

Full Length Research Paper

Evaluation of head yield and participatory selection of horticultural characters in cabbage (*Brassica oleraceae* var. *capitata*)

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Cabbage is an important leafy vegetable in sub-Saharan Africa, yet breeding and seed production activities take place in Europe and Asia. Participatory evaluation of varieties alongside head yield was carried out to select preferred varieties. Field experiments were conducted during the 2008 long rainy season and the 2008/09 short rainy season at AVRDC–The World Vegetable Center, Regional Center for Africa, Arusha, Tanzania. A randomized complete block design with three replications was adopted for the study. Results indicated that for each season marketable head yield differed significantly ($P < 0.05$) among the varieties. Performance for head yield varied in response to the biotic and abiotic environment. During the long rainy season Gloria F₁ and Victoria F₁ were best for head yield, while Quick Start and Rotan performed best for head yield during the short rainy season. For taste, head shape and firmness, Summer Summit F₁ was best. Tropical Delight was preferred for head size, firmness, and low incidence of loose heads. Gloria F₁ was identified as an early maturing variety with good head solidity. Good-tasting cabbage varieties are Summer Summit, Summer Glory and Bonus. Research on stability of performance for head yield over seasons, years and locations is important for future selection.

Key words: Cabbage, marketable head yield, farmer participatory research, sensory evaluation, Tanzania, vegetable production.

INTRODUCTION

Cabbage (*Brassica oleraceae* var. *capitata*) is one of the most important leafy vegetables worldwide (Talekar, 2000). It originated in Northern Europe, the Baltic Sea coast (Monteiro and Luan, 1998) and the Mediterranean region (Vural et al., 2000), where it has been grown for more than 3000 years and is adapted to cool moist conditions (Tindall, 1993; Thompson, 2002). Cabbage is cultivated for its head, which consists of water (92.8%), protein (1.4 mg), calcium (55.0 mg) and iron (0.8 mg); the leaves are eaten raw in salads or cooked. The optimum mean temperature for growth and quality head development is 15 - 18°C, with a minimum temperature of 4°C and a maximum of 24°C. Cabbage grows well on a range of soils with adequate moisture and fertility. It tolerates a soil pH range of 5.5 - 6.8 and it is a heavy feeder. To

maintain growth, cabbage requires a consistent supply of moisture, and should as a general rule receive a minimum of 2.5 cm of water per week. With proper management, cabbage can produce 25 - 30 t/ha. Cabbage heads are ready for harvest 80 - 120 days after germination, depending on genotype and climate.

The importance of head cabbage in tropical and subtropical regions has increased considerably in recent decades. Recent estimates indicate Africa has 100,000 ha planted with head cabbage (van der Vossen et al., 2004). Based on sales of commercial seed, at least 40,000 ha of white-headed cabbage is grown in Kenya, Uganda and Tanzania; 10,000 ha in Malawi, Zambia and Zimbabwe; 4000 ha in Ethiopia; and 3000 ha in Cameroon. Almost all white-headed cabbage is produced for local urban markets. Mozambique imports considerable quantities of headed cabbage from South Africa and until recently also did so from Zimbabwe. Mwashu (2000) reported a total production of head cabbage in

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Tanzania to be about 208,919 t in 1996. However, in the 2004/05 cropping season, head cabbage production was 250,000 t and Chinese cabbage production was 4,000 t (Zoss, 2006). In Tanzania, cabbage is grown mostly in the cooler highland areas of Arusha, Tanga, Iringa, Mbeya and Morogoro. In a survey of Arumeru district Massomo (2002) noted that cabbage cultivation started in the mid-1970s, with a sharp increase in the number of cabbage growers from 1997 to 2001. Cultivation occurs throughout the year in places where irrigation facilities are available (Massomo et al., 2004a). Farm are less than 0.5 ha and most farmers grow one or two cabbage crops per year, mostly in monoculture, with the exception of a few villages with irrigation facilities where up to four cabbage crops are produced annually (Massomo et al., 2004a). Farmers in Arusha apply farmyard manure and inorganic fertilizers to remedy declining soil fertility (Massomo et al., 2004b). More than 30 cabbage varieties (open pollinated and hybrids) are cultivated in Tanzania; popular varieties are Gloria F₁, Glory of Enkhuizen and Romenco (Massomo et al., 2003).

Cabbage breeding and seed production takes place outside Africa and no landrace exists. Seed is imported from Europe and Asia and is sold by seed companies and other retail outlets. Most of these varieties are described to be high yielding and with varying levels of resistance to black rot (*Xanthomonas campestris*). Important horticultural characters in cabbage are head size, shape and firmness, taste, resistance to bolting, late flowering and maturity. Evaluating cabbage varieties for adaptation and yield will help farmers, breeders and seed companies select and develop varieties best suited to the local environment and market.

Farmer participatory research is increasingly recognized as a demand-driven process, where the end users (farmers) participate in the design, evaluation and implementation of new technology rather than just the final testing. Traditional top-down, prescriptive approaches to agricultural research and extension have been criticized (Ceccarelli et al., 1996). Participatory research is a simple, more direct way of evaluating multiple traits to assess the value of a variety to farmers. The approach is client-oriented, not controversial and based on the pretext that farmers are researchers in their own right and have indigenous knowledge of local conditions (Ceccarelli et al., 1996). The involvement of farmers in the selection process facilitates acceptance and adoption. This approach has been used extensively in sorghum (Nkongolo et al., 2008) and barley (Ceccarelli et al., 2001). Farmers' participatory selection has been applied to rice (Oyemanmi et al., 2008).

Farmers' choice of a variety depends on a combination of characters (high and stable head yield, resistance to insect pests and diseases, good taste, storability and firmness, head shape and size). Information on the local adaptation and performance of cabbage varieties for yield is limited, as is participatory research on horticultural characters and sensory evaluation. This paper describes

the performance of cabbage varieties for yield and other characters; it explains how farmers participate in research to identify and select cabbage varieties with preferred horticultural characters for cultivation in Arusha district, Tanzania.

MATERIALS AND METHODS

Materials, location, experimental design and statistical analysis

Thirty-two hybrid and open pollinated cabbage varieties marketed by seed companies in Tanzania were used in the study (Table 1). A widely cultivated variety (Gloria F₁) was included as check. Field trials were conducted during the 2008 long rainy season and the 2008/09 short rainy season at AVRDC – The World Vegetable Center, Regional Center for Africa, Arusha, Tanzania (lat 4.8°S long 3.7°E; alt. 1290 m). In Arusha, the long rains start in March and continue through May/June; the short rains begin in September/November and continue through December. The dry season occurs from January to March. The mean minimum and maximum temperatures during the long rainy season are 13.2 and 26.4°C respectively. The mean minimum and maximum temperature for the short rainy season are 18.5 and 31.9°C. Annual rainfall of 1085 mm was recorded on-station.

Field experiments were conducted in May and repeated in October 2008. A randomized complete block design with three replications was used; each plot consisted of two ridges 8 m long and 0.30 m high, with 0.60 m between ridges. Cabbage seedlings were raised in multipot seedling trays for four weeks and then transplanted to the sides of the ridges with 0.50 m space between plants. The experiment was furrow-irrigated every two days for the first two weeks after transplanting, then once a week thereafter. Weeding was carried out manually and frequently to maintain weed-free plots. Fertilizer NPK (20-10-10) was applied at the rate of 200 kg/ha during transplanting. Urea was applied at the rate of 90 kg/ha in a split application 30 days after transplanting and 30 days thereafter. Both evaluations were maintained as no-spray (insecticides and fungicides). Head yield was computed from a net plot of 4 × 1.2 m and head characters (head length and width) were determined at harvest. Head length and width were measured in centimeters; five heads per plot were selected at random and each head was cut into two halves for measurement. The number of bolt heads and loose heads were counted and expressed as a percentage of the total heads harvested per plot. Head yield was separated into marketable and non marketable yield (t/ha).

Participatory variety selection

Participatory selection was conducted in the 2008 long rainy season to select cabbage varieties with horticultural characters preferred by farmers. Two groups participated in the evaluation. The first group comprised 35 cabbage farmers randomly selected from Moshi, Arumeru and Arusha, the major cabbage growing areas in Northern Tanzania's Arumeru district. The second group comprised of 29 researchers drawn from sub-Saharan Africa. Characters preferred by farmers (head size, shape and firmness; resistance to insect pests and diseases; resistance to bolting and loose heads; medium and late maturity; taste) were used to evaluate the cabbage varieties. Head solidity (firmness) was determined by applying pressure on the head using the thumb. Head shape and size were determined through visual observation. Farmers made their selections by dropping between one and five seeds (1= extremely poor and 5 = excellent) in a container in front of the cabbage row. The research team evaluated cabbage

Table 1. Identity, type and source of cabbage used in the trials.

Sn	Cabbage varieties	Type ^a	Breeder/supplier of seeds
1	Gloria F ₁	H	East Africa Seeds Co., Tanzania
2	02-12609 (hybrid)	H	East Africa Seeds Co., Tanzania
3	Cheers Hybrid	H	East Africa Seeds Co., Tanzania
4	Globe Master (F ₁)	H	East Africa Seeds Co., Tanzania
5	Glory of Enkhuizen	OP	East Africa Seeds Co., Tanzania
6	Riana F ₁	H	East Africa Seeds Co., Tanzania
7	Green Coronet F ₁	H	East Africa Seeds Co., Tanzania
8	Copenhagen Market	OP	East Africa Seeds Co., Tanzania
9	Super Master	H	East Africa Seeds Co., Tanzania
10	Chou F ₁ Tropical Cross	H	Technisem, France
11	Chou F ₁ Santa	H	Technisem, France
12	Chou F ₁ KK Cross	H	Technisem, France
13	Africana F ₁	H	Takil and Co., Kyoto, Japan
14	Bonus	H	Takil and Co., Kyoto, Japan
15	Quick Start	H	Takil and Co., Kyoto, Japan
16	Victoria F ₁	H	Mukpar Tanzania Ltd.
17	Dragon F ₁	H	Nongwoo Bio Co., Korea
18	Drum Head	OP	Hygrothech, South Africa
19	BEJO 2658 F ₁	H	Kibo Seeds, Tanzania
20	Pruktor F ₁	H	Kibo Seeds, Tanzania
21	Thomas F ₁	H	Kibo Seeds, Tanzania
22	Glory of Enkhuizen	OP	Kibo Seeds, Tanzania
23	Rotan F ₁	H	Kibo Seeds, Tanzania
24	Riana	H	Kibo Seeds, Tanzania
25	Spring Light	H	Known-You Seed, Taiwan
26	Besta	H	Known-You Seed, Taiwan
27	Good Season	H	Known-You Seed, Taiwan
28	Summer Tide	H	Known-You Seed, Taiwan
29	Summer Summit (Hybrid)	H	Known-You Seed, Taiwan
30	Tropical Delight (Hybrid)	H	Known-You Seed, Taiwan
31	Summer Glory (Hybrid)	H	Known-You Seed, Taiwan
32	Summer Autumn (Hybrid)	H	Known-You Seed, Taiwan

Type OP = Open pollinated; H = F₁ hybrid variety.

varieties for horticultural characters and overall performance using a five-point Likert scale, with 1 (least preferred) and 5 (most preferred) (Olowu and Oladeji, 2004). The mean score of performance for each variety was calculated. A variety with a mean score of equal and above the cut-off mean of 2.5 was declared as being preferred, while a mean score less than 2.5 was classified as least preferred. The mean score of the check was compared with the other varieties.

For each growing season, data was collected on head yield (t ha⁻¹), head length and width, leaf length and width. For each character, analysis of variance for each season and combined analysis of variance over seasons was conducted in a conventional manner, with genotype being a fixed factor and season (a combination of season and year) being a random factor (Gomez and Gomez, 1984). Data for each season and pooled over seasons, was subjected to statistical analysis as PROC GLM procedure of SAS Institute (1998). Entry means were separated using Duncan's Multiple Range Test (DMRT). Percentages and ranking were used to determine varieties preferred by cabbage farmers.

RESULTS AND DISCUSSION

Evaluation of head yield and yield components in 2008 trial

Significant differences ($p < 0.05$) were found among the entries during the long and short rainy seasons for marketable head yield (t/ha), nonmarketable head yield (t/ha), head length and width, leaf length and width (Table 2). During the long rainy season (2008), marketable head yield ranged between 23 and 49 t/ha (Table 3). Dragon F₁, Cheers HYB, Gloria F₁, and Victoria F₁ significantly out-yielded other varieties (Table 3). Head length was high in Gloria F₁ during the long rainy season. Summer Summit, Bejo, Thomas F₁, Victoria F₁, Glory of Enkhuizen, Summer Glory and Riana recorded the

Table 2. Mean squares for head yield and yield characters in cabbage during 2008 and 2008/09 and pooled for 2008 and 2008/09.

Source of variation	Df	Head length	Head width	Marketable weight – head yield (t/ha)	Nonmarketable weight – head yield (t/ha)	Leaf length (cm)	Leaf width (cm)
2008 season							
Varieties	31	18.50**	10.78*	108.94*	15.74*	81.07**	84.17***
Replication	2	0.64	10.44*	3.20	8.28**	4.34	5.41
Error	62	2.56	1.37	9.63	1.98	4.55	2.86
R2		0.78	0.81	0.85	0.80	0.90	0.97
CV		9.19	5.20	9.2	34.67	5.77	4.34
Mean		17.44	22.51	33.60	4.05	36.89	38.52
2008/09 season							
Varieties	31	7.26**	9.95**	64.82**	14.41**	43.17***	36.73***
Rep	2	4.21	2.07	2.23	4.11	11.74	5.8
Error	62	1.77	1.96	7.48	3.72	9.13	7.62
R2		0.67	0.72	0.81	0.66	0.70	0.71
CV(%)		8.55	6.67	9.65	37.88	9.80	8.63
Mean		15.58	20.95	28.33	5.00	30.80	31.97
Pooled data over seasons							
Varieties	31	22.02***	15.95**	158.91**	24.91**	117.62***	105.50***
Rep within seasons	4	3.90	9.86	5.17	3.43	11.69	9.80
Season	1	159.80***	110.31*	1265.0***	50.03*	2812.35**	1168.09***
Seasons x varieties	31	3.91**	4.68*	13.09*	5.26**	10.04*	17.05***
Error	124	2.17	1.80	8.38	2.92	6.01	6.00
R2		0.77	0.77	0.86	0.72	0.90	0.88
CV		8.94	9.19	9.34	37.57	12.00	7.12
Mean		16.51	21.73	30.97	4.56	34.64	36.24

* = significant at 5%, ** = significant at 1%.

highest marketable head yields during the short rainy season (Table 3). High head yield recorded for some varieties on-station is consistent with reports of Talekar (2000) and Ijoyah and Rakotomavo (2007) for head yield in cabbage.

The analysis of variance over seasons (trials) revealed highly significant entry means squares ($p < 0.01$) for seasons, varieties and varieties \times season interaction effects. These results suggest large genetic difference among the entries and that environmental differences between seasons influence the expression of head yield and yield characters. The relative differences for head yield and head characters are inconsistent within seasons and over seasons. The entry means over seasons for marketable head yield ranged between 21 and 42 t/ha and was best in Quick Start, Bejo, Thomas F₁ and Globe master. Entries, seasons and entries \times seasons interaction summarized 63, 16 and 6% respectively of total variation observed in the treatment sums. The ranking of the entries for head yield, length and width was inconsistent over seasons. The top ten entries (head weight, length and width) during the long

rainy season ranked differently than for the short rainy season and for both seasons. The percentage increase and decrease in head yield ranged between 1 and 16% and 0.3 and 49% respectively (Table 3). Gloria F₁ and Dragon F₁ recorded 49 and 42% for yield reduction, indicating their unsuitability for cultivation during the short rainy season. However, the short rainy season is characterized by inconsistent rainfall and high temperatures (31°C). The adaptation of Quick Start and Bejo to the short rainy season was evident in the head yields. Our study showed that the long rainy season was best for cabbage production in Arusha and the cultivation of any of the top five varieties evaluated during the long rainy season could provide considerable head yield. For production during the short rainy season, Quick Start and Bejo will provide appreciable head yield. The large difference for seasons and seasons \times entries interaction means squares indicate considerable influence of the environment. The foregoing indicates that head yield and characters are dependent on season. Hence the search for varieties with stable performance for head yield and characters over seasons and years is important.

Table 3. Means separation for head yield and head characteristics for 2008, 2008/09 and pooled for both year and percent increase and decrease of in head yield.

Variety	Hdl 2008	Hdl 2009	Hdl pooled	Hw 2008	Hw 2009	Hw Pooled	Mkwt (t/ha) 2008	Mkwt (t/ha) 2008/09	Mkwt (t/ha) Pooled	% Yield reduction	% Yield increase	Nmkwt (t/ha) 2008	Nmkwt (t/ha) 2008/09	Nmkwt pooled
Gloria F ₁	23 ^a	14 ^{a-e}	15 ^{fgi}	21 ^{fi}	17 ^{gh}	18 ^g	44.0 ^{ab}	23.33 ^{fg}	26.00 ^{ij}	47	-	0.75 ^{hi}	4.67 ^{b-h}	4.73 ^{bc}
02-12609 (hybrid)	22 ^d	14 ^{c-e}	16 ^{ig}	24 ^{b-e}	19 ^{c-g}	23 ^{a-d}	32.67 ^{ef}	22.67 ^{iy}	22.83 ^{jk}	31	-	0.67 ⁱⁱ	2.67 ⁱ⁻ⁱⁱ	4.00 ^{cd}
Pruktor F ₁	21 ^{ab}	13 ^{gh}	13 ⁱ	23 ^{c-h}	19 ^{a-g}	20 ^{ef}	36.33 ^{d-f}	22.33 ^{tg}	23.83 ^{jk}	39	-	4.03 ^{c-g}	7.66 ^{abc}	6.50 ^{de}
Glory of Enkhuizen-KB	20 ^{abc}	15 ^{a-f}	16 ^{e-g}	23 ^{c-h}	19 ^{c-g}	20 ^{ef}	34.00 ^{d-i}	32.33 ^{d-u}	34.00 ^{u-i}	5	-	2.77 ^{e-i}	11.00 ^d	7.33 ^{de}
Summer Glory	20 ^{a-e}	16 ^{a-d}	16 ^{e-g}	22 ^{d-h}	16 ⁿ	17 ^g	34.0 ^{d-i}	30.33 ^{d-e}	32.50 ^{d-g}	11	-	5.33 ^{d-e}	2.47 ⁱ⁻ⁿ	1.55 ^{ef}
Thomas F ₁	20 ^{a-e}	17 ^{abc}	18 ^{abc}	25 ^{abc}	21 ^{a-e}	21 ^{d-f}	35.67 ^{d-g}	35.00 ^{ab}	38.67 ^{bc}	2	-	3.21 ^{e-h}	2.16 ^{gh}	1.43 ^{fg}
Cheers Hybrid	20 ^{a-f}	16 ^{a-d}	19 ^{du}	21 ^{fi}	22 ^{abc}	23 ^{a-d}	44.33 ^{du}	28.67 ^{uu}	30.67 ⁱ⁻ⁱⁱ	35	-	0.69 ⁱ⁻ⁱⁱ	2.10 ^{yu}	1.34 ^{gh}
Bejo F ₁	19 ^{a-g}	17 ^{abc}	19 ^a	21 ^{ghi}	21 ^{a-e}	21 ^{d-f}	32.67 ^{e-i}	35.00 ^{ab}	39.67 ^{ab}	-	7	2.53 ⁱ⁻ⁱⁱ	2.4 ^{i-h}	1.54 ^{gh}
DragonF ₁	18 ^{b-h}	14 ^{fgh}	13 ⁿⁱ	18 ^k	21 ^{a-e}	22 ^{b-d}	49.00 ^a	28.50 ^{cae}	30.86 ⁱ⁻ⁿ	42	-	0.12 ⁱ	5.75 ^{d-g}	5.86 ^{de}
Globe Master (F ₁)	18 ^{b-h}	15 ^{c-f}	16 ^{c-g}	21 ^{fi}	23 ^{ad}	24 ^{ad}	35.67 ^{d-g}	31.50 ^{c-e}	36.00 ^{a-c}	12	-	3.67 ^{d-g}	5.35 ^{d-g}	4.42 ^{de}
Summer Summit F ₁	18 ^{b-h}	16 ^{a-d}	16 ^{c-g}	23 ^{c-h}	22 ^{abc}	22 ^{b-d}	34.67 ^{d-i}	36.33 ^a	38.20 ^{dc}	-	4.56	6.35 ^{d-a}	6.35 ^{d-i}	4.38 ^{de}
Sky AceF ₁	17 ^{d-h}	16 ^{a-d}	16 ^{e-g}	22 ^{fi}	19 ^{c-g}	20 ^{ef}	23.33 ^m	23.25 ^{tg}	23.29 ^{jk}	0.3	-	7.00 ^{ad}	7.00 ^{d-e}	7.00 ^{de}
Quick Start	17 ^{e-i}	18 ^d	18 ^{abc}	22 ^{fi}	18 ^{gh}	18 ^y	26.33 ^{k-iii}	31.50 ^{d-^e}	42.67 ^a	-	16.4	9.33 ^d	1.00 ⁱⁱ	0.51 ^{ef}
Summer Autumn	17 ^{e-i}	16 ^{a-d}	18 ^{abe}	22 ^{d-h}	21 ^{a-e}	21 ^{d-f}	32.33 ^{ef}	28.67 ^{c-e}	30.67 ⁱ⁻ⁱⁱ	11	-	6.67 ^{uc}	4.00 ^{c-ii}	3.27 ^{de}
Summer Tide	17 ^{e-i}	17 ^{abc}	19 ^a	23 ^{c-h}	22 ^{abc}	22 ^{b-d}	35.00 ^{d-n}	32.67 ^{a-d}	34.50 ^{d-i}	7	-	4.00 ^{c-g}	5.00 ^{d-g}	4.52 ^{de}
Chou F ₁ KK Cross	17 ^{e-i}	17 ^{abc}	18 ^{abc}	23 ^{c-h}	24 ^a	24 ^a	35.00 ^{d-h}	28.67 ^{c-e}	32.17 ^{d-g}	18	-	5.33 ^{b-e}	5.00 ^{b-g}	4.10 ^{de}
Rotan	17 ^{e-i}	17 ^{abc}	19 ^d	24 ^{b-e}	23 ^{du}	23 ^{a-d}	26.33 ^{k-iii}	30.33 ^{u-e}	32.17 ^{u-y}	-	13.0	2.12 ^{y-i}	4.17 ^{u-ii}	3.46 ^{de}
Glory of Enkhuizen	17 ^{fi}	15 ^{c-f}	16 ^{e-g}	27 ^a	23 ^{ad}	23 ^{ad}	23.0 ^m	21.67 ^{tg}	24.00 ^{jk}	6	-	5.33 ^{d-e}	3.67 ^{d-n}	2.89 ^{de}
Victoria F ₁	16 ⁱ	12 ^h	12 ^j	23 ^{c-h}	21 ^{a-e}	21 ^{d-f}	42.67 ^{bc}	32.86 ^{a-d}	35.33 ^{c-e}	23	-	3.07 ^{e-h}	3.33 ^{d-h}	2.77 ^{de}
Riana F ₁	16 ^{g-i}	12 ⁿ	12 ^j	24 ^{b-e}	20 ^{c-d}	23 ^{a-d}	39.00 ^{d-a}	30.00 ^{d-e}	32.17 ^{d-g}	23	-	3.80 ^{d-g}	3.83 ^{c-n}	2.56 ^{de}
Green Coronet F ₁	16 ^{g-i}	15 ^{c-f}	15 ^{fgh}	18 ^k	22 ^{abc}	22 ^{b-d}	34.67 ^{d-i}	27.33 ^{a-^e}	28.83 ^{g-i}	20	-	0.63 ⁿⁱ	4.67 ^{d-n}	4.17 ^{de}
Copenhagen Mkt	16 ^{hij}	16 ^{a-d}	16 ^{c-g}	19 ^{kn}	23 ^{du}	23 ^{a-d}	28.67 ⁱ⁻ⁱⁱⁱ	31.67 ^{a-^e}	33.33 ^{u-i}	-	9.4	5.00 ^{u-i}	7.33 ^{uuu}	5.67 ^{de}
Africana F ₁	16 ^{hij}	16 ^{a-d}	17 ^{b-e}	20 ^{ijk}	21 ^{a-e}	22 ^{b-d}	32.33 ^{e-i}	29.67 ^{c-^e}	32.17 ^{d-g}	8	-	5.00 ^{b-f}	8.00 ^{ab}	7.18 ^{de}
Bonus	16 ^{hij}	17 ^{a-d}	16 ^{e-g}	21 ^{fi}	20 ^{c-d}	21 ^{d-f}	27.33 ^{j-iii}	30.33 ^{u-^e}	33.00 ^{u-i}	-	9.89	7.67 ^{au}	7.33 ^{uuu}	7.18 ^{de}
Chou F ₁ Tropical Cross	15 ^{h-k}	17 ^{ab}	19 ^{ab}	21 ^{ghi}	20 ^{c-d}	21 ^{d-f}	29.00 ^{h-k}	29.33 ^{c-de}	31.64 ^{e-h}	-	1.12	5.00 ^{b-f}	5.67 ^{b-f}	5.50 ^{de}
Chou F ₁ Santa	16 ^{g-i}	15 ^{a-f}	16 ^{c-g}	23 ^{c-h}	23 ^{ad}	23 ^{a-d}	29.67 ^{g-k}	29.00 ^{c-e}	30.67 ⁱ⁻ⁿ	-	2.26	6.00 ^{d-a}	4.67 ^{d-n}	5.67 ^{de}
Good Season	15 ^{h-k}	13 ^{fgh}	15 ^{fgh}	22 ^{d-h}	22 ^{abc}	22 ^{b-d}	30.33 ^{u-y}	34.00 ^{du}	34.50 ^{u-i}	2	-	3.67 ^{u-y}	4.33 ^{u-ii}	4.83 ^{de}
Tropical Delight	14 ^l	14 ^{f-h}	15 ^{fgh}	22 ^{fi}	21 ^{b-c}	20 ^{ef}	35.67 ^{d-g}	28.67 ^{c-e}	30.50 ^{i-h}	20	-	5.31 ^{b-e}	6.67 ^{bcde}	5.83 ^{de}
Super Master	13 ^l	14 ^{f-h}	16 ^{fgh}	23 ^{c-h}	21 ^{b-c}	21 ^{d-f}	34.00 ^{u-i}	21.67 ^{iy}	24.00 ^{jk}	3136	-	6.00 ^{uuu}	7.33 ^{uuu}	8.33 ^{de}
Drum Head	13 ^l	15 ^{a-f}	15 ^{fgh}	22 ^{fi}	18 ^{gh}	23 ^{a-d}	25.33 ^{k-m}	16.00 ⁿ	21.67 ^k	37	-	5.33 ^{d-e}	8.00 ^{ab}	7.83 ^{de}
Besta	13 ^{k-l}	15 ^{a-f}	15 ^{fgh}	26 ^{ad}	20 ^{c-g}	20 ^{ef}	34.33 ^{d-i}	22.67 ^{tg}	25.83 ^{jl}	34	-	1.29 ^{gni}	8.33 ^{d-g}	5.17 ^{de}
Spring Light	12 ^l	16 ^{a-d}	16 ^{e-g}	22 ^{fi}	21 ^{b-c}	22 ^{b-d}	38.00 ^{c-e}	26.33 ^{tg}	28.0 ⁱⁿ	31	-	2.21 ^{gni}	4.16 ^{d-n}	5.08 ^{de}
Mean	17.44 ^a	15.58 ^b		22.59 ^a	20.95 ^b		33.60 ^a	28.33 ^b				4.05 ^b	5.09 ^a	

Hdl= Head length; Hdw = head width; Mkwt = marketable weight; Nmkwt = nonmarketable weight. Means within the same column followed by the same letter(s) are not significantly different at 5% probability level by DMRT.

Table 4. Percentage distribution of farmers' preference and rank (superscript) for characters in cabbage varieties during the 2008 long rainy season.

Cabbage varieties	Head Size (%)	Taste (%)	Earliness (%)	Firmness (%)	Head shape (%)	Head splitting (%)	Loose Head (%)	Days to harvest
Copenhagen Market	24	36	34	64	64	35	25	98
Glory of Enkhuizen	33	33	33	53	40	53	26	100
Drum Head	33	65	34	37	6	59	25	100
Globe Master (F ₁)	55	62	66	55	63	65	43	111
Green Coronet F ₁	30	53	52	59	56	71	45	113
Cheers Hybrid	80 ¹	62	68 ⁴	78	72 ³	73	43	101
02-12609 (hybrid)	35	50	33	29	28	55	43	113
Gloria F ₁	54	64 ⁴	74 ²	88 ⁴	77 ²	80 ³	51	85
Super Master	55	42	55	67	48	82 ¹	44	98
Riana F ₁	57	52	68	78	64	75	45	118
Victoria F ₁	48	53	53	76	56	54	50	100
Sky AceF ₁	19	61	35	46	50	82 ¹	50	102
DragonF ₁	79 ²	32	70	75	52	77	53	100
Bejo F ₁	47	51	48	62	58	56	52	128
Pruktor F ₁	44	62	35	45	56	70	52	104
Thomas F ₁	45	51	47	78	53	47	45	108
Glory of Enkhuizen-KB	35	48	44	48	43	36	44	126
Rotan	26	46	31	47	23	52	40	122
Spring Light	40	47	52	47	33	55	50	111
Besta	41	35	51	79	53	55	55	112
Good Season	52	59	60	62	63	56	53	111
Summer Tide	52	64	70 ³	75	63	78	54	99
Summer Summit F ₁	64	66 ³	65	95 ²	79 ¹	68	60 ²	100
Tropical Delight	73 ⁴	54	28	88 ³	51	21	58 ³	118
Summer Glory	22	73 ¹	78 ¹	67	68	49	42	82
Summer Autumn	64	50	55	75	66	36	64 ¹	100
Chou F ₁ KK Cross	76 ³	36	67	150 ¹	55	36	52	112
Africana F ₁	45	51	41	67	50	43	23	102
Quick Start	39	56	40	54	48	43	46	98
Bonus	46	68 ²	48	63	57	19	55	99
Chou F ₁ Tropical Cross	41	65 ⁴	39	68	57	19	45	123
Chou F ₁ Santa	43	55	51	58	66	57	44	118

Participatory variety selection

Demographic variables of the respondents

The mean age of the respondents was 25 years, with a gender distribution of 67, 33% male and female respectively. Tsoho (2004) noted that young adult farmers have a higher aspiration to accept new technologies than old conservative farmers. Most of the cabbage farmers operate at a small scale with fields less than one hectare and they have between 5 - 15 years' experience in cabbage cultivation.

Using head shape as selection criteria, farmers'

participatory research indicated that round-headed varieties Cheers Hybrid, Gloria F₁, and Summer Summit are preferred for head shape. Cheers Hybrid, Dragon F₁, Tropical Delight and Chou F₁/KK Cross recorded high preference percentage (Table 4) for head size. Earliness in cabbage could be a desirable character when the need arises for varieties with a short growth cycle to meet early market demands. Conversely, early maturing varieties do not store well in the field because they are liable to bolt; yield loss could be higher if market demand falls. Summer Glory, Gloria F₁, Summer Tide and Cheers Hybrid recorded high preference percentage for earliness and were categorized as early maturing varieties (Table

Table 5. Likert scale test of overall performance for horticultural characteristics among cabbage varieties by the research team during the 2008 long rainy season.

Cabbage variety	1	2	3	4	5	Mean score
Copenhagen Market	0.36	1.14	0.11	0.14	0.00	1.75
Glory of Enkhuizen	0.00	0.36	1.60	0.71	0.18	2.85
Drum Head	0.00	0.43	1.50	0.86	0.18	1.33
Globe Master F ₁	0.04	0.21	1.18	1.00	0.71	3.14
Green Coronet F ₁	0.00	0.21	1.18	1.00	0.36	2.75
Cheers Hybrid	0.04	0.00	0.96	1.71	0.71	3.42
02-1260 9 (hybrid)	0.14	0.14	0.53	1.71	0.36	2.88
Gloria F ₁	0.18	0.36	1.18	0.43	0.00	2.15
Super Master	0.04	0.21	1.28	0.57	0.71	2.81
Riana F ₁	0.04	0.21	0.78	1.57	1.07	3.67
Victoria F ₁	0.04	0.50	0.86	1.57	1.07	4.04
Sky Ace F ₁	0.14	0.86	0.53	0.43	0.18	2.14
Dragon F ₁	0.04	0.00	0.43	2.00	0.89	3.36
Bejo F ₁	0.00	0.21	1.18	1.43	0.71	3.53
Pruktor F ₁	0.07	0.29	1.28	0.71	0.18	2.53
Thomas F ₁	0.00	0.86	1.18	0.14	0.00	2.18
Glory of Enkhuizen-KB	0.07	0.79	0.86	0.43	0.00	2.15
Rotan	0.07	0.64	0.78	0.71	0.00	2.20
Spring Light	0.07	0.79	0.96	0.43	0.00	2.25
Besta	0.00	0.29	1.18	1.00	0.00	2.47
Good Season	0.00	0.57	1.18	0.43	0.36	2.54
Summer Tide	0.07	0.74	0.85	0.29	0.18	2.14
Summer Summit F ₁	0.04	0.29	1.07	1.14	0.18	2.72
Tropical Delight	0.07	0.14	0.64	1.00	1.25	3.10
Summer Glory	0.54	0.36	0.21	0.14	0.00	1.05
Summer Autumn	0.18	0.86	0.43	0.43	0.18	2.05
Chou F ₁ KK Cross	0.11	0.36	1.18	0.71	0.36	2.72
Africana F ₁	0.21	0.29	1.18	0.43	0.16	1.68
Quick Start	0.43	0.29	0.53	0.43	0.00	2.86
Bonus	0.04	0.29	1.28	0.71	0.54	2.00
Chou F ₁ Tropical Cross	0.29	0.57	0.10	0.14	1.00	3.10
Chou F ₁ Santa	0.00	0.74	0.74	0.43	1.00	2.93

Score: 1 = Poor, 2 = Fair, 3=Good, 4 = Very good, 5 = Excellent. Mean score (2.50) = 5.00 (maximum score)/2.

5). Loose heads, an undesirable horticultural characteristic, is associated with a high incidence of cabbage head caterpillar and occurs if cabbage is attacked at an early growth stage. Preference (expressed as percentage) for Summer Autumn F₁ Summer Tide, Tropical Delight and Bonus was high due to low incidence of loose heads. These varieties performed better for tolerance to bolting when compared with the check. Sky Ace, Super Master and Gloria F₁ were preferred for low incidence of bolting (Table 5). Sensory evaluation (taste) showed that Summer Summit, Summer Glory, Bonus and Chou F₁ Tropical Cross were preferred for good taste.

Summer Summit F₁ was preferred by the respondents for multiple characters (taste, firmness, head shape and reduced percentage of loose heads). Tropical Delight was better for head size, insect pests' tolerance, firmness and low incidence of loose heads. Gloria F₁ was identified as an early maturing variety with good head solidity and

shape, but with high incidence of bolting, which may be associated with earliness and poor field storability.

The responses of the research team from sub-Saharan Africa on the overall performance of the cabbage varieties during the 2008 long rainy season were analyzed on a Likert scale (Table 5). Victoria F₁, Riana F₁, Bejo F₁, and Tropical F₁ had high mean scores above 2.50, and were selected as best for overall field performance. Gloria F₁ recorded a mean score less than 2.15; this was below the average and it implies that some characters the research team found in other varieties are lacking in Gloria F₁. Both sampling units used for the participatory research differed in the preference for Gloria F₁ (Table 5).

Conclusion

In this study we evaluated cabbage varieties for heat yield and yield characters over seasons.

Participatory selection was used to select preferred varieties and characters. It was evident that sufficient genetic variation exists among the cabbage varieties evaluated. Relative difference for head yield, head length and width were highly inconsistent within season and over seasons as shown by significant entries and entry x seasons interaction, with no similarity among best performing entries within and over seasons. The late rainy season was best for cabbage production in Arumeru district.

Farmer assessment of cabbage varieties has the potential to improve the relevance of on-station researcher-designed trials to identify preferred characters. Farmers from Arumeru district identified head yield and size, head firmness, shape and taste as important characteristics for a good cabbage. Promising varieties that could perform as the check for head yield are Cheers HYB, Victoria F₁, Pruktor, Riana, Green Coronet, Tropical Delight, Summer Tide, Glory of Enkhuizen, Spring Delight and Besta. Preference and selection for varieties might differ within and between locations in the country, hence the need to conduct similar studies at other locations to note farmers' preferences and selections.

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