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Birhanu Gebeyehu
Department of Plant Sciences, Faculty of Agriculture, Bahir Dar University, Ethiopia

Correspondence
Birhanu Gebeyehu
Department of Plant Sciences, Faculty of Agriculture, Bahir Dar University, Ethiopia

Review on: Response of bread wheat (*Triticum aestivum* L.) to seeding rate on yield and yield components

Birhanu Gebeyehu

Abstract
Bread wheat (*Triticum aestivum* L.) is an economically important crop. However, its annual productivity is very low due to poor management practices like: inappropriate seeding rate and utilization of different fertilizer types. Therefore, paper to review the response of bread wheat (*Triticum aestivum* L.) to seeding rate on yield. Based on this review, application of different seeding rates has significant effects on yield and yield components of bread wheat. The results of this review showed that high-yield is obtained when wheat is sown from the seeding rate when increased from 75 to 200 $kgha^{-1}$. As the seeding rate increased from 75 to 200 $kgha^{-1}$ number of productive tillers, total numbers of tillers, total biomass yield and straw yield were increased. From this review, it is possible to conclude that increased seeding rate performed better and gave higher grain yield and highest grain yield advantage over the lower seeding rates.

Keywords: bread wheat, seeding rate, yield, yield components

1. Introduction

Bread wheat (*Triticum aestivum* L.) is an annual crop plant belonging to the family *Poaceae*, sub-family *Pooideae* and tribe *Triticeae* (Feldman and Levy, 2015) [18] and native to the Mediterranean region and southwest Asia (Gibson and Benson, 2002) [21]. It is one of the several species of cultivated wheat, now grown in temperate climates worldwide. Currently, it is also becoming one of the most important cereals grown on a large scale in the tropical and sub-tropical regions of the world (Onwueme and Sinha, 1999; Gibson and Benson, 2002) [47, 21].

Bread wheat (*Triticum aestivum* L.*)* is the second most important staple crop in the world (FAOSTAT, 2014) [17]. Importance of wheat crop in the world trade is greater than that of all other crops produced and most widely grown food crop in the world (FAO, 2015) [15].

Wheat is grown across a wide range of environments around the world with the broadest adaptation of all the cereal crop species. It is a cool season crop requiring a minimum temperature for growth of 3 ^{0}C to 4 ^{0}C, with optimal growth occurring around 25 ^{0}C and tolerance of temperatures to a maximum of about 32 ^{0}C (Leonard and Martin, 1963). Wheat flourishes in many different agro-climatic zones with production concentrated between latitudes 30 ^{0}N and 60 ^{0}N and longitudes 27 ^{0}S and 40 ^{0}E, but there are also wheat production areas beyond these limits from the Arctic Circle to higher elevations near the equator (Briggle and Curtis 1987). Although about three-fourths of the land area where wheat is grown receives an average of between 375 and 875 mm of annual precipitation, it can be grown in most locations where precipitation ranges from 250 to 1750 mm (Leonard and Martin, 1963). Wheat grows best on well-drained soils anywhere from sea level up to heights of about 4500 m above sea level.

According to FAO (2017) [16], about 759 million metric ton of wheat was produced in the year 2016 with an average productivity of 3.19 tons ha^{-1}.

Seeding rate has a significant influence on the majority of agronomic traits of bread wheat (FAO, 2014) [14]. Bread wheat sowing at the optimum seeding rate with appropriate fertilizer types would significantly enhance the number of grains per spike, the spike length, grain weight per spike and thousand grains weight and then finally produce high grain yield (Iqbal *et al*., 2010) [1]. But, seeding rate above or below the optimum may reduce the yield significantly (Ozturk *et al*., 2006) [50]. Then objective of this paper is to review the response of yield of bread wheat to different seeding rates.

2. Literature review

2.1 Brief Introduction to Bread Wheat

Bread wheat (*Triticum aestivum* L.) is an annual crop plant belonging to the family *Poaceae*, sub-family *Pooideae* and tribe *Triticeae* (Feldman and Levy, 2015) [18] and native to the Mediterranean region and southwest Asia (Gibson and Benson, 2002) [21]. Wheat is classified in the grass tribe (*Triticeae*) and the genus *Triticum* (Poehlman and Sleper, 1995) [51]. All wheat species, whether wild or cultivated, belong to the genus *Triticum* and the family *Poaceae*. The genus *Triticum* contains about 30 types of wheat that have enough genetic differences to be considered separate species or sub-species (Breth, 1975) [6].

Most archeological evidence suggests that the earliest domestication of wheat occurred around 7500–6500 BC in the fertile-crescent consisting of the mountain chains flanking the plains of Mesopotamia and the Syrian Desert (Mason and Spaner, 2006) [41]. Cultivation of bread wheat appears to have spread around the Near East by 7000 BC, and subsequently to the lowlands of Mesopotamia, Egypt, Mediterranean basin, Europe, central Asia, India, and Ethiopia by 4000 BC (Zeven, 1980) [68].

Therefore, today wheat is grown all over the world, with different varieties sown according to the various climates. In 2002, the world's main wheat producing regions were China, India, United States, Russian Federation, France, Australia, Germany, Ukraine, Canada, Turkey, Pakistan, Argentina, Kazakhstan and United Kingdom (Bruinsma, 2017).

2.2 Factors Affecting Seeding Rate of Bread Wheat

Ashenafi Mengistu (2000) [4] reported that, seeding rate depends on the tillering capacity of the crop varieties, sowing date, soil conditions, and cultivation intensity. For high yielding, short stature cultivars, a seed rate of 100-125 kgha^{-1} have been found desirable. In places where due to climate, early growth is restricted or the growing season is short, a higher seed rate more than 125 kgha^{-1} is recommended. For good crop of wheat, yielding 5000 kg ha^{-1}, there should be about 500 spikes per square meter. Such a stand can be achieved at a seed rate of 100kgha^{-1} with row spacing of 22.5 cm for all those cultivars which tiller readily and at a seeding rate of 125 kgha^{-1} with rows spaced at 20 cm for the cultivars which are low in tillering (Onwueme and Sinha, 1999) [47].

Lockhart and Wiseman (1983) [38] reported that, seeding rate generally, increases for varieties with larger seed size and low tillering capacity. Moreover, late sowing, broadcasting seeds, heavy clay soils and low soil moisture requires higher seeding rate. Similarly, Khah *et al.* (1989) [33] found that low-vigor spring wheat seed produced lower yields only when it resulted in low plant populations or when planting was later than normal. Reedy (2006) reported that early maturing and poor tillering varieties need closer spacing with higher seeding rate compared with long duration and profusely tillering varieties. Similarly, late-sown crops demand closer row spacing and higher seed rate to compensate for the lesser number of tillers and shorter growing periods. Furthermore, Marshal and Ohms (1987) found that grain yield of wheat can be increased significantly by high seeding rates. It was recognized, however, varieties with poor tillering ability required seed rates as high as 160 kg even when drilled (Tanner *et al*., 1991) [60]. Regarding the effect of seedbed condition on the seeding rate of the wheat crop, Gooding *et al*. (1997) [22] reported that, high seeding rates are required for poor seedbed, and for a grain with reduced germination capacity and vice versa.

Darwinkel *et al.* (1977) [10] concluded that high seeding rates are advantageous only when conditions such as delayed planting and low temperature inhibited tillering. Seeding rate had significant effect on the number of tillers at heading time. The highest average number tillers per plant (6.0) were obtained at the seeding rate of 100 kgha^{-1} while the lowest number of tillers per plant of 2.2 was obtained at 150 kgha^{-1} seeding rate. Using seeding rate of 100, 125 or 150 kgha^{-1}, the number of tillers increased consistently with increasing seeding rates. On the other hand, seeding rate of 125 kgha^{-1} gave the highest number of tillers (Worku Awdie, 2008) [66]. Darwinkel (1980) [11] explained that reducing seeding rate may result in more tillers and spikes per plant, and more spikelets but in many cases reduced grain yield per hectare. Moreover, Osman and Mohamed (1981) [48] reported that, positive responses to increasing seeding rates are associated with the increases in the number of tillers.

2.3 Effects of Seeding Rates on Yield of Bread Wheat

Plant density is important to determine plant height. Thickening plant density caused by changing plant height and stem thickness because of inter-specific competition to more absorption light (Naseri *et al*., 2012) [45]. The variations in plant height in response to seeding rate, wheat sown at higher seed rate produced greater plant height and lower seeding rate results in lower plant height. Wheat sown at higher seeding rates had significantly higher internode length and increased plant height. Low seeding rate less competition for space, nutrients, and water and thus short erect plants and minimum or no lodging was noted (Laghari *et al*., 2011) [37]. The height of plants grown at the lowest seeding rate (100 kgha^{-1}) was significantly lower than the heights of plants grown at seeding rates ranging from 125-175 kg ha^{-1} (Haile Deressa *et al*., 2013) [25].

At higher seeding rates, competition among the plants started before the maximum tillering stage, which was manifested in a low increase in spike production (Sarker *et al.*, 2007) [55]. Similarly, Suleiman *et al.* (2010) [59] also noted that spike length is affected by seeding rates. The shortest and highest spikes length was recorded by using the highest and lowest seeding rate respectively. Such decrease in spike length might be due to the competition between greater numbers of plants for the environmental conditions. This could have been reflecting in lower rates of photosynthesis and growth of those plants, which was expressed in a noticeable decrease in spike length (Nizamani *et al*., 2014) [46].

Grain yield of bread wheat is a product of three yield components: the number of ears per unit area, the number of kernels per ear and individual kernel weight. Ear number is the first yield component to be fixed, and, thus, assumes particular importance. Intensive productive tillering and a higher number of kernels per ear compensate for grain yield at low seeding rates (Und, 2002) [63]. Gafaar (2007) [\20] studied the growth, yield and its components of bread wheat as affected by the sowing densities, and found that increasing sowing density from 200 up to 400 plants per m^2 significantly increased. Suleiman *et al*. (2010) [59] also noted that grain yield ha^{-1} bread wheat was gradually and significantly increased as sowing density increased. The superiority of grain yield ha^{-1} in dense sowing could be attributed to the higher number of spikes per unit area which reverse the effect of the increasing in the grain yield $spike^{-1}$ obtained as the sowing density was decreased. Kumar *et al*. (2006) [36] and Otteson *et al*. (2007) [49] reported that increasing sowing rates with optimum fertilizer application resulted in increased grain yield. Changes in seeding density have special importance in wheat crops since they have a direct effect on grain yield (Ozturk *et al*., 2006) [50]. Seeding rate is an important agronomic practice to influence the productivity of bread wheat grain yield. As Tompkins *et al.* (1991) [62] concluded, the highest bread wheat grain yield was obtained by using the lowest seeding rate of 125 $kgha^{-1}$ among higher seeding rates tested ranging from 150-300 $kgha^{-1}$ since wider row spacing results better water and nutrient utilization thereby produces more number of effective tillers per unit area. On the other hand, (Sulieman, 2010) stated that seeding rate of bread wheat at 150 $kgha^{-1}$ gave significantly higher grain yield than 100 $kgha^{-1}$ seeding rate. As Nizamani *et al.* (2014) [46] reported that the result regarding agronomic traits revealed that seeding rate has significant influence on majority of agronomic traits of bread wheat and he concluded that wheat sown under seeding rate of 125 $kgha^{-1}$ had better growth, yield parameters and then higher grain yield. Cheema *et al.* (2006) [9] reported that the highest wheat grain yield (4293 $kgha^{-1}$) with seeding rate of 125 $kgha^{-1}$. These results also agree with those reported by Nizamani *et al*., (2014) [46] who reported that lower seeding rates had better yield due to vigorous crop growth. The significance of the effects of seeding rates on the growth and grain yield of wheat has also been proved by Sikander *et al.* (2003) [56] and the yield and yield components in bread wheat were affected significantly by seeding rate. A simple economic analysis calculating the increased cost of seed compared with the increased income suggests that it is economic to plant at the higher seeding rate (Jones *et al*., 2008) [32]. Tomar and Kumar (2004) [61] compared seeding rates of 100, 125, 150 $kgha^{-1}$ and found that yield was maximum at the highest seeding rate of 150 $kgha^{-1}$. Mennan and Zandstra (2005) [42] reported that wheat grain yield increased with increasing seeding rate and decreased with decreasing seeding rate from 250 to 200 or 150 $kgha^{-1}$. Most farmers in Ethiopia are using higher seeding rate than the recommended ones as a means for suppressing weeds (Regassa Ensermu *et al*., 1992) [53]. Higher seeding rate up to (175 $kgha^{-1}$) increased grain yield for broadcast sowing by compensating for seed buried deeper or left uncovered on the surface.

Increasing of spike per unit of area and reduction of a number of kernels per spike due to increasing of seeding rate was also reported (Varga *et al*., 2000; Zaheer *et al*., 2000; Hanson, 2001) [64, 67, 26]. More kernels per spike, low kernel weight due to lack of photosynthetic matter to fill kernel because of competition for light. Thus, there is a negative relationship between plant density and thousand grain weight. Donaldson *et al*. (2001) [12] showed that highest and lowest kernels per spike observed at lowest and highest plant densities respectively. At higher plant density most kernels would fade at an early stage because of competition between growing kernels to absorb preserved matters and as the result, low kernels would produce (Rahim *et al*., 2012) [59]. A number of kernels per spike are affected by cultivars (Majid and Mohsen, 2012) [39]. The relative advantage in grain yield of variety might be largely attributed to its higher number of kernels per spike and per m^2 (Solomon Gelalcha *et al*., 2000) [58]. The minimum kernels per spike in farmer's seed category may be due to the aging of the seed, which resulted in poor quality seedling and poor management practices and the environment during its development (Sinclair and Jamieson, 2008) [57]. Changes in seeding rates have special importance in wheat crops since they have a direct effect on grain yield and its components (Veselinka *et al.*, 2014) [65].

The higher seeding rate in bread wheat resulted in decreased 1000 kernel weight (Baloch *et al*., 2010; Laghari *et al*., 2011) [5, 37]. Several authors emphasized the influence of higher seeding rate on 1000 kernel weight (Hiltbrunner *et al*., 2005; Dubis and Budzynski, 2006) [27, 13]. They established that with a seeding rate of 600 in comparison to 480 seeds m^{-2} decreased thousand kernel weight. However, small and dense kernels are better than large and light kernels. Even with the lower number of spikes per unit area, produced higher grain yield due to its bolder grain size (WRC, 2006). A number of kernels per spike and kernel weight were in positive correlation with other and directly influenced wheat yield (Fellahi *et al*., 2013) [19].

In higher seed rates, a higher number of plants and tillers failed to produce higher biomass yield (Allam, 2003) [2]. However, according to Haile Deressa and Girma Fana (2010) [25] the highest biomass yield was obtained in the highest seeding rate (225 $kgha^{-1}$).

Richards *et al*. (2002) [54] demonstrated that harvest index as indicators of the genetic potential of the plant to produce economic yield, high harvest index under control treatment can be accompanied with high grain yield under water stress. Wheat cultivars that have high harvest index, most likely have high grain yield under field conditions. A positive relationship found between grain weight and harvest index. It means that increased of grain weight results increased harvest index (Koocheki *et al*., 2006) [35]. In another study, Varga *et al*. (2000) [64] observed reduction of seed weight due to an increase of seeding rate, while Zaheer *et al*. (2000) [67] reported reduction of harvest index as the increase of seeding rate. Ali *et al.* (2010) [1] compared seeding rates of 125, 150, 175, 200 $kgha^{-1}$ harvest index was highest under seeding rate of 150 $kgha^{-1}$.

The highest mean height of 95 cm was recorded in barley plots received 150 kg ha^{-1} (Arif *et al*., 2006) [3]. In contrast, control plots exhibited significantly lower plant height compared to all other treatments. The result agrees with Mitiku Woldesenbet *et al*. (2014) [43] who showed a significant effect on plant height where the tallest barley plants were obtained with application of the highest seeding rate. The highest number of effective tillers and total tillers was obtained from the highest seeding rate. In agreement with this result Arif *et al*. (2006) [3] reported significant increase in number of grains per spike of wheat by applying by highest seeding rate. The highest total biomass yield (11500 kg ha^{-1}) and straw yield (6114 kg ha^{-1}) were obtained from the highest seeding rate of (150 kg ha^{-1}) as compared to straw yield (2115 kg ha^{-1}) which is obtained from the lowest seeding rate. Harvest index was influenced significantly with application of the highest seeding rate (Hussain *et al*., 2003) [28]. The highest harvest index (47) was obtained with the highest seeding rate of (150 kg ha^{-1}) as compared to plots that received applied the lowest seeding rate. Mooleki *et al*. (2002) [44] reported that the increased rate of seed has increased the harvest index.

Plant density is important to determine plant height. Thickening plant density caused by changing plant height and stem thickness because of inter-specific competition to more absorption light (Naseri *et al*., 2012) [45]. The variations in plant height in response to seeding rate, wheat sown at higher seed rate produced greater plant height and lower seeding rate results in lower plant height. Wheat sown at higher seeding rates had significantly higher internode length and increased plant height. Low seeding rate less competition for space, nutrients, and water and thus short erect plants and minimum or no lodging was noted (Laghari *et al*., 2011) [37]. The height of plants grown at the lowest seeding rate (100 kgha^{-1}) was significantly lower than the heights of plants grown at seeding rates ranging from 125-175 kg ha^{-1} (Haile Deressa *et al*., 2013) [25].

At higher seeding rates, competition among the plants started before the maximum tillering stage, which was manifested in a low increase in spike production (Sarker *et al.*, 2007) [55]. Similarly, Suleiman *et al*. (2010) [59] also noted that spike length is affected by seeding rates. The shortest and highest spikes length was recorded by using the highest and lowest seeding rate respectively. Such decrease in spike length might be due to the competition between greater numbers of plants for the environmental conditions. This could have been reflecting in lower rates of photosynthesis and growth of those plants, which was expressed in a noticeable decrease in spike length (Nizamani *et al*., 2014) [46].

3. Conclusion

Based on this review, application of different seeding rates has significant effects on yield and yield components of bread wheat. The results of this review showed that high-yield is obtained when wheat is sown from the seeding rate when increased from 75 to 200 kgha^{-1}. As the seeding rate increased from 75 to 200 kgha^{-1} number of productive tillers, total numbers of tillers, total biomass yield and straw yield were increased. From this review, it is possible to conclude that increased seeding rate performed better and gave higher grain yield and highest grain yield advantage over the lower seeding rates.

4. References

1. Ali L, Iqbal N, Akbar N, Ali M, Sattar M. Effect of seed rate and row spacing on yield and yield components of wheat (*Triticum aestivum* L.). Journal of Agricultural Research 2010;48(2):151-156.
2. Allam AY. Response of three wheat cultivars to split application of nitrogen fertilization rates in sandy soil. Assiut Journal of Agricultural Sciences (Egypt). 2003. https://scholar.google.com/scholar?hl.
3. Arif M, Chohan MA, Ali S, Gul R, Khan S. Response of wheat to foliar application of nutrients. Journal of Agricultural and Biological Science 2006;1(4):30-34.
4. Ashenafi M. Triticale production for tropical environments. triticale an alternative potential dry land crop to alleviate food security in Ethiopia. MSc Thesis, University of Kassel, Germany. East African Journal of Sciences 2000;10(1):15-22.
5. Baloch MS, Shah I, Nadim MA, Khan MI, Khakwani AA. Effect of seeding density and planting time on growth and yield attributes of wheat. Journal of Animal and Plant Science 2010;20(4):239-240.
6. Breth SA. Durum wheat: New age for an old crop.1st edition, CIMMYT, Mexico 1975, 8.
7. Briggle LW, Curtis BC. Wheat worldwide. Wheat and wheat improvement 1987, 1-32.
8. Bruinsman J. The weed-competitive ability of Canada western red spring wheat cultivars grown under organic management. World agriculture: towards 2015/2030: an FAO Study. Rout Ledge Crop science 2017;47(3):1167-1176.
9. Cheema NM, Mian MA, Ihsan M, Rabbani G, Mahmood A. Studies on variability and some genetic parameters in spring wheat. Pakistan Journal of Agricultural Science 2006;43(1-2):32-35.
10. Darwinkel A, Ten Hag BA, Kuizenga J. Effect of sowing date and seeding rate on crop development and grain production of winter wheat. Netherlands Journal of Agricultural Science, 1977.
11. Darwinkel A. Ear development and formation of grain yield in winter wheat. Netherlands Journal of Agricultural Science 1980;28(3):156-163.
12. Donaldson E, Schillinger WE, Dofing Sm. Straw production and grain yield relationship in winter wheat. Crop science. International Journal of Agricultural Crop Science 4, no. 2001;13(2012):868-872.
13. Dubis B, Budzynski W. Response of winter wheat to the date and density of sowing. Acta scientiarum polonorum, Agricultural, 2006. (Poland). http://agris.fao.org/agris-search/search.do?recordID=PL2008000167
14. FAO (Food and Agricultural Organization). Crop prospects and food situation, the state of food and agriculture. Women in agriculture: Closing the gender gap for development. Rome 2014, 76-78.
15. FAO (Food and Agricultural Organization). Biannual report on global food production and market, USA, 2015, 7.
16. FAO (Food and Agricultural Organization). 2017. The state of food insecurity in the world 2015. Meeting the 2015 international hunger targets: Taking stock of uneven progress. Food and Agriculture Organization publications, Rome.
17. FAOSTAT (Food and Agriculture Organization Statistics). World crop production data. Available at: (http://www.faostat.fao.org/site. Accessed on March 23, 2014.http://faostat.fao.org (accessed 05.02.15.)
18. Feldman M, Levy AA. Origin and evolution of wheat and related *triticeae* species. in alien introgression in wheat, springer, Cham 2015, 21-76.
19. Fellahi Z, Hannachi A, Bouzerzour H, Boutekrabt A. Correlation between traits and path analysis coefficient for grain yield and other quantitative traits in bread wheat under semi-arid conditions. Journal of Agriculture and Sustainability 2013, 3(1).
20. Gafaar NA. Response of Some Bread Wheat Varieties Grown Under Different Levels of Planting Density and Nitrogen Fertilizer. Minufiya Journal of Agricultural Research 2007;32(1):165-183.
21. Gibson L, Benson G. Origin, history, and uses of oat (*Avena sativa*) and wheat (*Triticum aestivum*). Iowa state university, department of Agronomy 2002, 3.
22. Gooding MJ, Smith G, Davies WP, Kettle well PS. The use of residual maximum likelihood to model grain quality characters of wheat with variety, climatic and

nitrogen fertilizer effects. The journal of agricultural science 1997;128(2):135-142.

23. Gooding M. Wheat crop. Wheat Chemistry and Technology, (November), 2009, 19-50.
24. Haile D, Girma F. Integrated effect of seeding rate, herbicide rate and application timing on durum wheat (*Triticum turgidum* L.) yield, yield components and wild oat (*Avena fatua* L.) control, in South Eastern Ethiopia. Middle East Journal of Scientific Research 2010;5(3):184-190.
25. Haile Deressa, Nigussie-Dechassa, Abdo W, Girma F. Seeding rate and genotype effects on agronomic performance and grain protein content of durum wheat (*Triticum turgidum* L. var. durum) in South-Eastern Ethiopia. African journal of food, agriculture, nutrition and development 2013, 13(3).
26. Hanson BD. Effects of Imazethapyr and Pendimethalin on Lentil (*Lens culinaris*), Pea (*Pisum sativum*), and a subsequent winter Wheat (*Triticum aestivum*) crop. Weed technology 2001;15(1):190-194.
27. Hiltbrunner J, Liedgens M, Stamp P, Streit B. Effects of row spacing and liquid manure on directly drilled winter wheat in organic farming. European Journal of Agronomy, 2005, 12-15.
28. Hussain I, Khan MA, Ahmad K. Effect of row spacing on grain yield and the yield components of wheat (*Triticum aestivum* L.). Pakistan Journal of Agronomy 2003;2(3):153-159.
29. Hussain I, Khan MA, Khan EA. Bread wheat varieties as influenced by different seeding rates. Journal of Zhejiang University Science B 2006;7(1):70-78.
30. Iqbal N, Akbar N, Ali M, Sattar M, Ali L. Effect of seeding rate and row spacing on yield and yield components of wheat (*Triticum aestivum* L.). Adaptive research farm, Vehari. Pakistan Journal of Agriculture Research 2010;48(2):151-156.
31. Johnson GV, Raun WR, Westerman RL. Fertilizer nitrogen recovery in long-term continuous winter wheat. Soil Science Society of America Journal 1999;63(3):645-650.
32. Jones H, Lister DL, Bower MA, Leigh FJ, Smith LM, Jones MK. Approaches and constraints of using existing landrace and extant plant material to understand agricultural spread in prehistory. Plant genetic resources 2008;6(2):98-112.
33. Khah EM, Roberts EH, Ellis RH. Effects of seed aging on growth and yield of spring wheat at different plant population densities. Field crops research 1989;20(3):175-190.
34. Khan R, Gurmani AH, Gurmani AR, Zia MS. Effect of boron on rice yield under wheat-rice system. International Journal of Agricultural Biology 2006;8:805-808.
35. Koocheki AR, Yazdansepas A, Nikkhah HR. Effects of terminal drought on grain yield and some morphological traits in wheat (*Triticum aestivum* L.) genotypes. Iranian Journal of Agricultural Science 2006;8:14-29.
36. Kumar M, Babel AL. Available micronutrient status and their relationship with soil properties of Jhunjhunu Tehsil, district Jhunjhunu, Rajasthan, India. Journal of Agricultural Science 2011;3(2):97.
37. Laghari GM, Oad FC, Tunio S, Chachar Q, Ghandahi AW, Siddiqui MH et al. Growth and yield attributes of wheat at different seed rates. Sarhad Journal of Agriculture, 2011;27(2):177-183.
38. Lockhart JAR, Wiseman AJL. Introduction to crop husbandry including grassland. 5thedition. Royal agricultural college, Britain, Pakistan Journal of Biological Science 1983;3(1):82-86.
39. Majid Abdoli, Mohsen Saeidi. Effects of water deficiency stress during seed growth on yield and its components, germination and seedling growth parameters of some wheat cultivars. International journal of agriculture and crop sciences 2012;4(15):1110-1118.
40. Marshal GC, Ohms HW. Yield response of winter wheat cultivars to row spacing and seeding rate, Agronomy Journal 1987;79(6):1027-1030.
41. Mason HE, Spaner D. Competitive ability of wheat in conventional and organic management systems: Review of the literature. Canadian Journal of Plant Science 2006;86(2):333-343.
42. Mennan H, Zandstra BH. Effect of wheat (*Triticum aestivum*) cultivars and seeding rate on yield loss from *Galium aparine* (cleavers). Crop protection, 2005;24(12):1061-1067.
43. Mitiku W/Senbet, Singh TN, Teferi M, Tamado T. Effect of integrated nutrient management on yield and yield components of food barley *(Hordeum vulgare* L.) in Kaffa Zone, Southwestern Ethiopia. Science, Technology and Arts Research Journal 2014;3(2):34-42.
44. Mooleki SP, Schoenau JJ, Hultgreen G, Wen G, Charles JL. Effect of rate, frequency and method of NPSB application on soil, crop performance in east-central Saskatchewan. Canadian Journal of Soil Science 2002;82(4):457-467.
45. Naseri R, Soleymanifard A, Khoshkhabar H, Mirzaei A, Nazaralizadeh K. Effect of plant density on grain yield, yield components and associated traits of three durum wheat cultivars in Western Iran. International Journal of Agriculture and Crop Sciences 2012;4(2):79-85.
46. Nizamani G, Tunio S, Buriro UA, Keerio MI. Influence of different seed rates on yield contributing traits in wheat varieties. Faculty of crop production, Sindh agriculture university, Tando Jam, Pakistan. Journal of Plant Sciences 2014;2(5):232-236.
47. Onwueme IC, Sinha TD. Crop establishment practices in field crop production in tropical Africa: Principles and practices. CTA, Wageningen, Netherlands 1999, 469.
48. Osman AM, Mahmoud ZM. Yield and yield components of wheat (*Triticum aestivum* L.) and their interrelationships as influenced by nitrogen and seed rate in the Sudan. Journal of Agricultural Science 1981;97(3):611-618.
49. Otteson BN, Mergoum M, Ransom JK. Seeding rate and nitrogen management effects on spring wheat yield and yield components. Agronomy journal 2007;99(6):1615-1621.
50. Ozturk A, Caglar O, Bulut S. Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. Journal of Agronomy-Crop Science 2006;192:10-16.

51. Poehlman JM, Sleper DA. Breeding field crops. 4th edition, Lowa State University Press Corporation, USA. Breeding Field Crops 1995, 259-277.
52. Rahim Naseri, Abas Soleymanifard, Hamid Khoshkhabar, Amir Mirzaei, Kamvan Nazaralizadela. Effect of plant density on grain yield, yield components and associated traits of three 32 durum wheat cultivar in Western Iran. International Journal of Agriculture and Crop Sciences 2012;4(2):79-85.
53. Regassa Ensermu R, Kefyalew A, Mwangi WM. On-farm verification of improved bread wheat varieties and management practices in Gojam region of Ethiopia. CIMMYT regional wheat workshop for Eastern, Central and Southern Africa, 7; Nakuru (Kenya); 1992, 16-19.
54. Richards RA, Rebetzke GJ, Condon AG, Herwaarden AF. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. Crop science 2002;42(1):111-121.
55. Sarker MA, Malaker PK, Saifuzzaman M, Pandit DB, Effect of variety and sseed rate on the yield of wheat. Bangladesh Journal of Agriculture and Environment 2007;3:75-82.
56. Sikander TK, Hussain I, Sohail M, Kissana NS, Abbas SG. Effects of different planting methods on yield and yield components of wheat. Asian Journal of Plant Science 2003;2(10):811-813.
57. Sinclair TR, Jamieson PD. Yield and grain number of wheat: a correlation or causal relationship. Authors' response to "importance of grain or kernel number in wheat: a reply to Sinclair and Jamieson" by RA Fischer. Field Crops Research 2008;105(1-2):22-26.
58. Solomon Gelalcha, Desalegn Debelo, Bedada Girma, Zewdie Alemayehu, BalchaYaie. Milling and baking quality of Ethiopian bread wheat, in the eleventh regional wheat workshop for Eastern, Central and Southern Africa 2000, 87.
59. Suleiman MF, Ibrahim ME, Abdel-Aal SM, Zahran GA. Effect of seeding rates on productivity, technological and rheological characteristics of bread wheat (*Triticum aestivum* L.). International Journal of Current Research 2010, 14.
60. Tanner D, Sahle G. Weed control research conducted on wheat in Ethiopia. In: H. Gebre Mariam, D.G. Tanner & M. Hulluka, eds. Wheat research in Ethiopia: a historical perspective. Addis Ababa 1993. IAR/CIMMYT.
61. Tomar SM, Kumar GT. Seedling survivability as a selection criterion for drought tolerance in wheat. Plant breeding 2004;123(4):392-394.
62. Tompkins DK, Fowler DB, Wright AT. Water use by no-till winter wheat influence of seed rate and row spacing. Agronomy Journal 1991;83(4):766-769.
63. Und E. Relationships among yield, its quality and yield components in winter wheat (*Triticum aestivum* L.) cultivars affected by seeding rates. Die Bodenkultur, 2002;143(53):3.
64. Varga B, Svecnjak Z, Pospisil A. Grain yield and yield components of winter wheat grown in two management systems. Journal of Agriculture 2000;51(3):145-150.
65. Veselinka Zecevic, Jelena Boskovic, Desimir Knezevic, Danica Micanovic. Effect of seeding rate on grain quality of winter wheat. Chilean Journal of Agricultural Resource 2014;74:1.
66. Worku Awdie. Effects of nitrogen and seed rates on yield and yield components of bread wheat *(Triticum aestivum* L.) in Yelmana Densa district, Northwestern Ethiopia. M.Sc. Thesis. The school of graduate studies of Haramaya University. Harar, Ethiopia, 2008.
67. Zaheer A, Kisana NS, Mujaih MY, Iftikhar A, Mustafa SZ, Majid A. Effect of population density on yield and yield components of wheat. Pakistan Journal of Biological Science 2000;3(9):1389-1390.
68. Zeven AC. The spread of bread wheat over the old world since the Neolithicum as indicated by its genotype for hybrid necrosis. Journal of agriculture traditionally botanique appliquée 1980;27(1):19-53.