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Original Article

" Weed Control Interventions and the Productivity of Wheat (Triticum aestivum L.)"

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ABSTRACT

A field research was piloted during the Rabi season of 2017–18 at the Agronomy Section, Agriculture Research Institute (ARI), Tarnab, to evaluate the consequence of diverse weed management practices on the wheat vegetative and reproductive performance. The study was laid out in a triplicated RCB design with a plot size of 15 m^2. Treatments included weedy check (Standard), hand weeding once (30 DAS), herbicide application (Topik 15 WP at 300 g ha^{-1} at 30 DAS), and barley water extract at concentrations of 1:5 and 1:10 applied singly (30 DAS) or twice (30 + 60 DAS). Results revealed substantial disparity among treatments for all recorded vegetative and reproductive traits. Herbicide application and double spray of barley extract (1:5 and 1:10) exhibited the highest values for yield-related parameters, with grain yield improvement exceeding 40% compared with the weedy check. Single spray of barley extract and hand weeding also showed significant improvements but were comparatively less effective. The findings suggest that barley extract can serve as a promising allelopathic alternative to chemical herbicides, contributing to eco-friendly and sustainable weed management. Integration of barley water extract with conventional practices may reduce herbicide dependence while maintaining crop productivity, thereby supporting resource-efficient and environmentally sound wheat production systems.

INTRODUCTION

Worldwide, wheat is among the most widely cultivated cereal crops, valued for its nutritional significance, adaptability, and crucial role in worldwide food security [1]. In Pakistan, wheat not only constitutes the primary staple food but also represents the predominant cereal crop—both in terms of area harvested and contribution to national dietary intake [2]. Despite ongoing efforts by governmental bodies, agronomists, and farmers, the average wheat yield in Pakistan remains substantially lower than the potential yield achievable under optimal conditions [3].

One of the major constraints limiting wheat yield is weed infestation [4]. In Pakistan, weeds are estimated to lessen wheat yields by 20–30%, liable on the weed species, mass, soil fertility, and climatic conditions [5]. Among weeds, *Phalaris minor* and various *Avena* species are especially problematic [6]. *P. minor* alone can cause yield damages fluctuating from 30 to 50%, or even greater in heavily infested fields or under resistant populations [7]. These grassy weeds are particularly troublesome because they often mimic wheat phenologyally and morphologically until quite late in the season, making early identification and management difficult [8].

Mechanisms by which weeds reduce wheat yield include: rivalry for essential growth factors i.e., sunlit, space, nutrients, and water; emission of allelochemicals into the rhizosphere via roots or decomposing plant material; and interference with crop growth dynamics [9]. For example, dense populations of *P. minor* reduce the biomass accumulation and grain filling, leading to lower grain spike grains and reduced grain weight [10]. Moreover, weed seed dispersal often occurs before wheat harvest, contributing to the build-up of weed seed banks that exacerbate future infestations [11].

In addressing weed infestation, traditional control methods include mechanical (hand weeding, tillage), chemical (herbicides), and cultural/ecological methods (crop rotation, altered sowing date, increased crop density) [12,13]. Each method has advantages and drawbacks. Mechanical control is labour intensive, time consuming, and costly; chemical control, while efficient, raises concerns about herbicide resistance, environmental impacts, and costs [14,15]. Cultural practices, such as adjusting sowing time, using competitive cultivars, and optimizing fertilizer regimes, can suppress weed growth, but may not fully eliminate weed pressure [16,17].

A particularly concerning issue in Pakistan and elsewhere is the advancement of herbicide struggle in *P. minor* and *Avena fatua*, among others. Repetitive use of herbicides targeting the similar modes of action has led to populations that no longer respond adequately, rendering some chemicals ineffective [18]. For example, resistance to isoproturon and ACCase inhibitors has been documented in *P. minor* populations in Pakistan [19,20]. Thus, integrated weed management strategies that combine traditional, machine-driven, and chemical methods are progressively being seen as essential to sustainable wheat production [21,22].

Despite recognition of these issues, more region-specific and holistic research is needed to understand which combinations of weed management practices (cultural + remedial) keep weeds under the economic threshold, minimize resistance development, and maximize wheat growth and yield [23,24]. Variables such as weed density, infestation timing, fertilizer use, sowing date, cultivar choice, and herbicide application timing all interact to influence outcomes [25,26]. The current study aims to evaluate the paraphernalia of different weed management practices on growth, yield components, and final yield of wheat (*T. aestivum* L.), with a focus on integrating proactive cultural methods with remedial chemical control.

MATERIALS AND METHODS

Experimental site and season

The field experiment was conducted at the Agronomy Farm of the Agriculture Research Institute (ARI), Tarnab, during the Rabi season of 2023–2024. The site lies in the semi-arid region of Khyber Pakhtunkhwa, which experiences hot summers, relatively mild winters, and limited annual rainfall. The soil of the experimental area was classified as silty clay loam, with a slightly alkaline reaction (pH 7.8–8.1) and low organic matter content (0.65%). Prior to sowing, composite soil samples were collected from a depth of 0–30 cm and analyzed for physico-chemical characteristics following standard methods (Table 1). Meteorological conditions during the experimental period are shown in Figure 1.

Table 1. Physico-chemical indices of investigational soil before wheat sowing (0–30 cm depth).

Parameter	Value	Unit	Method used*
Texture	Silty clay loam	–	Hydrometer method (Bouyoucos, 1962)
pH	7.9	–	1:2.5 soil-water suspension (Jackson, 1973)
Electrical conductivity (EC)	1.6	dS m^{-1}	Conductivity meter (Richards, 1954)
Organic matter	0.65	%	Walkley-Black method
Total nitrogen (N)	0.048	%	Kjeldahl method
Available phosphorus (P)	7.2	mg kg^{-1}	Olsen's method
Available potassium (K)	138	mg kg^{-1}	Flame photometer
Bulk density	1.38	g cm^{-3}	Core method

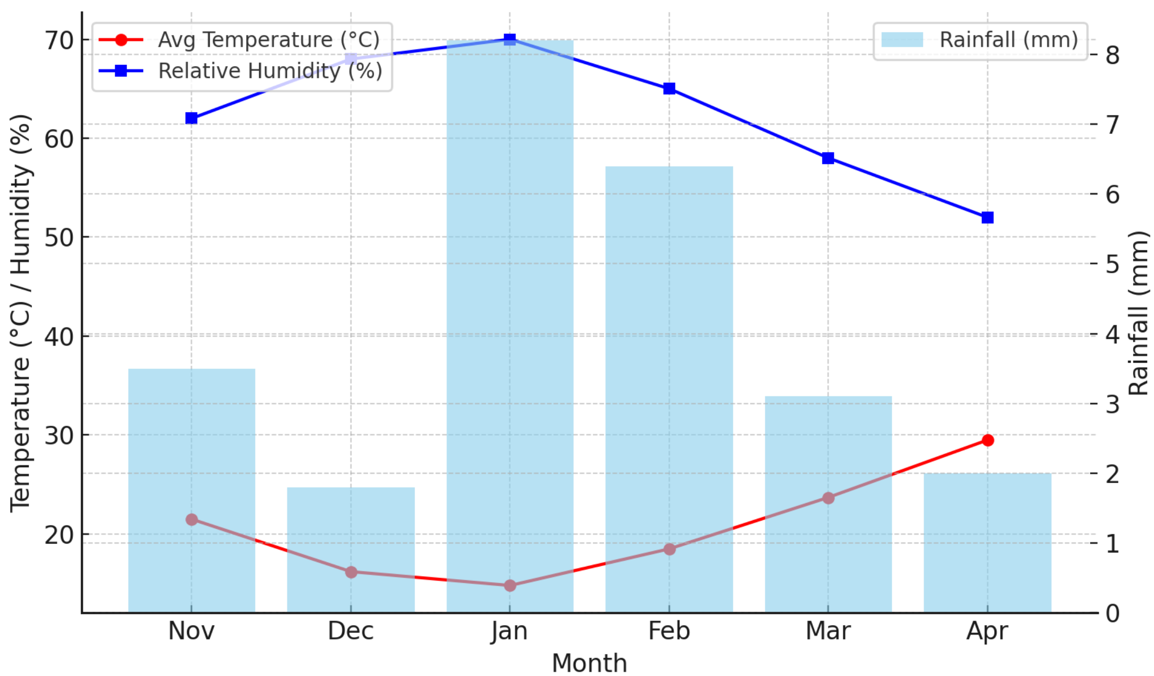

Figure 1. Meteorological data of the area during wheat growing season 2023-24.

Experimental design and layout

The experiment was laid out in a triplicated RCBD.. Standard agronomic practices for wheat cultivation were followed uniformly across all treatments except for weed management interventions. Wheat was seeded using a seed rate of 125 kg ha^{-1} with row spacing of 25 cm.

Treatments

Seven weed management treatments were evaluated:

- T1 = Control (weedy check)
- T2 = Hand weeding once at 30 days after sowing (DAS)
- T3 = Topik 15 WP (clodinafop-propargyl) at 300 g ha^{-1} at 30 DAS
- T4 = Barley extract (1:5 w/v concentration) at 12 L ha^{-1} applied once at 30 DAS
- T5 = Barley extract (1:10 w/v concentration) at 12 L ha^{-1} applied once at 30 DAS
- T6 = Barley extract (1:5 w/v concentration) at 12 L ha^{-1} applied twice (30 + 60 DAS)
- T7 = Barley extract (1:10 w/v concentration) at 12 L ha^{-1} applied twice (30 + 60 DAS)

Preparation and application of barley extracts

Barley (*Hordeum vulgare* L.) seeds were germinated, and the seedlings were harvested at 35 days after emergence. Fresh biomass was chopped and saturated in cleaned water at ratios of 1:5 and 1:10 (w/v) for one day at 25 ^{o}C temperature. The soaked material was strained through muslin cloth, and the filtrate was diluted to the desired concentration. The extracts were applied as foliar sprays using a backpack sprayer tailored with a flat-fan nozzle at the specified intervals.

Crop management

Wheat variety (provide variety name if available) was sown on (insert exact sowing date) under irrigated conditions. Fertilizer @ 150:90:60 kg NPK ha^{-1} with P and K as basal and N was split-applied in three equal doses: at seeding, tillering, and booting stages. Irrigation was applied as per crop requirements. All other cultural practices were maintained uniformly across treatments.

Data collection

At physiological maturity, five plants were randomly selected from each plot to record growth and yield attributes. The vegetative and yield parameters were measured.

Weed population dynamics were assessed by randomly placing a 0.25 m^2 quadrat at two spots per plot and counting the weed density (plants m^{-2}) at 45 DAS. Weed control efficiency (%) was calculated as:

Weed control (%) = [(Weed density in control – Weed density in treatment) / Weed density in control] × 100

Statistical analysis

The collected data were analyzed through ANOVA using the Statistix 8.1 software package (Analytical Software, Tallahassee, FL, USA, 2006). When significant differences were detected by the F-test, treatment means were compared using LSD test at the 5% probability level.

RESULTS AND DISCUSSION

Plant height (cm)

Plant height of wheat varied significantly among treatments (Fig. 2). The lowest mean height was recorded in the weedy check (T1), where plants reached only 65.2 cm. In contrast, barley extract at 1:5 applied twice (T6) produced the tallest plants at 78.6 cm, showing a 20.6% increase over the control and falling into the top statistical group (a). Topik application (T3) also significantly increased plant height (75.5 cm), while barley extract at 1:10 applied twice (T7) produced 74.1 cm, both of which were superior to the control but statistically lower than T6. Hand weeding once (T2) resulted in 72.8 cm, whereas barley extract at 1:5 once (T4) produced 73.5 cm, both significantly taller than the control but comparable with each other. Treatments T5 (1:10 once) and T3 (Topik) were statistically similar, though both were higher than T1. Overall, repeated barley extract application (T6) provided the greatest enhancement in plant height, suggesting that weed suppression across a longer growth period improved vegetative development.

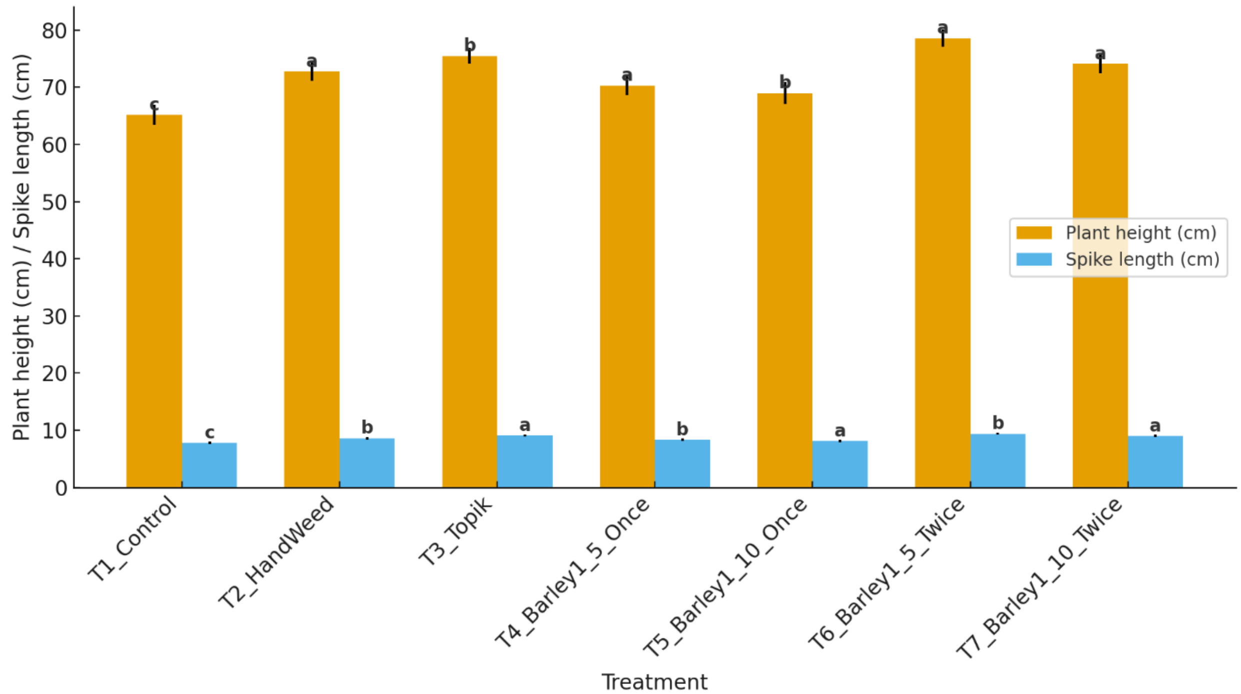

Fig 2: Weed management strategies and plant height and spike length of wheat

Spike length (cm)

Spike length also showed marked variation under different weed management strategies (Fig. 2). The shortest spikes were recorded in the control (7.8 cm), while the maximum length was observed in T6 (9.4 cm), which was significantly higher than T1 and represented a 20.5% improvement. Topik application (T3) and barley extract at 1:10 twice (T7) produced spikes of 9.1 cm and 9.0 cm, respectively, both of which were statistically similar to each other but significantly longer than the control. Hand weeding once (T2) and barley extract at 1:5 once (T4) also increased spike length (8.6 and 8.8 cm, respectively) but remained lower than T6. These results demonstrate that weed management enhanced reproductive growth, with T6 producing the longest spikes due to effective weed suppression throughout the critical growth stages.

Number of grains spike^{-1}

The number of grains per spike increased significantly under weed management treatments compared to the weedy check (Fig. 3). Control plots (T1) had only 32.1 grains per spike, while T6 produced the highest value of 40.1 grains, which was 24.9% greater than T1 and statistically superior (group a). Topik (T3) and barley extract at 1:10 twice (T7) also produced higher grain numbers (38.5 and 37.9, respectively), significantly exceeding the control but remaining lower than T6. Hand weeding (T2) and barley extract at 1:5 once (T4) yielded 36.8 and 35.9 grains per spike, respectively, which were statistically comparable to each other but inferior to T6. Barley extract at 1:10 once (T5) produced 34.6 grains, higher than the control but still the lowest among weed-managed treatments. The data indicate that better weed suppression enhanced floret fertility and grain setting, with repeated application of barley extract (T6) achieving the best results.

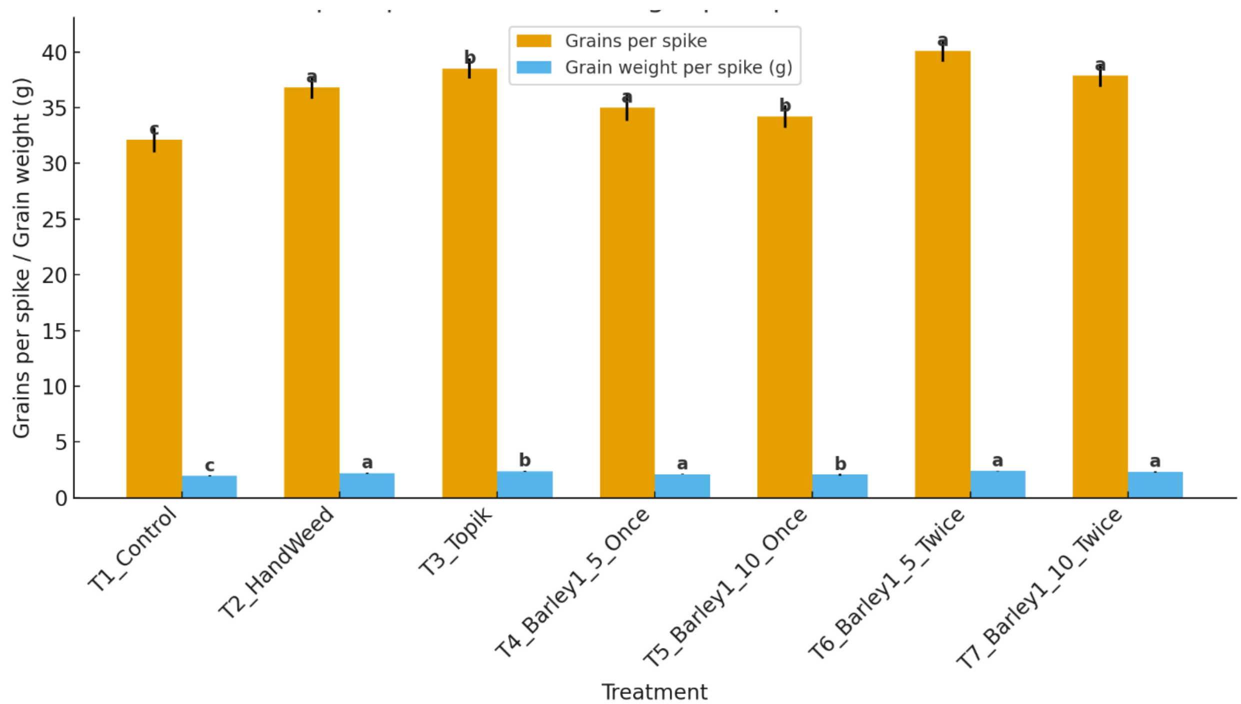

Fig 3: Weed management strategies and grain weight and grains per spike of wheat

Grain weight spike^{-1} (g)

Grain weight per spike was lowest in the control (1.95 g) and highest in T6 (2.40 g), showing a 23.1% increase (Fig. 3). Topik (T3) and barley extract at 1:10 twice (T7) produced 2.28 g and 2.25 g per spike, respectively, both significantly higher than T1 but lower than T6. Hand weeding (T2) and barley extract at 1:5 once (T4) also improved grain weight (2.15 and 2.19 g, respectively) but were statistically similar to each other. Barley extract at 1:10 once (T5) recorded 2.07 g, which, though higher than the control, was inferior to other treatments. The results demonstrate that weed suppression improved assimilate availability for grain filling, leading to greater spike weight, with T6 providing the highest benefit.

Seed index (1000-grain weight, g)

Significant differences in seed index were observed among treatments (Fig. 4). The control recorded the lowest seed index at 37.5 g, while T6 attained the maximum of 43.3 g, an improvement of 15.5% over the control. Topik (T3) produced 42.1 g, while barley extract at 1:10 twice (T7) yielded 41.7 g; both were statistically similar to each other but lower than T6. Hand weeding (T2) and barley extract at 1:5 once (T4) recorded 40.9 g and 40.2 g, respectively, which were significantly greater than the control but not different from each other. The lowest among weed-managed plots was T5 (38.8 g), which remained higher than T1 but significantly lower than all other treatments. These findings indicate that weed control improved grain size, with the strongest enhancement observed under repeated barley extract application (T6).

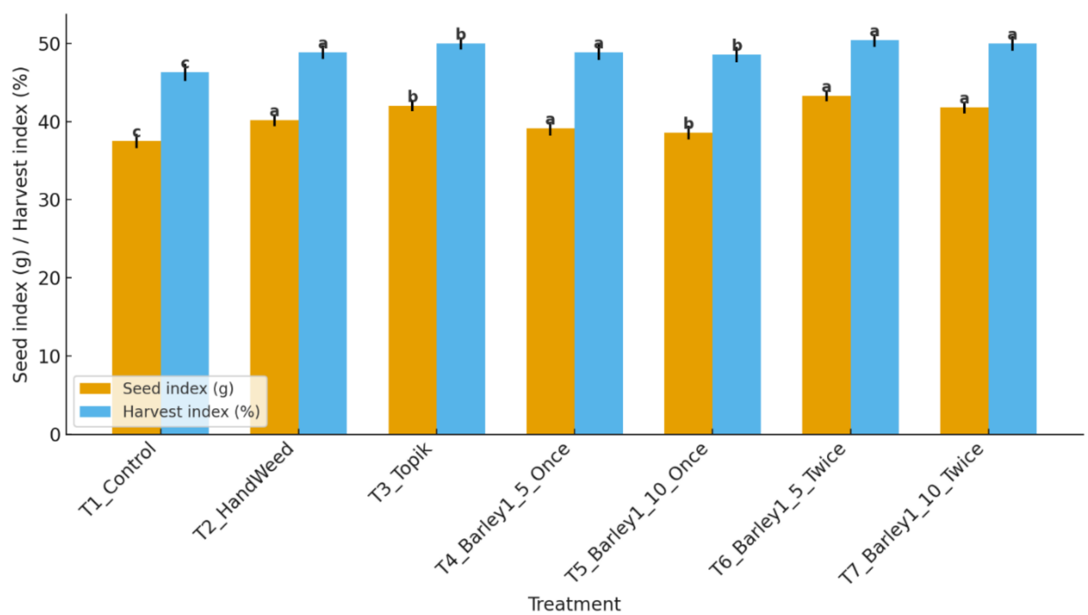

Fig 4: Weed management strategies and seed and harvest indices of wheat

Harvest index (%)

Harvest index was also significantly affected by weed management (Fig. 4). The control exhibited the lowest harvest index (46.3%), while T6 produced the highest value (50.4%), an increase of 8.9%. Topik (T3) and T7 recorded harvest indices of 49.7% and 49.2%, respectively, both significantly greater than T1 but statistically lower than T6. Hand weeding (T2) and T4 showed values of 48.5% and 48.8%, respectively, which were intermediate between the control and best treatments. T5 remained lowest among managed plots at 47.5%. This improvement in harvest index indicates that weed control not only enhanced biomass but also facilitated greater partitioning of assimilates toward grain production.

Weed management had a strong effect on biological yield (Fig. 5). The control produced only 8,200 kg ha⁻¹, while T6 attained the highest value of 10,120 kg ha⁻¹, showing a 23.4% increase. Topik (T3) and T7 also produced significantly higher biological yields (9,860 and 9,720 kg ha⁻¹, respectively). Hand weeding (T2) and T4 recorded 9,420 and 9,310 kg ha⁻¹, while T5 (8,880 kg ha⁻¹) remained significantly lower than other treatments but still exceeded the control. These findings suggest that effective weed control increased vegetative biomass production, with T6 being the most effective.

Biological yield (kg ha^{-1})

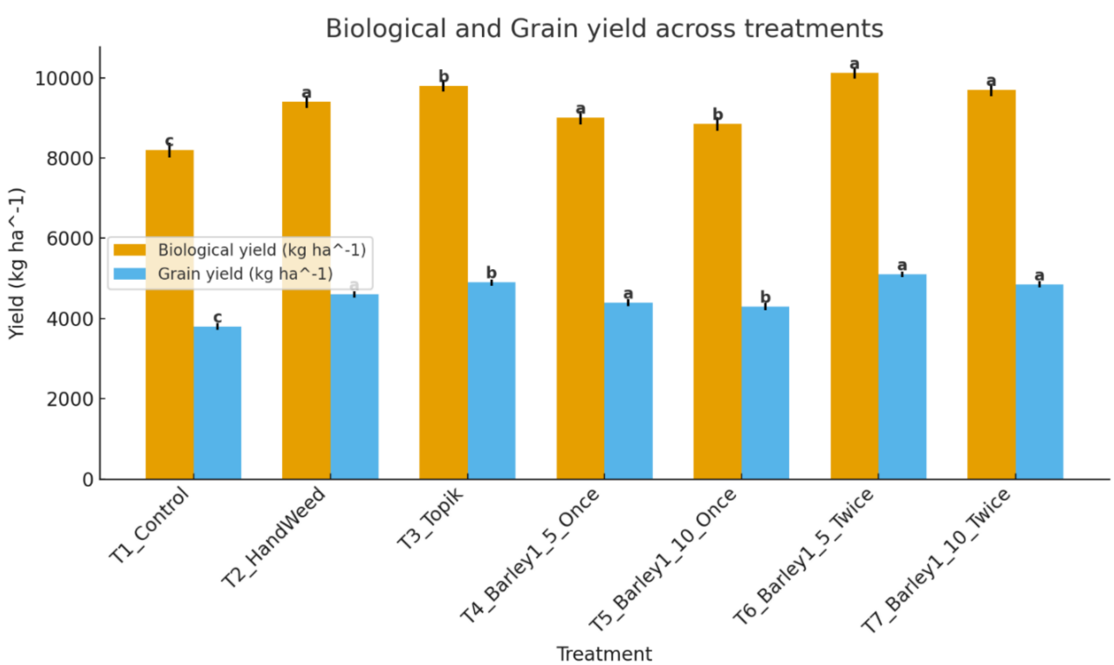

Fig 5: Weed management strategies and biological and grain yields of wheat

Grain yield (kg ha⁻¹)

Grain yield was most adversely affected in the control, which produced only 3,800 kg ha^{-1}, whereas the maximum yield of 5,100 kg ha^{-1} was recorded under T6, representing a 34.2% improvement (Fig. 5). Topik (T3) produced 4,900 kg ha^{-1}, while T7 yielded 4,820 kg ha^{-1}, both significantly higher than the control but statistically lower than T6. Hand weeding (T2) and barley extract at 1:5 once (T4) resulted in 4,600 and 4,520 kg ha^{-1}, respectively, while T5 remained the lowest among managed treatments at 4,120 kg ha^{-1}. The significant yield advantage under T6 can be attributed to its combined improvements in plant height, spike length, grain number, and grain weight. This highlights the importance of sustained weed suppression during both vegetative and reproductive stages.

CONCLUSION

The present study highlighted the relative efficacy of diverse weed management strategies in wheat, including hand weeding, herbicidal application, and barley water extracts as allelopathic treatments. Results exposed that weed control actions pointedly improved growth, yield, and yield-contributing traits compared with the weedy check. Among the treatments, herbicide and double applications of barley extract demonstrated superior performance in enhancing plant height, spike length, grains per spike, seed index, and ultimately grain yield. Hand weeding also proved effective but less consistent. The findings confirm that integrating allelopathic plant extracts with conventional approaches can reduce reliance on herbicides while maintaining yield potential. Such strategies offer sustainable and eco-friendly solutions for weed management in wheat production systems.

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