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Full-Length Research Article

Registration of the Oat (*Avena sativa*) Variety "Walqaa" for Vertisols in the Central Highlands of Ethiopia

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ABSTRACT

In this study, fifteen oat varieties including the standard checks were evaluated for agro-morphological traits, nutritional qualities, disease, and insect pest reactions during the main cropping seasons of 2015- 2018. Based on the overall performance, two best-performing oat varieties (CI-1742 and SRCPX80Ab2596) were selected and verified with the two standard checks at the Kuyu and Ginchi sub-site of Holetta Agricultural Research Center during the main cropping season of 2018. The overall mean result indicated that the released variety, Walqaa (SRCPX80Ab2596), showed the highest mean DM yield followed by the recent check (SRCPX80Ab2291) while the check variety (CI-8251) which was released earlier and commonly used for vertisol gave the lowest DM yield. Walqaa (SRCPX80Ab2596) had the highest percent increase in DM yield, CP yield, and digestible yield advantages over the standard check variety (CI-8251) which was released earlier and commonly used for vertisol conditions. Similarly, the Walqaa (SRCPX80Ab2596) had a relatively better percent increase in DM yield, CP yield, and digestible yield advantages over the recently released variety (SRCPX80Ab2291). Moreover, the Walqaa (SRCPX80Ab2596) had seeds yield advantage over the earlier released variety (CI-8251). The nutritional qualities indicated that the candidate varieties had advantages over the standard check variety (CI-8251) in terms of the leaf-to-stem ratio, CP, and IVDMD contents. Generally, the Walqaa (SRCPX80Ab2596) had a relatively better leaf-to-stem ratio, CP, and IVDMD advantages over the standard check variety (CI-8251). The national variety releasing committee evaluated the varieties at field conditions in October 2018. Based on their evaluation result, oat variety Walqaa (SRCPX80Ab2596) was officially released in November 2019 for production in the high altitude areas and similar agro-ecologies of the country. The pre-basic and basic seeds of the released variety Walqaa (SRCPX80Ab2596) are maintained by the feeds and nutrition research program of Holetta Agricultural Research Center.

Keywords: Oat, quality, variety release, variety verification, yield

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1. INTRODUCTION

Among other cultivated forage crops, oat (*Avena sativa* L.) is widely utilized in the highland farming system of Ethiopia. It is adapted to a wide range of soil types, altitudes and rainfall conditions. It can tolerate waterlogged conditions better than most of the other cereals (Alemayehu, 1997). As compared to the other cereal crops, oat is broadly adapted to marginal environments with low fertility soils, cool-wet and low rainfall climates (Hoffman, 1995; Buerstmayr et al., 2007; Ren et al., 2007). It is widely known that oat varieties are relatively best in cool and moist climates, have poor soil fertility status, and tolerate a very wide pH range and soils of poor drainage, fertility, and texture (Boonman, 1993). Lulseged (1981) and IAR (1987) have also reported that experiments done in the different testing sites in the highlands showed adaptations to waterlogging, resistance to diseases except for rust, performs better on poor soils and its utilization as forage becomes widely practiced. Oat is used for human food and livestock feed worldwide (Peterson et al., 2005; Achleitner et al., 2008). Oat is a dual-purpose crop and is used as both forage and grain (Suttie and Reynolds, 2004). It is a good source of energy, protein, vitamin B, phosphorus, and iron (Tiwana et al., 2008). It has adequate soluble carbohydrates and fibers (Peterson et al., 2005). The availability of good quality forage along with sufficient quality is essential to maintain a high level of milk and meat production in the country. Oat forms an exceptional fodder crop because of its excellent growth habit, quick regeneration ability, high palatability, succulence, and high nutritive value for animals.

Thousands of oat lines have been collected and tested for environmental adaptation and forage yield in the highlands (Astatke, 1976). Although some 20-25 varieties have been selected and maintained, their characteristic diversity has not been well investigated. Until recently, the focus of research works on forage crops in general and oats, in particular, has been limited to the evaluation and selection of species or varieties in terms of adaptation to edaphic and agro-ecological conditions as well as herbage yield potential. Choosing the proper variety for a given situation is a good step toward efficient production through further improvement. However, environmental adaptation and herbage yield alone is not adequate parameters to characterize and develop a variety for a given purpose. Recent observation of twenty-one oat varieties selected from both previous world collections and CIMMYT introduction at Holetta has indicated that the varieties are quite different in most of the major traits/parameters measured such as plant height, herbage yield, and grain yield.

In Ethiopia, vertisol covers 10.2% or 12.5 million ha of which 7.6 million ha occur in the Ethiopian highlands and are the fourth most important soils after Lithosol (16.2%), Cambisol (15.3%) and Nitosol (11.8%) (Mesfin and Jutzi, 1989). Despite this soil is very fertile, its productivity is constrained by unique soil physical properties. Due to the high water-holding capacity of this soil, aeration becomes a limiting factor for root growth and activity unless counterbalanced by morphological and physiological adaptation of the roots. Muluneh (2006) reported that the yield of vetch species produced on red soil (Holetta) was more than double compared to the results recorded on black soil (Ginchi) because the soil of Ginchi site is waterlogged which inhibits soil aeration, nutrient absorption and root growth that made plants stunted and reduced growth rate. Getnet and Ledin (2001) also reported that soil type was found to be the most important factor affecting biomass yield and hence herbage production on the well-drained red soil was almost double compared to the black soil. Different varieties respond differently to different soil types, climatic, and management conditions. Recommendations made on oats so far have been on some general aspects of the varieties, mainly environmental adaptation and herbage yield. Accordingly, few varieties have informally reached and being under production by farmers in some areas of the highlands. However, from some formal and informal surveys made in the highlands, it has generally been realized that the lack of specific recommendations for specific purposes has been the major problem faced by farmers concerning oat utilization as livestock feed. Accordingly, the selection of promising oat varieties for vertisol conditions is vital to improving the productivity of these varieties under black vertisols. Therefore, this paper presents the forage yield performance, nutritional qualities, agro-ecological adaptation, disease reaction, and other morpho-agronomic and management recommendations of the recently released oat variety Walqaa (SRCPX80Ab2596) for vertisol conditions.

2. MATERIALS AND METHODS

2.1 Description of the Study Sites

This study was conducted in the central highlands at Kuyu and Ginchi sub-sites of Holetta Agricultural Research Center during the main cropping seasons of 2015-2018 under rainfed conditions. The rainfall of the study sites is bimodal and about 70% of the precipitation falls in the period from June to September, while the remaining 30% falls in the period from March to May. The trial sites' geographical position and physicochemical properties of the soil are summarized in Table 1.

Table 1. Test locations and physicochemical properties of the soils

Parameters	**Kuyu**	**Ginchi**
Latitude	9° 00'N	9°02’N
Longitude	38° 30'E	38°12’E
Altitude (masl)	2400	2200
Distance from Addis Ababa (km)	29	75
Annual Rainfall (mm)	1044	1095
Daily minimum temperature (°C)	6.2	8.4
Daily maximum temperature (°C)	21.2	24.6
Soil type	Vertisol	Vertisol
Textural class	Clay	Clay
pH(1:1 H_2o)	5.63	6.50
Total organic matter (%)	5.63	1.30
Total nitrogen (%)	0.16	0.13
Available phosphorus (ppm)	6.95	16.50

2.2 Experimental Materials, Design, and Layout

One hundred fifty oat accessions were screened for one cropping season in terms of yield and yield components at Kuyu sub-site of Holetta Agricultural Research Center and the best performing twenty accessions were selected and advanced for further evaluation at Kuyu and Ginchi locations for two cropping seasons. Based on yield performance data, the fifteen best-performing accessions were selected and promoted to advanced variety trial for two years at Kuyu and Ginchi trial sites. Similarly, based on two years of yield performance data and nutritive values, two promising varieties (CI-1742 and SRCPX80Ab2596) were selected to be verified for their better yield performances and nutritional qualities at Kuyu and Ginchi trial sites. Non replicated 10m x 10m plot size was used for verification of the varieties. The recommended seeding rate of 100 kg/ha was used at sowing and the seed was sown in rows of 20 cm. Diammonium Phosphate (DAP) fertilizer at the rate of 100 kg/ha was uniformly applied to all varieties during sowing. All recommended management practices were uniformly applied for all varieties during the experimental periods.

2.3 Data Collection and Sampling

Measurements of plant height were taken from three plants randomly in each plot using a height measuring meter from the ground level to the tip of the panicle. For the determination of biomass yield, varieties were harvested at the forage harvesting stage. The weight of the total fresh biomass yield was recorded from each plot in the field and the estimated 500 g of their representative samples were taken from each plot to the laboratory. The estimated 500 g sample taken from each plot was weighed to know the total sample fresh weight using a sensitive table balance and manually fractionated into leaf and stem. The morphological parts were separately weighed to know their sample fresh weight, oven-dried for 72 hours at a temperature of 65^oC, and separately weighed to estimate the proportions of these morphological parts. The proportion of each morphological fraction in percent was then computed as the ratio of each dry biomass fraction to total dry biomass multiplied by 100. The crude protein yield was calculated by multiplying crude protein content with the total biomass yield and then dividing by 100%. The digestible yield was also determined by multiplying IVDMD with the total biomass yield and then dividing by 100%.

2.4 Laboratory Analysis

The oven-dried samples, at a temperature of 65^oC for 72 hours, were used for laboratory analysis to determine the chemical composition and *in vitro* dry matter digestibility of the varieties. The dried samples were then ground to pass a 1-mm sieve and the ground samples were used for laboratory analysis. The analysis was made for the different nutritional parameters. Total ash content was determined by oven drying the samples at 105^0C overnight and by combusting the samples in a muffle furnace at 550^oC for 6 hours (AOAC, 1990). Nitrogen (N) content was determined following the micro-Kjeldahl digestion, distillation, and titration procedures (AOAC, 1995), and the crude protein (CP) content was estimated by multiplying the N content by 6.25. The structural plant constituents like neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson procedure (1985). The *in vitro* dry matter digestibility (IVDMD) was determined according to the Tilley and Terry procedure (1963).

3. RESULTS AND DISCUSSION

3.1 Adaptation

The released variety Walqaa (SRCPX80Ab2596) is well adapted for the high-altitude areas of the country. The variety performed very well in areas with an altitude of 1500 to 3000 meters above sea level which has an annual rainfall of 700 to 1500 mm. It could also be possible to extend the production of the released variety to other areas with similar agro-ecologies after doing adaptation trials. The released variety produces relatively better forage DM yield when the recommended fertilizer rate and seeding rate are applied in vertisol and other soil types at planting. Generally, the released oat variety has better forage DM yield and seed yield performance in the high-altitude areas when the variety sown after the first shower of rain in June.

3.2 Varietal Evaluation

Two best-performing varieties of oat (CI-1742 and SRCPX80Ab2596) were selected from fifteen varieties for a Variety Verification Trial (VVT). The selected two varieties of oat were sown at Kuyu and Ginchi sub-site of Holetta Agricultural Research Center and sub-site. The National Variety Releasing Committee (NVRC) evaluated the varieties at field conditions in October 2018. Based on their evaluation result, the best-performing oat variety Walqaa (SRCPX80Ab2596) was officially released in November 2019 to be utilized by various end-users in the highland areas. The mean plant height of the candidate varieties with the standard checks is summarized in Table 2. The result indicated that the released variety had the highest mean plant height when compared to other varieties and the two standard checks.

Table 2. Average plant height (cm) of oat varieties tested at Holetta Agricultural Research Center sub-sites

Variety	Location		Mean
	Kuyu	**Ginchi**	
CI-1742	105.0	75.0	90.0
SRCPX80Ab2596	140.0	88.3	114.2
R. Check: SRCPX80Ab2291	115.8	105.0	110.4
Check for vertisol: CI-8251	134.2	81.7	108.0
Mean	**123.8**	**87.5**	**105.7**

R. check = Recent check

3.3 Agro-morphological Characteristics

The released oat variety Walqaa (SRCPX80Ab2596) adapted well and gave better forage biomass yield in the highland areas ranging in altitude from 1500 to 3000 masl. The performance of the released oat variety is promising in the areas where annual rainfall ranges from 700 to 1500 mm. The released variety gave better forage biomass yield and seed yield in vertisol and other soil types. Despite vertisol is very fertile, its productivity is highly constrained by unique soil physical properties. However, the released variety tolerates the waterlogging and aeration problems to produce better yield under vertisol conditions. The released variety Walqaa (SRCPX80Ab2596) requires 85 to 100 days after planting to reach the forage harvesting stage. At the forage harvesting stage, the variety has a better leaf-to-stem ratio which is a good indication of quality feed. The released variety produces better forage biomass yield and seed yield when planted with a seeding rate of 100 kg/ha. The spacing of 20 cm between rows gave a better yield when the variety was sown with rows. For better establishment and yield, Diammonium Phosphate (DAP) fertilizer at the rate of 100 kg/ha should be applied at planting and the variety should be sown in early June. A summary of agro-morphological and nutritional characteristics of the released oat variety Walqaa (SRCPX80Ab2596) is indicated in Table 3.

Table 3. Agronomical, morphological and nutritional characteristics of Walqaa (SRCPX80Ab2596)

Characteristics	**SRCPX80Ab2596**
Species	*Avena sativa*
Common name:	oat
Variety name:	Walqaa (ወልቃ) (SRCPX80Ab2596)
Adaptation:	For highland areas
Soil type:	Vertisol
Altitude (m.a.s.l):	1500 – 3000
Rainfall (mm):	700 – 1500
Seeding rate (kg/ha):	75 – 100
Row planting (kg/ha)	75
Broadcasting (kg/ha)	100
Spacing for row planting (cm):	Inter-rows 20
Planting date:	Early June
Fertilizer rate (kg/ha):	100 kg DAP or 46/18 kg N/P_2O_5
Time of fertilizer application:	DAP at planting
Plant height at forage harvest (cm):	100 – 140
Days to forage harvesting (soft dough stage):	85 – 100
Days to seed harvesting	145 – 155
Leaf to stem ratio	1.0 – 1.2
Yield (qt/ha):	
Forage dry matter (DM):	50 – 100
Seed:	10 – 20
CP:	3.88 – 7.75
Digestible:	26.92 – 53.84
Straw:	60.0 – 100.0
1000 seed weight (gm):	30 – 35
Harvest index (%):	10 – 20
Fodder quality (g/kg DM):	
Ash:	97.7
CP:	77.5
NDF:	712.6
ADF:	483.0
ADL:	114.7
IVDMD:	538.4
Year of release	2019
Breeder/maintainer	HARC

3.4 Yield Performance

The forage biomass yield performance of oat varieties varied across locations during the experimental periods (Table 4). The result indicated that the highest mean DM yield (7.94 t/ha) was recorded at Kuyu while the Ginchi site produced the lowest (5.00 t/ha) mean DM yield. The released variety Walqaa (SRCPX80Ab2596) gave the highest mean DM yield (7.17 t/ha) followed by the recent check (SRCPX80Ab2291) while the check variety (CI-8251) which was commonly used for vertisol gave the lowest (5.61 t/ha) DM yield. The result indicated that the candidate varieties had percent yield advantages over the standard check which was commonly used for vertisol (Table 5). The candidate varieties had the highest percent increase in DM, CP and IVDMD yields over the standard check variety which was commonly used for vertisol. The released variety Walqaa (SRCPX80Ab2596) produced the highest percent increase in DM yield of 27.81 and 6.22% over the standard check CI-8251 and SRCPX80Ab2291 variety, respectively. Moreover, 36.59 and 5.66% increases in CP yield were recorded for the released variety Walqaa over the standard check CI-8251 and SRCPX80Ab2291 variety, respectively. Similarly, 29.53 and 5.75% increase in IVDMD were recorded for the released variety Walqaa over the standard check CI-8251 and SRCPX80Ab2291 variety, respectively. Generally, the released variety Walqaa (SRCPX80Ab2596) gave the highest percent increase in DM yield, CP yield, and digestible yield advantages over the two standard checks.

Table 4. Forage biomass yields (t/ha) of oat varieties tested at Holetta Agricultural Research Center sub-sites

	Location		
Variety	**Kuyu**	**Ginchi**	**Mean**
CI-1742	7.77	4.95	6.36
SRCPX80Ab2596	9.30	5.04	7.17
R. Check: SRCPX80Ab2291	7.06	6.44	6.75
Check for vertisol: CI-8251	7.63	3.58	5.61
Mean	**7.94**	**5.00**	**6.47**

R. check = Recent check

Table 5. The yields percent increase of oat varieties over the standard checks

Variety	**DM Yield**	**% increase**	**CP yield**	**% increase**	**IVDMD yield**	**% increase**
CI-1742	6.36	-5.78 (13.37)	0.50	-5.66 (21.95)	3.40	-6.85 (15.25)
SRCPX80Ab2596	7.17	6.22 (27.81)	0.56	5.66 (36.59)	3.86	5.75 (29.53)
R. Check: SRCPX80Ab2291	6.75	-	0.53	-	3.65	-
Check for vertisol: CI-8251	5.61	-	0.41	-	2.98	-

R. check = Recent check; Number in parenthesis indicates % increase from the check which is commonly used for vertisol (CI-8251)

The seed yield performance of oat varieties is indicated in Table 6. The result showed that the highest mean seed yield (15.68 qt/ha) was recorded at Kuyu while the Ginchi site produced relatively the lowest (15.13 qt/ha) seed yield under vertisol conditions. The candidate variety (CI-1742) gave the highest mean seed yield (16.70 qt/ha) followed by the released variety Walqaa (SRCPX80Ab2596) while the variety released earlier and commonly used for vertisol (CI-8251) produced the lowest seed yield. Generally, the released variety Walqaa (SRCPX80Ab2596) had a 6.01% increase in seed yield over the previously released and commonly used vertisol variety (CI-8251).

Table 6. Seed yield (qt/ha) of oat varieties and their mean seed yield advantage over the standard checks.

Variety	Locations		Mean	% Increase over checks
	Kuyu	Ginchi		
CI-1742	16.45	16.94	16.70	13.07 (14.07)
SRCPX80Ab2596	15.02	16.01	15.52	5.08 (6.01)
R. Check: SRCPX80Ab2291	15.90	13.64	14.77	
Check for vertisol: CI-8251	15.35	13.92	14.64	
Mean	**15.68**	**15.13**	**15.41**	

R. check = Recent check; Number in parenthesis indicates percent increase over the check for vertisol (CI-8251).

3.5 Quality Attributes

The chemical composition and *in-vitro* dry matter digestibility of oat varieties are summarized in Table 7. The result indicated that the candidate variety (CI-1742) had the highest (108.3 g/kg DM) ash content followed by the recently released standard check variety (SRCPX80Ab2291) which had an ash content of 106.8 g/kg DM, indicating a high mineral concentration in the plant. On the other hand, the standard check variety (CI-8251) which was released earlier and used commonly for vertisol had the lowest (93.9 g/kg DM) ash content followed by the currently released variety named Walqaa (SRCPX80Ab2596) which had an ash content of 97.7 g/kg DM. The CP content of the tested oat varieties showed a difference, ranging from 72.7 to 79.0 g/kg DM. The highest CP content (79.0 g/kg DM) was recorded for the recently released standard check variety (SRCPX80Ab2291) followed by variety CI-1742 and the Walqaa (SRCPX80Ab2596) variety while the earlier released standard check variety (CI-8251) gave the lowest CP content. The lowest NDF (701.0 g/kg DM) and ADF (454.4 g/kg DM) contents were recorded for the earlier standard check variety (CI-8251) while the candidate variety (CI-1742) had the lowest (454.4 g/kg DM) ADL content when compared to other varieties. On the other hand, variety CI-1742, the recently released variety (SRCPX80Ab2291) and the standard check variety (CI-8251) showed the highest NDF (730.2 g/kg DM), ADF (509.4 g/kg DM) and ADL (116.5 g/kg DM) contents, respectively. The IVDMD contents of the tested oat varieties ranged from 531.8 to 540.7 g/kg DM. The SRCPX80Ab2291 produced the highest IVDMD content followed by the Walqaa (SRCPX80Ab2596) while the standard variety (CI-8251) gave the lowest IVDMD content. The candidate varieties had advantages over the standard check variety which was released and commonly used for vertisol in terms of the leaf-to-stem ratio, CP and IVDMD (Table 8). The result indicated that the highest percent increase (23.2%) in the leaf-to-stem ratio was recorded for the Walqaa (SRCPX80Ab2596) over the standard check variety (CI-8251) which was released earlier and commonly used for vertisol. The highest CP percent increase of 7.98 and 6.60% over the standard check was recorded for CI-1742 and the Walqaa (SRCPX80Ab2596), respectively. The IVDMD of the candidate varieties also showed an advantage over the standard check variety (CI-8251). The Walqaa (SRCPX80Ab2596) showed IVDMD advantages of 1.24% over the standard check variety (CI-8251).

Table 7. Chemical compositions and *in-vitro* dry matter digestibility of oat varieties

	g/kg DM					
Variety	**Ash**	**CP**	**NDF**	**ADF**	**ADL**	**IVDMD**
CI-1742	108.3	78.5	730.2	490.8	102.6	534.4
SRCPX80Ab2596	97.7	77.5	712.6	483.0	114.7	538.4
R. Check: SRCPX80Ab2291	106.8	79.0	727.2	509.4	111.6	540.7
Check for vertisol: CI-8251	93.9	72.7	701.0	454.4	116.5	531.8

R. check = Recent check

Table 8. Percent increases of oat varieties over the standard checks

Variety	**LSR**	**% increase**	**CP**	**% increase**	**IVDMD**	**% increase**
CI-1742	1.02	8.5 (7.4)	7.85	-0.63 (7.98)	53.44	-1.17 (0.49)
SRCPX 80Ab2596	1.17	24.5 (23.2)	7.75	-1.90 (6.60)	53.84	-0.43 (1.24)
R. Check SRCPX80Ab2291	0.94	-	7.90	-	54.07	-
Check for vertisol: CI-8251	0.95	-	7.27	-	53.18	-

R. check = Recent check; LSR= Leaf to stem ratio; CP= Crude protein; IVOMD= in-vitro dry matter digestibility; Number in parenthesis indicates % increase from the check which commonly used for vertisol (CI-8251)

3.6 Reaction to Diseases and Pests

Data recording on major diseases and insect pests was done for all oat varieties starting from preliminary observation in the test locations. Based on the standard rating scale of 1-9, where 1 is highly resistant and 9 is highly susceptible, the candidate varieties were found to be tolerant to moderately tolerant for the recorded major disease and insect pests in the test locations during the study periods. No chemical was applied during the evaluation of the varieties starting from the initial screening to verification to control the major disease and insect pests. The Walqaa (SRCPX80Ab2596) was tested for its diseases and insect pests reactions and found to be tolerant to major diseases and insect pests which can affect the variety. The tolerance reaction of the variety could be integrated with other diseases and insect pests' management strategies for better results. Generally, the released variety had better tolerance to major diseases and insect pests.

CONCLUSIONS

The morpho-agronomic performance and nutritional characteristics of tested oat varieties varied across the test environments due to the differential response of the varieties to various biotic and abiotic factors. The released variety Walqaa (SRCPX80Ab2596**)** adapted and gave better yield in the highland areas ranging in altitude from 1500 to 3000 masl. The performance of the released variety is promising in the areas where annual rainfall ranges from 700 to 1500 mm. The released variety has better forage biomass yield and seed yield on vertisol and other soil types. The released variety produces better forage DM yield and seed yield when a recommended fertilizer rate and seeding rate are applied at planting. The nutritional qualities indicated that the candidate varieties had advantages over the standard check variety in terms of the leaf-to-stem ratio, CP, and IVDMD contents. Generally, the released variety Walqaa (SRCPX80Ab2596) had relatively better leaf-to-stem ratio, CP, and IVDMD contents advantages over the standard check (CI-8251) variety which was released earlier and commonly used for vertisol conditions. Therefore, the national variety releasing committee evaluated the varieties at field conditions in October 2018. Based on their evaluation result, oat variety Walqaa (SRCPX80Ab2596) was officially released in November 2019 for production in the high-altitude areas and similar agro-ecologies of the country. The pre-basic and basic seeds of the released variety are maintained by the feeds and nutrition research program of Holetta Agricultural Research Center.

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CONFLICT OF INTEREST

There is no conflict of interest, according to the authors.

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