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VARIETAL RESPONSE OF CABBAGE TO DROUGHT CONDITIONS IN LA TRINIDAD, BENGUET, PHILIPPINES

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ABSTRACT

Evaluation of varieties of crops with high tolerance to drought and other stresses is one climate change adaptation strategy. Since future climate conditions are not predictable, it is therefore crucial to evaluate different crop varieties that can withstand drought conditions in La Trinidad, Benguet, Philippines which has an elevation of 1,521 m asl. Five varieties of cabbage which include Ace Green, Gladiator, Lucky Ball, Rare Ball, and Scorpio were evaluated for two cropping seasons from 2013-2015 to determine their performance under drought condition. The experiments were laid-out following Randomized Complete Block Design with two replications. Drought imposition was done by subjecting plants to moderate drought (45-55 centibars soil matric potential) coinciding with the heading stage of cabbage. The cabbage varieties had varied performance in the two evaluation periods. Drought during the heading stage (starting at 70 DAT) resulted in delayed head initiation, poor heading percentage, low head weight, and decreased yield. Among the varieties evaluated, Lucky Ball and Ace Green consistently produced high yield and heading percentage in both evaluation periods.

keywords: *drought score,heading stage, yield, relative water content, soil matric potential*

INTRODUCTION

Vegetables are the best food crops for overcoming micronutrient deficiencies. Aside from these, they provide farmers with higher income per hectare compared to staple crops (AVRDC, 2006). Vegetables from Benguet, Philippines supply 80% of the needs of the Philippine metropolis. The major vegetables grown in the locality are cabbage, Chinese cabbage, broccoli, cauliflower, potatoes, carrots and other temperate vegetables. Cabbage is one of the main vegetables produced in terms of volume and often sold outside Benguet (Local Government of Benguet, 2015).

Technologies in vegetable production are introduced every year. However, despite these, maximum production seems to be elusive due to various factors. One of these factors is the scarcity of water supply. There is low water supply during dry seasons restricting more intensive production of vegetables. The problem is even compounded by the effects of climate change resulting in long dry spells or the “El Niño” phenomenon.

Recently, global warming has been worsening water supply, limiting this in most agricultural regions. Thus, it is relevant to understand the mechanisms that enable plants to cope with water deficit (Xoconostle-Cázares *et al*., 2011). Drought conditions greatly influence the yield and quality of vegetables, thus drastically reducing vegetable productivity (de la Peña and Hughes, 2007). In 2015, Benguet was reported to have been affected by drought. According to PAGASA (2015), drought occurs when there is reduction of more than 60% reduction from the average rainfall for three consecutive months.

Drought stress can be minimized by means of cultural practices that will increase availability of stored water and proper water management. Another means of minimizing the problem is through the use of varieties that are drought tolerant. Having improved and adapted vegetable germplasm is cost-effective for farmers. This minimizes the effect of drought stress due to climate change, thus, the study was conducted to evaluate the performance of cabbage varieties under drought conditions in La Trinidad, Benguet from 2013 to 2015.

MATERIALS AND METHODS

Study Site, Experimental Treatments and Growth Conditions

The field experiments were conducted at the Climate-Smart Agriculture Center station of Benguet State University in La Trinidad, Benguet, Philippines using two cropping seasons from 2013 to 2015. Five hybrid cabbage varieties namely, Lucky Ball, Rare Ball, Scorpio, Ace Green and Gladiator were sourced-out from different seed companies. Seeds were sown in seeding trays filled with compost and were watered regularly. An area of $50m_2$ was prepared and divided into two blocks. Each block was further subdivided into five plots, each measuring 1 m x 5 m. The field has the following soil properties: sandy clay, pH 4, 0.24% N, 4.88% OM, 778 ppm P, 53.30 ppm K, 1.15 g cm-3 bulk density, 2.26 g cm-3, 49% porosity. Compost was applied at 2.5 $kg/5m_2$ one week before transplanting. One month old seedlings were transplanted early November of 2013 and 2014 in the field with a distance of 30 cm x 30 cm between hills and rows. The treatments were laid-out following Randomized Block Design with two replications. The cabbages were harvested in February, 2014 and February, 2015.

Drought Stress Imposition

Drought imposition was done following the procedure used by Taligan and Tad-awan (2004). Plants were irrigated until establishment after this was stopped when the soil matric potential (SMP) reached 45-55 centibars (cb) giving a condition of moderate drought. After drought scores were taken, rewatering was resumed until SMP reached 20 cb or normal conditions, with which recovery rating was taken.

Observation and Data Collection

Meteorological data and soil matric potential. Data on temperature, relative humidity and rainfall were gathered during the two growing seasons. A Jet-fill tensiometer was placed in the middle of the field to determine the SMP in centibars at a depth of 0.23 m.

Relative water content and drought score. From each sample plant, three leaves were taken and were used as representatives of the whole leaf to measure the relative water content (RWC). Ten leaves were obtained immediately after excision and the fresh weights were taken. After the leaves had been immersed in distilled water for 12 hours, the turgid weights (TW) were obtained. Samples were weighed (FW) then placed in an oven at 80_oC until these have reached constant weights, after which the dry weights (DM) were obtained. RWC was computed using the formula:

RWC (%)=(FW-DW)/(TW-DW) x 100
Where:
FW – fresh weight
DW – dry weight
TW – turgid weight

Drought scores. These were taken when wilting of plants occurred. Visual scores were based on leaf wilting and on the visual condition of the canopy. The scoring system used was as described by Taligan and Tad-awan (2004), where 0=No stress or all leaves were turgescent in all plants, 3=30% of the leaves wilted or 30% of the plant population wilted; 5=50% of the leaves wilted or 50% of the plant population wilted, 7=80% of the leaves wilted or 80% of the plant population wilted; and 9=Complete wilting and death of the plants.

Heading characteristics and yield parameters. The number of days to head initiation was counted when the shoot leaves started to bend inward. The heading percentage per plot was also determined at harvest. The average head weight (g) was obtained by getting the mean of 10 sample heads and the total yield ($kg/5m_2$) was gathered as the weight of all the harvested heads per plot.

Pest and disease incidence. Diamond-back moth infestation was recorded at the vegetative stage while blackrot and clubroot incidence were evaluated at harvest.

Postharvest data. Sample heads were taken just after harvest for postharvest evaluation under ambient condition. The shelf-life of the cabbage varieties was determined by counting the number of days from display to the day the heads were still fit for consumption. Weight loss (%) was determined using the following formula:

% WL = Initial Weight – Final Weight x 100

Statistical Analysis

All quantitative data were subjected to analysis of variance (ANOVA) for RCBD using MSTAT-C. The significance of differences among treatment means was tested using the Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

Climatic conditions. Mean temperature ranged from 18-21°C in the first trial and 17.5-19°C in the second trial (Table 1). The temperature during the conduct of the study was favourable for cabbage growth, however, rainfall was so low or nil. The prolonged absence of rain leads to drought which causes injury to the crop and significantly reduces the economic yield (Ketring, 1983). PAGASA reported Benguet in 2015 as one among the 23 provinces affected by drought as indicated by above 60% reduction in average rainfall for three consecutive months (DA, 2015).

Soil Matric Potential. The soil matric potential (SMP) was relatively high at 70-90 days after transplanting (DAT) from January to February of each cropping period. These periods also correspond to the time when rainfall was either low or nil (Table 1). Figure 1 shows that the soil moisture condition had fallen to moderate drought level starting at 65 DAT and progressed until 90 DAT. High SMP at 70-90 DAT indicates that the cabbage plants were stressed at heading stage until harvesting. A similar trend was observed in the second evaluation. The high SMP indicates successful drought imposition during the growth period of the cabbage plants.

Drought scores. Scoring for drought stress was done during the heading stage when drought stress was observed or when SMP reached 45 cb. Thirty percent of the plant population in all varieties showed wilting when the SMP reached 45 cb. Cabbage is classified as intermediate susceptible to water stress (Nortje and Henrico, 1988). Moreover, cabbage is particularly sensitive to drought stress during the period of head formation up to harvest (USDA, 2014). According to Levitt (1986), drought resistance in cabbage can be due to efficient cuticle and tolerance to cell dehydration as a result of osmotic adjustment. Specific leaf traits of the varieties may have contributed to their drought tolerance.

Relative Water Content (RWC). The RWC of the cabbage varieties differed in the two evaluation periods (Table 2). Higher RWC values were observed for all varieties in the 2013-2014 cropping season, however, these were not significantly different among the varieties. Significant differences were only observed on the RWC of the cabbage varieties in the second evaluation period. The differences in the RWC may be attributed to the ability of the leaves to absorb more water and the ability to control water loss through stomatal closure (Bayoumi *et al*., 2008). Relative water content is a meaningful index of plant water status (Smart and Bingham, 1974). In other crops such as spring wheat, there was positive correlation of RWC and drought tolerance (van Heerden and de Villiers, 1996). However, the high relative water content of Gladiator variety did not necessarily result in high yield under drought stress.

Heading Characteristics of the Cabbage Varieties

Days to head formation. Lucky Ball was the earliest to form head in the first evaluation but did not differ significantly from Ace Green and Gladiator (Table 3). In the second evaluation, no significant differences were observed in the days to heading. Differences observed in the days to heading can be attributed to differences in maturity of the varieties.

Heading Percentage. High heading percentage

Table 1. Meteorological data during the conduct of the study in La Trinidad, Benguet, Philippines (2013-2015)

MONTH	TEMPERATURE (OC)		RELATIVE HUMIDITY (%)		RAINFALL (mm)	
	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015
November	20.96	18.80	82.12	82.12	0.69	48.80
December	20.03	18.25	84.37	87.00	2.72	22.40
January	20.05	17.50	81.50	78.00	0.00	0.30
February	18.13	17.55	81.00	83.12	0.00	2.30

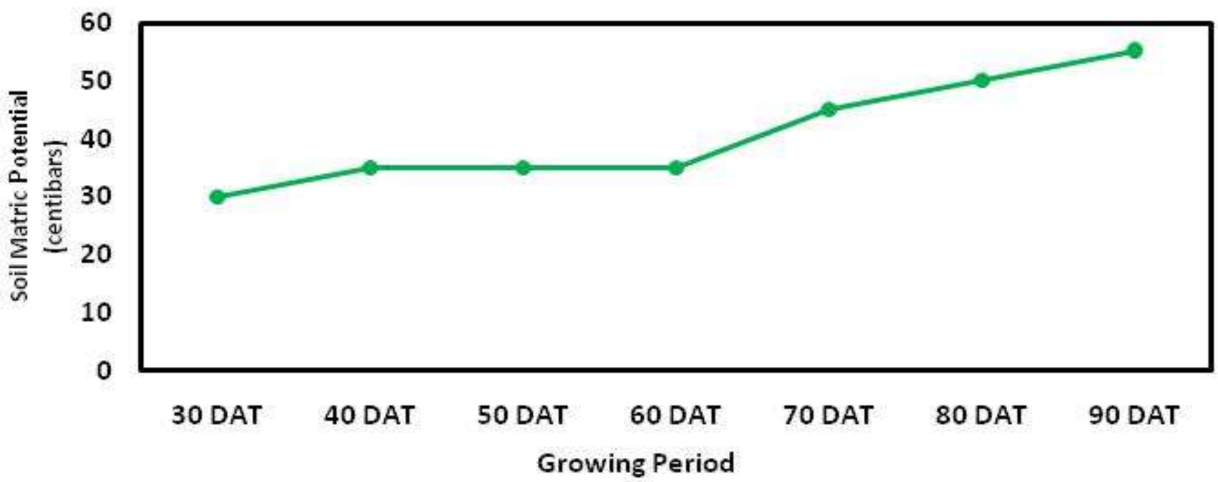

Fig 1. Soil matric potential from 30 to 90 days after transplanting (DAT)

Table 2. Relative water content of cabbage varieties evaluated under drought stress

ENTRY	RELATIVE WATER CONTENT (%)	
	2013-2014	2014-2015
Ace Green	93.69	61.50d
Gladiator	91.46	91.01a
Lucky Ball	93.73	82.27c
Rare Ball	93.30	87.50b
Scorpio	93.01	52.50e
CV (%)	1.08	13.00

is desired since it could mean high yield. High heading percentage was observed in the first trial while notably a lower percentage was derived in the second trial. In the first evaluation, the cabbage varieties showed 96-100% heading percentage while only 18-30% in the second evaluation (Table 3). This difference may be attributed to more severe water stress during the second trial which greatly reduced the heading performance of the different cabbage varieties. In the second evaluation, Gladiator had significantly lower heading percentage than the other varieties.

Yield and Yield Components

Average head weight. In the first evaluation, the cabbage varieties did not significantly differ in their average head weight which ranged from 469 to 557.9 g. However, in the second evaluation,

Table 3. Number of days from transplanting to head initiation of cabbage varieties under drought stress

ENTRY	DAYS TO HEAD FORMATION		HEADING PERCENTAGE (%)	
	2013-2014	2014-2015	2013-2014	2014-2015
Ace Green	54ab	68	100.00	28.34a
Gladiator	54ab	73	100.00	18.34b
Lucky Ball	50a	60	98.08	30.00a
Rare Ball	55bc	65	96.16	26.67a
Scorpio	56cd	70	100.00	28.17a
CV (%)	1.44	2.34	2.46	10.90

Means in a column with common letters are not significantly different at 5% level by DMRT

Scorpio significantly produced the heaviest heads but was comparable to Ace Green and Lucky Ball (Table 4). When ranked, Lucky Ball and Ace Green consistently produced heavier heads in both evaluations. Head weight was observed to be related to compactness (Siddiqui, 2015). Compactness can be a varietal character but it can also be influenced by environmental factors and management practices (Neibauer and Maynard, 2002). Lucky Ball and Ace Green have compact heads which may have resulted to heavier heads while others have loose heads which may have resulted to lighter heads. Gladiator produced the heaviest heads in 2013-2014 but had lighter heads in the succeeding trial. The low average weight of heads observed could be due to poor head formation which contributed to smaller heads. A more severe drought condition was observed during the second trial than the first trial. According to Bawang (2006), irrigation of cabbage at 2 to 3 weeks before harvest can result to an increase in the weight of cabbage heads. Moreover, presence of irrigation during head development produced heavier, larger, less pointed heads and less volume occupied by the core compared to non-irrigated cabbages during heading stage (Radovich *et al*., 2005).

Total yield per plot and computed yield ton per hectare. Gladiator produced the highest yield followed by Lucky Ball although no significant differences among the varieties were observed in the first evaluation (Table 4). In the second evaluation, Ace Green had the highest yield but was comparable to Lucky Ball, Scorpio and Rare Ball while the lowest yield was obtained from Gladiator. The low yield obtained could be associated to the low number of heads, poor head formations, low head weight and low survival rate of the cabbage varieties. It was observed that the yield was lower as compared with the world average of 10-40 t ha^{-1} (Ogbodo *et al*., 2009). The low yield could be attributed to the drought stress at 70-90 DAT or heading stage. Drought stress can decrease head yield of cabbage at about 65% and this is caused by reduced head size (Maggio *et al*., 2005). In this study, head sizes were noticeably smaller in the second evaluation periods.

The consistently high yielders were Ace Green and Lucky Ball in both growing seasons. High yield of these varieties could be attributed to their compact and heavy heads and moderate infestation of insect pests like cutworm and diamond-back moth. The result may suggest the suitability of Ace Green and Lucky Ball to drought stress conditions. This proves that cabbage is intermediately susceptible to water stress which eventually leads to lower yield (Smittle *et al.*, 1994).

Reaction of Cabbage Varieties to Insect Pests and Diseases

Ace Green and Rare Ball varieties were moderately resistant to diamond-back moth while the other varieties were resistant in the first evaluation. Most of the varieties were resistant to diamond-back moth infestation except Gladiator which was moderately resistant in the second evaluation. No clubroot and blackrot were observed during both evaluations.

Postharvest Characters

Weight loss and shelf-life. Significant differences

Table 4. Average head weight, total yield and computed yield of cabbage varieties under drought stress

VARIETY	AVERAGE HEAD WEIGHT(g)		TOTAL YIELD (kg 5 m-2)		COMPUTED YIELD (t ha-1)	
	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015
Ace Green	523.86	129.00ab	13.05	2.20a	26.10	4.40
Gladiator	557.91	80.00c	14.66	0.88b	29.32	1.76
Lucky Ball	553.39	120.40ab	13.13	2.17ab	26.26	4.34
Rare Ball	512.53	85.00b	12.28	1.36ab	24.56	2.17
Scorpio	469.48	146.50a	11.23	1.64ab	22.46	3.28
CV%	5.23	16.00	5.66	15.00		

Means in a column with common letters are not significantly different at 5% level by DMRT

Table 5.Weight loss and shelf-life of cabbage varieties under drought stress

VARIETY	WEIGHT LOSS (%)		SHELF-LIFE (days)	
	2013-2014	2014-2015	2013-2014	2014-2015
Ace Green	21.32cd	9.94b	14	12a
Gladiator	18.82ab	8.95ab	16	8b
Lucky Ball	21.64d	9.00ab	14	12a
Rare Ball	18.17a	9.07ab	14	13a
Scorpio	19.99bc	8.10a	16	13a
CV%	2.47	10.64	0.0	8.62

Means in a column with common letters are not significantly different at 5% level DMRT

were observed in terms of weight loss among the varieties after two weeks of storage under ambient condition in both evaluation periods (Table 5). Rare Ball and Gladiator had the lowest weight loss while Lucky Ball obtained the highest weight loss in the first trial. In the succeeding trial, Scorpio recorded the lowest weight loss while the highest weight loss was noted in Ace Green. Weight loss in the cabbages during storage is attributed more to moisture loss. After harvest, water loss occurs and this is usually accompanied by deterioration of visual appearance and consumer acceptability, leading to a direct loss of marketable produce (Boxall *et al*., 2002).

Moreover, the varieties significantly differed in terms of shelf-life under ambient condition during the second evaluation period. All the varieties had longer shelf-life of 14-16 days in the first evaluation but in the second evaluation, the shelf-life of the cabbage ranged from 8-13 days. This observed shorter shelf-life might be due to small heads harvested.

CONCLUSION AND RECOMMENDATION

The study was conducted to evaluate the response of cabbage varieties to drought condition in La Trinidad, Benguet, Philippines. Drought stress at heading stage significantly affected the relative water content, head formation, heading percentage, head weight, and yield of the different cabbage varieties. Lucky Ball and Ace Green consistently produced high head yield, formed head earlier and had high heading percentage. Thus, these varieties can be recommended to be planted by farmers in Benguet and other areas with similar conditions to ensure cabbage productivity during times of drought.

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