Agricultural and Biological Sciences Journal
Vol. 7, No. 2, 2021, pp. 27-33
http://www.aiscience.org/journal/absj
ISSN: 2381-7178 (Print); ISSN: 2381-7186 (Online)

Response of Bread Wheat (*Triticum aestivum L.*) Varieties to Plant Densities in Lemu-Bilbilo District of Arsi Zone, Southeastern Ethiopia

Dereje Dobocha*, Debela Bekele, Wegayehu Worku, Fasil Shimeles, Zenebe Mulatu, Almaz Admasu

Agronomy and Crop Physiology Program, Ethiopian Institute of Agricultural Research, Kulumsa Agricultural Research Center, Asella, Ethiopia

Abstract

The agronomic optimum plant density is decisive for future improvements in wheat production and productivity. A field experiments were conducted to study the effect of varieties and planting densities on yield and yield components of bread wheat at Lemu-Bilbilo district, Arsi Zone, on farmers' fields during 2016 and 2017 main cropping seasons. The experiments were laid out in a randomized complete block design in split plot arrangements in which bread wheat varieties (Danda'a, Digelu and Hidase) were assigned to main plots and plant densities (100, 200, 300, 400 and 500 plants m^{-2} with seed rate of 125 kg h^{-1} as control) to subplots with three replications. Results pointed major factors varieties and plant densities showed significant differences for all parameters tested in specific sites and years except thousand kernels weight which was not significantly affected by different plant densities. Danda'a variety resulted in the highest grains $spike^{-1}$ (64.12), grain yield (6053.59 kg ha^{-1}) and biological yield of (14.29 t ha^{-1}) whereas; 300 plants m^{-2} was the optimum plant density for all the studied parameters. The difference in spike length, harvest index and thousand kernels weight of Danda'a variety was significantly at par with Hidase variety while the plant height was with Digelu variety. The interaction of varieties and plant densities did not show significant difference on parameters that have been taken except for grain and biological yields. The optimum grain and biological yields were found from Danda'a variety combined with plant density level of 300 plants m^{-2}. Therefore, the plant density of 300 plants m^{-2} may be practiced for better production and productivity of Danda'a variety at Lemu-Bilbilo district and similar agro-ecologies.

Keywords

Bread Wheat, Plant Densities, Varieties, Yield and Yield Components

Received: March 15, 2021 / Accepted: April 14, 2021/ Published online: April 29, 2021

1. Introduction

Wheat (*Triticum aestivum* L.) is cultivated in Ethiopia for several periods with little change in farm implements and farming practices among smallholder farmers and constitutes roughly 20 to 30% of the annual cereal production and plays an appreciable role of supplying the production with carbohydrates, proteins and minerals [1]. It is one of the most important cereals in human diets, increasing its relevancy as the global population is projected to increase by 30% in 2050 [2]. Thus, a continuous increase in wheat demand is expected, which will be mainly satisfied by improving crop yield per unit area [3] as expansion in cultivated land is unlikely due to negative social and environmental impacts

* Corresponding author
E-mail address: derejegoda@gmail.com (D. Dobocha)

[4]. At a global scale, the wheat yield gap (deviation of actual from potential yield) was estimated at 36% [3]. Among the most relevant management factors for improving wheat yields and closing the yield gap is the use of the optimum seeding rate for an appropriate plant density [5].

The major wheat producing areas in Ethiopia are located in Arsi, Bale, Shewa, Ilubabor, Western Hareghe, Sidamo, Tigray, Northern Gonder and Gojam zones [6]. Wheat is predominantly grown by subsistence farmers under rain-fed conditions and it ranks 4th after teff, maize and sorghum in area coverage and 3rd in total important cereal crop productions in the country [7]. Most of the farming households are involved annually in wheat production, but that still does not satisfy the country's annual domestic demand. According to the grain and feed annual report of United States Department of Agriculture [8], Ethiopia's wheat production self-sufficiency is only 75% and the remaining 25% of wheat has to be imported commercially and through food aid. Hence, a large quantity of wheat is imported every year to meet the rising domestic consumption demand. Among the factors responsible for low wheat yield were delay in sowing, traditional sowing methods, inappropriate seed rate and improper row spacing are very important [9].

Many farmers in developing countries prefer to use a higher seed rate than recommended, because they perceive it as a good strategy to control weeds and reduce the risks of crop production. Above-optimum seeding rates increase cost of production and might potentially decrease yield by increasing disease pressure, insects, and lodging [10]. Meanwhile, below-optimum seeding rates may reduce resource use efficiency, yield, and final profit [11], depending on the level of resource availability [12]. Consequently, defining the agronomic optimum plant density, which is the minimum number of plants per unit area required to maximize yield, is critical for future improvements in wheat yield. In sight of the above circumstances, the present study was undertaken to find out the effect of plant density on yield and yield attributed traits of bread wheat varieties at Lemu-Bilbilo district, highlands of Arsi zone.

2. Materials and Methods

2.1. Description of the Study Areas

Field experiments were conducted at Lemu-Dima on two farm sites areas of Lemu Bilbilo district, Oromia regional state, Ethiopia during 2016-2017 main cropping seasons. Lemu Bilbilo district is located 235 km away from Addis Ababa to Southeast direction. The geographical location of the experimental field is at 07° 36' 91"-07° 37' 72"N and 39° 14' 44"-39° 16' 43"E, and situated at altitudes of 2591-2632 m above sea level. The average mean minimum and maximum temperature are 7.9 and 18.6°C, respectively. It receives mean annual rainfall of 1020 mm with pseudo bi-modal distribution and maximum (202mm) occurs in August (KARC, unpublished). Wheat, malt and food barley, faba bean and field pea are the most common crops cultivated in study site. Nitosols dominated the soil of the experimental areas [13] and silty clay in texture [14].

2.2. Experimental Design and Procedure

The experiments were laid out in a randomized complete block design in split plot arrangement consisting of 3 bread wheat varieties (V1 = Danda'a, V2 = Digelu and V3 = Hidase) assigned to main plot and 6 plant densities (D1 = 100 plants m^{-2}, D2 = 200 plants m^{-2}, D3 = 300 plants m^{-2}, D4 = 400 plants m^{-2} and D5 = 500 plants m^{-2} and D6= Recommended seed rate of 125 kg ha^{-1} (as a control) assigned to subplot with 3 replications. Urea (46% N) 100 kg ha^{-1} was used as source of N in split form of application (1/3 at planting and 2/3 at tillering) as top dress. Basal application of NPS was used at the rate of 121 kg ha^{-1} at time of planting to all experimental units. The growth size of the subplot was 4m×2.6m (10.40m^2) and net harvestable plot size of 2.4m×2.6m (6.24m^2). The distance between subplot and blocks (rep) were 0.5m and 1.5m, respectively. Other agronomic practices were properly carried out as per the recommendations of the areas. Finally, the seed rate kg ha^{-1} for densities of plants m^{-2} are calculated by using the following formula: Seed rate (kg ha^{-1}) = number of plants m^{-2} ∗ 1000-kernels weight (g) / field establishment (%)

2.3. Data Collected

Agronomic parameters collected included plant height(cm), spike length(cm), Grains spike^{-1}, grain yield(kg ha^{-1}), Thousand Grain Weight (g), Biological yield(kg ha^{-1}) and Harvest Index (%) which is calculated by the ratio of grain yield to biological yield. To estimate grain yield of grain yield, the net plot sizes of 2.4m×2.6m (6.24m^2) were harvested from each plot in December. After threshing, the harvested materials (grains) were cleaned, weighed and adjusted to 12.5% moisture level. The total grain yields recorded on a plot basis were converted to kg ha^{-1} for statistical analysis.

2.4. Statistical Analysis

The crop data were subjected to analysis of variance using the General Linear Model procedure of R computer software version 3.6.1[15]. The two years data were combined over sites and analyzed. Whenever treatment effects were significant, the mean differences were separated using the

Least Significant Difference (LSD) test at 5% level of significance.

3. Results and Discussion

Plant height

The analysis of variance showed that plant height was significantly ($p<0.05$) affected by varieties and plant densities m^{-2}, but the interaction of varieties and plant densities m^{-2} didn't show significant. The results revealed that the shortest plant height was recorded from Digelu variety and did show significant difference among the rest Danda'a and Hidase varieties, but the plant height of Danda'a and Hidase was significantly at par (Figure 1). There were significant differences between 100 plants and control (125 kg ha^{-1}), but the difference between the rest plant densities and control was not significant (Figure 4). The result was in line with the findings of [16] who reported plant height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors.

Spike length

A result of this study for spike length was presented in Table 1. Analysis of variance indicated that variety and planting density had significant effects on the spike length of bread wheat while the interaction between variety and planting density on the spike length was non-significant. There were significant differences between Digelu and the remaining two varieties but the difference between Danda'a and Hidase was not significant. So it can be concluded from these results that spike length is genetic characters of a variety. This result was compatible with those of [17] who conveyed that individual genotypes responded differently to spike length for different varieties of wheat. The researches so far recounted that varieties have different genetic potential regarding the spike length [18]. On the other hand, spike length was increased with the increasing plant densities up to 300 plants m^{-2} which showed non-significant difference with plant densities of 400 and 500 plants m^{-2}. The maximum value 7.90 cm was observed at 300 and 400 plants m^{-2}. In line with this result, the previous study showed that the length of spike plays a vital role in wheat towards the grains $spike^{-1}$ and finally the yield [19].

Grains $spike^{-1}$

The analysis of variance revealed significant ($p <0.05$) effects were detected for the major factors varieties and densities for grains $spike^{-1}$ whereas the influence of the interaction of varieties and plant densities were not perceived for the character number of grains $spike^{-1}$. The highest number of grains $spike^{-1}$ (64.12) was recorded from Danda'a variety and showed significant among the rest two varieties, but the difference among Digelu and Hidase varieties were statistically at par (Table 1). The previous findings stated that, the grain number and grain weight in wheat are influenced by both genetic and environmental factors [20]. Conversely, with different planting density, grains $spike^{-1}$ increased from 100-300 plants m^{-2} and then decreased as planting density increased. The increase in grains number per spike contributes considerably to improve wheat grain yield potential [21]. The highest value of grains $spike^{-1}$ (62.84) was recorded from 300 plants m^{-2} whereas the lowest grains $spike^{-1}$ (55.24) was obtained from the lowest plant densities per unit area. Consistent to the findings of the present study, [9] reported that wheat planted at optimum seed rate gave maximum grains $spike^{-1}$. The grains number and grains weight in wheat are influenced by both genetic and environmental factors [20]. In the same way further research showed that different seed rate had significant effect on grains $spike^{-1}$[22].

Table 1. The effects of varieties and planting density on spike length, grain per spike, 1000-grain weight and harvest index of bread wheat.

Pant density m^{-2}	Spike length (cm)	Grain $spike^{-1}$	1000-grain weight(g)	Harvest index (%)
Varieties				
Danda'a	7.80a	64.12a	47.55a	42.47a
Digelu	6.60b	55.75b	37.03b	34.30b
Hidase	7.70a	55.05b	47.67a	41.92a
LSD (5%)	0.43	7.97	2.27	6.27
CV (%)	4.40	10.40	3.90	12.00
Plant density m^{-2}				
100	6.80c	53.24c	44.01	37.55b
200	7.20bc	56.82bc	44.09	38.29b
300	7.90a	62.84a	43.87	42.40a
400	7.90a	62.38a	43.79	43.13a
500	7.50ab	59.24ab	43.56	39.71ab
125(kg ha^{-1})	6.90c	55.33c	45.19	36.29b
LSD (5%)	0.55	3.88	NS	3.42
CV (%)	5.00	4.40	2.60	5.80

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, NS: Not significant.

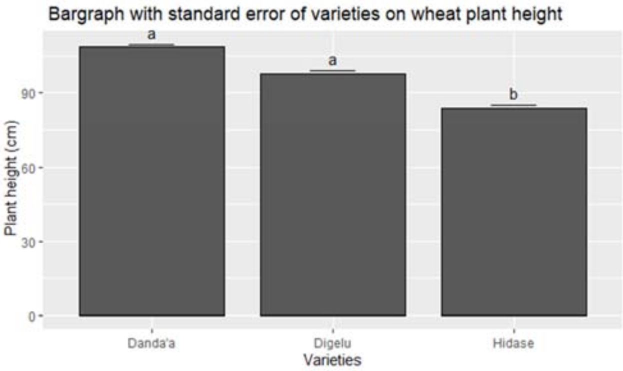

Figure 1. Effect of varieties on plant height of bread wheat (a).

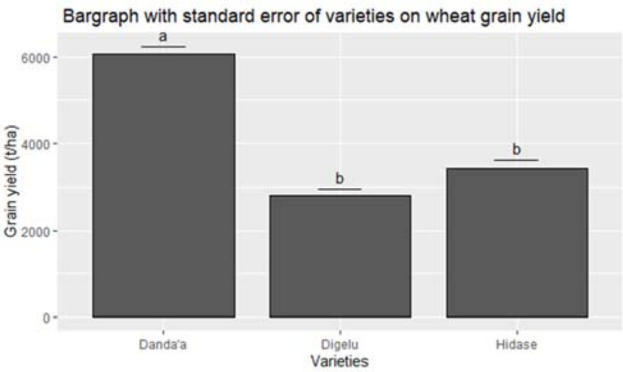

Figure 2. Effect of varieties on grain yield of bread wheat (b).

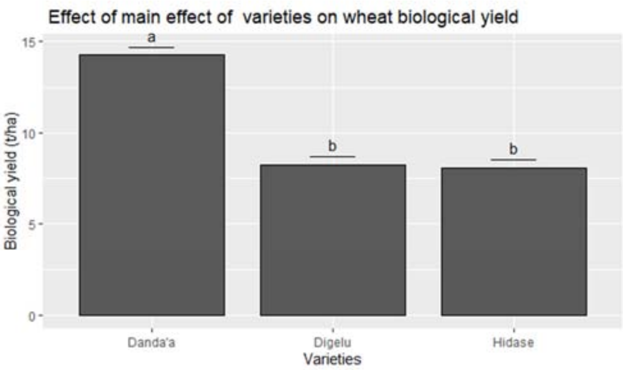

Figure 3. Effect of varieties on biological yield of bread wheat (c).

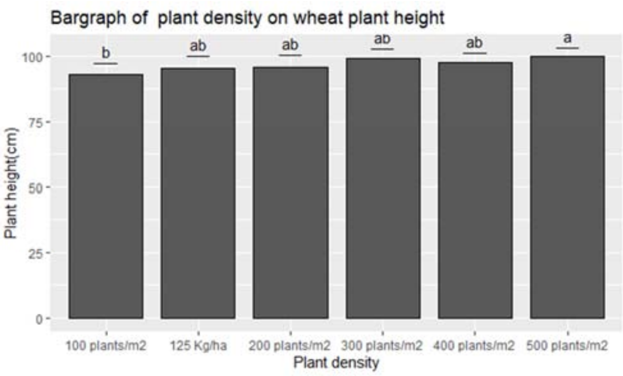

Figure 4. Effect of plant densities on plant height of bread wheat (d).

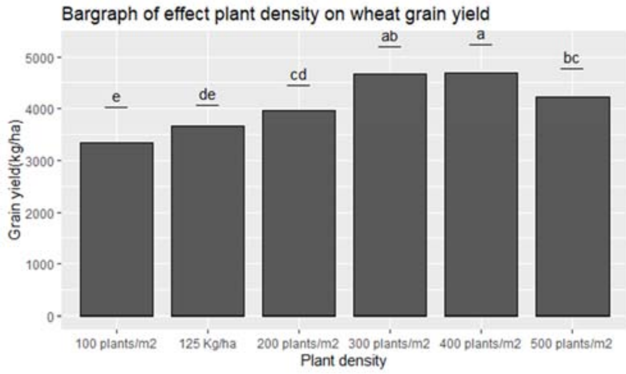

Figure 5. Effect of plant densities on grain yield of bread wheat (e).

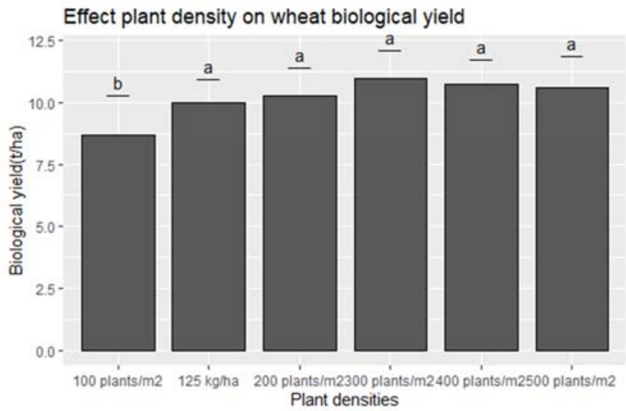

Figure 6. Effect of plant densities on biological yield of bread wheat (f).

Grain yield

Results of analysis of variance exhibited the effects of varieties, planting densities as well as varieties and plant densities interactions revealed significant ($p <0.05$) on grain yield. The statistics suggested there were significant differences between the grain yield of Danda'a, Digelu and Hidase varieties, but the grain yield difference between Digelu and Hidase varieties were statistically similar (Figure 2). However, the grain yield increased to its peak value at 300 plants m^{-2}, which was higher than100 plants m^{-2}, 200 plants m^{-2} and control, while statistically at par with 400 and 500 plants m^{-2} (Figure 5). Furthermore, there were significant differences between the yield of 100 and 200 plants m^{-2}. Previous studies have showed that, plant density is an important factor that influences the growth and yield formation in wheat [23]. On the other hand, the interaction of varieties and plant densities revealed that, the grain yield of Danda'a variety was consistently increased as the plant density increased from 100 to 400 plants m^{-2}, then decreased as plant density increased from 400 to 500 plants m^{-2} and control whereas it was consistently increased as the plant density increased from 100 to 400 plants m^{-2}, then decreased as plant density increased from 400 to 500 plants m^{-2} and control for both Digelu and Hidase varieties (Figure 7). The current results were agreed with those of [10], who reported that increasing seeding rates above-optimum increased cost of production and might potentially decrease yield by increasing disease pressure, insects, and lodging. This was agreement with studies of [24], who itemized that as the plant density increased from 180 to 240 plants m^{-2}, no further improvement in grain yield was achieved because the increase in spikes per unit area was accompanied by a reduction in grains per spike and thousand kernels weight.

Biological yield

Main effect of varieties and plant densities as well as their interactions were significantly ($P<0.05$) affected biological yield of bread wheat. Significantly higher mean value of biological yield was obtained from Danda'a variety whereas; lower mean value of biological yield was obtained from Hidase variety which is statistically at par with Digelu (Figure 3). This result was in line with the findings of [25] and [26] who stated that biological yield was significantly influenced by wheat varieties. With respect to plant density, the highest biological yield was recorded from D3 (300 plants m^{-2}) and revealed a significant difference to the lowest plant density D1 (100 plants m^{-2}), but significantly at par with the rest other plant densities (Figure 6). This is consisted with the result of [26]. Biological yield of Danda'a variety interaction with all plant densities showed insignificant and exceeds significantly the rest of Digelu and Hidase varieties interactions with all plant densities (Figure 8). The increased in biomass production in Danda'a variety might be attributed to the increased plant height as a function of increased plant densities m^{-2}. The present result is in agreement with the finding of [27], who testified a positive association between biomass yield and plant height. Parallel with the present finding, [28] also stated that biomass yield was significantly affected as a function of varieties and seeding rate. The result was related with that of [25] who indicated that biological yield had significantly affected due to varieties and plant density interactions.

Harvest index

Result of harvest index was presented in Table 1. Harvest index was significantly ($P<0.05$) affected by the main factors of varieties as well as plant densities and non-significantly affected along with the interaction effect of plant densities and varieties (Table 1). Significantly higher mean harvest index of (42.47%) was obtained from Danda'a variety which was statistically at par with that of Hidase variety (41.92%) harvest index. The result was in agreement with the findings of [29] who stated the higher the harvest index value, the greater the physiological potential of the crop for converting dry matter to grain yield. In line with this study result [30], found that the ability of a cultivar to convert the dry matter into economic yield is indicated by its harvest index. The highest harvest index (43.13%) was obtained at planting density of 400 seeds m^{-2} which was significantly at par with that of 300 and 500 plants m^{-2}. Analogous to the present finding, [9] specified that harvest index was significantly affected by seeding rate. Harvest index had interrelationship with grain yield and above ground biomass yield that the highest harvest index was the result of greater grain yield and lowest harvest index was mainly due to increased plant height that increased biomass yield extremely rather than grain yield which lead to decrease of harvest index [30].

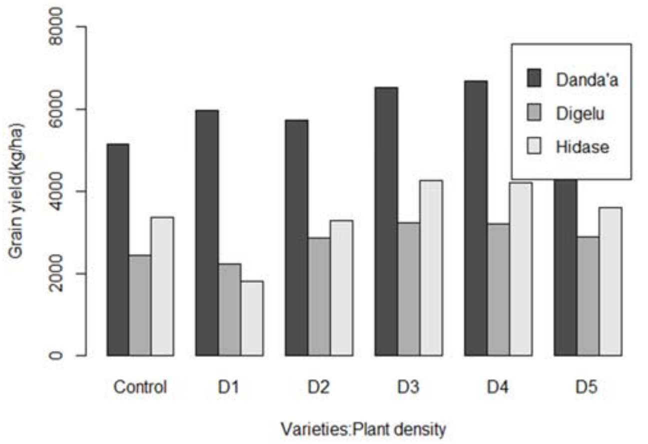

Figure 7. Interaction effect of plant densities and varieties on grain yield of bread wheat combined over sites and years. D1: 100 plants m^2, D2: 200 plants m^2, D3: 300 plants m^2, D4: 400 plants m^2, D5: 500 plants m^2 (g).

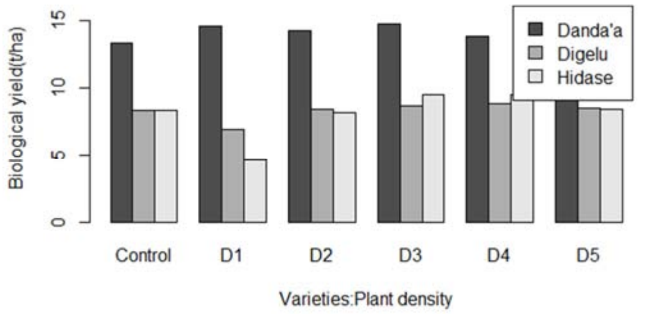

Figure 8. Interaction effect of plant densities and varieties on biological yield of bread wheat combined over sites and years. D1: 100 plants m^2, D2: 200 plants m^2, D3: 300 plants m^2, D4: 400 plants m^2, D5: 500 plants m^2 (h).

Thousand kernels weight

Thousand kernels weight (TKW) was affected significantly ($P<0.05$) by the varieties and non-significantly ($P<0.05$) affected by plant densities and variety plus plant density interactions. The TKW of the variety Danda'a (47.55 gm) and Hidase (47.67 gm) were significantly higher than the variety Digelu (37.03gm) (Table 1). The result was in line with the findings of [29], who reported TKW is a quality parameter to assess the grain quality in wheat and influenced by genetic makeup of varieties.

4. Conclusion

The results showed that using of different varieties and plant densities had significant effect on parameters that have been taken except the thousand kernels weight (TKW) which was not significantly affected by plant densities. The interaction of varieties and plant densities also did not show significant difference on plant height, spike length, grains per spike, harvest index and TKW except for grain and biological yield. Danda'a variety resulted in the highest grains spike^{-2} (64.12), grain yield (6053.59 kg ha^{-1}) and biological yield (14.29 t ha^{-1}) whereas; its spike length, harvest index and TKW were significantly at par with Hidase and plant height with Digelu variety. Based on the present study, the use of 300 plants m^{-2} was the optimum plant density for all the studied traits. The varieties and plant density levels interactions showed that on average most profitable grain and biological yields were produced at plant density of 300 plants m^{-2} combination with Danda'a variety. Therefore, based on the study results the plant density level of 300 plants m^{-2} was identified and could be recommended for the production and productivity of Danda'a bread wheat variety at experimental sites and similar agro-ecologies.

References

[1] Katherine Margaret Nelson, (2013). Analysis of Farmer Preferences for Wheat Variety Traits in Ethiopia: A Gender-Responsive Study. A Thesis Presented to the Faculty of the Graduate School of Cornell University.

[2] United Nations, D. of E. and S. A., Population Division. (2019). World population prospects highlights. doi: 10.18356/13bf5476-en.

[3] Neumann, K., Verburg, P. H., Stehfest, E., and Müller, C, (2010). The yield gap of global grain production: a spatial analysis. *Agric. Syst*. 103 (5), 316–326. doi: 10.1016/j.agsy.2010.02.004.

[4] Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., et al. (2011). Solutions for a cultivated planet. Nature 478 (7369), 337–342. doi: 10.1038/nature10452.

[5] Lollato, R. P., Ruiz Diaz, D. A., DeWolf, E., Knapp, M., Peterson, D. E., et al. (2019). Agronomic practices for reducing wheat yield gaps: a quantitative appraisal of progressive producers. Crop Sci. 59 (1), 333. doi: 10.2135/cropsci2018.04.0249.

[6] Bekele Hunde, Kotu, H. Varkuijl, W. Mwangi and D. G. Tanner, (2000). Adaptation of improved wheat technologies in Adaba and Dodola woredes of the Bale highlands, Ethiopia. Mexico D. F: International Maize and Wheat Improvement Centre (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

[7] Central Statistics Agency, (2014). Agricultural sample survey: area and production of major crops, Maher season. Vol. 1. Addis Ababa, Ethiopia.

[8] United States Department of Agriculture, (2014). USDA Foreign Agricultural Service. Global Agricultural Information Network. Grain and Feed annual report. Number: ET-1401.

[9] Iqbal, N., N. Akbar, M. Ali, M. Sattar and L. Ali, (2010). Effect of seed rate and row spacing on yield, and yield components of wheat (*Triticum aestivium L.*). *Pakistan.J.Agric.Res*., 48 (2).

[10] Laghari, G. M., Oad, F. C., Tunio, S., Chachar, Q., Ghandahi, A., et al. (2011). Growth and yield attributes of wheat at different seed rates. *Sarhad J. Agric*. 27 (2), 177–183

[11] Whaley, J. M., Sparkes, D. L., Foulkes, M. J., Spink, J. H., Semere, T., et al. (2000). The physiological response of winter wheat to reductions in plant density. *Ann. Appl. Biol*. 137 (2), 165–177.

[12] Fischer, R. A., Moreno Ramos, O. H., Ortiz Monasterio, I., and Sayre, K. D. (2019). Yield response to plant density, row spacing and raised beds in low latitude spring wheat with ample soil resources: an update. Field Crops Res. 232, 95–105.

[13] Amanuel G; Kühne R; Tanner D; Vlek P, (2000). Biological nitrogen fixation in faba bean (Vicia faba L.) in the Ethiopian highlands as affected by P fertilization and inoculation. Biology and Fertility of Soils, 32: 353-359.

[14] Dobocha, D., Abera, G. and Worku, W, (2019). Grain quality and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.) varieties in response to nitrogen fertilizer in Arsi highlands, southeastern Ethiopia. *African Journal of Agricultural Research*, 14 (32), pp. 1544-1552.

[15] Bowman, D. C. and J. M. Lees, (2013). The Hilbert-Huang transform: Tools and methods. *R Version*, 2.1.3, pp: 05-16.

[16] Fang, X. M., She H. Z., Wang, C., Liu, X. B., Li, Y. S., Nie, J., Ruan, R. W., Wang, T. and Yi, Z. L, (2018). Effects of Fertilizer Application Rate and Planting Density on Photosynthetic Characteristics, Yield and Yield Components in Waxy Wheat. *Cereal Research Communications*, 46 (1), pp. 169–179.

[17] Otteson B. N., M. Mergoum and J. K. Ransom, (2007). Seedinf rate and nitrogen Management effects on spring wheat yield and compnents. *Aron. J*., 99: 1615-1621.

[18] Khan, M. A., J. Anwar, A. Sattar and M. A. Akhtar, (2001). Effect of seed rate on wheat yield under different sowing dates and row spacing. J. Agric. Res.39 (3-4): 223-229.

[19] Shahzad M. A., Shahi S. T., Khan, M. M, (2007). Effect of sowing dates and seed seed treatment on yield and quality of wheat. Pakistan Journal of Agricultural Sciences, Department of Agronomy, Wasi-ud-Din Sub-Campus Depalpur University of Agriculture, Faisalabad Pakistan.

[20] Bustos DV, Hasan AK, Reynolds MP, Calderini DF, (2013). Combining high grain number and weight through a DH-population to improve grain yield potential of wheat in high-yielding environments. *Field Crops Res*. 145: 106–115.

[21] Li Y, Cui Z, Ni Y, Zheng M, Yang D, Jin M, et al. (2016). Plant Density Effect on Grain Number and Weight of Two Winter Wheat Cultivars at Different Spikelet and Grain Positions. *PLoS ONE* 11 (5): e0155351. doi: 10.1371/journal.pone.0155351.

[22] Shah, Z., Ahmad, S. R., Rahman, H., Shah, M. Z, (2011). Sustaining rice-wheat system through management of legumes. II. Effect of green manure legumes and N fertilizer on wheat yield. *Pak. J. Bot*. 43, 2093-2097.

[23] Grassini P, Thorburn J, Burr C, Cassman KG, (2011). High-yield irrigated maize in the Western US Corn Belt: I. On-farm yield, yield potential, and impact of agronomic practices. *Field Crops Res*. 120 (1): 142–150.

[24] Zhang, Y., Dai, X. L., Jia, D. Y., Li, H. Y., Wang, Y. C., Li, C. X., Xu, H. C., He, M. R, (2016). Effects of plant density on grain yield, protein size distribution, and bread making quality of winter wheat grown under two nitrogen fertilisation rates. *Eur. J. Agron*. 73: 1–10.

[25] Shalaldeh, G. and Thalji, T, (2007). Impacts of plant population on wheat and barley genotypes under salinity conditions. *Journal of Agronomy*.

[26] Schillinger, W. F, (2005). Tillage method and sowing rate relations for dryland spring wheat, barley, and oat. *Crop Science*, 45: 2636-2643.

[27] Zewdie Bishaw, Paul C. Struik and Anthony J. G. Van Gastel, (2014). Assessment of on-farm diversity of wheat varieties and landraces: evidence from farmer's field in Ethiopia. African Journal of Agricultural Research, 9 (38): 2948-2963.

[28] Jemal Abdulkerim, Tamado Tana and Firdissa Eticha (2015). Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Plant population levels at Kulumsa, South Eastern Ethiopia. Asian Journal of Plant Sciences 14 (2): 50-58, ISSN 1682-3974.

[29] Abebe Megers, et. al. (2020). Effect of Plant Population on Growth, Yields and Quality of Bread Wheat (*Triticum Aestivum* L.) Varieties at Kulumsa in Arsi Zone, South-Eastern Ethiopia. *International Journal of Research Studies in Agricultural Sciences (IJRSAS)*, 6 (2), pp. 32-53.

[30] Abiot M, (2017). Effects of Seeding Rate and Row Spacing on Yield and Yield Components of Bread Wheat (T*riticum aestivum* L.) in Gozamin District, East Gojam Zone, Ethiopia. Journal of Biology, Agriculture and Healthcare www.iiste.org ISSN 2224-3208 (Paper) ISSN 2225-093X (Online) Vol. 7, No. 4, 2017.