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RESEARCH ARTICLE

Effects of Seed Rate on Seed Multiplication Ratio, Seed Quality And Yield of Malt Barley Seed Classes Under Irrigated Conditions in Northwest Amhara

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Abstract

Field experiments were conducted to identify seed rate enhancing seed multiplication ratio, seed quality and yield on Ibone (174/03) malt barely variety performance in Koga district during 2019 and 2020 irrigation seasons. Three seed classes (breeder, pre-basic and basic seeds) and seed rates (40, 60, 80 and 100 kg.ha^{-1}) were compared. The experimental design randomized complete block in factorial arrangement with three replications. Analysis of variance was showed that the interaction effect of seed class and seed rate was not significant (P>0.05) for the parameters of days to maturity, plant height, spike length, seed yield, seed multiplication ratio and thousand seed weight. The study result depicted that seed rate had brought significant effect on the seed yield and multiplication ratio of malt barely. Results indicated that lower seed rates gave better seed multiplication ratio in the districts. Increasing seed rate from 40 to 80 kg.ha^{-1} has increased seed yield from 3356.1 kg.ha^{-1} to 3696.8 kg ha $^{-1}$ though seed yield difference between seed rates of 60 and 80 kg.ha^{-1} was statistically non-significant (p>0.05). Increasing seed rate from 40 to 60 kg.ha^{-1} has continuously improved seed yield from 3356.1 to 3592.1 kg.ha^{-1} in all seed class in the districts, but the difference was statistically non-significant. In conclusion, seed rates as low as 60 kg.ha^{-1} can be used at all seed classes to accelerate early generation seed multiplication within the fast track variety release program in Western Amhara Region.

Keywords: quality parameters, seed class, seed multiplication ratio, seed yield.

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important and widely grown cereal crops in the world. The crop is an important feed, malt, and food crop in Russia, Canada, Australia, Ukraine, Turkey, Spain, Morocco, Germany, Kazakhstan, Iran, Syria, USA, France, Polland, Ethiopia, and UK (FAO, 2008). Ethiopia is the second largest barley producer in Africa, following Morocco, and accounting 25% of the total production (FAO, 2014). In Ethiopia, barley is an important crop that is mainly grown by subsistence farmers in a wide range of environments with an altitude range of 1500 to 3500 m.a.s.l. (Bekele et al., 2005; Yirga et al., 1998). It is the fifth most important cereal crop after teff, wheat, maize, and sorghum in area coverage in the country (CSA, 2017). The crop is predominantly categorized as food and malting barley based on their uses (Gezahegn and Kefale, 2016). The share of malting barley production is quite low as compared to food barley in Ethiopia (Bekele et al., 2005) despite the country having favorable environment and potential market opportunity. The annual total barley production in Ethiopia estimates about 1,856,704.28 tons from 944,401.34 ha of land with the productivity of 1.966 t.ha^{-1} during 2015-2016 main seasons (CSA, 2016). Among the factors that explain the success of this crop in the country, seed quality ranks high, since it represents the vehicle through which the plant breeder's creations are incorporated into new cultivars and made available to farmers. One of the most important basic needs for higher agricultural production is quality seed that can be characterized by high viability and vigor. Maintenance of seed quality from the harvest till growing season is of the utmost importance in a seed production program. The amount of new improved varieties seed obtained from the plant breeding

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process is never enough to meet the market demand, so that its multiplication for several generations is always necessary prior to marketing. Thus, shortening of the long seed multiplication chain is the best strategy for fast supply of improved varieties seed early to farmers. Rapid Production of certified seed is following an efficient conversion of breeder seed in to following seed categories. The conversion ratio can be increased by improving seed multiplication ratios and ultimately through good agronomic practices (GAPs).

Those responsible for seed multiplication can employ two strategies to achieve their goals, focusing either on the cropping area necessary to produce the estimated tonnage or by manipulating the multiplication ratio (MR). While the approach on the cropping area seeks to obtain the maximum possible seed yield per unit of land in one growing season, the multiplication ratio focuses on obtaining the maximum possible number of seeds per plant. For early generation seed production of a new variety, the multiplication ratio (yield per seed per plant) is more important than yield per unit area (Gaur et al., 2010).

Environmental factors and agronomic practices have a significant effect on malting barley grain quality and yield with seeding rates having a pronounced effect (Izydorczyk and Edney, 2017). Seed rate is an important agronomic factor that influences seed multiplication ratio. Using higher seed rates causes low seed multiplication ratio, leading to poor seed and variety replacements rates, exposing farmers to use farm saved seed. Lower seed rates are important to enhance fast supply of early generation seed through increased seed multiplication ratio (Gastel et al., 2002; Karta et al., 2015)

Knowing to what extent seeding rate can be reduced to produce individual plants carrying more seeds, i.e. increase the multiplication ratio, is extremely useful to breeding programs and seed producers responsible for the multiplication of higher seed categories. This is due to the limited amount of early generation seeds. The search for alternatives for a single seed to multiply and generate the largest possible number of progenies is a major achievement.

The objective of this work was to compare the effects of low malt barley seeding rates and seed class on the multiplication ratio (MR), the seed yield, and the physical and physiological quality parameters of malt barely seed produced.

Materials and Methods

Description of the Study Areas

Field experiment conducted in 2019 and 2020 dry season under irrigation condition at Mecha (Koga) districts of west Gojam in Amhara Region. The districts are the major producer of malt barely under irrigation in the region. Koga irrigation scheme is located in the Tana Basin under Mecha district, south of the Amhara Region, Ethiopia. It lies between 11°20' to 11°32' North Latitude and 37°02' to 37°11' East Longitude. Koga irrigation scheme is located 41 km to the West of Bahir Dar city and 543 km to the North of the capital city, Addis Ababa at 37°7'29.72" Easting and 11°20'57.85" Northing and 1953 m a.s.l. The average annual rainfall of the area is 1124 mm per year. The mean maximum and minimum temperatures are 26.8 ^{0}C and 9.7 ^{0}C, respectively. The data on climatic parameters such as rainfall, maximum and minimum temperature recorded at Koga meteorological stations in the study area for 2019 and 2020 irrigation cropping seasons are indicated in Figure 1 and Figure 2.

Treatments and Experimental Design

A factorial experiment consisting of three seed classes (breeder, pre-basic and basic) and four seed rates (40, 60, 80 and 100 kg.ha^{-1}) was laid out in randomized completed block design (RCBD) with three replications. The test crop, Malt barley variety; IBON174/03 was sown in a unit plot size of 2.5 m× 1.2 m with row spacing of 20 cm apart. The spacing between rows, plots and replications was 0.2 m, 0.5 m and 1 m, respectively, and the net harvestable plot was 2.5 m x 1m (2.5 m^2) area. Planting was done in early December, by hand drilling in rows and cover lightly with soil. The whole doses of recommended 121 kg.ha^{-1} NPS fertilizers were applied basal applied in both sides of rows just during sowing as per the treatment. The recommended dose of 50 kg.ha^{-1} N fertilizer around the study area was applied uniformly to all plots in the form of urea. The urea-N was split applied in which one half of N was applied at planting and the remaining one half was applied one month after planting and first weeding. The preceding crop was bread wheat in the districts. Seedbed was prepared by cultivating the soil 3 times with shovel and spade to a depth of 20 cm and followed by planking. The first weeding were 25-30 days after planting whereas the second weeding was 50-55 days after planting. Diseases and insect pests were not a problem during the experimental periods. Regular monitoring also conducted to avoid bird damage. The experiment was conducted under furrow irrigation method, which is the most commonly used irrigation system in the districts. A three to four days irrigation interval

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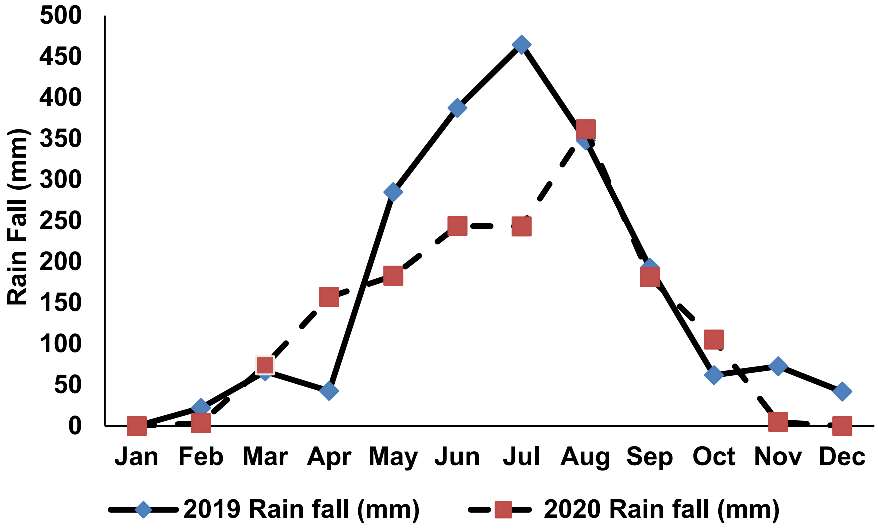

Figure 1. Monthly rainfall of the study area for the year 2019 and 2020 irrigation conditions at Koga district, Amhara region, Ethiopia.

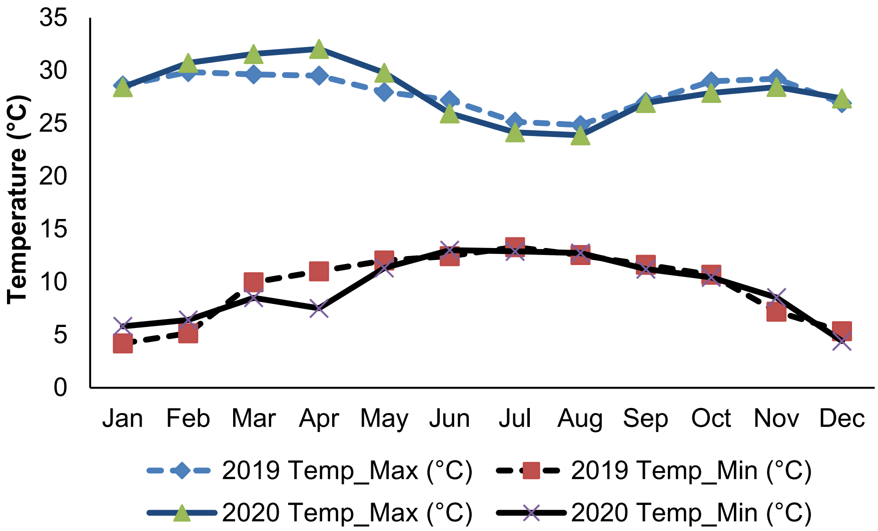

Figure 2. Monthly maximum and minimum temperature of the study area for the year 2019 and 2020 irrigation conditions at Koga district, Amhara region, Ethiopia.

was maintained for the first four weeks. Thereafter, irrigation was applied at 7 days interval until 15 days to harvest, when irrigation was stopped completely (EARO, 2004) and all agronomic management of the trials was done as per the recommendation for the crop.

Data Collection and Measurements

Ten plants randomly sampled and tagged for data collection. Data on maturity date, plant height, spike length, seed yield, seed multiplication ratio, 1000-seed weight, standard germination, speed of germination, seedling shoot length and root length, seedling dry weight, seed vigor index I and seed vigor index II data were collected at appropriate stage and time pertinent for each parameter.

Statistical Data Analysis

The collected data on various field and quality parameters under study were subjected to analysis of variance (ANOVA) using the GLM procedures of SAS (Statistical Analysis System) version 9.4 computer software program (SAS Institute Inc, 2014). Significance of differences between means was expressed using the least significance difference (LSD) test at $P<0.05$ probability level.

Results and Discussion

Analysis of variance (ANOVA) for the effects of year, seed rate, seed class and their interactions on all malt

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barely parameters measured during investigation are presented in Table 2. Seed rate and seed class interaction showed no significant effect (P>0.05) on the parameters of days to maturity, plant height, spike length, seed yield, seed multiplication ratio and 1000 seed weight. The interaction between year and seed class were significant only for seed yield. However, the interaction between year and seed rate were showed no significant effect (P>0.05) on all parameters of malt barely.

The interaction among year, seed rate and seed class were significant only for plant height, seed yield and seed multiplication ratio. Malt barely seed yield and yield related traits were significantly influenced by the growing years/seasons (Table 2). The difference between growing years for the measured traits is expected because the two growing years have distinct Temperature conditions. The analysis of variance showed that the measured traits such as days to maturity, seed yield and seed multiplication ratio at P<0.05 probability level were significantly influenced by the main effects of seed rate. Thousand seed weight was not significantly influenced by the main effect of seed rate and seed class at P>0.05. Plant height, spike length and thousand seed weight were not significantly influenced by the main effects of seed rate at P>0.05.

Effects of Seed Rate and Seed Class on Seed Yield and Yield Related Traits

Analysis of variance for days to maturity, plant height, spike length, seed yield, seed multiplication ratio and thousand seed weight in 2019 and 2020 are presented in Table 3. Plant height is ranged from 86.83 to 87.29 cm (Table 3). The shortest plants were recorded from the highest seed rate (80 kg.ha^{-1}) while the tallest plants were scored from the seed rate of 40 kg.ha^{-1} but not statistically significant from across seed rate treatments. This finding agrees with El-Banna et al. (2011) who reported variations in plant height in different barley and wheat genotypes. The general decreasing trend was observed for plant height with increasing seed rate from 40 to 100 kg.ha^{-1} (Table 3). The tallest plants from the highest planting density might be due to competition for light may influence the plants to grow up at higher planting density than the lower planting density. This result agreed with Imran et al. (2015) and Dawadi and Sah (2012) who investigated that plant height increased with planting density.

Table 1. Initial physical and physiological seed quality of breeder, pre-basic and basic seeds of the two years (2019 and 2020).

Seed class	2019			2020		
	Purity (%)	Germination (%)	Moisture content (%)	Purity (%)	Germination (%)	Moisture content (%)
Breeder seed	99	88	11.5	99.5	92	12.6
Pre-basic seed	98.5	89	12.4	99	90	11.9
Basic seed	98	86	12	98	87	12

Table 2. Mean square values for effects of year, seed rate, seed class and their interaction on malt barely seed yield & yield related traits at Koga (2019 and 2020 irrigation seasons).

Source of variation	Df	DM	PH	SL	SY	SMR	TSW
Rep	2	31.51	3.13	0.19	61,641	12.93	0.88
YR	1	3626.68***	1049.58***	2.13**	132,618 ns	42.68ns	49.83**
SC	2	44.35ns	1.34ns	0.22ns	175,804 ns	43.95ns	0.67 ns
SR	3	72.13*	1.84ns	0.03ns	444,808**	7533.67**	7.68 ns
YR*SC	2	18.6ns	5.42ns	0.14ns	375,766*	71.59ns	8.67 ns
YR*SR	3	16.87ns	15.7ns	0.19ns	82,825 ns	14.99ns	3.45 ns
SC*SR	6	28.07ns	64.93ns	0.27ns	140,627 ns	26.35ns	1.00 ns
YR*SC*SR	6	10.06ns	71.91*	0.35ns	296,022**	64.94*	1.77 ns
Error	46	18.28	29.31	0.23	81447	27.16	5.84
CV		4.03	6.23	5.6	7.97	9.19	4.96

Note: ns, * and ** indicate non-significant, significant and highly significant at 5% level of probability respectively. Df= degree of freedom, DM=Days to maturity, PH= plant height, SL= spike length, SY =seed yield, SMR= seed multiplication ratio and TSW= thousand seed weight.

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Seed yield is ultimate outcome of various physiological, biochemical and phonological processes occurring in the plant system. Seed class and their interaction effects of seed class by seed rate had no significant influence on seed yield and seed multiplication factors of malt barley, whereas the main effects of seed rate had highly significant change on seed yield and multiplication ratio (P<0.01) (Table 3). On the other hand, seed rate has caused significant change in seed yield and seed multiplication ratio in the districts though its effect has significantly varied across years. As increasing seed rate from 40 to 60 kg.ha^{-1}, seed yield increased as increasing order but slightly increase as further increases seed rate to 100 kg.ha^{-1}. This finding is similar with the finding of Karta et al. (2015) who reported that increasing seed rate from 50 to 100 kg.ha^{-1} has continuously improved seed yield at 20 cm row spaces. The seed rate of 80 kg.ha^{-1} had non-significantly increased seed yield over 60 kg.ha^{-1} and 100 kg.ha^{-1} (maximum recommended seed rate) in the study areas. On the other hand, the seed rate of 60 kg.ha^{-1} had not significantly decreased malt barley seed yield by 4.65% and 0.97% over the maximum recommended seed rates. This depicted that planting of malt barley with seed rate of 60 kg.ha^{-1} minimizes seed yield reduction than using 40 kg.ha^{-1}. The apparent significant response of malt barley to seed rate in the districts found in this study indicates lowering of seed rates to 60 kg.ha^{-1} for production of malt barley seed is a minimal yield loses.

Average seed multiplication ratio was recorded to be 56.70 (Table 3) in the districts. The highest seed multiplication ratio was 83.9 at seed rate of 40 kg.ha^{-1}. This means that if one has 10 kg nucleus seed of malt barely and it is sown at rate of 40 kg.ha^{-1}, the expected output will be 839 kg of seeds, assuming good agronomic management is followed. With limited availability of nucleus seeds from breeding plots, this is an important option to enhance accelerated seed multiplication. This result was agreed with Karta et al. (2015) who stated that 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}, the expected output will be 826 kg seed, assuming good agronomic management is followed.

Physical and Physiological Quality Parameters of Malt Barley Seed

Analysis of variance for purity percentage, standard germination, moisture content, speed of germination, seedling dry weight, seedling length, vigor index one and vigor index two at Koga irrigation site in 2019 and 2020 are presented in Table 3. Seeds harvested from

Table 3. Response of malt barley on maturity date, plant height and spike length to seed rate and seed class at Koga (combined over years).

Treatments	DM	PH	SL	SY (kg.ha^{-1})	SMR	TSW
Year						
1st (2019)	113.19a	83.11b	8.39b	3538.6	55.93	47.9b
2nd (2020)	99.00b	90.75a	8.73a	3624.4	57.47	49.56a
LSD (<0.05)	2.03	2.57	0.23	ns	ns	1.15
Seed class						
Breeder seed	107.58	86.88	8.66	3483	55.14	48.76
Pre-basic seed	105.79	86.73	8.55	3637.7	57.42	48.88
Basic seed	104.92	87.19	8.47	3623.8	57.54	48.55
LSD (<0.05)	ns	ns	ns	ns	ns	ns
Seed rate (kg.ha^{-1})						
40	108.94a	87.05	8.56	3356.1b	83.90a	47.92
60	105.94b	87.29	8.50	3592.1a	59.87b	48.91
80	105.11b	86.54	8.59	3696.8a	46.21c	48.6
100	104.39b	86.83	8.58	3681a	36.81d	49.49
Mean	106.10	86.93	8.56	3581.50	56.70	48.73
LSD(<0.05)	2.87	ns	ns	191.49	3.5	ns
CV	4.03	6.23	5.6	7.97	9.19	4.96

Note: Means in the same column followed by the same letters are not significantly different from each other at 5% level of probability. DM=Days to maturity, PH= plant height, SL= spike length, SY =seed yield, SMR= seed multiplication ratio and TSW= thousand seed weight.

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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<0.05) interaction of seed rate and seed class through irrigation for tested quality parameters, such as seed vigor index and seedling dry weight. On the other hand, the main effect of seed rate was not significant (P<0.05) for purity percentage, standard germination, seedling length, seed vigor index and seedling dry weight.

The interaction among year, seed rate and seed class did not significantly affected all physical and physiological quality parameters of malt barely seed. Except standard germination all physical and physiological quality parameters were significantly influenced by the growing years per seasons (Table 4). The difference between growing years for the measured parameters is expected because the two growing years have distinct temperature conditions. As a function of seedling dry weight and germination percentage, the maximum seed vigor II value (7.5) recorded at seed rate of 60 kg.ha^{-1} and seed class of pre basic while the lowest value was at seed rate at 40 kg.ha^{-1} and seed class breeder seed (Table 5). Generally, lower seed rates disfavored seed vigor index at seed classes of basic and breeder seed with the lowest value was at seed rate of 40 kg.ha^{-1}. Dry weight of a single seedling from normally germinated seeds recorded a maximum value was 0.077 mg seed rates 60 kg.ha^{-1} with seed class of pre basic seed.

All seed quality parameters were not significantly influenced by different seed classes, seed rates and their interaction effects but significantly vary across years. The quality traits such as purity percentage, moisture content, speed of germination, seedling dry weight, seedling length, vigor index one and vigor index two significantly influenced by years, but standard germination and moisture content were non-significantly vary across years presented in (Table 4). The second year significantly favors the quality parameters than the first trail season. This might be the temperature condition. Commonly those seedlings produced longer shoots and roots were from vigor seeds. This result was in agreement with the findings of Gharineh and Moshatati (2012) who reported that more seedling length and seedling dry weight of the heavy seeds might be attributed to large food reserves of the seeds. As prescribed in the Ethiopian National Seed Standard of malt barely (Table 5) were met the minimum requirements (90% for breeder/pre-basic and basic seed) according to the Quality and Standards Authority of Ethiopia (QSAE, 2000). The higher food reserve in the endosperm results higher cob weight and leads to vigorous crop in the field. This result agreed with the results reported by Shahwani et al. (2014) that the bread wheat variety sown with bolder seeds resulted in significantly higher seed germination of 95.29% as compared to the wheat variety sown with small sized seeds with 91.70% germination.

The quality of seeds does not change at different seeding rates, such as using lower seeding rates which increase the seed multiplication ratio. This result is similar with (Vazquez et al., 2008) who reported that there are no changes on the physiological quality of soybean seeds originated from low plant-density crops. The absence of negative effects on seed

Table 4. Mean square values for effects of year, seed rate, seed class and their interaction on malt barely physical and physiological seed quality traits at Koga (2019 and 2020 irrigation seasons).

Source of variation	Df	PP%	G%	MC	SDW	RL	VI	VII	SPG
Rep	2	0.4285	14.90	0.34	0.000045	22.39	460675	0.43	9.55
YR	1	6.5040**	18.50ns	0.12ns	0.0023***	178.67**	406877**	24.36**	97.30**
SC	2	0.002ns	1.73ns	0.18ns	0.00013ns	2.91ns	33918ns	1.17	2.76ns
SR	3	0.084ns	12.92ns	0.04ns	0.00017ns	0.68ns	14647ns	1.34	3.66ns
YR*SC	2	0.022ns	10.07ns	0.24ns	0.00048***	6.78*	18413ns	4.64**	0.21ns
YR*SR	3	0.138ns	1.71ns	0.01ns	0.00034**	1.09ns	50673ns	3.21**	0.74ns
SC*SR	6	0.046ns	3.68ns	0.16ns	0.00049**	2.45ns	31651ns	4.89**	2.70ns
YR*SC*SR	6	0.088ns	1.10ns	0.24*	0.00035**	3.11ns	39235ns	3.38**	0.58ns
Error	46	0.206	6.81	0.10	0.000067	1.57	34333	0.69	2.19
CV		0.460	2.70	3.98	13.27	7.88	6	13.81	6.50

Note: ns, * and ** indicates non-significant, significant and highly significant at 5% level of probability, respectively. Df= degree of freedom, SPG=Speed of germination, SG= Standard germination, SL= Shoot Length, RL= Root Length, SDW= Seedling dry weight, VI = Vigor index one and VII = Vigor index two.

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Table 5. Average mean of purity percentage, standard germination, speed of germination, shoot length, root length, seedling dry weight, vigor index one and vigor index two of seed rate and seed class at Koga (combined over years).

Treatments	PP%	SG%	Mc	SDW	SL	RL	VI	VII	SPG
Year									
1st (2019)	99.24b	96.19	7.89	0.06b	18.32a	14.33b	3140.00b	5.44b	23.94a
2nd (2020)	99.84a	97.21	7.81	0.07a	16.39b	17.48a	3290.40a	6.61a	21.62b
LSD	0.22	ns	ns	0.004	0.44	0.59	0.01	0.39	0.70
Seed class									
Breeder	99.54	96.63	7.95	0.06	17.14	16.09	3211.20	5.79	22.39
Pre-basic	99.54	96.48	7.80	0.06	17.63	16.12	3254.60	6.22	23.01
Basic	99.54	97.00	7.80	0.06	17.29	15.50	3179.70	6.06	22.94
LSD (<0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
Seed rate (kg.ha^{-1})									
40	99.53	97.61	7.91	0.06	17.20	15.61	3202.20	5.68	22.81
60	99.58	95.86	7.81	0.07	17.52	16.02	3213.60	6.34	22.16
80	99.60	96.11	7.87	0.06	17.22	15.97	3189.60	5.99	22.92
100	99.45	97.22	7.82	0.06	17.49	16.00	3255.40	6.08	23.23
LSD (<0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV	0.46	2.70	3.98	13.27	5.34	7.88	6.00	13.81	6.50

Note: Means in the same column followed by similar letters are not significantly different from each other at 5% level of probability. SPG=Speed of germination, SG= Standard germination, SL= Shoot Length, RL= Root Length, SDW= Seedling dry weight, VI = Vigor index one and VII = Vigor index two.

quality of low seed rate crops allows for the use of this strategy as an acceptable option when the objective is to maximize the number of seeds per plant (MR), however, not when the focus is to optimize seed yield per unit area. Therefore, the use of low seeding rate is an important tool that must be restricted to plant material of high economic value, which is the case for promising materials from plant breeding programs.

Conclusion and Recommendation

Results indicated that lower seed rates gave better seed multiplication ratio in the study area. Increasing seed rate from 40 to 80 kg.ha^{-1} has increased seed yield from 3356.1 kg.ha^{-1} to 3696.8 kg.ha^{-1} though seed yield difference between seed rates of 60 and 80 kg.ha^{-1} was statistically non-significant (P>0.05). Increasing seed rate from 40 to 60 kg.ha^{-1} has continuously improved seed yield from 3356.1 to 3592.1 kg.ha^{-1} in all seed class in the study area, but the difference was statistically non-significant. Laboratory studies indicated that all seed quality parameters were non-significantly influenced by different seed classes, seed rates and their interaction effects but significantly vary across years. All seed samples from the treatments met the minimum requirements for malt barely seed standards. Therefore, from the present study it can be concluded that, seed rates as low as 60 kg.ha^{-1} can be used for all seed class to accelerate early generation seed supply within the fast track variety release programs in Ethiopia.

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