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Effect of Seed Rates and Weeding Frequency on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) on Vertisols 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.

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ABSTRACT

Bread wheat (*Triticum aestivum* L.) plays a crucial role in ensuring food security in 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 on Vertisols in Toke Kutaye district during 2020 main cropping season. Treatments consisted of five levels of seed rates (75, 100, 125, 150, and 175kgha^{-1}) and four levels of weeding frequency (zero weeding, once weeding (15DAE), 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 wheat biomass yield (11.03tha^{-1}), grain yield (4.47tha^{-1}) and straw yield (6.6tha^{-1})were obtained using 175kgha^{-1}seed rate with thrice hand weeding. Highest relative yield loss (71.3%) was recorded from weedy plot with 75kgha^{-1}seed rate, while the lowest loss (1.2%) was recorded at 175kgha-

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[1]seed rate with thrice hand weeding. Highest net benefit of ETB 73,170ha^{-1}, marginal rate of return 884.4% and value to cost ratio of ETB 8.34 per unit of investment was obtained from 175kgha^{-1} seed rate combined with thrice hand weeding. Therefore, use of 175kgha^{-1} seed rate with thrice hand weeding was found profitable, and recommended for bread wheat production in Toke Kutaye district.

Keywords: Bread wheat; Seed rates; weeding frequency; yield and yield components.

1. INTRODUCTION

Wheat provides 37% of the total calories and 40% of the protein in the Ethiopian diet. 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 [1]. According to Toke Kutaye District Agricultural and Natural Resource Office report of 2019 [2], wheat covered in an area of about 7,773 ha and produced about 295,64.2 tons with average productivity of 3.8 tha^{-1}which is much below the regional yield potential of 6.0 tons ha^{-1} (Oromia Regional State Agricultural Growth Program, 2013) as well as much below the yield of experimental plots which is 5 tons ha^{-1} [3].

Seed rate is one of the most important agronomic factors which need great emphasis for maximum yield of crops. Besides, seed rate determines the crop vigor and ultimately yield. 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 (Alemayehu et al., 2015). This indicates that the need to conduct research to determine the optimal seed rate in each growing area as one of the important agronomic management to improve production and productivity of wheat.

Weeds compete with crop plants for essential growth factors like light, moisture, nutrients and space. Weeds increase harvesting costs and reduce quality of product [4]. Apart from increasing the production cost, weeds also intensify the disease and insect pest problem by serving as alternative hosts, and uncontrolled weed growth throughout the crop growth caused a yield reduction of 57.6 to 73.2% [5].

Wheat productivity is remarkably reduced by weed infestation in the study area. Farmers in the area are aware of weed problem in their fields but often they cannot cope-up with heavy weed infestation during the peak-period of agricultural activities because of labor shortage, hence most of their fields are weeded late or left un-weeded. Such ineffective weed management is considered as the main factor for low yield of wheat resulting in yield loss of up to 58.6% when there is uninterrupted weed growth [6].

Weed infestation is the main bottleneck in crop production in the study area, especially during the rainy season. The high rainfall and abundant sunlight encourage rapid and vigorous growth of weeds and consequently, crops are heavily infested with weeds. However, among farmers in the study area, awareness and practice on bread wheat weeding at the right time and frequencyare less. There is inadequate authentic and accurate information regarding optimum seed rate and weeding frequencyfor enhancing bread wheat productivity and profitability in Toke Kutaye. 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

Experiment was conducted at Mutulu Kebele in Toke Kutaye district of West Shewa Zone of Oromia Regional State. Toke Kutaye is a district in West Shewa Zone which is 126 km away from Addis Ababa and 12km from Ambo town and located at longitude 37.78°, latitude 8.95° and altitude 2240 m.a.s.l. The experimental site is 15km away from Guder town which a major agricultural market in the district.

Bread wheat variety, Shorima (ETBW5483) was used as experimental material. Shorima is a bread wheat variety released in 2011 and it is adapted to highlands of Arsi, Holeta, Debre Zeit, parts of Gojam, East Wollega and other similar regions. It grows well in an altitude range of 2100 to 2700 m a.s.l. with annual rainfall of 700-1100 mm. Shorima produces yield varing 2.9 to 7.1tha^{-1} in research field and 2.3 to 4.3tha^{-1} in farmer's field and it is resistant to yellow rust, stem rust, septoria and leaf rust.

Treatments of the experiment consisted of five levels of seed rates (75, 100, 125, 150 and 175kgha^{-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.

Experimental field was ploughed four times using oxen driven local plough (*Maresha*) before planting the bread wheat varieties. Last plowing was undertaken during sowing, and then after field layout was done and the treatmentswere assigned to the experimental plots. Size of each experimental plot was 3m x 2.5 m (7.5 m^2). Distance between replications, plots and rows were 1m, 30cm and 20cm, respectively with a total of 15 rows in each plot.

Blended NPSB (18.9% N + 37.7% P_2O_5 + 6.95% S + 0.1% B) and urea fertilizers at the rate of 100kg ha^{-1}, each were used as source of crop nutrient. NPSB was applied during sowing time,while urea was applied in split application, half during sowing mixed with NPSB, and the remaining half was side-dressed during tillering stage of the wheat crop [7].

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.

3. 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 (Stroud and Parker, 1989).

Weed population: Weed populations were counted on 15 days after emergence. The population count was carried out using 0.25m x 0.25m quadrant thrown randomly at three spotsin each plot and converted to population density per m^2. Weeds in the quadrant were identified and the number of plants of individual weed species was counted.

Relative Weed Density (RWD): It was calculated using the following formula as described by Dalga et al. (2014):

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

Weed Intensity: The ratio of weed population per unit area to equivalent area of crop population were computed as described by Tariful et al., (1998)

$$\textbf{Weed intensity} = \frac{\text{Total number of particular weed}}{\text{Total number of wheat crop}}$$

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.* [8]:

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

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.

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 **f**rom 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 (Singh and Stockpot, 1971).

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) [9]. 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 (1984). Whenever the effect of the treatments found to be significant, the means were compared using a 5% level of Least Significant Difference (Steel et al., 1997). Correlation analysis was made among yield and yield components of wheat.

The economic analysis was done using partial budget procedure described by CIMMYT [10]. 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% [10]]. 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.

4. RESULTS AND DISCUSSION

As climate and meteriological data is crucial in achieving improved production and productivity of bread wheat, 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 25.5ºc and 8.8ºc, respectively which is generally considered to be normal.

4.1 Total Number of Tillers

The analysis of variance shows that main effect of seed rates, weeding frequency and their interaction had highly significant ($p<0.01$) effect on total number of tillers. The highest total number of tillers (4.5 tillers) was recorded at 75kgha^{-1} seed rates with thrice hand weeding (Table 1). The lowesttotal number of tillers per plant (1.23) was recorded from 175 kgha^{-1} seed rates with weedy check plots which were statistically at par with 150, 125, 100 and 75kgha^{-1} seed rates with weedy check. This result was due to the competition effect of weed species for available growth resources that hinders photosynthetic efficiency. The result of this study was supported by Naveed *et al.* [11] who stated that weeds are a strong competitor and compete with crops for space, nutrient, moisture, light and carbon dioxides that they could reduce the yield components of the crop.

4.2 Number of Effective Tillers

The number of effective tillersper plant was highly significantly ($p<0.01$) influenced by main effect of seed rates, weeding frequency and their interaction. The interaction of 75kgha^{-1}seed rates with thrice hand weeding enhanced higher effective tillers per plant (3.2) which was statistically at par with 100 and 125kgha^{-1} seed rates with thrice hand weeding (Table 2). Moreover, low number of effective tillers was recorded on weedy check with all seed rates in this experiment. This might be due to weed free plots in thrice hand weeding and less competition for space, light and nutrients which contributed for the formation of more effective tillers per plant. This finding agreed with the results of Shah *et al*. [12] who reported that maximum weed control enhanced the production of effective tillers per m^{-2} which subsequently contributed towards the increase in wheat yield.

4.3 Spike Length (cm)

The analysis of variance indicated that spike length of the bread wheat was highly significantly ($p< 0.01$) influenced by main effect of seed rates, weeding frequency and their interaction. The longest spike length (8.37cm) was recorded from the interaction of 75kgha^{-1} seed rate with thrice hand weeding which was statistically at par with 100 and 125kgha^{-1}plus thrice weeding (Table 3). However, the shortest spike length of 3.07 cm was recorded from 175kgha^{-1}seed rate with zero weeding which was statistically at par with 150kgha^{-1}seed rate plus un-weeded plots. The difference in spike lengths was due to interference of weeds for growth resources. Thrice weeded plots produced the longest spike length due to higher availability of nutrients in absence of competition. These results agreed with the report of Ejaz et al., (2002) that the shorter spike length and lower number of grains per spike was obtained at higher seed rates due to higher competition. Similarly, Mukhtar [13] stated that panicle length per plant increased as weed interference period decreased and weed-free period increased. Further, Megarsa *et al*. [14] reported that the longest spike length of barley was recorded from weed free plot due to favorable environment that contributed for healthy growth and development of crop which in turn created conducive environment for flowering and panicle formation. Bekele *et al*. [15] reported that the longest spike length of bread wheat was recorded from weed free plot due to higher availability of growth resources.

Table 1. Interaction effects of seed rates and weeding frequency on number of total tillers 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^{hij}	2.39^{efg}	3.13^{bcd}	4.5^{a}	2.88
100	1.53^{hij}	2.29^{fg}	2.9^{cde}	3.73^{b}	2.61
125	1.43^{ij}	2.23^{fg}	2.63^{def}	3.53^{b}	2.46
150	1.30^{j}	2.10^{fgh}	2.5^{efg}	3.4^{bc}	2.33
175	1.23^{j}	2.00^{ghi}	2.4^{efg}	3.23^{bcd}	2.22
Mean	1.40	2.20	2.71	3.68	2.5

*LSD (0.05) SR = 0.73 WF = 0.24 SR*WF = 0.32 CV(%) = 7.8. Means with the same letters are not significantly different at 5%probablity level*

Table 2. Interaction effects of seed rates and weeding frequency on number of effective tiller per plant 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	1.37^{jkl}	1.93^{ghi}	2.53^{cde}	3.2^{a}	2.26
100	1.3^{kl}	1.87^{ghi}	2.47^{cdef}	3.13^{ab}	2.19
125	1.27^{kl}	1.73^{hij}	2.33^{def}	3.07^{ab}	2.1
150	1.23^{kl}	1.6^{ijk}	2.2^{efg}	2.8^{bc}	1.96
175	1.17^{l}	1.43^{jkl}	2.1^{fgh}	2.67^{cd}	1.84
Mean	1.27	1.71	2.33	2.97	2.07
LSD(0.05) SR = 0.56 WF = 0.15 SR * WF = 0.2 CV(%) = 9.55					

Means with the same letters are not significantly different at 5%probablity level

Table 3.Interaction effects of seed rates and weeding frequency on spike length 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	4.57^{gh}	5.33^{fg}	6.43^{cde}	8.37^{a}	6.17
100	4.43^{gh}	5.33^{fg}	6.27^{de}	8^{ab}	6.01
125	4.33^{hi}	5.23^{fgh}	5.97^{def}	7.83^{ab}	5.84
150	3.5^{ij}	4.77^{gh}	5.8^{ef}	7.23^{bc}	5.33
175	3.07^{j}	4.73^{gh}	5.8^{ef}	6.87^{cd}	5.12
Mean	3.98	5.08	6.05	7.66	5.69
LSD(0.05) SR = 1.18 , WF = 0.39 , SR*WF = 0.53 , CV(%) = 9.31					

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

4.4 Number of Spikeletper Spike

The number of spikelet per spike was highly significantly ($p< 0.01$) influenced by main effect of seed rates, weeding frequency and their interaction. The number of spikelet per spike was higher at thrice hand weeding and lower at un-weeded plots (Table 4). Accordingly, the highest number of spikelet per spike (13.4) was obtained on 75$kgha^{-1}$seed rates with thrice hand weeding which was statistically at par with 100 and 125$kgha^{-1}$plusthrice hand weeding. Moreover, minimum number of spikelet per spike was observed on weedy check with all seed rate treatments. The highest number of spikelet per spike on lower seed rate at thrice weeding could be due to less competition from weed species for available growth resources and the availability of more spaces due to low amount of seed rate used which created favorable conditions for the formation of morenumber of spikeletper spike. This result agreed with the findings of Shah *et al*. [12] who reported that reduced seed rate may result in higher number of tillers and spike per plant and more spikelet per spike. However, the lowest spikelet per plant (6.1) was obtained from the interaction of 175$kgha^{-1}$seed rates with weed check plots which was statistically par with the rest of seed rate treatments. This was due to the competition effect of weed species for available resources like soil nutrients, moisture,space and light.

4.5 Number of Seeds Per Spikelet

The analysis of variance indicates that number of seeds per spikelet was significantly ($p< 0.02$) influenced by main effect of weeding frequency and interaction effect of seed rates and weeding frequency, but not influenced by main effect of seed rates. Number of seeds per spikelet was higher in thrice hand weeded plots and lower in un-weeded plots (Table 5). Higher seeds per spikelet (3.3) were recorded at the interaction of 75$kgha^{-1}$seed rates with thrice hand weeding which was statistically at par with 100, 125 and 150 $kgha^{-1}$seed rates. This result was due to the less competition of weed species for available growth resources and lower crop plant density which allows better distribution of available resources that creates favorable conditions to improve photosynthetic efficiency which leads favorable condition for the formation of more seeds per spikelet. The lesser number of seeds per spikelet (1.1) was recorded from the interaction of 175$kgha^{-1}$seed rate with weedy check plots which was at par with the remaining seed rates with weedy check. This could be due to the competition effect of weed spices for available resources and higher plant population that influenced the formation of more seeds per spikelet. This resultagreed with the findings of Tesfaye *et al*. [5] and Bekele *et al*. [15] who reported the highest number of grains per spike of bread wheat from weed free plot due to efficient utilization of water, nutrients and light and lower weed population and dry weight of weeds at weed free plots.

4.6 Biomass 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 dry biomass yield of bread wheat. The maximum biomass yield of bread wheat (11.03tha^{-1}) was obtained on treatment that received 175$kgha^{-1}$seed rates with thrice hand weeding which was statistically at par with 150$kgha^{-1}$with thrice hand weeding (Table 6). However, lowest dry biomass yield (2.87tha^{-1})was obtained from the interaction of 75$kgha^{-1}$seed rates with weedy check plotswhich was at par with 100$kgha^{-1}$seed rate. The higher biomass yield in this study was probably due to highercrop plant populations per plot and also due to weed free plots that created favorable conditions for absorption of available resources by the crop roots. The lowest biomass yield was due to less plant population per plot and shortest plant height, and also due to high infestation of weeds which had not interrupted till crop harvest. This finding supported by Naveed *et al.* [11] report that stated weeds asnaturally strong competitors and compete with crops for space, nutrients, moisture, light and carbon dioxide, therefore they could reduce the straw and grain accumulation. Furthermore, the total dry biomass had shown increment with an increasing seed rate. This might be due to the high density of crop plant followinghigh seed ratethat resulted suppressed and lower weeds infestation.

Table 4. Interaction effects of seed rates and weeding frequency on number of spikelet per spike 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	7.57^{ghij}	8.63^{efg}	11.1^{bc}	13.4^{a}	10.17
100	7.53^{ghij}	8.3^{fgh}	10.97^{bc}	12.2^{ab}	9.75
125	6.73^{hij}	8.13^{fgh}	10.67^{bcd}	11.9^{ab}	9.36
150	6.50^{ij}	8.00^{fgh}	10.10^{cde}	11.63^{bc}	9.06
175	6.10^{j}	7.67^{ghi}	9.27^{def}	11.20^{bc}	8.56
Mean	6.89	8.15	10.42	12.07	9.38
LSD(0.05) SR = 1.78 WF = 0.61 SR*WF = 1.09 CV (%) = 8.92					

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

Table 5. Interaction effects of seed rates and weeding frequency on number of seeds per spikelet 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	1.43^{ef}	2.13^{cd}	2.97^{ab}	3.30^{a}	2.46
100	1.40^{ef}	2.13^{cd}	2.97^{ab}	3.30^{a}	2.45
125	1.37^{ef}	1.80^{cde}	2.80^{ab}	3.17^{a}	2.28
150	1.20^{ef}	1.60^{def}	2.40^{bc}	3.13^{ab}	2.08
175	1.10^{f}	1.60^{def}	2.40^{bc}	3.10^{b}	2.27
Mean	1.3	1.85	2.71	3.2	2.27
LSD (0.05) SR = 0.65 WF = 0.20 SR *WF = 0.38 CV(%) = 10.05					

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 dry biomass yield (t ha^{-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	2.87^{m}	4.20^{k}	6.13^{fgh}	7.47^{cd}	5.16
100	3.33^{lm}	4.43^{jk}	6.40^{efg}	7.93^{c}	5.53
125	3.83^{kl}	5.13^{ij}	6.77^{def}	8.93^{b}	6.17
150	3.97^{kl}	5.43^{hi}	7.13^{de}	10.53^{a}	6.77
175	4.00^{k}	5.80^{ghi}	7.30^{cd}	11.03^{a}	7.03
Mean	3.60	4.99	6.75	9.18	6.13
LSD(0.05) SR = 1.83 WF = 0.69 SR*WF = 0.75 CV (%) = 7.04					

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

4.7 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 (4.47tha^{-1})was obtained at the interaction of 175kgha^{-1} seed rates with thrice hand weeding (Table 7). While the lowest grain yield(1.33tha^{-1}) was obtained from treatment that received 75kgha^{-1} seed ratewithun-weeded plots which was at par with 100kgha^{-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*. [8] 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.

4.8 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 8). 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 150kgha^{-1} seed rates with thrice hand weeding (Table 8). This was due to the higher plant density, higher plant height, higher vegetative growth along with weed free plots that allowedfree availability of resources to the plant. However, the lowest straw yields (1.53and 1.8 tha^{-1}) wereobtained from the interaction of 75kgha^{-1}and 100kgha^{-1}seed rates withweedy check respectively, which was statistically similar with 75kgha^{-1}seed 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*. [16] 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.

4.9 Thousand Seed Weight

Thousand seed weight is an important yield parameter that contributes for improved production and productivity of crops. The analysis of variance indicated that main effect of weeding frequency and interaction effect of seed rates and weeding frequency had highly significant (P<0.01) effect on thousand seed weight, while the main effect of seed rates had no significant effect. The highest thousand grain weight (49.8g) was obtained from the interaction of 75kgha^{-1} seed rates with thrice hand weeding which was at par with 100 and 125kgha^{-1} seed rates with thrice hand weeding (Table 9). This was due to availability of more space for better light interception, more nutrients and moisture for grain development, as compared to high density per plots. Moreover, there was no competition for available growth resources with weed starting from crop emergence to harvest because plots were weeded thrice. This result agreed with the report of Dawit *et al*. 6] who stated that the highest thousand grain weight was recorded from low plant density with completely free of weeds. As the seed rate decreased under weed free condition the crop plant will have more space for better light interception, more nutrients and moisture for grain development, this in turn improved the supply of assimilates to be stored in the grain, which increased individual grain weight. On the other hand, lowest thousand grain weight (43.17g) was recorded at the interaction of 175kgha^{-1} seed rates with un-weeded plots which was statistically at par with 100, 125 and 150kgha^{-1}seed rates plus un-weeded plots. This was due to unavailability of more space for better light interception, competition for available nutrients and moisture during grain development, and also due to high infestation of weed population which had disturbed till crop harvest. This finding supported by Naveed *et al*. [11] who stated that weeds are naturally strong competitors, and compete with crops for space, nutrient, moisture, light and carbon dioxide, and reduce the weight of grain.

4.10 Harvest index (%)

The analysis of variance indicated that harvest index was highly significantly (p<0.01) influenced by main effect of weeding frequency and interaction effects of seed rates and weeding frequency. The highest harvest index (49.77%) was recorded from the interaction of 75kgha^{-1} seed rates withthrice hand weeding, which was statistically at par with all seed rates treatments with twice and thrice hand weeding (Table 10). However, the lowest harvest index (37.17%) was recorded from un-weeded plots with 175kgha^{-1} seed rates, which wasstatistically at par with 75,100, 125 and 150kgha^{-1} seed rates plus weedy check, and 125, 150 and 175kgha^{-1} seed rates with once hand weeding. The variation in harvest index values under different interactions wasprobably due to variation in number of total tillers, number of grains per spike, 1000 grain weight and the grain yield. This result agreed with Nano *et al*. [16] who reported that the highest harvest index was recorded at hand weeding and hoeing treatment, while the lowest harvest index was recorded at un-hoeing and weedy plot.

4.11 Relative Yield Loss (%)

Analysis of variance showed that main effect of seed rates, weeding frequency and their interaction had significant ($p<0.05$) effect on relative yield loss of bread wheat in the study area. The highest relative yield loss (71.3%) was occurred from the interaction of 75kgha^{-1}seed rate with weedy check plots,which was

Table 7. 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 8. 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

Table 9. Interaction effects of seed rates and weeding frequency on thousand seed weight (g) 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	43.93^{gh}	45.20^{f}	47.73^{d}	49.80^{a}	46.67
100	43.87^{hi}	45.10^{f}	47.63^{d}	49.50^{ab}	46.53
125	43.73^{hi}	44.87^{f}	47.43^{d}	49.17^{abc}	46.3
150	43.23^{hi}	44.67^{fg}	47.03^{de}	48.93^{bc}	45.97
175	43.17^{i}	44.63^{fg}	46.57^{e}	48.70^{c}	45.77
Mean	43.59	44.89	47.28	49.22	46.24
LSD(0.05) SR = 1.88 WF = 0.39 SR*WF = 0.75 CV(%) = 5.2					

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

Table 10. Interaction effects of seed rates and weeding frequency on harvest indexof bread wheat at Toke Kutaye District in 2020

Seed rate ($kgha^{-1}$)	Weeding frequency				
	Weedy check	Once weeding	Twice weeding	Thrice weeding	Mean
75	42.25^{cde}	44.49^{abc}	49.11^{a}	49.77^{a}	46.41
100	40.46^{cde}	43.2^{bcd}	48.64^{ab}	49.54^{a}	45.46
125	40.38^{cde}	40.46^{cde}	48.28^{ab}	49.21^{a}	44.58
150	37.65^{de}	39.82^{cde}	47.95^{ab}	48.85^{ab}	43.57
175	37.17^{e}	38.43^{de}	45.17^{abc}	48.45^{ab}	42.31
Mean	39.58	41.28	47.83	49.16	44.46
LSD(0.05) SR = 2.99 WF = 1.82 SR*WF = 3.68 CV(%) = 8.55					

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

statistically at par with $100kgha^{-1}$seed rate with un-weeded plot (Table 11). This result was probably due to higher competitive effect of weed species at low density of bread wheat plants.

This result agreed with the reports of Tesfaye *et al*. [5] who stated thatuncontrolled weed throughout the crop growth period caused a yield reduction of 57.6 to 73.2% in Ethiopia. However, the lowest relative yield loss of 1.2% was recorded from the interaction of $175kgha^{-1}$ seed rates with thricehand weeding. This was due to low weed population (density) that made less competes for available growth resources and suppressing effects of high bread wheat density on weed species. Similarly, Yusuf and Ologbon [17] described that from cultural weed control methods, hand weeding and hoeing were reduced weeds up to 80% and resulted in 69% wheat yield increment.

4.12 Economic Analysis

The economic analysis was done using partial budget procedure as described by CIMMYT [10]. Seed cost and labor cost for weeding was used for analysis. This analysis was performed in order to evaluate the economic feasibility of the treatments at the minimum rate of return 50 to 100 % [10]. Seed yield and straw yield of bread wheat from experimental plots were adjusted down ward 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. Farm gate prices of bread wheat grain were ETB 20 kg^{-1} and straw price ETB $0.25kg^{-1}$of the average of one month from the time of crop harvesting, bread wheat seed price ETB $25kg^{-1}$and labor cost for weeding ETB 100 per person per day were used for variable cost determination, while other input costs used as constant for all treatments. Result of partial budget analysis indicated that the highest net benefit of ETB $73,170ha^{-1}$ witha marginal rate of return of 886.4% and value to cost ratio of ETB 8.34 per unit of investment was obtained from $175kgha^{-1}$ seed rates combined with thrice hand weeding (Table 12).

Table 11. Interaction effects of seed rates and weeding frequency on relative yield loss (%) 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	71.3^{a}	58.07^{bc}	46.27^{ef}	31.6^{i}	51.81
100	66.17^{a}	55.8^{bc}	44.07^{fg}	30.87^{i}	49.23
125	59.93^{b}	54.33^{cd}	38.9^{gh}	22^{j}	43.79
150	58.77^{bc}	49.93^{de}	33.8^{hi}	9.23^{k}	37.93
175	55.8^{bc}	46.27^{ef}	33.07^{i}	1.2^{l}	34.08
Mean	62.39	52.88	39.22	18.98	43.37
LSD(0.05) SR = 17.39 WF = 3.82 SR*WF = 7.61 CV(%) =7.67					

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

Table 12.Partial budget analysis of seed rates and weeding frequency for bread wheat production at Toke Kutaye District in 2020

Treatments	Grain yield (t ha^{-1})	Adjusted Grain yield(t.ha^{-1})	Straw yield (tha^{-1})	Adjusted straw yield (tha^{-1})	Gross field benefit (ETB ha^{-1})	Total variable cost (ETBha^{-1})	Net benefit (ETB ha^{-1})	MRR (%)	Value to cost ratio
S_1W_0	1.33	1.197	1.53	1.377	24284.25	1875	22409.3	-	11.95
S_2W_0	1.53	1.377	1.8	1.62	27945	2500	25445	485.7	10.18
S_3W_0	1.83	1.647	2	1.8	33390	3125	30265	771.2	9.68
S_4W_0	1.87	1.683	2.13	1.917	34139.25	3750	30389.3	19.9	8.1
S_5W_0	2.00	1.8	2.2	1.98	36495	4375	32120	276.9	7.34
S_1W_1	1.9	1.71	2.07	1.863	34665.75	4942	29723.8	D	6.01
S_1W_2	2.43	2.187	3.7	3.33	44572.5	5475	39097.5	634.3	7.14
S_2W_1	2.00	1.8	2.43	2.187	36546.75	5567	30979.8	D	5.56
S_2W_2	2.53	2.277	3.87	3.483	46410.75	6100	40310.8	194.1	6.61
S_3W_1	2.07	1.863	3.07	2.763	37950.75	6192	31758.8	D	5.13
S_1W_3	3.1	2.79	4.37	3.933	56783.25	6275	50508.3	5827.1	8.05
S_3W_2	2.77	2.493	4.0	3.6	50760	6725	44035	D	6.55
S_4W_1	2.27	2.043	3.17	2.853	41573.25	6817	34756.3	D	5.1
S_2W_3	3.13	2.817	4.8	4.32	57420	6900	50520	1.88	7.32
S_4W_2	3	2.7	4.13	3.717	54929.25	7350	47579.3	D	6.47
S_5W_1	2.43	2.187	3.37	3.033	44498.25	7442	37056.3	D	4.98
S_3W_3	3.53	3.177	5.4	4.86	64755	7525	57230	1073.6	7.61
S_5W_2	3.03	2.727	4.27	3.843	55500.75	7975	47525.8	D	5.96
S_4W_3	4.13	3.717	6.4	5.76	75780	8150	67630	1664	8.3
S_5W_3	4.47	4.023	6.6	5.94	81945	8775	73170	886.4	8.34

Where: Cost of labor 100ETB/day/Person, seed cost 25 ETB/Kg, 20 ETB/kg price of bread wheat grain, and 0.25 ETB/kg price of straw at local markets. D=Dominance treatment, S=Seed rate and W=Weeding

Table 13. Correlation between yield and yield components of bread wheat in Toke Kutaye District in 2020

	TT	ET	SL	SPP	SPS	TSW	DBY	GY
TT								
ET	0.947**							
SL	0.95**	0.95**						
SPP	0.945**	0.93**	0.95**					
SPS	0.91**	0.96**	0.92**	0.93**				
TSW	0.94**	0.96**	0.94**	0.95**	0.94**			
DBY	0.75**	0.79**	0.76**	0.76**	0.79**	0.84**		
GY	0.72**	0.76**	0.73**	0.74**	0.76**	0.82**	0.98**	
SY	0.75**	0.79**	0.76**	0.76**	0.8**	0.85**	0.99**	0.96**

Where: TT = Total tillers, ET=Effective tiller, SL=Spike length, SPP = Spikelet per spike, SPS=Seed per spikelet, TSW=Thousand Seed weight, DBY=Dry Biomass yield, GY= Grain yield, SY=Straw yield,

4.13 Correlation Analysis of Growth Parameters, Yield and Yield Components

According to correlation analysis of grain yield and yield components of bread wheat, grain yield was strongly and positively correlated with total number of tillers (0.72**), number of effective tiller (0.76**), spike length (0.73**),number of spikelet per spike (0.74**), number of seeds per spikelet (0.76**), thousand seed weight (0.82**) and dry biomass yield (0.98**) (Table 13). This implies,with improving value of these yield components, grain yield of bread wheatcan befurther improved and vice versa. Abebual *et al*. [18] also reported the significant positive correlation of grain yield with number of effective tillers produced per plant, number of tillers produced per plant, aboveground dry biomass yield, harvest index, spike length, number of seeds per spike and thousand seed weight.

5. CONCLUSIONS

Based on the results of this study the weeds are one of the major factors of yield loss in bread wheat fields in the study area. Yield component of bread wheat such as total tillers, effective tillers, spike length and spikelet per spikewere influenced by the amount of seed rates used and weeding frequency. 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 175kgha^{-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 175kgha^{-1} with thrice hand weeding.The highest biomass yield (11.03tha^{-1}), grain yield (4.47tha^{-1}) and straw yield (6.6 tha^{-1}) were recorded on 175kgha^{-1}seed rate with thrice hand weeding. The highest 1000 seed weight was scored from 75 kgha^{-1} seed rate with thrice hand weeding. Relative yield loss was also low (1.2%) due to interaction of 175kgha^{-1} seed rate with thrice hand weeding and higher (71.3%) at the rate of 75kgha^{-1}seed rates with un-weeded plots due to the competition effects of weed for available resources.The partial budget analysis also indicated that 175kgha^{-1} seed rates with thrice hand weeding produced the maximum net profit (ETB73,170ha^{-1}) with marginal rate of return of 886.4% and value to cost ratio of 8.34 ETB.

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 175kgha^{-1} seed rates combined with thrice hand weeding. Therefore, 175kgha^{-1} seed rate and thrice hand weeding is recommended for bread wheat production in Toke Kutaye district and similar agro-ecologies. 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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