Asian Plant Research Journal

8(2): 14-22, 2021; Article no.APRJ.73150
ISSN: 2581-9992

Agronomic Performance of Bread Wheat (*Triticum aestivum* L.) Influenced by Seed Rates and Weeding Frequency at Mutulu Kebele in Toke Kutaye District

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/APRJ/2021/v8i230170
Editor(s):
(1) Vinayaka K.S, Kumadvathi First Grade College, India.
Reviewers:
(1) Leticia Caravita Abbade, Universidade Federal do Tocantins, Brazil.
(2) Atiqullah Khaliqi, Badghis Higher Education Institution, Afghanistan.
Complete Peer review History: https://www.sdiarticle4.com/review-history/73150

Original Research Article

Received 20 June 2021
Accepted 26 August 2021
Published 27 August 2021

ABSTRACT

Bread wheat (*Triticum aestivum* L.) is one of the major cereal crops in central high land of Ethiopia. However, its production and productivity is constrained by weed infestation and inappropriate seed rate used. Hence, an experiment was conducted to determine the optimal seed rate and weeding frequency for bread wheat production in Toke Kutaye district of West Shewa Zone of Oromia Regional State during 2020 main cropping season. Treatments consisted of five levels of seed rates (75, 100, 125, 150, and 175 kgha^{-1}) and four levels of weeding frequency (zero weeding, once weeding (15 DAE), twice weeding (15 and 45 DAE) and thrice weeding (15, 45 and 75 DAE). Experiment was laid out in Randomized Complete Block Design (RCBD) with factorial combination replicated thrice. Results of the study revealed that the interaction of seed rate and weeding frequency significantly ($P \leq 0.05$) influenced phenological and growth parameters except days reqired for 50% emergence and yield of bread wheat. Highest relative yield loss (71.3%) was recorded from weedy plot with 75 kgha^{-1} seed rate, while the lowest loss (1.2%) was recorded at 175 kgha^{-1}seed rate with thrice hand weeding. Highest net benefit of ETB 73,170 ha^{-1} , marginal rate of return 884.4% and value to cost ratio of ETB 8.34 per unit of investment was obtained from 175 kgha^{-1} seed rate combined with thrice

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hand weeding. Therefore, use of 175 $kgha^{-1}$ seed rate with thrice hand weeding was found profitable, and recommended to be practiced by wheat growers of the study area and similar agro-ecologies.

Keywords: Agronomic performance; bread wheat; seed rate and weeding frequency.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the world's leading cereal food grain serving as a staple food for more than one third of the global population [1]. Globally, it is cultivated on approximately 218 million hectares of land [2]. It is one of the most important cereal crops in Africa covering 9.51 million ha with production of 20.62 million tone. It provides 37% of the total calories and 40% of the protein in the Ethiopian diet. Ethiopia is the largest wheat producer in sub Saharan Africa (FAOSTAT, 2014). The total bread wheat cultivated area in the country is about 1,696,082.59 ha, with an annual production of 453,702,098.28 tons and average productivity of 2.675 tha^{-1} [3].

According to CSA report of 2018/2019, in Oromia wheat was cultivated on 898,682.57 ha with average productivity of 2.971 $tha^{-1}$and about 85% of bread wheat was grown in Arsi, Bale and Shewa areas [3]. According to West Shewa Zone Agricultural and Natural Resource Office report of 2019, wheat production accounts for 123,730 ha and produced about 4,490,09.9 tons with a productivity of 3.6tha^{-1} [4].

Optimum seed rate encourages nutrient availability, proper sun light penetration for photosynthesis, good soil environment for uptake of soil nutrients, and water use efficiency; and all necessary for crop vigor and consequently increases the production and productivity of the crop. Hence, it is required to conduct research to determine the optimal seed rate in each growing area to improve production and productivity of wheat. High seed rate increases the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield. If low seed rate is used yield will be less due to lesser number of plants per unit area [5].

Weed infestation has been reported as a major constraint to wheat production in Ethiopia in both the peasant and the state farm sectors [6]. Therefore, this study was undertaken to evaluate the effect of seed rate and weeding frequency and to determine the optimum and economical seed rate and weeding frequency for wheat production in the study area.

2. MATERIALS AND METHODS

The experiment was conducted at Mutulu Kebele in Toke Kutaye district of West Shewa Zone of Oromia Regional State during the main cropping season of 2020. Toke Kutaye is a district in West Shewa Zone which is 126 km away from Addis Ababa and 12 km from Ambo town (WSHZRA, 2020) and located at longitude 37.78^{o}, latitude 8.95^{o} and altitude 2240 m.a.s.l. The experimental site is 15km away from Guder town which a major agricultural market in the district. According to Ambo meteorology station the main rainy season of the study area was from June to August. The total amount of rainfall recorded was 912mm, and the highest and the lowest temperature recorded were 25.5^{o}c and 8.8^{o}c, respectively.

As climate and meteriological data is crucial in achieving improved production and productivity of the crop, according to Ambo meteorology station the main rainy season of the study area was from June to August. The total amount of rainfall recorded was 912 mm, and the highest and the lowest temperature recorded were 25.5oc and 8.8oc, respectively which is generally considered to be normal.

Treatments of the experiment consisted of five levels of seed rates (75, 100, 125, 150 and 175$kgha^{-1}$) and four levels of weeding frequency(zero (no)weeding, once weeding at 15 days after emergence (DAE), twice weeding at 15 and 45 DAE and thrice weeding at 15, 45 and 75 DAE). Experiment was laid dawn in Randomized Complete Block Design (RCBD) with factorial combination (5*4) replicated thrice.

The wheat seeds were sown by drilling in 2.5 m long rows in each plot as per the treatments on July 15, 2020. All weed species were manually hand removed based on the weeding frequency treatments. Harvesting was done at physiological maturity manually using hand sickles and dried for one week under open field until it properly dried, and then trashed manually by sticks.

2.1 Data Collection and Measurements

Weed flora identification: Weeds were identified and recorded using color manuals. A weed identification guide for Ethiopia was used for the study.

Weed population: Weed populations were counted on 15 days after emergence. The population count was carried out using 0.25 m x 0.25 m quadrant thrown randomly at three spotsin each plot and converted to population density per m2. Weeds in the quadrant were identified and the number of plants of individual weed species was counted.

Relative yield loss due to weeds: It was calculated from a particular treatment as the ratio of the difference between the maximum seed yield and the seed yield of the treatment divided by the maximum seed yield multiplied by 100 as described by Amare et al. [7]:

Where, MY= maximum yield from a treatment, YT = yield of a particular treatment.

Days to 50% emergence: The period from the date of planting to the appearance of about 50% of emergence in each plot above the soil surface was recorded through a visual observation.

Days to 50% heading: Days from sowing to the stages when 50% of plants started flowering was recorded through visual observation.

Days to grain filling period: It was calculated from heading to maturity (days to physiological maturity minus days to heading).

Days to 90% physiological maturity: The number of days from date of sowing to a stage at which 90% of the plants have reached physiological maturity. It is the time when 90% of the spike changes their color into brown.

Plant height (cm): The average height of ten randomly taken pre-tagged plants was measured from the ground to the top of the spike excluding the awn at harvesting time from each treatment.

$$Relative\ Weed\ Density(\%) = \frac{\text{No. } Particular\ Weed}{\text{No. Population of Total Weed}} X100$$

The ratio of weed per unit area to equivalent area of crop population were computed as described by

Weed Intensity: Population.

$$\frac{\text{Total number of particular weed}}{\text{Total number of wheat crop}}$$

$$Relative\ Yield\ Loss(RYL\%) = \frac{\text{MY} - \text{YT}}{MY} X100$$

Total tillers per plant: The totalnumber of tillers per plant was obtained from the average of ten randomly pre-tagged plants tillers count ofeach treatment at physiological maturity.

Number of effective tillers per plant: The average number of effective tillers per plant was calculatedfrom the ten randomly pre-tagged plants effective tillers countof each treatment at physiological maturity.

Spike length: The main spikes from the ten sample spikes were measured in cm and the average representsthe spike length in cm for each plot across the treatment level.

Number of spikelet per plant: The average number of spikelet was counted from ten randomly pre-tagged plants of each treatment.

Number of seed per spikelet: The average number of seed per spikelet was counted from the ten randomly pre-tagged plants of each treatment.

Dry biomass yield (kgha-1): It wasmeasured from the net area of each plot; the plantswere harvested near to the ground and dried to the sun for one week until it attained uniform weight. The dry biomass yield was measured in kilogram.

Grain yield (kgha-1): The grain yield from the net area of individual plot was measured and adjusted to moisture of 12.5% and yield in plot were converted to hectare.

Straw yield (kgha-1): The straw yield was obtained by subtracting the grain yield from total above ground dry biomass yield.

Harvest index (%): It was calculated by dividing the economical yield (grain yield) to biological yield (seed + straw) multiplied by 100.

Thousand seed weight (g): The weight of 1000 randomly sampled seeds per plot was measured with sensitive balance.

The analysis of variance for the collected data was done using SAS software (Version 9.3). The interpretation of the result was made based on the standard procedure applicable to Randomized Complete Block Design (RCBD) as suggested by Gomez and Gomez [8]. Whenever the effect of the treatments found to be significant, the means were compared using a 5% level of Least Significant Difference. Correlation analysis was made among yield and yield components of wheat.

The economic analysis was done using partial budget procedure described by CIMMYT [9]. Seed cost and labor cost for weeding were used for analysis. Partial budget analysis for bread wheat production was done to claiculate the profitability of treatments. This analysis was performed in order to evaluate the economic feasibility of the treatments at the minimum rate of return 50 to 100% [5]. Seed and straw yields of bread wheat from experimental plots were adjusted downward by 10% for management and plot size differences to regulate the difference between the experimental yield and the yield that farmers could expect from the same treatment.

3. RESULTS AND DISCUSSION

The major weed species identified in the study area were *Guizotiascabra(vis.)* and *Galinsoga parviflora* with relative density of 12.29 and 11.43%, population density of 38.3 and 35.7 m^2, and intensity of 0.29 and 0.27, respectively. Moreover, *Plantago lanceolata* and *Eleusin indica* had a relative density of 11.32 and 10.79% with a population density of 35.3 and 33.7 m^2 and an intensity of 0.27 and 0.26, respectively. Similarly, *Amaranthus hybridus, Avenafatua,* and *Lolium temulentum* had a relative weed density of 9.51, 8.9 and 6.3% with a population density of 29.7, 28 and 19.7m^2, and an intensity of 0.23, 0.22 and 0.15, respectively. Other weeds constituted about 4.49% of total weed population with a density of 14m^2 (Table 1).

In this study, broad leaf weeds were recorded the highest population densities (12.29%), while grassy weeds had only 10.79% density (Table 2). Out of the total population, broad leaf and grassy weeds covered 52.46 and 30.56%, while the unidentified weed species covered 16.99%. This result agreed with the work of Burgos et al. (2006) who described that broad leaf weeds (72%) and grasses (24%) dominated from the total weed spectrum, whereas sedges (4%) constituted only minor proportion in wheat field. Similarly, Nano et al. [10] described those broad-leaved weeds like *Rumex dentatus, Malwaparviflora* and *Medicago denticulate* were of great concern in wheat cropping system.

3.1 Days to 50% Emergence

The result indicated that there was no significant difference (p<0.05) among the main effects of seed rates, weeding frequency, and their interactions on days to 50% emergence in the study area, hence its data is not presented. This was because of the stored food in the endosperm of the seed were favorable enough for the 50% days of emergence and there was no weed competition during this stage of growth (Table 1).

Table 1. Weed population, intensity and relative density of the experimental field during 2020 cropping season

Local name	Scientific name	Family	Weed category	Population (m^{-2})	Weed intensity
Asandaaboo	*Galinsoga parviflora*	*Asteraceae*	Broad leaf	35.7	0.27
Ajanbila	*Avenafatua*	*Poaceae*	Grass	28.0	0.22
RaafuuLagaa	*Amaranthus hybridus* L.	*Amarantaceae*	Broad leaf	29.7	0.23
Hadaa	*Guizotiascabra (*Vis.*)*	*Asteraceae*	Broad leaf	38.3	0.29
Inkirdaadaa	*Lolium temulentum*	*Poaceae*	Grass	19.7	0.15
Maxxannee	*Galiumspurium*L.	*Rubiaceae*	Broad leaf	11.7	0.09
Coqorsaa	*Eleusin indica*	*Poaceae*	Grass	33.7	0.26
Qorxobbii	*Plantago lanceolata*	*Plantaginaceae*	Broad leaf	35.3	0.27
Qoraattii	*Argemone mexicana*L.	*Papaveraceae*	Broad leaf	13.0	0.10
MargaaJabbii	*Phalaris paradoxa*L.	*Poaceae*	Grass	14.0	0.11
Kan biroo	Others			53.0	0.41
Total				**312**	**2.4**

RWD= Relative weed density

3.2 Days to 50% Heading

The analysis of variance shows that days to 50% heading was significantly ($p<0.01$) influenced by the main effect of weeding frequency and the interaction of weeding frequency and seed rates, but not influenced by main effect of seed rates. The interaction effect of 75 $kgha^{-1}$seed rates with no weeding took longer time (55 days) to develop 50% heading which was statistically at par with 100 and 125 $kgha^{-1}$ with un-weeded plot, while the interaction of 175 $kgha^{-1}$with thrice hand weeding took shorter time (47 days) which was statistically at par with 150 $kgha^{-1}$seed rates to develop heads (Table 2). This result was due to competition effect of weed species for available resources like space, soil nutrients, moisture and light. Similarly, Nano et al. [10] reported that uninterrupted weed growth delayed the days to spike emergence of bread wheat.

3.3 Days to Grain Filling

The analysis of variance showed that days to grain filling was significantly ($p<0.01$) influenced by the main effect of weeding frequency, and interaction effect of seed rates and weeding frequency, but not by main effect of seed rates. The longest days of grain filling period (31days) was recorded at 75$kgha^{-1}$seed rate with thrice hand weeding which was statistically at par with 100$kgha^{-1}$plus thrice weeding. This result was due to low plant density and weed free plots allowed to have more spaces for better light interception and photosynthesis that made conducive environment for an extended grain filling period. While the shortest days to grain filling period (16.27 days) was recorded on175$kgha^{-1}$seed rate with weedy check which was at par with 150 $kgha^{-1}$plus weedy check (Table 3).These results were due to weed competition for available growth resources like soil nutrients, moisture and space; and high plant population that made narrow spacing for light interception and carbon dioxide for photosynthesis. Saleh and Mahdi [11] pointed out that weed infestation comes at the stage of grain filling or at late stages of crop growth. Bekele et al., [6] reported that the shading out of wheat plants by the weeds might have reduced sunlight penetration, thereby prolonging the vegetative growth and resulting in delayed flowering and physiological maturity.

Table 2. Interaction effects of seed rates and weeding frequency on days to 50% heading of bread wheat at Toke Kutaye District in 2020

Seed rate ($kgha^{-1}$)	Weeding frequency				
	Weedy Check	Once Weeding	Twice weeding	Thrice weeding	Mean
75	55.00^{a}	50.33^{ef}	49.33^{fg}	47.67^{hij}	50.58
100	54.00^{ab}	50.33^{ef}	48.67^{gh}	47.33^{ij}	50.08
125	53.00^{bc}	50.30^{ef}	48.30^{ghi}	47.00^{j}	49.67
150	52.00^{cd}	50.00^{ef}	48.00^{hij}	47.00^{j}	49.25
175	51.00^{de}	50.00^{ef}	48.00^{hij}	47.00^{j}	49.00
Mean	53.00	50.19	48.47	47.20	49.72
LSD (0.05)	SR = 1.98 WF =0.75 SR * WF = 1.26 CV(%) =4.87				

Where SR = seedrate, WF = weeding frequency. Means with the same letter(s) are not significantly different at 5% probability level

Table 3.Interaction effects of seed rates and weeding frequency on grain filling period of bread wheat at Toke Kutaye District in 2020

Seed rate ($kgha^{-1}$)	Weeding frequency				
	Weedy check	Once weeding	Twice weeding	Thrice weeding	Mean
75	18.47^{h}	24.47^{e}	27.50^{c}	31.00^{a}	25.36
100	18.13^{hi}	23.80^{e}	27.20^{c}	30.67^{a}	24.95
125	17.27^{ij}	23.67^{ef}	26.67^{c}	29.33^{b}	24.24
150	17.03^{jk}	22.80^{fg}	25.70^{d}	28.70^{b}	23.56
175	16.27^{k}	22.67^{g}	25.40^{d}	28.67^{b}	23.25
Mean	17.43	23.48	26.49	29.67	24.27
LSD (0.05)	SR = 3.88WF = 0.71 SR * WF = 0.19 CV(%) = 6.52				

Means with the same letter(s) are not significantly different at 5% probability level

3.4 Plant Height

The analysis of variance showed that plant height of bread wheat was significantly ($p<0.01$) influenced by main effect of weeding frequency, and the interaction of seed rates and weeding frequency, but not by main effect of seed rates. The tallest plant height (83.73 cm) was recorded at 75kgha^{-1}seed rates with thrice hand weeding (Table 4). This was due to low plant population and weed free plots that had low competition for available resources for the growth of bread wheat seedlings. However, the shortest height (68.4 cm) was recorded at weedy plots with 175 kgha^{-1} seed rates. This might be due to competition effect of weed spices for available growth resources. Chaudhary et al. [12] also reported that significantly higher plant height was observed under weed free treatment than weedy plot. However, Bekele et al., [6] reported that highest plant height of bread wheat was obtained from weedy plot than weed free plot due to inter space competition for light.

3.5 Days to 90% Physiological Maturity

Days to 90% physiological maturity was significantly ($p< 0.01$) affected by the main effect weeding frequency, and interaction effect of seed rates and weeding frequency. The longest days to reach 90% physiological maturity (78.33 days)was recorded at 75 kgha^{-1}seed rate with thrice hand weeding, which was statistically at parity with 100, 125, 150 and 175 kgha^{-1} seed rates with thrice hand weeding. While shortest days (67.3 days) to reach 90% physiological maturity was recorded from plots treated with 175 kgha^{-1} seed rate with weedy check (Table 5). The delay in maturity as result of thrice weeding in all seed rates treatment might be due to less competition by weeds for available nutrients and moisture during growth period. Moreover, the earlier maturity at high plant population and weed check could be due to strong competition for available resources which causes poor deep root development and reduces crop growing period. Fekadu and Skjelvag [13] reported that maturity period was reduced in weed affected barley, perhaps due to weed competition during growing period.

3.6 Grain Yield

The analysis of variance showed that main effect of seed rates, weeding frequency and their interaction had highly significant ($P<0.01$) effect on grain yield of bread wheat. The highest grain yield (4.47 tha^{-1}) was obtained at the interaction of 175 kgha^{-1} seed rates with thrice hand weeding (Table 6). While the lowest grain yield(1.33 tha^{-1}) was obtained from treatment that received 75 kgha^{-1} seed ratewithun-weeded plots which was at par with 100 kgha^{-1}seed rates with weedy check plots. The increase in plant density followed by weed free plots allows free allocation of available growth resources. Amare et al. [7] also reported that the plants raised under complete weed free environment were free from weed competition thus utilized the available resources and increased productive tiller per unit area, grains per spike,100 grain weight and the final grain yield.

3.7 Straw Yield

The analysis of variance indicated that main effect of seed rates, weeding frequency and their interaction had highly significant ($p<0.01$) effect on straw yield of bread wheat at the study area (Table 7). Higher straw yield (6.6t.ha^{-1}) was obtained at interaction of 175kgha^{-1}seed rates with thrice hand weeding which was statistically at par with interaction of 150 kgha^{-1} seed rates with thrice hand weeding (Table 7). This was due

Table 4.Interaction effects of seed rates and weeding frequency on plant height of bread wheat at Toke Kutaye District in 2020

Seed rate (kgha^{-1})	Weeding frequency				
	Weed check	**Once weeding**	**Twice weeding**	**Thrice weeding**	**Mean**
75	72.8^{ijk}	75.83^{h}	79.53^{e}	83.73^{a}	77.97
100	72.43^{jk}	75.7^{h}	78.8^{ef}	82.7^{b}	77.41
125	71.83^{k}	75.67^{h}	78.13^{fg}	81.33^{c}	76.74
150	69.63^{l}	73.53^{i}	77.47^{g}	80.57^{cd}	75.3
175	68.40^{m}	73.13^{ij}	76.03^{h}	79.63^{de}	74.29
Mean	71.02	74.77	77.99	81.59	76.34

*LSD (0.05); SR = 3.39; WF = 1.14; SR*WF = 1.09; CV (%) = 5.42*

Means with the same letter(s) are not significantly different at 5% probability

Table 5. Interaction effects of seed rates and weeding frequency on days to 90% physiological maturity of bread wheat at Toke Kutaye District in 2020

Seed rate ($kgha^{-1}$)	Weeding frequency				
	Weedy check	Once weeding	Twice weeding	Thrice weeding	Mean
75	71.4^{hij}	73.33^{efg}	76^{bcd}	78.33^{a}	74.77
100	70.67^{ijk}	72.67^{fgh}	75^{cde}	78^{a}	74.08
125	70^{jk}	72.33^{fghi}	74.67^{de}	77^{ab}	73.5
150	69.4^{k}	72.33^{fghi}	74^{ef}	77^{ab}	73.18
175	67.33^{l}	71.8^{ghi}	73.93^{ef}	76.7^{abc}	72.44
Mean	69.76	72.49	74.72	77.41	73.59

*LSD(0.05); SR= 2.6; WF = 1.06; SR*WF = 2.19; CV(%) = 5.32*
Means with the same letter(s) are not significantly different at 5% probability level

Table 6. Interaction effects of seed rates and weeding frequency on grain yield of bread wheat at Toke Kutaye District in 2020

Seed rate ($kgha^{-1}$)	Weeding frequency				
	Weedy check	Once weeding	Twice weeding	Thrice weeding	Mean
75	1.33^{k}	1.90^{j}	2.43^{gh}	3.10^{d}	2.19
100	1.53^{k}	2.00^{j}	2.53^{fg}	3.13^{d}	2.29
125	1.83^{j}	2.07^{ij}	2.77^{ef}	3.53^{c}	2.55
150	1.87^{j}	2.27^{hi}	3.00^{de}	4.13^{b}	2.82
175	2.00^{j}	2.43^{gh}	3.03^{d}	4.47^{a}	2.98
Mean	1.71	2.13	2.75	3.67	2.57

*LSD (0.05); SR = 0.65; WF = 0.27; SR*WF = 0.26; CV(%) = 6.23*
Means with the same letter(s) are not significantly different at 5% probability level

Table 7. Interaction effects of seed rates and weeding frequency on straw yield (tha^{-1}) of bread wheat at Toke Kutaye District in 2020

Seed rate ($kgha^{-1}$)	Weeding frequency				
	Weedy check	Once weeding	Twice weeding	Thrice weeding	Mean
75	1.53^{k}	2.07^{ijk}	3.70^{efg}	4.37^{cd}	2.92
100	1.80^{jk}	2.43^{i}	3.87^{def}	4.80^{bc}	3.23
125	2.00^{ijk}	3.07^{h}	4.00^{de}	5.40^{b}	3.62
150	2.13^{ijk}	3.17^{gh}	4.13^{de}	6.40^{a}	3.96
175	2.20^{ij}	3.37^{fgh}	4.27^{cde}	6.60^{a}	4.10
Mean	1.93	2.82	3.99	5.51	3.56

*LSD(0.05); SR = 1.19; WF = 0.46; SR*WF = 0.62; CV(%) = 10.48*
Means with the same letter(s) are not significantly different at 5% probability level

to the higher plant density, higher plant height, higher vegetative growth along with weed free plots that allow edfree availability of resources to the plant. However, the lowest straw yields (1.53 and 1.8 tha-1) were obtained from the interaction of 75 kgha-1and 100 kgha-1seed rates with weedy check respectively, which was statistically similar with 75 kgha-1seed rates plus once weeding. This lower straw yield was due to the lower plant density across the plots and the interference of weeds for available growth resources. This result agreed with the findings of Nano et al. [10] who stated that severe weeds competition for growth resources caused significant reduction in number of tillers there by resulting in low straw yield in bread wheat.

4. CONCLUSION

To conclude, the findings of the study revealed that the interaction of seed rate and weeding frequency significantly (P≤ 0.05) influenced phenological and growth parameters except days reqired for 50% emergence and yield of bread wheat. The highest relative yield loss (71.3%) was recorded from weedy plot with 75 $kgha^{-1}$seed rate, while the lowest loss (1.2%) was recorded at 175 $kgha^{-1}$seed rate with thrice hand weeding. The highest net benefit of ETB 73,170 ha^{-1}, marginal rate of return 884.4% and value to cost ratio of ETB 8.34 per unit of investment was obtained from 175 $kgha^{-1}$ seed rate combined with thrice hand weeding. The yield components of bread wheat such as total tillers, effective tillers, spike length, spikelet per spike and seeds per spikelet were relatively lower when seed rate was increased from 75 to 175 $kgha^{-1}$ with un-weeded plots due to competition effect between bread wheat plants and weed species for available resources. However, grain, straw and biomass yields increased as seed rates increased from 75 to 175 $kgha^{-1}$ with thrice hand weeding.

The maximum grain yield of 4.47 tons ha^{-1} and the highest net benefit of ETB 73,170 ha^{-1} with marginal rate of return of 884.4% and value to cost ratio of 8.34 were recorded from 175 $kgha^{-1}$ seed rates combined with thrice hand weeding. Therefore, 175 $kgha^{-1}$ seed rate and thrice hand weeding is recommended for bread wheat production. Therefore, use of 175 $kgha^{-1}$ seed rate with thrice hand weeding was found profitable, and recommended to be practiced by wheat growers of the study area. However, further studies at different locations for more than one cropping seasons should be considered to provide broader recommendation for bread wheat production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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