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Research Article

Appraising Herbicide Tank Mixtures for Weed Suppression, Crop Safety and Net Returns in Wheat

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ABSTRACT

Wheat is a staple crop in Pakistan but susceptible to yield losses from weeds infestations. Weeds compete with wheat for vital resources such as nutrients, water and sunlight leading to substantial economic losses in wheat production. The chemical control is widely adopted due to its efficiency although excessive and improper use of herbicide can lead to persistence in the soil, promote herbicide resistance and result in diverse weed flora in wheat fields. The implication of herbicide mixtures with multiple mode of action is recommended to enhance weed control efficacy and delay resistance development. In this study a field experiment was conducted by following a Randomized Complete Block Design (RCBD) with three replications and a plot size of 8 m × 3 m. A total nine treatments were applied including herbicide mixtures *viz*. T_1= Atlantis (Iodo + Mesosulfuron) at 14.4 g a.i ha^{-1} WDG + Buctril Super (Bromxynil+MCPA) at 148.2 g a.i ha^{-1} EC, T_2= Skopik Gold (Florasulam+Mesosulfuron) 14.8 g a.i ha^{-1} OD T_3= Metafin Super (Tribenuron+metsulfuron) 70.642 g a.i ha^{-1} WDG + Maitu (Clodinafop propargyl+ Flucarbazone sodium) at 32.11 a.i g ha^{-1} OD T_4= Trivax Super (Fluroxypyr+ Florasulam+ MCPA) at 1185.6 a.i ha^{-1} SC T_5= Trivax Ultra (Mesosulfuron+ Florasulam+ MCPA) at 112.5 g a.i ha^{-1} OD T_6= Buctril Super (Bromxynil+MCPA) at 148.2 g a.i ha^{-1} EC, + Maitu (Clodinafop propargyl+ Flucarbazone sodium) 32.11 a.i g ha^{-1} OD T_7= Buctril Super (Bromxynil+MCPA) at 148.2 g a.i ha^{-1} EC, + Axial (Pinoxaden) at 41.25 g a.i ha^{-1} EC T_8= Wheat Star (Clopyralid+Fluroxypyr+ Tribenuron) 244.53 g a.i ha^{-1} WDG, + Axial (Pinoxaden) at 41.25 g a.i ha^{-1} EC T_9= Weedy Check. The treatment Metafin Super in combination with Maitu produced the highest grain yield (4401.0 kg ha^{-1}), biological yield (9334.1 kg ha^{-1}) and spike length (13.19 cm). Additionally, the application of Skopik Gold resulted in the highest harvest index (61.73%), 1000-seed weight (46.75g) and suppressed the weeds showing a least density of 10.0 and 8.67 plants m^{-2} at 30 and 60 days after treatment, respectively as compared to weedy check. The finding of this study concluded that mixture of Florasulam+Mesosulfuron was effective in controlling the weed population that could reduce the yield gaps owing to weed competition in wheat.

Keywords: Tank mixtures, Weed control, Weed infestation, Herbicide resistance, Wheat production

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INTRODUCTION

Wheat (*Triticum aestivum*) is an important crop and a staple food in Pakistan (Tahir et al., 2023). Wheat as a monocot, self-pollinating crop that belongs to Poaceae family (Lev-Yadun et al., 2000). Wheat grain comprises 1.6-2% lipids, 1.1-2% inorganic ions, 60-90% carbohydrates, 10.9-16% proteins, and B and E vitamins'(Rueda-Ayala et al., 2011). This crop is consumed as a staple food for 36%

of the global population including Pakistan (Arif et al., 2023). In 2023-24, wheat was sown over 9.6 million hectares (Mha), compared to 9.0 Mha of the previous year, indicating an increase of 6.6%. Wheat production was also increased to 31.4 million tons, from 28.2 million tons of the previous year corresponding to a surge of 11.6% in Pakistan. It is notable that this crop contributes 9.0% to agricultural value addition and 2.2% in GDP of Pakistan (GOP, 2024). The production of wheat is affected by numerous biotic including disease like leaf blotch, *Stagonospora nodorum* blotch, tan spot, yellow rust, loose smut, ear blight, powdery mildew, weeds (Nóia Júnior et al., 2023; Radzikowski et al., 2023) and abiotic factors like extreme and low temperatures, drought stress, salinity, and mineral nutrient deficiencies (Wan et al., 2022).

Among all these factors, weeds contribute significantly to the production losses and weed infestation is responsible for reduced wheat yield. Weeds compete with other plants for resources like moisture, carbon dioxide, water, sunlight, nutrients, and many other growth variables. The literature suggests a variable number of weed species in the wheat fields in different countries, however approximately 45 weed species have been identified in Pakistan along with 33 in Iran, 90 in India, and 73 in Bangladesh (Popal, 2024). Wheat fields are mostly infested by grasses such as Little seed canary grass (*Phalaris minor*), Wild oat (*Avena fatua*), Bermuda grass (*Cynodon dactylon*), Hairy crabgrass (*Digitaria sanguinalis*), sedges such as Purple nutsedge (*Cyperus rotundus*) and broadleaf weeds like common lambsquarters (*Chenopodium album*), Goosefoot (*Chenopodium murale*), Bitter dock (*Rumex obtusifolius*), Wartcress (*Coronopus squamatus*), Scarlet pimpernel (*Anagallis arvensis*), Field bindweed (*Convolvulus arvensis*), Creeping thistle (*Cirsium arvense*), Sweet clover (*Melilotus officinalis*), Cudweeds (*Gnaphalium spp.*), Asiatic pennywort (*Centella asiatica*) etc. (Matloob et al., 2020). According to reports, weed infestation caused 20-50% losses in wheat grain output (Ullah et al. 2023), while weeds in Pakistan are estimated to cause up to 36 million tons of yield losses yearly which may exceed the combined damage effect by disease and insect pests (Zafar et al., 2010). The monetary worth of these losses is estimated to approximately 3 billion US dollars (Naseer-ud-Din et al., 2011).

As with many crops, weeds management is essential in the initial phases of crop growth, that is 30 to 60 days later crop emergence in the case of wheat (Korav et al., 2018). The management of weeds is carried out by different approaches including hoeing, mechanical, cultural, biological and chemical control in wheat (Khan et al., 2016). However, mechanical and manual weeding are costly, time-consuming and crop mimicry can occasionally make it impossible to control weeds (Lakra and Husain, 2020). Chemical weed management is non-laborious, an effective, less time taking and economic strategy of controlling diverse weed populations in wheat fields (Beiermann et al., 2022). Herbicides are being used worldwide to control weed populations effectively. However, the extensive and irrational application of these chemicals have detrimental effects on crop plants' phenology, physiological, and biochemicals characteristics, resulting in phototoxicity and lower yields (Hasanuzzaman et al., 2020). A study found that spraying 75 WP isoproturon to wheat field just after planting resulted in a phytotoxic impact (Navjyot et al., 2016). Fault lines in herbicide application (excessive dosage, incorrect techniques, equipment, and spray volume) can change plant physiology, metabolism, and development, which eventually leads to phytotoxicity and decreased crop output (kumar and Puja, 2018). The repeated use of same herbicide or applying doses lower than the recommended levels has resulted in the development of resistant biotypes of weeds (Yadav et al., 2013). It is important to consider, that incorrect and excessive herbicide usage can harm the ecosystem and lead to the herbicide resistance weed populations (Shah et al., 2019). The application of herbicide tank mixtures with multiple mode of action provides significantly better weed control, improves crop safety, and results in higher economic yields compared to using single herbicide in wheat (Ahmed et al., 2020). The combinations of herbicide are used to manage weeds in an efficient and cost-effective manner. In order to increase wheat yield, a combination of two herbicides was used to suppress broadleaf weeds that were resistance to 2, 4-D and resistance *P. minor* biotypes that were not controlled by isoproturon (Kumar et al., 2013). It is crucial to assess tank combinations of herbicides to have a broad-spectrum weed control in order to manage the dynamics and diverse weed flora in wheat. The current research aimed to evaluate the effectiveness of various herbicide tank mixtures in controlling weed populations in wheat crop while also examining their effects on crop safety and economic yield.

MATERIALS AND METHODS

Experimental site

The field experiments were conducted during the winter 2023-24 at research area of the MNS-University of Agriculture Multan, Pakistan (30˚14''N, 71˚43''E) Figure 1.

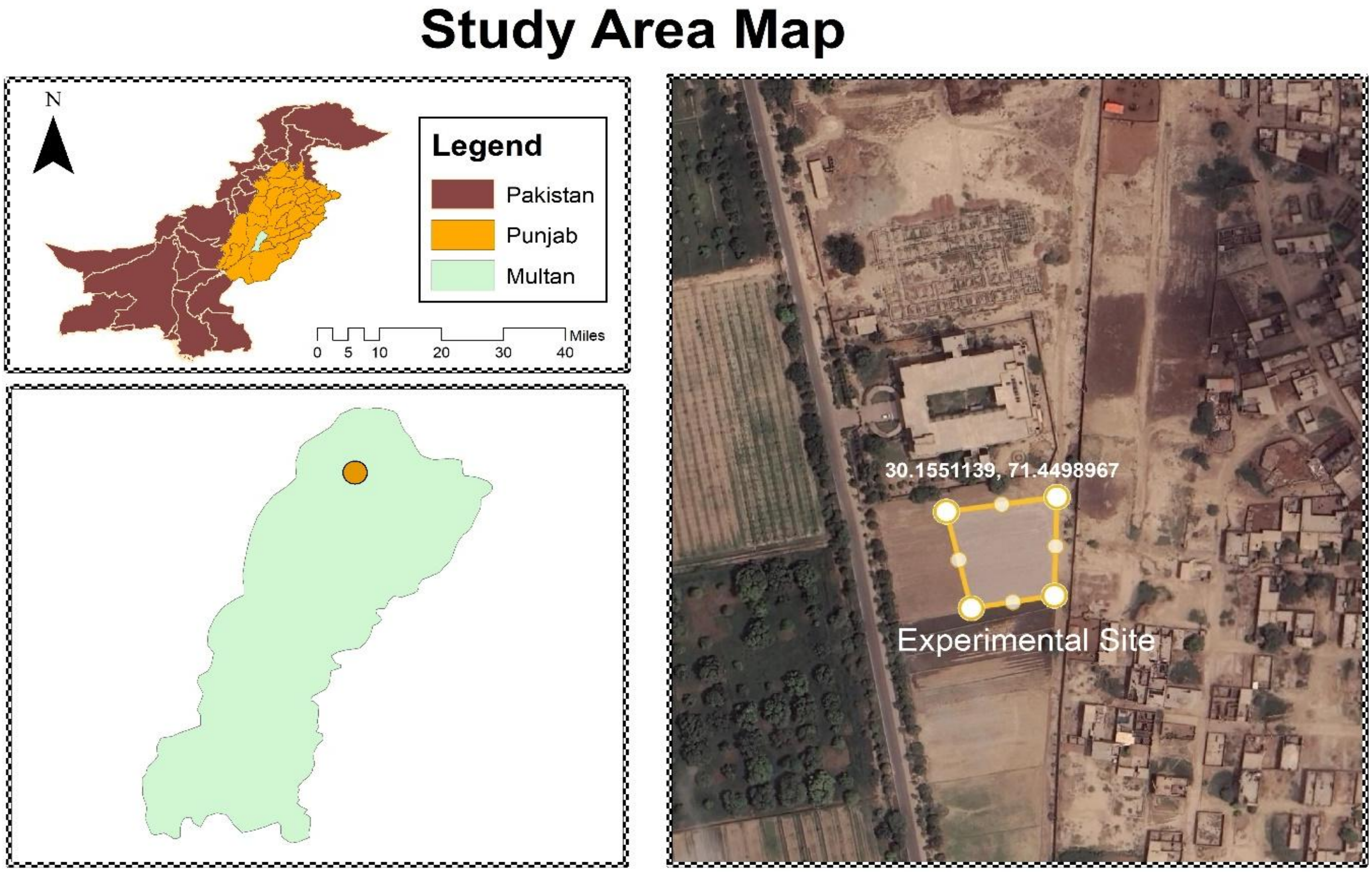

Figure 1. Map of experimental site, yellow boundary line showing the plot where wheat was sown.

Climate

This trial was conducted in a semi-arid area where medium rainfall primarily occurs in July-august due to the monsoon season and low rainfall occurs from October to May. From March to June, the area experienced extremely high temperatures along with elevated humidity levels. The experimental site was located at an altitude of approximately 122 m above sea level. Meteorological data, including maximum and minimum temperatures and rainfall throughout the crop period, were collected from the automatic meteorological station (AMS) in Multan (Figure 2). According to AMS records, the average maximum and minimum temperatures were 34.7 °C and 10.0 °C, respectively.

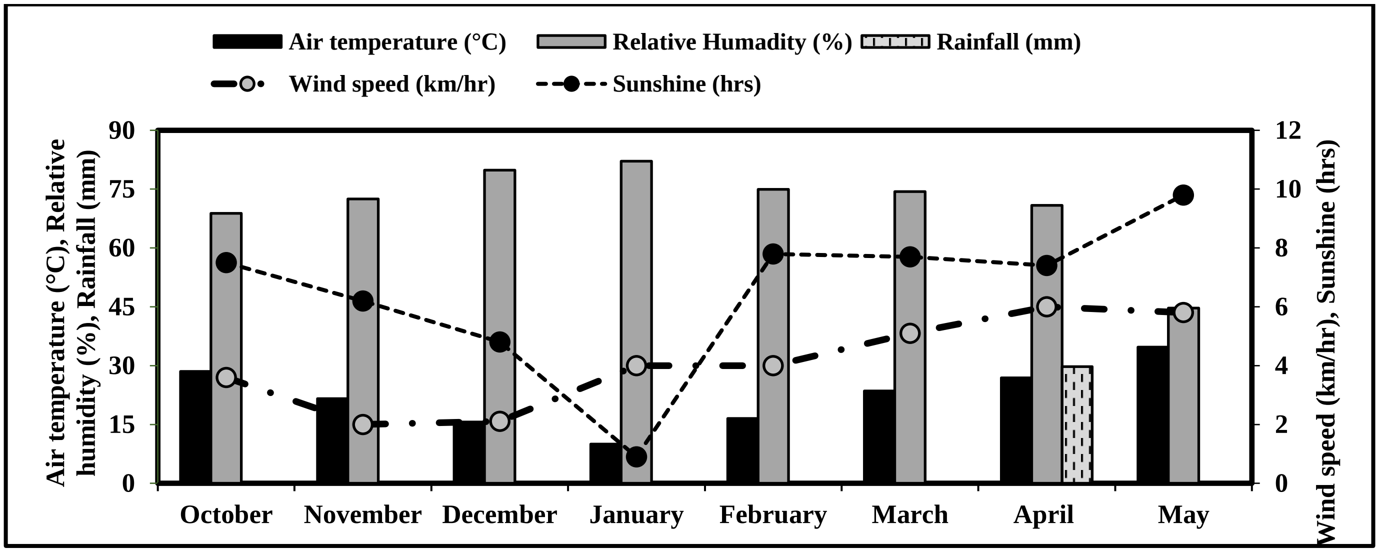

Figure 2. Daily weather variables (maximum and minimum temperature, relative humidity, rainfall, sunshine hours and wind speed).

Research Design and Treatments

The experiment was conducted using a Randomized Complete Block Design (RCBD), with three replications and each plot having a dimension of 8 m × 3 m. The tank mixture treatments were T_1= Atlantis (Iodo + Mesosulfuron) at 14.4 g a.i ha^{-1} WDG + Buctril Super (Bromxynil+MCPA) at 148.2 g a.i ha^{-1} EC, T_2= Skopik Gold (Florasulam+Mesosulfuron) 14.8 g a.i ha^{-1} OD, T_3= Metafin Super (Tribenuron+metsulfuron) 70.642 g a.i ha^{-1} WDG + Maitu (Clodinafop propargyl+ Flucarbazone sodium) at 32.11 a.i g ha^{-1} OD, T_4= Trivax Super (Fluroxypyr+ Florasulam+ MCPA) at 1185.6 a.i ha^{-1} SC, T_5= Trivax Ultra (Mesosulfuron+ Florasulam+ MCPA) at 112.5 g a.i ha^{-1} OD, T_6= Buctril Super (Bromxynil+MCPA) at 148.2 g a.i ha^{-1} EC, + Maitu (Clodinafop propargyl+ Flucarbazone sodium) 32.11 a.i g ha^{-1} OD, T_7= Buctril Super (Bromxynil+MCPA) at 148.2 g a.i ha^{-1} EC, + Axial (Pinoxaden) at 41.25 g a.i ha^{-1} EC, T_8= Wheat Star (Clopyralid+Fluroxypyr+ Tribenuron) 244.53 g a.i ha^{-1} WDG, + Axial (Pinoxaden) at 41.25 g a.i ha^{-1} EC, and T_9= Weedy Check.

Crop Husbandry

Land preparation for wheat crop involved two ploughings and two cultivations to prepare a seedbed of good tilth. The Akbar-2019 variety of wheat was used for planting, and a tractor mounted seed drill was utilized to sow 75 kg of seed per hectare, ensuring uniformity in the crop stand. Irrigation was applied based on the crop requirements and environmental conditions, while all other intercultural practices, aside from those being investigated, were maintained consistently. A balanced basal dose of nitrogen, phosphorous, and potassium was applied using urea (100 kg ha^{-1}), DAP (125 kg ha^{-1}), and K_2SO_4 (50 kg ha^{-1}), respectively. Nitrogen application was splitted to enhance plant uptake: one-third was incorporated into the soil during seedbed preparation, along with the full doses of phosphorous and potassium. The second dose of nitrogen was applied with the first irrigation, and the remaining was added during the second irrigation. Canal water was used for all irrigations. Guidelines of Punjab Agriculture Department were followed closely, ensuring uniform agronomic practices across all treatments throughout the study.

Data collection

The growth and yield traits, such as, plant height (cm), tillers (m^{-2}), spike length (cm), number of spikelets, grains per spike, 1000-seed weight (g), biological yield (kg ha^{-1}), grain yield (kg ha^{-1}), and harvest index (%) were recorded at harvest (Equation 1). At maturity, ten plants were randomly selected from each experimental plot, and the above parameters were measured. Additionally, two samples of thousands of grains were collected from each plot, weighed using analytical balance, and their average was calculated. The harvest index for wheat was determined by formula:

$$Harvest\ index\ (\%) = \frac{Economic\ yield}{Biological\ yield} \times 100 \quad (1)$$

The wheat from each experimental plot was harvested, weighed on an analytical weighing balance and converted to biological yield (kg ha^{-1}). Biological yield in wheat is calculated by equation 2:

$$Biological\ yield\ (kg\ ha^{-1}) = Dry\ biomass\ (kg\ m^{-2}) \times 10{,}000 \quad (2)$$

The wheat plants were threshed after harvesting, and the grain weight was measured and converted into grain yield (kg ha^{-1}). Grain yield in wheat is calculated using the formula in equation 3:

$$Grain\ Yield\ (kgha^{-1}) = Dry\ grain\ weight\ (Kg\ m^{-2}) \times 10{,}000 \quad (3)$$

Weed density (Plants m^{-2}) was recorded at 30 and 60 days after application of herbicides by randomly placing two quadrats, each measuring 0.25 m^2 in each plot. The weeds were categorized into groups (grass, broadleaf, and sedge) and counted. The weeds were then placed in paper bags for oven drying at 70 °C for 48 hours to determine constant biomass. Weed density is expressed as plants m^{-2}.

The green leaves of wheat were used to measure the physiological attributes, transpiration rate (*E*), water use efficiency (*WUE*), stomatal conductance (*gs*), photosynthesis rate (*A*), sub-stomatal conductance (*Ci*)]. At full canopy development (60-90 DAS), net leaf photosynthesis rate and stomatal conductance were accessed on ten randomly selected plants in each plot using the CIRAS instrument (CIRAS-3 Hansetech Instrument Ltd, Pentney, UK).

Statistical Analysis

The collected data was analyzed using statistix 8.1 software based on the randomized complete block design (RCBD). The means of treatments were compared using the least significant difference (LSD) at $p \leq 0.05$.

RESULTS

Growth Yield and Physiological Attribute

The influence of various treatments of herbicide tank mixture on plant height (cm) is presented in table 1. The treatment of Skopik Gold (Florasulam+Mesosulfuron at 14.8 g a.i ha^{-1}) produced the highest wheat plant height showing an average height of 82.53 cm. Nevertheless, the effect of applied herbicides on plant height was non-significant. The treatment Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) + Atlantis (Iodo+mesosulfuron 14.4 g a.i ha^{-1}) mixture led to a statistically significant increase in the number of tillers (m^{-2}) reaching at 450.00±15.28 tiller m^{-2}, while a minimum number of tillers 277.67±4.33d (tiller m^{-2}) were observed in the treatment Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) since this herbicide was phytotoxic to wheat as well. The results suggest that the combination of herbicides efficiently reduced the weed competition which boosted the tiller formation to achieve a higher grain yield (Table 1). However, the lower tiller count is attributed to the effect of weed growth on the tiller growth in wheat under weedy check. The finding explores the critical insights of weed control in vegetative and reproductive growth.

Spike length (cm) of wheat was significantly affected by mixtures of herbicides. The treatment Metafin Super (Tribenuron+metsulfuron 70.642 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium at 32.11 a.i g ha^{-1}) resulted in the maximum spike length (13.19±0.03 cm) followed by the Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) and Buctril Super (Bromxynil+MCPA at 148.2 g ha^{-1}) + Atlantis (Iodo+mesosulfuron 14.4 g ha^{-1}) showing the spike length 13.07±0.05 cm and 13.03±0.03 cm, respectively. While the treatment weedy check recorded the shortest spike length (12.90±0.02 cm) indicating the competition for the resources among weeds and wheat. The higher number of spikelets (20.77±0.03) was recorded in the treatment Atlantis (Iodo+mesosulfuron 14.4 g a.i ha^{-1}) + Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) with a similar spikelet per spike (20.73±0.09) in Metafin Super (Tribenuron+metsulfuron 70.642 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium at 32.11 a. i g ha^{-1}). The minimum spikelets per spike 19.97±0.06 were observed in the weedy check indicating the higher competition among the wheat and weeds and reduced yield in this treatment.

The influence of herbicide tank mixture on the number of grains per spike is presented in the Table 1. The results are statistically significant as LSD ($p \leq 0.05$) value 1.526 indicates a statistical difference among various treatments. The maximum grains per spike (81.57±0.69) were recorded for the wheat plants growing in plots treated with Buctril Super (Bromxynil+MCPA 148.2 g a.i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) followed by Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) and Atlantis (Iodo+mesosulfuron 14.4 g a.i ha^{-1}) + Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) with grains per spike 81.40±0.26 and 81.00±0.38, respectively.

In weedy check plots, minimum 74.70±0.71 grains per spike were found which underscore the significance of weed control in maximizing the grain production as the weeds can significantly reduce the number of grains by competing with the essential resources. The 1000-seed weight (g) of wheat was maximum (46.75 g) produced by the Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}) with a similar result for the Metafin Super (Tribenuron+metsulfuron 70.642 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium at 32.11 a. i g ha^{-1}) treated plots having 45.81 g 1000-seed weight (Table 1). The better seed weight is generally associated with a robust seedling growth which contributesto the higher yield in the subsequent plots, while minimum seed weight (42.84 g) was recorded for wheat plants of the weedy check plots reflecting the competition for resources caused by weeds.

The biological yield (kg ha^{-1}) was highest in the Metafin Super (Tribenuron+metsulfuron 70.642 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium at 32.11 a.i g ha^{-1}) treated plots and a similar result was observed for the Atlantis (Iodo+mesosulfuron 14.4 g a.i ha^{-1}) + Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) with the biological yield 9334.10±216.33 kg ha^{-1}, 8964.10±32.69 kg ha^{-1} and 8924.30±50.58 kg ha^{-1}, respectively (Table 1). The treatment weedy check which realized the lowest biological yield 4220.97±147.92 kg ha^{-1} highlighted the magnitude of weed competition induced yield losses in wheat. Metafin Super (Tribenuron+metsulfuron 70.642 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium at 32.11 a. i g ha^{-1}) marked a significant impact on the grain yield as maximum grain yield was attained at 4401.07±202.14 kg ha^{-1} (Table 1). A similar pattern of grain yield was observed in response to other three treatments i.e., Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}), Atlantis (Iodo+mesosulfuron 14.4 g a.i ha^{-1}) + Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}), and Trivax Super (Fluroxypyr+ Florasulam+ MCPA at 1185.6 a.i ha^{-1}) showing a grain yield of 4184.33±72.80 kg ha^{-1}, 4184.20±63.54 kg ha^{-1} and 4401.07±202.14 kg ha^{-1}. The weed check with the minimum grain yield 1767.80±24.10 kg ha^{-1} clearly represents the substantial adverse impact of weeds which leads to significant reduction of yield potential of wheat under limited space, light, nutrients and water.

In this study, maximum value of harvest index was noted for wheat crop growing in the Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}) treated plots (Table 1). The treatment Buctril Super (Bromxynil+MCPA 148.2 g a.i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) and Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium 32.11 a. i g ha^{-1}) had a lowest harvest index of 39.42±0.35% and 37.25±0.37%. In weedy check plots, weed competition reduced the efficiency of plant to convert overall biomass yield in to harvestable grain.

The results presented in Table 2 indicated significant differences for the weed density (Plants m^{-2}) among the treatments at both the 30 and 60 days after treatment (DAT). The treatment weedy check had the highest weed density at 30 DAT (98.00±11.72 plants m^{-2}) which were significantly greater than all the other treatments (LSD $p \leq 0.05$ = 14.170). The treatment Wheat star (Clopyralid+Fluroxypyr+ Tribenuron 244.53 a. i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) showed the second highest weed density at 30 DAT (54.00±2.00 plant m^{-2}) suggesting a less effective weed control. While the lowest weed density was found in the treated plots of Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}) and Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) with a density of 10.00±0.58 plant m^{-2} and 10.00±1.15 plants m^{-2}, respectively. In contrast to data recorded at 30 DAT, the weed density at 60 DAT (LSD $p \leq 0.05$ = 0.406) showed the highest weed density (95.33±7.86 plants m^{-2}) in Wheat star (Clopyralid+Fluroxypyr+ Tribenuron 244.53 a. i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) treated plots followed by the weedy check (73.33±9.26 plants m^{-2}) plots. The consistent low densities in Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}) 8.67±0.67 plants m^{-2} and Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) 12.00±0.58 plants m^{-2} reflected the sustained herbicide activity to reduce the weed density for a higher yield in wheat.

Table 2 displays the results of dry biomass (g m^{-2}) in response to the applied treatments. The results showed that the maximum weed dry biomass (g m^{-2}) was found in the weedy check plots with a highest dry biomass at both 30 DAT which was 5.74±0.24 g m^{-2} (LSD $p \leq 0.05$ = 0.406) and at 60 DAT was 5.90±0.44 g m^{-2} (LSD $p \leq 0.05$ = 0.572). In contrast, Wheat star (Clopyralid+Fluroxypyr+ Tribenuron 244.53 a. i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) exhibited a relatively higher weed biomass 1.41±0.14 g m^{-2} at 30 DAT and 2.01±0.34 g m^{-2} at 60 DAT. While the treatment Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}) and Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) showed a lowest biomass consistently below 0.5 g m^{-2} which highlight their effectiveness in the reduction of weed biomass and minimization of competition for essential resources like space, light, water and nutrients.

Table 1. Influence of herbicide tank mixtures on agronomic and yield parameters of wheat.

Treatments	**Plant height (cm)**	**Tillers (m^{-2})**	**Spike length (cm)**	**Spikelets per spike**	**Grains per spike**	**1000-seed weight (g)**	**Biological yield (kg ha^{-1})**	**Grain yield (kg ha^{-1})**	**Harvest index (%)**
Atlantis (Iodo+mesosulfuron) + Buctril Super (Bromxynil+MCPA)	77.04±4.25	450.00±15.28a	13.04±0.06bc	20.77±0.03a	81.00±0.38a	44.94bc	8964.10±32.69a	4184.20±63.54a	46.67±0.54c
Skopik Gold (Florasulam+Mesosulfuron)	82.53±1.47	295.00±8.66bcd	13.03±0.03bcd	20.60±0.06ab	78.83±0.18b	46.75a	6777.67±64.95c	4184.33±72.80a	61.73±0.55a
Metafin Super (Tribenuron+metsulfuron + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	79.42±0.33	285.00±5.77cde	13.19±0.03a	20.73±0.09a	79.13±0.52b	45.81ab	9334.10±216.33a	4401.07±202.14a	47.11±1.22c
Trivax Super (Fluroxypyr+ Florasulam+ MCPA)	81.70±2.12	300.33±2.91bc	12.92±0.05cde	20.60±0.06ab	80.70±0.61a	44.78bc	8924.30±50.58a	4160.83±72.17a	46.62±0.55c

Trivax ultra (Mesosulfuron+ Florasulam+ MCPA)	81.85±1.61	277.67±4.33de	13.07±0.05ab	20.63±0.09ab	81.40±0.26a	44.04cd	6401.03±144.31c	2631.00±191.30c	41.13±3.05de
Buctril Super (Bromxynil+MCPA) + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	80.07±0.21	312.67±3.84b	12.90±0.02de	20.50±0.06b	78.57±0.24b	43.88cd	7387.73±243.61b	2750.93±75.20bc	37.25±0.37e
Buctril Super (Bromxynil+MCPA) + Axial (Pinoxaden)	80.67±0.39	284.67±5.17cde	12.92±0.05cde	20.60±0.06ab	81.57±0.69a	44.77bc	7664.57±188.92b	3021.20±75.00b	39.42±0.35de
Wheat star (Clopyralid+Fluroxypyr+ Tribenuron) + Axial (Penoxaden)	82.98±0.74	302.33±4.33bc	12.87±0.06e	20.60±0.06ab	78.80±0.59b	44.45bcd	7647.93±287.12b	4264.40±59.34a	55.86±1.38b
Weedy check	79.44±0.84	273.33±4.26e	12.65±0.02f	19.97±0.06c	74.70±0.71c	42.84d	4220.97±147.92d	1767.80±24.10d	41.95±0.92d
LSD *p ≤ 0.05*	NS	21.14	0.143	0.206	1.526	1.689	443.1	346.7	4.001

NS: non-significant, Means not sharing a letter in common differ significantly at 5% probability level by LSD test at 5% level of probability.

Table 2. Influence of herbicide tank mixtures on weed density and dry biomass.

Treatments	**30 DAT**		**60 DAT**	
	Density (Plants m^{-2})	**Dry biomass (g m^{-2})**	**Density (Plants m^{-2})**	**Dry biomass (g m^{-2})**
Atlantis (Iodo+mesosulfuron) + Buctril Super (Bromxynil+MCPA)	34.00±4.62c	1.02±0.12bc	16.00±2.31de	0.29±0.05c
Skopik Gold (Florasulam+Mesosulfuron)	10.00±0.58e	0.48±0.07de	8.67±0.67e	0.16±0.01c
Metafin Super (Tribenuron+metsulfuron + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	29.33±2.40cd	0.99±0.07c	36.00±2.31c	0.56±0.10c
Trivax Super (Fluroxypyr+ Florasulam+ MCPA)	16.00±3.46de	0.74±0.13cd	12.67±2.67e	0.38±0.05c
Trivax ultra (Mesosulfuron+ Florasulam+ MCPA)	10.00±1.15e	0.29±0.06e	12.00±0.58e	0.33±0.05c
Buctril Super (Bromxynil+MCPA) + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	18.67±1.76de	0.77±0.17cd	26.00±0.58cd	0.33±0.07c
Buctril Super (Bromxynil+MCPA) + Axial (Pinoxaden)	26.00±1.15cd	0.63±0.10cde	37.33±2.40c	0.67±0.02c
Wheat star (Clopyralid+Fluroxypyr+ Tribenuron) + Axial (Penoxaden)	54.00±2.00b	1.41±0.14b	95.33±7.86a	2.01±0.34b
Weedy check	98.00±11.72a	5.74±0.24a	73.33±9.26b	5.90±0.44a
LSD *p ≤ 0.05*	14.170	0.406	12.747	0.572

DAT: Days after treatment, Means not sharing a letter in common differ significantly at 5% probability level by LSD test at 5% level of probability.

The results of stomatal conductance (*gs*) showed a significant (LSD ≤ *p*0.05 = 1.640) variation among the treatments with Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}) having the maximum *gs* (4.00±0.58 mmol m^{-2} s^{-1}). The result showed that the mixture of Florasulam+Mesosulfuron enhanced the gaseous exchanges which potentially benefited the photosynthesis by the uptake of more CO_2 (Table 2.1). In contrast, lower gs (1.00±0.02 mmol m^{-2} s^{-1}) was observed in the treatment Trivax Super (Fluroxypyr+ Florasulam+ MCPA at 1185.6 a. i ha^{-1}) and Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium 32.11 a. i g ha^{-1}) resulted in the gs of 1.33±0.33 mmol m^{-2} s^{-1} which indicate the restricted gaseous exchange. Sub-stomatal conductance (*Ci*) reflects the CO_2 levels in the plant tissues which was maximum in the weedy check (868.67±14.38 µmol H_2O m^{-2} s^{-1}). In contrast, Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}) and Trivax Super (Fluroxypyr+ Florasulam+ MCPA at 1185.6 a. i ha^{-1}) showed a lower *Ci* i.e., 400.33±1.67 and 469.67±28.20d µmol H_2O m^{-2} s^{-1} which indicate a better utilization of internal CO_2 that is capable to enhance the photosynthetic efficiency of the wheat.

The transpiration rate (*E*) was statistically significant among the treatments as shown by LSD *p*≤0.05 = 0.009. The *E* was maximum for wheat plants sprayed with Wheat star (Clopyralid+Fluroxypyr+ Tribenuron 244.53 a. i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) indicating the increased water losses and possibly higher physiological activity or stress response. The lower *E* (0.10±0.00 µmol H_2O m^{-2} s^{-1}) was observed in the treatment Atlantis (Iodo+mesosulfuron 14.4g a.i ha^{-1}) + Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}; Table 2.1). The results showed that the photosynthetic rate (A) was significantly (LSD *p*≤0.05 = 0.04) affected by the treatments displaying highest A value of 0.18±0.01 µmol CO_2 m^{-2} s^{-1} for the wheat plants sprayed with Skopik Gold (Florasulam+Mesosulfuron 14.8 g a.i ha^{-1}). In contrast, the lowest A (0.05±0.00 µmol CO_2 m^{-2} s^{-1}) was recorded in the Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) which reflects the adverse impact of weed plant competition on the photosynthetic efficiency and overall crop performance.

The vapor pressure deficit (*VPD*) measures the evaporative demand of the water and this parameter was statically significant (LSD, *p*≤0.05 = 0.365) among the various treatments of herbicide tank mixture. The results in Table 2.1 represent that the maximum *VPD* was recorded in the weedy check (4.53±0.02 Kpa) followed by the treatment Wheat star (Clopyralid+Fluroxypyr+ Tribenuron 244.53 g a.i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) (4.41±0.18 Kpa). While the minimum *VPD* (3.50±0.06 Kpa) was observed in the Buctril Super (Bromxynil+MCPA 148.2 g a.i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}). Water use efficiency (*WUE*) was maximum (7.68±0.27 kg ha^{-1} mm^{-1}) for wheat plants growing in the weedy check plots. The results of Table 3 also indicate the treatments like Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) and Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium 32.11 a.i g ha^{-1}) showed a lower WUE which may be due the less water was used that may not have translated into higher crop biomass or yield that possibly due to the less weed control or suboptimal herbicide performance (LSD, p≤0.05 = 0.778).

Table 3. Influence of herbicide tank mixtures on physiological attributes of wheat.

Treatments	**Stomatal conductance** (mmol m^{-2} s^{-1})	**Sub-stomatal conductance** (µmol H_2O m^{-2} s^{-1})	**Transpirational rate** (µmol H_2O m^{-2} s^{-1})	**Photosynthetic rate** (µmol CO_2 m^{-2} s^{-1})	**Vapor pressure deficit** (KPa)	**Water use efficiency** (kg ha^{-1} mm^{-1})
Atlantis (Iodo+mesosulfuron) + Buctril Super (Bromxynil+MCPA)	2.33±0.33b	430.33±1.45e	0.10±0.00c	0.14±0.02b	3.64±0.04bc	0.63±0.26d
Skopik Gold (Florasulam+Mesosulfuron)	4.00±0.58a	400.33±1.67e	0.13±0.03c	0.18±0.01a	3.55±0.21c	0.54±0.01d
Metafin Super (Tribenuron+metsulfuron + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	1.67±0.67b	431.33±18.89e	0.10±0.00c	0.10±0.02bcd	3.74±0.06bc	1.14±0.20d

Trivax Super (Fluroxypyr+ Florasulam+ MCPA)	1.00±0.02b	469.67±28.20de	0.17±0.03bc	0.07±0.00de	3.68±0.15bc	2.10±0.62c
Trivax ultra (Mesosulfuron+ Florasulam+ MCPA)	2.00±1.00b	602.67±2.73c	0.17±0.03bc	0.05±0.00e	3.94±0.03b	3.22±0.11b
Buctril Super (Bromxynil+MCPA) + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	1.33±0.33b	721.00±92.59b	0.17±0.03bc	0.06±0.01de	3.73±0.13bc	3.25±0.13b
Buctril Super (Bromxynil+MCPA) + Axial (Pinoxaden)	2.33±0.33b	543.33±2.40cd	0.23±0.03ab	0.07±0.02de	3.50±0.06c	3.33±0.00b
Wheat star (Clopyralid+Fluroxypyr+ Tribenuron) + Axial (Penoxaden)	1.67±0.33b	551.33±5.46cd	0.27±0.03a	0.11±0.01bc	4.41±0.18a	1.97±0.03c
Weedy check	2.00±0.58b	868.67±14.38a	0.17±0.03bc	0.08±0.01cde	4.53±0.02a	7.68±0.27a
LSD p ≤ 0.05	1.640	103.861	0.009	0.004	0.365	0.778

DAT: Days after treatment, Means not sharing a letter in common differ significantly at 5% probability level by LSD test at 5% level of probability.

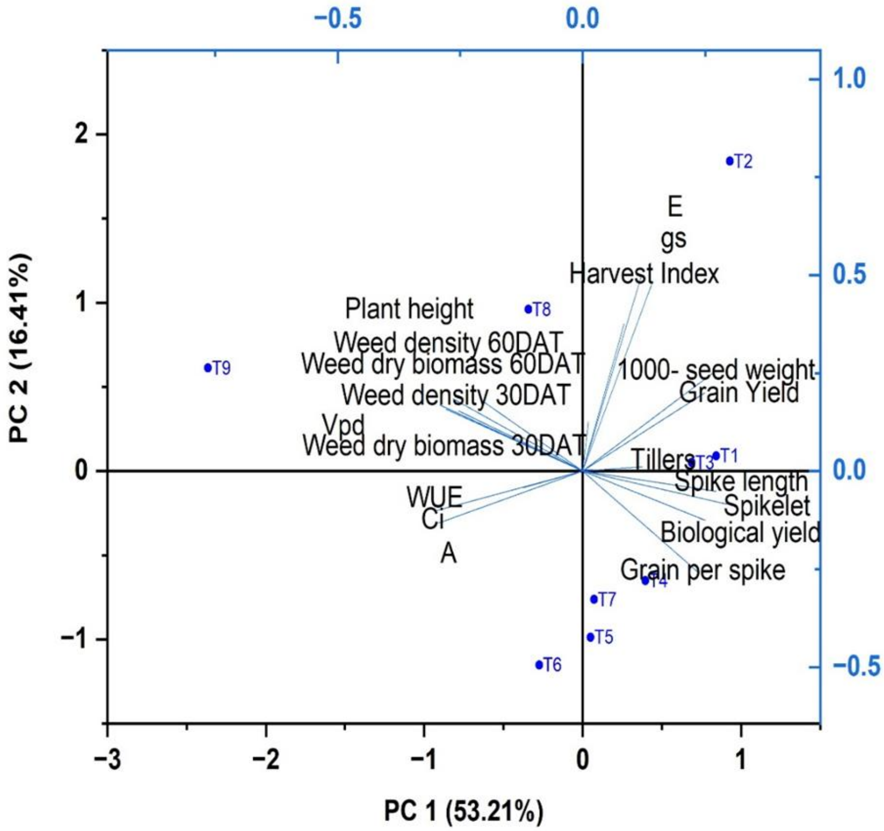

Figure 3. PCA Biplot showing effects of herbicide treatments on wheat traits and weed biomass.

This PCA biplot illustrated the impact of various herbicide treatments (T1 to T9) on wheat traits and weed characteristics. The x- axis (PC1), which accounts fo4 53.21% of the variation, is associated with yield related traits like grain yield, harvest index, and 1000-seed weight showing that treatments aligned along this axis tend to enhance these traits. The y-axis (PC2), explaining 16.41% of the variation, separates treatments like T9 and T8 from the other, indicating that these treatments have distinct effects on weed density and biomass, likely due to their differing weed suppression and effectiveness (Figure 3)

DISCUSSION

Weeds infestation limits sustainable wheat production in irrigated areas of Pakistan. The crop growth and development are adversely affected through weed competition with crop for nutrients, space, water, and sunlight. Furthermore, weeds also release toxic chemicals that inhibit the growth of wheat plants and resulting in low wheat productivity (Marwat et al., 2013). It has been reported that losses of wheat grain yield were 20 to 50 percent due to weed infestation (Ullah et al., 2023). Weeds can diminish agricultural productivity by depleting essential resources, harboring pests, disrupting water flow, and diminishing both the yield and quality of crops, leading to higher input cost (Zimdahl and Basinger 2024). Wheat plant height is an important agronomic trait that can affect weed competition, yield, plant architecture, and lodging resistance. Under favorable conditions, taller plants can produce more biomass and accumulate more grain yield. The treatments of Skopik Gold (Florasulam+Mesosulfuron at 14.8 g a.i ha^{-1}) produced the highest wheat plant height showing an average height of 82.53 cm. These results are in line with the findings of Pala and Mennan (2019) who stated that increment in plant height was attained in treatments where weeds were controlled with herbicide than the weedy check. The number of tillers in a wheat field refers to the secondary shoots or stems that grow from the base of the main wheat plant. Tillering is an important aspect of wheat growth and development that can have both positive and negative effects on crop yield and quality. The number of tillers here referred to increase the yield of wheat crop. The maximum tillers were recorded in experimental unit where Atlantis (Iodo+mesosulfuron) + Buctril Super (Bromxynil+MCPA) as post-emergence was applied to control weeds.

Buctril-super suppressed weeds efficiently, so in the absence of weeds the crop plants established well and produced the maximum number of tillers m^{-2}. Malik et al. (2009) reported that number of tillers was significantly improved with the control of broadleaved weeds when Buctril-super was applied at recommended doses compared to other herbicides. In this study, maximum spike length was observed for the plants growing in Metafin Super (Tribenuron+metsulfuron + Maitu (Clodinafop propargyl+ Flucarbazone sodium) treated plots which may be attributed to the minimum weed competition and healthy plant growth. The increased spike length under the treatment of weedicide to control weeds in wheat is well reported by Asad et al., (2017). The number of spikelets per spike in wheat plays a crucial role in determining grain yield. Each wheat spikelet has more than one grain, making it one of the most essential grain yield components (Zhou et al., 2021). The increased number of spikelets per spike was attained in the herbicide applied plots that may be due to the control of weeds. The maximum number of spikelets per spike was recorded in treatments of Buctril Super (Bromxynil+MCPA at 148.2 g a.i ha^{-1}) +Atlantis (Iodo+mesosulfuron 14.4 g a.i ha^{-1}). The findings regarding spikelets per spike was in line with Kamboj et al. (2017) and Wara et al. (2020).

These authors reported maximum number of spikelets in the herbicide treated plots. The number of grains per spike plays a crucial role in determining the yield of wheat. Research has shown that modifying wheat spike morphology can increase grain number and size, thus improving overall yield (Guo et al., 2018). The minimum number of grains per spike was recorded in weedy check that may be due to higher population of weeds and competition between weeds and wheat for nutrients and water. The lack of weed management allowed weeds to compete with the wheat plants, leading to stunted crop growth. The maximum number of grains per spike was recorded in response to Buctril Super (Bromxynil+MCPA 148.2 g a.i ha^{-1}) + Axial (Pinoxaden 41.25 g a.i ha^{-1}) application, followed by Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g a.i ha^{-1}) and Buctril Super (Bromxynil+MCPA at 148.2 g ha^{-1}) + Atlantis (Iodo+mesosulfuron 14.4 g ha^{-1}) with grains per spike 81.40±0.26 and 81.00±0.38, respectively. The results are supported by Hussain et al. (2013) who stated that grains per spike were significantly increased under herbicide application due to better availability of resources for plant growth.

The results of current study show a positive impact of herbicide on the 1000-seed weight as the tank mixture outperformed the weedy check. The reason for the maximum increase of grain weight in Skopik Gold (Florasulam+Mesosulfuron) is probably due to the efficacy in restricting the growth of weeds, reducing their density and giving the opportunity for the wheat to grow without weed competition. This scenario increased the photosynthetic rate leading to higher yields. It can be inferred that the use of herbicide tank mixtures increases the crop growth, dry biomass and ultimately the grain yield. The maximum biological yield was recorded in Metafin Super (Tribenuron+metsulfuron + Maitu (Clodinafop propargyl+Flucarbazone sodium), in contrast minimum biological yield was recorded in weedy check. The reduced biomass in weedy check may be due to the excessive weeds and competition among weeds and wheat, effect of environmental conditions that also favor the reduced germination per meter square while the weed dominance also restricts the supply of natural resources. Abbas et al. (2009) and Marwat et al. (2008) also recorded higher biological yields in the herbicide treated plots.

The higher grain yield in treated plots could be the outcome of efficient weed control by the combination of Metafin Super (Tribenuron+metsulfuron and Maitu (Clodinafop propargyl+ Flucarbazone sodium). The results of our study are inclined with the findings of Asad et al. (2017) and Hassan et al. (2003). These authors reported that herbicide application has a positive impact on grain yield. During this study, weed dry biomass was decreased with the application of different herbicides. The treatments comprising of Mesosulfuron, Florasulam and MCPA showed a lowest weed dry biomass consistently below 0.5 g m^{-2} which highlight their effectiveness in the reduction of weed dry biomass and minimization of competition for essential resources like space, light, water and nutrients. The effective weed management is important for the optimization of crop yield as it reduce the resource competition there by promoting better crop growth and productivity (Sharma et al., 2021). However, the lowest weed density was found in the treated plots of Skopik Gold (Florasulam+Mesosulfuron 14.8 g ha^{-1}) and Trivax ultra (Mesosulfuron+ Florasulam+ MCPA at 112.5 g ha^{-1}) with a density of 10.00±0.58 plant m^{-2} and 10.00±1.15 plants m^{-2}, respectively which indicate a strong efficiency of applied herbicides (Nandula et al., 2019).The maximum crop biomass was recorded in experimental units where Metafin Super (Tribenuron+metsulfuron 70.642 g a.i ha^{-1}) + Maitu (Clodinafop propargyl+ Flucarbazone sodium at 32.11 a. i g ha^{-1}) as post-emergence was applied to control weeds. These results are in agreement with Sheikhhasan et al., (2012) who reported that herbicides effectively increased crop biomass by decreasing weed density. In this study, the physiological parameters of wheat including photosynthetic rate, transpiration rate, stomatal, sub-stomatal conductance, vapor pressure deficit and water use efficiency were higher in the herbicide treated plots compared to the weedy check. The improvement in physiological parameters could be attributed to the fact that herbicide treatment initially impacted on the growth suppression of weeds which enhance the photosynthetic activity in the wheat. This phenomenon may be linked to the stomatal oscillations at the early stages of herbicide application which might have limited the CO_2 uptake. Previous studies have also reported that herbicide directly affect the photosynthetic activity by disrupting the critical process like carbon reduction cycle, thylakoid electron transport, CO_2 supply to regulate the stomata and chlorophyll activity (Naseer-ud-Din et al., 2011; Vandoorne et al., 2012).

Economic Analysis

The economic analysis, based on CIMMYT (1988) guidelines, calculated the benefit cost ratio (BCR) and net profit to compare the effectiveness of different treatments. Thus, analysis is critical for selecting the most beneficial treatment. Key factors such as variable cost, fixed cost, net benefit, and additional returns were asses to determine the BCR for each treatment. The production cost for wheat was estimated using current market rates for inputs, labor, and outputs during the crop growth period. Economic returns (PKR h^{-1}) were calculated to evaluate the profitability and feasibility of each treatment option. The economic analysis revealed that the fixed cost for each treatment was Rs. 274,875 (as shown in the table). The variable costs of the treatment are detailed in the table. The highest gross income of Rs. 410,459 was achieved with the Skopik Gold (Florasulam+Mesosulfuron) treatment, which resulted in an increased grain yield.

Table 4a. Cost analysis of agriculture operations and inputs per hectare for the cultivation of wheat.

Sr. No.	Operation/ input	Frequency /Amount	Price (PKR)	Expenditure (PKR ha-1)
1	Land preparation	2 rotavator 2 cultivations 1 planking	4000 per rotavator 2000 per cultivation 750 per planking	31875/-
2	Seed	75 Kg ha-1	175 per kg	13125/-
4	Seed drilling	2000 per acre		5000/-
5	Fertilizer	1.5 bags DAP ha-1 1.5 bag urea	11440 DAP 4700 Urea	60525/-
	Irrigation	4 irrigations	2000 per irrigation	20000/-
6	Fungicide	3 g per kg seed1	500	1250/-
7	Harvesting	7.5 maunds per ha-1 cutting 1.5 maunds threshing		30600/-
9	Land rent	45000 per acre for six months	45000	112500/-
	Total			274,875/-

Table 4b. Economic analysis of wheat straw and seed yield under treatment and weed check plot.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	
Wheat seed yield (kg)	4184	4401	4161	2631	2751	3021	4264	4184	1768	kg ha-1
10% loss	418	440	416	263	275	302	426	418	177	To bring at farmer level
Adjusted seed yield	3766	3961	3745	2368	2476	2719	3838	3766	1591	10% discount
Income from seed yield	263613	277267	262133	165753	173309	190336	268657	263605	111371	PKR 85 per kg
Straw yield kg/ha	2593	4933	4763	3770	4637	4643	3384	4780	2453	kg ha-1
10% straw loss	259	493	476	377	464	464	338	478	245	To bring at farmer level
Adjusted straw yield	2334	4440	4287	3393	4173	4179	3045	4302	2208	10% discount
Income from straw yield	70020	133192	128614	101791	125194	125371	91355	129057	66236	PKR 30 per kg
Gross income	333633	410459	390746	267544	298502	315707	360013	392662	177607	PKR ha-1
Herbicide	6250	3238	3750	3248	3248	1675	3125	3125	0	800 per day per acre
Spray rent and application	2000	2000	2000	2000	2000	2000	2000	2000	0	PKR ha-1
Cost varied	8250	5238	5750	5248	5248	3675	5125	5125	0	PKR ha-1
Net benefit	325383	405221.1	384996	262296	293254.4	312031.5	354887.6	387536.9	177607	PKR ha-1

T1: Weedy check; T2: Atlantis (Iodo+mesosulfuron) + Buctril Super (Bromxynil+MCPA); T3: Skopik Gold (Florasulam+Mesosulfuron); T4: Metafin Super (Tribenuron+metsulfuron + Maitu (Clodinafop propargyl+ Flucarbazone sodium); T5: Trivax Super (Fluroxypyr+ Florasulam+ MCPA); T6: Trivax ultra (Mesosulfuron+ Florasulam+ MCPA); T7: Buctril Super (Bromxynil+MCPA) + Maitu (Clodinafop propargyl+ Flucarbazone sodium); T8: Buctril Super (Bromxynil+MCPA) + Axial (Pinoxaden); T9: Wheat star (Clopyralid+Fluroxypyr+ Tribenuron) + Axial (Penoxaden)

Table 4c. Benefit cost analysis of treated herbicides in the wheat

Treatments	Variable cost	Fixed cost	Total cost	Gross income	Net benefit	Net return	BCR
	PKR ha-1						
Weedy check	0	274875	274875	177607	177607	-97268	0.65
Atlantis (Iodo+mesosulfuron) + Buctril Super (Bromxynil+MCPA)	8250	274875	283125	333633	325383	50508	1.18
Skopik Gold (Florasulam+Mesosulfuron)	5238	274875	280113	410459.1	405221.1	130346.1	1.47
Metafin Super (Tribenuron+metsulfuron + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	5750	274875	280625	390746.1	384996.1	110121.1	1.39
Trivax Super (Fluroxypyr+ Florasulam+ MCPA)	5248	274875	280123	267543.9	262295.9	-12579.1	0.96
Trivax ultra (Mesosulfuron+ Florasulam+ MCPA)	5248	274875	280123	298502.4	293254.4	18379.4	1.07

Buctril Super (Bromxynil+MCPA) + Maitu (Clodinafop propargyl+ Flucarbazone sodium)	3675	274875	278550	315706.5	312031.5	37156.5	1.13
Buctril Super (Bromxynil+MCPA) + Axial (Pinoxaden)	5125	274875	280000	360012.6	354887.6	80012.6	1.29
Wheat star (Clopyralid+Fluroxypyr+ Tribenuron) + Axial (Penoxaden)	5125	274875	280000	392661.9	387536.9	112661.9	1.40

CONCLUSIONS

The study concluded that herbicide tank mixtures significantly increased crop yield and reduced weed competition in wheat fields. By mixing herbicides with several mode of action, these combinations were able to effectively manage a range of weed populations, including putative resistant biotypes that may otherwise be challenging to control. This approach not only decreased the incidence of phytotoxicity but also enhanced crop safety, encouraging healthy wheat growth and higher output potential. Therefore, utilizing herbicide mixtures provides a sustainable and economical method of controlling weeds in wheat production, thereby improving crop yields and enhancing farmer's net earnings. Furthermore, the findings emphasize how crucial it is to use herbicides responsibly in order to avoid problems like herbicide resistance and environmental effects. By strategically using tank combinations, the need for frequent herbicide treatments is decreased, reducing the hazards of overuse and maintaining ecological balance. In summary, using herbicide tank mixture in wheat farming could effectively control resistant weed biotypes, increase yields, and enhance crop safety, offering a sustainable, economically viable solution for productivity.

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AUTHOR CONTRIBUTIONS

Muhammad Sohail: Data curation, Investigation, Writing – original draft, Amar Matloob: Supervision, Funding, Methodology, Validation, Visualization, Data curation, Investigation, Resources, Writing – review & editing, Adnan Fareed: Data curation, Investigation, Visualization, Writing – original draft, Khuram Mubeen: Writing – review & editing, Muhammad Asif Shahzad: Writing – review & editing..

COMPETING OF INTEREST

No conflicts of interest have been disclosed by the authors.

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