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Research Article

Evaluation of Commercial Head Cabbage (*Brassica oleracea* L.) Varieties in Kellem Wollega Zone

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Abstract

Cabbage *(Brassica oleraceae* var.capitata) is one of the most important leafy vegetables worldwide and is adapted to cool moist conditions. The experiment was conducted at two sub-sites of Haro Sabu Agricultural Research Center from 2020-2024 at Belam FTC and in 2024 at Gute Anani FTC of Kellem Wollega zone, during main cropping season. Six commercial head cabbage were evaluated with objective the objective of selecting and recommending high yielder, disease and insect pest tolerant head cabbage varieties at for potential areas of Kellem Wollega. Analysis of variance(ANOVA revealed that the main effect of variety showed highly significant effect on days to head initiation and significant on plant height, plant spread, head length, average head weight, marketable yield, total yield and disease reaction. Similarly the main effect of environment showed highly significance on all recorded parameters. The highest ($26.4tha^{-1}$) and the lowest ($20tha^{-1}$) marketable yield were recorded from Bakker and Delta varieties. Hence Bakker and Olter varieties were recommended for the yield increment of head cabbage in the studied areas of Western Oromia.

Keywords

Bakker, Head Cabbage, Head Weight, Olter

1. Introduction

Cabbage (*Brassicaoleraceae*var.*capitata*) is one of the most important leafy vegetables worldwide and is adapted to cool moist conditions [12, 14]. This leafy vegetable can grow well on wide range of soil types provided adequate moisture and fertilizer is supplied. Cabbage is cultivated for its head, which consists of water (92.8%), protein (1.4mg), calcium (55.0mg) and iron (0.8mg); the leaves are eaten raw in salads or cooked. The optimum means temperature for growth and quality head developmentis15-18 ℃, with a minimum temperature of 4 ℃ and a maximum of 24 ℃. Cabbage grows well on arrange of soils with adequate moisture and fertility. It tolerates a soil pH range of 5.5-6.8 and it is heavy feeder [8]. The average water content of cabbage heads is about 90percent, with a high vitamin B, C and calcium and phosphorous content. Smaller heads of poor quality are produced when the crop is grown under limited water supply, particularly during the later part of the growing period [5].

Cabbage is cultivated in mid altitude and highland areas of Ethiopia. It is mostly produced by stallholder farmers. Cabbage is mostly produced during the rainy season, although some commercial farmers produce it during dry season using irrigation. According to [2], the average annual production of

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cabbage in the Ethiopia during 2021/2022 production season was estimated to be 39,767.197 tons which was produced on 6,546.11 hectares of land with productivity of 60.75qu/ha. Accordingly the production of head cabbage estimated in 2022 was produced on 3510.66 hectares and the average production was 29771.48tons with productivity of 84.80Qu/ha [2]. Despite increasing the area of production from 6420.62 to 6546.11hectares the production of head cabbage was decreased from 544,230.83quintqls to 397,671.97quintals [1, 2]. However Oromia region share the highest percentage in area of production, production in quintals and productivity her hectares. In 2022 main cropping season Oromia shares 53.63% and 74.86% area of production and production in quintals, respectively, which indicates Oromia region had the potential for head cabbage production. In Kelem Wollega zone the productivity of head cabbage was 10.21toneha^{-1} [2] which was very low relative to its potential productivity and comparison to world head cabbage production. According to [5], under rain fed conditions, yields of 25 to 35 toneha^{-1} fresh heads are normal, with a maximum of about 50toneha^{-1} when sprayed and well-fertilized. Under ideal climatic conditions and good irrigation and crop management, yields can be as high as 85ton/ha.

Despite the potential production of head cabbage in Kellem Wollega, low yield of head cabbage producing farmers and organization is not solved yet. This low yield might be due lack of improved select variety, agronomic practices and different diseases. Among this low yield attributing problems; lack of selected improved variety is the core issue which should solved first. For this reason the experiment was conducted with the objective of selecting and recommending high yielder, disease and insect pest tolerant head cabbage varieties for potential areas of Kellem Wollega Zone.

2. Material and Methods

2.1. Experimental Materials and Design

The experiment was conducted at Bellam FTC from 2021 to 2024 and Gute Anani FTC in 2024 of Haro Sabu Agricultural Research Center sub-sites. Six improved commercial head cabbage varieties (Olter, Bakker, Delta, Royal, Monarch and Popvriend) were evaluated to each others.

The experiment was laid out in randomized complete block design (RCBD) with three replications. Each variety was planted in the main field in a gross plot size of 3.6m*2.5m with blanket recommended spacing of 50cm and 40cm between rows and plants, respectively. The three middle rows were used for data collection leaving the two rows as borders. All agronomic practices (transplanting time, cultivation, and weeding) and fertilizer were applied uniformly for all plots according to the recommendation of the crop.NPS and urea fertilizers were used in the rate of 200Kgha^{-1} and 100Kgha^{-1}, respectively.

2.2 Data Collection and Data Analyses

Ten plants were randomly sampled from middle three rows. Data on plant height (cm), head diameter (cm), head length (cm) and average head weight (kg) were recorded per plant and head basis. While measurements such as days head in initiation, days to maturity, weight of marketable yield toneha^{-1}(tone) weight of unmarketable yield toneha^{-1}(tone), total yield hectare^{-1}(tone) and disease (black rot) were taken on plot basis.

All collected data were analyzed using SAS and GenStat software. Least Significant Differences (LSD) was used to compare the treatment mean using Duncan's Multiple Range at the 5% level of significance.

3. Result and Discussion

3.1. ANOVA

The combined analysis of variance (ANOVA) for growth parameters, yield components and yield data of six head cabbage varieties grown at Belam FTC and Gute Anani FTC from 2021 to 2024 revealed significant varietal difference (Table 1).

Table 1. *Analysis of Variance for commercial head cabbage varieties evaluation in Haro Sabu Agricultural Research Center.*

Source of variation	D.f	Mean squares										
		DHI	DM	PH (cm)	PS (cm)	HD (cm)	HL (cm)	AHW (kg)	WMY (tpha)	WUMY (tpha)	TY (tpha)	BR
Replication	2	0.70ns	7.54ns	14.71ns	26.02ns	9.83ns	5.27ns	0.17ns	242.69ns	27.85ns	425.89ns	3.73ns
Variety	5	49.73**	2.81ns	9.29*	28.74*	3.37ns	2.83*	0.06*	92.36*	6.18ns	116.57*	0.91*
Environment	4	2317.85**	369.93**	228.74**	1105.70**	101.98**	132.61**	1.66**	241.72**	59.82**	396.59**	2.37**

Source of variation	D.f	Mean squares										
		DHI	DM	PH (cm)	PS (cm)	HD (cm)	HL (cm)	AHW (kg)	WMY (tpha)	WUMY (tpha)	TY (tpha)	BR
Variety * Environment	20	19.88*	13.13ns	6.82ns	12.73ns	4.66ns	4.07ns	0.06ns	106.69**	12.75*	171.13**	0.88**
Residual	58	9.85	7.88	5.29	19.07	4.14	2.46	0.05	35.14	5.89	49.12	0.53
CV (%)		8.59	3.48	9.2	12.57	17.13	11.71	32.98	26.39	118.76	28.59	32.01

Where Df, DHI, DM, PH, PS, HD, HL, AHW(kg), WMYtpha, WUMYtpha, TYtpha, BR and CV are, degree freedom of error, days to head initiation, days to maturity, plant height, plant spread, head diameter, head length, average head weight, weight of marketable yield tone/ha, weight of unmarketable yield tone/ha, total yield tone/ha and coefficient of variation, respectively.

3.2. Days to Head Initiation and Days to Maturity

From the combined mean of analyses days to 50% head initiation was revealed highly significance ($p \leq 0.01$) effect on head cabbage varieties, however days to maturity was non-significant (Table 1).The earliest days to head initiation (34) days was recorded from Popvriend variety while the latest (39.07) days to head initiation was recorded from Delta variety (Table 2).

The main differences among varieties on days to head initiation might be genetic factor which either accelerate or lag the lifecycle of the crop. This is similar with the work of [11] who reported different days head initiation for different varieties.

3.3. Plant Height and Plant Spread

Analysis of variance showed that there were a significant ($P \leq 0.05$) effect on plant height and plant spread, while there were highly significant on environment for both plant height and plant spread ($p \leq 0.01$) (Table1). The longest (26.07cm) and the shortest (23.79cm) plant height were recorded from Delta and Monarch varieties (Table 2). Accordingly, the longest (36.15cm) and the shortest (32.21cm) plant spread were recorded for the same variety as in plant height, respectively. The current study was in line with work of [11] who reported significant plant height on different head cabbage varieties in which the highest (30.74cm) result was observed for Monarch variety and the minimum (21.93cm) was recorded for Gloria variety. Similarly, [9] reported that significant effect of different varieties on plant height and plant spreading in which Wonder ball was the tallest (28cm) and Green coronet was the shortest (24.2cm) cultivar. Likewise [9] also reported significant effect of plant spreading on different head cabbage varieties; where the highest and the lowest plant spreading was recorded for Omphalus and Green challenger, respectively.

3.4. Head Diameter and Head Length

Analysis of variance showed that there was a significant ($p \leq 0.05$) effect on head length due to varieties and there was non-significant effect on head diameter due to variety. However there was highly significant effect ($p \leq 0.01$) on both parameters due to environment and there was no interaction effect of variety and environment (Table 1). The longest (14.23cm) and the shortest (12.99cm) head length were recorded from Royal and Bakker varieties, respectively (Table 2). The significant effect of variety on head length might be due to head firmness different varieties which directly related with compactness and looseness of the head.These results suggest large genetic difference among the variety and that environmental differences between varieties influence the expression of crop growth characters. In line with this current study, [7] reported significant of variety on head length and head width of thirty-two hybrid and open pollinated head cabbage varieties. Similarly [6] reported that significant effect of varieties on head diameter of four varieties.

Table 2. *Combined mean of yield and yield components of commercial head cabbage varieties.*

Varieties	DHI	DM	PH (cm)	PS (cm)	HD (cm)	HL (cm)	AHW (kg)	WMY (tpha)	WUMY (tpha)	TY (tpha)
Bakker	37.13ab	80.33	24.68ab	34.6ab	11.47	12.99b	0.71ab	26.4a	2.67	29.07a
Olter	37.2a	80.8	24.81ab	35.33ab	11.95	13.29ab	0.72ab	24.5ab	1.5	26.00ab

Varieties	DHI	DM	PH (cm)	PS (cm)	HD (cm)	HL (cm)	AHW (kg)	WMY (tpha)	WUMY (tpha)	TY (tpha)
Monarch	36.93ab	80.33	23.79b	32.21b	11.39	13.13ab	0.6b	22.11abc	2.95	25.06ab
Delta	39.07a	81.47	26.07a	36.15a	11.83	13.4ab	0.74ab	20c	1.64	21.65b
Popvriend	34c	80.47	25.15ab	34.44ab	11.9	13.41ab	0.65ab	20.84bc	1.41	22.25b
Royal	34.87bc	80.53	25.57a	35.6a	12.72	14.23a	0.77a	20.93bc	2.09	23.02b
Mean	36.53	80.66	25.01	34.72	11.88	13.41	0.7	22.47	2.04	24.51
LSD	2.29	NS	1.68	3.19	NS	1.15	0.17	4.33	NS	5.12
CV (%)	8.59	3.48	9.2	12.57	17.13	11.71	32.98	26.39	118.76	28.59

Where DHI, DM, PH, PS, HD, HL, AHW(kg), WMYtpha, WUMYtpha, TYtpha and CV are days to head initiation, days to maturity, plant height, plant spread, head diameter, head length, average head weight, weight of marketable yield tone/ha, weight of unmarketable yield tone/ha, total yield tone/ha and coefficient of variation, respectively.

3.5. Average Head Weight

The analysis of variance showed that there was a significant ($p<0.05$) effect on variety and highly significant effect on environment ($p<0.01$) where as there was no significant effect on the interaction of variety and environment (Table 1). The significant effect of environment on head weight might be due to head firmness of different varieties which directly related with compactness and looseness of the head. The highest (0.770kg) and the lowest (0.60kg) head weight were recorded from Royal and Monarch varieties, respectively (Table 2). This significant head weight also attributed to their varietal responses to attain firmed or loose head, since varieties differ in their development in head formation and maturity (Richardson, 2013). In line with this result, [7] reported that significance effect of head weight on head cabbage varieties. Similarly, [11] reported that significant head weight for different head cabbage varieties in which Royal and DSA Copenhagen was attained maximum and minimum head weight, respectively. In agreement to the current study, [6] significance effect f environment oh head weight in which different cabbage varieties exhibit different response in different environmental conditions. On the similar way [13] reported significant average head weight for different varieties in which the highest (2.56kg) and the lowest (1.17kg) per plant were recorded for Bigsun111 and Supper Green varieties, respectively.

3.6. Marketable Yield and Unmarketable Yield

The effect of variety showed significant ($p<0.05$) on marketable yield, where as the effect of environment and its interaction with variety revealed highly significant ($p<0.01$), however, the effect of variety was not significant and the environment and its interaction with variety was significant on unmarketable yield (Table 1). The significance effect of variety and environment on marketable yield might be due to different head length and weight of different varieties. This also related with head firmness which might directly affects marketable, unmarketable and total yield of head cabbage. On the other hand highly significant effect environment and its interaction with variety on marketable and unmarketable yield might be due to fluctuation of rainfall, moisture, and temperature and soil fertility over years which may reduce or increase marketable yield of head cabbage. The highest ($26.4tha^{-1}$) marketable yield was recorded for Bakker variety and the lowest ($20tha^{-1}$) marketable yield was recorded for Delta variety (Table 2). This study was agreement with [7] who reported significant effect of variety on marketable yield; where marketable head yield was ranged between 23 and 49t/ha. Likewise another author reported that the variety 'Caribbean Queen' provided the highest mean yields of marketable heads of cabbage per hectare at 45.4t/ha compared to 'Benelli' at 37.0t/ha and 'Cairo'at$33.6tha^{-1}$ [8].

3.7. Total Yield

The effect of variety showed significant ($p<0.05$) on total yield, where as the effect of environment and its interaction with variety revealed highly significant ($p<0.01$) (Table 1). The significance effect of variety, environment and their interaction on total yield might be due significant effect of variety and environment on marketable which directly influence total yield of head cabbage. High yield of cabbage largely depends on the specific environmental conditions; therefore, a well-known variety or hybrid is chosen and produced in a familiar environment (climate conditions, pathogens) using complete agricultural practices and mechanization [3]. The highest ($29.07tha^{-1}$) and the lowest ($21.65tha^{-1}$) total yield were obtained from Bakker and Delta varieties, respectively. In agreement with result [6] reported that significance effect of variety and environment on total and

marketable yield at different environmental conditions. Similarly [10] reported significant effect of varieties on total yield in which the maximum (164.14tha^{-1}) and the minimum (129.49tha^{-1}) were recorded for Royal and DSA Copenhagen varieties, respectively. Beside high yielder Bakker and Olter varieties were more stable over year and location than other varieties (Figure 1).

3.8. Disease Reaction of Varieties

The major recorded disease of head cabbage at the studied areas was black rot *(Xanthomonas campestris pv. campestris*). Black rot is a bacterial disease that spreads through water. It affects leaves, and often results in head rot. It can be severely yield limiting. A few cabbage varieties have some degree of tolerance, but for the most part, resistant cultivars are not currently available [15]. The main factor of variety was significantly affected by black rot; whereas the main factor of environment and its interaction with variety was highly significant (Table 1). The significance effect of variety, environment and their interaction might be due to climatic, rainfall, sunlight and moisture fluctuation over years which may favor or disfavor the occurrence of this disease. The highest (2.67) disease record was from Royal variety; whereas the lowest (2.07) disease record was from Olter, Delta and Popvriend varieties (Table 3). In agreement with this result [4] suggested that there was a significant effect of black rot on different cultivars of head cabbage.

Table 3. *Combined mean of black rot on commercial head cabbage varieties.*

Varieties	Blackrot
Bakker	2.33ab
Olter	2.07b
Monarch	2.4ab
Delta	2.07b
Popvriend	2.07b
Royal	2.67a
Mean	2.27
LSD(0.05)	0.53
CV(%)	32.01

3.9. Comparison Plot for Genotypes Based on the Concentric Circle

An ideal variety is one which is nearest to the center of circle. Hence in the current study, the plot reflected that Bakker variety is the most ideal variety. This also reflects that; the variety has highest marketable yield and more stable. Good varieties are those which are closer to the ideal varieties. However, Royal, Popvriend and Delta are the worst varieties as their position in the plot are located far from the concentric circle.

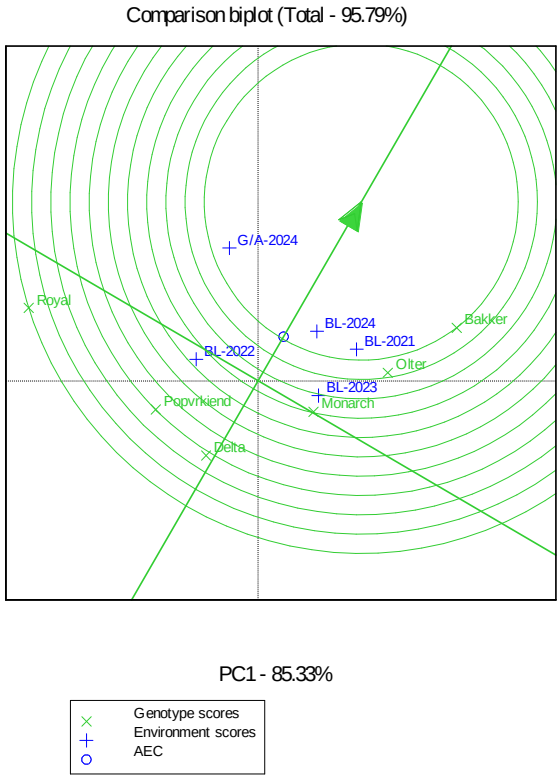

Figure 1. *GGEbi-plot based on variety focused scaling for comparis on o variety or marketable yield stability.*

4. Conclusion and Recommendation

The evaluation of head cabbage varieties were done to study the adaptability and performance of improved commercial head cabbage varieties. Significant difference was shown on different yield related parameters *viz* plant spread, head length, average head weight among varieties. The highest and the lowest average head weight was recorded from Royal and Monarch varieties, respectively. Similarly the highest marketable yield was recorded for Bakker variety and the lowest marketable yield was recorded for Delta variety. Generally, on the base of combined analysis, significantly highest mean value of weight of marketable yield was obtained from Bakker and Olter varieties. These varieties also stable than all other varieties evaluated and tolerant to black rot diseases. Thus, they are recommended for demonstration in studied areas and similar agro-ecologies.

Abbreviations

ANOVA	Analysis of Variance
CSA	Central Statistical Agency
CV	Coefficient of Variation
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
UME	University of Minnesota Extension

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Author Contributions

Kibiru Kena: Conceptualization, Methodology, Supervision, Visualization, Writing – original draft, Writing – review & editing

Alemayehu Latera: Data curation, Formal Analysis, Methodology, Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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