TOWARDS CABBAGE *(BRASSICA OLERACEA* VAR. *CAPITATA* L*)* SEED PRODUCTION IN THE TROPICS.

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ABSTRACT

Some morphological and flowering characteristics of ten cabbage varieties obtained from Warwick–Horticultural Research Institute, UK have been evaluated with the aim of selecting suitable varieties for the study of flowering and seed development in the tropics and to ascertain the viability of cabbage seed produced under high temperatures (20-30°C). Plants raised from seed in peat-based compost in plastic pots were grown in a controlled environment room (CER) at 20°C with 12h photoperiod and 400mmol.m^{-2}.s^{-1} photosynthetic photon flux and in a glasshouse receiving natural light with a blackout system to give a 12-h photoperiod and maintained between 20 to 30°C. Eight weeks after sowing, two pots of each variety from each environment were transferred to another CER for vernalization at 4 °C for 8 weeks, after which they were returned to their respective controlled environments. Vernalization at 4°C promoted flowering in all varieties, however, varieties 11446, 6556 and 9617 flowered earlier and seeds produced in tropical conditions (20-30°C) were viable and vigorous with most varieties having 80% germination or higher. The varieties varied significantly in terms of number of leaves, height of stem and length of leaves, but canopy shape index did not vary significantly and was approximately one. The taller varieties of cabbage flowered easily, consistently showed higher levels of greenness and had lower incidence of tip-burn and splitting of the heads as compared to the shorter varieties. Varieties 3720, 5237 and 113011 can be considered as early maturing types.

INTRODUCTION

Cabbage is one of the most popular exotic vegetables in Ghana. It is a high value crop since there is a demand from most expatriate staff, restaurants, hotels and a large section of the population, especially in the cities and urban areas. The crop is also popular because cabbages are easy to cultivate, durable in the market place, have high nutritive value (Dickson and Wallace, 1986; Norman, 1992) and there is increasing evidence that their consumption is associated with reduced incidence of some types of cancer (Chiang *et al.*, 1993)

All the seeds of cabbages grown in Ghana are imported; however local production of the seed appears to be possible. The country spends substantial amounts on importation of seeds of exotic vegetables. For example, in 2002, 588,000 dollars was spent on importation of exotic seeds compared with 118,000 dollars in 1999 (Eurotrace, 2004). Seeds of cabbages are very expensive and this causes considerable constraint to its large scale production since few farmers can afford the high prices. The seeds are imported because cabbage requires low temperatures to induce flowering (Nieuwhorf, 1969; Yumaguchi, 1983), a phenomenon known as vernalization, but the average annual temperature in Ghana even at high altitudes is about 24°C. It is believed that, even if plants can be vernalized, flowering and seed development will be poor due to high temperatures and heavy rains (Wang *et al.*, 2000). Despite these challenges, some scientists have advocated locally produced seeds in the tropics (George, 1984; Buttenchon, 1985) citing reasons such as the shortage of foreign exchange, the dangers of importing poorly adapted varieties, the fact that germination is often poor and the potential introduction of diseases and pests. The need to study the possibility of local seed production of some of the popular exotic vegetables has therefore become imperative. We report here some morphological and floral characteristics of ten cabbage varieties evaluated with the aim of selecting suitable varieties for the study of flowering and seed development in the tropics and to ascertain the viability and vigour of cabbage seed produced under high temperatures (20-30°C).

MATERIALS AND METHODS

Seeds of ten cabbage cultivars (obtained from Warwick–Horticultural Research Institute, Warwick-HRI, UK) were sown at a depth of 2mm in each 4cm-square cell (filled with 46 g Levington F2S compost) of plastic modular trays. When seedlings were 24 days old, they were transplanted into plastic pots of 23cm top diameter containing 3kg Levington M2 soil mix. The pH of the compost was 5.5. Five plants of each of the ten varieties were kept in a controlled environment room (CER) held at 12h photoperiod and 400mmol.m^{-2}.s^{-1} photosynthetic photon flux and temperature of 20°C. Another group of five plants of each variety were kept in a glasshouse receiving natural light with a blackout system to give a 12-h photoperiod and maintained between 20 to 30°C. The pots were arranged in a randomised complete block design in both controlled environments. Eight weeks after sowing, two plants of each variety from both the CER and the glasshouse were transferred to another CER for vernalization at 4 °C for 8 weeks, after which they were returned to their respective controlled environments.

Parameters measured included the number of leaves, height of stem, canopy spread, length of the most recent fully expanded leaf at 40 days after sowing, greenness (measured fortnightly from two weeks after transplanting for 8 weeks using a Minolta SPAD meter), days from sowing to flowering, number of nodes, leaves, girth (2cm from the soil level) and height at flowering.

Due to the absence of pollination agents in the controlled environments, five of the varieties that flowered were hand pollinated (selfed) and seeds collected. Germination (%) and coefficient of velocity (CV) as described below were subsequently determined to assess the viability and vigour of seed produced under temperatures (20-30 °C) that were higher than are normal for cabbage seed production. Fifty seeds of each of the five varieties were sown into 4cm-square plastic modular trays filled with Levington F2S compost at a depth of 0.5cm and kept at 20°C. The emergence of seedlings was recorded daily. The final germination was counted at the ninth day. The CV, a measure of vigour, was calculated as follows:

$$CV = \frac{\sum_i N_i}{\sum_i N_i D_i} \times 100$$

Where Ni = number emerging in day i.

Di = days from sowing.

The CV gives an indication of the rapidity and uniformity of seedling growth. Higher CV means higher vigour (Scott *et al.*, 1984; Kittock and Law, 1968).

Analysis of variance was used to determine the variation among cultivars for all parameters measured except proportions on flowering, head splitting, tip burn and sign of heading where logistic analysis (Binomial) was adopted using Genstat-release 7.2 statistical package. The CV was square root transformed to normalize the error distribution before the analysis was performed.

RESULTS AND DISCUSSION

Two of the ten varieties of cabbage (V11446 and V6556) used for the study were able to flower without vernalization in the glasshouse (Figure 1a).

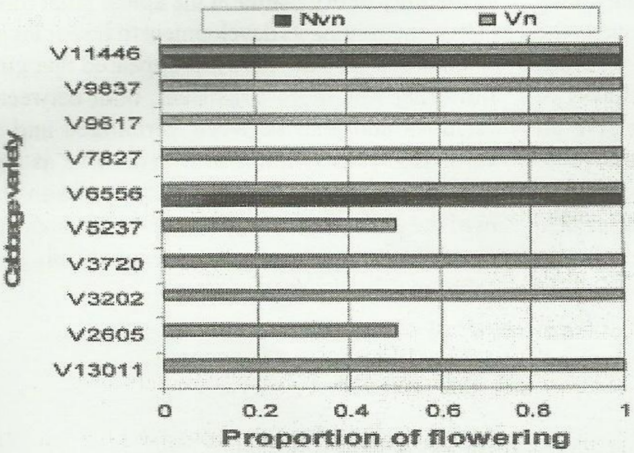

Figure 1a: Flowering responses of ten varieties of cabbage after plant vernalization (8 weeks) and grown at 20-30°C (glasshouse) (Vn = vernalized plants; Nvn = Non-vernalized plants)

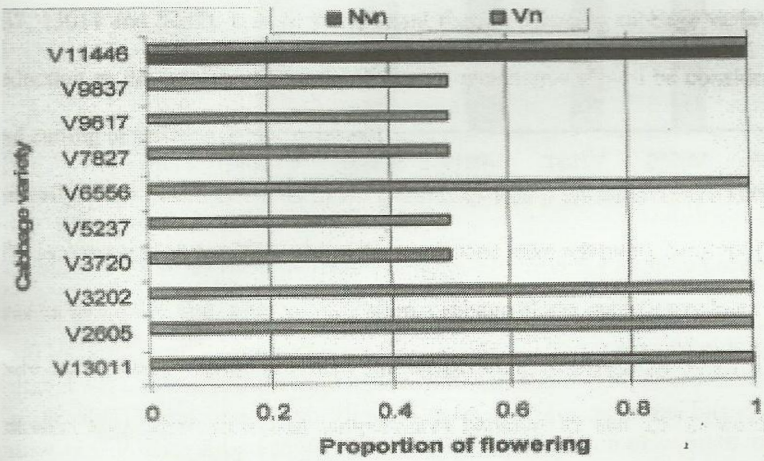

Figure 1b: Flowering responses of ten varieties of cabbage after plant vernalization (8 weeks) and grown at 20°C (controlled environment room, CER) (Vn = vernalized plants; Nvn = Non-vernalized plants)

vernalized at 4°C and grown at the tropical temperatures (20-30°C). However, only four varieties (11446, 6556, 3202, 13011) had all the vernalized plants flowering both in the glasshouse and in the CER.

The mode of flower stalk appearance after plant vernalization placed the cabbage varieties into three categories; those that were able to flower without head formation (varieties 11446 and 6556); those that formed a loose or small head and unfolded later to allow flower stalks to elongate (9617, 7827, 3202, 3720 and 2605) and those with dense heads where flower stalk elongation was only possible after the heads were cut (varieties 9837, 13011 and 5237). It is very important that, in selecting cabbage varieties for seed production in the tropics, the mode of flower appearance should be considered because head cutting or splitting is labour intensive.

Generally, more plants flowered in the glasshouse where the temperature varied from 20-30°C as compared to the CER where the conditions were relatively constant (20°C). This gives an indication that, after vernalization, cabbage plants may flower better in the field where temperature varies, provided the temperature is within 20-30°C. These results contradict the earlier view that temperatures between 15 and 25 °C would cause the vernalization effect of low temperature in cabbage to be reversed (devernalization) (Heide, 1970, cited by Weibe *et al.*, 1992; Friend, 1985). The fact that some varieties can flower at such high temperatures gives great hope for cabbage seed production in the tropics.

Variety 6556 (non-vernalized) was not able to flower in the CER (Figure 1b) probably because it was not given enough time since the experiment was terminated earlier due to disease outbreak. One of the plants that flowered without vernalization (11446) did not form a head while the other (6556) formed a loose head. There was an indication that all the varieties of cabbage have a tendency to flower when

The varieties 11446 and 6556 flowered significantly earlier than the others (Figure 2), and were the varieties that were able to flower without vernalization. This suggests that the earliness of flowering after plant vernalization may give an indication of varieties that could most easily be induced to flower. Apart from the two varieties (11446 and 6556), 9617 flowered significantly earlier than the rest. Varieties 3720 and 13011 were very late in flowering after plant vernalization, consequently they may be difficult to induce to flower without vernalization.

availability of dry matter at the apical point (dome), thereby permitting its development to flower initiation (Fontes and Ozbun, 1972). It appeared that girth at flowering was more consistent, both between the varieties and also between vernalized and non-vernalized plants, and thus it may serve as a good indicator of time of flowering. Ito and Saito (1961) used the girth of 15.7-18.0 mm (5-6 mm diameter) as an indicator of stages for vernalization for the cabbage cultivar, Yosin.

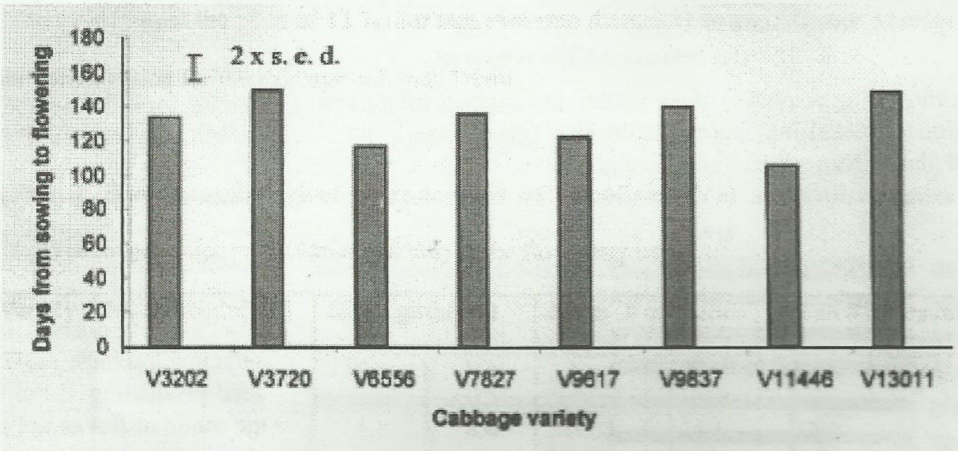

Figure 2: Days from sowing to flowering of eight varieties of cabbage which had been vernalized in the glasshouse.

Varieties 11446 and 6556 that were able to flower without vernalization did not differ from each other in their height, girth, number of nodes and leaves at the time of flowering (Table 2). Also, there were no significant differences between vernalized and non-vernalized plants in terms of these four morphological characteristics, however, non-vernalized plants had more leaves (P=0.68), more nodes and were generally taller than the vernalized plants. During the eight week period of vernalization (at 4°C), vernalized plants were expected to grow more slowly than the non-vernalized ones due to lower thermal time accumulated and this may have accounted for the lower number of nodes and leaves of the vernalized plants. Chilling during vernalization was found to suppress leaf initiation and leaf growth at the shoot apex, which consequently allowed increased

The ten varieties varied significantly in terms of the number of leaves, height of the stem and the length of the most recently developed leaf (Table 3). It appeared that stem height had a relationship with flowering. Varieties 11446 and 6556, which were able to flower even without vernalization, were significantly taller than the rest, whereas vernalised plants of most of the short cultivars (e.g. varieties 2605 and 3720) did not all flower in both controlled environment rooms (Figures 1a and 1b). The varieties did not show any significant differences in canopy shape index and the values for each of the cultivars in both growth rooms was approximately one. This indicated that all the cultivars had a similar shape and the canopy length was approximately similar to the canopy breadth.

Table 2: Some morphological characteristics of vernalized (Vn) and non-vernalized (Nvn) cabbage varieties (11446 and 6556) at the flowering stage.

Variety	Mean height(cm)		Mean girth(cm)		Mean # of nodes		Mean # of leaves	
V6556	Nvn	Vn	Nvn	Vn	Nvn	Vn	Nvn	Vn
V11446	27.7	27.5	8.8	8.0	56.3	28.5	32.7	24.0
V11446	63.3	33.0	8.0	8.0	36.3	20.5	25.7	13.5
F-test	ns		ns		ns		ns	
s.e.d.	20.87		0.83		20.01		7.51	
df	3		3		3		3	

ns = not significant at 5% # = number Nvn = non vernalized Vn = vernalized

Table 3: Horticultural characteristics of ten cabbage varieties (non-vernalized plants) at 40 days after transplanting.

Variety	Number of leaves		Canopy shape index #		Height of stem (cm)		Length of most recent leaf (cm)	
	GH	CER	GH	CER	GH	CER	GH	CER
V2605	12.2	11.6	1.34	1.121	3.70	3.80	18.8	13.4
V3202	12.2	12.6	1.07	1.08	3.00	3.80	17.2	14.3
V3720	13.4	14.6	1.09	1.13	3.60	4.60	15.0	11.5
V5237	13.0	12.4	1.18	1.04	4.40	4.70	16.8	14.5
V6556	13.0	11.4	1.08/	1.02	6.90	9.20	15.8	14.0
V7827	14.2	12.2	1.10	1.41	5.50	4.30	17.2	11.5
V9617	10.8	9.80	1.12	1.12	4.00	4.40	20.0	13.5
V9837	14.0	12.2	1.15	1.12	4.00	6.30	18.2	14.5
V11446	12.2	11.2	1.09	1.14	13.80	19.30	16.6	16.6
13011	14.4	14.0	1.11	1.04	4.40	4.30	19.4	15.7
F-test	*	**	ns	ns	**	**	*	**
Rep	5	5	5	5	5	5	5	5
Df	36	36	36	36	36	36	36	36
SED	0.931	0.994	0.096	0.129	1.215	1.113	1.884	1.241

#Canopy shape index = Canopy length/canopy breadth

GH = glasshouse CER = controlled environment room

ns = Difference not significant at 5% significance level

*Significant difference between at least two varieties at 5% significance level

**Significant difference between at least two varieties at 1% significance level

There were significant differences between some of the varieties of cabbage ($F_{(9, 36)}=9.60$, $P<0.001$) in terms of greenness (amount of chlorophyll) over all dates (Figure 3). Generally, there was an increase in greenness for the first six weeks after which there was a decline with the exception of varieties 5237 and 7827 that increased at the eighth week. The two varieties (11446 and 6556) which flowered without vernalization showed a consistent high level of greenness as compared to the others throughout the eight weeks. In addition, the two varieties (2605 and 3720) that were consistently less green even had some of their vernalized plants not able to flower either in the CER or in the glasshouse. Greenness (amount of chlorophyll in a plant) is closely related to the nitrogen content.. Correlations of R=0.91 between the measured SPAD value (greenness) and leaf N concentration of rice have been reported (Anderson *et al,* 1993). This gives an indication that the amount of nitrogen in the plant may be one of the important factors promoting flowering in cabbage. Earlier, Colder and Cooper (1961) reported that cold requiring plants such as *Dactylis glomerata* lose their need for low temperature in the presence of high nitrogen levels. Shortage of nitrogen also delayed curd initiation and maturity in the cauliflower (Parkinson, 1952 cited by Hand, 1988). It is probable that where nitrogen deficiency retards floral initiation it is due to a reduction of the level of metabolites at the stem apex. From these findings, the amounts of nitrogen in relation to flowering of cabbage need to be investigated.

The mean proportion of plants showing splitting, tip burn and sign of heading at 70, 60 and 40 days after transplanting (DAT) respectively showed significant differences between some of the varieties (Table 4).

Varieties 2605 and 3720 were most susceptible to head splitting, especially the vernalized plants. Almost all the plants that had head splitting also had tip burn of the leaves and, these phenomena may be physiologically related. Plants kept in the controlled environment room where conditions were almost constant (20°C) showed less incidence of tip burn as compared to plants in the glasshouse. This agrees with the suggestion that high temperature may contribute to tip burn disorder. Nagata and Stratton (1994) used elevated temperatures of 28-37°C for testing susceptibility to tipburn in new lettuce cultivars. Misaghi and Grogan (1979) also reported that symptoms of tip burn can be induced even in detached lettuce heads if temperatures of

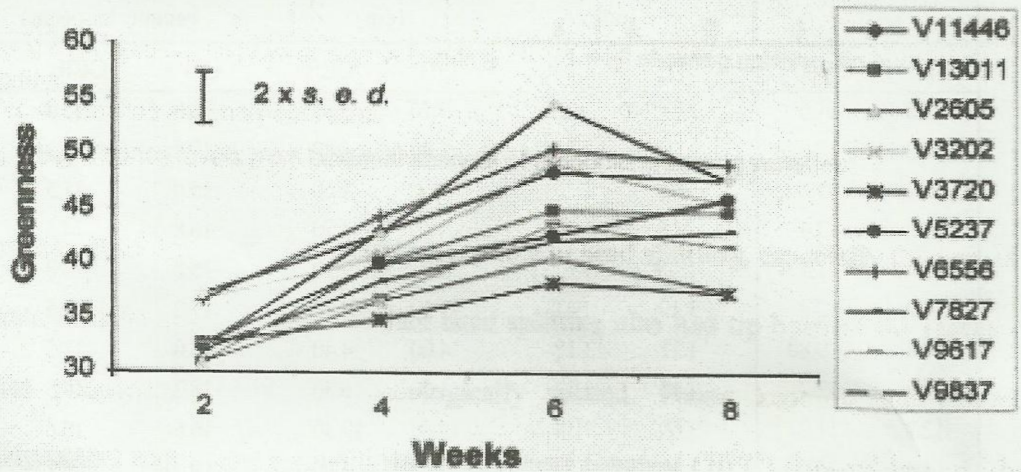

Figure 3: The relative greenness (chlorophyll content) of plants with time after transplanting.

Table 4: Mean proportion of plants showing splits (70 DAT), tip burn (60 DAT) and sign of heading (40 DAT) for ten varieties of cabbage (DAT = days after transplanting)

Variety	Splitting				Tip burn				Sign of heading			
	CER (20°C)		Glasshouse (20-25°C)		CER (20°C)		Glasshouse (20-25°C)		CER (20 °C)		Glasshouse (20-25°C)	
	Nvn	Vn	Nvn	Vn	Nvn	Vn	Nvn	Vn	Nvn	Vn	Nvn	Vn
V2605	0.7	0.5	0.3	0.5	1.0	0.0	1.0	1.0	0.7	0.0	0.1	1.0
V3202	0.0	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.7	0.5
V3720	1.0	1.0	0.3	1.0	0.3	0.5	1.0	1.0	0.3	1.0	1.0	1.0
V5237	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.5	1.0	0.5	1.0	1.0
V6556	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.0
V7827	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.7	1.0	1.0
V9617	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0
V9837	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0
V11446	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
V13011	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.0	0.7	1.0	1.0	0.0
Sig.	P=0.001		P=0.0001		P=0.032		P<0.01		P=0.001		P<0.001	
No of plants	2	3	2	3	2	3	2	1	3	2	3	2

Key: 0 = no splitting, tip burn or sign of head 1 = all showing splitting, tip burn or sign of heading

CER =Controlled environment room.

Sig. =Significance levels from binomial analysis of proportions among varieties.

25-28 °C are applied for a few days. The tall varieties (11446 and 6556) which flowered without vernalization had less incidence of the tip burn disorder.

The sign of heading at 40 days after transplanting gives an indication of earliness of maturity since early maturing cabbages start forming a head at that stage. Varieties 3720, 5237 and 13011 can be considered as early maturing types. Varieties 11446, 9617 and 6556 did not show any sign of heading because 11446 is not a head forming cabbage and the other two are late maturing varieties. The rest of the varieties (2605, 3202, 7827 and 9837) can be regarded as intermediate between the early and late maturing varieties.

The germination (%) and the CV of seeds obtained from cabbage plants raised in the glasshouse (20-30°C) were compared with the original seeds obtained from Warwick-HRI (Figures 4 and 5).

Seventy five (75) is the minimum acceptable germination percentage of cabbage seeds in most countries (FAO, 1993; Douglas and Imman, 2002; Minnesota Seed Rules and Laws, 2003). With the exception of variety 7827 where seeds produced at 20-30°C gave an average germination percentage of 38, the rest gave germination percentages above 75. Again, the germination (%) of the seeds produced was not significantly different from that of the original seeds obtained from Warwick-HRI for all varieties tested except variety 7827.

The CV indicated that seeds produced in the glasshouse (20-30°C) were slightly more vigorous

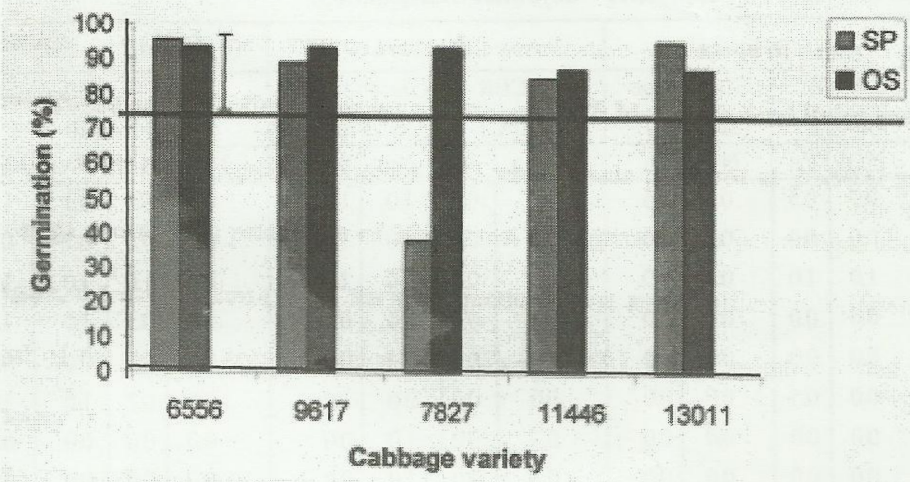

Figure 4: Germination percentages of five varieties of cabbage produced in the glasshouse (20-30°C). Number of seeds in each of the four replicates was 50. SP= seeds produced at 20-30°C; OS = original seeds obtained from Warwick HRI.

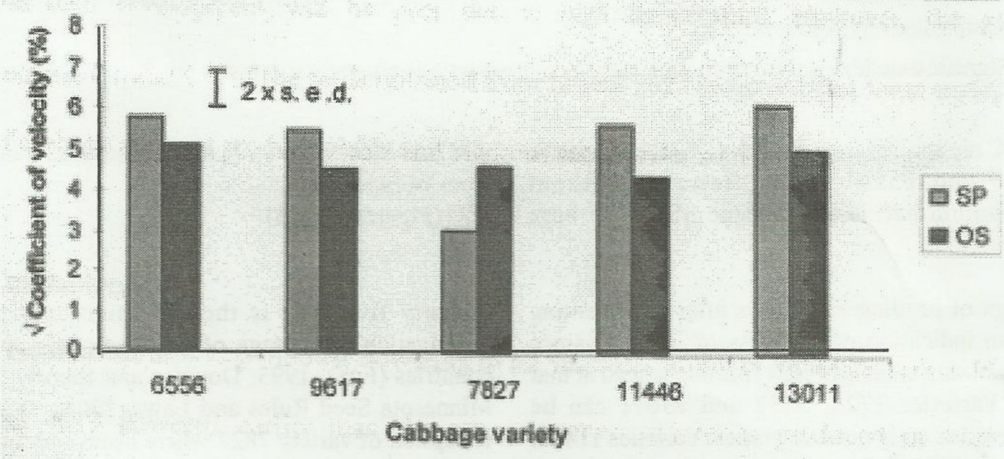

Figure 5: √Coefficient of velocity (CV) of five varieties of cabbage produced in the glasshouse (20-30°C).. Number of seeds in each of the four replicates was 50. SP= seeds produced at 20-30°C; OS= original seeds obtained from Warwick-HRI.

than the original seeds except variety 7827 where the original seeds performed better. The slight reduction in CV observed in seeds obtained from Warwick-HRI may be due to the long storage. These results suggest that some cabbage varieties can produce viable and vigorous seeds in a tropical environment (20-30°C), which is contrary to the view of Wang (2000) who indicated that, even if the plants can be vernalized, flowering and seed development will be poor due to high temperature. However, the poor germination and CV of the seeds obtained from variety 7827 indicated that some varieties of cabbage may not produce viable and vigorous seeds under such high temperatures.

CONCLUSION

Vernalization at 4°C promoted flowering in all varieties, however varieties 11446, 6556 and 9617 flowered earlier than the other varieties and seeds produced in tropical conditions (20-30°C) were viable and vigorous with most having 80% germination or higher. The exception was variety 7827 which performed poorly in terms of germination and CV. The varieties varied significantly in terms of number of leaves, height of stem and length of leaves but canopy shape index did not vary significantly and was approximately one. The taller varieties of cabbage (11446, 6556) flowered easily and consistently showed higher levels of greenness as compared to the shorter varieties. There was a strong suggestion that earliness of flowering after plant vernalization may give an indication of the ease by which varieties could be induced to flower without vernalization. Apart from the varieties 11446 and 6556 which flowered without vernalization, varieties 9617 and 3202 could be used for future studies on flowering and seed development in the tropics because they are head forming types that flower early and easily after plant vernalization without head cutting or splitting. However, unlike variety 9716, variety 3202 is susceptible to tipburn and is early maturing.

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