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Lower Seed Rates Favor Seed Multiplication Ratio with Minimal Impact on Seed Yield and Quality

Karta Kaske[1], Abebe Atilaw[2] and Astawus Esatu[1]

[1]*Seed Research Section, Kulumsa Research Center, P. O. Box 489, Asella, Ethiopia*

[2] *Technology Multiplication and Seed Research Directorate, EIAR, P.O. Box, 2003, Addis Ababa, Ethiopia*

አህፅርኦት

ፈጣን የሆነ የዝርያ መልቀቅ ዘዴን በመከተል የስንዴ ዋግ ችግርን ለመታገል እንዲያስችል በሄክታር መጠቀም የሚቻለውን የዘር መጠን በመቀነስና የብዜት መጠንን በመጨመር የተቀላጠፈ የመነሻ ዘር አቅርቦትን ማረጋገጥ ይቻላል፡፡ ይህንን መሠረት በማድረግ አራት ዓይነት የዘር መጠኖችን (50፣ 75፣ 100፣ 125 ኪግ በሄክታር) ከአራት የመስመር ርቀቶች (10፣ 20፣ 30 ሳ.ሜ.) ጋር በመሆን በዘር ብዜት መጠን፣ በዘር ምርታማነትና በዘር ጥራት (ብቅለትና ጥንካሬ) ላይ ያላቸውን ተፅዕኖ ኢ.ኤ.አ. ከ2012 እስከ 2014 ድረስ በአሳሳና በቁሉምሳ የሙከራ ጣቢያዎች ተገምግሟል፡፡ ውጤቱ እንደሚያሣየው በሁለቱም ቦታዎች በአነስተኛ የዘር መጠን ከፍተኛ የዘር ብዜትን አስገኝቷል፡፡ አሳሳ ላይ የዘር መጠንን ከ50ኪግ ወደ 125 ኪግ በሄክታር ከፍ ማድረግ የዘር ምርታማነትን ከ3838 ኪግ በሄክታር ወደ 4687 ኪግ በሄክታር ከፍ ማድረግ የተቻለ ቢሆንም በ75 ኪግ እና በ125 ኪግ በሄክታር የዘር መጠኖች መካከል የነበረው የምርታማነት ልዩነት ጉልህ አልነበረም፡፡ በተመሳሳይ መልኩ ቁሉምሳ ላይ በተለይ በ20 ሳሜ የመስመር ስፋት ላይ የዘር መጠንን ከ50 ኪግ ወደ 100 ኪግ በሄክታር ከፍ ማድረግ የዘር ምርታማነት ጭማሪን ቢያሳይም ልዩነቱ ግን ጉልህ አልነበረም፡፡ በዘር ብቅለትና በዘር ጥንካሬ ላይ የተደረጉ የላቦራቶሪ ፍተሻዎች ያሳዩት በ20 ሳ.ሜ. የመስመር ስፋት ላይ በ100 ኪግ በሄክታር ከተዘሩት ማሳዎች የታጨደው ዘር ከፍተኛውን የዘር ጥንካሬ ይዞ እንደነበር ነው፡፡ በአጠቃላይ በአገሪቱ ውስጥ እየተከናወነ ባለው የተፋጠነ የዝርያ መልቀቅ ሂደት ውስጥ የስንዴን የመነሻ ዘር ብዜት ለማቀላጠፍ የዘር መጠንን እስከ 50 ኪግ በሄክታር ቀንሶ መጠቀም የሚቻል መሆኑ በዚህ ጥናት ተረጋግጧል፡፡

Abstract

Field and laboratory studies were conducted in split plot design of three replications to determine effects of four sowing rates (50, 75, 100, 125 kg ha^{-1}) and three row spacing (10, 20, 30 cm) on seed multiplication ratio, seed yield, and seed quality of wheat at Kulumsa and Assasa from 2012 to 2014. Results indicated that lower seed rates gave better seed multiplication ratio at both locations. Increasing seed rate from 50 to 125 kg ha^{-1} has increased seed yield at Assasa site from 3838 kg ha^{-1} to 4687 kg ha^{-1} though seed yield difference between seed rates of 75 and 125 kg ha^{-1} was statistically non-significant ($p>0.05$). Increasing seed rate from 50 to 100 kg ha^{-1} has continuously improved seed yield from 4171 to 4389 kg ha^{-1} at 20 cm row spaces at Kulumsa, but the difference was statistically non-significant. Laboratory studies indicated that seedling vigor index-II of seeds harvested from plots of 20 cm spacing and seed rate of 100 kg ha^{-1} have given highest value (1096.1 mg.%). In conclusion, seed rates as low as 50 kg ha^{-1} can be used at row space of 20 cm to accelerate early generation seed supply within the fast track variety release program in Ethiopia.

Introduction

Wheat covers the fourth largest area of cereal production in Ethiopia, preceded by tef, maize and sorghum with annual production of 3.4 million tons (CSA, 2015). Biotic and abiotic threats hamper wheat production with rusts taking the major share. At present, besides the formal variety development and release procedure, a special variety release/registration scheme is being followed to tackle the challenge of rust epidemics (Adefris and Daniel 2013). New improved varieties developed by NARS should be multiplied and made available to farmers in the shortest possible time to realize the benefits of investments in agricultural research. The rate at which the variety is multiplied and accessed restricts the availability of seed and its adoption and rapid diffusion through formal or informal channels (Gastel *et al*., 2002).Fast track variety release/registration is a recent approach in which rust resistant varieties are deployed to end users before they become susceptible to new races (Adefris and Daniel 2013). The approach includes accelerated early generation seed multiplication (securing large quantity of seed before release of the variety).

Wheat plant population density is an important agronomic trait that can influence yield and seed quality of the crop (Kindred and Goodings, 2005; Theobald *et al*., 2006; Kolb *et al*., 2012; Naveed *et al*., 2014; Tokatlidis, 2014; Zecevic *et al*., 2014; Zhang *et al*., 2016). From seed rate experiments conducted in Ethiopia, it was recommended that cultivars with either poor emergence or poor tillering capacity required higher seed rates (Tanner *et al*., 1991). However, no reports exist on advantages or disadvantages of lower seed rates especially on early generation seed multiplication under seed production schemes of the country. Studies conducted in other parts of the world indicated that lower wheat plant density can favor grain protein content (Gooding *et al*., 2002). Zhang *et al.* (2016) observed that under normal nitrogen application conditions thousand-grain weight decreased as wheat plant density increased. Since protein and seed size content have a strong association with seed vigor (Ries and Everson, 1973; Nik *et al*., 2011) there is a need to explore the optimum seed rate of wheat under recommended fertilizer application levels for seed production objectives.

Besides the positive impact on seed quality, lower seed rates are important to enhance fast track variety release by accelerating early generation seed supply through increased seed multiplication ratio (Gastel *et al*., 2002). Reports are available on effects of seed rate on grain yield of wheat under Ethiopian context (Assefa *et al*., 2015), but information on effects of lower seed rates (plant population) on seed yield, seed multiplication ratio, and seed quality are rarely explored in the country. Hence, the present experiment was initiated to come up with optimum (lower than recommended) seed rates for multiplication of early generation seed on wheat variety development procedures.

Materials and Methods

Site description

The field experiment was conducted at two sites (Kulumsa and Assasa) in the wheat belt of southeastern Ethiopia. Assasa is a testing site located in the major wheat growing area at 7.13^{o}N and 39.21^{o}E with elevation of 2,360m above sea level. It is characterized by relatively short growing season with terminal moisture stress. Kulumsa is the main station of the national wheat research coordination located at 8.00^{o}N and 39.15^{o}E with elevation of 2,200 m above sea level.

At Kulumsa the experiment was conducted on gently sloping (2%), deep (100-150 cm) and well drained Ertic-luvisols of dark to dark brown color with surface soil pH of around 6 (Abayneh, 2003). The soils at Assasa are Gleysols (clay loam soils) occur on flat plain with surface pH of 5.8.

Design and treatment

Basic seed of bread wheat (var. Danda'a) produced at Kulumsa Research Center in each year was used for the study. The experiment was laid out in split-plot design: row spacing (10, 20, 30 cm) as main plot and seed rate (50, 75, 100, 125 kg ha^{-1}) as sub-plot treatment in replicates of three. Fertilizer rates were 100 kg di-ammonium phosphate and 50 kg urea as recommended for the specific locations. Plots maintained weed free (mainly hand weeded) throughout the growth period. Depending on the incidence of rusts the fungicide TILT 250 EC at rate of 0.5 L ha^{-1} in 2012 and Rex Duo in 2014 were applied while there was no rust incidence in 2013.

Laboratory experiment

Seeds from 2014 harvests from the two locations were subject to germination and seed vigor testing. Germination test was conducted following the procedures described in (ISTA, 2014) with some modifications. Germination test was carried out using 100 seeds from each split-plot and each replication (replications for germination test were based on the field experiments). Seeds were placed on top of a standard germination paper (400 g/m^2) saturated with distilled water and placed in bowls under room temperature ranging from 18 to 25 ^{o}C for 7 days. Normal/abnormal seedlings and dead seeds were separately counted. Germination was recorded in percentage basis.

Vigor index-II as described in (Fiala, 1987) was used to determine vigor in this study. Ten normal seedlings were randomly selected and dried for 24 hours at 80±1^{o}C in a dry oven. Finally, oven dried seedlings were weighed using electronic balance (0.0000 g). Vigor index-II was calculated by multiplying germination percent (%) with the single seedling dry weight (mg).

To record thousand seed weight, a thousand seeds were counted using electronic seed counter and weight using sensitive balance with precision of 1.0 g.

Data collection and analysis

Seed yield, seed multiplication ratio, and thousand seed weight were collected and subject to analysis of variance, mean separation, and regression analysis using the R software version 3.1.2 (The R Foundation for Statistical Computing, 2014).

Results and Discussions

Seed yield and seed multiplication ratio

Bartlett's test of homogeneity of variances across locations indicated that variances at Kulumsa and Assasa were significantly heterogeneous (*$p<0.05$*). Within each location, the same test was applied to evaluate if the data set fulfills assumptions for combined analysis of variance across three years. Variances across years were homogenous within location (*$p>0.05$*), hence analysis of variance was carried out within each location.

Analysis of variance for seed yield and seed multiplication ratio at the two locations in 2012, 2013, and 2014 are presented in Table 1. The ANOVA indicated that row space by seed rate interaction effect was highly significant (*$p<0.01$*) at Kulumsa while it was non-significant at Assasa. Neither row space nor seed rate has independently posed significant influence on the performance of seed yield at Kulumsa. On the other hand, seed rate has caused significant change in seed yield at Assasa though its effect has significantly varied across years.

Table 1: Mean Squares of seed yield (kg/ha) and seed multiplication ratio from two location and three years

Source	DF	Seed yield (kg ha^{-1})		Seed multiplication ratio	
		Kulumsa	Assasa	Kulumsa	Assasa
Year (Y)	2	ns	ns	ns	ns
Block within year	6	ns	ns	ns	ns
Row space (A)	2	ns	ns	ns	*
YxA	4	***	ns	***	ns
Error (a)	12	206917	713458	13	96.3
Seed rate (B)	3	ns	***	***	***
YxB	6	***	*	***	ns
AxB	6	***	ns	ns	ns
YxAxB	12	***	ns	***	ns
Error (b)	54	60663	259731	29.6	46
CV %		6.3	11.4	6.4	11.4
Grand mean		4049.0	4378.0	52.2	54.7

*;**;****significant at 0.05; 0.01; 0.001*

ANOVA results for effects of seed rate and row space on seed multiplication ratio at Kulumsa and Assasa are indicated on Table 1. The two factors have influenced seed multiplication ratio independent from each other. Effects of both seed rate and row space at Kulumsa were significantly dependent on year. Regardless of year, the two factors have significantly influenced seed multiplication ratio at Assasa.

Average performances of seed yield and seed multiplication ratio of bread wheat (var Danda'a) at Kulumsa and Assasa over three years are presented on Table 2. Mean seed yield was 4378 and 4078 kg ha^{-1} at Assasa and Kulumsa, respectively. The overall seed yield performance was better at Assasa site. Increasing seed rate from 50 to 125 kg ha^{-1} has increased seed yield at this site though the difference was statistically non-significant, and there was only 5.4% yield increase between seed rates of 75 and 125 kg ha^{-1}. Conversely, increasing row space from 10 to 30 cm has decreased seed yield by 9.6% at Assasa though it has negligible impact at Kulumsa.

Effects of seed rate at Kulumsa varied at different row spaces with average yield ranged from 3834 kg ha^{-1} at row space of 20 cm and seed rate of 125 kg ha^{-1} to 4389 kg ha^{-1} at the same row space and seed rate of 100 kg ha^{-1} (Figure 1). Increasing seed rate from 50 to 100 kg ha^{-1} has continuously improved seed yield at 20 cm row spaces while the reverse was true at 10 cm and 30 cm spaces.

Table 2: Response of wheat (var. Danda'a) seed yield and seed multiplication ratio to seed rate and row spacing at Kulumsa and Assasa sites

	Seed yield (kg ha^{-1})		Seed multiplication ratio	
	Kulumsa	Assasa	Kulumsa	Assasa
Seed rate				
50	4132	3838	82.6	76.8
75	4030	4445	53.7	59.3
100	4082	4538	40.8	45.4
125	3943	4687	32.6	37.5
LSD(0.05)	403	834	5.8	11.2
Row space				
10	4014	4613	52.9	57.9
20	4156	4354	52.6	54.3
30	3970	4168	52.9	54.4
LSD(0.05)	233	482	3.4	6.4
	4049	4378	52.4	54.8

Average seed multiplication ratio was recorded to be 52.4 and 54.8 at Kulumsa and Assasa, respectively (Table 2). The highest seed multiplication ratio at Kulumsa was 82.6 at seed rate of 50 kg ha^{-1}. This means that if one has 10 kg nucleus seed of wheat, and it is sown at rate of 50 kg ha^{-1}, then the expected output will be 826 kg seed, if adequate agronomic management is followed. With limited availability of nucleus seeds from breeding plots, this is an important option to enhance accelerated seed multiplication.

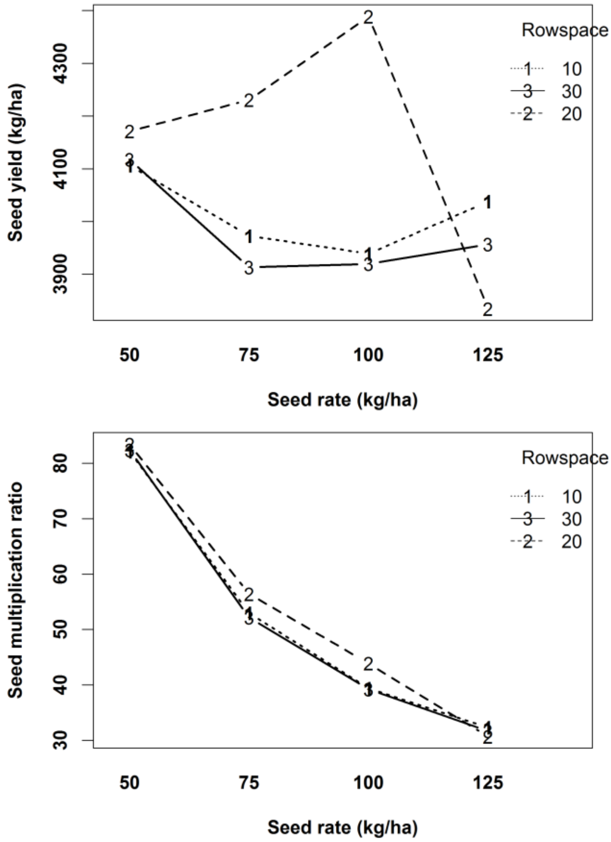

Figure 1: Interaction effects of row spacing and seed rate on average performances of seed yield and seed multiplication ratio of bread wheat (var Danda'a) at Kulumsa for three years /LSD(0.05)=894.3kg for seed yield and 11.7 for seed multiplication ratio/

Seed vigor index and seedling dry weight

Seeds harvested from each experimental unit were subject to germination test and from normal seedlings, seedling dry weight was recorded. Vigor index (multiple of germination percentage and seedling dry weight) was also calculated. Analysis of variance indicated that there was a significant (*p<0.01*) interaction of seed rate and row spacing at Assasa for tested quality parameters such as seed vigor index, seedling dry weight, and germination percentage while not at Kulumsa. On the other hand, the main effect of seed rate was significant (*p<0.01*) for seed vigor index and seedling dry weight at Kulumsa.

Table 3: Analysis of variance for seed quality parameters at Assasa and Kulumsa

Source	DF	Vigor Index II	Seedling dry weight
Location (L)	1	ns	ns
Block within location	4	ns	ns
Row Space (A)	2	ns	ns
L xA	2	ns	ns
Main plot error	8	6126	0.624
Seed rate (B)	3	**	ns
L xB	3	ns	ns
AxB	6	***	ns
L x A x B	6	**	*
Pooled error	36	3918	0.464
CV %		6.7	6.2
Grand mean		983.3	10.6

As a function of seedling dry weight and germination percentage, the average seed vigor index value at Assasa ranged from 1013.6 to 1167.2 mg. % with the highest average value recorded at seed rate of 100 kg ha^{-1} and row spacing of 20 cm while the lowest value was at same seed rate but at 30 cm row spacing (Figure 1). Generally, lower seed rates disfavored seed vigor index at row spaces of 10 and 20 cm with the lowest average value in both cases was at seed rate of 75 kg ha^{-1}. Seed vigor index at row spacing of 10 cm continued to increase as seed rate increased from 75 to 125 kg ha^{-1} but the reverse was true at row spacing of 30 cm.

Dry weight of a single seedling from normally germinated seeds ranged from 10.71 mg to 12 mg at Assasa. The effects of seed rate on seedling dry weight was significantly dependent on the row spacing. Seeds harvested from plots with 100 kg ha^{-1} and 20 cm row spacing had exhibited superior seedling dry weight. Increasing seed rate at 30 cm spacing did not improve seedling dry weight while the reverse was observed at 10 cm row spacing.

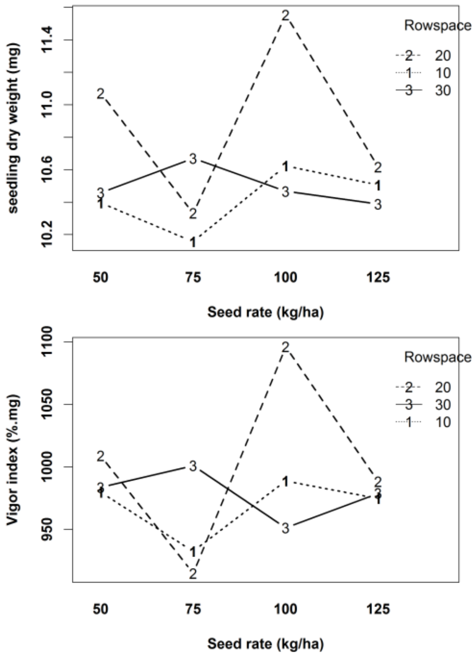

Figure 2: Interaction effect of seed rate and row spacing on seed vigor index and seedling dry weight of wheat from Assasa and Kulumsa (LSD (0.05) vigor index = 148.5, LSD (0.05) seedling dry weight = 1.5 mg)

In our present plant population study, seed rate and seed weight are major sources of variation in seed vigor (Moshatati and Gharineh, 2012). Under high population (seed rate), stands compete for limited nutrient, water, and light resource and subject to excessive vegetative growth resulting in smaller seeds. Seed size has shown significant correlation ($p<0.001$) with seed vigor (Figure 3). This shows that when seeds have better chances to store more reserves they result in seedlings with better growth rate (Moshatati and Gharineh, 2012).

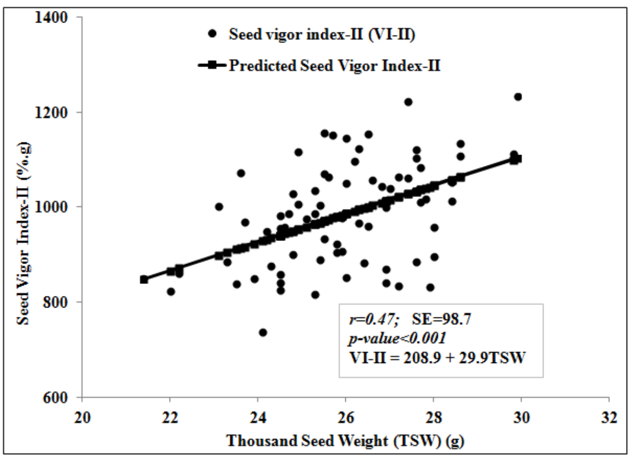

Figure 3: Association of seed vigor index with thousand seed weight (g)

Conclusion and Recommendations

Results indicated that lower seed rates gave better seed multiplication ratio at both locations. Increasing seed rate from 50 to 125 kg ha^{-1} has increased seed yield at Assasa site from 3838 kg ha^{-1} to 4687 kg ha^{-1} though seed yield difference between seed rates of 75 and 125 kg ha^{-1} was statistically non-significant ($p>0.05$). Increasing seed rate from 50 to 100 kg ha^{-1} has continuously improved seed yield from 4171 to 4389 kg ha^{-1} at 20 cm row spaces at Kulumsa, but the difference was statistically non-significant. Laboratory studies indicated that seedling vigor index-II of seeds harvested from plots of 20 cm spacing and seed rate of 100 kg ha^{-1} have given highest value (1096.1 mg.%). In conclusion, seed rates as low as 50 kg ha^{-1} can be used at row space of 20 cm to accelerate early generation seed supply within the fast track variety release programs in Ethiopia.

However, the present study has limitations in that it considered one variety only. Moreover, similar fertilizer levels were administered for all treatments under investigation; and the roles of unlimited nutrient sources in seed multiplication factor, seed yield and seed quality were not considered in this study. Therefore, this study warrants further studies including a number of varieties with various fertilizer levels.

References

Abayneh Esayas. 2003. Soils of Kulumsa Agricultural Research Center. Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Adefris Teklewold, and Daniel Mekonnen. 2013. Varietal Development and Release for Enhancing the Seed System in Ethiopia. p. 147–168. *In* Teklewold, A., Fikre, A., Alemu, D., Desalegn, L., Kirub, A. (eds.), The Defining Moments in Ethiopian Seed System. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

Assefa Workineh, Yemane Nega, and Dawit Habte. 2015. Planting density , and nitrogen and phosphorus fertilization effect on different bread wheat (Triticum aestivum L .) genotypes in Southern Tigray , Ethiopia. World Sci. Res. J. 3: 20–28.

CSA. 2015. Crop Production Report. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Fiala, F. 1987. Handbook of Vigor Test Methods. International Seed Testing Association, Zurich, Switzerland.

Gastel AJ, G Van, Z Bishaw, and BR. Gregg. 2002. Wheat seed production. *In* Curtis, B.C., Rajaram, S., Macpherson, H.G. (eds.), Bread Wheat. Food and Agricultural Organization (FAO), Rome, Italy.

Gooding MJ, A Pinyosinwat, and RH Ellis. 2002. Responses of wheat grain yield and quality to seed rate. J. Agric. Sci. 138: 317–331.

ISTA. 2014. International Rules for Seed Testing. International Seed Testing Association, Zürichstr. 50, CH-8303 Bassersdorf, Switzerland.

Kindred DR and MJ Goodings. 2005. Heterotic and seed rate effects on nitrogen efficiencies in wheat. J. Agric. Sci. 142: 639–657.

Kolb LN, ER Gallandt, and EB Mallory. 2012. Impact of Spring Wheat Planting Density, Row Spacing, and Mechanical Weed Control on Yield, Grain Protein, and Economic Return in Maine. Weed Sci. 60: 244–253.

Moshatati A and MH Gharineh. 2012. Effect of grain weight on germination and seed vigor of wheat. Int. J. Agric. Crop Sci. 4(2012): 458–460.

Naveed K, MA Khan, MS Baloch, K Ali, MA Nadim, EA Khan, S Shah, and M Arif. 2014. Effect of different seed rates on yield attributes of dual-purpose wheat. Sarhad J. Agric. 30: 83–91.

Nik MM, M Babaeian and A Tavassoli. 2011. Effect of seed size and genotype on germination characteristic and seed nutrient content of wheat. Sci. Res. Essays 6: 2019–2025.

Ries SK and EH Everson. 1973. Protein Content and Seed Size Relationships with Seedling Vigor of Wheat Cultivars1. Agron. J. 65(6): 884. Available at https://dl.sciencesocieties.org/publications/aj/abstracts/65/6/AJ0650060884.

Robertson LD and G Lowry. 2004. Seed Quality and Seed Production. p. 19–21. *In*: Robertson LD., SO Guy, BD Brown BD. (eds.), Southern Idaho Dryland Winter Wheat Production Guide. Univeersity of Idaho.

Tanner DG, A Gorfu, and K Zewdie. 1991. Wheat Agronomy Research in Ethiopia. Institute of Agricultural Research, Addis Ababa.

Theobald, CM, MI Roberts, M Talbot, and JH Spink. 2006. Estimation of economically optimum seed rates for winter wheat from series of trials. J. Agric. Sci. 144: 1–14.Tokatlidis, I.S. 2014. Addressing the yield by density interaction is a prerequisite to bridge the yield gap of rain-fed wheat. Ann. Appl. Biol. 165: 27–42.

Zecevic V, J Boskovic, D Knezevic, and D Micanovic. 2014. Effect of seeding rate on grain quality of winter wheat. Chil. J. Agric. Res. 74: 23–28.

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