

Enhancing the production and productivity of bread wheat (*Triticum aestivum* L.) through agronomic managements in North-Western Ethiopia

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Abstract

Objective

Bread wheat (*Triticum aestivum* L.) is the most important crop in North-Western Ethiopia. However, its productivity is very low as compared to its potential due to poor agronomic practices like inappropriate seeding rate, improper row adjustment, and other factors. Material and Methods: A Field experiment was conducted at Debere-Elias in East Gojjam Zone, at Wonberema and at Adet in West Gojjam Zones during 2018 and 2019 main cropping season to assess the effect of seeding rate and row spacing on yield and yield component of bread wheat. Eight seeding rates (75, 100, 125, 150, 175, 200, 225, and 250 kg ha⁻¹) and two row spacing (20 and 30 cm) were tested in a factorial arrangement in a randomized complete block design (RCBD) with three replications. Results: The combined results showed that agronomic parameters like total tiller, effective tiller, and grain yield were significantly affected by the main effect of seeding rate in all locations. The grain yield highly significantly affected by interaction, hence, at Adet 150 kg ha⁻¹ seeding rate with 20 cm row spacing gave the highest (4540 kg ha⁻¹) grain yield whereas at Wonberema 175 kg ha⁻¹ seed rate with 30 cm row spacing gave better grain yield (3409.0 kg ha⁻¹) and at Deber-Elias seed rate of 150 kg ha⁻¹ with 30 cm row spacing gave better grain yield (3375 kg ha⁻¹). Conclusions: Therefor 150 kg ha⁻¹ with 20 cm recommended for Adet and Deber-Elias and similar agro ecologies whereas 175 kg ha⁻¹ with 30 cm recommended for Wonberema and similar areas.

1. Introduction

Bread wheat (*Triticum aestivum* L.) is an annual crop native to the Mediterranean and southwest Asia area and it is becoming the most important cereal grown on a large scale in the tropical and subtropical regions of the world [1]. Ethiopia is Africa's second-largest wheat producer after South Africa and the largest producer in sub-Saharan Africa [2]. It ranks fourth after tef, maize and sorghum in area coverage [3]. The main wheat-growing areas of Ethiopia are the highlands of the central, southeastern and northwest parts of the country, which is found between 6 and 16° N and 35 and 42° E, at altitudes ranging from 1500 to 2800 m.a.s.l. and with mean minimum temperatures of 6°C to 11°C [4]. In Ethiopia, bread wheat is used in different forms such as bread, porridge, soup, and roasted grain. In addition to the grain, the straw is used for animal feed, thatching roofs, and bed decking. According to [3], Amhara region shared 554,661.74 ha of the total wheat area and 14,047,074.81 tones of grain production in the country. Despite its high importance in the region, the average productivity of bread wheat is about 2.53 t ha⁻¹ which is lower than the national average 2.74 t ha⁻¹ [3]. Among the factors responsible for low productivity, improper seed rate and row spacing are very important [5]. Different seed rates and row spacing were recommended for wheat production in Amhara region. Seed rates of 80 and 100 kg ha⁻¹ were used by Bureau of Agriculture for varieties having high and low tillering capacity, respectively, with 30 cm row spacing [6]. Adet Agricultural research center used seed rate of 150 kg ha⁻¹ with 20 cm row spacing [6]. But, many farmers in Amhara region prefer to use a higher seed rate beyond the recommended. This is especially true in Debre Elias, Wonberema, and Yilmana Densa districts; they use higher seed rates ranging from 200 kg ha⁻¹ [7] to 250 kg

ha⁻¹ (personal communications with farmers). In Debere-Elias and Wonberema, farmers were practicing wheat based mono-cropping system cause to the soil fertility gradually decrease so the plant, unable to give more tillers and only the main stem can give fertile spike. Therefore to compensate lower tillers they used a high seed rate. Low seed rate delay the maturity because of late emerging tillers and would have uneven maturity which is difficult for combiner harvesting; so to make maturity uniform they used high seed rates. Farmers perceive that using high seed rates as a good strategy to control weeds, and also can compensate the risks of crop failure during germination due to unfavorable environmental condition and practices. However, planting higher seed rate beyond the optimum is not encouraged because of its negative impact on tillering capacity, lodging and seed weight because plants compete for light, space, nutrient. On the other hand, low seed rate will decrease yield due to low population per unit area. Additionally, row spacing can determine the area available to each plant which in turn determines nutrient and moisture availability to the plant. If the row is too wide, the crop is unable to rapidly shade the inter-row area to capture sunlight, and weeds quickly become established. If the row is too narrow, inter-row crop competition is very high results in low yield, difficult for disease and insect control, and difficult for management. To solve such a problem this proposal was initiated to maximize productivity and production of bread wheat through optimization of seeding rate and row spacing.

2. Materials and Methods

2.1. Description of the Study Areas

The studies were conducted during 2018 and 2019 main cropping season in East Gojjam at Debre-Elias district and West Gojjam at Wonberema and Yilmana Densa districts (Fig. 1). Debre-Elias was located at 10°0'0"-10°25'00" N and 37°5'0"-37°30'0" E with an altitude of 2425 meters above sea level (m.a.s.l.). Wonberema is located at 10°20'0"-10°40'0" N and 36°35'0"-37°0'0" E with an altitude of 2600 m.a.s.l. Yilmana Densa located between 11°5'0"-11°25'0" N and 37°20'0"-37°40'0" E with an altitude ranging from 2216 to 2696 m.a.s.l. (Fig. 1). The rainfall pattern of the study area is unimodal, and the mean annual rainfall is ranging from 1184 mm to 2402 mm, of these high amount the rainfall received from June to October; the mean minimum and maximum temperature ranged from 11 to 15 °C and 23 to 27 °C, respectively (Fig. 2). The experimental sites with maize precursor were selected for the study. The soil of the experimental sites was Nitosol and analysis on some of the selected soil physicochemical properties for composite surface soil (0–20 cm depth) samples collected at planting. The analysis soil sample showed that pH ranged from slightly to moderately acidic [8], organic carbon ranged from low to medium [9], the total nitrogen of the area was medium [9], available phosphorus ranged from low to medium [10] and the cation exchange capacity of the study area was very high [8] (Table 1). The overall result of soil analysis showed the need to design for reduce soil acidity, improve organic carbon and total nitrogen through integrated soil fertility management approach.

Table 1
The soil physico-Chemical properties of soil of the experimental area

Parameters	D-Elias	Adet	Wonberma	Rate	Method	Reference
Chemical properties of soil						
pH	5.01	5.6	5.2	SA-MA	1:2.5 soil: water suspension	[8]
%C	2.282	1.211	1.916	L-M	Walkley-Black	[9]
%N	0.196	0.159	0.189	M	Kjeldhal	[9]
p ppm	7.797	4.915	9.887	L-M	Olsen	[10]
CEC	40.7	40.9	40.86	VH	Ammonium acetate	[8]
Texture	Physical properties of soil					
Clay+ silt	37	45	37			
clay	23	24	24	[11]		
silt	14	21	13			
sand	63	55	63			
Remark	sandyclayloam	sandyclayloam	sandyclayloam			

2.2. Treatments, Experimental Design and procedure

A factorial combination of eight seeding rates (75,100,125,150,175, 200, 225, and 250 kg ha⁻¹) and two row spacing (20 and 30 cm) was evaluated in RCBD with three replications. Each in a gross plot size of 3 m width and 2 m length, while the net plot size was 4.8 m² and 5.2 m² for 30 and 20 cm row spacing respectively. All the phosphorous and 1/3rd of Nitrogen was applied at planting while the remaining 2/3rd Nitrogen was applied during mid-tillering stage of bread wheat. The experimental field was prepared according to the local practice. Thus, the land was ploughed four times using oxen before planting to pulverize the soil and make control of early emerging weeds. Seeds of bread wheat variety 'Kekeba' was uniformly hand drilled and covered by soil on 18th of June to 26th of July in 2018 and on 20th of June to 28th of July in 2019. The spacing between blocks and plots were 1 m and 0.5 m, respectively. One hoeing at early tillering stage and hand weeding was carried out to keep the plots free from weeds and to provide better aeration. The next two hand weeding activities were operated at mid-tillering and booting stage of bread wheat. Harvesting was done manually by sickle at physiological maturity

2.3. Data collection and analyses

Data were collected from a total of eight experimental sites (in the first year three sites and second year five sites) and averaged value of each parameter for the year was considered for analysis. The combined analysis showed that the interaction effect of seed rate, row spacing and location was significant, therefore,

the result were discussed based on individual locations. Data on plant height, spike length, number of tillers, effective tillers, seed per spike, thousand seed weight, and hectoliter weight were collected from the net plot using random sampling. Grain (Gy) and biomass yield (By) were collected from the whole net plot. The data were subjected to analysis of variance (ANOVA) using SAS (statistical analysis System) GLM procedures version 9.0. Combined analysis over years was made considering location as a random variable. Least Significance Difference (LSD) test at 5% or 1% of probability levels was used for mean separation when the analysis of variance indicates the presence of significant differences [12].

2.4. Partial budget analysis

The mean grain and straw yield data over sites were adjusted down by 10% and subjected to partial budget analysis [13]. Total costs that varied (seed cost, planting and harvesting cost) for each treatment was calculated and treatments were ranked by sorting their total variable cost (TVC) in ascending order and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The labor cost at Adet, Debere-Elias and Wonberema was 60, 80 and 100 ETB per person per day respectively, seed cost at Adet, Debere-Elias, and Wonberema were 16.85, 17.8 and 16.7 ETB kg^{-1} , respectively. At Adet, selling price of grain and straw was 13.0 and 2.70 ETB kg^{-1} , respectively, while at Debere-Elias, selling price of grain and straw was 14.0 and 2.20 ETB kg^{-1} , respectively, and at Wonberema selling price of grain and straw was 13.5 and 2.0 ETB kg^{-1} , respectively. The inputs that were prevailing at the local market at the time of their use were considered for working out the cost of cultivation. Net returns per hectare were calculated by deducting the cost of production per hectare from gross income per hectare. A treatment that is non-dominated and having the highest net benefit is said to be economically profitable [13] and MRR% was calculated by change in net benefit over change in total variable cost times 100.

3. Results and Discussion

3.1. Growth-related parameters of bread wheat

The combined result from the analysis of variance showed that plant height was not significantly affected by the main effect as well as by their interactions in all locations (Table 2). The height of the crop is mainly controlled by the genetic makeup of a genotype and by the environmental factors [14]. Spike length was very highly significantly ($p < 0.01$) and highly significant ($p < 0.05$) affected by seed rate at Adet and Debere-Elias respectively, but seed rate had no significant difference ($p \geq 0.05$) on spike length at Wonberema; Plant height and spike length were not significantly ($P \geq 0.05$) affected by row spacing in all locations (Table 2). The highest spike length (8.4 & 9 cm) were recorded from 75 kg ha^{-1} seed rate, while the lowest spike length (7.15 & 8.2 cm) was obtained from seeding rate of 250 kg ha^{-1} , at Adet and Debere-Elias, respectively (Table 3). This finding was in harmony with the findings of [15] who reported that increasing seed rate from 125 kg ha^{-1} to 200 kg ha^{-1} , the spike length reduced by 8.57%. Similarly, [16] reported that increasing the seeding rate from 100 kg ha^{-1} to 150 kg ha^{-1} , the spike length decreased by 3.35%.

3.2. Yield related components of bread wheat

The combined result from the analysis of variance indicated that the main effect of seed rate had significant ($p < 0.05$) effect on seed per spike at Adet and Debere-Elias but, seed rate had non-significant effect ($p \geq 0.05$) on seed spike⁻¹ at Wonberema (Table 2). Row spacing as well as the interaction had no significant effect of seed per spike in all locations. The present finding was similar to the finding of [17] who stated that row spacing had no statistically significant difference on the number of seed per spike. The maximum seeds spike⁻¹ (55.3 & 51.6) were obtained from seed rate of 75 kg ha⁻¹ at Adet and Debere-Elias, respectively, whereas the minimum seeds spike⁻¹ (41.98 & 43.4) were obtained from seed rate of 250 kg ha⁻¹ at Adet and Debere-Elias, respectively, (Table 3). Seed spike⁻¹ was higher from lower seed rate as compared to the highest seeding rate in all locations, this might be due to the availability of more free space between plants at the lower seed rates and less intra-plant competition for the available resources. However, at higher seed rate competition among growing grains for the preserved matters became higher and resulted in low grains developments per spike [18]. The present result were in harmony with the findings of [18] who reported that higher seed rates produced a significantly decreased number of grains (kernels) spike⁻¹.

Table 2

Significance value (P value) on grain yield and yield related parameters of bread wheat at Adet, Debre-Elias and wonberema districts (combined over 2018 and 2019)

SV	DF	Ph	Sl	Sps	Tt	Et	Gy	By	Tsw	Hlw
Lo	2	*	*	*	**	**	***	***	ns	ns
Sr	7	ns	**	**	***	***	***	***	ns	ns
Rs	1	ns	ns	ns	**	**	ns	ns	ns	ns
Sr*Rs	7	ns	ns	ns	ns	ns	**	ns	ns	ns
Lo*Sr	14	ns	ns	ns	*	*	*	ns	ns	ns
Lo*Rs	2	ns	ns	ns	ns	ns	ns	ns	ns	ns
Lo*Sr*Rs	21	*	*	*	**	*	*	ns	*	*
*=significant, ** highly significant, ***=very highly significant, ns = non-significant, Lo=location, Sr=seed rate, Rs = row spacing, Ph=plant height, Sl=spike length, Sps=seed per spike, Tt=total tiller, Et=effective tiller, Gy=grain yield, By=biomass yield, Tsw=thousand seed weight and Hlw=hectoliter weight										

Table 3

The main effect of seed rate and row spacing on plant height, spike length and seed per spike of bread wheat at Adet, Debre-Elias and wonberema during (2018&2019)

Wheat at Adet, Debere-Elias and Wonberema during (2016a2017)										
	Adet				Debere-Elias			Wonberema		
Seed Rate kg ha ⁻¹		PH	SL	SPS	PH	SL	SPS	PH	SL	SPS
	75	97.9	8.4 ^a	55.3 ^a	95.7	9 ^a	51.6 ^a	90.8	8.2	50.2
	100	97	8.2 ^{ab}	51.9 ^{ab}	95.1	8.5 ^{bcd}	49.3 ^{ab}	93.8	8.1	49.5
	125	96.8	7.9 ^{abc}	47.9 ^{bdc}	97.1	8.7 ^{abc}	50.6 ^{ab}	92.1	8.1	49.1
	150	96.8	7.7 ^{bdc}	50.9 ^{abc}	98.4	8.5 ^{bdc}	48.6 ^{ab}	93.5	8.2	47.6
	175	96.7	7.6 ^{cde}	46.4 ^{cde}	97.1	8.5 ^{bcd}	49.1 ^{ab}	90.3	7.8	47.1
	200	94.8	7.5 ^{cde}	44.7 ^{ed}	96.9	8.9 ^{ab}	50.9 ^a	91.3	7.9	44.6
	225	96.1	7.4 ^{de}	45.96 ^{cde}	97.2	8.3 ^{dc}	45.9 ^{bc}	90.1	7.7	44.3
	250	95.4	7.15 ^e	41.98 ^e	95.6	8.2 ^d	43.4 ^c	90.4	7.4	45
P value (0.05)		ns	***	***	ns	**	*	ns	ns	ns
Row spacing	20	96.8	7.8	48.3	96.5	8.5	48.6	90.9	7.93	47.1
	30	96.2	7.7	47.9	96.8	8.6	48.8	92.2	7.89	47.2
P value (0.05)		ns	ns	Ns	ns	ns	ns	ns	ns	ns
CV (%)		3.23	6.6	13.0	2.6	4.2	8.7	3.3	5.7	8.5
R ²		0.77	0.89	0.76	0.47	0.50	0.59	0.47	0.47	0.42
***represent very highly significant difference at P < 0.001, **represent highly significant difference at p < 0.01, ns represents non-significant difference, PH= Plant height, SL= Spike length and SPS= Seed per spike										

Total tillers and Effective tillers were highly significantly ($p < 0.01$) affected by the main effect in all location, but at Adet row spacing had non-significantly ($P > 0.05$) effect on effective tiller and also the interaction of seed rate and row spacing had non-significant effect on total tillers and effective tillers in all location (Table 2). The maximum total and effective tillers were recorded from the highest seed rate with narrow row spacing and vice versa (Table 4). Number of total and effective tillers increased as seed rate increased, this increment might be due to high number of population per unit area. [15] Confirmed that higher sowing rates increased the number of tillers m^{-2} due to more number of seeds sown and numbers of plants emerged. As seed rate increased from 75 kg ha⁻¹ to 250 kg ha⁻¹, the number of effective tillers expected to be

decreased due to more intra-specific competition for limited resources. However, in acidic and low fertility soil, the plant unable to produce more tillers per plant rather the plant had only a single main productive stem because of high competition for a limited available resource, lately emerging tillers become died which results minimum number of effective tiller per unit area, then increasing seed rate would increase the number of effective main plants (Table 4).

Regarding to row spacing the maximum total and effective tillers were recorded at 20 cm row spacing this might be plants utilized all available resources more efficiently including light, water, air and nutrients for producing more tiller per square meter than 30 cm row spacing (Table 4). The present results were in agreement with the findings of [5] who observed that narrow row spacing increased number of tillers per unit area significantly over wider row spacing. [15] also reported that the maximum effective tiller was recorded from the higher seed rate than the lower seed rate. However, the present result was in contrast with [19] reported that the maximum productive tiller was recorded from a lower seed rate than a higher seed rate because of productive tiller per plant was higher at lower seed rate than higher seed rate. Similarly, [20] reported that at higher seed rates, competition among the plants started before the maximum tillering stage, which was manifested reduced tiller production.

Table 4

The main effect of seed rate and row spacing on total tiller and effective tiller of bread wheat at Adet, Debere-Elias and Wonberema combined (2018&2019)

Debere-Elias and Wonberema combined (2016-2017)							
	Adet		Debere-Elias		Wonberema		
Seed rate kg ha ⁻¹		TT	ET	TT	ET	TT	ET
75		488.7 ^c	480.1 ^c	289.7 ^c	265.9 ^c	229.2 ^d	276.9 ^e
100		456.8 ^c	447 ^c	375.5 ^b	348.8 ^b	318.8 ^d	305.7 ^{ed}
125		534.6 ^c	522.1 ^c	377.6 ^b	345.4 ^b	320.2 ^d	302.5 ^e
150		633.7 ^b	617.8 ^b	382.3 ^b	345.5 ^b	360.1 ^c	337 ^{cd}
175		651.6 ^b	635.0 ^b	422.1 ^{ab}	385.9 ^{ab}	377.2 ^c	356.9 ^{bc}
200		694.8 ^{ab}	661.9 ^{ab}	419 ^{ab}	381.6 ^{ab}	383.4 ^{bc}	357.6 ^{bc}
225		682.6 ^b	660.5 ^{ab}	426.6 ^{ab}	380.3 ^{ab}	412.7 ^{ab}	385.8 ^{ab}
250		773.3 ^a	741.4 ^a	471.6 ^a	426.7 ^a	423.6 ^a	392.2 ^a
P value (0.05)		**	***	***	***	***	***
Row spacing	20	637.4a	614.5	432 ^a	392 ^a	379.3 ^a	356.1 ^a
	30	591.5b	577.2	359.1 ^b	328 ^b	342.5 ^b	322.6 ^b
P value (0.05)		*	ns	***	***	***	***
CV (%)		16.9	17.5	11.8	12.4	8.03	8.4
***represent very highly significance difference at P < 0.001, **represent highly significance difference at p < 0.01, ns represents non-significant difference, TT=Total tiller and ET=effective tiller							

3.2.1. Grain and Above-biomass yield

The combined result from the analysis of variance over year showed that above-biomass yield was significantly affected by seed rate in all location, however, it was not significantly ($p \geq 0.05$) affected by row spacing and the interaction in all locations (Table 2). At Adet and Debere-Elias the maximum above-biomass yield (10854.7 & 7823.2kg ha⁻¹) were obtained from seed rate of 150 kg ha⁻¹ while the minimum above-biomass yield obtained from the lowest seed rate (Table 5). This might be as the seed rate increase the total population increased but the plant was tin because of high nutrient competition then weight become decreased. The present result was in agreement with [5] who found that above biological yield was increased as seeding rate increased from 125 kg ha⁻¹ to 150 and 175 kg ha⁻¹. But, at Wonberema the maximum and minimum above-biomass yield was obtained from seed rate of 250 and 75 kg ha⁻¹

respectively, because the tillering capacity of the plant was reduced then further increase seed rate total population increased therefore above-biomass yield increased.

Table 5

The main effect of seed rate and row spacing on biomass and straw yield of bread wheat at Adet, Debre-Elias and Wonberema combined (2018 & 2019)

		Adet		Debere-Elias		Wonberema	
Seed rate kg ha ⁻¹		BY	SY	BY	SY	BY	SY
75		10854.7 ^c	6580.7 ^c	6046.5 ^d	3591 ^d	7264.4 ^d	4155.9 ^c
100		11322.1 ^{bc}	7037.8 ^{bc}	6607.8 ^{cd}	3829.6 ^{cd}	7550.1 ^{bcd}	4769.6 ^{bc}
125		11677.4 ^{ab}	7205.6 ^{abc}	7143.2 ^{abc}	4342.1 ^{bc}	8004.6 ^{ab}	4736.8 ^{bc}
150		12267.6 ^a	7693.5 ^a	7823.2 ^a	4721 ^{ab}	7388.9 ^{cd}	4134.3 ^c
175		11749.5 ^{ab}	7348.0 ^{ab}	7135.8 ^{abc}	4449.6 ^{abc}	7972.8 ^{abc}	4870.2 ^b
200		11968.5 ^{ab}	7657.9 ^{ab}	7039 ^{abc}	4223.2 ^{bcd}	8126.6 ^{ab}	5090.1 ^{ab}
225		12019.2 ^{ab}	7606.9 ^{ab}	7549.1 ^{ab}	5047 ^a	8238.6 ^a	5130.7 ^{ab}
250		11728.1 ^{ab}	7507.0 ^{ab}	6954.9 ^{bc}	4275.9 ^{bc}	8264.2 ^a	5677.7 ^a
P value (0.05)		*	**	**	**	**	**
Row spacing	20	11634.6	7263.8	6858.7	4152.6	7785.1	4747.3
	30	11634.6	7395.6	7140.2	4301.4	7917.4	4894
P value (0.05)		ns	ns	ns	ns	ns	ns
CV (%)		7.6	10.3	9.9	15.3	6.4	11.7
**represent highly significance difference at p < 0.01, ns represents non-significant difference BY=Biological yield and SY=Straw yield							

Grain yield was highly significantly ($p < 0.01$) affected by the interaction of seed rate and row spacing in the three locations (Table 2). At Wonberema, seed rate of 175 kg ha⁻¹ with row spacing of 30 cm gave maximum grain yield (3409 kg). At Adet, the similar maximum grain yield (4539.7 kg ha⁻¹) was obtained from seed rate of 150 kg ha⁻¹ with 20 cm row spacing and 150 kg ha⁻¹ with row spacing of 30 cm. At Debere-Elias, the maximum grain yield (3375.1 kg ha⁻¹) was obtained from seed rate of 150 kg ha⁻¹ with 20 cm. From this result use of higher seed rate beyond 175 kg ha⁻¹ and lower seed rate below 125 would reduce the grain yield in all location (Table 6). In agreement with the present finding, [21] concluded that

grain yield was maximum at seeding rate of 150 kg ha⁻¹, followed by 175 and 200 kg ha⁻¹ compared to 125 kg ha⁻¹. The same result also reported by [5] who concluded that seeding rate of 150 kg ha⁻¹ produced significantly higher grain yield (4120 kg ha⁻¹), followed by 175 and 200 kg ha⁻¹ seeding rates (3904 and 3785 kg ha⁻¹). [22] showed that 150 kg ha⁻¹ seeding rate produced significantly the highest grain yield. Furthermore, [23] reported that using 150 kg seed ha⁻¹ produced higher grain yield of 5103.3 kg ha⁻¹ than other seeding rates (100, 125, 175 and 200 kg ha⁻¹).

Table 6

The interaction effect of seed rate and row spacing on grain yield of bread wheat at Adet, Debre-Elias and Wonberema combined (2018 & 2019)

	Adet		Debere-Elias		Wonberema	
Seed Rate in kg ha ⁻¹	20 cm	30 cm	20 cm	30 cm	20 cm	30 cm
75	4296.7 ^{abc}	3921 ^c	2490.1 ^{cd}	2636.8 ^{cd}	3113.1 ^{abcd}	3103.9 ^{abcd}
100	3997.7 ^{bc}	4405.3 ^{ab}	2849.9 ^{bc}	2749.2 ^{bcd}	2811.5 ^{def}	2749.5 ^{ef}
125	4532.7 ^a	4211 ^{abc}	2864.4 ^{bc}	2778.7 ^{bcd}	2939.7 ^{cde}	3272.2 ^{abc}
150	4539.7 ^a	4539.7 ^a	3074.3 ^{ab}	3375.1 ^a	3153.8 ^{abcd}	3355.4 ^{ab}
175	4343.7 ^{abc}	4370.3 ^{ab}	2798.7 ^{bcd}	3062.9 ^{ab}	3120 ^{abcd}	3409 ^a
200	4206.0 ^{abc}	4331.7 ^{abc}	2645.1 ^{cd}	3274.6 ^a	2929.9 ^{cde}	3143 ^{abcd}
225	4484 ^a	4169.0 ^{abc}	2609.1 ^{cd}	2430.2 ^d	3183.9 ^{abc}	3031.9 ^{bcde}
250	4286.3 ^{abc}	4155.7 ^{abc}	2624 ^{cd}	2539.2 ^{cd}	3050.7 ^{bcde}	2489.3 ^f
P value at (0.05)	**		**		**	
CV %	6.4		8.5		6.9	
**represent highly significant difference at p < 0.01, CV=coefficient of variance in percent, means with the same letter within the column are not significantly significant						

3.2.2. Straw yield

The combined result from the analysis of variance showed that seed rate affected straw yield highly significantly (p < 0.01), but both row spacing and the interaction had no significant effect in all location (Table 3). At Adet the maximum straw yield (7693.5 kg ha⁻¹) was obtained from seed rate of 150 kg ha⁻¹, while the minimum straw yield (6580.7 kg ha⁻¹) was recorded from seed rate of 75 kg ha⁻¹. At Debre-Elias, the maximum straw yield (5047 kg ha⁻¹) was obtained from seed rate of 225 kg ha⁻¹, while the minimum straw yield (3591 kg ha⁻¹) was recorded from seed rate of 75 kg ha⁻¹. At Wonberema, the maximum and minimum straw yield (5677.7 and 4134.3 kg ha⁻¹) was obtained from seed rate of 250 and

150 kg ha⁻¹, respectively (Table 5). The present result showed that the maximum straw yield was obtained from highest seed rate but, the minimum straw yield was obtained from lowest seed rate that means increasing seed rate would increase straw yield this was due to the fact that higher seeding rates resulted more plant population and greater plant height which resulted in higher straw yield. This result was in harmony with [21] and [24] reported that as seeding rate increased, correspondingly straw yield increased due to higher stand number at crop establishment period. Similarly, [25] confirmed that increasing seeding rates up to 350 or 400 grains m⁻² increased grain, straw and biological yields. Regarding to row spacing, the result of analysis of variance depicted that straw yield was not affected by row spacing ($p > 0.05$) in all locations.

3.3. Quality related parameter of bread wheat

The combined result from the analysis of variance indicated that the main effect, as well as the interaction, had no significant ($p \geq 0.05$) effect on thousand seed weight and hectoliter weight of bread wheat (Table 2). Generally as seed rate increased thousand seed weight and hectoliter weight decreased; these might be due to high competition among spikes as a result little assimilates would be available to grain filling and finally thousand kernels (seed) and hectoliter weight would reduce due to high plant population. [26] and [27] concluded that increasing seed rate the thousand grains weight would reduce in wheat. Similar [28] reported that increasing seeding rate from 350–800 seeds per m² significantly decreased hectoliter weight in wheat.

Table 7

The main effect of seed rate and row spacing on hectoliter weight and thousand seed weight of bread wheat at Adet, Debre-Elias and Wonberema combined (2018&2019)

	Adet		Debere-Elias		Wonberema		
Seed rate kg ha ⁻¹	TSW	HLW	TSW	HLW	TSW	HLW	
75	31.9	68.5	33.2	75.1	30.3	73.4	
100	33.2	68.3	33.1	74.8	29.8	73.6	
125	31.9	68.4	30.3	74.4	29.1	72.9	
150	33.4	68.9	31.8	73.9	28.9	73	
175	32.5	68.6	30.9	73.2	28.3	72.7	
200	32.2	68.5	30.8	74.6	27.6	72.5	
225	32	68.5	26.6	73.2	28.3	73.5	
250	30	68.4	30.5	73.9	27.7	72.3	
P value (0.05)	ns	ns	ns	ns	ns	ns	
Row spacing	20	32.3	68.49	30.8	74.4	29.1	73
	30	32	68.54	31.7	74.1	28.4	72.9
P value (0.05)	ns	ns	ns	ns	ns	ns	ns
CV (%)	6.4	1	6.8	2.1	6.4	1.1	
ns represents non-significant difference, HLW= hectoliter weight and TSW=Thousand seed weight							

Table 8
Effect of seed rate and row spacing on economic analysis of bread wheat production at Wonberema
(combined 2018&2019) cropping season

Trt	GY kg ha ⁻¹	Adj GY kg ha ⁻¹	SY kg ha ⁻¹	Adj SY kg ha ⁻¹	GB birr ha ⁻¹	TVC birr ha ⁻¹	NB birr ha ⁻¹	MRR%
75 30	3103.9	2793.5	4023.2	3872.0	44893.0	5325.1	39567.9	
100 20	2811.5	2530.4	4860.0	4374.0	42907.7	5596.3	37311.4D	
125 30	3272.2	2945.0	4753.0	4277.7	47082.0	5834.6	41247.4	329.6
100 30	2749.5	2474.6	4679.2	4211.3	41829.0	5902.0	35927.0D	
75 20	3113.1	2801.8	4009.5	3608.6	44945.5	5940.0	39005.5D	
125 20	2939.7	2645.7	5044.4	4540.0	44797.3	6147.3	38649.9D	
150 20	3153.8	2838.4	4076.2	3668.6	46122.0	6484.7	39637.3D	
175 30	3409.0	3068.1	4716.0	4244.4	49908.2	6980.7	42927.5	146.6
150 30	3355.4	3019.9	4192.3	3773.1	48314.3	7018.9	41295.4D	
200 30	3143.0	2828.7	5259.2	4733.3	47654.0	7665.8	39988.2D	
175 20	3120.0	2808.0	5024.4	4522.0	46951.9	7830.4	39121.6D	
250 30	2489.3	2240.4	5901.3	5311.2	40867.3	7857.0	33010.3D	
200 20	2929.9	2636.9	4921.0	4428.9	44456.1	7974.1	36482.0D	
225 20	3183.9	2865.5	5279.3	4751.4	48187.1	7984.3	40202.9D	
225 30	3031.9	2728.7	4982.0	4483.8	45805.2	8040.3	37764.9D	
250 20	3050.7	2745.6	5087.1	4578.4	46222.8	9042.8	37180.0D	

TVC= Total Variable Cost, D=Dominance, Trt=Treatments, Cost of seed 16.7 ETB kg⁻¹, Planting and harvesting Cost ETB 100 per person per day; Sale price of bread wheat grain Birr 13.50 ETB kg⁻¹, Sale price of bread wheat straw 2.0 ETB kg⁻¹, MRR=Marginal rate of return

Table 9
Effect of seed rate and row spacing on economic analysis of bread wheat production at Debere-Elias
(combined 2018&2019) cropping season

Trt	GY kg ha ⁻¹	Adj GY kg ha ⁻¹	SY kg ha ⁻¹	Adj SY kg ha ⁻¹	GB birr ha ⁻¹	TVC birr ha ⁻¹	NB birr ha ⁻¹	MRR%
75 30	2637	2373.1	3945.8	3551.2	41036	4593.1	36443	
100 20	2850	2564.9	3886.6	3497.9	43604	4921	38683	683.06
75 20	2490	2241.1	3236.3	2912.7	37783	5085	32698D	
100 30	2749	2474.3	3772.7	3395.4	42110	5165.6	36944D	
125 30	2779	2500.8	4330.4	3897.4	43586	5222.7	38363D	
125 20	2864	2578	4353.7	3918.3	44712	5472.9	39239	100.7
150 20	3074	2766.9	4734.7	4261.2	48111	5853.8	42257	792.4
150 30	3375	3037.6	4707.2	4236.5	51847	6281.1	45565	774.14
175 30	3063	2756.6	3932.5	3539.3	46379	6361.5	40017D	
200 30	3275	2947.1	4658	4192.2	50483	7020.6	43462D	
175 20	2799	2518.8	4966.7	4470	45098	7041.3	38056D	
200 20	2645	2380.6	3788.3	3409.5	40829	7267.3	33562D	
225 20	2609	2348.2	4853.8	4368.4	42485	7386.4	35099D	
250 30	2539	2285.3	4249.5	3824.6	40408	7395.6	33012D	
225 30	2430	2187.2	5240.1	4716.1	40996	7431.2	33565D	
250	2624	2361.6	4302.3	3872.1	41581	8344.2	33237D	
TVC= Total Variable Cost, D=Dominance, Trt=Treatments, Cost of seed 17.8 Birr per kg; Planting and harvesting Cost Birr 80 per person per day; Sale price of bread wheat grain Birr 14.0 per kg; Sale price of bread wheat straw 2.20 Birr per kg, MRR=Marginal rate of return								

Trt	GY kg ha ⁻¹	Adj GY kg ha ⁻¹	SY kg ha ⁻¹	Adj SY kg ha ⁻¹	GB birr ha ⁻¹	TVC birr ha ⁻¹	NB birr ha ⁻¹	MRR%
20								
<i>TVC= Total Variable Cost, D=Dominance, Trt=Treatments, Cost of seed 17.8 Birr per kg; Planting and harvesting Cost Birr 80 per person per day; Sale price of bread wheat grain Birr 14.0 per kg; Sale price of bread wheat straw 2.20 Birr per kg, MRR=Marginal rate of return</i>								

Table 10
Effect of seed rate and row spacing on economic analysis of bread wheat production at Adet (combined 2018&2019) cropping season

Trt	GY kg ha ⁻¹	Adj GY kg ha ⁻¹	SY kg ha ⁻¹	Adj SY kg ha ⁻¹	GB birr ha ⁻¹	TVC kg ha ⁻¹	NB birr ha ⁻¹	MRR
75 30	3921	3529	6428	5785.47	61496.5	3707.33	57789.1	
100 20	3998	3598	6771	6094.17	63227.3	4040.77	59186.6	419.1
75 20	4297	3867	6733	6059.7	66632.6	4076.25	62556.3	9497.4
100 30	4405	3965	7304	6573.87	69291.5	4224.19	65067.3	1697.2
125 30	4211	3790	7317	6585.57	67049.7	4354.51	62695.2D	
125 20	4533	4079	7094	6384.87	70271.7	4542.15	65729.6	208.3
150 20	4539	4086	7635	6871.77	71668.3	4915.32	66752.9	274.2
150 30	4539	4086	7752	6976.53	71951.1	5235.83	66715.3D	
175 30	4370	3933	7782	7004.07	70043.5	5383.65	64659.9D	
175 20	4344	3909	6914	6222.6	67622.3	5893.46	61728.8D	
200 30	4332	3899	7682	6914.07	69348.9	5965.49	63383.4D	
200 20	4206	3785	7633	6869.97	67759.1	6150.45	61608.7D	
225 20	4484	4036	7756	6980.67	71310.6	6327.31	64983.3D	
225 30	4169	3752	7457	6711.57	66898.5	6360.91	60537.6D	
250 30	4156	3740	7442	6697.53	66705	6421.7	60283.3D	
TVC= Total Variable Cost, D=Dominance, Trt=Treatments, Cost of seed 16.85 ETB kg ⁻¹ ; Planting and harvesting Cost ETB 60 per person per day; Sale price of bread wheat grain Birr 13.0 ETB kg ⁻¹ ; Sale price of bread wheat straw 2.70 ETB kg ⁻¹ , MRR=Marginal rate of return								

Trt	GY kg ha ⁻¹	Adj GY kg ha ⁻¹	SY kg ha ⁻¹	Adj SY kg ha ⁻¹	GB birr ha ⁻¹	TVC kg ha ⁻¹	NB birr ha ⁻¹	MRR
250 20	4286	3858	7573	6815.43	68551.4	7133.17	61418.2D	
TVC= Total Variable Cost, D=Dominance, Trt=Treatments, Cost of seed 16.85 ETB kg ⁻¹ ; Planting and harvesting Cost ETB 60 per person per day; Sale price of bread wheat grain Birr 13.0 ETB kg ⁻¹ ; Sale price of bread wheat straw 2.70 ETB kg ⁻¹ , MRR=Marginal rate of return								

4. Conclusion and recommendations

In general, significant differences in grain yield and most of agronomic parameters of bread wheat were observed due to seeding rates and row spacing. From the present study, it is possible to conclude that seeding rate affect most of the yield and yield-related components of bread wheat in all locations, but most of the yield and yield-related components of bread wheat were not significantly affected by row spacing in all locations. Based on the result of this study hectoliter weight, spike length, seed per spike were superior at low seeding rate as compared to higher seed rate whereas total tiller, effective tiller, straw yield were high at higher seed rate as compared to low seed rate in all locations.

Partial budget analysis was performed to investigate the economic feasibility of the treatments. The present research finding showed that at Adet seeding rate 150 kg ha⁻¹ with 30 and 20 cm row spacing gave better grain yield 4540 kg ha⁻¹ but based on the partial budget analysis it was not economically feasible but 150 kg ha⁻¹ seeding rate with 20 cm row spacing was economically feasible and gave 4540 kg ha⁻¹ and also had 274.2 MRR. Therefore, 150 kg ha⁻¹ seeding rate with 20 cm row spacing recommended at Adet as 1st option and 125 kg ha⁻¹ seeding rate with 20 cm row spacing used as 2nd option. A seed rate of 175 kg ha⁻¹ with 30 cm row spacing gave better grain yield 3409.0 kg ha⁻¹, and also economically feasible with positive 146.6 MRR so it is recommend for Wonberema areas. At Debere-Elias 150 kg ha⁻¹ with 30 cm and 150 kg ha⁻¹ with 20 cm gave 3375 & 3074 kg ha⁻¹ with 774.14 and 792.4 MRR, respectively, and also economically feasible so, 150 kg ha⁻¹ with 30 cm row spacing recommended as 1st and 150 kg ha⁻¹ with 20 cm row spacing as 2nd for Debere-Elias and similar areas.

5. Limitation

The experiment conducted with one varieties to similar experiment should be conducted with varieties having different maturity and tillering capacity.

Declarations

Alemayehu Assefa

Conceptualized and analyzed the data.

Alemu Abate

Conceptualized and analyzed the data. All authors read and approved the final manuscript.

Conflict of interest:

The author declares that there is no conflict of interest.

Ethics approval:

not applicable

Consent to participate:

Not applicable. The study was based on primary data, and no direct involvement of human participants occurred.

Consent to publish:

Not applicable. The manuscript does not contain any individual person's data in any form.

Clinical Trial Number

Not applicab

Funding:

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Author Contribution

****Bitwoded Derebe**** : Conceptualized this study, executed experiments, analyzed, interpreted the data, and wrote the manuscript. ****Alemayehu Assefa****: Conceptualized and analyzed the data. ****Alemu Abate**** : Conceptualized and analyzed the data. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability:

not applicable

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Figures

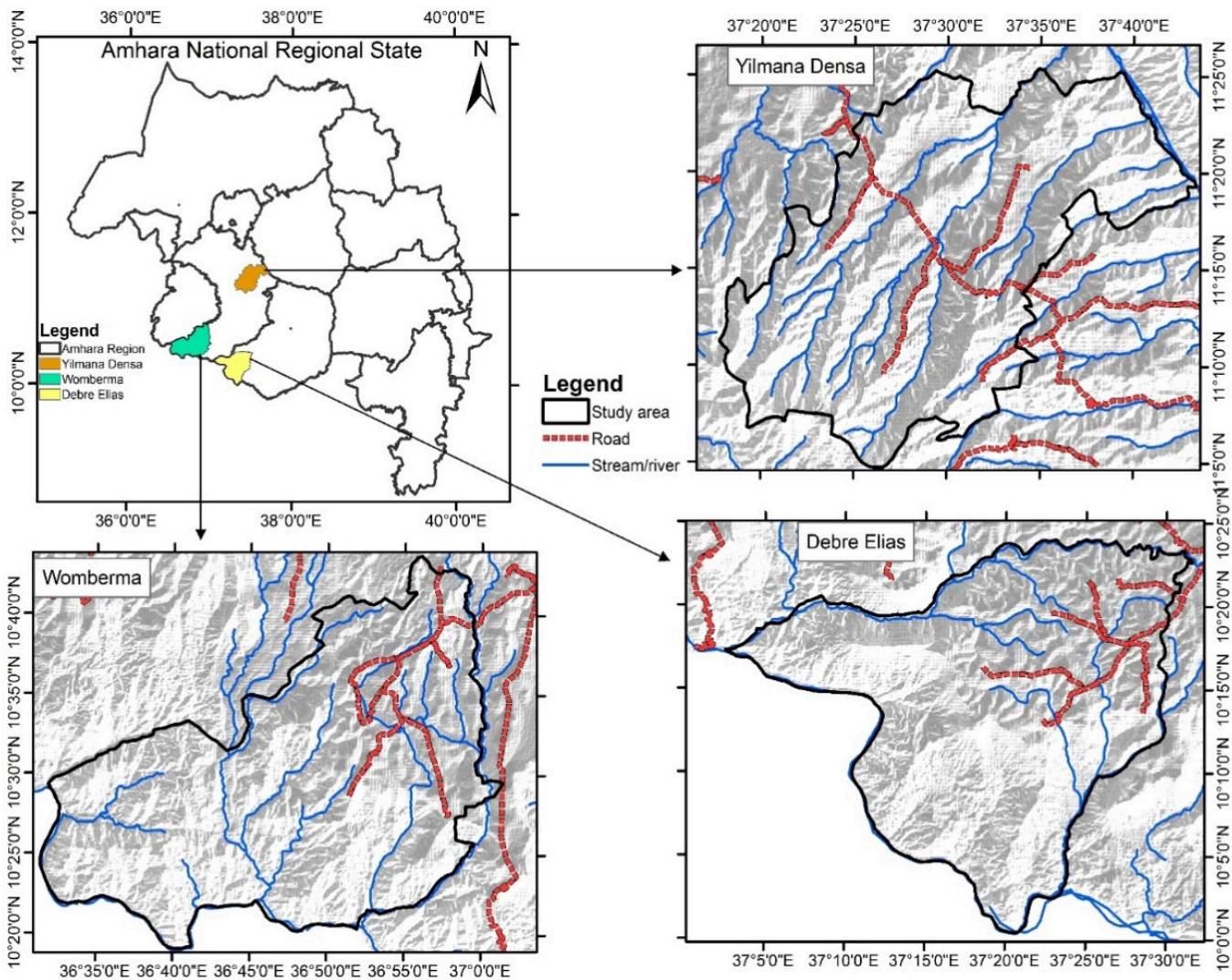


Figure 1

Maps of the study areas

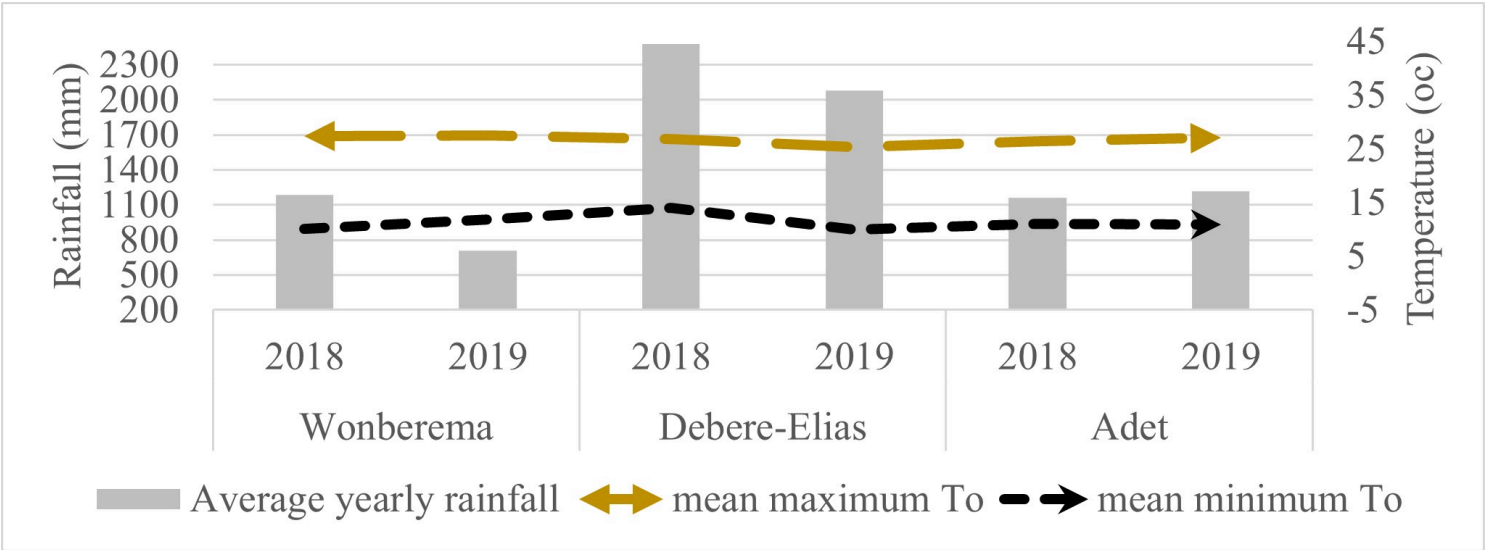


Figure 2

The Annual average rainfall, Annual mean maximum, and minimum temperature over years in the study areas (2018 and 2019)