# EFFECTIVENESS OF RELATIVE WATER CONTENT AS A SIMPLE FARMER'S TOOL TO DETERMINE PLANT WATER DEFICIT

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## Abstract

**Cabbage (*Brassica oleracea var. capitata* L.) is a botanically and commercially important vegetable cultivated all year round in the tropics. Although cabbages are easily grown under a wide variety of conditions and are adaptable to most climatic conditions, successful cultivation of this crop is hampered by incidences of water stress. To produce quality acceptable heads that are marketable, supply of right amount of water is paramount. To monitor whether the plants are getting enough amount of water there is need to use a reliable, simple, and indicative method. Relative water content has been proposed as a simple tool that could be employed with ease and precision by a farmer. To test the effectiveness of Relative Water Content (RWC) as a simple farmer's friendly parameter, cabbage variety Pruktor and Michel F1 (potted) were subjected to four treatments in two seasons. The treatment were: 0%, 25%, 50% and 100% of soil field capacity arranged in a complete randomised design. Samples to determine RWC were collected in three day intervals. Water stress did not affect head formation but decreased growth, leaf area, head size, and total yield. In both experiments, yellowing and selective shedding was observed mostly in 0% and 25% treatment. Relative water content declined significantly with day after treatment and decreasing water supply. Among the control, plants with lower RWC had smaller head compared with those of relatively higher RWC. This indicates RWC as a simple parameter that could be used to monitor water status of the plant during growth to enhance production of good quality marketable head and maintain crop yield.**

**Keywords:** cabbage, water stress, growth, relative water content, yields

## Introduction

Horticultural commodities are very vulnerable to water stress as their saleable products constitutes up to 90% water. Water is essential for all physiological processes of plants including cell division, synthesis of nucleic material, enzymes, photosynthesis, and respiration among many other processes. Plant growth is largely driven by water uptake into the cell vacuole (Taiz 2000). For instance Water comprises more than 90% of biomass of cabbage as calculated from Xu and Leskovar (2014). It follows that any slight water deficit (drought) or oversupply like in the case of flooding could greatly affect expected yields. For example, water deficit reduces yield with up to 30 % (Potopová et al. 2016). This is because water is important in leaf expansion which largely constitutes the cabbage head therefore the size. Water stress is expected to become wide spread with the current anthropogenic climate change hence limiting horticultural production.

Tissue water content has been interlinked with several physiological processes like photosynthesis. This means that carbohydrates manufacture which steer plant growth is hampered largely due to closure of stomata during water stress. Water deficit also triggers other physiological processes like accumulation of simple sugars and amino acids that acts as osmoprotectacts (Chaves and Oliveira 2004; Wanjiku and Bohne 2017). These osmolytes consumes the stored carbohydrates exacerbating growth.

It follows that, any tool that would predict the water content of the plant that is simple would be helpful especially for the small scale farmer, in avoiding economic loss associated with water deficit. Relative water content is a simple parameter that has been strongly correlated with many important physiological processes that are paramount for plant growth and productivity. According to (González and González-Vilar 2001), water stress increases the reduction in cabbage tissue water levels hence affecting leaf elongation, nitrogen metabolism and cell membrane properties thus causing a reduction in cabbage productivity. Stomatal activity, which is also affected by water stress, can influence $CO_2$ absorption and thus impact photosynthesis and cabbage growth. The objective of this study is therefore to elucidate the effectiveness of relative water content (RWC) as a simple farmer's tool to determine water stress in horticulture commodity such as cabbage.

Cabbage (*Brassica oleracea* L.) is a green, annual vegetable cultivated in both small scale and large scale for its dense leafed heads. Cabbage is rich in essential vitamins such as vitamin B, vitamin B-6 and vitamin B-1 (Raiola et al. 2018; Winch 2006). When eaten raw it is an excellent source of natural anti-oxidant against cancer. It also a source of vitamin K which has a role in bone metabolism and blood clotting. Cabbage also contains adequate amounts of minerals like potassium, magnesium, manganese and iron. Iron is important in the formation of red blood cells. Potassium is an important component of cell and body fluid while Manganese is a co-factor for anti-oxidant enzyme (Raiola et al. 2018). Cabbage is used for medicinal purposes such as morning sickness and asthma. According to FAO (2006), cabbage is a high income earner to many farmers and has greatly contributed to Kenya's Gross Domestic product and food security (Export Processing Zone Authority 2005).

## Material and methods

Experiments were carried out in a shed net for two seasons: January to March (2018) and May to August (2018) at the Taita Taveta University, School of Agriculture, Earth and Environmental Science, Ngerenyi, Kenya (longitude-03°25' 57" S, latitude 38°20'36" E, elevation 163 m a.s.l.). The soil is alfisols mixed with farm yard manure and nitrogen, phosphorus and potassium (N. P. K). The 8kg soil was potted in 10 L containers. Cabbage (*Brassica oleracea* L.) were seeded first in a nursey before transplanting into the 10 Litre containers. In the first experiment the variety Pruktor was used and Michel F1 was used for the second. The shed net day temperatures for the two seasons were generally similar in the ranges of 15 °C to 28 °C.

## Drought experimental design

All containers with plants were saturated and weighed separately before moving them into the greenhouse. They were randomly allocated treatments: FC0, FC25, FC50 and FC100 of soil field capacity arranged in a complete randomised design. The control (100%) plants were irrigated everyday with equivalent amount of water lost via evapotranspiration. Every other day, stressed plants (except 0%) were weighed and separately irrigated with either 50% (slow stress) or 25% (fast stress) of their original weight. Each drought plant was evaluated daily for wilting symptom. The experiment was terminated when half of the plants had no fresh leaves. During the drought period, relative water content growth parameters and morphological changes were evaluated while at the end of the drought period dry weight was determined.

## Relative leaf water content (RWC) determination

Leaf discs from fully expanded leaves from three randomly chosen plants were used to determine RWC. The fresh weight of the leaf discs (FW) was recorded, water-soaked for 24 hrs at room temperature after which turgid weight (TW) was recorded. Leaf discs were oven dried for 24 h at 105°C for dry weight (DW). Then RWC was calculated as follows:

$$RWC = [(FW - DW)/(TW - DW)] \times 100$$

### Growth measurement

At the beginning of drought treatment, growth was quantified in terms of height, number of leaves, and root collar diameter (RCD) from all the plants. Dry mass was determined at the end of the experiment, whole plants were used. They were oven-dried at 70°C for 72 hrs before dry weight was determined.

### Statistical analysis

All statistical analysis were performed with R 3.1.3 (R Development 2014). Data collected were subjected to multivariate analysis of variance (MANOVA) with drought treatments and Day after treatment (DAT) as the main effects. Interactions between DAT x treatment were also determined. Where needed, data was log transformed to meet statistical assumption of normal distribution for MANOVA. Statistical significance was considered at $\alpha = 0.05$ and separation of means was done using Tukey test.

### Results

At the beginning of the experiments, all transplants had similar growth characteristics in terms of plant height (cm), number of leaves and stem dimeter (cm). They were all successfully acclimatized for seven days before the initiation of drought stress treatment (data not shown). Moreover, they had similar relative water content (RWC) up to day 3 when the plants in different treatments started to differ significantly (Fig. 1). The differences in RWC continued to differ significantly among treatments, although not steadily, until the termination of the experiments. Despite the decline in RWC, the number of plant leaves in FC0 and FC25 remained constant. After fourteen days of initiation of drought treatment, the lower leaves would yellow and senesce. The plant in FC0 and FC25 expanded slowly while those of F50 and F100 would expand rapidly and new ones would form (data not shown).

Drought also affected the morphological outlook of plants in different treatments with the plants at FC0 being the smallest (Fig. 2) and having the least number of leaves (Fig. 2 and Table 1).

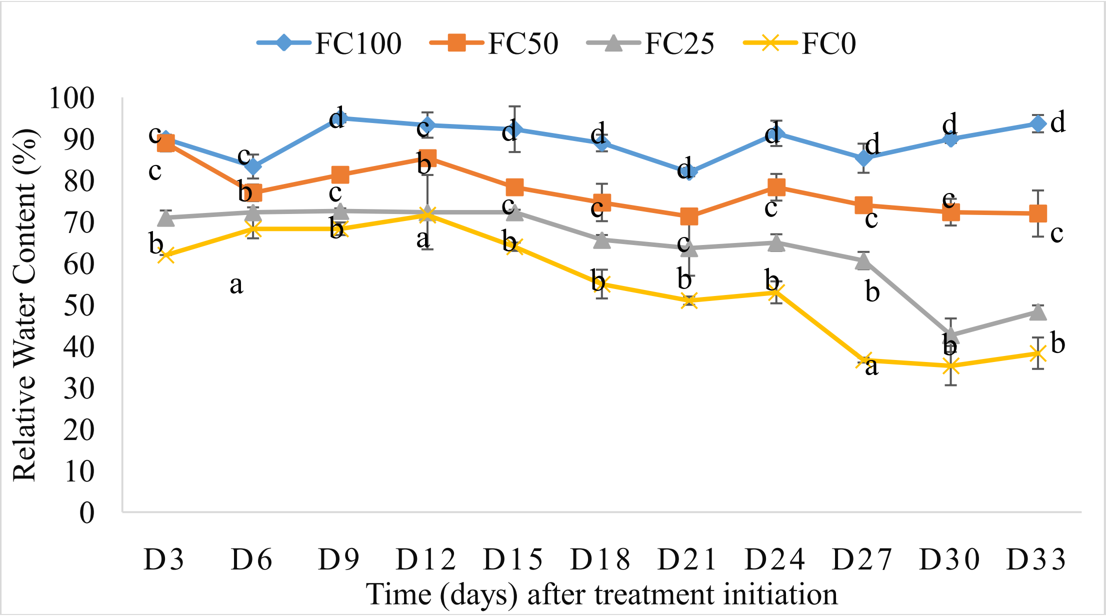

Fig. 1: Leaves' RWC of Michele F1 white cabbage during a drought experiment. Mean ± SD, n = 6. Different letters show significant differences between treatments.

Fig. 2: Morphological appearance of Pruktor F1 white cabbage amidst drought experiment.

Although the leaves were not showing wilting symptoms, the colour of all treated plants (FC0, FC25, and FC50) changed from green to blue and in some plants purple colouration would emerge compared with the control plants. The leaves of all drought treated plants developed thick cuticle and wax deposit which w evident. Pest attack, majorly aphids, were also seen on stressed plants and significantly so for plants in the FC0 and FC25 treatments (data not shown).

Drought conditions affected time taken for cabbage head formation and their marketable yields.
In FC0 and FC25 the time to form heads were relatively longer hence delayed head formation, while that of FC50 was hastened compared to the control, FC100 (Fig. 2)

Once the experiment were terminated, all the plants were uprooted and their stem diameter, root collar diameter, number of leaves and dry mass was determined. The plants stem length and root collar diameter were similar and did not differ significantly among the treatments. However the number of leaves and the dry mass differed significantly among the treatments. The control had the highest number of leaves and the highest dry mass compared to drought treated plants (Table 1).

Table 1: Dry weight (g), number of leaves (count) and plant height of Michele F1 white cabbage during drought treatment. Different letter signify treatment mean (n = 6) differences at α ≤ 0.001.

| Treatments | Dry weight (g) | Leaves No. (count) | Height (cm) |
|---|---|---|---|
| FC100 | 97.7 ± 4.6 d | 19.0 ± 2.8 d | 15.7 ± 1.9 a |
| FC50 | 68.2 ± 3.7 c | 16.0 ± 1.4 c | 14.6 ± 2.5 a |
| FC25 | 58.8 ± 1.2 b | 13.6 ± 0.9 b | 16.8 ± 2.4 a |
| FC0 | 29.8 ± 0.1 a | 11.4 ± 0.9 a | 15.9 ± 1.9 a |

The length and the width of the leaves in various treatments differed significantly with those of the FC0 being the shortest in terms of leaf length and the narrowest in terms of leaf width (Data not shown).

## Discussion

Most vegetables constitute higher percentage of water at large and any deficient greatly affects their biomass and quality(Stagnari, Galieni, and Pisante 2016). Thus high water content is paramount in vegetable quality aspects. With climate change the occurrence of drought is foreseen to occur rampantly and erratically therefore, critical methods to monitor plant water status often is vital. The method ought to be affordable, minimally destructive and effective.

From Fig. 1 above, decreasing water availability to the plants (FC100 < FC50 < FC25 < FC0) leads to a decline in relative water content. The RWC monitoring showed that, decline in RWC leads to decline in most of the growth parameter (height, leaf number, leaf length, width and total dry mass) and yields. This decline in most of these parameters is because water availability is critical for cell division, enlargement and many biological activity that constitute growth. Water is also critical for photosynthesis which manufacture food substrate for respiration that provide ATP for various physiological and biochemical processes. Soon when the water declined, to a critical level, the plants declined their stomata conductance hence limiting carbon dioxide which is a crucial raw material for photosynthesis(Xu and Leskovar 2014) hence decline in yields (Potopová et al. 2016).

According to literature, leaf tissue starvation will result to decreased cell division, cell wall lignification thus resulting to leaves with decreased leaf area that are thick and gross in appearance. The lower leaves finally start to senesce and finally abscise(Habash et al. 2014; Munné-Bosch and Alegre 2004; Richardson et al. 2013). This is similar to our results in the treatment with FC0 and FC25 which had the lowest RWC throughout the treatments. Despite the lower leaves yellowing and falling away, these treatments (FC0 and FC50) retained a number of leaves that were thickening with time demonstrating some resilience to drought especially FC0 that survived at least 40 days from the initial irrigation.

Low relative water content of the cell is correlated with declining water potential and accumulation of organic solutes like glucose, fructose, sucrose, proline, glucosinolates among other osmolytes (Jahangir 2010; Verslues et al. 2006). Although these solutes assist the cell in osmotic adjustment and to retain biological water activity, they predispose plant to insect attack (Mattson and Haack 1987). This would therefore be the reason why the plants in treatment FC0 and FC25 were with high incidences of aphids (*Brevicorynebrassicae*). This is with agreement of a study conducted by Jahangir (2010) who found greater susceptibility of the cabbage cultivar to *Brevicorynebrassicae* due to a high concentration of 2-hydroxy-3-butenyl glucosinolate in leaves.

Anthocyanin formation was also observed on plants in various water stress treatment other than the control plants. The intensity of colouration was more on FC0 and FC25 and less intense on FC50. The anthocyanin accumulation is to some extent associated with abiotic stress and so in agreement to our results in protecting the photosynthetic apparatus under abiotic stress (Nicotra et al. 2010). They are associated with defence mechanism of the plant. Nevertheless, anthocyanin are said to be of health benefit to man(Tangney and Rasmussen 2013). This suggests that a degree of abiotic stress is paramount to confer these health benefits polyphenol. In regard to our experiment a range between FC50 and FC100 would trigger accumulation of these beneficial compounds but also better marketable yields than those experienced in our experiment at FC50.

## Conclusion

Incidences of water stress (drought) and its devastating effects will continually be experienced in any given crop cycle especially in the tropics. However, RWC could be used effectively to monitor the level of stress or plant adjustment to cope with such incidences of water stress. Relative water content does not only monitor the biological water activity in the plant tissues, it could also be used as a tool to monitor probability pest attacks or prospects of accumulating important health benefiting phytochemical as discussed above.

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