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Effects of Lower Seed Rate and Seed Class on Multiplication Ratio, Quality, and Yield of Malt Barley (*Hordeum Distichon L.*) Under Rainfed Condition in Debre Birhan, Ethiopia

Belayneh Shibie Mekonnen[1], Tilay Anbes Wasie[2]*
1) *Debre Birhan Agricultural Research Center, P. O. Box 112, Debre Birhan, Ethiopia.*
2) *Adet Agricultural Research Center, P.O.Box 08, Bahir Dar, Ethiopia*
*) *Corresponding Author: belayneh.bs@gmail.com*

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Abstract*— The average yield of barley in Ethiopia is low (2.5 t /ha), as compared to the genetic yield potential of the released varieties (4.0 t -5.0 t /ha). This low productivity is due to several constraints such as poor quality and inadequate breeder seed availability for further multiplication of early-generation seeds. Thus, the experiment was conducted to determine the effects of seed rate and seed class on seed multiplication ratio, seed yield, and seed quality of malt barley at Debre Birhan from 2019 to 2020. An experiment consisted of a factorial combination of four seed rates (40, 60, 80, and 100) kg/ha and three seed classes (breeder, pre-basic and basic) laid out in randomized complete block design with three replications. The results revealed that seed rates significantly influenced (P<0.05) seed yield and seed multiplication ratio. On the contrary, all seed quality parameters evaluated was not significantly affected by seed rates and seed classes of malt barley. The maximum (71) and minimum (39) seed multiplication ratios were recorded from the lower seed rate (40kg/ha) and the recommended seed rate 100 kg/ha respectively. On the other hand, the maximum (3960.90kg/ha) and minimum (2844.70kg/ha) seed yield were obtained from the recommended seed rate of 100kg/ha and lower seed rate of 40kg/ha respectively. However, 40kg/ha has a 28.18% yield penalty as compared to the recommended rate in the study area. As a recommendation, seed rates as low as 80 kg/ha can be used at the three seed classes with high impute and good management to accelerate early generation seed supply in the Debre Birhan and similar areas during the main production season. However, when breeder or nucleus seed shortage occurs, seed rates as low as 60 kg/ha can be used at the three seed classes of malt barley to accelerate early generation seed supply.

Keywords*— *Seed multiplication ratio; Seed quality; Seed class; Seed rate

I. INTRODUCTION

T Barley (Hordeum vulgare L) is an ancient cereal crop and ranks as the fourth-largest grown cereal crop in the world [16]. Ethiopia is the second-largest barley producer, with a share of 25% of the total production in Africa [8]. Ethiopia produces an estimated 2,339,109.88 tons of barley annually from 926,106.90 hectares, with an average productivity of 2.5 t/ha [5]. In the country's highlands, barley serves multiple purposes, including food, animal feed, malt production, and income generation for smallholder farmers. Traditionally, barley grains are used to prepare various local foods and beverages such as Dabo, Kolo, Genfo, Kitche, Beso, Tela, Borde, and other traditional dishes [31]

Barley yield in Ethiopia remains low at 2.5 t/ha, far below the genetic potential of released varieties (4–5 t/ha). This productivity gap is largely due to poor seed quality and an extended seed multiplication chain for newly released early-generation seeds. As a result, seed and variety replacement rates are low, leading to widespread use of farm-saved seed. The amount of seeds of new improved varieties obtained from the plant breeding process is never adequate to meet the market demand, so its multiplication for several generations is always required before marketing. Thus, shortening the long seed multiplication chain is the best strategy for ensuring a timely supply of improved varieties to farmers. The rapid production of certified seed depends on the efficient conversion of breeder seed into the next generation. Improved seed multiplication ratios, supported by good agronomic practices, enhance this conversion process, ensuring a more efficient transfer of breeder seed to subsequent seed classes [33]. Seed multiplication can be achieved by either focusing on the cropping area to produce the desired tonnage or manipulating the multiplication ratio. While the cropping area maximizes seed yield per land unit, the multiplication ratio aims to increase the number of seeds per plant. For early-generation seed production, the multiplication ratio (seeds per plant) is more critical than yield per unit area [27].

Seed rate is an important factor that influences the seed multiplication ratio. Lower seed rates result in a higher multiplication ratio, as they allow individual plants to produce more seeds [3]; [18]. This is particularly useful for a limited amount of starter seeds to multiply the next generations at large. However, there is limited research on how lower seed rates and seed classes affect seed yield, multiplication ratio, and quality in Debre Birhan under rain-fed conditions. Therefore, this experiment was conducted to determine the optimal lower seed rate for the rapid multiplication and supply of early-generation seed for a newly released malt barley variety.

II. Materials And Methods

A. Description of the study area

The experiment was conducted for two consecutive years from 2019 to 2020 cropping seasons in rained conditions at Debre Birhan, Amhara Regional State of Ethiopia. It is located at a distance of about 130 km northeast of Addis Ababa on the main road to Dessie. The experimental site is geographically located at 09° 35' 45" to 09° 36' 45" latitude and from 39° 29' 40" to 39° 31' 30" longitude with elevation ranging from 2800 to 2845 meters above sea level (m.a.s.l.). It receives a mean annual rainfall of 927.10 mm and is characterized by an unimodal rainfall pattern with maximum (293.02 mm) and minimum (4.72 mm) peaks in August and December, respectively. The average monthly maximum and minimum temperatures range from 18.3°C to 21.8°C and 2.4 to 8.9°C, respectively[10]. The dominant soil type of the experimental site is light grey soil, which is generally good for malt barley cultivation, and the soil pH also reaches 5.43. Major crops grown in Debre Birhan are barley, wheat, faba bean, and potato in increasing orders of area cultivated under these crops. The monthly rainfall and average monthly maximum and minimum temperature of the study area during the experimentation period are presented in Fig.I

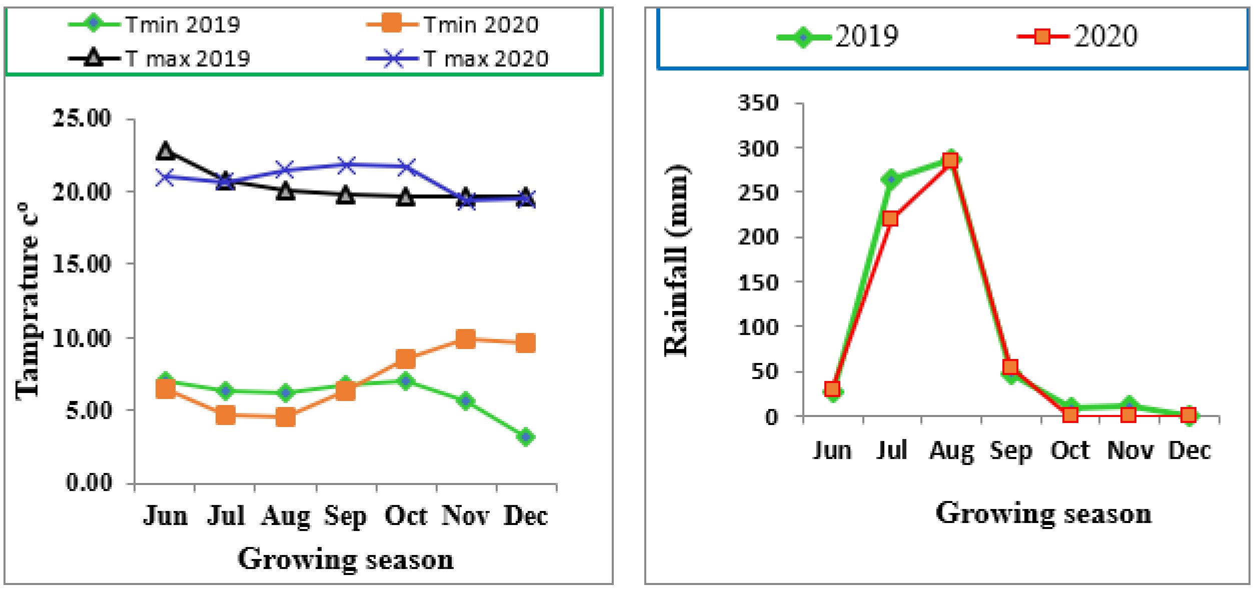

Fig. 1. Monthly rainfall and average maximum and minimum temperatures in the two years of the study district

B. Treatments, design, and experimental procedures

The experiment was arranged as a factorial combination consisting of three seed classes and four seed rates laid out in a randomized complete block design with three replications. The seed classes of breeder, pre-basic, and basic were coded as SC1, SC2, and SC3, respectively. Similarly, seed rates of 40, 60, 80, and 100 kg/ha were coded as SR1, SR2, SR3, and SR4, respectively. The germination percentage, seed purity, and seed moisture content of breeder seed (95.25%, 98%, and 12%), pre-basic seed (95%, 98%, and 13%), and basic seed (95.25%, 98.8%, and 12%) were recorded before planting. The test crop was double-row malt barley of the variety IBON174/03 and was sown in a plot size of 2.5 m × 1.2 m with row spacing of 20 cm apart. The spacing between rows, plots, and replication was 0.2 m, 0.5 m, and 1 m, respectively, and the net harvestable plot was 2.5 m x 1 m in area. Planting was done in early June, with the hand-drilling method of planting in rows and covering lightly with soil. The recommended NPS fertilizer rate, 121 kg/ha, was applied during sowing. The recommended dose of 50 kg/ha urea was applied with two splits in which one-half of nitrogen was applied at planting and the remaining one-half was applied one month after planting and first weeding. All remaining agronomic management of the experiment was done as per recommendations of the crop.

C. Selecting a Template (Heading 2)

The data of days to maturity, plant height (PH), spike length (SL), seed yield (SY), seed multiplication ratio (SMR), thousand seed Standard Germination Test: A standard germination test was done by using Four hundred (400) seeds were randomly taken from mixed pure seeds and divided into four replicates of 100 seeds each. The seeds were sown in a sterilized sand medium and kept in a seed germinator at room temperature. The final count was done on the 8th day after planting for barley. Seedlings were evaluated in terms of normal, abnormal seedlings, hard, and dead seeds.

Shoot and root length: The seedling shoot length and seedling root length were assessed after the final count in the standard germination test. Ten normal seedlings were randomly selected from each replicate. The shoot length was measured from the point of attachment to the cotyledon to the tip of the seedling. Similarly, the root length was measured from the point of attachment to the cotyledon to the tip of the root. The average shoot or root length was computed by dividing the total shoot or root lengths by the total number of normal seedlings measured [6]

Seedling dry weight: The seedling dry weight was measured after the final count in the standard germination test. Ten seedlings randomly selected from each replicate were cut free from their cotyledons, placed in envelopes, and dried in an oven at 80 ± 1°C for 24 hours. The dried seedlings were weighed to the nearest milligram, and the average seedling dry weight was calculated. Vigor Index test: The seedling vigor index was calculated for each sample as per [2] and expressed in numbers by using the formula below. Seedling vigor index I was calculated by multiplying the standard germination with the average sum of shoot length and root length after 8 days of germination, and vigor index 2 was again calculated by multiplying the standard germination with mean seedling dry weight (drying at a temperature of 800°C for 24 hours). The formula for these parameters: Vigor Index I = Standard germination × mean seedling length (roots + shoots length) Vigor Index II = Standard germination × mean seedling dry weight. Speed of germination: Speed of germination is also another indicator used for assessing the vigor of seeds. It was calculated as the number of normal seedlings that were counted daily up to 8 days and divided by the number of days. The same were added till the final count as per the following formula[38].GS = number of normal seedlings + … + number of normal seedlings number of days to first count (4th) number of days final count (10th)

D. Data analysis

The collected data were subjected to analysis of variance (ANOVA) with GLM as per the experimental designs for each experiment using SAS software version 9.4 [33] to estimate the variation among treatments. After verifying normality and homogeneity of error variance across years, a combined analysis for the two years was done by using the procedure of SAS software version 9.4 [22]. The data were computed for all characters evaluated as per Gomez and Gomez [33]. For significant results, mean separation was done using the least significance difference (LSD) test at the 1% or 5% level of probability.

III. Results And Discussion

The combined analysis of variance for maturity date, plant height, spike length, seed yield, seed multiplication ratio, and thousand seed weight of malt barley at Debre Birhan over the years 2019 and 2020 is presented in TABLE I.

A. *Effects of seed rate and seed class on the maturity date, plant height, spike length, and thousand seed weight of malt barley*

Planting malt barley using seed rates of 40 kg/ha and 100 kg/ha produced the longest spike length of 7.84 cm and shorter spike length of 7.44 cm, respectively (TABLE II). The seed rate, seed class, and their interaction (seed rate * seed class) had no significant effect ($p < 0.05$) on the maturity date and thousand seed weight of malt barley (TABLE I). This result is in contrast with the finding of [20], who noted that as the seeding rate increases, most phenological parameters, like maturity date, get shorter. Thousand seed weights had no variation across seed rates. This might be because of the seed rate range had not above the optimum seed rate which causes severe computation of growth factors. On the other hand lowering the seed rate causes high tillering which has non uniformly maturing and seed size and color but as lowering seed rate 40kg/ha has no seed quality problem. This result is in agreement with the findings of [34] and [1], as the seed rate increased there was a substantial decrease in the mean value of the thousand seed weight of malt barley.

TABLE I. THE COMBINED MEAN SQUARE VALUES FOR PHENOLOGICAL, GROWTH, AND YIELD-RELATED TRAITS OVER THE YEARS.

S.V	Df	DM	PH(cm)	SL(cm)	SY(kg ha-1)	SMR	TSW(g)
rep	2	207.18	10.81	0.1	381463	156.5	15.26
YR	1	217.01**	1100.59**	31.26**	855030 ns	383.68 ns	49.87ns
SC	2	34.06ns	27.57ns	0.01ns	107107 ns	67.45 ns	3.80 ns
SR	3	33.24ns	65.47*	0.65**	4034399**	3435.90**	12.997ns
SC*SR	6	12.50ns	3.71ns	0.06ns	316855 ns	117.51 ns	13.04ns
YR*SC*SR	6	21.76ns	29.99ns	0.28ns	484611 ns	150.50 ns	24.16 ns
CV		3.41	5.35	4.67	20.88	22.76	8.72

Note: S.V:source of variation, Df:degree of freedom, MD: maturity date, PH: plant height, SY: seed yield,SMR: seed multiplication ratio, TSW: thousand seed weight ,Rep: replication, YR: year, SC:seed class, SR:seed rate

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TABLE II. SHOWS HOW SEED RATE AND SEED CLASS AFFECT THE PHENOLOGICAL, GROWTH, AND YIELD-RELATED TRAITS OF MALT BARLEY OVER MULTIPLE YEARS.

Seed class	DM	PH(cm)	SL(cm)	SY (kg/ha)	SMR	TSW(g)
Breeder	122.88	79.13	7.62	3533.3	55.07	47.75

Pre basic	120.54	80.27	7.62	3434	51.95	46.98
Basic	122.13	81.27	7.6	3406.2	52.44	47.55
LSD (<0.05)	ns	ns	ns	ns	ns	ns
Seed rate(kg/ha)						
40	123.33	78.15b	7.84a	2844.70c	71.12a	48.42
60	122.67	79.69b	7.67ab	3376.00b	56.27b	46.38
80	120.67	80.30ab	7.48bc	3649.60ab	45.62c	47.24
100	120.72	82.74a	7.44c	3960.90a	39.61c	47.66
LSD (<0.05)	ns	2.88	0.24	484.53	8.12	ns
CV	3.41	5.35	4.67	20.88	22.76	8.72

Note: MD:maturity date,PH:plant height,SL:spike length, SY:seed yield, SMR:seed multiplication ratio,TSW:thousand seed weight

B. *Effects of seed rate and seed class on seed yield, and seed multiplication ratio of Malt Barley*

The analysis of variance showed that seed yield (SY) and seed multiplication ratio (SMR) of malt barley were significantly affected by seed rate (P<0.01) (TABLE I). However, seed yield and SMR were not significantly influenced by seed class, the interaction between seed rate and seed class, or the three-way interaction of seed rate, seed class, and year (P>0.05) (TABLE I). The highest seed yield (3960.90 kg/ha) was recorded at a seed rate of 100 kg/ha, while the lowest yield (2844.70 kg/ha) was observed at 40 kg/ha (TABLE II). Seed yield increased progressively with increasing seed rates from 40 to 100 kg/ha, which is consistent with the findings of [18], who reported that increasing seed rate from 50 to 100 kg/ha improved seed yield at 20 cm row spacing. The blanket seed rate recommendation for malt barley production in the study area was 100 kg/ha. The spike length of malt barley is non-significantly different among seed rates 75 to 125kg/ha as reported [21] and [36]

The significant response of malt barley to seed rates in this study indicates that lowering the seed rate to 60 kg/ha for seed multiplication results in minimal yield loss. However, the main effect of seed class had no significant impact on seed yield (TABLE II). The similar performance among breeder, pre-basic, and basic seed classes may be due to the strict management of variety maintenance in lower seed classes.

Regarding seed multiplication ratio (SMR), the highest SMR (71.12:1) was observed at a seed rate of 40 kg/ha, while the lowest SMR (39.61:1) was recorded at the recommended seed rate of 100 kg/ha (TABLE II). This indicates that reducing the seed rate increases the seed multiplication ratio, likely due to the lower seed rate promoting more productive tillers. This finding aligns with [38], who reported that lower plant densities increase the multiplication ratio by allowing each plant to produce more progeny seeds.

In support of this, [14] highlighted that seed multiplication ratios are influenced by genotype, seeding rate, and environmental factors. Similarly, [35] emphasized the importance of balancing plant population with agronomic practices for optimal seed multiplication. [22] further stressed that maintaining strict variety management ensures uniform performance across seed classes.

Additionally, [11] pointed out that barley seed multiplication is strongly affected by plant population and environmental conditions. [29] confirmed that reducing seeding rates enhances tillering and increases seed multiplication ratios in cereals. Together, these studies underline the positive relationship between lower seed rates and higher seed multiplication ratios, suggesting that adjusting seeding rates can be a useful strategy for optimizing seed production.

The seed multiplication ratio is directly related to seed yield but inversely related to seed rate. At the lower seed rate (40 kg/ha), the SMR was 14.82% higher than the ratio at the highest seed rate (100 kg/ha). These results align with studies by [4]:[25] and [32], who reported that grain yield per plant increases as seed rates decrease. For example, planting 10 kg of nucleus seed at 40 kg/ha would yield an expected output of 711.20 kg of seed, while using 60 kg/ha would produce 562.70 kg of seed. A similar result was reported by [18], where 10 kg of wheat seed planted at 50 kg/ha produced 826 kg of seed, but at 125 kg/ha, only 325 kg was produced.

This outcome can be achieved with high input and intensive agronomic management. Given the limited availability of nucleus seeds, using a lower seed rate is an important strategy to enhance early-generation seed multiplication. The maximum seed yield was obtained at a seed rate of 100 kg/ha with pre-basic seed class (Figure IIB), while the highest seed multiplication ratio was achieved at a seed rate of 40 kg/ha with breeder seed class (Figure IIA).

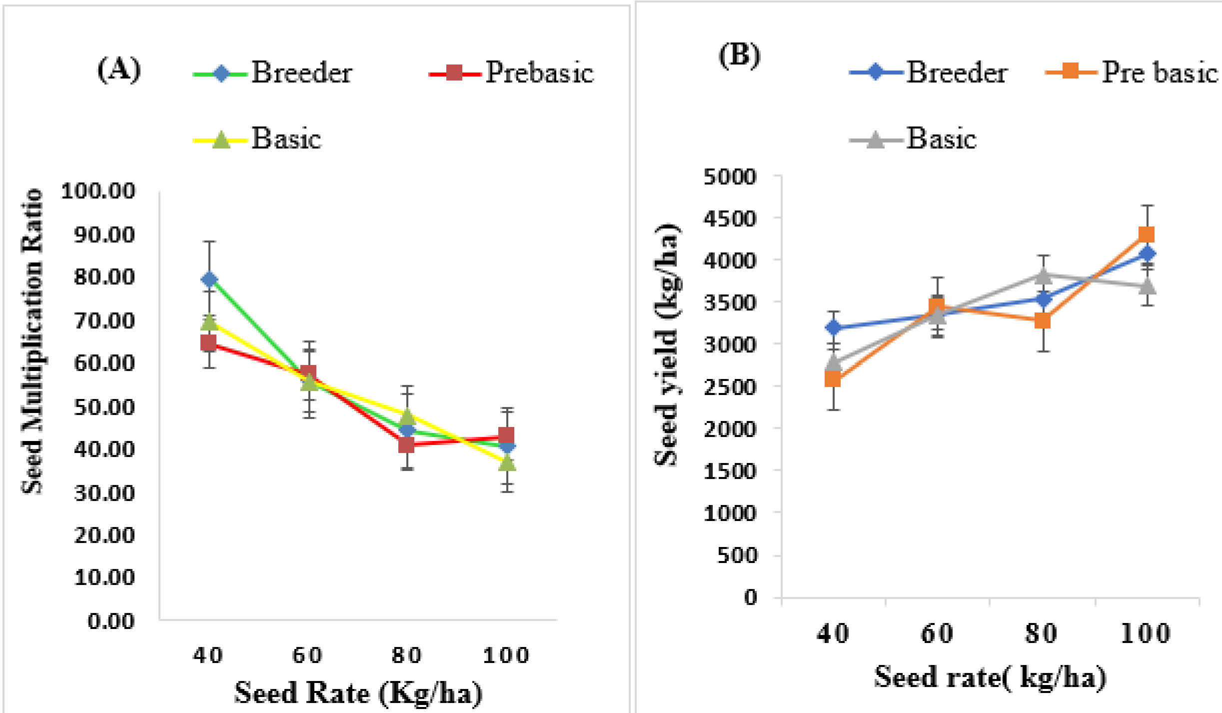

Fig. 2. Illustrates The Interaction Effects Of Seed Rate And Seed Class On Seed Multiplication Ratio (A) And Seed Yield (B).

C. Seed physiological and physical quality traits of malt barley seeds

The combined analysis of variance for the physiological and physical quality traits of malt barley seeds, including seed physical purity percentage (PP%), seed germination percentage (G%), seed moisture content (MC%), speed of germination (SPG), seedling dry weight (SDW), seedling shoot length (SHL), seedling root length (RL), seed vigor index I (VI), and seed vigor index II (VII), at Debre Birhan during the years 2019 and 2020, is presented in TABLE III. [24] found that moisture content influences seed viability, while Singh et al. (2021) highlighted the importance of proper drying for seed longevity. [28] established a connection between early seedling traits and vigor, and [23] emphasized the role of seed vigor in ensuring rapid establishment and improved yield

TABLE III. THE COMBINED MEAN SQUARES OF SEED QUALITY PARAMETERS OVER THE YEARS

S.V	Df	PP%	G%	MC	SDW	SHL	RL	VI	VII	SPG
rep	2	1.76	2.54	0.2	4.19E-05	1.38	0.48	31868	0.32	9.19
YR	1	0.13ns	84.50**	42.78**	1.71E-03**	103.57**	241.74**	5326152**	13.82**	226.90**
SC	2	0.51ns	1.63ns	0.44*	7.84E-06ns	0.37ns	0.08ns	4843ns	0.06ns	5.93ns
SR	3	1.01ns	3.74ns	0.35ns	9.75E-06ns	0.24ns	1.64ns	10815ns	0.08ns	4.27ns
SC*SR	6	0.68ns	0.53ns	0.25ns	5.88E-06ns	0.28ns	1.13ns	24042ns	0.05ns	5.80ns
YR*SC*SR	6	2.53ns	3.74ns	0.3	1.60E-05ns	0.31 ns	0.82ns	12058ns	0.16ns	6.15ns
CV		1.1	1.87	3.66	9.52	7.34	6.36	5.93	9.43	7.51

S.V=source of variation, Df=degree of freedom,PP%=physical purity ,G%=germination percentage,MC=moisture content,SDW=seedling dry weight,,SHL=shoot length,RL=root length,VI=vigour index one,VII=vigour index two, SPG=speed of germination

The analysis of variance showed no significant effects of seed class, seeding rate, or their interaction on malt barley seed quality traits ($P > 0.05$) across the years (TABLE III). This indicates that these factors have minimal impact on seed quality, although trends suggest that Breeder seed tends to exhibit slightly better germination, vigor, and early growth [14]; [30]; [26]; [28]. Similarly, [11] observed minor differences in seed quality among seed classes, while [24] and [35] stressed the importance of proper seed handling in maintaining quality. [23] highlighted that agronomic practices and environmental factors are key determinants of seed performance.

Moreover, seed quality was unaffected by varying seeding rates, including lower rates that increase the seed multiplication ratio. This finding aligns with [9], who reported no significant impact on soybean seed quality at lower plant densities. Low seeding rates are advantageous when the goal is to maximize the number of seeds per plant, particularly in cases with limited high-value early-generation seed material, such as in plant breeding programs. However, this approach is less ideal for optimizing seed yield per unit area.

Although seed quality parameters (PP%, G%, and MC%) did not vary significantly across seed classes, seeding rates, or their interaction (TABLE IV), all treatments met the Ethiopian seed quality standards [6] for Breeder, Pre-basic, and Basic seeds, in terms of physical purity, germination percentage, and moisture content. While higher seeding rates (80-100 kg/ha) may slightly reduce shoot elongation due to plant competition, they do not significantly affect germination or seedling vigor. Overall, the results indicate that malt barley seed quality remains stable across different seed classes and seeding rates, making it adaptable to various seed multiplication and crop production systems [12].

TABLE IV. RESPONSE OF MALT BARLEY SEED QUALITY PARAMETERS TO SEED RATE AND SEED CLASS OVER THE YEARS

Seed class	**SHL**	**RL**	**VI**	**VII**	**SPG**	**PP%**	**G%**	**MC%**	**SDW**
Breeder	8.71	12.66	2083.8	3.1	23.74	98.88	97.63	10.1	0.032
Pre basic	8.46	12.77	2060.4	3.06	22.8	99.17	97.25	9.8	0.032
Basic	8.54	12.69	2058.1	3.16	23	99	97.13	9.9	0.033
LSD<0.05	ns	ns	ns	ns	ns	ns	ns	ns	ns
Seed rate kg/ha									
40	8.74	12.5	2078.6	3.05	22.59	98.67	97.94	9.97	0.031
60	8.5	12.47	2038.9	3.2	23.24	99.17	97.39	9.95	0.033
80	8.52	13.13	2095	3.06	23.12	99.06	96.89	9.72	0.032
100	8.51	12.72	2057.3	3.11	23.77	99.17	97.11	10.04	0.032
LSD (<0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV	7.34	6.36	5.93	9.43	7.51	1.1	1.87	3.66	9.52

Note: PP%=physical purity percentage, G%=germination percentage, MC= moisture content percentag, SDW=seedling dry weight, SHL=shoot length, RL=root length, VI=vigor index one, VII=vigour index two, SPG=speed of germination

IV. CONCLUSION AND RECOMMENDATION

The study demonstrated that seed rates significantly influenced seed yield and seed multiplication ratio in malt barley, with a reduction from 100 kg/ha to 40 kg/ha increasing the seed multiplication ratio from 39 to 71 over both years. However, lower seed rates led to a yield penalty of 28.18% at 40 kg/ha compared to the recommended rate. Despite this yield reduction, seed quality remained unaffected, with all parameters meeting Ethiopian seed quality standards across seed classes. This suggests that lower seed rates can be utilized without compromising seed quality. Given these findings, a seed rate of 80 kg/ha is optimal for all malt barley seed classes in Debre Birhan when combined with high input and intensive agronomic management. In cases of seed shortages, rates as low as 60 kg/ha can be used to accelerate early-generation seed supply, provided proper management practices are in place.

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