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Participatory variety selection of rust-resistant improved bread wheat varieties in East Gojjam Zone, Northwest Ethiopia

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Wheat is one of the major cereal crops produced at different agroecologies of the East Gojjam Zone of the Amhara region. However, access to improved bread wheat varieties is minimal. Due to this and other factors, the area's potential for wheat crops is not exploited. So, developing and promoting technologies that suit the area is necessary. Thereby, this experiment was conducted at Aneded, Basoliben, and Debre Eliyas districts to select and recommend high-yielding and diseases-resistant improved bread wheat varieties through participatory variety selection. Boru, Daka, Shaki, Lemu, Wane, and a local Kakaba were used as testing materials. The treatments were laid out in a randomized complete block design with three replications for the mother trial and farmers were used as replications for baby trials. Both agronomic and farmers' data were collected based on the recommended standards. Data collected from the mother trial was subjected to analysis of variance whereas pairwise matrix ranking was used for data collected from baby trials. The analysis of variance showed the existence of significant differences at (P≤0.05) among the varieties for days to heading, days to maturity, spike length, and grain yield. However, no significant difference was observed among the varieties for plant height. The grain yield ranged from 3920.8 to 6137.9 kgha^{-1} with a mean value of 5399.7 kgha^{-1} and a coefficient variation of 14.5%. The highest grain yield was obtained from Boru (6137.9 kgha^{-1}) followed by Daka (5802.9 kgha^{-1}). The lowest grain yield was obtained from Wane (3920.8 kgha^{-1}), followed by Kakaba (5344.2 kgha^{-1}). Boru and Daka varieties were also top-ranked by farmers due to their best agronomic performances. Thus, the two improved bread wheat varieties are recommended for production in the study areas and the areas having the same and/or similar agroecological characteristics.

Key words: Bread wheat, mother trial, baby trial, farmers' preference, disease.

INTRODUCTION

Ethiopia is the second largest producer of wheat in Africa (next to Egypt) and produces 5.5 Mt wheat, which is

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equivalent to 21.7% of wheat produced and 18.3% of wheat area harvested in Africa (FAOSTAT, 2020). Though there is enormous potential to increase Ethiopia's wheat production both vertically and horizontally, it is still limited due to key challenges such as the prevalence of biotic and abiotic stresses. According to CSA (2020/2021), the national productivity was 3046 $kgha^{-1}$ and East Gojjam's productivity was 3212 $kgha^{-1}$.

Wheat stripe (yellow) rust caused by *Puccinia striiformis* west. f. sp. tritici and leaf rust (*Puccinia triticina* Eriks.) are major constraints to increased yield globally (Das et al., 1992). Yield losses due to rusts are variable because of differences in weather conditions, cultivar susceptibility, and availability of inoculums. However, grain losses have been significant and estimated to reach 30-70% or even greater on susceptible varieties (Murray et al., 1994). High moisture and warm weather favor leaf rust development while stripe rust is important under cool and moist environmental conditions (Knott, 1989). To reduce losses cultural control methods, application of chemicals, and use of resistant cultivars are employed by wheat growers is the best strategy (Raupp et al., 2001). Wheat rusts are the main biotic stress impacting wheat yield in Ethiopia (Meyer et al., 2021)

Participatory varietal selection in the agriculture of developing countries is the existence of important cropping systems in marginal regions of the countries where the adoption of modern improved varieties is low or negligible (Walker, 2006). Rigid release requirements and unrepresentative testing conditions lead to mismatches between what is offered by breeders and what is desired by farmers (Witcombe and Virk, 1997). So, participating farmers in research especially, in conventional research is the pre-eminent method to meticulously work with farmers by integrating their indigenous knowledge into variety selection.

In Ethiopia, efforts have been made to develop and popularize various improved crop varieties across different locations through Participatory Variety Selection (PVS) (Asaye et al., 2013). However, the farmers' selection criteria for these crops were not adequately assessed and well documented from all parts of the country, especially in the East Gojjam Zone of the Amhara region. Previously farmers of the study area had no access to participate in selecting and evaluating the recommended technologies for their specific area. The dependency of farmers on a single crop variety and result in low productivity could be due to their limited involvement during the variety selection process.

Therefore, this experiment was conducted to improve production and productivity of the study area through selecting and promoting improved bread wheat varieties specific problems, evaluating and recommending high-yielding and diseases resistant improved bread wheat varieties through PVS, assessing farmers' selection criteria for improved bread wheat varieties of their choice and identifying the most important criteria for future bread wheat improvement work in the area.

MATERIALS AND METHODS

Study site description

The experiment was conducted in East Gojjam Zone during the main cropping season of 2020-2022. The trial was executed in the Aneded, Basoliben, and Debre Eliyas districts. The specific testing kebeles of the respective districts were Yobienechifo (On-station), Limchin (On-farm), and Yekegat (On-farm). Seeds were planted during the main cropping season which is locally known as mehir which extends from late June to early July. In all locations, the dominant soil type is Nitisol with a slightly acidic nature and the elevation ranges from 2000 to 2460 m.a.s.l. The annual temperature varies between 11 and 27°C. The annual rainfall in the zone is unimodal and it varies from 1181 to 1501 mm.

Experimental material

Five improved bread wheat varieties viz., Boru, Daka, Shaki, Lemu, Wane, and a local check Kakaba were used as testing materials. The experiment was designed in a mother–and–baby trial arrangement. The mother trial was laid out in Randomized Complete Block Design (RCBD) with three replications, while the baby trials were arranged in a single plot. Each variety had a plot size of 2.4 m × 2.5 m in the mother trial, while each variety had a plot size of 5 m × 5 m in the baby trials. The experiment had an interspacing of 0.2 m. For the mother trial, the space left between plot to plot and block to block were 0.5 and 1.5 m, respectively. The net harvestable area was 6 m^2.

Crop management

The experimental land was plowed three times by a tractor. Since the soil was affected by acidity with a pH of 4.8, 2.3 tons ha^{-1} of lime was applied a month before sowing. The recommended seed rate was 150 kg ha^{-1}, 200 kg ha^{-1} NPS, and 200 kg ha^{-1} UREA fertilizers were applied. The full dose of recommended NPS fertilizer was applied at the time of planting while UREA was applied twice in half. The first half spilled was applied at planting and the second half at the booting stage. Hand weeding was done four times. There was no herbicide, insecticide, and/or fungicide application.

Data collection

Agronomic data such as days to heading, days to maturity, plant height, spike length, grain yield, and major disease attributes such as yellow rust, leaf rust, and septoria were recorded. Yellow rust and leaf rust data was collected based on the modified cob's method while septoria data was recorded using a double-digit approach.

Farmers' selection criteria

A total of 120 randomly selected wheat-producing farmers participated in selecting the varieties at vegetative and maturity growth stages. Among the participants 70 were men and 50 were women. Twelve agricultural development agents and district agricultural experts also participated in the variety selection.

First, the men and women farmers were grouped separately to avoid dominance and assimilation of attitudes. Each group listed any selection criteria it believed to be important. After some criteria

Table 1. ANOVA and Mean Performance of various agronomic traits for the mother trial (on-station).

No.	Variety	DTH	DTM	PH	SL	GY	GY advantage over the local check Kakaba (%)
1	Boru	66.7^{b}	128.2^{ab}	101.7^{a}	8.5^{a}	6137.9^{a}	14.9
2	Daka	67.5^{b}	128.8^{a}	102.7^{a}	8.4^{a}	5802.9^{a}	8.6
3	Kakaba (check)	59^{d}	123^{c}	99.4^{a}	7.6^{cb}	5344.2^{ab}	-
4	Lemu	70.3^{a}	128.3^{ab}	101.4^{a}	8.7^{a}	5781.3^{a}	8.2
5	Shaki	66.3^{b}	122.2^{c}	101.7^{a}	8.1^{ab}	5366.7^{ab}	0.4
6	Wane	61.2^{c}	128.2^{ab}	97.6^{a}	7.0^{c}	3920.8^{b}	
Mean		65.7	126.2	100.8	8.1	5399.7	-
CV		2.3	1.2	3.1	6.1	14.5	-
LSD		2.1	2.1	4.4	0.7	1085	-
Significance level							
Genotype		***	***	Ns	***	***	-
Genotype×Year		**	Ns	Ns	Ns	Ns	-

DTH= Days to heading, DTM= days to maturity, P = plant height (Centimeter), SL= spike length (Centimeter), GY= grain yield (kg/ha), Ns= no significant, *p <0.05, **p<0.01, ***p<0.001.

were listed a pair-wise comparison and ranking were used to select the best criteria. All the selection criteria were tabulated in a matrix scoring table, and each selection criterion was compared with each of the others in a pair-wise fashion. Pair-wise comparison and ranking were used to compare and rank the selection criteria and again each variety was compared and ranked against the selected criteria. Then the farmers evaluated each variety against the selected criteria's set using the pairwise ranking method again.

Data analysis

Mother trial

Levine's test of homogeneity showed the p-value was not significant (p<0.12). Since the homogeneity test of variances results are not significant the two years had equal variances. Thus, the two years of data were merged and subjected to the Analysis of Variance (ANOVA) using Statistical Analysis Software (SAS, 9.4) and the mean separation was computed using the Least Significant Difference (LSD) test at a 5% probability level.

RESULTS AND DISCUSSION

The analyzed result of agronomic traits data indicates the presence of significant variance among the tested varieties except for plant height:

1) Days to heading: Lemu took the longest days to heading (70.3), followed by Boru (66.7) and Daka (66.5). The shortest days to heading were registered by Kakaba (59).
2) Days to maturity: The longest days to maturity were recorded by the variety Daka (128.8) followed by Lemu (128.3), Boru (128.2), and Wane (128.2). The shortest day to maturity was recorded on the variety Shaki (122.2) followed by Kakaba (123).
3) Plant height: Among the tested varieties, Daka was the tallest plant (102.7 cm) whereas the shortest height was recorded by Wane (97.6 cm).
4) Spike length: A significant difference was observed among the tested varieties for spike length which ranged from 7.0 to 8.7cm. Lemu (8.7 cm) had the longest spike length followed by Boru (8.5 cm) and Daka (8.4 cm). The shortest spike length was recorded from Wane (7.0 cm) followed by Kakaba (7.6 cm).
5) Grain yield (GY): Significant variability was observed among the tested varieties for grain yield. It ranged from 3920.8 to 6137.9 kgha^{-1} with a mean value of (5399.7 kgha^{-1}) and a coefficient of variation of 14.5%. The highest grain yield was obtained from Boru (6137.9 kgha^{-1}) followed by Daka (5802.9 kgha^{-1}). The lowest grain yield was obtained from Wane (3920.8 kgha^{-1}), followed by Kakaba (5344.2 kgha^{-1}) (Table 1).

The yield advantage of Boru over the local check (Kakaba) was 14.9% followed by Daka (8.6%), Lemu (8.2%), and Shaki (0.4%). Meanwhile, Wane had no yield advantage over Kakaba.

Disease

Table 2 shows that Boru had the lowest severity percentage and high level of resistance in both yellow rust and leaf rust. It is also best resistant to septoria.

Farmers' variety selection criteria

The farmers put their value for each variety by pairwise ranking against the weighted criteria. At On-Station, Boru was ranked first with a total score of 23 and Kakaba was

Table 2. Shows the severity and reaction levels of diseases for each variety.

No.	Variety	YS	YR	LS	LR	SP
1	Boru	5	R	2	R	31
2	Daka	7	R	4	R	53
3	Kakaba	20	MS	5	MR	74
4	Lemu	14	MR	5	R	53
5	Shaki	8	MR	4	R	66
6	Wane	10	MS	5	R	76

YS=Yellow rust severity, YR=yellow rust reaction, LS =leaf rust severity, LR=leaf rust reaction, SP=septoria double-digit score, R=resistant, MR=moderately resistant, MS= moderately susceptible.

Table 3. Farmers' selection criteria, preference scores, and rank of baby trials at Aneded district (on-station).

No.	Variety	DR	KPS	DT	PH	TC	Total score	Rank
1	Boru	5	5	4	4	5	23	1
2	Daka	4	3	2	2	2	13	3
3	Kakaba	2	4	3	5	4	18	2
4	Lemu	3	0	0	0	1	4	6
5	Shaki	1	1	3	2	3	10	4
6	Wane	0	2	3	2	0	7	5

DR = Disease resistance, KPS = kernel per spike, DT = drought tolerant, PH = plant height, and TC = tillering capacity.

Table 4. Farmers' selection criteria, preference scores, and rank of baby trials at Basoliben district (Limchin).

No.	Variety	DR	SS	KPS	TC	SL	Total score	Rank
1	Boru	4	5	5	5	5	24	1
2	Daka	5	4	3	4	4	20	2
3	Kakaba	2	2	1	2	2	9	4
4	Lemu	3	3	3	3	3	15	3
5	Shaki	1	1	0	0	1	3	6
6	Wane	0	0	3	1	0	4	5

DR = disease resistance, SS = seed size, KPS = kernel per spike, TC = tillering capacity, SL= pike length.

ranked second with a total score of 18. Boru was preferred to other varieties. Similarly, the development agents and the researchers selected this variety (Table 3).

In Basoliben the same as Aneded district first farmers listed down several selecting criteria and prioritized them through pair-wise ranking. This was done by men and women farmer groups. Then the farmers put their value for each variety by pairwise ranking against the weighted criteria. Boru was ranked first with a total score of 24 and Daka was ranked second with a total score of 20. Boru was highly preferred to other varieties. Similarly, Boru was selected by the development agents and the researchers (table 4).

In Debre Eliyas the same as other districts first farmers listed down several selecting criteria and then it was prioritized through pairwise ranking. This was done by men and women groups. Then the farmers put their value for each variety by pairwise ranking against the weighted criteria.

Boru and Daka were ranked the same with a total score of 20. In this site, Boru and Daka were highly preferred to other varieties. The development agents and the researchers selected as Daka was the best substitute for Boru and Boru was also the best substitute for Daka (Table 5).

Table 6 shows that the three districts' results have been combined and it indicates that Boru has fitted the farmers' choice followed by Daka. Boru was ranked first with a total score of 67 and Daka was ranked second with a total score of 53. Boru and Daka were selected by the farmers in their order.

Table 5. Farmers' selection criteria, preference scores, and rank of baby trials at Debre Eliyas district.

No.	Variety	DR	SS	KPS	SL	PH	Total score	Rank
1	Boru	4	3	3	5	5	20	1
2	Daka	5	4	4	3	4	20	1
3	Kakaba	3	5	4	1	2	15	2
4	Lemu	2	1	1	2	1	7	4
5	Shaki	0	2	3	4	3	12	3
6	Wane	1	0	0	0	0	1	5

DR = disease resistance, SS = seed size, KPS = kernel per spike, SL = pike length, PH = plant height.

Table 6. Farmers' selection criteria, total scores, and rank of baby trials in three districts.

No.	Variety	DR	KPS	DT	PH	TC	SS	SL	Total score	Rank
1	Boru	13	13	4	9	10	8	10	67	1
2	Daka	14	10	2	6	6	8	7	53	2
3	Kakaba	7	9	3	7	6	7	3	42	3
4	Lemu	8	4	0	1	4	4	5	26	4
5	Shaki	2	4	3	5	3	3	5	25	5
6	Wane	1	5	3	2	1	0	0	12	6

DR = Disease resistance, KPS = kernel per spike, DT = drought tolerant, PH = plant height, TC = tillering capacity, SS = seed size, SL= pike length.

CONCLUSION AND RECOMMENDATION

The statistically analyzed result and farmers' selection criteria provide information for designing and developing appropriate techniques to improve varieties that are better adapted to the specific environment.

Generally, Boru and Daka were selected by farmers' preference based on their selection criteria and the biological response in the research station had similar results.

Since Boru and Daka were top high yielder, disease resistant, and preferred varieties by farmers, Seed enterprises should multiply and distribute the pure seeds of Boru and Daka varieties to the farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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