African Journal of Plant Science Vol. 5(1), pp. 8-14, January 2011
Available online at http://www.academicjournals.org/ajps
ISSN 1996-0824 ©2011 Academic Journals

Full Length Research Paper

Physiological disorders of Brassicas /Cole crops found in Swaziland: A review

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Accepted 18 November, 2010

Physiological disorders of Brassicas/Cole crops are abnormalities in leaf and stem morphology, colour, or both which are not caused by infectious diseases or insects. The abnormalities occur as a result of environmental stress, nutritional deficiencies or excesses on the plant. Reported causes of physiological disorders include genetic, environmental factors, nutrition, and cultural practices such as irrigation practices and tying leaves (blanching) for curd protection in cauliflower. Information was obtained through review of existing literature and informal surveys in the four agro-ecological zones of Swaziland coupled with brief interviews of key farmers and producers of Brassicas. Physiological disorders encountered in this study included premature bolting of *Brassica juncea*, head splitting in head forming Brassicas, failure of or multiple head formation called blindness, riciness in cauliflower, oedema, internal tip burn, black petiole, pepper spot, vein streaking necrosis and necrotic spot in cabbage. Measures to alleviate these physiological disorders of Brassicas are suggested.

Key words: Physiological disorders, Brassicas/Cole crops, alleviating disorders, climate change.

INTRODUCTION

Brassicas or Cole crops are very important vegetable crops in the world. The Brassicas provide the greatest diversity of products derived from a single genus. As vegetables, they provide leaves, flowers, stems and roots that are used either fresh or in processed form (Dixon, 2006). *Brassica oleracea* (Cole or cabbage group) and Oriental types (Chinese cabbage and its relatives), are of immense importance for human nutrition, containing vitamins and cancer preventing substances. The species *Brassica oleracea* (except rape = *Brassica napus*), was developed in Central and Western Europe from wild species found along the Mediterranean shoreline (Nieuwhof, 1969), whose progenitor was an annual herb. To date, Brassicas are important vegetable crops in all southern African countries including Swaziland.

Swaziland is a developing country classified in the middle income group, however it is struggling with poverty problems (Zwane and Masarirambi, 2009) and the HIV and AIDS pandemic. Agriculture is considered the backbone of the economy, contributing about 11% of gross domestic product (GDP) [Thompson, 2009]. Brassicas are some of the most popular vegetable crops of Swaziland. They are produced mainly under irrigation during the cool winter season and few are grown during the summer or rainy season because of the associated leaf diseases. Whatever seasons the crops are produced; they are subjected to a number of diseases and physiological disorders, which affect produce quality. Most of the physiological disorders are often caused by environmental stress resulting from unpredictable and uncontrollable weather conditions and or mineral deficiencies, usually micronutrients. The quality of Brassica crops for fresh consumption is determined by appearance (colour, shape, size, freedom from physiological disorders and decay), firmness, dry matter, organoleptic (flavour) and neutraceptic (health benefits) properties (Becker and Bjorkman, 1991; Guerena, 2006; Ceponis et al., 1987; Verma, 2009). Freedom of Brassica crops from physiological disorders is very important not only from an appearance point of view, but also because

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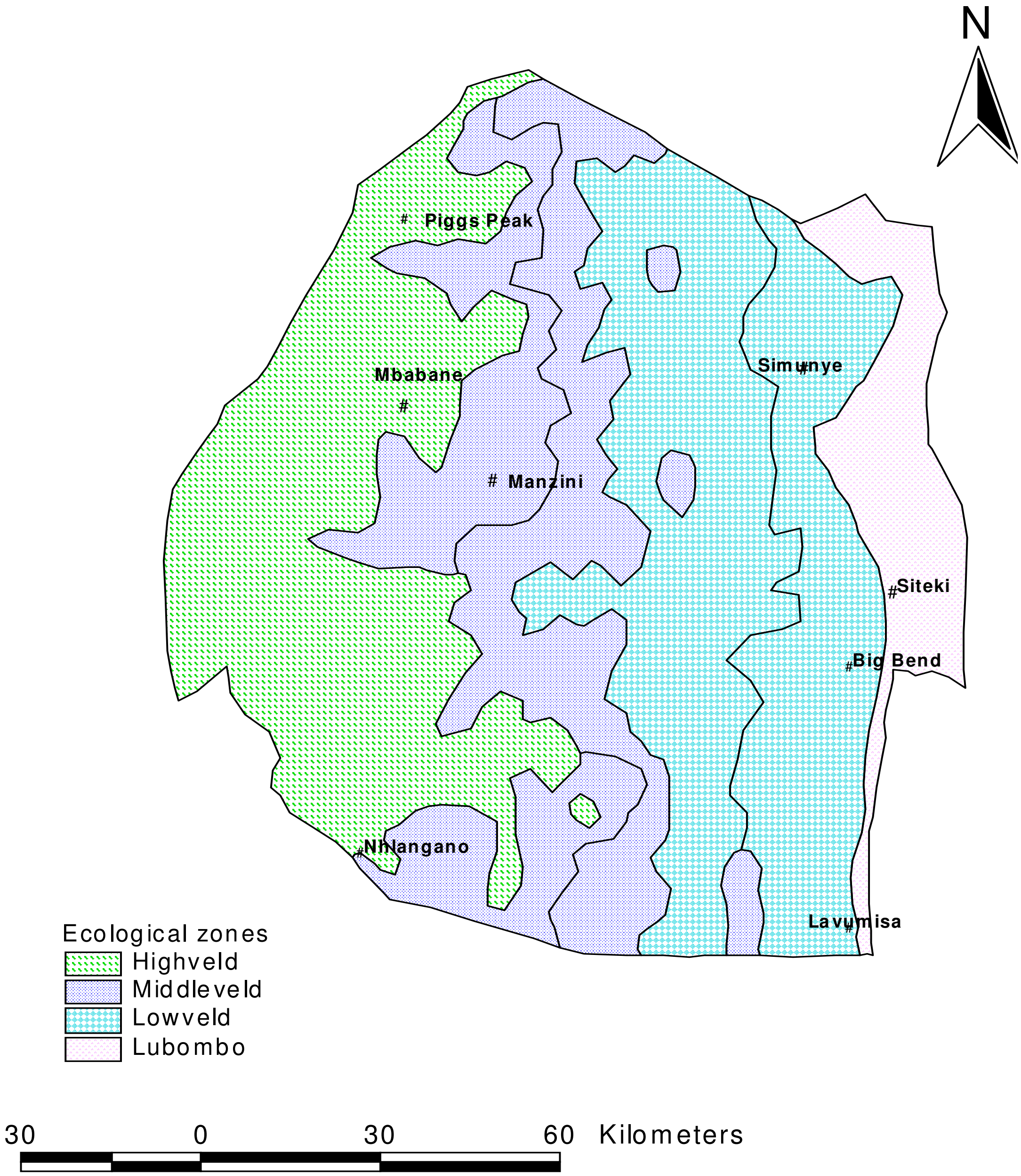

Figure 1. Ecological zones of Swaziland.

other attributes, such as nutritional status and shelf life may be affected as well. Previously, common physiological disorders of tomato fruit found in Swaziland were described (Masarirambi et al., 2009) but the various physiological disorders of Brassicas encountered in Swaziland will be discussed as a subject previously not documented.

METHODOLOGY

The objective of this review was to identify common physiological disorders of Brassicas produced under Swaziland environmental conditions in the four agroecological zones and suggest ways of alleviating these adverse conditions by situational/environmental manipulation and use of locally available resources. The study was a qualitative research. Information was sought through desk review of existing literature and informal surveys in the four agroecological zones of the country were carried out. Brief interviews of key farmers in Brassica producing areas were conducted. Samples of Brassica crops found on sale in the markets were observed, disorders were identified and described. Postharvest disorders of Brassicas found in Swaziland markets are also reported.

The country has four geographical zones with distinct topography, geology, soils, vegetation and climatic patterns (Figure 1). In the west is the Highveld, which is mountainous and has a

Table 1. Physiological disorders of Brassicas /Cole crops found in Swaziland.

Crops	BL	BN	BD	BS	BU	BM	BT	BR	VS	TB	NS	HS	LF	RC	WT
Cabbage	*		*	*	*	*			*	*	*				
Brussels sprouts	*		*	*	*	*			*	*	*				
Cauliflower	*						*	*		*		*	*	*	*
Broccoli	*						*	*				*			
Leaf mustard		*													

*Occurance of disorder. BL, Blindness; BN, Bolting; BD, Boron deficiency; BS, Black speck; BM, Black midrib BT, Buttoning, BR, Browning; VS, Vein streaking; NS, Necrotic spot; HS, Hollow stem; LC, Leafiness; RC, Riciness; BU, Bursting; TB, Tip burn; WT**,** Whiptail.

vegetation of mainly commercial forests with the bulk of the land being used for subsistence farming (Thompson, 2009; Government of Swaziland, 2007). It experiences a temperature range of 4.5 to 33ºC (Dlamini and Lupupa, 1995). It has rivers, waterfalls and gorges with some protected and managed natural areas including Malolotsha, Hawane and Phophonyane (Government of Swaziland, 2005).

The Middleveld is characterised with temperatures ranging from 2.5 to 37.2ºC (Dlamini and Lupupa, 1995). This region has fertile valleys which favour intensive farming. It has the most diversely cultivated and heavily populated area in the country (Thompson, 2009). Protected nature reserve areas include Mantenga and Mlilwane (Government of Swaziland, 2005). Further east, there is the Lowveld with the largest area coverage of 40% of the country and is drought prone (Dlamini and Lupupa, 1995). There is the Western Lowveld which is underlain by sandstone/claystone and the Eastern Lowveld which is underlain by basalt (Masarirambi et al., 2010). It has a vegetation of shrubs, and mean temperatures range from 2.6 to 41.8ºC with the bulk of commercial farms growing crops under irrigation, including the three sugar estates in the country and citrus fruit plantations. The nature reserves in the area are: Mlawula, Hlane, Shewula, Mbuluzi, Simunye and Nisela game reserves (Government of Swaziland, 2007; Thompson, 2009). The fourth region is the escarpment called Lubombo plateau with an altitude of 600 m above sea level and climatic conditions similar to the Middleveld (Dlamini and Lupupa, 1995). Given the mountainous topography of the Lubombo plateau, only one eighth of the land is arable and the rest is suitable for animal grazing (Dlamini and Lupupa, 1995).

FINDINGS AND DISCUSSION

Information recorded in this review on various Brassica physiological disorders found in Swaziland was not quantified. The numerous disorders and the Brassica crops affected are presented in Table 1. Various disorders encountered are described and possible ways of avoiding them are suggested. It is envisaged that there is need for a thorough follow up survey to this study to quantify the incidence and severity of various disorders discussed in this review.

Physiological or non-pathogenic disorders in general

Physiological or non-pathogenic disorders of crop plants are mainly caused by changing environmental conditions such as temperature, moisture, unbalanced soil nutrients, inadequate or excess of certain soil minerals, extremes of soil pH and poor drainage (Ceponis, 1987; Chiang et al., 1993; Guerena, 2006; Jarvis and McKeen, 1991). These disorders involve both genetic (G) and environmental (E) interactions and this complex interplay of (G x E) factors are poorly understood for most disorders, and in some cases contradictory results have been reported apart from numerous names for many disorders (Becker and Bjorkman, 1991). Physiological disorders can be divided into groups: nutrient imbalances (internal tipburn); genetic predisposition (blindnees, buttoning, head splitting and bolting) and watering disorders (head splitting, buttoning) (Norman, 1992). Various means can be used to alleviate these various physiological disorders like manipulation of the environment and adequate supply of nutrients especially K, which is known to reduce the incidence of black petiole and pepper spot disorders in cabbage, which affect marketing quality (Becker and Bjorkman, 1991; Guerena, 2006).

Physiological disorders of cabbage and brussels sprouts

Various physiological disorders of cabbage (*Brassica oeleracea* L var captitata), Chinese cabbage (*Brassica chinensis*) and Brussels sprouts (*Brassica oleracea* Gemmifera group) have been reported and these include blindness, bolting, boron deficiency, bursting/split heads, tip burn or necrosis of leaf margins, black petiole, pepper spot and vein streaking necrosis (Ceponis, 1987; Chiang et al., 1993; Guerena, 2006; Verma, 2009). Brussels sprouts and Chinese cabbage are only becoming important with the introduction of baby or speciality vegetables in Swaziland.

Blindness

This disorder occurs in cabbage and Brussels sprouts. It results in no head formation or multiple small heads form. Causes are several, which include pre- and/ or post-transplanting factors, such as damage to the terminal growing point due to low temperature, cutworm damage or rough handling of transplants (Fritz et al., 2009; Verma, 2009).

Bolting

This is not a problem in Swaziland although its potential induction during the second year of growth can be exploited in cabbage seed production at higher elevations as obtainable in the Highveld (Figure 1).

Boron deficiency

This disorder is characterized by pith water soaked symptoms on leaves, which turn brown with time (Norman, 1992; Verma, 2009). Deformation of curds and complete destruction is possible. Affected curds are bitter to the taste. Application of a boron containing amendment can control browning. This is presently done in the Middleveld and Highveld agroecological zones of Swaziland.

Bursting/splitting of heads

Heads split or burst usually due to heavy rains or over-watering or delayed harvest of cabbage. Rapid growth causes splitting of heads. Early maturing cultivars are most susceptible. This disorder may be alleviated by avoiding over-watering and maintaining uniform growth with proper irrigation. Harvesting on time and use of resistant cultivars preferably late cultivars may help alleviate this problem.

Tipburn

This non-pathogenic disorder is a world wide problem reported on five continents (Chiang et al., 1993). This disorder is characterized by necrosis on leaf-margins, edges or tips of cabbage, Brussels sprouts and cauliflower (Ceponis et al., 1987; Saure, 1998; Guerena, 2006). Brown spots which develop have a tendency to break down during transport and in storage, thereby providing ingress to opportunistic decay causing organisms. The problem is caused by Ca deficiency, rapid growth due to excessive nitrogen, high temperature and water stress (Guerena, 2006). According to Saure (1998), tipburn is generally considered to be a Ca-related disorder, caused by localized Ca deficiency of leaves or leaf margins, but actually seems to be rather a stress-related disorder. The problem is one of Ca translocation to the plant even if it is present in adequate amounts in the soil to accommodate rapid growth. Supplemental N applications and the form of N applied especially nitrate as opposed to ammonium form should be timed to avoid rapid growth in the later stages of plant development (Guerena, 2006). This disorder may also be avoided by ensuring adequate root growth by manipulating cultural practices and use of less susceptible cultivars. Tipburn may be followed by opportunistic infections or secondary rot pathogens like *Erwinia.*

Black speck or pepper spot

This disorder occurs with varying degrees of severity on the outer leaves of the head, but can often be seen well into the center of the head (Becker and Bjorkman, 1991; Studstill et al., 2007). Symptoms can appear in the field or after harvest. Black speck becomes visible after a period of cold storage. Midribs look as if ground black pepper was sprinkled on them thus the name “pepper spot’ (Studstill et al., 2007). The exact cause of pepper spot is not known (Studstill et al., 2007). However combination of G x E factors is likely to influence formation of this disorder for better or for worse.

Black petiole or black midrib

This is an internal disorder that has occasionally been noted in recent years in Swaziland. As heads approach maturity, the dorsal side of the internal leaf petioles or midribs turns black at or near the point where the midrib attaches to the core (Becker and Bjorkman, 1991). The affected area may extend 5 to 7.5 cm along the midrib. The cytoplasm in the parenchyma cells is found collapsed when examined under magnification. However cells in vascular bundles are usually free from discoloration. This disorder is believed to be associated with P-K imbalance and results when K level in the soil is low while P concentration is high. Relatively higher N levels aggravate the problem. The G x E interaction plays an important role. This disorder manifests itself after some time in storage. Black petiole disorder may be avoided by getting a correct balance of K and P and avoiding excessive N fertilization. The recommended levels of K are 200-300 kg/ha and P are 25-40 kg/ha (Tjeertes, 2004). Use of resistant cultivars and environmental manipulation may offer solutions.

Vein streaking necrosis

Necrotic lesions similar in size to those of pepper spot sometimes occur on the surface of the leaf in the vicinity of leaf midribs (Becker and Bjorkman, 1991). The cause of the problem is not known. Some virus diseases have been shown to produce symptoms that are similar to pepper spot and vein streaking necrosis (Becker and Bjorkman, 1991).

Necrotic spot

This disorder is characterized by lesions similar to those of pepper spot. Unlike pepper spot groups of cells die simultaneously, and they are frequently associated with vascular tissue, rather than with stomata (Becker and Bjorkman, 1991; Verma, 2009). Unlike vein streaking, necrotic spots affects parenchyma cells while the epidermal cells appear unaffected. Symptoms appear as sunken oval spots on leaves or on the midrib. The disorder usually develops during storage, while symptoms are not shown at harvest. It is advisable to use cultivars which are less susceptible to this disorder. In susceptible cultivars, the disorder becomes worse in controlled atmosphere (CA) storage when compared to refrigerated storage (Becker and Bjorkman, 1991). Cabbage previously stored under CA may be imported into Swaziland from South Africa.

Physiological disorders of cauliflower and broccoli

Cauliflower (*Brassica oleracea* var. *botrytis*) and broccoli (*Brassica oleracea* var *italic* or *gumosa*) is affected by several physiological disorders which include browning, buttoning, leafiness, riciness and mineral deficiency symptoms (Norman, 1992; Verma, 2009).

Buttoning

This disorder is characterized by production of small unmarketable curds called buttons. Plants that develop buttons are small and have small leaves that do not cover the developing head (Norman, 1992; Fritz et al., 2009). The cause of this disorder is a limited nitrogen (N) supply the delay in transplanting, among other causes. Inadequate water or other plant growth stresses have been implicated as causal factors. According to Norman (1992) and Fritz et al. (2009), any check in growth due to dry soil or delay in planting out may cause small curds to be formed. Too little or too much hardening, cold weather for 10 days or more at 4 to 10°C, diseases, insects and micronutrient deficiencies have been reported to also cause broccoli and cauliflower buttoning (Fritz et al., 2009). This disorder may be alleviated by supply of adequate amounts of N and timely field transplanting. Minimization of transplant shock and maximization of conditions which favour vegetative growth will reduce occurrence of the disorder. Use of younger, smaller transplants and cultivars with longer juvenile period may mitigate the problem of buttoning.

Blindness

This disorder results in no curd formulation, the plants remain vegetative. Several causes of blindness have been reported earlier for cabbage and these include poor fertility, insect damage, disease, genetic irregularities or cold temperature. High temperatures (days over 30°C and nights of 26°C) delay and prevent proper curd development and affect subsequent quality (Fritz et al., 2009; Verma, 2009). Blindness in cauliflower occurs in most areas in Swaziland during the hot summer months and occasionally in winter in the Lowveld (Figure 1). It is important therefore to grow cauliflower in winter in most areas of Swaziland to avoid this disorder. The most ideal areas of broccoli production are found in the Middleveld and the Highveld during winter.

"Leafy curds" or Leafiness

This condition is characterized by green leaves found between sections of the curd and is thought to be caused by relatively high temperatures and delayed harvesting (Norman, 1992; Loughton, 2009). This disorder can be alleviated by growing cauliflower during the cool winter season in Swaziland and by timely harvesting. Irregularly shaped curds and loose curds are not marketable and cause losses to growers who may resort to local sales at reduced prices. Local consumers have no problem with leafy curds because leaves are appreciated and consumed as spinach. However uniform curds without intercepting leaves are preferred in the market.

Riceness

A disorder of the head in which the curds acquire a velvety appearance somewhat like a pot of boiled rice. In this condition there is elongation of peduncles of individual flower buds that result in a granular appearance of the curd (Norman, 1992). The condition may be caused by the development of small white flower buds, attributed to high temperature during curd development (Norman, 1992; Frits et al., 2009). Defect increases with rapid growth and heavy N side-dressings. Good seed of appropriate cultivars (Norman, 1992), favourable cool weather as prevails in the cool season of Swaziland from May to about beginning of August and harvesting at the appropriate time may prevent this disorder. Proper management of soil moisture and fertility helps in alleviating this condition.

Mineral deficiency symptoms

Disorders caused by mineral deficiency symptoms include browning, whiptail and internal chlorosis among others. However previous work did not link any soil nutritional status in the different agroecological zone to any crop nutritional disorders (Haque and Lupwayi, 2003). Haque and Lupwayi (2003) did not consider vegetable crops in their work, which was rather generalized and lacked detail even of the agronomic crops they tried to consider. It is recommended that soil tests and nutrional foliar analysis be done in any commercial venture of Brassica crop production in order to reduce any potential losses due to mineral deficiencies.

"*Whiptail": Molybdenum deficiency*

This disorder occurs mostly in cauliflower (Fritz et al., 2009) and is caused by inadequate molybdenum in the soil or low soil pH. Acidic soils are common around Luyengo, Manzini region in the middleveld of Swaziland. Cauliflower affected by molybdenum deficiency is characterized by strap-like leaves and a deformed growing point. Occasionally only a leaf midrib develops. This disorder is common in soils with a pH of less than 5.5 and often corrected by proper liming or an application of 1.1 kg/ha (ammonium molybdate). Cultivars differ in susceptibility; therefore growers should select appropriate cultivars for their area.

Browning

Cauliflower color has to be white or pale cream. Boron deficiency and exposure of curds to sunlight during development causes browning (Norman, 1992; Fritz et al., 2009). Direct exposure of curds to sunlight should be avoided because it leads the curds to develop yellow or red pigment (Fritz et al., 2009). Light can be excluded by tieing the leaves when the curd is about 8 cm in diameter. Leaves may also be broken over the head. In hot weather blanching may take three to four days while in cold weather it may take eight to 12 days. Some cultivars have inner wrapper leaves which provide natural curd protection. Condition first develops within the stem and the centre of the curd at the base of the curd branches. This condition is not visible until curds show external discoloration.

Cauliflower left uncovered will discolour due to activation of peroxidase enzyme by sunlight and the curd will loosen in the sun's heat. Leaves may be tied together to protect curds from the sun. Curds develop within the tied leaves in 5 to 15 days. Different color codes required for blanching different dates. "Self-blanching types" have no need for tying. In self-blanching types curds are shielded from the sun by inwardly folding overlapping leaves.

Hollow stem

This disorder occurs in many parts of the world. In Swaziland it has been observed in locally grown crops and crops imported from South Africa. It occurs in broccoli and cauliflower. Hollow areas extend from below curd when the core or fleshy center splits due to uneven growth rate with the rest of the plant. The cavity may extend to either end of the plant to produce a cavity to the outside environment (Loughton, 2009; Fritz et al., 2009). There is potential for infection by bacteria and fungi and spoilage follows. This condition is most severe when growth is rapid. Several causes of hollow stem have been reported including environmental stress (Guerena, 2006). Sudden and rapid growth which is usually irregular, high N levels and low plant populations are conditions which favor hollow stem (Zink, 1968; Loughton, 2009; Boersma et al., 2009). Boron deficiency has also been reported to be associated with this malady (Loughton, 2009), although it is not critical. In fact, Boersma et al. (2009) and Zink (1968) reported that Bo was not associated with hollow stem. Supplemental application of K to broccoli transplants increased the incidence of hollow stem in subsequent broccoli spears (Wyatt et al., 1989). Curds with hollow stems are unmarketable.

Hollow stems can also arise from excessive N fertilization. Deficiency of boron or its unavailability in limed soils is the cause of this condition. Leaves of boron deficient plants are sometimes blistered and yellow. This disorder can be corrected by applying 1.1 to 3.4 kg/ha of boron in the form of borax. Other means of controlling this disorder include increasing plant density, avoiding excessive soil fertility, encouraging conditions which reduce plant growth rate.

Physiological disorders of leaf mustard

Leaf mustard (*Brassica juncea*) is a cool season annual grown for its leaves which are cooked like spinach. Leaf mustard is a very popular leafy vegetable in Swaziland and the rest of the southern African region. It is preferred for its mild bitter taste reminiscent of indigenous vegetables like *imbuya* (*Amaranthus hybridus), inkhakha* (*Mormodica balsamina*) and *chuchuza* (*Bidens pilosa*). Leaf mustard can successfully be grown in the cool season in Swaziland from the last half of May to beginning of August depending on agro-ecological zones and mustard type. It can also be grown in summer sometimes inter planted with the main staple maize (*Zea mays*) also known as *umbila* in the local language.

The greatest challenge of growing leaf mustard is its susceptibility to premature bolting especially in summer. Early bolting in leaf mustard is undesirable because the crop is grown for its delicious leaves which can be used as spinach in stews. Various causes of early bolting have been reported (McGregor, 1981; Morrison and Stewart, 2002). The causes of early bolting in mustard are G x E related. Research has been done at the University of Swaziland to find ways of alleviating bolting in leaf mustard (Dlamini, 2007; Nkhabindze, 2007). Nkhabindze (2007) investigated the combined effects of topping (cutting of the apex or removal of the shoot tip) with application of a nitrogenous fertiliser (lime ammonium nitrate) on *Brassica juncea* at different rates and reported a promotion of vegetative growth with increasing rate of application, whilst the onset of flowering was delayed. The onset of flowering took 74 days where N was applied at 60 kg/ha while untreated plants flowered in 63 days. Where topping was done without N application, the plants took 68 days to flowering while a combination of topping and N application at 60 kg/ha extended the onset of flowering to 75 days.

Dlamini (2007) used compost at the rates 0, 10, 15, 20, 25 and 30 tons/ha and reported an increase in vegetative growth of *Brassica juncea* which was accompanied by delayed onset of flowering. Plants which were not treated with compost started flowering as early as 60 days after planting. Relatively higher compost rates of 25 and 30 tons/ha promoted vegetative growth and the date of flowering was extended to between 65 and 75 days due to compost application at 25 and 30 tons/ha, respectively.

Conclusion

Climate change effects are likely to increase the incidence of *Brassica* crop disorders due to global warming in cases where negative affects result in stress, nutritional deficiencies or excesses. Therefore, growers should learn to positively identify the various physiological disorders that occur in their agro-ecological zones/areas and be able to manipulate the environment and to use locally available resources such as fertilization of *Brassica* crops with animal manure to mitigate nutritional deficiencies in order to control particular disorders. Evaluation of cultivars adaptable to the different agro-ecological zones coupled with sound horticultural practices, such as timely seedling trans-planting, adequate fertilization and irrigation will go a long way towards alleviating the devastating effects of physiological disorders of Brassicas in Swaziland. Further work is warranted pertaining to breeding and agronomy of Brassicas in the four agroecological zones of Swaziland with the goal of developing potential cultivars for export in the Southern African Development Community (SADC) region and beyond.

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