that these losses can reach up to 38%. The initial 60 days after sowing are considered a critical period for weed-crop competition in chickpea (Chandrakar and Raj, 2018).

A wide range of weeds are found in chickpea in rain fed areas. A list of major weeds includes *Asphodelus tenuifolius* Cav., *Carthamus oxycantha* M. Bieb., *Medicago denticulata* Willd., *Anagallis arvensis, Lathyrus aphaca* L. *Euphorbia helioscopia* L., *Convolvulus arvensis* L., *Cyprus rotundus, Vicia sativa* L. Ehrh., *Cynodon dactylon* L. Pers. and *Fumaria indica* Hausskn. *A. tenuifolius* Cav. is a very harmful, and noxious weed in chickpea, wheat, mustard, linseed and lentil in Pakistan (Riaz *et al*., 2021). *A. tenuifolius* Cav. is certainly an aggressive weed species that commonly occurs in the sandy zones of Pakistan. It poses a significant challenge to chickpea cultivation as it competes with the crop throughout the growing season. Studies have shown that this weed species can cause an average yield loss of 45% annually in the sandy zones of Pakistan (Khan *et al*., 2011). Conducting field experiments to evaluate different weed management techniques is crucial for developing effective strategies that can be recommended to farmers. These experiments help researchers and agronomists assess the performance and impact of various weed management methods under different conditions. By comparing different techniques, they can determine the most suitable and efficient approaches for controlling weeds in chickpea crops (Merga and Alemu, 2019).

Implementing integrated weed management in chickpea cultivation involves the integration of cultural practices and herbicide application, which can lead to sustainable and effective weed control while minimizing the reliance on herbicides alone. This approach helps promote long-term weed management strategies that are economically viable, environmentally friendly, and tailored to the specific needs of chickpea growers (Merga and Alemu, 2019).

Objectives

1. To figure out the most suitable natural and/or synthetic herbicides for these weeds.
2. To transfer the generated technology to end user through extension department Karak i.e chickpea growers of Khyber Pakhtunkhwa.

Materials and Methods

Different experiments were conducted at farmer fields in Karak which is the major chickpea growing area of KPK. The experiments were conducted in a randomized complete block (RCBD) design with three replications. Each replication size was 10m x 3m. The experiment was comprising of evaluation of the efficacy of different chickpea herbicides viz: Pendimethalin, Dual gold and Fenaxaprop-p-ethyl.

Biochemical treatments including allelopathic extract of *Asphodelus tenuifolius* Cav., *Convolvulus arvensis* L. and *Lathyrus* spp. These biochemical herbicides are environment friendly with low costs that were collected from chickpea growing areas. Plants were cut from base with the help of stickle. The collected samples were washed with tap water and then dried in shade. The dried weed samples were grinded with the help of grinder and made from each sample and applied for testing the herbicidal efficacy of the extracts.

Mulching materials including black plastic, white plastic and weeds leaves (whichever available in the season and locality) were included in the proposed field trails.

Treatments

T_1: Control (For comparison)
T_2: Herbicides (Pendimethalin)
T_3: Herbicides (Dual gold)
T_4: Herbicides (Fenxaprop-e-ethyl)
T_5: Mulching (Black) polythene
T_6: Mulching (White) polythene
T_7: Mulching (Available weed biomass)
T_8: Allelopathic weed extract (*Asphodelus tenuifolius* Cav.) post emergence.
T_9: Allelopathic weed extract (*Convolvulus arvensis* L.) post emergence.
T_{10}: Allelopathic weed extract (*Lathyrus* spp.) post emergence.

Data was recorded on the following parameters

Weed dynamics:

- *A. tenuifolius* Cav. density (m^{-2}) Before application of weed management practices
- *A. tenuifolius* Cav. density (m^{-2}) after application of weed management practices
- *A. tenuifolius* Cav. fresh weight (Kgm^{-2})
- *A. tenuifolius* Cav. dry weight (Kgm^{-2})

***A. tenuifolius* Cav. density (m^{-2}) before application of weed management practices:** *A. tenuifolius* Cav. density was determined by randomly throwing a 50 × 50 cm quadrate three times in each subplot. Before implementing weed management practices, the number of *A. tenuifolius* Cav. plants were counted within the quadrates. The means were determined and then converted to density (m^{-2}).

***A. tenuifolius* Cav. density (m^{-2}) after application of weed management practices:** The density of *A. tenuifolius* Cav. was calculated by randomly throwing 50 x 50 cm quadrates three times in each subplot. Following the application of the weed control treatments, the number of *A. tenuifolius* Cav. plants within the quadrate were counted. The mean was computed and so changed into the density (m^{-2}).

***A. tenuifolius* Cav. fresh weight (Kg m^{-2}):** The *A. tenuifolius* Cav. plants were collected from quadrates. The plants were tightly packed into bundles and then weighed with an electric balance. The fresh weight was recorded and converted into fresh weight (Kgm^{-2}).

***A. tenuifolius* Cav. dry weight (Kgm^{-2}):** The sample was placed in an oven for complete desiccation for 72 hours at 70 °C after obtaining the fresh weight. The dry weight was then measured using an electronic balance and transformed into dry weight (Kgm^{-2}).

Agronomic parameters

- Plant height (cm) at maturity
- Number of nodes plant^{-1}
- Number of branches plant^{-1}
- Leaf area index (LAI)
- Number of pods plant^{-1}
- Number of grains pod^{-1}
- 500 grain weight (g)
- Biological yield (kg ha^{-1})
- Grains yield (kg ha^{-1})

- Cost benefit ratio (CBR)

Plant height (cm): Using a measuring tape or ruler to measure the height of each of the ten plants individually, from the base (ground level) to the highest point of the plant. Note down the height measurements for each of the five plants selected from each treatment. Calculate the average height for each treatment.

Number of nodes plants^{-1}: Ten plants from each treatment was randomly selected in order to calculated the number of nodes plants^{-1} by counting the nodes on the main stem.

Number of branches plant^{-1}: Number of branches from 10 plants were selected in order to calculated the number of branches plant^{-1} and then averaged.

Leaf area index (LAI)

Leaf area index is a dimensionless quantity, is the leaf area (upper side) only per unit area of the soil below. It is expressed as cm^2 ground area. Leaf area was determined by using the leaf area meter. Leaf area index (LAI) will be determined as follows

$$\text{Leaf area index} = \frac{\text{Leaf area per plant(cm2)}}{\text{Ground area (cm2)}}$$

Number of pods plant^{-1}: Ten matured plants were selected randomly from each treatment and their number of pods plant^{-1} were counted and their average was calculated.

Number of grain pod^{-1}: To record the number of grains pod^{-1}, ten pods were randomly selected in each treatment. Number of grains pod^{-1} were counted in each pod ultimately the mean was computed for each treatment.

500 grain weight (g): Ten samples of 500 grains were harvested, balanced, recorded and then averaged for each plot in (g).

Biological yield (kg ha^{-1}): The biological yield was determined by choosing plants from five rows in each plot, weighing them, and then converting the results into kg ha^{-1}.

Grains yield (kg ha^{-1}): The harvested middle rows from each subplot were threshed to separate and clean the seed before calculating the grains yield. The following formula was used to convert the grains yield data into kg ha^{-1}.

$$\text{Grain yield (kg per ha)} = \frac{\text{Grain yield of harvested plot (kg)}}{\text{Area harvested}} \times 10000m^2$$

Cost benefit ratio (CBR): Using the following formula, the cost-benefit ratio was calculated:

$$\text{Cost benefit ratio (CBR)} = \frac{\text{Added income}}{\text{Added cost}}$$

Statistical analysis

The data was statistically analyzed, and the least significant difference (LSD) was determined using the method developed by Steel *et al*. (1997). The data was statistically analysed, and the least significant difference (LSD) was determined using the approach developed by (Steel *et al*., 1997) or several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds.

Results and Discussions

Asphodelus tenuifolius Cav. density (m^{-2}) before and after treatments application

The data displayed in (Table 1), the weed density before and after the application of various control treatments for weed control. Before the application of the treatments, the weed density recorded in all the treatments was found to be statistically similar, indicating that there were no significant differences in weed density among the treatments prior to the treatment application. However, after the application of the various weed control treatments (Herbicides, mulches and allelopathic weed extracts), significant differences were recorded in the weed density. The application of herbicides, allelopathic extracts, and mulches had a distinguished impact on reducing weed density. The significant differences in weed density after treatment application indicated that the treatments were effective in controlling weeds and potentially mitigating yield losses in the crop by reducing competition from weeds. According to data on density prior to the application of the treatments, the plots assigned for the control treatment and the allelopathic extract of *Convolvulus arvensis* L. had maximum densities of (75.0 and 74.0 m^{-2}), respectively. The application of herbicide Dual gold, however, showed a minimal weed density of (69.3 m^{-2}). Due to the fact that the weed density was measured before the treatments were applied, the difference was not the result of the treatments. Data was collected to examine the effectiveness of weed management techniques used after treatments were applied.

In terms of weed control efficiency, the applied weed control methods differed significantly from one another. Due to the application of various control treatments, there was a noticeable improvement in weed density. The application of Pendimethalin resulted in the lowest density of *A. tenuifolius* Cav. (6.10 m^{-2}), which was followed by the application of Fenoxaprop-p-ethyl also showed a significant reduction in *A. tenuifolius* Cav. density, with a recorded value of (8.87 m^{-2}). This indicates that Pendimethalin and Fenoxaprop-p-ethyl was effective in suppressing the growth and proliferation of this weed species. While, the control plots, where no weed management technique was applied, had the highest *A. tenuifolius* Cav. density (83.46 m^{-2}). This implies that without any intervention, the weed population proliferated significantly. Similarly, the black polythene mulch treatment had the lowest *A. tenuifolius* Cav. density (10.83 m^{-2}) of all the mulch treatments. Among the tested aqueous allelopathic extracts, the lowest *A. tenuifolius* Cav. density (16.46 m^{-2}) was observed in the plots where *Asphodelus tenuifolius* Cav. allelopathic extract was used. This suggests that the allelopathic extract from *Asphodelus tenuifolius* exhibited some level of inhibitory effect on the growth of *A. tenuifolius* Cav. Sibtain *et al*. (2015) described that the yield loss estimation, when chickpea fields have an infinite density of *A. tenuifolius* Cav., the yield losses amount to 60%. Furthermore, the study found that there is a linear relationship between the density of *A. tenuifolius* Cav. plants and the reduction in chickpea productivity. Specifically, for every one additional *A. tenuifolius* Cav. plant per square meter, there is a predicted yield reduction of 2.52%. Khan *et al*. (2019) reported that the application of herbicides (Pendimethalin and Fenoxaprop-p-ethyl) reduced the density of *A. tenuifolius* Cav.

Table 1: *Asphodelus tenuifolius Cav. density (m^{-2}) before and after application of various control methods in chickpea crop at District Karak.*

Treatments	Asphodelus density (m^{-2}) before treatment	Asphodelus density (m^{-2}) after treatment
Control (For comparison)	75.0	83.46 a
Herbicide (Pendimethalin)	73.3	6.10 h
Herbicide (Dual gold)	69.3	8.13 h
Herbicide (Fenxaprop p ethyl)	72.0	7.03 h
Mulching (Black polythene)	69.0	10.83 g
Mulching (White polythene)	71.3	23.56 e
Mulching (Available weed biomass)	69.6	29.40 d
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	70.6	16.46 f
Allelopathic weed extract (*Convolvulus arvensis* L.)	74.0	32.53 c
Allelopathic weed extract (*Lathyrus* sp.)	72.3	37.90 b
LSD (0.05%)	N.S	2.08

Table 2: *Asphodelus tenuifolius Cav. fresh weight (kgm^{-2}) after application of various control methods in chickpea crop at District Karak.*

Treatments	*Asphodelus tenuifolius* fresh weight (kgm^{-2})
Control (For comparison)	41.44 a
Herbicide (Pendimethalin)	1.30 i
Herbicide (Dual gold)	3.06 h
Herbicide (Fenxaprop-p-ethyl)	1.91 hi
Mulching (Black polythene)	4.79 g
Mulching (White polythene)	13.85 e
Mulching (Available weed biomass)	16.55 d
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	11.40 f
Allelopathic weed extract (*Convolvulus arvensis* L.)	18.29 c
Allelopathic weed extract (*Lathyrus* sp.)	21.58 b
LSD (0.05%)	1.20

Asphodelus tenuifolius Cav. fresh weight (kgm^{-2})

Based on the statistical analysis conducted on the data provided in (Table 2), it was determined that the different weed control treatments had a significant effect on the fresh weight of *Asphodelus tenuifolius* Cav. This indicates that the various weed control treatments were successful in influencing the growth and development of *A. tenuifolius* Cav. Data revealed that the plots treated with Pendimethalin herbicide recorded the minimum fresh weight of *A. tenuifolius* Cav. (1.30 kgm^{-2}), which was statistically at par to the plots treated with Fenoxaprop-p-ethyl (1.91 kgm^{-2}). This suggests that both herbicides were effective in reducing the fresh weight of *A. tenuifolius* Cav. Whereas, the control plots, where no weed control treatment was applied, had the highest fresh weight of *A. tenuifolius* Cav. (41.44 kgm^{-2}). This indicates that without any interference, the growth and biomass accumulation of *A. tenuifolius* Cav. were not suppressed, leading to a higher fresh weight. Among various mulching treatment, the plots where mulching with black polythene was applied showed a fresh weight of *A. tenuifolius* Cav. of (4.79 kgm^{-2}). This shows that mulching had some suppressive effect on the growth of *A. tenuifolius* Cav., reducing its fresh weight compared to the control plots. Among the allelopathic weed extract, the plots treated with the allelopathic weed extract from *Asphodelus tenuifolius* Cav. exhibited a fresh weight of *A. tenuifolius* Cav. of (11.40 kgm^{-2}). This suggests that the extract had some inhibitory effect on the growth of *A. tenuifolius* Cav., although the effect was not as strong as the herbicides. Overall, the data demonstrates that the weed control treatments, particularly the herbicides Pendimethalin and Fenoxaprop-p-ethyl, were effective in reducing the fresh weight of *A. tenuifolius* Cav. Our results are in line with those of Khan *et al*. (2018), who found that fresh weight of *A. tenuifolius* Cav. decreased under the use of Pendimethalin and Fenxaprop-p-ethyl herbicides while increasing in the control treatment. According to Ashraf *et al*. (2017), plants have a variety of allelopathic compounds that can be utilized as herbicides to control weeds. Kumar *et al*. (2015), also found the lowest fresh weed biomass after using Pendimethalin.

Asphodelus tenuifolius Cav. dry weight (kgm^{-2})

Based on the analysis of the data presented in (Table 3). The use of various treatments had a considerable impact on the dry weed biomass as well. The statistical analysis of the data revealed that the weed management measures decreased the dry weed biomass. This indicates that the selected treatments were successful in suppressing the growth and biomass accumulation of weeds. Data revealed that the plots treated with Pendimethalin herbicide recorded the minimum dry weight of *A. tenuifolius* Cav. (0.43 kgm^{-2}), which was statistically at par treated with Fenoxaprop-p-ethyl and Dual gold (0.78 and 1.02 kgm^{-2}), respectively. This suggests that these herbicides were more effective in suppressing the growth and biomass accumulation of *A. tenuifolius* Cav. compared to the other treatments. While on the other hand, the control plots, where no weed control treatment was applied, had the maximum dry weight of *A. tenuifolius* Cav. (18.92 kgm^{-2}). This suggests that without any intercession, the growth and biomass accumulation of *A. tenuifolius* Cav. were not suppressed, leading to higher dry weed biomass. Among mulches treatments, lowest dry weight (6.72 kgm^{-2}) of *A. tenuifolius* Cav. was recorded in black polythene mulch, while highest dry weight (16.55 kgm^{-2}) was obtained from available weed biomass mulch treatment. Whereas, the plots treated with the *Asphodelus tenuifolius* Cav. allelopathic exhibited dry weed biomass of (8.89 kgm^{-2}). This indicates that these treatments were effective in reducing the dry weight of *A. tenuifolius* Cav. compared to the control plots. Our results matched with Merga and Alemu (2019) who reported that the application of Pendimethalin significantly decreased the dry weight of weeds. Our finding was also supported by previous work of Kanatas and Gazoulis (2022) who stated that the application of herbicides resulted in the lowest weed dry weight and the highest grain production of chickpea crop.

Table 3: *Asphodelus tenuifolius Cav. dry weight (kgm^{-2}) after application of various control methods in chickpea crop at District Karak.*

Treatments	*Asphodelus tenuifolius* dry weight (kgm^{-2})
Control (For comparison)	18.92 a
Herbicide (Pendimethalin)	0.43 h
Herbicide (Dual gold)	1.02 h
Herbicide (Fenxaprop-p-ethyl)	0.78 h
Mulching (Black polythene)	2.07 g
Mulching (White polythene)	6.72 e
Mulching (Available weed biomass)	16.55 d
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	8.89 d
Allelopathic weed extract (*Convolvulus arvensis* L.)	9.98 c
Allelopathic weed extract (*Lathyrus* sp.)	11.40 b
LSD (0.05%)	0.87

Plant height (cm)

Analysis of variance revealed that a significant impact of various weed control methods on the plant height of chickpea crop. Data presented in (Table 4), that the selection of weed control techniques significantly affects the chickpea plant growth and development, which in turn can affect their yield and production. Results showed that the plots treated with Pendimethalin herbicide recorded the maximum plant height of (46.66 cm), which was followed by the plant height of (44.66 cm) observed in the plots treated with Fenoxaprop-p-ethyl herbicide. This revealed that both herbicides were effective in promoting taller growth of the chickpea plants. While, the control plots, where no weed control treatment was applied, had the minimum plant height of (29.66 cm). These results exhibited that without any intrusion, weed competition adversely affected the growth and height of the chickpea plants. Among mulching treatments, the plots where black polythene mulch was applied exhibited a maximum plant height of (37.66 cm), while the lowest plant height of (30.66 cm) was observed in white polythene mulch. This suggests that mulching with black polythene had a positive influence on the plant height of the chickpea crops, although the effect was not as pronounced as the herbicide treatments. One of the allelopathic weed extract, highest plant height (41.00 cm) was obtained from *Asphodelus tenuifolius* Cav. weed extract treatment, while the lowest plant height (32.00 cm) was recorded in allelopathic weed extract of *Lathyrus* sp. Our results showed that optimizing plant height through effective weed control measures is important for achieving better yield and production outcomes in chickpea crops. These finding were supported by previous work of Khan *et al.* (2019) who recommended judicial use of Pendimethalin for suppression of weeds and promoting plant height of the chickpea crop. Khan *et al.* (2018) verified that the use of herbicides such as Pendimethalin offered effective weed control while also promoting height of chickpea plant.

Table 4: *Plant height (cm) after application of various control methods in chickpea crop at District Karak.*

Treatments	Plant height (cm)
Control (For comparison)	29.66 g
Herbicide (Pendimethalin)	46.66 a
Herbicide (Dual gold)	45.66 ab
Herbicide (Fenxaprop-p-ethyl)	44.66 b
Mulching (Black) polythene	37.66 d
Mulching (White) polythene	30.66 g
Mulching (Available weed biomass)	35.00 e
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	41.00 c
Allelopathic weed extract (*Convolvulus arvensis* L.)	34.00 e
Allelopathic weed extract (*Lathyrus* sp.)	32.00 f
LSD (0.05%)	1.15

Number of nodes plant^{-1}

The analyzed data in (Table 5) revealed that there were significant differences in the number of nodes per plant among the different weed control treatments. The number of nodes per plant is an important parameter that plays a key role in chickpea yield and productivity. Having a higher number of nodes per plant generally indicates better branching and more opportunities for pod development and ultimately higher chickpea yield. Therefore, the significant differences observed in the number of nodes per plant highlight the importance of effective weed control treatments in optimizing crop growth and productivity. Data showed that the plots treated with Pendimethalin herbicide recorded the maximum number of nodes per plant, with an average of (32.33) nodes. This was followed by the plots treated with Fenoxaprop-p-ethyl, which had an average of (30.66) nodes per plant. These herbicides were effective in promoting increased node formation and branching of the chickpea plants. Whereas, the control plot, where no weed control treatment was applied, recorded the minimum average number of nodes plant^{-1} at (18.00) nodes. Among the applied mulches, the plots with black polythene mulch exhibited the highest average number of nodes per plant, with (27.00) nodes. This was followed closely by the plots with white plastic mulch, which had an average of (24.00) nodes plant^{-1}. These mulching materials contributed to favorable conditions for node development and branching. Our results about mulches are justified by prior finding of Iqbal *et al.* (2021), who stated that maximum number of nodes plant^{-1} was produced by black plastic and white plastic mulch. In relation to allelopathic weed extract, the plots treated with extract of *Asphodelus tenuifolius* Cav. had a maximum average number of (26.00) nodes plant^{-1}, that was statistically unlike treated plots with extract of *Lathyrus* sp. had a value of (19.66) nodes plant^{-1}. Overall, the results showed that effective weed control treatments, such as Pendimethalin and Fenoxaprop-p-ethyl herbicides, as well as the use of black polythene mulch and *Asphodelus tenuifolius* Cav. extract, promoted a higher number of nodes plant^{-1} in chickpea crops. This revealed better nodes plant^{-1} and potentially higher chickpea production.

Table 5: *Number of nodes plant^{-1} after application of various control methods in chickpea crop at District Karak.*

Treatments	Number of nodes plant^{-1}
Control (For comparison)	18.00 h
Herbicide (Pendimethalin)	32.33 a
Herbicide (Dual gold)	28.66 c
Herbicide (Fenxaprop-p-ethyl)	30.66 b
Mulching (Black polythene)	27.00 d
Mulching (White polythene)	24.00 e
Mulching (Available weed biomass)	23.00 ef
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	26.00 d
Allelopathic weed extract (*Convolvulus arvensis* L.)	21.66 f
Allelopathic weed extract (*Lathyrus* sp.)	19.66 g
LSD (0.05%)	1.43

Number of branches plant^{-1}

There are notable variations in the number of branches plant^{-1}, according to the statistical analysis of the data presented in (Table 6). The tabulated data indicates significant differences in the number of branches plant^{-1} among the various weed management techniques. According to the mean values provided in the data, the highest number of branches per plant (10.33) was observed in the plots where Pendimethalin herbicide was applied for weed control. This mean value was followed by the values of (9.33 and 8.66) for Fenoxaprop-p-ethyl and Dual gold herbicides, respectively. These treatments resulted in similar levels of branching in chickpea plants. On the other hand, the control plot, where no weed control treatment was applied, had the lowest number of branches plant^{-1} (3.66). This result was matched with prior work of Iqbal *et al.* (2021). These findings indicate that the use of Pendimethalin and Fenoxaprop-p-ethyl herbicides, resulted in higher numbers of branches plant^{-1} in chickpea crops compared to the control and other herbicide treatments. Among mulching treatments, highest number of branches plant^{-1} (8.33) was recorded in black polythene mulch, while lowest number of branches plant^{-1}(6.00) was found in available weed biomass mulch. Similarly, in relation to allelopathic weed extract, the highest number of branches plant^{-1} (7.33) was observed in *Asphodelus tenuifolius* Cav. extract, whereas the lowest number of branches plant^{-1}(4.66) was obtained from Lathyrus sp. mulch. It's important to note that these mean values represent the average number of branches observed in the respective treatment groups and can serve as indicators of the effectiveness of different weed control methods in promoting branching in chickpea plants. Our findings are supported by previous work of Sibtain *et al.* (2015), who stated that severe infestation of *A. tenuifolius* Cav. significantly affects the primary branches of chickpea plants.

Table 6: *Number of branches plant^{-1} after application of various control methods in chickpea crop at District Karak.*

Treatments	Number of branches plant^{-1}
Control (For comparison)	3.66 h
Herbicide (Pendimethalin)	10.33 a
Herbicide (Dual gold)	8.66 bc
Herbicide (Fenxaprop-p-ethyl)	9.33 b
Mulching (Black polythene)	8.33 c
Mulching (White polythene)	6.66 de
Mulching (Available weed biomass)	6.00 ef
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	7.33 d
Allelopathic weed extract (*Convolvulus arvensis* L.)	5.33 fg
Allelopathic weed extract (*Lathyrus* sp.)	4.66 g
LSD (0.05%)	0.95

Leaf area index (LAI)

The surface of a leaf plays a vital role in plant development, including the chickpea plant. It is known that chickpea leaves are often sensitive to herbicides. Moreover, the leaf area index, which represents the total leaf area per unit ground area, is an important factor in photosynthesis and overall plant productivity. Based on the statistically analyzed data, significant differences were observed in the treatments applied to the leaf area index of chickpea plants. The data (Table 7) analysis reveals important insights regarding the leaf area index in relation to different treatments applied to chickpea crops. The plots treated with herbicides Pendimethalin and Fenoxaprop-p-ethyl exhibited the highest leaf area index values of (1.85 and 1.84), respectively. This indicates that these herbicides had a positive impact on chickpea growth, promoting leaf development and potentially enhancing photosynthetic efficiency. Whereas, the control treatment, which had a high weed infestation, showed the minimum leaf area index value of (1.23). This shows that weed competition negatively affected chickpea growth, resulting in a lower leaf area index. Among the mulch treatments, black polythene mulch resulted in a relatively high leaf area index value of (1.55), while, lowest leaf area index (1.39), was observed in available weed biomass mulch. This suggests that the use of black polythene mulch contributed to favorable conditions for chickpea growth, potentially by suppressing weed competition and providing a conducive environment for leaf expansion. Other treatments, the values of plots treated with allelopathic weed extract of *Asphodelus tenuifolius* Cav. (1.49) were relatively lower compared to the herbicide-treated and black polythene mulch treatments. Furthermore, it can be concluded that Pendimethalin and Fenoxaprop-p-ethyl herbicides had a significant selective inhibitory effect on the weeds present in the chickpea crop. This selective control of weeds likely contributed to the higher leaf area index values observed in the herbicide treated plots, indicating improved chickpea growth. Overall, these findings emphasize the importance of effective weed management practices for optimizing leaf area index and promoting healthy chickpea growth. These results are in line with previous work of Khan and Khan (2013). The use of suitable weed control techniques can help suppress weeds and create conditions that facilitate optimal leaf area index, ultimately leading to improved photosynthesis and potential yield gains in chickpea crops (Abbas *et al*., 2016).

Table 7: *Leaf area index (LAI) after application of various control methods in chickpea crop at District Karak.*

Treatments	Leaf area index (LAI)
Control (For comparison)	1.23 i
Herbicide (Pendimethalin)	1.85 a
Herbicide (Dual gold)	1.63 b
Herbicide (Fenxaprop-p-ethyl)	1.84 a
Mulching (Black polythene)	1.55 c
Mulching (White polythene)	1.43 e
Mulching (Available weed biomass)	1.39 f
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	1.49 d
Allelopathic weed extract (*Convolvulus arvensis* L.)	1.36 g
Allelopathic weed extract (*Lathyrus* sp.)	1.33 h
LSD (0.05%)	0.01

Number of pods plant^{-1}

The number of pods plant^{-1} is a crucial parameter that directly influences the grain yield of chickpea crops. The statistical analysis of the data presented in (Table 8) showed significant variations in the number of pods plant^{-1} due to the application of different weed control treatments. Statistical analysis showed that the treatment with Pendimethalin recorded the highest number of pods plant^{-1} (31.66), that was statistically similar to Fenoxaprop-p-ethyl herbicide (30.66). These results indicate that these herbicides were effective in controlling the growth of weeds, reducing competition with the crop, and ultimately leading to increased pod formation. While, the control treatment, which did not receive any weed control treatment, exhibited the lowest number of pods plant^{-1} (9.00). This shows that weed competition in the absence of weed control measures negatively affected pod development. This result also sustained by earlier work of Iqbal *et al*. (2021). Various mulching treatments, the treatments covered with black polythene mulch documented the maximum number of pods plant^{-1} (27.00), whereas available weed biomass mulch resulted in relatively lower number of pods plant^{-1} (22.00). In terms of allelopathic weed extract, *Asphodelus tenuifolius* Cav. weed extract reveals the number of pods plant^{-1} (24.00). On the basis of our results showed that the herbicides Pendimethalin and Fenoxaprop-p-ethyl were found to be efficient in controlling the growth of weeds. By suppressing weed competition, these herbicides created more favorable conditions for chickpea growth, leading to higher pod numbers per plant. Overall, these findings highlight the importance of effective weed control in maximizing the number of pods plant^{-1} and ultimately improving the yield of chickpea crops. Selecting suitable herbicides, such as Pendimethalin and Fenoxaprop-p-ethyl can help reduce weed competition and promote optimal pod development. Implementing weed control measures early in the crop growth stage can be particularly beneficial in achieving higher pod numbers and improving overall crop productivity (Pereira *et al*., 2015).

Table 8: *Number of pods plant^{-1} after application of various control methods in chickpea crop at District Karak.*

Treatments	Number of pods plant^{-1}
Control (For comparison)	9.00 h
Herbicide (Pendimethalin)	31.66 a
Herbicide (Dual gold)	29.00 b
Herbicide (Fenxaprop-p-ethyl)	30.66 a
Mulching (Black polythene)	27.00 c
Mulching (White polythene)	23.66 d
Mulching (Available weed biomass)	22.00 e
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	24.00 d
Allelopathic weed extract (*Convolvulus arvensis* L.)	19.00 f
Allelopathic weed extract (*Lathyrus* sp.)	16.00 g
LSD (0.05%)	1.54

Number of grains pod^{-1}

Statistical analysis data presented in (Table 9) exhibited the impact of different weed control treatments on the number of grains pod^{-1} in chickpea crops. The significant differences observed in the means of the applied treatments indicate variations in grain production influenced by the different weed control methods employed. The means of the data revealed that the highest number of grains pods^{-1} (2.00) was recorded in the plots treated with the herbicide Pendimethalin for weed control. This mean value was statistically similar to the treatment with Fenoxaprop-p-ethyl, which recorded a mean grains pod^{-1} count of (2.00). Conversely, the control treatment, which did not receive any weed control treatment, exhibited the lowest number of grains pods^{-1} (1.30). This reduction in grains pod^{-1} count can be attributed to the denser growth of weeds, whichcompeted with the chickpea crop for resources (Iqbal *et al*., 2021).

Table 9: *Number of grains pods^{-1} after application of various control methods in chickpea crop at District Karak.*

Treatments	Number of grains pods^{-1}
Control (For comparison)	1.30 d
Herbicide (Pendimethalin)	2.00 a
Herbicide (Dual gold)	1.66 abc
Herbicide (Fenxaprop-p-ethyl)	2.00 a
Mulching (Black polythene)	1.80 ab
Mulching (White polythene)	1.53 bcd
Mulching (Available weed biomass)	1.53 bcd
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	1.60 bcd
Allelopathic weed extract (*Convolvulus arvensis* L.)	1.40 cd
Allelopathic weed extract (*Lathyrus* sp.)	1.30 d
LSD (0.05%)	0.36

Among the applied mulches, the use of black polythene mulch resulted in a maximum number of grains pod^{-1} count of (1.80). While, the lowest number of grains pod^{-1} (1.53) was found in white polythene mulch and weed biomass mulch. Furthermore, various allelopathic weed extract, the application of *Asphodelus tenuifolius* Cav. weed extract received the highest number of grains pod^{-1} (1.60), while *Lathyrus* sp. weed extract recorded lower mean grains pod^{-1} counts of (1.30). The findings suggest that the herbicides Pendimethalin and Fenoxaprop-p-ethyl were effective in controlling weed growth, resulting in higher grain pod production. The use of black polythene mulch also positively influenced grain pod development. It is important to note that the control plots and the treatments with less effective mulches and allelopathic weed extract had lower grain pod counts, indicating the negative impact of weed competition on chickpea crop productivity. Based on these results, it is suggested to prioritize the use of herbicides such as Pendimethalin and Fenoxaprop-p-ethyl for effective weed control, which can contribute to increased grain pod formation in chickpea crops. Additionally, considering mulching techniques, such as black polythene mulch, can further enhance grain pod production. Implementing these suggestions in weed management practices can help optimize chickpea yields and improve overall crop performance. Our findings are consistent with those of Sibtain *et al*. (2015), who revealed that weeding of *A. tenuifolius* Cav. resulted in the most chickpea grains pod^{-1}. Similarly, Chaudhary *et al.* (2011) suggested that reducing weed populations can lead to an improvement in the number of grains pod^{-1}.

500 grain weight (g)

The analyzed data presented in (Table 10), regarding the 500 grain weight demonstrates significant differences resulting from the application of various treatments. Grain weight is a crucial factor influencing crop yield, and understanding the effects of different treatments on grain weight can provide valuable insights for optimizing crop productivity. The statistical analysis of the data indicates significant differences in the 500 grain weight among the different treatments. The maximum 500 grain weight (1.65 and 165.07 g) was observed in the plots treated with Pendimethalin and Fenoxaprop-p-ethyl herbicides, followed by the treatment with Dual gold herbicide, which had a 500 grain weight of (156.66 g). In contrast, the control plots, which were not subjected to any weed control treatment, exhibited the minimum 500 grain weight of (122.81 g). The control plots, with the highest number of weeds, recorded the minimum seed weight. Weeds not only compete with the crop for resources but also impede its growth and reduce overall yield potential. Among the mulch treatments, highest 500 grain weight (154.04 g) was observed in black polythene mulch, while the lowest 500 grain weight (142.76 g) was recorded in the treatment covered with available weed biomass. In term of allelopathic weed extracts, the highest 500 grain weight (149.90 g) was found in the plots treated with *Asphodelus tenuifolius* Cav. weed extract. This indicates that the application of *A. tenuifolius* Cav. weed extract as an allelopathic treatment had a positive impact on the development and weight of the chickpea grains. The results revealed that the plots with denser weed populations had lower 500 grain weight, indicating the negative impact of weed competition on crop development and yield. Conversely, the plots where weeds were effectively controlled with herbicides (Pendimethalin and Fenoxaprop-p-ethyl) exhibited higher 500 grain weight. These treatments created a weed-free environment, allowing the crop to flourish and achieve better growth and yield. The findings emphasize the importance of weed management in maximizing crop productivity. Effective control of weeds through the application of appropriate herbicides can help create an environment conducive to crop growth and development, leading to higher grain weights and improved yield (Khan *et al*., 2019). Similar results were stated by Sibtain *et al.* (2015), who found that as the density of *A. tenuifolius* Cav. plants increased, there was a decrease in the weight of chickpea grains and a reduction in overall grain yield in chickpea crops. Similarly, Sajid *et al.* (2012) also defined various method of weed control considerably increased weight of grains.

Table 10: *500 grain weight (g) after application of various control methods in chickpea crop at District Karak.*

Treatments	500 grain weight (g)
Control (For comparison)	122.81 h
Herbicide (Pendimethalin)	165.46 a
Herbicide (Dual gold)	156.66 b
Herbicide (Fenxaprop-p-ethyl)	165.07 a
Mulching (Black polythene)	154.04 b
Mulching (White polythene)	146.84 d
Mulching (Available weed biomass)	142.76 e
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	149.90 c
Allelopathic weed extract (*Convolvulus arvensis* L.)	136.80 f
Allelopathic weed extract (*Lathyrus* sp.)	133.04 g
LSD (0.05%)	2.69

Biological yield (kgha^{-1})

The statistically analyzed data in Table 11 reveals significant differences in the biological yield of chickpea plants due to the application of different weed control treatments. This is an important finding as the biological yield holds equal importance for farmers, especially in the autumn season when it is utilized as green fodder in the Southern districts of Khyber Pakhtunkhwa. The results revealed that the highest biological yield (4532.9 kgha^{-1}) was observed in the plots treated with Pendimethalin herbicide, which was followed by Fenoxaprop-p-ethyl with biological yields of (4177.2 kgha^{-1}). Results showed that the application of Pendimethalin and Fenoxaprop-p-ethyl effectively controlled weed growth, allowing the chickpea crop to thrive and achieve higher biological yields. Conversely, the control plots exhibited the lowest biological yield of (3156.6 kgha^{-1}). These findings indicate that high weed density in control treatment had a detrimental effect on chickpea crops, leading to suppressed crop growth and reduced canopy development, ultimately resulting in lower biological yields. These results were supported by previous work of Khan *et al.* (2019). Among the mulch treatments, the use of black polythene mulch resulted in the highest biological yield of (3841.1 kgha^{-1}). On the other hand, available weed biomass mulch weed control measures were applied, exhibited the lowest biological yield of (3567.2 kgha^{-1}). Similarly, various allelopathic weed extract, the maximum biological yield (3737.0 kgha^{-1}) was obtained from the application of *Asphodelus tenuifolius* Cav. weed extract, while the lowest biological yield (3361.2 kgha^{-1}) was documented in *Lathyrus* sp. weed extract treatment. Based on these results, it is recommended to arrange weed control strategies such as the use of Pendimethalin and Fenoxaprop-p-ethyl herbicides, as well as the implementation of black polythene mulch. These approaches will help reduce weed competition, promote healthy crop growth, and ultimately increase the biological yield of chickpea crops. These results were lined with earlier work of Khan *et al.* (2018, 2019). Farmers should consider implementing these weed control measures to optimize their crop productivity and ensure a higher biological yield for fodder purposes (Kanatas and Gazoulis, 2022)

Table 11: *Biological yield (kgha^{-1}) after application of various control methods in chickpea crop at District Karak.*

Treatments	Biological yield (kgha^{-1})
Control (For comparison)	3156.6 j
Herbicide (Pendimethalin)	4532.9 a
Herbicide (Dual gold)	3922.0 c
Herbicide (Fenxaprop-p-ethyl)	4177.2 b
Mulching (Black polythene)	3841.1 d
Mulching (White polythene)	3642.6 f
Mulching (Available weed biomass)	3567.2 g
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	3737.0 e
Allelopathic weed extract (*Convolvulus arvensis* L.)	3457.8 h
Allelopathic weed extract (*Lathyrus* sp.)	3361.2 i
LSD (0.05%)	67.25

Grains yield (kgha^{-1})

The grains yield of chickpea is a crucial component of crop. The means of the data in (Table 12) demonstrate the grains yield of chickpea crop as affected by different weed control treatments. The statistical analysis of the data reveals that significant differences were recorded among the various applied treatments. The grains yield means indicate that the maximum grains yield of (1438.2 kgha^{-1}) was recorded in the plots treated with the herbicide Pendimethalin. The herbicide Fenoxaprop-p-ethyl also resulted in high grains yield of (1361.1 kgha^{-1}). Whereas, due to poor weed control and the presence of growing weeds in the field, the control plots had the minimum grains yield of (1014.1 kgha^{-1}). Among the applied mulches, the maximum grains yield of (1244.4 kgha^{-1}) was observed in the plots with black polythene mulch, which was statistically different to the grains yield of (1156.9 kgha^{-1}) the plots covered with available weed biomass mulch. In relation to allelopathic weed extract, the highest grains yield (1204.6 kg ha^{-1}) was found in the weed extract of *Asphodelus tenuifolius* Cav., while the lowest grains yield (1113.4 kg ha^{-1}) was observed in the weed extract of *Lathyrus* sp. Our results exhibited that the weeds can cause significant yield losses in both grains yield and biological yield if they are not controlled before the critical period of weed competition. Our findings were also matched with previous work of Amaral *et al.* (2015). Weeds are strong competitors and compete with the crop for resources, leading to a reduction in grains yield. The herbicides Pendimethalin and Fenoxaprop-p-ethyl effectively control the growth of weeds in the chickpea crop, resulting in increased grains yield (Khan *et al.*, 2018, 2019). Plots with lower weed density tend to achieve higher grains yield, highlighting the importance of weed management in maximizing crop productivity (Khan *et al.*, 2019; Sibtain *et al.*, 2015).

Table 12: *Grains yield (kgha^{-1}) after application of various control methods in chickpea crop at District Karak.*

Treatments	Grains yield (kgha^{-1})
Control (For comparison)	1014.1 h
Herbicide (Pendimethalin)	1438.2 a
Herbicide (Dual gold)	1300.3 c
Herbicide (Fenxaprop-p-ethyl)	1361.1 b
Mulching (Black polythene)	1244.4 d
Mulching (White polythene)	1188.4 e
Mulching (Available weed biomass)	1156.9 f
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	1204.6 e
Allelopathic weed extract (*Convolvulus arvensis* L.)	1134.4 fg
Allelopathic weed extract (*Lathyrus* sp.)	1113.4 g
LSD (0.05%)	23.88

Cost benefit ratio (CBR)

The cost benefit ratio is an important economic indicator that helps determine the profitability of different weed management techniques. By calculating the cost benefit ratio for each weed management technique, such as herbicides, mulches, and allelopathic weed extracts, as well as the control group, it is possible to identify the maximum gain. The higher the cost benefit ratio, the more economically beneficial the treatment is considered. In the studied data, it was observed that the herbicides Pendimethalin, Fenoxaprop-p-ethyl, and Dual gold, along with the mulches black polythene, white polythene and available weed biomass, and the allelopathic weeds extract from *Asphodelus tenuifolius* Cav., *Convolvulus arvensis* L. and *Lathyrus* sp. showed different cost benefit ratios compared to the control treatment as shown in (Table 13). Results revealed that the maximum cost benefit ratio was recorded for the plots treated with herbicide Pendimethalin (1:3.1), which was followed by Fenoxaprop-p-ethyl (1:2.9). Whereas, the minimum cost benefit ratio (1:1.9) was recorded for control treatment. Both herbicides effectively controlled the growing weeds, resulting in increased economic returns. These treatments demonstrated a higher return on investment compared to other management techniques. Among the mulches, mulching (black polythene) exhibited the cost benefit ratio of (1:2.6). This indicates that the economic returns from this specific treatment were relatively lower compared to the herbicide treatments. On the other hand, the allelopathic weed extract of *A. tenuifolius* Cav. showed the cost benefit ratio of (1:2.5). This suggests that the economic benefits derived from allelopathic weeds extract relatively lower compared to mulching techniques as well as herbicide treatments. On the basis of our finding, data revealed that the Pendimethalin and Fenoxaprop-p-ethyl herbicides were found to be efficient in weed control, and their application resulted in a higher cost benefit ratio, indicating increased economic output from the crop. These results were supported by earlier work of Iqbal *et al.* (2021) Mulching with black polythene and white polythene, as well as the allelopathic weed extract from *A. tenuifolius* Cav., also contributed to improved cost benefit ratios (Waqas *et al.*, 2016). By analyzing the cost benefit ratio, farmers can assess the economic viability of different weed management techniques and make informed decisions regarding the most profitable approach for their crop production reported by Khan *et al.* (2017).

Table 13: *Cost benefit ratio (CBR) after application of various control methods in chickpea crop at District Karak.*

Treatments	Grains yield (kgha^{-1})
Control (For comparison)	1:1.9
Herbicide (Pendimethalin)	1:3.1
Herbicide (Dual gold)	1:2.8
Herbicide (Fenxaprop-p-ethyl)	1:2.9
Mulching (Black polythene)	1:2.6
Mulching (White polythene)	1:2.4
Mulching (Available weed biomass)	1:2.3
Allelopathic weed extract (*Asphodelus tenuifolius* Cav.)	1:2.5
Allelopathic weed extract (*Convolvulus arvensis* L.)	1:2.3
Allelopathic weed extract (*Lathyrus* sp.)	1:2.2

Conclusions and Recommendations

The conclusions drawn from the research on weed control of *Asphodelus tenuifolius* Cav. and associated weeds in chickpea crop are as follows:

- The use of herbicides Pendimethalin and Fenoxaprop-p-ethyl in chickpea crop in sandy soil of district Karak, Khyber Pakhtunkhwa, Pakistan, is an effective, feasible, and economical approach for weed management.
- Chickpea crop is a poor competitor with growing weeds, and its yield is negatively affected by the dense population of weeds.
- It is important for farmers to have proper knowledge about weed management practices as some methods can alter the growth of the chickpea crop.
- Judicious use of herbicides before the critical period of weed competition is necessary to increase the income of chickpea farmers.
- The density of weeds in the chickpea crop was significantly affected by the weed control treatments, particularly the herbicides Pendimethalin and Fenoxaprop-p-ethyl, which effectively reduced the density of *A. tenuifolius* Cav. and other weeds.
- The maximum benefit-cost ratio was achieved when using Pendimethalin and Fenoxaprop-p-ethyl herbicides, as they were economical and required less labor.
- It is suggested to use herbicides Pendimethalin and Fenoxaprop-p-ethyl, as well as black polythene mulch, for weed control in chickpea

crops, as they have been found to be the best and most economical solutions for controlling *A. tenuifolius* Cav. and other weeds.
- Further study is suggested to confirm the results under different environmental condition.

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Novelty Statement

From our results revealed that the importance of effective weed management strategies, specifically the use of appropriate herbicides and mulching techniques, to enhance the productivity and profitability of chickpea crops in the field conditions of District Karak, Khyber Pakhtunkhwa, Pakistan.

Author's Contribution

Imtiaz Khan: Developed the research concept, set the study's goals, and supervised all aspects of its completion.
Abdullah: Performed data analysis, writing, table development and interpretation.
Muhammad Ishfaq Khan: The manuscript was critically evaluated and modified.
Muhammad Ibrahim: Participated in collecting data, conducted experiments, and collected results from experiments.
Saima Hashim, Shomayela Afzal and Khalid Nawab: Conducted an extensive review of relevant literature and contributed to the revision of the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

References

Abbas, G., A. Ahmed, M. Amer, Z. Abbas, M.U. Rehman, A. Hussain and G.A. Khan. 2016. Impact of pre-emergence herbicides for the control of weeds in chickpea (*Cicer arietinum* L.) under hot arid climate. J. Bioresour. Manage., 3(2): 7. https://doi.org/10.35691/JBM.6102.0054

Amaral, L.R., J.P. Molin and J.S. Schepers. 2015. Algorithm for variable-rate nitrogen application in sugarcane based on active crop canopy sensor. Agric. J., 107(4): 1513-1523. https://doi.org/10.2134/agronj14.0494

Ashraf, R., B. Sultana, S. Yaqoob and M. Iqbal. 2017. Allelochemicals and crop management: A review. Curr. Sci. Persp., 3: 1-13.

Chandrakar, S. and V.C. Raj. 2018. Response of chickpea (*Cicer arietinum* L.) cultivars to weed management practices. A review. Biosci. Trends, 11(3): 262-267.

Chaudhary, S.U., J. Iqbal and M. Hussain. 2011. Weed management in chickpea grown under rice based cropping system of Punjab. Crop Environ., 2(1): 28-31.

Dutta, A., A. Trivedi, C.P. Nath, D.S. Gupta and K.K. Hazra. 2022. A comprehensive review on grain legumes as climate-smart crops: Challenges and prospects. Environ. Chall., 7: 100479. https://doi.org/10.1016/j.envc.2022.100479

Food and Agriculture Organization of the United Nations (FAO). FAOSTAT; 2021. Available: http://faostat3.fao.org/home/index.html#Download.

Iqbal, K., S.U. Siddiqui, I. Khan, A. Ghafoor and M.I. Khan. 2021. Chickpea varietal response to integrated weed management under different irrigation regimes. Acta Ecol. Sin., 41(2): 164-169. https://doi.org/10.1016/j.chnaes.2020.06.005

Kanatas, P.J. and I. Gazoulis. 2022. The integration of increased seeding rates, mechanical weed control and herbicide application for weed management in chickpea (*Cicer arietinum* L.). Phytoparasitica, 50(1): 255-267. https://doi.org/10.1007/s12600-021-00955-3

Khan, I.A., M. Waqas, S.M.A. Shah, N. Khan and R. Khan. 2017. Evaluation of different techniques for economical control of weeds associated to chickpea. Tunis. J. Plant Prot., 12: 115-122.

Khan, I.A. and R. Khan. 2013. Weed flora in chickpea at District Karak, Khyber Pakhtunkhwa, Pakistan. Thai. J. Agric. Sci.,

46(2): 71-74.
Khan, I., M.I. Khan and Hashmatullah. 2019. Integration of allelopathy and herbicide to control *Asphodelus tenuifolius* Cav. in chickpea crop. Acta Ecol. Sin., 39(2): 181-184. https://doi.org/10.1016/j.chnaes.2018.07.001
Khan, I., M.I. Khan, H. Ullah, M. Haroon and B. Gul. 2018. Assessment of integrated weed management approaches on *Asphodelus tenuifolius* Cav. in chickpea. Planta Daninha, 36. https://doi.org/10.1590/s0100-83582018360100150
Khan, M.I., G. Hassan, I. Khan, K.B. Marwat, N.U. Khan and R. Gul. 2011. Tolerance of chickpea (*Cicer arietinum* L.) cultivars to the major chickpea herbicides. Pak. J. Bot., 43(5): 2497-2501.
Kumar, C.A. and P. Ram. 2015. Effect of integrated weed management on weed dynamics of soybean [*Glycine max* (L.) Merrill] under Chhattisgarh plain. Indian J. Agric. Res., 49(1): 53-58. https://doi.org/10.5958/0976-058X.2015.00007.4
Merga, B. and N. Alemu. 2019. Integrated weed management in chickpea (*Cicer arietinum* L.). Cogent Food Agric., 5(1): 1620152. https://doi.org/10.1080/23311932.2019.1620152
Muehlbauer, F.J. and A. Sarker. 2017. Economic importance of chickpea: Production, value, and world trade. In the chickpea genome. Springer Cham., pp. 5–12. https://doi.org/10.1007/978-3-319-66117-9_2
Pakistan Bureau of Statistics (PBS), 2020. Available: http://www.pbs.gov.pk/agri-stattables
Pang, J., N.C. Turner, T. Khan, J.L. Xiong, T.D. Colmer, R. Devilla, K. Stefanova and K.H.M. Siddique. 2017. Response of chickpea (*Cicer arietinum* L.) To terminal drought leaf stomatal conductance, pod abscisic acid concentration, and seed set. J. Exp. Bot., 68(8): 1973-1985. https://doi.org/10.1093/jxb/erw153
Pereira, G.A.M., L.H. Barcellos Jr, D.V. Silva, R.R. Braga, M.M. Teixeira, A.A. Silva and J.I. Ribeiro. 2015. Application height in herbicides efficiency in bean crops. Plant. Daninha, 33: 607-614. https://doi.org/10.1590/S0100-83582015000300023
Riaz, G., Z.M.U.F. Khan, A.A. Awan, M. Sardar, S.M.T. Malik and S. Muhammad. 2021. Multivariate analysis of weeds of chickpea, mustard and wheat crop fields of tehsil Isakhel, District Mianwali (Punjab), Pakistan. Pak. J. Weed Sci. Res., 27(2): 153-162. https://doi.org/10.28941/pjwsr.v27i2.924
Sajid, M., A. Rab, I. Jan, I. Ahmad, I.A. Khan and M.A. Khan. 2012. Effect of herbicides and row spacing on the growth and yield of pea. Pakistan Journal of Weed Science Research, 18(1).
Sibtain, M., A. Tanveer, M.M. Javaid and H.H. Ali. 2015. Wild onion (*Asphodelus tenuifolius* Cav.) competition in rainfed chickpea-chickpea cropping system. Plant. Daninha, 33: 67-75. https://doi.org/10.1590/S0100-83582015000100008
Steel, R.G.D., J.H. Torrie and D. Dickey. 1997. Principles and procedures of statistics. Multiple comparisons. 3rd Ed. McGraw Hill Book Co., New York, USA. pp. 178-198.
USDA, 2021. https://fdc.nal.usda.gov/fdc-app.html#/food-details/174288/nutrients (Accessed August 30, 2021).
Waqas, M., I.A. Khan, A.S. Abu-Rizaiza, M. Ihsan and I. Daur. 2016. Assessment of herbicides and mulches against weeds and yield of chickpea cultivars. Int. J. Biosci., 9(1): 282-290.